PROGRAM MANUAL

FOR THE

TRAIN OPERATIONS MODEL

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1 INTRODUCTION

1.1 OVERVIEW

This document is the Program Manual for the Train Operations Model (TOM)®, the TOM Version 3.8 edition. The manual has been organized so that future changes can easily be incorporated. There is no printed version.

This document contains many screen pictures of actual runs with the TOM. If some of these pictures seem too small, it is suggested that you use the zoom feature in WORD or Adobe Acrobat to blow them up. They are full size pictures.

A computer model of this size and complexity always has the potential for future improvement. Thus as the model is improved, parts of this manual will become outdated; however, the basic format will remain the same and is described here.

The TOM contains all of the computer tools to simulate the operation of a rail system on a computer. It is transportable among rail systems and anticipates new technical developments in railway operation within the foreseeable future. As used here, a rail system is any form of guided ground transportation.

Simulation of operations means that given the inputs particular to a specific railway, outputs are produced which characterize train motion and energy consumption as both time functions and in summary form.

Application of the TOM to a rail network involves input, output and processes (or tools). The inputs to a TOM are grouped into five general areas.

Simulation Control. Data necessary to control and direct the simulation.

Rail Network Control. Data necessary to control and direct the operation of trains on the rail network.

Train Information. This information includes data, which include the physical parameters necessary to characterize the makeup of trains, their cars, and the propulsion, braking and auxiliary power characteristics of each car.

Right of Way Information. The information includes data, which contain the description of tracks or guideways along which the trains are running. These include grades, curves, speed limits, locations of stations and stops and routes.

Power System Information. Included here are data, which describe the electrical feed system which powers the trains in the rail network. This information is not required for a rail system, which runs on fossil fuel.

The outputs of the TOM are grouped into three areas.

Train Motion. This includes information about the position, speed, and acceleration of each train operating on the system.

State of Control System. Information on the signals, switches and routings at any given time is given here.

Energy Consumption. This includes information about the energy or fuel used by each train on the system as well as the end use (i.e. auxiliary power, propulsion losses, train resistance losses, etc.). It also includes all of the voltages, currents and powers at all salient points for electrified systems.

The processes or tools required for a TOM are grouped into six general categories.
Construction Tools. These tools are computer programs, which can convert raw rail network or manufacturer’s data into input suitable for the Simulator Tools are included here.

Simulator Tools. The simulators are computer programs, which use the refined input data to simulate the rail system operation and produce time functions and summary output. Three simulators comprise the TOM. These include a Train Performance Simulator (TPS), which simulates the performance of a single train on the rail network; a Train Movement Simulator (TMS) which simulates the performance of the multi-train network under a train control system; and an Electric Network Simulator (ENS) which simulates power flows on the system.

Manipulation Tools. These tools are computer programs, which manipulate the input to and output of the Simulation Tools for appropriate tasks. The output from the Manipulation Tools can be used as final output and as input to the Simulation Tools.

Control Tools. Control tools are computer programs, which control the use of and interaction among the Construction, Simulation and Manipulation Tools and the Input and Output.

Visual Displays and Viewers. These are output screens, which allow the user to observe the motion of the railway, graphs of parameters of interest, and the input and output files.

Supplementary Programs. These are programs which use the data generated by the TOM, as well as other information to compute various aspects of simulated train operation.
A block diagram of the TOM is shown in Figure 1-1.

![Train Operations Model Block Diagram](image)

Figure 1-1 Train Operations Model Block Diagram

The block diagram shows the overall flow process of the model. The **File Construction Module (FCM)** is used to convert the raw rail transportation system data into files, which are readable by the simulators or by other programs within other modules. Most of these files are stored in a **Rail System Database (RSDB)**, which can be accessed by the user and read by the simulators, modules, utilities and other programs.

The three simulators read the files in the RSDB and produce output, which is deposited in the RSDB and used by the other simulators, modules, utilities and other programs.

The **TPS** simulates a single train on the rail network and produces output, which is read as input by the **ENS**, the **TMS** and the **File Manipulation Module (FMM)**. The output from the TPS resides in the RSDB.

The **ENS** simulates a system of trains, the prescribed running of which is determined beforehand, and calculates the power consumption as seen at the metering points as well as the voltages and currents at all salient points in the electrical network under which the trains are fed power. The output from the ENS is used by the FMM, the **Energy Cost Module (ECM)**, and the **Rail Voltage Model (RVM)** and resides in the RSDB.

The **TMS** simulates a system of trains, which is controlled by a train control system, either manual, automatic fixed block or automatic moving block. While the system of trains is being simulated, the power consumption can also being calculated at the metering points as well as the voltage and currents of all salient points in the electric network under which the trains run. The output from the TMS is used by the FMM and the ECM and resides in the RSDB.
The FMM is a group of computer programs, which manipulates the output of the simulators and produces files, which reside in the RSDB. These manipulations are used for special purposes to be described in detail in Section 4.

The ECM is a group of computer programs, which summarize outputs from the ENS and TMS to determine the main components of energy cost, namely, demand and energy use. The output from these programs is located in the RSDB.

The RSDB holds all of the files, which are input and output of the simulators and modules. There is a naming convention for these files, which is described in some detail in Appendix 9.1. A utility program (DB) allows the user to interact directly with this database.

A supplementary program, the Rail Voltage Model (RVM), estimates the rail to ground voltage on DC electrified systems.

The TOM is the package of the category of tools just described. It is designed for persons experienced with computers and railway operations, although on line help can aid less experienced people.

This program manual is organized into several sections, following the tools that the TOM contains.

This section presents a brief description of the model, the construction philosophy, how the model is operated and instructions on how to use the TOM.

Section 2 describes the operation of the simulators in some detail. These sections are organized in the following format.

Sections 3-5 highlight the modules, which support the simulators and/or manipulate their input or output files.

A description of the FCM and the input screens, which are used to enter data, is presented in Section 3.

A review of all of the purposes for manipulating input and output files is contained in Section 4.

The FMM screens are presented and described in this section as well.

The programs and screens used in the ECM are described in some detail in Section 5.

Sections 6 - 7 contain detailed descriptions of the utilities.

Section 6 describes the Database (DB) utility.

Section 7 presents the details of the Graphics (GRAPH) utility.

Section 8 contains a description of the operation of the Supplementary Tools, including the Rail Voltage Model (RVM).

Finally, Section 9 contains the appendices. The appendices present more detailed information about the TOM and its components, as well as brief descriptions of the algorithms and mathematical models used for the programs in the model.

In addition to this Program Manual, there are a series of Instruction Manuals, which can be used as guidelines for applying the TOM to rail systems throughout the world. In this connotation, rail system definition includes main line railroads, heavy and light rail, trolleybuses, high-speed rail and MAGLEV and people movers.
There are several manuals in the series:

Volume 1 – An Introduction to the Instruction Manual for Applying the TOM
Volume 2 – Instruction Manual for Applying the TOM to Transit Systems DC Electric – English Units
Volume 3 – Instruction Manual for Applying the TOM to Transit Systems DC Electric – Metric Units
Volume 4 – Instruction Manual for Applying the TOM to Transit Systems AC Electric – English Units
Volume 5 – Instruction Manual for Applying the TOM to Transit Systems AC Electric – Metric Units
Volume 6 – Instruction Manual for Applying the TOM to Railroads Fueled – English Units
Volume 7 – Instruction Manual for Applying the TOM to Railroads Fueled – Metric Units
Volume 8 – Instruction Manual for Applying the TOM to Rail Systems; Technology Aspects
Volume 9 – Instruction Manual for Procedures and Shortcuts in the TOM
Volume 10 – Instruction Manual for Including the Return Circuit in Electric Rail Systems
Volume 11 – Instruction Manual for Exercising the AC Drive Propulsion Model
Volume 12 – Instruction Manual For DC Electric Power System Evaluation Methodology
Volume 13 – Instruction Manual AC Electric Power System Methodology
Volume 14 – Instruction Manual Exercising the Rail Voltage Model for DC Traction Systems
Volume 15 – Instruction Manual for Exercising the new Substation Model

Volumes 2-7 cover nearly all transit systems and railroads in the world.

Unlike the Program Manual, which is protected, these volumes are unprotected. Thus the user is free to make notes or rewrite sections according to his preferences.

The primary purpose for using the TOM is evaluation. The evaluation generally takes the form of a study, with certain objectives, which may or may not be well defined. As the study is conducted, new objectives may result, because of unanticipated results. Within the framework of evaluation, designs may be modified and further evaluated, so that in this sense, the TOM may be considered a design tool.

The TOM is used together with other standard software, such as Microsoft Office (in particular, WORD, EXCEL and POWERPOINT). This combined package of Instruction Manuals is most effective in assembling client data as well as presenting results. In some instances, the TOM interacts directly with these office programs, while in other cases; the user handles the office packages directly.
1.2 **BRIEF DESCRIPTION OF THE MODEL**

This section of the manual develops the approach, philosophy and organization of the TOM. It presents a concise picture of the model and its purpose.

### 1.2.1 Objectives

The package of TOM computer programs was designed to meet functional and architectural objectives.

#### 1.2.1.1 Functional Objectives

The functional objectives define what the package is expected to accomplish. They are:

- To realistically simulate schedule performance and power or fuel consumption of existing and future guided transportation systems operating under existing or new train control systems.
- To evaluate electric power distribution systems for guided ground transportation.
- To separate the system's energy consumption into its important end uses and to provide the means to identify cause-effect relationships between the end uses and equipment design and operating practices.
- To provide the means to develop, refine and test energy cost reduction strategies before they are tested and implemented on the real system. These strategies would include new train control systems, which use energy cost reduction as part of their operating algorithms.

#### 1.2.1.2 Architectural Objectives

The architectural objectives define how the package is built. They are:

- To be modular at all levels so that any module can be developed, tested and verified, independently and can be inserted or replaced in the package without a major retrofit, which affects the package integrity.
- To possess a maximum of hardware independence and to be written in a widely used language. (In practice, no large package can come close to being machine independent, but steps can be taken to minimize the effort required to move the package from one computer to another.)
- To have enough flexibility in structure to accommodate new models, new energy conserving strategies, new technology and new programs.

### 1.2.2 Approach

The approach to simulating a guided transportation system; i.e., to determine its schedule performance, power flows and energy consumption, and other pertinent information, involves the following steps:

1. For each train in the system, assemble raw data on its physical and performance characteristics, the route and schedule it is to follow, and the physical characteristics of the route it is to follow.
2. Assemble raw data on the electrical configuration and component characteristics of the network supplying power to the trains (for electric powered guided transportation systems).
3. Assemble raw data on the train control network, which commands the system operation. This includes such things as block lengths and location, speed commands, and switch and crossover locations.
4. The raw data assembled in steps 1 - 3 are processed and put into a form, which is acceptable to the simulators.
5. Treating each train separately, calculate tables of its speed, position and power or fuel draw against time (hereafter called a power profile). From these tables, assemble a master table, which for selected time instants which span the period under investigation, contains information on the motion characteristics and power draw of every train on the system.
6. At each of the selected time instants, calculate the voltages, currents and real and reactive power flows for all salient points in the electrical network (for electric powered guided transportation systems).
7. Check to see that no interference or conflicts are occurring among the trains. If conflicts do occur, resolve them.
8. Integrate the power flows over all of the time instants in the simulation period to produce overall energy consumption.

In steps 1-8, the rail system's performance and energy consumption are synthesized from its end uses (examples of these end uses are energy consumed by on-board auxiliaries, losses in propulsion equipment, third rail losses, etc.). Thus, the simulation provides a means to identify the end uses, calculate the overall performance and consumption and test sensitivities of both to changes in design and to operation of the system. It also provides a method to evaluate existing electric power and train control systems for any rail network. It can also be used as the basis of design evaluation.

The TOM is designed to be run by competent engineers who have electrical, computer and rail transportation system experience. Recognizing this, allowances are made for knowledgeable professionals to interact with the package at two levels:

1. To identify and create strategies that are systematic enough to be automated and consequently can become permanent package features; and,
2. To directly interact with the package so that knowledgeable trial-and-error can be used to find solutions.

The overall package is assembled from the principal modules shown in Figure 1-1. Each of the programs within the modules is an independent entity developed, tested, verified and used, separately. All programs are written in FORTRAN and Visual Basic. Each principal program is modular in structure to facilitate continued development, maintenance and upgrading. At every level, each module is defined with respect to its function, input and output.

1.2.3 Principal Modules

The TOM consists of 9 principal components: a Train Performance Simulator (TPS), an Electric Network Simulator (ENS), a Train Movement Simulator (TMS), an Energy Cost Module (ECM), a File Construction Module (FCM), a File Manipulation Module (FMM), Supplementary Programs, a Graphics Utility (GRAPH) and a Database Utility (DB). The deployment of the principal and support components of the package was shown in Figure 1-1. Summary descriptions of each of these components were presented in Section 1.1. A more detailed description of each of these is given here.
1.2.3.1 Train Performance Simulator (TPS)

The TPS requires the following items as input:
- vehicle parameters such as weight, propulsion system characteristics (tractive effort and efficiencies vs. speed and tractive effort), train resistance, numbers and types of vehicles in train, auxiliary electric loads, and passenger load factors
- wayside parameters such as power distribution system type (DC, single phase AC or three phase AC), voltage
- right-of-way profile (grade, curve, speed restriction and/or speed command as a function of location)
- system operational characteristics such as acceleration and braking rates, maximum speed and station dwell times

The program simulates the operation of a single train under the input conditions. Outputs include power profiles (real power for DC distribution and real and reactive power for AC distribution as a function of location) and details of the run. For trains which use fuel to propel them, such as diesel locomotives hauling passengers or freight cars, details and summaries of fuel consumption are provided. The program will accept trains with dynamic braking capability and the energy can be fed into storage devices aboard the vehicle (batteries or flywheels), dissipative devices aboard the vehicle (resistors) or to storage/dissipative devices, other trains external to the train (regeneration) using the power distribution system or storage devices along the right of way.

Various forms of coasting (running trains with a power off condition) can be accommodated.

There are many other programs that can perform some or all of these functions. This program is unusual, not in terms of its functions, but its structure. First, it is modular and therefore can continue to easily grow. For instance, if new propulsion system models, or more accurate train resistance formulae are needed, the existing modules in which these are contained can easily be augmented or replaced. Second, it is part of a complete package of programs, all of which act together to simulate performance, capacity and power or fuel consumption and rail network operation.

1.2.3.2 Electric Network Simulator (ENS)

This program accepts the following items as input:
- single train power and time profiles as a function of location along the right-of-way,
- timetables for movement of multiple trains,
- power rail, catenary or trolley impedance, running rail impedance, substation locations and characteristics, operating voltage both nominal, maximum and minimum, characteristics of the distribution network, the substations, and metering point locations. Wayside energy storage devices can also be included.

This program simulates the movement of the trains by taking snapshots of the entire system at fixed intervals of time.

The calculated output of this program is a complete electrical picture of the system including power flows, voltages, currents and losses at all salient points. In particular, power through metering points (forward and reverse), power distribution system losses and substation losses are computed. Capability for regeneration to other trains and/or through regenerative substations (even though metering points) and wayside energy storage is also included.
The simulator works with the TPS previously described and uses its output files (power profiles) as input.

### 1.2.3.3 Train Movement Simulator (TMS)

This program accepts the following items as input:

- single train power and time profiles as a function of location along the right-of-way,
- timetables for movement of multiple trains,
- power rail, catenary or trolley impedance, running rail impedance, substation locations and characteristics, operating voltage both nominal, maximum and minimum, characteristics of the distribution network, the substations, and metering point locations. Wayside energy storage devices can also be included. (This feature is optional, so that fuel driven trains and electric powered trains can be operated without the feature.)
- track layout, which is a description of the location of all of the tracks, switches and crossovers on the train network

The program simulates the movement of the trains by taking snapshots of the entire system at fixed intervals of time.

The TMS is similar to the ENS except that it allows the system of trains to run under a train control system, which is issuing commands to the trains. A picture of the whole rail network is shown for each snapshot. The user can interact with the trains by setting switches and interlockings, which would eliminate train interference. Train conflicts can be identified and resolved.

### 1.2.3.4 File Construction Module (FCM)

The FCM is a series of computer programs, which interact with the user to transform raw rail system and vehicle data to files which are acceptable input to the TPS, ENS and TMS. A brief description of each of these programs is given here.

**File of Filenames Construction**

The file of filenames is the first file called by each of the simulators TPS, ENS and TMS. This file contains all of the filenames of the files to be opened as either input to or output from the simulator. The File of Filenames Construction (FOF) program helps the user gather the files for any particular simulator run.

**Control File Construction**

The control file is an input file to the TPS. Control and system type parameters, such as displays desired, train movement direction, maximum speed, acceleration and deceleration, and coasting parameters, are developed using this process. The Control File Construction (CLF) program helps the user construct these files. [tomclfvb.DLL]

**Train File Construction**

The train file is an input file to the TPS. The Train File Construction (TNF) program uses a propulsion model, which calls on actual manufacturer's data to determine propulsion system efficiencies in power and brake modes. It can accommodate cam or chopper control with DC series or separately excited motors and inverters with AC induction motors, for DC power distribution systems. It can also accommodate phase control with DC series or separately excited motors for AC power distribution systems. For trains, which require fuel to power them, it uses fuel consumption curves. [tomtnfvb.DLL]
It also contains input on the train makeup, its physical characteristics and energy storage characteristics.

In the following list of tools, those that are provided with symbols indicate that a DLL (Dynamic Link Library) program, written in FORTRAN code, is called by the Visual Basic portion of the tool. The DLL compilation is listed.

**Station File Construction**

The station file is an input file to the TPS. For each passenger station or stopping point, the file contains the name of the station; its position along the right of way, the dwell time of the train when it stops at the station and the passenger load factor of the train to the next station. The Station File Construction (STF) program helps the user build such files. [tomrowvb.DLL]

**Right of Way File Construction**

Right of way files include the Grade, Curve, Speed Restriction, Speed Command and Route files, all of which are input to the TPS. These files include a position along the right of way with the value of some parameter, which is in force from the last position along the right of way. The Right of Way Construction (ROW) program helps the user build such files. [tomrowvb.DLL]

**Network File Construction**

The network file is an input file for the ENS and TMS. The electric network file contains all of the parameters, which describe the electrical distribution system under which the trains operate. The Network File Construction (NFF) program helps the user construct the electric network. [tomnffvb.DLL]

**Negative Network File Construction**

The negative network, which represents the return circuit for DC Electric Distribution Systems, is an input file to the RVM. This file contains all of the parameters, such as running rail resistance, ground resistance and rail to ground leakage resistance, which are necessary to describe the negative return circuit. The Negative Network File Construction (NNF) program helps the user to construct the input file. [tomnnfvb.DLL]

**Operating Time File Construction**

The operating time file is an input file for the ENS and TMS. The file contains the time range over which the simulation is to run, and the time interval between snapshots for simulation. The Operating Time File Construction (OTF) program aids the user in the building of this file. [tomotfvb.DLL]

**Train Location File Construction**

The train location file is an input file for the ENS and TMS. The file contains the information to locate the trains on the track network. The Train Location File Construction (TLF) program aids the user in the building of this file. [tomtlfvb.DLL]

**Current Measurement File Construction**

The current measurement file is an input file for the ENS and TMS. The file contains positions on the track where current is to be measured. The Current Measurement File Construction (CMF) program assists the user to build that file. [tomcmfvb.DLL]

**Primary Circuit File Construction**
The primary circuit file is an input file for the ENS and TMS, which is used to generate a network file with return circuit analysis capability. The Primary Circuit File Construction (PCF) Program assists the user to build this file.
Return Circuit File Construction

The return circuit file is an input file for the ENS and TMS, which is used as part of a network file with return circuit analysis capability. The Return Circuit File Construction (RCF) program assists the user to build this file. Return circuits cannot be used on AC Train Systems i.e. trains running under AC distribution.

Rail Voltage Table Construction

The Rail Voltage Table is one of the inputs to the RVM. The Rail Voltage Table is a 3-dimensional table of rail voltage factors which are used to calculate the maximum rail to ground voltage for every train. These factors depend on the electrical characteristics of the negative network as well as the position of the train relative to the substations. The Rail Voltage Table Construction (RVT) program assists the user to build the file.

Track Layout File Construction

The track layout file is an input file to the TMS. The file contains all of the essential information on the tracks, switches and crossovers along the right of way as well as train control system information such as block locations and speed codes.

Station Description File Construction

The station description file is an input file to the TMS. It contains a physical description of station platforms, including position along the right of way, length and track number served.

Stop Distance Calculator

The stop distance file is not an input file to any simulator, but rather is a guide to the user on setting up block lengths or placing wayside detectors. This file contains the stopping distances for a series of speeds for each position along the track. The Stop Distance Calculator (STP) aids the user in constructing such a file.

Meter Consolidation File Construction

The meter consolidation file is an input file for a program in the ECM. This file contains a list of meters on the system grouped for coincident demand purposes. The Meter Consolidation File Construction (MCF) program assists the user to make this listing.

1.2.3.5 File Manipulation Module (FMM)

The FMM is a series of computer programs, which interact with the user to manipulate input and output files for several different purposes. A brief description of each of these programs is given here.

Elevation File Construction

An elevation file, which shows the elevation of the track as a function of position, is constructed from a grade file. The Elevation File Construction (ELV) program generates the elevation file.
Grade Separation Computer

Given the elevation files for two tracks, the Grade Separation Computer (GSC) shows the elevation of each track and the difference in elevation between the tracks for chosen points along the right of way.

Propulsion Efficiency Conversion

The Propulsion Curve Efficiency (PEC) program converts a train file (input to the TPS) from one which has the propulsion efficiencies expressed as a function of speed and traction effort to one which has the propulsion efficiencies expressed as a function of speed and % of maximum traction effort at that speed.

Traction Curve Fitter

The Traction Curve Fitter (TCF) program fits part of a Traction Effort vs Speed curve to a function of the form, for which the Traction Effort is a sum over powers of the reciprocals of Speed. For example, if only two terms are considered in the sum, the form of the function would be C(0) + C(1)/v, where the constants are determined using a least squares fit.

Power Profile Averager

This Power Profile Averager (PAV) program develops an average power profile given two or more power profiles (TPS Output) from different trains. For example, a train made up of mixed AC drive and cam control cars with identical performance characteristics could be simulated by running two trains, one of them with all chopper cars and the other with all cam control cars. Using PAV, the mixed train power profile is developed from the other two power profiles.

Power Profile Appender

This process (PPA) appends several power profiles, which are output from the TPS and combines them into one power profile. This utility is exercised when it is convenient to run train performance on several connected track segments separately, and later combine the results for input into the ENS or TMS or other programs.

Power Profile Clipper

This process (PPC) allows the user to remove records from the beginning and end of a power profile, which are output from the TPS and create another power profile, which is shorter than the original. This utility can be conveniently used for trains which are fuel powered in non-electrified territory and electric powered in electrified territory. It can also be used when the user desires to only study portions of the system under electric power. The new power profile can be used as input into the ENS or TMS or other programs.

Motion Characteristics

This process (MC) allows the user to view three areas of the Detailed Output file of the TPS. These areas are the Traction and Motion Characteristics area (Traction, Acceleration and Train Resistance Curves); Train Run Summary area (Distance, Time, Average Speed, Maximum Speed and Acceleration, etc.) and Energy End Use region (How energy is used.).

Load Curve Extender

This process (LCP) is useful to expand meter load curve (output from the ENS or TMS) cycles over time, when it is known that the original load curve is cyclic in nature. Such would be the case for a rail system operating with constant headway between identical trains or when the timetable repeats after a certain time interval.
**Meter Reader**

The **Meter Reader (MR)** is set up to permit the user to capture meter readings in either demand or load curve format and paste them in a spreadsheet for further analysis such as in electric energy cost estimation.

**Occupancy Checker**

The **Occupancy Checker (OC)** checks the results of an **ENS** or **TMS** run to determine if there are trains, which are too close to each other on the same track. It lists all trains on the same track within a fixed distance of each other.

**Route Checker**

The **Route Checker (RC)** analyzes the power profile to determine the train’s route through the track network. It lists the beginning position and track number, the positions and track numbers of all track number changes made by the train and the end position and track number. A listing is made of all **TPS** input files, which were used to construct the power profile. These **TPS** input files can be viewed directly.

**Line Name Translator**

The **TOM** assigns the names of lines to circuits in the power system. The assignment results in a one to four alpha-numeric characters names. The **Line Name Translator (LNT)** process results in a translation of these four character names into translated names which refers to line location and track numbers. This file, in the form of a table, provides a translation for reports and more transparent meaning.

**Impedance Calculator**

The **Impedance Calculator (IC)** is used to calculate dynamic impedances of a return circuit. The resulting file is called the **Return Circuit Impedance** file, which is used to generate a **Network** input file for the **ENS** or **TMS**, which has return circuit analysis capability. Dynamic impedances are impedances which move along with trains and reflect the changing nature of the return circuit in which the train is imbedded.

**Minimum Train Voltage Finder**

The **Minimum Train Voltage Finder** scans the **Current Measurement Output** file to determine the lowest voltages that trains experience on the line. It orders those voltages from the lowest to highest and specifies the position, track number and identity of the train, which causes the lowest voltage.

**Mean Useful Voltage Finder**

The Mean Useful Voltage of a region of an electric network is defined in International Standards EN 50388 (2012) or IEC 62313. It is the average value of the train voltage in the region over a selected period of time. It can refer to all of the trains running in the region during the time period or a single train running in the region. This process computes the mean useful voltage for any given region, for any train and for any condition of power drawn, including regeneration, power, coasting and stationary conditions.

**Maximum Train Current Finder**

The **Maximum Train Current Finder** scans the Current Measurement Output file to determine the highest currents that trains draw on the line. It orders those currents from the highest to lowest and specifies the position, track number and identity of the train, which causes the highest current.
Current Analyzer

The Current Analyzer calculates the instantaneous and RMS currents in either a Primary or Return Circuit, which has been used to generate a Network file, which is subsequently used as input into the ENS or TMS. The information developed by this program can be used as inputs to calculate heating effects on cables, track bonds, running rail, third rail and catenary. Instantaneous current can be displayed in graphical form to present a picture of current flows as a function of time through these power system components.

The analyzer is also used to display currents in three areas: Current Measurement (Results of ammeter measurements. Ammeters are placed by the user.;) Converters (Current, Voltage and Power Summaries of the Converters for DC systems) and Line Current (Summaries of line currents in Primary and Return Circuits).

Voltage Averager

The Voltage Average Process is a way of making the running of the TPS and ENS dependent on each other. Through a voltage averaging process, voltages for traction are made dependent on minimum voltage seen in the distribution network. Thus the voltage seen by the train is dependent on the power drawn by that train. This is a method which simulates reality better than making train voltage independent of power drawn. However, it is a less conservative approach to power system evaluation.

Auto Offset Process

The Auto Offset Process allows the user to automatically change the offset (point where trains moving in opposite directions pass each other) in fixed headway two track systems. This process is extremely useful for finding points of low voltage, where trains run differently than their advertised schedule. It is also useful for finding schedules which tend to save more energy when trains regenerate.

Auto Sub Out Process

The Auto Sub Out Process allows the user to automatically determine whether low voltage problems exist when substations are taken out of service for maintenance. The process will take substations out of service one at a time and summarize the results on performance.

Auto Rail Voltage Process

The Auto Rail Voltage Process permits the user to calculate maximum values of rail voltage for a given run scenario by variation of rail to ground leakage resistance and ground resistance over a range of values. This process will inform the user how sensitive the system under study is to the selection of these resistances.

1.2.3.6 Energy Cost Module(ECM)

The ECM consists of two computer programs, which use the output of the ENS or TMS to compute such things as power demand at meters, coincident power demand and energy consumption. It does not compute energy costs directly, but rather provides the basis for a simple manual computation of these costs. This approach was taken since power rate structures vary greatly among transportation authorities. The ECM contains programs, which aid the user in summarizing the results of ENS or TMS runs from an energy perspective. It contains two programs.

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1 As used in this manual, the Primary Circuit refers to the hot side of the power distribution system. It includes everything from the power collector to the utility producing the power. In contrast, the Return Circuit refers to the cold side of the power distribution system. It includes the running rail or other method to return current. In DC power distribution, the Primary Circuit is the positive circuit, whereas the Return Circuit is the negative circuit or return.
Energy-Demand Consolidation

The Energy-Demand Consolidation (EDC) Program uses as input a set of coincident meter load curves to summarize the meter readings over stated demand intervals. It also develops the energy use over that time interval.

Appended and Consolidated Load Curve

The Appended and Consolidated Load Curve (APL) Program uses as input, meter load curves which have been generated by the ENS. It appends these load curves and consolidates them by only selecting those meters which are designated for consolidation (i.e., they belong to the same power company or some other reason for consolidation). The time span of the resulting appended coincident load curve is the union of the set of time spans from the individual load curves.

1.2.3.7 Database Utility (DB)

The Rail System Database (RSDB) contains all of the input and output files of the simulators. The utility DB contains the computer programs which allow the user to add and delete rail systems, read files within the database, and delete files particular to a particular rail system. Files cannot be created here, but they can be modified. The DB utility also allows the user to run the simulators when accessing the appropriate files of filenames.

1.2.3.8 Graphics Utility (GRAPH)

The GRAPH utility creates plots useful to the user in describing characteristics of the rail system. These plots include elevation curves, propulsion curves, train running results, meter load curves, train graphs, electrical graphs and wayside storage graphs. Each of these categories is described separately.

An elevation curve plots elevation vs. position along the right of way on which trains run.

A train resistance curve which plots resistance vs. speed for any grade.

Four types of propulsion curves can be displayed by the GRAPH. These include tractive effort vs. speed, electrical brake effort vs. speed, propulsion efficiency in power and propulsion efficiency in electrical brake.

Five types of train running results can be plotted. These results are produced by the TPS. These include speed vs. position, power vs. position, acceleration vs. position, speed vs. time and position vs. time. The former three plots also show the position of the passenger stations or the stopping points. The speed vs. position graph shows the speed restrictions or speed commands governing the simulation.

The meter load curve is the power vs. time, which flows through a single meter or a group of meters for the purpose of conjunctive power measurement. The meter load curve file, which is used as the basis for this plot, is output from the ENS and the TMS.

Train graphs show the position in time of a system of trains running on a two-track system. The train graphs also include the positions of the passenger stations or stopping points in the graph. The train lines are colored differently depending on whether they are taking power or regenerating.

Electrical graphs are plots of voltage or current, which result from the current measurement output file of the ENS or TMS. These graphs include train voltage vs. position, which also can show substation and/or passenger station location, line current vs. time, measured current vs. time, voltage vs. time and rail voltage
vs position. The measured current vs. time plot uses data, which result from the placing of current
measuring devices along the third rail, trolley or catenary. Graphs of various types of line currents, which
are the result of primary and return circuit analysis, can be produced.

Wayside storage graphs are plots of voltage, power or energy of wayside storage stations using the current
measurement output file of the ENS or TMS.

Graph scales can be set manually or automatically. The user can set the coordinates of any of the graphs
manually by specifying the minimum and maximum of the x and y-axes and the step size between tic
marks for both axes. Automatic setting of the scales chooses the maximum and minimum of the (x, y)
coordinates of the graph to set the scale. Step size is always one-tenth of the difference between maximum
and minimum for each axis.

1.2.3.9 Supplementary Programs

There are several supplementary programs, which have been added to the TOM.

Rail Voltage Model

The Rail Voltage Model (RVM) has been designed to estimate maximum rail to ground voltage in train
networks with DC Power Distribution. There are two methods by which this estimate can be made. These
methods are termed the Old Method and the New Method. The terms are applied to versions of the model
lower than 3.5 (Old Method) and 3.5 and higher (New Method). Both methods can be used with version
3.5 and higher.

The Old Method can only estimate maximum rail to ground voltage in very simple two track networks and
with a single train running on the network.

Rail voltage estimates can be made on more complicated networks by separating them into pieces, where
each piece is a simple network described above.

The New Method can estimate maximum rail to ground voltage in any train network with no limits on the
number of trains running. It utilizes the return circuit to make the estimate and depends on the currents
moving through the rails and the electrical characteristics of the earth, ballast and ties.

Time Calculator

The time calculator program will convert time expressed in various ways to times expressed in other
ways. It will also add two times or subtract one time from another. In case of addition and subtraction,
the time is also expressed in different ways. The minimum time unit is one second. Time can be
expressed in one of five ways and likewise is displayed in all five ways. The five ways are:

- Decimal, using hours i.e. 2.345 hrs
- Decimal, using minutes i.e. 2345.32 min.
- Integer, using seconds i.e. 4567 sec.
- Symbolic, using hours:minutes i.e. 4:13.234
- Symbolic, using hours:minutes:seconds i.e. 4:13:24

The time calculator may be used as a tool for constructing timetables and start and end times for ENS and
TMS runs.

Metric English Converter

The Metric to English Converter converts any physical units, which are used by the TOM, from English
to Metric and from Metric to English.

Complex Number Calculator
The **Complex Number Calculator** provides a way to produce complex number operations and functions which may be useful in circuit calculations.

**Linear Interpolator**

The purpose of this tool is to use the equation \( Y = a \cdot X + b \) to find the \( Y \) value corresponding to a value for \( X \), given the points \((X_1, Y_1)\) and \((X_2, Y_2)\). Inputs are \( X_1, X_2, X, Y_1 \) and \( Y_2 \) and the result is \( Y \).

**Extremumizer**

The program uses a parabolic interpolation to find the extremum, either a maximum or minimum. The coefficients \( a, b \) and \( c \) of the parabolic equation \( y = a \cdot x^2 + b \cdot x + c \) are found given the \((x,y)\) coordinates of three points on the parabola.

### 1.2.4 Simulator and Program Operation

#### 1.2.4.1 Setup Program

Setting up the **TOM** for the first time is much like any other software. Instructions are sent out with the Internet download package. Simply follow the instructions as the setup installs the **TOM**. **The TOM will run under all Windows Operating Systems**.

The **TOM** will require certain designated directories in order to run.

Files are located within specific directories. The directories and associated files are listed below:

<table>
<thead>
<tr>
<th>Directory</th>
<th>Files</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>c:\tom</td>
<td>Application Directory for TOM</td>
<td></td>
</tr>
<tr>
<td>c:\tom</td>
<td>Executable (.EXE)</td>
<td>Program Files</td>
</tr>
<tr>
<td></td>
<td>Icons</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Auxiliary Files</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Subsystem Model Files</td>
<td></td>
</tr>
<tr>
<td>c:\tom\tomdat\ext</td>
<td>Rail System Database Files</td>
<td>ext = wma, mia etc., rail system file extensions</td>
</tr>
<tr>
<td>c:\tom\TOMMANNEW</td>
<td>Program manual files</td>
<td></td>
</tr>
<tr>
<td>c:\tom\TOMInstructionManuals\tomdat archives</td>
<td>Archives of the data files used in the instruction manuals</td>
<td></td>
</tr>
</tbody>
</table>

The application directory is required to be **c:\tom**.
1.2.4.2 Initiation of the TOM

To initiate the TOM, click on the icon ![Train Operations Model](image) which results in the screen.

![Figure 1-2 TOM Main Screen](image)

Click on
- **TPS** for Train Performance Simulator
- **ENS** for Electric Network Simulator
- **TMS** for Train Movement Simulator
- **FCM** for File Construction Module
- **FMM** for File Manipulation Module
- **ECM** for Energy Cost Module
- **DB** for Database Utility
- **GRAPH** for Graphics Utility
- **Help** for help information
- **Rail Voltage Model** for rail voltage estimates.
Exit to exit program
A rail system may be selected by clicking on the Select Rail System combo box. This feature allows the user to set the rail system for all simulators and modules of the TOM. Clicking the combo box results in the following screen.

Figure 1-3 Selection of a Rail System Mnemonic for the TOM Session
Selection of the TEST rail system results in the following screen.
Figure 1-4 TOM Main Screen After Selection of the TEST Rail System

Click the Save command button to save the selection for the next opening of the TOM. Not clicking the button will start the TOM without a Rail System Selection.

Saving the selection will result in the next screen.
The TOM has the capability of running in English or Metric units.

The TOM is provided with the default units set in advance. Either Metric or English can be specified by the user.

The user can pre-select the desired units for the entire session or select units separately for each module. To pre-select the units for the entire session, select the desired Default Units as shown in the following screen.
Figure 1-6 Selection of the Default Units as English or Metric

Help is available for every screen in the TOM. Clicking the Help command button on the TOM main screen, explains how to get help. The following screen is displayed.
Every screen in the TOM has the following help feature. Clicking the question mark (?) and pointing it to an object on the screen will provide help on that object. More detail on the File Viewer program, which produced this screen, is presented in Section 8.1.

If the screens of the TOM appear funny, with some of the letters cut off of command buttons, it usually means that the computer is not set properly to handle the program. Clicking the top right hand corner (below the X) of the TOM Main Screen will provide advice, as shown in the following screen.
The number of TWIPS per pixel for the present computer is shown in the message. These are usually set by clicking the right mouse button on the desktop, followed by a click on Properties, followed by a click on Settings and/or Appearance. Color should be set at Medium (16 bit) and font size to Normal. After the settings are made, check the TWIPS per pixel for the present computer again, until the correct 15 is obtained in both the vertical and horizontal directions.

The TOM was designed so that the factory settings of most computers will be set correctly.
2 OPERATING THE SIMULATORS

2.1 TRAIN PERFORMANCE SIMULATOR (TPS)

The details concerning input, output, processes and methodology of the Train Performance Simulator are given in Appendix 9.8. The operation of the simulator is outlined here.

The TPS is initiated by clicking on the TPS command button of the TOM screen shown in Figure 1-2. This will cause a screen similar to the following to appear:

![Figure 2-1 TPS Main Screen](image_url)
A rail system is selected from the list either by double clicking on the Rail System Mnemonic (Code) or by clicking once on the designation followed by one click on the Select command button. This modifies the screen as follows:

![Figure 2-2 TPS Main Screen After Rail System Selection](image)

This is the list of files, which contain the filenames of input files to the Train Performance Simulator. These files are contained in the Rail System Directory that was selected. To run the TPS, click on a filename in the list and click on the Select command button or alternatively double click on the filename. To view a file of filenames, click on the filename and then click on the Review command button.
Several files in the list may be selected together. This may be done by holding down the left mouse button and dragging it over the files to be selected if these files appear in successive order. If it is desired to select files not in successive order, hold down the \textless{}<\text{ctrl}\textgreater{} key while clicking on the files. The screen will appear as follows.

![Figure 2-3 TPS Main Screen After Rail System Selection - Running Multiple TPS](image)

If the \textit{Select} command button is clicked with multiple files selected, each of the files will be run successively by the TPS. Double clicking on any file will run the TPS for that file only. Clicking on the \textit{Review} command button with multiple files selected, will display the last file selected in the list.

If no file is selected, and either the \textit{Select} or \textit{Review} command button is clicked, the user will receive an error message.
For a single TPS run, the setup is shown next.

![TPS Main Screen - Setup for Single TPS Run](image)

A click on a single file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

A click on the Select command button or a double-click on the TPS File of Filenames in the file list box executes the TPS.
After the TPS run is complete, the Summary Output file can be immediately viewed by clicking the Yes command button on the final screen shown below.
This will produce the summary results in the File Viewer of the TOM. The File Viewer is part of the DB utility.
Figure 2-7 TOM File View of Completed TPS Run

Clicking the Graphic Utility command button in Figure 2-5 or Figure 2-6 will expose the GRAPH Module. This feature allows the user to immediately view the results of the TPS run with the graphics package, discussed in more detail in Section 7.

Clicking the Database Utility command button in Figure 2-5 or Figure 2-6 will expose the DB Module. This feature allows the user to immediately view the results of the TPS run with the database package, discussed in more detail in Section 6.

Clicking the EXCEL Ready command button produces the next screen.
Figure 2-8 Results of Executing the EXCEL Ready command button

The Clipboard now has information which can be pasted into a table in an EXCEL Spreadsheet. This table has a useful format to be especially used in reports, which the user develops. More detail on the table formats are presented in Appendix 9.21.

A further discussion of the features of this screen appear in Section 8.1.
2.2 **ELECTRIC NETWORK SIMULATOR (ENS)**

The ENS is initiated by clicking the ENS button of the TOM screen shown in Figure 1-2. This will cause a screen similar to the following to appear:

![Figure 2-9 ENS Main Screen](image)

Figure 2-9 ENS Main Screen
A rail system is selected from the list either by double clicking on the Rail System Mnemonic (Code) or by clicking once on the mnemonic followed by one click on the Select command button. This modifies the screen as follows:

Figure 2-10 ENS Main Screen After Rail System Selection

This is the list of files, which contain the filenames of input files to the Electric Network Simulator. These files are contained in the Rail System Directory that was selected. To run the ENS, click on a filename in the list and click on the Select command button or alternatively double click on the filename. To view a file of filenames, click on the filename and then click on the Review command button.

Several files in the list may be selected together. This may be done by holding down the left mouse button and dragging it over the files to be selected if these files appear in successive order. If it is desired to select
files not in successive order, hold down the <crtl> key while clicking on the files. If the Select command button is clicked with multiple files selected, each of the files will be run successively by the ENS. Double clicking on any file will run the ENS for that file only. Clicking on the Review command button with multiple files selected, will display the last file selected in the list. An example of this feature is shown next.

![Electric Network Simulator](image)

If no file is selected, and either the Select or Review command button is clicked, the user will receive an error message.

Figure 2-11 Multiple ENS Operation
A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

The **Save Summary Output** checkbox is shown in the default position; namely, that the summary output will be saved.

A click on the **Select** command button, once a file is slicked or a double click on the file will initiate operation of the **ENS**.
Figure 2-12 ENS Main Screen after File of Filenames is Selected

When the ENS is complete, the following screen is displayed.
Figure 2-13 ENS Main Screen after Simulator has Run

The screen shows the duration of the run. A click on the Yes button produces a TOM File View of simulator output. Summary output can immediately be viewed by clicking on the Yes command button on the screen.
Figure 2-14 TOM File View of ENS Output (Top of File Viewer Screen)

Clicking the **View Summary** command button or scrolling the **File Viewer** screen to the bottom is shown in the next screen.
If saving the Summary Output file is desired, clicking the Save File As command button, will save the file, with the filename specified to the right of the Save File As command button.

Of course, if the Save Summary Output checkbox was checked in the screen of Figure 2-9, the Summary Output file was already saved and there is no need to click the Save File As command button.

The filename is not under the control of the user and uses the ENS File of Filenames name with the prefix SUMS.

Clicking the EXCEL Ready command button produces the next screen.
Figure 2-16 Results of Executing the EXCEL Ready command button

The Clipboard now has information which can be pasted into a table in an EXCEL Spreadsheet. This table has a useful format to be especially used in reports, which the user develops. More detail on the table formats are presented in Appendix 9.21.

Checking the Activate Monitor check box on the ENS screen of Figure 2-9 causes the following Notepad screen to appear. This feature is useful when running the ENS for very large systems. It allows one to check the progress of the simulation as desired.
Following the instructions on the Notepad document, leads to the following screen.

Figure 2-17 Notepad Document Used to Monitor ENS Running

Figure 2-18 Monitor of ENS Running. ENS is running Snapshot at 10:32:40.
2.3 **TRAIN MOVEMENT SIMULATOR (TMS)**

The TMS is initiated by clicking the TMS button of the TOM screen shown in Figure 1-2. This will cause a screen similar to the following to appear:

![TMS Main Screen](image)

Figure 2-19 TMS Main Screen
A rail system is selected from the list either by double clicking on the Rail System Mnemonic (Code) or by clicking once on the mnemonic followed by one click on the select button. This modifies the screen as follows:

Figure 2-20 TMS Main Screen After Rail System Selection

Pre-selection of the rail system TEST on the TOM main screen will result in this screen upon opening of the TMS main screen.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.
The file selected can contain ENS information in which case the ENS is run simultaneously with the TMS. The next two sections discuss running the TMS without ENS and with ENS, respectively.

2.3.1 TMS Without ENS

An input file is selected. This immediately causes the following screen to appear which shows the track and train display together with several user options:

![Figure 2-21 TMS Track and Train Display Screen Before Start](image)

This is the simulator before simulation has started. It represents a 10 main track network, with many types of non-main or connecting track segments. It is used for illustrative purposes, because it contains many of the track segment and node types handled by the TMS.

Much more detailed information is included in Section 9.16 the meaning and philosophy of the approach to train movement simulation used in the TOM. In addition, more information is presented under the FCM – Track Layout File Input in Section 3.3.2.

The TMS graphical screen contains several menus, which include File, Edit, View, State, Action, Train Control, Infrastructure, Simulation and Help. These menu items serve a variety of functions, which are briefly described.

**File** - Includes the following items and functions related to peripherals:
**Start** – Starts the simulation at the first snapshot.
**Restart** – Restarts the simulation at the second snapshot.
**Exit** – Exits the program. No files are saved.

**Edit** - Includes the standard windows editing functions of Select Text, Select Graphics, Select All, Copy and Paste. At any time during the simulation, a click on the Select All item, followed by a click on the Copy item, copies the screen to the clipboard, from which it may be pasted into any other program such as WORD, EXCEL, POWERPOINT, etc. for presentation or preservation purposes.

**View** - Includes the standard window’s type views of Size to Fit and Full Screen, both of which are self explanatory. Use of these functions can sometime cause problems with the simulation and are not recommended.

**State** – Includes the following functions as related to the state of the TMS:

- **Normal Mode** – Enables the Normal State of the TMS, in which trains are running on the system.
- **Switch Set Mode** – Enables the Switch Set State of the TMS, in which switch and crossover position interlockings can be changed.
- **Train Info Mode** – Enables the Train Information State of the TMS, in which information on each of the trains on the screen can be displayed. A click of the mouse on the train will display the train number, ID, length, position (front end), track number, speed, speed command, stop distance, and if the ENS is running simultaneously with the TMS, the train voltage and power.
- **Trk Seg Info Mode** – Enables the Track Segment Information State of the TMS, in which information on each of the track segments(blocks) on the screen can be displayed. A click of the mouse on the track segment will display the segment ID, the end node IDs and positions, the average grade and curvature, the speed command and the segment type.
- **Node Info Mode** – Enables the Node Information State of the TMS, in which information on each of the nodes on the screen may be displayed. A click of the mouse on the node will display the node ID, position and type.

**Action** – Includes the following functions as related to actions by the user:

- **Start** – Starts the simulation at the first snapshot.
- **Proceed One Step** – Moves the trains forward by one time step or snapshot.
- **Blocks Visible** – Enables the track segment endpoints.
- **Blocks Invisible** – Disables the track segment endpoints.
- **Interlocking On** – Enables the interlocking of switches and crossovers
- **Interlocking Off** – Disables the interlocking feature.
- **Advance Time 5 Snapshots** – Advances the simulation time by 5 Snapshots
- **Advance Time 10 Snapshots** – Advances the simulation time by 10 Snapshots
- **Advance Time 30 Snapshots** – Advances the simulation time by 30 Snapshots
- **Advance Time 60 Snapshots** – Advances the simulation time by 60 Snapshots
- **Advance Time 120 Snapshots** – Advances the simulation time by 120 Snapshots
- **Set Time Manually** – Allows the setting of any time, to which the TMS will proceed. The time can be an advanced time or a previous time.
- **End TMS** – Ends the simulator in such a way as to save all output files.

**Train Control** – Includes the following items as related to train control

- **MTC Conflicts On** – Manual Train Control with conflicts recognized setting alarms.
- **MTC Conflicts Off** – Manual Train Control with conflicts ignored.
- **ATC Fixed Block On** – Automatic Train Control with self settings of switch and crossover interlockings.
- **ATC Fixed Block Off** – Automatic Train Control fixed block turned off.
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**ATC Moving Block On** – Automatic Train Control with self settings of switch and crossover interlockings and moving block protection on main track.

**ATC Moving Block Off** – Automatic Train Control moving block turned off.

**Infrastructure** – Includes the following items related to wayside facilities such as passenger stations or stops, substations or tie stations (breaker houses) and current measurement devices.

- **Stations On** – Displays the passenger stations or stops.
- **Stations Off** – Turns the passenger stations or stops display off.
- **Station Information** – Enables information about the passenger stations to be displayed with a mouse click on the station. Information includes station name, position of platform mid-point and platform length.

If the ENS is running with the TMS then:

- **Substations On** – Displays the substations and tie stations (breaker houses).
- **Substations Off** – Turns substations and tie stations (breaker houses) display off.
- **Substation Information** – Enables information about the substations and tie stations (breaker houses) to be displayed with a mouse click on the station. Information includes substation or tie station ID, position, track number and feed voltage.

- **Cur Meas On** – Displays current measurement devices (ammeters) along the track.
- **Cur Meas Off** – Turns current measurement device display off.
- **Cur Meas Information** – Enables information about current measurement devices (ammeters) to be displayed with a mouse click on the device. Information includes device ID, position, track number and current.

**Simulation** – Includes the following items related to simulation environment.

- **Set No Real Time** – Allows the simulator to run as fast as the computer will allow it to run.
- **Set Real Time** – Allows the simulator to run in real time, if the computer runs the simulation faster than real time.
- **Set 60x Real Time** – Allows the simulator to run 60x faster than real time, if the computer runs the simulation faster than 60x faster than real time.
- **Set 30x Real Time** – Allows the simulator to run 30x faster than real time, if the computer runs the simulation faster than 30x faster than real time.
- **Set 10x Real Time** – Allows the simulator to run 10x faster than real time, if the computer runs the simulation faster than 10x faster than real time.
- **Set 5x Real Time** – Allows the simulator to run 5x faster than real time, if the computer runs the simulation faster than 5x faster than real time.
- **Set 2x Real Time** – Allows the simulator to run 2x faster than real time, if the computer runs the simulation faster than 2x faster than real time.

**Help** - Includes the following items.

- **Contents** – Displays the main contents of help available. This display includes more detailed information about the menus and menu items and operation of the TMS.
- **About the TMS** – Lists copyright info on the TMS.

Much more detailed information is included in Section 9.16 on the meaning and philosophy of the approach to train movement simulation used in the TOM. In addition, more information is presented under the FCM – Track Layout File Input in Section 3.3.2.

Several of the of the menu items are now described with the help of illustrations in the following sections.

**2.3.1.1 File Menu**

The following screen shows the TMS screen after a click on the File Menu, exposing the file menu items.
Figure 2-22 The Track and Train Display after a Click on the File Menu

Note that the Restart item is grayed, indicating that this function is not available at this time.

A click on the Start item produces the following screen, on which the trains now make their appearance.
The trains are all stationary at this point in the simulation. Track segments or blocks which are **UNRESTRICTED** are shown in green. **RESTRICTED** track segments are shown in bright red. **OCCUPIED** track segments are shown in dark red. The trains, including their length are shown in white, slightly above the tracks. Later, as the trains are in motion, their stopping distances are shown in dark blue. A train which has a conflict will be shown in yellow.

### 2.3.1.2 State Menu

A click on the State menu produces the following screen.
Figure 2-24 Illustration of the Track and Train Display Screen– The State menu items

The previous screen showed the Track and Train Display Normal State screen. Thus, it is grayed out in this display.

Activation of any of these State menu items will cause the Track and Train Display screen to enable that state. Other states available are Switch Set Mode, Train Info Mode, Trk Seg Info Mode and Node Info Mode.

Working from the bottom up, a click on the Node Info Mode item produces the following screen.
Figure 2-25 Illustration of the Track and Train Display Screen – The State Menu – Node Info Mode Item

The nodes are shown as yellow circles. The track segments lie between the nodes.

A click on any node will show the information on that node as shown in the next screen.
The information shown at the upper left include the node ID, position and node type. If the node is a switch or crossover, the present position of the switch (normal or turnout) or crossover (normal or turnout) is also shown.

A click on the Trk Seg Info Mode item of the State menu produces the following screen.
Figure 2-27 Illustration of the Track and Train Display Screen– The State Menu – Trk Seg Inf Mode Item

The track segments are now shown, by making the endpoints (nodes) visible. A click on any track segment produce the screen which follows.
Figure 2-28 Illustration of the Track and Train Display Screen– The State Menu – Trk Seg Inf Mode Item – Track Segment Information

A click on the track segment provides the following information: Segment ID, Track Number, End Nodes (End Node Positions), Grade, Curve, Least Restrictive Speed Code (Speed Command) and Type of Track Segment.

If the TMS is running under manual train control with conflicts enabled or automatic train control (obtained by clicking the Train Control menu followed by a click on MTC Conflicts On, ATC Fixed Block On or ATC Moving Block On items, the condition of the track segment is also displayed; either UNRESTRICTED OR CLEAR, RESTRICTED or OCCUPIED. This is shown in the next screen.
Figure 2-29 Illustration of the Track and Train Display Screen—The State Menu—Track Seg Inf Mode Item—Track Segment Information with Train Control

In addition to the information presented in the upper left of the screen in Figure 2-27, the condition of the track segment or block is specified.

A click on the State menu followed by a click on the Switch Set Mode item produces the following screen.
Figure 2-30 Illustration of the Track and Train Display Screen – The State Menu – Switch Set Mode Item

Clicking on the switchpoint changes switches. Clicking on the crossover point changes the interlocking of a crossover.

Under the Action menu, there are two items, which are related to changing switch position. These items are Interlocking Off and Interlocking On. With interlocking enabled (clicking Interlocking On – also the default condition), clicking on a switch point involving crossovers or a single adjacent track crossing, will automatically set up the route, by changing the crossovers’ interlocking and changing the other switch. Activation of two turnout sections of a double crossover is not possible with interlocking enabled. The interlocking enabled feature does not allow the changing of crossover interlockings.

With interlocking disabled (clicking Interlocking Off), the position of each switch is changed by a click on the switch point. The next two screens illustrate the features of switching with interlocking enabled and disabled.
Figure 2-31 Illustration of the Track and Train Display Screen – The State Menu – Switch Set Mode Item – Changing Switch Positions with Interlocking Enabled

The next screen shows the interlocking disabled condition.
Figure 2-32 Illustration of the Track and Train Display Screen – The State Menu – Switch Set Mode Item – Changing Switch Positions with Interlocking Disabled

Clicking the Normal Mode item of the State menu, and then advancing the simulation several snapshots by clicking the mouse in the upper right of the screen produces the following screen.
Figure 2-33 Illustration of the Track and Train Display Screen – The State Menu – Normal Mode Item – Advancing the Simulation Several Snapshots by Clicking the Mouse

Provided track segments are not associated with switches or crossovers or OCCUPIED (dark red), blocks may be changed from bright green (UNRESTRICTED or CLEAR) to bright red (RESTRICTED) or visa versa, by clicking the mouse button on the track segment.

Nodes are shown as yellow circles if they’re not switch or crossover points. Switch points are shown as white circles. Crossover points are shown as bright purple circles. Main track segments are shown horizontally, while non-main track segments are shown skewed.

Changing the condition of a track segment or block is shown in the next screen.
Figure 2-34 Illustration of the Track and Train Display Screen – The State Menu – Normal Mode Item – Changing the Condition of a Track Segment or Block

A second click on the same track segment would change it back to UNRESTRICTED or CLEAR.

A click on the Train Info Mode item in the State menu produces the following screen.
Figure 2-35 Illustration of the Track and Train Display Screen – The State Menu – Train Info Mode Item

Clicking on a train will produce the pertinent information on that train as shown in the next screen.
Figure 2-36 Illustration of the Track and Train Display Screen – The State Menu – Train Info Mode Item – Train Information Display

For trains, which run on fuel, carried with them, the rate of fuel consumption is also displayed, together with the present rate of fuel consumption for all trains running on the network. Clicking the Fuel Consumption Check box on the Track Layout File Input screen in Figure 3-286 activates this function.
To leave any of the static states of the simulation, which are Set Switch Mode, Train Info Mode, Node Info Mode and Trk Seg Info Mode, it is necessary to return to the Normal Mode state. This is accomplished by clicking the **Normal Mode** item in the **State** menu. The next screen shows the result.
Although items in the Action menu have already been used, these items are now discussed in more detail.

### 2.3.1.3 Action Menu

In the **Normal Mode** state, a click on the **Action** menu produces the following screen.
Figure 2-39 Illustration of the Track and Train Display Screen – The Action Menu

The Action menu has the following items.

- **Start** – Now grayed because simulation has started.
- **Proceed One Step** – Advances the simulation by one snapshot.
- **Nodes Visible** – Now grayed because nodes are visible. If the nodes were not visible, clicking this item would make them visible.
- **Nodes Invisible** – Click this item to make the nodes invisible.
- **Interlocking On** – Enables interlocking of switches and crossovers for obvious routes. Item is now grayed until Set Switch Mode in State menu is selected.
- **Interlocking Off** – Disables interlocking of switches and crossovers for obvious routes. Item is now grayed until Set Switch Mode in State menu is selected.
- **Advance X Snapshots** – Several menu items allow the simulation to advance X snapshots, when clicked.
- **Advance to End** – Advances the simulation to the end time as specified in the Operating Time file.
- **Set Time Manually** – Allows the user to enter a time (which may be a previous time) to which the simulator advances or returns.
- **End TMS** – End the simulation by saving all output files, in contrast to the Exit item of the File menu, which ends the simulator without saving any output files.

Clicking the **Proceed One Step** item of the Action menu results in the following screen.
The simulation advances one snapshot.

Clicking the Nodes Invisible item of the Action menu results in the following screen.
Figure 2-41 Illustration of the Track and Train Display Screen – The Action Menu – Nodes Invisible Item

The nodes are no longer visible. The nodes can be made visible again by choosing the Nodes Visible item in the Action menu or by selecting either the Trk Seg Info Mode item or Node Info Mode item in the State menu.

Clicking the Advance Time 10 Snapshots item of the Action menu advances the simulation by ten snapshots as shown in the next screen.
Similar action occurs when any of the Advance Time X Snapshots items of the Action menu are chosen. The simulation will advance by X snapshots.

Notice that the train on track 8 has advanced into a RESTRICTED track segment. This has occurred because the present operation of the simulator is under manual train control with the conflicts disabled. These settings appear in the Train Control menu, and are discussed later.

Choosing the Advance to End item of the Action menu results in the following screen.
Figure 2-43 Illustration of the Track and Train Display Screen – The Action Menu – Advance to End Item

In this case, the simulation advances to the end time specified in the Operating Time file. Clicking the mouse in the upper right of the screen or selecting the Proceed One Step item of the Action Menu results in the following screen.
Figure 2-44 Illustration of the *Track and Train Display Screen* – The *Action Menu* – *Advance to End Item* – *One Snapshot Beyond the End*

Clicking the mouse again in the upper right of the screen or selecting any of the *Advance Time X Snapshots* items in the *Action* menu or the *Proceed One Step* item in the *Action* menu of this screen will result in the following screen.
Figure 2-45 Illustration of the *Track and Train Display Screen* – The *Action Menu* – *Advance to End Item* – *End Time Simulator Alarm*

Clicking **OK** on the alarm will close the simulator and save all output files, as if the **End TMS** item of the *Action menu* was selected.

This same screen would appear if any of the **Advance Time X Snapshot** items of the *Action menu* were selected previously in the screen of Figure 2-42.

Clicking the **Set Time Manually** item of the *Action menu* in the screen of Figure 2-42 produces the following screen.
If the time entered is before the start time of the simulation, the simulator will revert to the second snapshot of the simulation. This is the same effect as if the Restart item of the File menu were selected. All simulator settings are preserved, i.e. switch settings, track segment settings, etc.

If the time entered is beyond the end time of the simulation, the simulator will run to the end time and produce the screen of Figure 2-44. It will then close and save all output files.

Both the start and end times of simulation are specified in the Operating Time file.

If the time entered is previous to the present simulation time and not before the start time of the simulation, the simulator sets the trains where they would be at the previous time, leaving all other simulator settings the same as in the present time.

If the time entered is beyond the present time and not after the end time of simulation, the simulation is run to the future time in the same manner as if the Advance Time X Snapshots item of the Action menu were selected.

The next screen shows a setting for the Set Time Manually item of the Action menu. This setting is previous to the present time and is entered by first clicking the setting text box of the dialog box and then entering the time in the correct format of hh:mm:ss, as shown in the next screen.
Figure 2-47 Illustration of the Track and Train Display Screen – The Action Menu – Set Time Manually Item – Previous Time Entered

Clicking the OK button in the dialog box results in the next screen.
The simulator is now set at the previous time.

Clicking the End TMS item of the Action menu at this time would close the simulator and save all output files which would include the simulation up to the previous present time. In other words, no information is lost. Note that when running the ENS along with the TMS, the resulting ENS output files would not be valid, because they contain records from previous histories. The only way that the ENS output files would be valid is for the simulation to move from the start time to some present time and never go back to any previous time. In this case, the ENS output files would be valid to that present time even if it is less than the end time of the simulation as specified in the Operating Time file.

Leaving the Action menu, the Train Control menu is now discussed.

### 2.3.1.4 Train Control Menu

Clicking on the Train Control menu produces the following screen.
Train control refers to the control of a system of trains on a track network. Train control can be manual or automatic.

Manual train control (MTC) requires that the dispatcher or operator of a train manually set routes by setting switches and crossover interlockings. In terms of the TMS, the user is the dispatcher or operator. One feature that the simulator has, which is not present in real train networks, is the ability to run through switches and crossovers with opposing settings. When the simulator begins, this is the default case. MTC can also be accomplished with a fixed block system of protection. Under fixed block systems, a train may not enter an OCCUPIED track segment or a RESTRICTED track segment (train rule). In TMS terminology, this is the MTC with Conflicts enabled. As trains move, conflicts, which are potential violations of the train rule, are sensed and the user is alerted by an alarm. The user then responds with some action, such as setting a switch, or ending the simulation to resolve a conflict. Resolving a conflict outside of the TMS generally requires the user to introduce a time delay between two or more trains by changing timetables, speed restrictions or commands and/or passenger station dwell times. Track segment end positions may also be modified to resolve conflicts. Section 2.3.4 will discuss this whole problem in more detail.

Automatic train control (ATC) can involve intervention by the dispatcher or operator, but normally routing is done automatically. ATC can be of two types: fixed block and moving block.

Under fixed block systems, a train may not enter an OCCUPIED track segment or a RESTRICTED track segment. As trains move, conflicts are sensed and resolved automatically within the TMS. Conflicts, which cannot be resolved within the TMS, result in an alarm to the user, who then must resolve the conflict outside of the TMS. Again, resolving a conflict outside of the TMS generally requires the user to introduce
a time delay between two or more trains by changing timetables, speed restrictions or commands and/or passenger station dwell times. Track segment end positions may also be modified to resolve conflicts. Section 2.3.4 will discuss this whole problem in more detail.

In contrast to fixed block ATC, moving block ATC changes the conflict detection system on main track segments. Track segments, which are parts of switches and crossovers, still operate under fixed block conflict detection. With moving block ATC and on main track, the distance between a train and an approaching train is used as the criteria for conflict detection, rather than the distance between an approaching train and an OCCUPIED track segment, as is the case with fixed block ATC. In other words, since the zone of protection is the stop distance of the approaching train, for moving block protection, if the front or rear end of a train is within that stop distance, a conflict occurs and must be resolved. In the case of fixed block protection, if the end of an OCCUPIED track segment is within that stop distance, a conflict occurs and must be resolved.

Clicking the MTC Conflicts On item of the Train Control menu produces the following screen.

Figure 2-50 Illustration of the Track and Train Display Screen – The Train Control Menu – MTC Conflicts On
Clicking the mouse several times on the upper right of the screen to advance train movement or using any advance time item in the Action menu produces the following result after several snapshots.
A conflict has been detected. The train involved is now colored yellow instead of white. The conflict is the detection of an approach to a RESTRICTED track segment, which is the turnout of a transition switch. This track segment is within the stopping distance of the approaching train.

To resolve the conflict, the position of the switch must be changed. Clicking OK on the Alarm dialog results in the following screen.
To remove the conflict click the State menu followed by a click on the Set Switch Mode item. This action results in the following screen.
Figure 2-53 Illustration of the Track and Train Display Screen – The Train Control Menu – MTC Conflicts On – Conflict Condition Remains – Switch Set Mode Enabled

Changing the switch, choosing the Normal Mode item of the State menu and clicking the mouse on the upper right of the screen results in the following screen.
Figure 2-54 Illustration of the Track and Train Display Screen – The Train Control Menu – MTC Conflicts On – Conflict Resolved

Clicking the ATC Fixed Block On item of the Train Control menu and advancing time several snapshots results in the following screen.
As the train on track 8 proceeds, the stop distance detector detects that the crossover on track segment 7 has the wrong interlocking. For one snapshot, the train changes from white to yellow indicating a conflict. However, no conflict alarm is produced on the screen since under ATC the interlocking is automatically changed. The next snapshot causes the train to become white again, indicating that the conflict is resolved.

Operation under moving block ATC produces the same result. Choosing ATC Moving Block item of the Train Control menu puts the simulator into that type of operation. The difference can be illustrated on main track segments by using a simple single track system, shown next.
As the trains move closer together in the final approach, the next two screens illustrate the difference between moving and fixed block ATC.
In this case, the train to the right detects the track segment occupied by the train to the left. This action sets off the conflict alarm. In the case of a moving block ATC, the next screen illustrates the difference.
In this case, the train on the left first detects the front end of the train to the right and initiates the conflict alarm. This conflict cannot be resolved in the TMS.

The next three screens illustrate the difference between moving and fixed block ATC with one train overtaking another.
As the trains move closer together in the final overtake, the next two screens illustrate the difference between moving and fixed block ATC.
In this case, the train to the left detects the track segment occupied by the train to the right. This action sets off the conflict alarm. In the case of a moving block ATC, the next screen illustrates the difference.
In this case, the train on the left first detects the rear end of the train to the right and initiates the conflict alarm. This conflict cannot be resolved in the TMS.

The items of the Train Control menu are interlocked, so to speak. The following table illustrates the interlocking.

<table>
<thead>
<tr>
<th>Item</th>
<th>MTC Conflicts</th>
<th>ATC Fixed Blocks</th>
<th>ATC Moving Blocks</th>
</tr>
</thead>
<tbody>
<tr>
<td>MTC Conflicts Enabled</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>ATC Fixed Blocks Enabled</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
</tr>
<tr>
<td>ATC Moving Blocks Enabled</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td>MTC Conflicts Disabled</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>ATC Fixed Blocks Disabled</td>
<td>ON or OFF</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>ATC Moving Blocks Disabled</td>
<td>ON or OFF</td>
<td>ON or OFF</td>
<td>OFF</td>
</tr>
</tbody>
</table>

Thus the hierarchy of train movement under train control proceeds from the highest to lowest as: ATC Moving Blocks → ATC Fixed Blocks → MTC Conflicts → MTC No Conflicts (Default on Start)

Running with MTC Conflicts or ATC will produce an Alarm output file (TMA*.ext). This file reports all of the conflicts and the resolution actions. This file is named in the File of Filenames Input File for the TMS, which is described in Section 3.3.1.
After running the example shown in Figure 2-22, the Alarm file can be viewed in the file viewer as shown in the following screen.

![Figure 2-62 Example of Alarm Output File for the TMS](image)

As the conflicts and conflict resolutions are encountered, they are recorded in this file.

### 2.3.1.5 Infrastructure Menu

Certain items of wayside infrastructure can be displayed on the Track and Train Display screen once simulation has started. These items include passenger stations and for the case of the TMS running with the ENS, substations and tiestations and current measuring devices. The items available are shown in the next screen.
Figure 2-63 Illustration of the Track and Train Display Screen – The Infrastructure Menu

Note that this is the case for running the TMS without the ENS. The items involved with the ENS are discussed in Section 2.3.2.5.

Passenger stations may be displayed and information about them obtained by clicking on the display. This feature is only available if the user constructs a Station Description file (SD-*.*). This construction is possible using the FCM. Section 3.3.3 provides the methodology for creating this file.

To display the passenger stations, the SD file must be added to the list of files in the TMS file of filenames. This process can be accomplished using the FCM as well. See Section 3.3.1.

The passenger stations may only be displayed after train movement has started. To display the passenger stations, click the Infrastructure menu and then click the Stations On item. The result will be a display of the passenger stations.
Figure 2-64 Illustration of the *Track and Train Display Screen* – The *Infrastructure Menu* – Stations On Item

Displaying the *Infrastructure* menu at this point results in the following screen.
The passenger station display may be removed by clicking the Stations Off item. Clicking the Station Information item followed by a mouse click on one of the passenger stations produces the following display.
2.3.1.6 Simulation Menu

The simulation environment is the condition under which the TMS is running. The condition is the time as related to real time. Several choices are available to the user.

Choices available are: No choice, real time choice and several faster than real time choices. To access the choice, click the Simulation menu followed by a click on the appropriate choice.

The choice No Choice allows the simulator to run at full computer capability. For fast computers and depending on the complexity of the train network, full capability may itself be less than real time, in which case the chosen selection would be irrelevant.

The choices will affect the advancing time and setting time functions under the Action menu. Once the advanced or setting time selections are made, the user is committed to waiting out the simulation for that time interval.

In some cases and on some computers, the slower choices may not work. This is especially true if the computer is slow and the train network is large.
To abort, two successive clicks on the x in the top right corner of the screen are required. This completely aborts the TMS portion of the model. It must be restarted from the TMS main screen.

Clicking the Simulation menu produces the following screen.

![Figure 2-67 Illustration of the Track and Train Display Screen – The Simulation Menu](image)

Clicking on one of the choices will set the simulator to run in real time close to that choice provided it is possible.

### 2.3.1.7 Help Menu

This Help is designed to guide the user through the simulation process on the following how to do: moving trains, setting blocks and switches, obtaining train and train control information and electrification parameters, conflict alerts, conflict resolution and several other topics.

A click on the Help menu produces the following screen.
Figure 2-68 Illustration of the Track and Train Display Screen – The Help Menu

A single choice is available: Contents

Clicking on the Contents item of the Help menu produces the following screen.
Figure 2-69 Illustration of the Track and Train Display Screen – The Help Menu – Contents Item
Clicking on the button of the Content item for which help is desired, say for example, the Zoom Feature button, the following screen appears.
Figure 2-70 Illustration of the Track and Train Display Screen – The Help Menu – Contents Item – Zoom Feature Content Button

Clicking the OK button will return to the Contents item screen of Figure 2-68. Clicking the OK button of that screen will result in the previous screen, which is shown next.
2.3.1.8 Zoom Feature

The zoom feature allows the user to "zoom in" on the track layout, horizontally, or in the position direction. No zooming feature is available, or needed for the main track number direction. The zoom feature is available in all modes of operation. To zoom, place the cursor in the area above the track layout, hold the left mouse button down drag it in the positive position direction (left to right), and then release the button.

The "zoomed" track layout will be approximately the area covered by the dragged mouse.

To return to the normal position, hold the left mouse button down and drag the mouse anywhere above the track layout area, from left to right.

An example of zooming is shown with the help of the Washington Metro (WMATA) Blue-Orange-Yellow lines. When the TMS starts simulation, the WMATA screen with nodes made visible and passenger stations displayed looks as follows.
This is the layout of the Washington Metro Blue-Orange-Yellow lines as it was a few years ago. Track numbers begin at the top and read downward.

From left to right the Orange Line is tracks 3&4. From left to right, the Blue Line is Tracks 5&6 then Tracks 3&4 and then again Tracks 5&6. From left to right the Yellow Line is Tracks 5&6 and then Tracks 7&8.

The Blue Line merges with the Orange Line at C/L Junction and D/G Junction, while the Yellow Line merges with the Blue Line at C/K Junction.

The zoom feature is applied between C/K Junction and C/L Junction resulting in the following screen.
Figure 2-73 Illustration of the Track and Train Display Screen – WMATA Blue-Orange-Yellow Lines At Start of Simulation – Zoom Feature Applied Between Junctions

A finer zoom can be applied in the area of C/K Junction and is shown in the following screen.
Figure 2-74 Illustration of the Track and Train Display Screen – WMATA Blue-Orange-Yellow Lines At Start of Simulation – Zoom Feature Applied At Junction

The zoom feature is especially handy to observe conflicts at complex interlockings at junctions.

2.3.1.9 TMS Ending

There are two ways to end the TMS.

Select the Exit item on the File menu.
Select the End TMS item on the Action menu.

Ending the TMS using the Exit item on the File menu aborts the simulation without saving output files. This ending method is usually executed during conflict resolution, where there is no need to keep output files.

The second ending, End TMS item on the Action menu saves the output files. Executing this method for the run TMS-A.tes, after the simulation has reached its end, results in the next screen.
Figure 2-75 Ending a TMS Without ENS by Executing the End TMS item of the Action menu
Clicking the Yes command button to review the Summary Output results in the next screen.
Figure 2-76 Summary Output File when Ending a TMS Without ENS

Clicking the View Alarm File command button of the screen in Figure 2-74 result in the next screen.
Figure 2-77 Example of Alarm File

This TMS was conducted with an Automatic, Fixed Block train control, so that all conflict resolution is completed automatically.
2.3.2 TMS With ENS

Running the TMS with ENS means that the trains run using electric power and electric network simulation is conducted simultaneously with train movement. Only the features, which are pertinent to running the ENS simultaneously with the TMS, are discussed in this section. These features are in addition to the features discussed in the previous Section (2.3.1).

Choosing a File of Filenames for the TMS with ENS capability is required, and this action is accomplished by selecting a file on the TMS screen. This file must contain a Network input file and may contain a Current Measurement (Cur Meas) input file. The TMS main screen, with the choice of a File of Filenames, which has ENS capability is shown next.
Starting the simulation produces a screen, which is slightly different from running without ENS. Clicking the **Start** item in the **File** menu (or alternatively clicking the **Start** item in the **Action** menu) followed by a click on the **Nodes Visible** item of the **Action** menu produces the following screen.

### 2.3.2.1 File Menu

Clicking the Select command button will open the **Track and Train Display** screen of the TMS.

Figure 2-78 TMS Main Screen After Rail System Selection (ENS Capable File Chosen)
Two items have been added to the Time entry at the top left of the screen. These items or the electric power (POWER) and minimum voltage (MIN VOLT) experienced in the electric network feeding the trains. The minimum voltage will occur at one of the trains and the electric power is the coincident reading of all of the electric meters on the system.

2.3.2.2 State Menu

The train information display is different when running with ENS. Clicking the Train Info Mode item of the State menu and then clicking the mouse on a train produces a display, which is illustrated in the next screen.
2.3.2.3 Action Menu

All of the items in the Action menu are the same when running the TMS with ENS. However, the End TMS item of the menu produces a different result as is shown in the next few screens.

After the simulation is allowed to run to the end time, clicking the End TMS item of the Action menu produces the following screen.
Clicking the Review Summary Output Yes command button will display the following file.
Scrolling the File Viewer to the bottom or clicking the View Summary command button produces the following screen.

Figure 2-82 TOM File View of TMS With ENS Output (Top of File Viewer Screen)
Figure 2-83 TOM File View of TMS With ENS Output (Bottom of File Viewer Screen)

Running the TMS without ENS can be done under one of two applications. The first application is without any energy content and this run produces the following screen under the same circumstances.
The second application is to run the TMS on a rail system using fuel rather than an electric rail system. The results are shown below.
2.3.2.4 Train Control Menu

There are no additional features when running the TMS with ENS in the Train Control menu.

2.3.2.5 Infrastructure Menu

A click on the Infrastructure menu in the screen of Figure 2-78 produces the following screen.
There are two additional menu items that have been enabled when the TMS runs with ENS: Substations On and Cur Meas On.

Clicking the Substations On item produces the following screen.
The substations and tiestations (breaker houses) feeding the catenary, trolley or third rail and ground return are shown. The substations are shown in yellow and the tiestations in gray.

Clicking the **Infrastructure** menu again, produces the following screen.
Figure 2-88 Illustration of the Track and Train Display Screen with ENS – Infrastructure Menu After Substations On Item Was Selected

Two additional items appear: Substations Off and Substation Information.

Clicking the Substations Off item returns one to the previous screen of Figure 2-78.

Clicking the Substation Information item enables the substations and tiestations to provide information as illustrated in the following screen.
The substation or tiestation name (ID), position and the track number it is feeding and the voltage at the feed point is displayed. Note that when a single substation or tiestation has several track feed points, the symbol is repeated for each of them.

After obtaining all of the information, return to the train movement or Normal Mode state by either clicking the Substations Off item of the Infrastructure menu or the Normal Mode item of the State menu. In the latter case, the substations will remain on while simulation time is advanced, while in the former it will not.

Clicking the Normal Mode item of the State menu, followed by a click on the upper right hand of the screen will advance train movement one snapshot and the result is the following screen.

---

**Figure 2-89 Illustration of the Track and Train Display Screen with ENS – Infrastructure Menu After Substations On Item Was Selected – Display After Clicking On a Substation**
Figure 2-90 Illustration of the Track and Train Display Screen with ENS – Infrastructure Menu After Substations On Item Was Selected – Advancing Time by One Snapshot

The same result could be obtained by clicking the Substations Off item and then by clicking the Substations On item of the Infrastructure menu, followed by a click on the top right of the screen or by clicking the Substations Off item and then by clicking the Substations On item of the Infrastructure menu, followed by a click on the Proceed One Step item of the Action menu.

Clicking the Car Meas On item of the Infrastructure menu activates the Ammeters as shown in the following screen.
Figure 2-91 Illustration of the Track and Train Display Screen with ENS – Infrastructure Menu After Substations On Item and Car Meas On Items Were Selected

The Zoom feature is now used to obtain a better view of the ammeters, which are shown as dark purple circles in the next screen.
Figure 2-92 Illustration of the **Track and Train Display Screen with ENS – Infrastructure Menu After Substations On Item and Cur Meas On Items Were Selected – Zoomed View**

Note that an ammeter has been placed on the third rail, trolley or catenary on each side of the substations and tiestations of the main tracks. Although ammeters can be placed on non-main or connecting track segments, they will not be displayed.

Placing the ammeters like this for every substation and tiestation is good practice, especially on complicated networks, for it is a powerful aid in determining whether the electric network is completely connected, or where the user thinks everything is positioned.

Ammeters not appearing in the first snapshot means that no electric lines are present. Also, if the simulator fails, clicking the **Yes** button on the **TMS Main** screen will provide information as to what electric lines may be missing or what ammeters may be missing.

Clicking on the **Infrastructure** menu produces the following screen.
Figure 2-93 Illustration of the Track and Train Display Screen with ENS – Infrastructure Menu After Substations On Item and Cur Meas On Items Were Selected – Zoomed View – Display of Infrastructure Menu

Note that two new items are now enabled: Cur Meas Off and Cur Meas Information. Clicking the Cur Meas Off item will cause the ammeters to become invisible.

Clicking the Cur Meas Information item produces the following screen.
Figure 2-94 Illustration of the Track and Train Display Screen with ENS – Infrastructure Menu After Substations On Item and Car Meas On Items Were Selected – Zoomed View – Display of Infrastructure Menu – After Car Meas Information Item Is Selected

Clicking on an ammeter will produce information on that ammeter. This action is illustrated in the following screen.
2.3.2.6 Simulation Menu

There are no additional features when running the TMS with ENS in the Simulation menu. The TMS with ENS runs slower, so that less of the real time features will be present.

2.3.2.7 Help Menu

There are no additional features when running the TMS with ENS in the Help menu. The ENS portion of the Help features is present in both cases.

2.3.2.8 Zoom Feature

There is nothing additional when running the TMS with ENS in the Zoom feature. Both Substations and Tiestations and Ammeters are zoomed in the position direction at the same scale.
2.3.9.9 TMS Ending

There are two ways to end the TMS.
Select the Exit item on the File menu.
Select the End TMS item on the Action menu.

Ending the TMS using the Exit item on the File menu aborts the simulation without saving output files. This ending method is usually executed during conflict resolution, where there is no need to keep output files.

The second ending, End TMS item on the Action menu saves the output files. Executing this method for the run TMS-Ae.tes, after the simulation has reached its end, results in the next screen.
Figure 2-96 Ending a TMS With ENS by Executing the End TMS item of the Action menu

Clicking the **Yes** command button to review the **Summary Output** results in the next screen.
Figure 2-97 Summary Output File when Ending a TMS With ENS

If saving the Summary Output file is desired, clicking the Save File As command button, will save the file, with the filename specified to the right of the Save File As command button.

The filename is not under the control of the user and uses the TMS File of Filenames name with the prefix SUM$.

Clicking the EXCEL Ready command button produces the next screen.
Figure 2-98 Results of Executing the EXCEL Ready command button

The Clipboard now has information which can be pasted into a table in an EXCEL Spreadsheet. This table has a useful format to be especially used in reports, which the user develops. More detail on the table formats are presented in Appendix 9.21.
2.3.3 TMS On Non-Electric Mainline or Commuter Railroads

The TMS is a powerful tool for fuel management on non-electrified mainline or commuter railroads. Fuel consumption is measured, when the TMS runs with fueled locomotives or cars.

The next screen shows the layout of a 250 mile freight railroad.

Figure 2-99 Track Layout of 250-Mile Freight Railroad

The start of the simulation is shown on the next screen, which has been zoomed.
Figure 2-100 Train Movement Simulation – Fuel Consumption Rate at Each Snapshot

The fuel consumption rate for all trains on the system in gal/hr is shown at the top left.

With the Train Information item of the State menu selected, the fuel consumption rate of each train can be determined. An example is shown on the next screen.
2.3.4 Conflict Resolution With The TOM

The main purpose for running the TMS is conflict detection and resolution.

A conflict occurs when two trains attempt to occupy the same track area at the same time or a train attempts to maneuver thru a switch set to the opposing move. Conflict alert is the process by which the user is alerted if a conflict occurs.

A click on the Action menu followed by a click on the Conflicts On item turns conflict alert on even under Manual Train Control (MTC). A conflict alarm will appear if a conflict occurs. A click on the Action menu followed by a click on the Conflicts Off item disables the alarm. For ATC with both Fixed and Moving Block, the conflict alarm is on, but switch and crossover interlockings are set automatically. It is only when conflicts cannot be resolved automatically, that the user is alerted.

Conflict resolution is a process of eliminating train conflicts. In terms of TMS terminology, train conflicts occur when a train senses that it is about to enter a RESTRICTED or OCCUPIED track segment.
If the conflict can be resolved by changing a switch or crossover interlocking or changing a track segment from RESTRICTED to UNRESTRICTED, it is considered a temporary conflict and can be resolved within the TMS.

If the conflict cannot be resolved within the TMS, it means that another train is causing the conflict, either by directly influencing the train in question or by impeding a switch or crossover change.

In the latter case, the conflict is resolved by introducing delay between the two trains. Changing the timetable, changing dwell times at stations, introducing other stops can do this or changing speed limits or speed commands. There are other ways to change delay, which are probably less useful, and these are accelerating and braking rate changes and coasting. If there is a desire to reduce power, coasting may be a serious consideration.

Timetable changes are made directly in the Train Location file.

Speed restriction or speed command changes are done using the Speed Restriction file or Speed Command file for either or both trains.

Dwell time changes and additional stops are done using the Station file for either or both trains.

Change of accelerating and braking rates and coasting are done using the Control file.

With the exception of timetable changes, all of the above changes involve rerunning the TPS with the changed files.

A second way to resolve conflicts is by modifying the Track Layout file, either by modifying, adding or subtracting nodes on main track segments or by changing the interlocking lengths on switches or crossovers in the vicinity of the conflict.

The steps taken to resolve conflicts outside the TMS are as follows:

- Use the TMS to detect the conflict with ATC.
- With MTC Conflicts Off, determine the amount of delay required between or among conflicting trains.
- Use alternative methods for resolving conflicts within the transportation authority’s constraints.

For electric trains, determine the energy cost or savings for eliminating the conflict by the different means.

For non-electric mainline railroads or commuter rail, it is possible to determine strategies of conflict resolution, which optimize fuel consumption. This provides a tool for fuel management.
3 FILE CONSTRUCTION MODULE (FCM)

The File Construction Module (FCM) is a series of computer programs which interact with the user to transform raw rail system data into files which can be accepted as input to the other simulators and modules of the TOM. The module is called by clicking on the FCM button of the TOM screen in Figure 1-2.

Figure 3-1 FCM Main Screen Before Rail System Selection

A rail system is selected by double clicking on the mnemonic or by a single click on the mnemonic followed by a click on select. This results in the following screen.
Pre-selection of the rail system TEST on the TOM main screen will result in this screen upon opening of the FCM main screen.

The FCM is divided into six parts, five of which correspond to TPS, ENS, TMS, ECM and RVM input. The sixth part is connected with the Subsystem Models button. The five parts of the FCM are listed in the screen and can be selected by the user by checking the appropriate box. A click on the Close button closes the module and returns the user to the previous screen.

3.1 **INPUT FOR THE TPS**

A click on the TPS Input box of the screen shown in Figure 3-2 allows the user to select the construction of one of the following input files for the TPS as shown in the following screen.
The following files may be selected:

- **Fnames** - TPS File of Filenames Input
- **Control** - TPS Control Input
- **Train** - TPS Train Input
- **Station** - TPS Station Input
- **Grade** - TPS Grade Input
- **Curve** - TPS Curve Input
- **Spd Res** - TPS Speed Restriction Input
- **Spd Cmd** - TPS Speed Command Input
- **Route** - TPS Route Input

A double click on the appropriate file selection causes the selected filename to appear in the box above the choices and produces screens, which lead the user to create the appropriate file.
3.1.1 TPS File of Filenames Input

Selection of Filenames in the screen produces the following screen.

![Figure 3-4 File of Filenames File for TPS Input](image)

This screen is used to create the TPS File of Filenames Input. Three buttons are visible in the center of the screen: View One, Select One and Delete One. A list of filenames, contained in the database of the transportation system selected, is above these buttons. A single click on one of the filenames in the selection list highlights that file. The file may then be viewed, selected or deleted.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

Clicking on the button View One produces the following TOM File Viewer screen:
A click on X or Close will close the view of the file. A click on Exit will exit the TOM.

A click on the Select One button of Figure 3-4 imports the file into the screen for editing:
Figure 3-6 File of Filenames file for TPS Input Selected

The file can now be edited using the editing features of the TOM.

Clicking on the Delete One button activates the delete feature. A prompt comes up to ask the user if he really means to delete the file, to which he may respond Yes or No.

To edit the file of filenames, which has been selected, the following procedure is used. To change an input file in the file of filenames, simply click on the selection to be changed in Input File Type list in the upper right of the screen. For example, a click on Station File produces the screen:
Figure 3-7 Change the Station File in the File of Filenames

A new station file may be selected from the list of available files by clicking on the selection followed by a click on the Select One button, or alternatively a double click on the selection.

A click on a file name in the file list box followed by a short mouse movement over the list box causes the caption of the file to be displayed in the tool tip text.

A click on a file name in the Input File Name box followed by a short mouse movement over the list box causes the caption of the file to be displayed in the tool tip text. A click with the right mouse button causes the file to be displayed in the File Viewer from which it can be edited by clicking the Edit command button in the File Viewer.

Items in the File Caption, Output Filenames and Name of File boxes can be changed using standard windows editing procedures. To eliminate any type of output file simply click on the appropriate select box under Output Files Desired. The editing procedure, which was just described, can also be used to create a file from scratch. Using the screen of Figure 3-4, and selecting grade input file under the Input File Type, followed by a double click on the file gr-e1.tes in the Select From list, the following screen appears.
Follow this same procedure to build all of the input files for the file of filenames.

The output files are selected by clicking on one or more of the Output Files Desired check boxes, which enters a x mark in the corresponding box. For example, checking the Detailed box produces the following screen.
Figure 3-9 Add a Detailed Output Filename File in the File of Filenames

The detailed filename can now be edited with the mouse and keyboard to select the desired filename. Likewise the file caption can be added in the File Caption box and editing the appropriate box can set the Name of File. A completed screen for the file of filenames for TPS input is shown next.
Figure 3-10 Completed Screen for the File of Filenames for TPS Input

Click the Create File command button to finish the job. This action results in the following screen.
Figure 3-11 Completed Job for the File of Filenames for TPS Input

Clicking the Yes button gives the user a TOM File View of the file just created.

The file created can be immediately executed by clicking the TPS command button on the screen.
This file of filenames for TPS input is now of the form readable to the TPS.

The procedure just described for creation of the File of Filenames for TPS Input is the same procedure that is used to create any input file to the model. The user will be referred to this procedure when creating and editing input files. It is also useful to note that files may be edited directly from the TOM File Viewer display of the file.

Clicking the Edit button, will bring up the screen for any input file, ready for editing.

Clicking the Copy to Notepad or Copy to Clipboard buttons and then editing can also result in modifying an input file. However, this is not recommended unless the user is willing to take the time to be extra careful on the format. Editing in this manner will not allow the file created to be placed in the Rail System Database. The formats of input files created through use of the FCM are always acceptable to the computer programs of the model.

There are two other buttons on the many of the screens, which deserve comment. The Reset button completely resets the screen, starting from scratch. It is best used when problems arise and the user can no longer fix them. The Close button closes the program and returns the user to the next higher level screen. More detail is available on the TOM File Viewer in Section 8.1.

3.1.2 TPS Control Input

Selection of Control in the screen of Figure 3-3 produces the following screen.
A list of control files in the database for the rail system selected is shown at the left and middle of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

Selection of the Name of File to be created or modified is at the left and bottom of the screen. This is edited in the usual window manner.

The Control file can have input units, which are either English or Metric and output units, which are either English or Metric. This is selected by checking the appropriate box at the left of the screen. A description for the kind of units expected is given in Section 9.3.

The TPS Input/Output Units combo box controls the units for TPS input and output. The TPS can be run with input files in either English or metric units. If the input files are in English units, the output can either be in English units (Eng/Eng) or metric units (Eng/Met). If the input files are in metric units, the output files can only be in metric units (Met/Met).
At the top of the screen, there are three check boxes: Detailed Output Selection, Coasting and Brake Taper. Checking any one of these boxes will lead to sub screens of the main screen.

**Detailed Output Selection** is the choice for selection of the output in the detailed output file of the TPS. Click on this to determine the choices. **Coasting** is a no power condition on the train (no power/no brake). If coasting is to be enabled, click here.

Click the **Brake Taper** to enter the data for a brake taper. A brake taper is the variation of brake rate with speed. It is usually required with DC Motors. This taper is due to the commutation limits of the D.C. motor when delivering high current at high voltage as is done in high speed electrical braking. Thus the electrical braking force at high motor speed is generally reduced. This is reflected by setting the braking rate to be a function of speed, lower at high speed ‘tapering’ to higher at lower speed. If a brake taper is set, the **Normal Brake Rate** is set to -.01, indicating that the brake tape now controls the brake rate.

Below the **Detailed Output Selection** there are two selection items:

The first is the **Train Power Output** combo box, which provides a choice between Instantaneous Power and Average Power. This choice determines how the power of the train is output. It can either be instantaneous or averaged. Power is always output to the power profile every display time interval. If the power output choice is “Instantaneous Power”, then the power calculated during the last calculation time interval of the display interval is output. If the choice is “Average Power”, the power is averaged over all of the calculation time intervals in the display time interval. Click on entry to choose.

The second is the **Train Running Direction** combo box. The choice can either be in increasing or decreasing values of position (or distance) with time. Click on **Increasing Position Run** to choose the former or **Decreasing Position Run** to choose the latter.

There are several frames, which contain text boxes with entries for the various parameters of the control file. The user can edit these boxes to provide input. Default values are already set for all of the boxes.

The first frame is the **Calculation and Display Times** frame.

The **Calculation Time Interval** is the time interval for which the calculation is repeated in the running of the TPS. This is in contrast to the display time interval when the calculation results are displayed. The ratio of the calculation to display time intervals is always an integer. The default value of the **Calculation Time Interval** is 1 second. (The minimum value is .02 sec.) Normal editing procedures can change the value.

The **Number of Calculations per Display** is the ratio of the display to calculation time intervals. The default value of the **Number of Calculations per Display** is 1. (Note: If a Power Profile is to be generated by the TPS which uses this Control file and if that Power Profile is later to be used in an ENS or TMS, then the Operating Time file used as input to the ENS or TMS must have the snapshot time interval and the display time interval of equal value.

The **Display Time Interval** is grayed, indicating that no entry can be made here. The display time is just the product of the **Calculation Time Interval** and the **Number of Calculations per Display**.

The next frame **Acceleration, Deceleration and Jerk**, contains several text boxes, which are now described.

The **Maximum Acceleration** permitted by the train is entered. Even if the train accelerates down grade, the onboard train control limits the acceleration to this value. The default value is 0. (English units are miles per hour per second and metric units are meters per second squared.) For most rail systems, the default is the appropriate entry.

The **Maximum Deceleration** permitted by the train is also entered. Even if the train decelerates up grade, the onboard train control limits the deceleration to this value. The default value is 0. (English units are miles per hour per second and metric units are meters per second squared.) For most rail systems, the default is the appropriate entry.

The **Normal Accelerate Rate** for the train is entered. The on board train control sets the tractive effort to limit the acceleration to this value on level tangent track. If this value is set, then downgrade acceleration
will exceed this value and upgrade acceleration will lag this value. Setting this quantity is equivalent to
load weighing. The default value is 3. (English units are miles per hour per second and metric units are
meters per second squared.)

The Normal Accelerate Jerk Rate Limit for the train is entered. Jerk is the rate of change of acceleration
or deceleration. The on board train control sets the tractive effort to limit the jerk in acceleration to this
value. (English units are miles per hour per second per second and metric units are meters per second
cubed.) The value of 0.0 means that no jerk limit is set. Normal editing procedures can change the value.
The default value is 0.0.

The Normal Brake Rate for the train is entered. The on board train control sets the brake effort to limit the
deceleration to this value on level tangent track. If this value is set then upgrade deceleration will exceed
this value and downgrade deceleration will lag this value. Setting this quantity is equivalent to load
weighing. If a brake taper is set, the Normal Brake Rate is set to -.01, indicating that the brake tape now
controls the brake rate.
The default value is 3. (English units are miles per hour per second and metric units are meters per second
squared.)

The Normal Brake Jerk Rate Limit for the train is entered. Jerk is the rate of change of acceleration or
deceleration. The on board train control sets the tractive effort to limit the jerk in braking to this value..
(English units are miles per hour per second per second and metric units are meters per second cubed.) The
value of 0.0 means that no jerk limit is set. Normal editing procedures can change the value. The default
value is 0.0.

The Reaction Time or Delay Time of the train is entered. This is the time between receipt of a signal to
stop or slow down and the actual initiation of braking. It is not used in the TPS or ENS, but is reserved for
the TMS, where it is incorporated into the stop distance. Under manual train control, this would represent
the operator and equipment response time, and would be incorporated into the signalling system. The
default value is 500 milliseconds (1/2 second).

The Speeds frame is discussed next.
The Maximum Speed of the train is entered. In areas where speed restrictions or speed commands exceed
this value, the train speed will be limited to this value. In areas where speed restrictions or commands lag
this value, the speed commands and restrictions limit the train speeds. The default value of 0 indicates that
the train follows the speed restrictions and commands. (English units are miles per hour and metric units
are kilometers per hour.)

The Head Wind Speed is entered. The head wind is the component of wind velocity parallel to the front of
the train. It is expressed in mph in English units and kph in metric units. The headwind is assumed to be
constant throughout the run independent of the curvature in the track along the right of way. It is used in the
computation of train resistance. (English units are miles per hour and metric units are kilometers per hour.)
The default value is 0.

The Train Initialization frame contains the initial speed and position and the passenger load factor at the
start of the run.
The Initial Speed of the train if the train does not start at a station is entered. If the train starts at a station
the initial speed is 0. The default value is 0. (English units are miles per hour and metric units are
kilometers per hour.) A value would be entered here if the train did not start at a station and an initial
position and speed were required to begin the trajectory.

The Initial Position of the train if it does not start at a station is entered. A default value of 0 indicates that
the train will start at the first or last station in the station file depending on whether the run is increasing or
decreasing position. (English units are miles and metric units are kilometers.) A value would be entered
here if the train did not start at a station and an initial position and speed were required to begin the
trajectory.
The Passenger Load Factor expressed in percent of weight of passengers to weight of full load (100%) of
passengers at the start of the run, if the run does not start at a station, is entered. The default value is 0.
Note that the Initial Position, Initial Speed and Passenger Load Factor at Start of Run have values different from zero, only if the train does not start at a station. In most, if not all cases, the train will start from a terminal station.

3.1.2.1 Detailed Output Selection

When the Detailed Output Selection box is selected, the following screen appears.

The default selection for the choices for the detailed output file for the TPS is already selected. Ten items out of a total of thirty-five possible can be selected for any TPS run. The thirty-five items are found in the Selection Choices for Detailed Output combo box.

All of the default choices can be changed. The Detailed Output Selection list box contains a list of detailed output data, which have been selected for the TPS detailed output. Click on any entry to erase. Double click on any entry replaces it with another, which is the current value of the Selection Choices for Detailed Output combo box.

If the current selection in the Detailed Output Selection list box is blank, selection of a value in the Selection Choices for Detailed Output combo box will enter that value in the blank space.

The last selection on the left of the screen of Figure 3-14 in the Train and Right of Way Data combo box shows the kind of data to be displayed in the detailed output file of the TPS. The choices are: No Data, Train Data, Train and Right of Way Data (default).
The Select button at the bottom right of the screen is clicked when the selection of the output choices is completed. This incorporates those choices in the resulting control file.

The Reset button completely resets the screen, starting from scratch. It is best used when problems arise and the user can no longer fix them.

The Close button closes the program and returns the user to the next higher level.
3.1.2.2 Coasting Option

Selection of the Coasting option of the Main screen for the Control File for TPS Input of Figure 3-13 results in the following addition to Main screen.

![Figure 3-15 Main Screen for the Control File for TPS Input with Coasting Option](image)

The Coasting frame is made visible.

Two coasting modes are available to the TPS. These modes are referred to as anticipatory coasting and sawtooth coasting. Anticipatory coasting occurs when the train proceeds into a power off (no power/no brake) condition in anticipation of a lower speed restriction.

The second form of coasting is sawtooth coasting. In this case, the train will accelerate to the current speed command or restriction and then revert to a no power condition until its speed drops by a certain amount. Two options are available for sawtooth coasting. In the first option, a coast speed is set and the train accelerates to this speed and then begins coasting until it drops the certain amount (termed the speed band), then it accelerates again to the coast speed and so on, thus the term sawtooth coasting. The second option
of sawtooth coasting uses the speed restrictions or speed commands as the coast speed. The speed band has the same meaning as in the first option. In the Coast Enabled box, choose either Sawtooth or Anticipatory.

If Anticipatory coasting is selected only the Coast Speed and Coast Drag are specified. If Sawtooth coasting is selected, the Coast Speed, the Coast Drag and the Coast Speed Band must be entered.

The Coast Speed is the speed to which the train accelerates before it begins coasting (English units are miles per hour and metric units are kilometers per hour.). For Sawtooth coasting, if the Coast Speed is the speed restriction, then the default 0 is selected. A Coast Speed must be entered for Anticipatory coasting.

In Sawtooth coasting the Speed Band is the range over which the speed drops before power is reapplied (English units are miles per hour and metric units are kilometers per hour.). A Speed Band is required for Sawtooth coasting. The default value is 3.

Although coasting is a no power condition, for electric trains with electric (dynamic braking), the electric brake is sometimes kept active so that it would build up braking force upon application. The drag caused by this brake during coasting is called the Coast Drag and it is expressed as a fraction of full braking effort. The default value is 10% or 0.1.

Normal editing procedures are used to enter or change the values of all coast parameters.

### 3.1.2.3 Brake Taper Option

Selection of the Brake Taper option produces the following screen.

![Brake Taper Input](image)

Figure 3-16 Brake Taper Screen
This is the input for the brake taper. Enter the speed, followed by a comma for the delimiter followed by the brake rate followed by a carriage return. Repeat the process for up to 10 speed, brake effort points. (For speed, English units are miles per hour and metric units are kilometers per hour.) (For the brake rate, English units are miles per hour per second and metric units are meters per second squared.) Click on the Select button when complete.

The Reset button completely resets the screen, starting from scratch. It is best used when problems arise and the user can no longer fix them. The Close button closes the program and returns the user to the next higher level.

The final action to create the TPS control file is to click on the Create File button on the main screen of Figure 3-15, which produces the following screen.

Click on the Yes button produces TOM File View of the file just created.

The Reset button completely resets the screen, starting from scratch. It is best used when problems arise and the user can no longer fix them. The Close button closes the program and returns the user to the next higher level, which is the main screen for the FCM module in Figure 3-3.
3.1.3 TPS Train Input

Selection of Train in the TPS Input Selection screen of Figure 3-3 produces the following screen.

![Main Screen for the Train File for TPS Input](image)

**Figure 3-18 Main Screen for the Train File for TPS Input**

A list of train files in the database for the rail system selected is shown at the left and middle of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

Selection of the Name of File to be created or modified is at the left and bottom of the screen. This is edited in the usual window manner.

The train file can be constructed in either English or metric units.

Select the method for calculating train resistance for the train by clicking on the option at the top of the middle column of inputs. Two methods are available.

The first uses a Davis type equation in which parameters such as flange coefficient and cross sectional area are set elsewhere. This method is presented in Appendix 9.8.5.2 together with the second method, which uses coefficients for each car in the train. Click Davis Equation for the former and Single Car Coefficients for the latter.
Select the type of propulsion system to use for the train by clicking on the option second from the top of the middle column of inputs. Two methods are available for electric propulsion and two for fueled units. In the first electric propulsion method (Electric - Input), the tractive effort and efficiency curves are input directly. In the second electric method (Electric - Model), models are used to compute these curves. If a Train file is imported into the screen, changing the setting of this combo box from Electric – Input to Electric - Model, will initiate a procedure, through which the original screens, which created the Train file was will appear. This procedure requires that the original Propulsion Model Detailed Output file (TC-*.*) (see Section 3.1.3.4) exists in the directory. All files which are created in this manner are stored as Train files with the Electric – Input format.

The first method (Fuel - Straight Line) for fueled units, uses a straight-line method which relates fuel consumption directly to power developed at the rail. The second method (Fuel - Fuel Curves) uses the fuel curves provided by the manufacturer of the engines. The default is (Electric - Input).

In the next selection in the middle column of input, which is Maximum Speed, if the train speed can exceed 175 both in English or Metric units, select the (>175), otherwise select the (<=175) entry. The default value is (<=175). The former entry is also used for high-speed train work.

There are seven box inputs for the train listed in the middle column. Each of these is briefly explained.

Select the Train Part of Name (2 Alpha-numeric) of the four-character ID, which appears in the output power profile (See Appendix 9.9.1.6). The other two characters come from the station file. See also the construction of the Station file. The default value is AA. Normal editing procedures can enter or change the value.

Select the Number of Types of Cars in Train. A car can be different in type if it has any different car related parameter, such as weight, length, train resistance, etc. With the exception of # cars, if any entry in the Train Makeup Input column of Figure 3-37 is different among the cars, that car is a different type. The default value is 2. Normal editing procedures are used to enter or change the value.

Enter the frontal Cross Sectional Area of Train for aerodynamic drag. This value is used only if the Davis Equation type is used for train resistance. The default value is 100 for English units and 7.9 for Metric units. (English units are square feet and metric units are square meters.)

Enter the Fuel Heat Content per Unit Volume for the fuel used in the engine. (English units are British Thermal Units (Btu) per gallon of fuel and metric units are kWh per imperial gallon.) This quantity need only be entered for fuel driven trains. The default value is 134000 for English units and 111578 for Metric units.

Enter the Flange Coefficient for train resistance. This value is used if the Davis Equation type is used for train resistance. (English units are lbs. / ton / miles per hour and metric units are newtons / tonne / kilometers per hour.) The default value is 0.045 for English units and 0.2163 for metric units.

Enter the Wheel Diameter of the driving wheels. The value is used only if the electric propulsion model (Electric -Model) is used to calculate the tractive effort and propulsion efficiency curves. (English units are inches and metric units are meters.) The default value is 28 for English units and 0.7 for metric units.

Enter the Gear Ratio. The value is used only if the electric propulsion model (Electric -Model) is used to calculate the tractive effort and propulsion efficiency curves. The default value is 5.414.

A click under the Help command button produces the following screen.
Figure 3-19 File Construction Module – Train File Input – Main Screen with Train Resistance Calculator Command Button Visible

There are four options, which can be selected, at the bottom of the middle column. These options are: Train Makeup Input, Propulsion Input, Friction Brake Input, and On Board Storage Input. New screens are called up for each of these inputs.

3.1.3.1 Train Resistance Calculator and Converter

The next figure shows the File Construction Module -Train File Input - Main Screen.
Figure 3-20 Main Screen for the Train Input File

Clicking under the Help command button produces the next screen.
A click on the **Train Resistance Calculator** command button produces the following screen.
Figure 3-22 Train Resistance Calculator and Converter Screen

Click the English Units check box to work in English units or click the Metric Units check box to work in Metric units. The default value is the value on the File Construction Module – Train Input – Main Screen.

3.1.3.1.1 Davis Equation Variables

Enter the total number of cars, including the locomotives.

Enter the total number of axles in the train, both driving and non-driving.

Enter the flange coefficient, per the Davis Equation.

Enter the cross sectional area of the train, per the Davis Equation.

Enter the lead car or locomotive aerodynamic coefficient, per the Davis Equation.

Enter the trail car or trail locomotive aerodynamic coefficient, per the Davis Equation.
Selecting a train file in the File Construction Module – Train Input – Main Screen and then clicking the Import from Screens command button at the bottom of this screen accomplish importing.

The next screen shows a sample, where all entries have been completed.

Figure 3-23 Entering the Davis Equation Variables

Add a speed of 20 and a weight of 220, then click Calculate Using Davis Equation command button to obtain the next screen.
Figure 3-24 Train Resistance Using the Calculate Using Davis Equation command button

The **Train Resistance** text box displays the results of the train resistance calculation in lbs or nts.

The **Train Resistance per Weight** text box displays the results of the train resistance per unit weight calculation in lbs/ton or nts/tonne.

### 3.1.3.1.2 Coefficient Equation Variables

Train resistance can also be expressed by coefficients for each vehicle in the train. These coefficients are of the form:

\[ C_1 + C_2W + (C_3 + C_4W)V + C_5V^2 \]

Where, W is the weight of the car or locomotive and V is its speed.

The **Coefficient Method** is used as an alternative to the **Davis Train Resistance Equation**. It is a more general method.
The coefficient $C_5$ differs, depending on whether the car or locomotive is in lead or trailing. Thus there are two $C_5$ coefficients: $C_5$ (Lead) and $C_5$ (Trail).

Enter the coefficients or alternatively, click the **Convert** command button to convert the coefficients of the **Davis Equation Method** to calculate train resistance to the coefficients of the **Coefficient Equation Method**.

![Image](image.jpg)

Figure 3-25 Convert Davis Equation Variables to Coefficient Equation Variables

Selecting a train file in the **File Construction Module – Train Input – Main Screen** and then clicking the **Import from Screens** command button at the bottom of this screen accomplish importing.

All of the Davis equation coefficients must be entered in order to effect the conversion.

Click the **Calculate Using Coefficient Equation** command button to compute the train resistance using the coefficient method.
The **Train Resistance** text box displays the results of the train resistance calculation in lbs or nts.

The **Train Resistance per Weight** text box displays the results of the train resistance per unit weight calculation in lbs/ton or nts/tonne.

The **Construct Table** command button, which appears at the bottom of the screen, is clicked when a table of train resistance vs speed is desired. More on this capability is discussed in Section 3.1.3.1.6.

### 3.1.3.1.3 Import from Screens

#### 3.1.3.1.3.1 Davis Equation Variables

Click on the **Import from Screens** command button to import the coefficients for train resistance into the screen. The empty train weight is imported. The crush load or maximum train weight is displayed in the **Train Full Weight** text box. It is grayed, since it is for reference only. The user may then enter any new train weight between the empty weight and full weight in the **Train Weight** text box and recalculate the train resistance with the new weight.
Figure 3-27 Import From Screens – Davis Equation Variables

3.1.3.3.2 Coefficient Equation Variables

Click on the Import from Screens command button to import the coefficients for train resistance into the screen. A train file must have previously been imported into the File Construction Module – Train Input – Main Screen by double clicking on one of the train files for this procedure to work. An example is shown next.
Figure 3-28 Import from Screens – Coefficient Variables

Click the Select Type Car combo button to select the type car. The coefficients are shown for each type car in the train.
Figure 3-29 Coefficient Equation Variables – After Import from Screens command – Car Type 2

Clicking the **Calculate Using Coefficient Equation** command button completes the train resistance calculations based on the **Train Makeup Input** data in the file shown.
Figure 3-30 Coefficient Equation Variables – After Import from Screens Command – After Click on the Calculate Using Coefficient Equation Command Button

For the case of coefficients of the Coefficient Equation Method for calculating train resistance by importing from screens by using the Import from Screens command button, a Load Factor text box appears after calculating train resistance using the Calculate Using Coefficient Equation command button is clicked. This first calculation after the import is effected using the empty weight of the train. After the first calculation is completed, the user can set a Load Factor, which can vary from 0 to 100 %, which will raise the weight of the train linearly, between empty weight and full or maximum weight as the load factor varies between 0 and 100. Thus the train resistance can be calculated at any train weight.

If the Import from Screens command button was not clicked and the coefficients were entered by hand or converted from Davis Equation Variables by previously clicking the Convert command button, clicking the Calculate Using Coefficient Equation calculates the train resistance by assuming that the lead and trailing cars all have the same coefficients for C1…C4 and the lead car has coefficient C5 (Lead) and the trailing cars have coefficient C5 (trail).

3.1.3.1.4 Show Formula

3.1.3.1.4.1 Show Davis Formula
Click the **Show Davis Formula** command button to display the Davis equation formulae used in the TOM.

![Figure 3-31 Show Davis Formula Results](image)

### 3.1.3.1.4.2 Show Coefficient Formula
Click the **Show Coefficient Formula** command button to display the Coefficient equation formulae used in the TOM.
3.1.3.1.5 Transfer Commands

3.1.3.1.5.1 Transfer Davis to Screens
Click the Transfer Davis to Screens command button to transfer the information from the Davis Equation Variables block to two screens: the File Construction Module – Train Input – Main Screen and the File Construction Module – Train Input – Train Makeup Input screen. Entries must be made for both the # cars and # axles in the File Construction Module – Train Input – Train Makeup Input screen. These entries must be consistent with the entries for Number of Cars and Number of Axles in this screen.

3.1.3.1.5.2 Transfer Coefficients to Screens
Click the Transfer Coefficient to Screens command button to transfer the information from the Coefficient Equation Variables block to two screens: the File Construction Module – Train Input – Main Screen and the File Construction Module – Train Input – Train Makeup Input screen.

Click the Select command button to select entries and return to the Main Screen of the Train File for TPS Input.

The Reset command button completely resets the screen.

The Close command button closes the program and returns the user to the Main Screen for the Train File for TPS Input.
Click the Exit command button to close the Train Operations Model Toolbox.

3.1.3.1.6 Train Resistance Table
Clicking the Construct Table command button at the bottom of the screen of Figure 3-30 produces the next screen.

![Train Resistance Table](image)

Figure 3-33 File Construction Module – Train Resistance Table
To the left of the screen is a list of Train Resistance Table files in the Rail System Database for the rail system selected.

Double click on a file will view it in the TOM File Viewer.

Alternatively, click on the file and on the View One command button to view it.

To delete a file, click on the file and click on the Delete One button. Clicking on the file and pressing the delete key as well can delete a file.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

The text boxes to the right of the screen are completed.

In the combo box at the top of the screen, select the Car option if the train resistance is to be expressed as Total Train Resistance /Total Number of Cars (On a per car basis). Select the Train option if the train resistance is to be expressed as Total Train Resistance.

Enter the Passenger Load Factor of the train in percent. This is a number between 0 and 100, which indicates the weight of the train, which varies linearly between empty weight (0) and full weight (100). The default value is 0, an empty train.

Enter the Maximum Speed and Speed Increment for which the train resistance table entry will be calculated. Train resistance values will be calculated beginning at speed 0 and at successive increments until the maximum speed is exceeded. The default values are 0 and 5, respectively.

Enter the grade in percent. A value of 20 lbs/ton (English Units) and 98 nts/ton will be added to the train resistance entry for each % grade. The default value is 0.

These values for the Empty and Full Weights of the train are shown. These values cannot be changed here. Depending on the value of the Passenger Load Factor entry, the weight of the train used for the train resistance calculation will lie between these values.

The File Caption is added by the user to better identify the file.

The Reset and Close command buttons have their usual meaning.

Click the Create File command button to complete the table, which can be reviewed in the File Viewer as shown in the next screen.
Figure 3-34  File Construction Module – Train Resistance Table Create File Command Executed

Click the **Graph Results** command button to view a graph of the table.

Click the **Yes** command button to view the table.
Figure 3-35 Train Resistance Table File Top Portion.
3.1.3.2 Train Makeup Input Option

3.1.3.2.1 Train Makeup Input Screen

Selecting the Train Makeup Input option results in the following screen.

![Train Resistance Table File Bottom Portion.](image-url)
For each different Type Car in the train, input the following items: (number of) # cars, # prop/car (Number of Propulsion Units per car, normally, one for a powered car or locomotive and zero for a trailing freight or passenger car. Propulsion systems are modeled on a per car or locomotive basis.), # axles/car and # seats/car, Aux Power/Car [Auxiliary Power per car], length/car, Empty Wt/Car [Empty Weight of Car] and, Full Wt/Car [Full (Crush loaded) Weight of Car], Aero Drag [Aerodynamic Coefficient of the Car], Eq Rot Wt/Car [Equivalent Rotational Weight of the Car] and TR Coef 1… TR Coef 5 [Train Resistance Coefficients of the Car].

Explanation of and units for various inputs:

### Input

- **Aux Power/Car**: kW, Metric: kW
  - this value is assumed to be constant for the TPS run.

- **Length/Car**: ft, Metric: m
  - used to compute the train length for rear of train position.

- **Empty Wt/Car**: ton, Metric: tonne
  - no passenger load or freight load.

- **Full Wt/Car**: ton, Metric: tonne
  - crush passenger load or full freight load.

- **Aero Drag**: lbs/ft²/mph², Metric: nt/m²/kph²
  - Only for Davis Train Resistance case

- **Eq Rot Wt/Car**: tonne
  - Rotating inertia of motors, gears and wheel and axels.

### Train Resistance Coefficients

- **TR Coef 1**: lbs
- **TR Coef 2**: lbs/ton
- **TR Coef 3**: lbs/mph
- **TR Coef 4**: lbs/ton/mph
- **TR Coef 5**: lbs/mph²

---

**Figure 3-37 Train Makeup Input Screen for the Train File for TPS Input**

This figure shows the input screen for the train file for TPS input, allowing users to input data for each type of car in the train, including the number of cars, propulsion units, axles, seats, auxiliary power, length, empty and full weight, aero drag, and equivalent rotational weight. The table in the input screen lists the various fields and their corresponding explanations for both English and Metric units.
The relation between the Traction Curves and the Propulsion Units in a Train of Cars or Vehicles is sometimes confusing to new users of the TOM. This document explains that relation in more detail with examples.

In most rail systems in the world, there are powered cars and non-powered cars. In rail transit, the most general configuration is trains of all powered cars. In mainline railroads, for passenger cars, there may be trains of all powered cars as well as trains of locomotive-powered hauled passenger coaches (non-powered) or locomotive hauled freight cars.

The Traction Curves (Tractive Effort vs Speed or Electrical Braking Effort vs Speed) are always entered on a Propulsion Unit basis.

The Traction Curves for the Train are computed internally in the TPS as follows.

Traction Effort per Train = Traction Effort per Propulsion Unit x Number of Propulsion Units per Train.

The Traction Effort per Propulsion Unit is entered into the Traction Effort vs Speed Grids of the File Construction Module – Train File Input – Propulsion Input screens.

The Number of Propulsion Units is entered in the # Prop entry in the Train Makeup Input grid of the File Construction Module – Train File Input – Train Makeup Input screen.

A click on the Add Column to End option adds an additional column to the end of the entry grid. Likewise a click on the Remove Column from End option deletes the last column of the grid. The value for the Number of Types of Cars in Train for the Main Screen for the Train File for TPS Input of Figure 3-18 is automatically adjusted for the number of columns in the grid.

Use the Select button to select entries and return to the Main Screen for the Train File for TPS Input. The Reset button completely resets the screen. The Close button closes the program and returns the user to the next higher level, which is the Main Screen for the Train File for TPS Input of Figure 3-18. In this case, the screen “remembers” its settings.

3.1.3.2.2 Locomotive Hauled Frame
Click under the Help command button on the Train Makeup Input Screen to obtain access to the Locomotive Hauled frame, which contains aids for users of mainline railroad applications.
The Locomotive Hauled frame contains three command buttons, which are useful for aiding the user to deal with locomotive-hauled trains. The Build Train command button permits the user to build a locomotive-hauled train by selecting the locomotives and cars to be added to the train. The Manage Car Library command button allows the user to manage the car library by adding, deleting or modifying the data for locomotives and cars in the library. The Locomotive Dispatch command button provides the user with a method of testing the amount of motive power in the train consist for a dispatch policy that requires that a certain speed be maintained over a ruling grade or that a certain tractive effort be present at start on a ruling grade.

3.1.3.2.2.1 Build Train

Before clicking the Build Train command button, it is necessary to import a Locomotive Train File into the File Construction Module - Train File Input - Main Screen. A Locomotive Train File by definition has only one vehicle with one or more propulsion systems. After importing a Locomotive Train File into the screens, click the Build Train command button.
Figure 3-39 File Construction Module – Train File Input – Build Train Screen

The **Build Train** screen contains all of the capability for building a train, which consists of a Lead Locomotive, Trailing Locomotives (Same locomotive name as the lead) and Freight and/or Passenger Cars. The **Train File** of the Lead locomotive is the base for building the train. This file is the one imported into the **File Construction Module – Main Screen**.

The **Lead Locomotive Train File** must be in the same directory of the selection.

The **Lead Locomotive Name** is the name of the locomotive, which **Train File** belongs to the lead locomotive. This is obtained automatically from the **Car Library**.

Enter the number of trailing locomotives in the text box, followed by a click on the **Add Trailing Locos** command button in order to add the trailing locomotives to the train consist.
The trailing locomotives can be added anywhere except before the lead locomotive. They can be added after cars have been added.

Choose the Type of car from the Car Library by clicking the Select Type Car combo box. Enter the number of cars of that type into the text box to the right of the combo box. Click the Add Type Car command button to add these cars to the train consist. Continue repeating this process until the train build is complete.
The list of the buildup of the train consist shows the train as it is being built. The type of locomotives (Lead or Trailing) and the Names of the cars and the numbers of each are displayed. Any row, except that of the Lead Locomotive can be deleted from the list box by clicking on the row, followed by a click on the Delete command button below.

The length of the train being built is displayed in feet (meters) and miles (kilometers) for English (Metric) units.

Clicking the Locomotive Dispatch command button exposes the Locomotive Dispatch screen. This screen allows the user to test the motive power selected for maintaining speed on ruling grade dispatch rule.
Clicking the Manage Car Library command button exposes the Manage Car Library screen. This screen allows the user to add or modify cars in the Car Library as the train is being built.

Clicking the Ruling Grade Check command button exposes the Ruling Grade Determination screen, through which analysis can be done on grades in a right-of-way above a certain value.

Once the train is built, there are three remaining tasks to be completed on the File Construction Module – Train Input File – Main Screen.

Add a File Caption.

Change the Train ID.

The Select command button will show the Train Input – Main Screen, which can be completed according to the three above items.

The Reset, Close and Exit command buttons have their usual meaning.

3.1.3.2.2.2 Manage Car Library

The Manage Car Library Screen is called by clicking the Manage Car Library command button on the Train Makeup Input Screen.

![Manage Car Library Screen](image)

Figure 3-42 Manage Car Library Screen

The Car Library has two parts: The Locomotive Library and the Freight and Passenger Car Library.

3.1.3.2.2.1 Locomotive Library Management
Clicking the Select Locomotive combo box permits the user to select a locomotive from the Car Library. The parameters, which describe the locomotive, are displayed in the Locomotive Data frame below the combo box. A new locomotive may also be selected by clicking on New in the Select Locomotive combo box.

![Figure 3-43 Manage Car Library Screen – Selection of a Locomotive](image)

The Locomotive Name is a unique identifier of the locomotive or car registered in the Car Library. Enter or modify with no (,) commas.

The Locomotive Train File is registered in the Car Library. It is a Train File, which is a one car train; namely, the locomotive. All of the propulsion and braking characteristics are imbedded in this train file. This file must also exist in the sub-directory in which the train file is opened.

The Number of Propulsion Units aboard the locomotive is registered in the Car Library. The value is normally 1. Enter or modify as required.

The Locomotive Auxiliary Power is registered in the Car Library. Enter or modify as required. The units are kW. If cars are using auxiliary power, such as passenger cars, refrigerator cars, etc., this power can be added later in the Train Makeup Input screen.

The Locomotive Length over Couplers is registered in the Car Library. Enter or modify as required. The English units are feet and the Metric units are meters.

The Locomotive Empty Weight is registered in the Car Library. Enter or modify as required. The English units are tons and the Metric units are tonnes.
The Locomotive Full Weight is registered in the Car Library. Enter or modify as required. The English units are tons and the Metric units are tonnes.

The Locomotive Equivalent Rotational Weight is registered in the Car Library. Enter or modify as required. The English units are tons and the Metric units are tonnes.

The Locomotive Train Resistance Coefficients are registered in the Car Library. Enter or modify as required.

Train resistance is expressed by coefficients for each locomotive in the train. These coefficients are of the form:

\[ C_1 + C_2 W + (C_3 + C_4 W)^2 V + C_5 V^2 \]

Where, \( W \) is the weight of the vehicle and \( V \) is its speed.

The Coefficient Equation Method is used in the Car Library.

The coefficient \( C_5 \) differs, depending on whether the locomotive is in lead or trailing. Thus there are two \( C_5 \) coefficients: \( C_5 \) (Lead) and \( C_5 \) (Trail). The trailing locomotives are always \( C_5 \) (Trail).

3.1.3.2.2.2.2 Freight and Passenger Car Library Management

Clicking the Select Car combo box permits the user to select a freight or passenger car from the Car Library. The parameters, which describe the car, are displayed in the Car Data frame below the combo box. A new car may also be selected by clicking on New in the Select Car combo box.
The Car Name is a unique identifier of the car registered in the Car Library. Enter or modify with no (,) commas.

The Car Length over Couplers is registered in the Car Library. Enter or modify as required. The English units are feet and the Metric units are meters.

The Car Empty Weight is registered in the Car Library. Enter or modify as required. The English units are tons and the Metric units are tonnes.

The Car Full Weight is registered in the Car Library. Enter or modify as required. The English units are tons and the Metric units are tonnes.

The Car Equivalent Rotational Weight is registered in the Car Library. Enter or modify as required. The English units are tons and the Metric units are tonnes.

The Car Train Resistance Coefficients are registered in the Car Library. Enter or modify as required. Train resistance is expressed by coefficients for each locomotive in the train. These coefficients are of the form:

\[ C_1 + C_2 W + (C_3 + C_4 W) V + C_5 V^2 \]

Where, \( W \) is the weight of the car and \( V \) is its speed.

The Coefficient Equation Method is used in the Car Library.

Cars always trail so the coefficient \( C_5 \) is always \( C_5 \) (Trail).

3.1.3.2.2.2.3 Car Library Management Procedures

The following information on the screen applies to both Locomotives and Freight and Passenger Cars.

Add a new Locomotive or new Car to the Car Library:

If the item to be added to the Car Library is a Locomotive, then the procedure follows:

To add a new locomotive to the car library, create a Locomotive Train File and import it into the File Construction Module - Train File Input - Main Screen. After importing the new locomotive file, click the Train Makeup Input checkbox. On the Train Makeup Input screen, click the Build Train command button and answer Yes to the posed question. Do you wish to add a new locomotive to the Locomotive Library?

Then click the Add New command button on this screen.

If the item to be added to the Car Library is a car (non-powered), then the procedure follows:

Enter the required information in the text boxes or import another car and modify the entries. Make sure that the name of the new car to be added is not duplicated in the library. Click the Add New command button to complete the procedure.

Save the Locomotive or Car data to the Car Library:

Use the Save command button after a locomotive or car is modified.
If the item to be saved to the Car Library is a Locomotive, then the procedure follows:

Click the Save command button to obtain the following prompt:

The locomotive data have been changed in the Locomotive Library and the Locomotive Train File screen. Do you wish to recreate the Locomotive Train file now?

If the answer is yes, the Locomotive Train File is recreated. If the answer is no, the following message is displayed:

**** WARNING ******* The Locomotive Train File has been not been created. The Locomotive Train File and the Locomotive Library will not be in agreement until this Train File is created. The Train File must then be recreated manually.

If the item to be saved to the Car Library is a car (non-powered), then the procedure follows:

Modify the information in the text boxes. Click the Save command button to complete the procedure.

Delete the Locomotive or car from the Car Library.

In the case of the locomotive, the Locomotive Train File is not deleted. The user is informed with a prompt.

Click the Select command button to select entries and return to the Train Makeup Input screen.

The Reset command button completely resets the screen.

The Close command button closes the screen and returns the user to the Train Makeup Input screen for the Train file for TPS Input.

The Exit command closes the TOM.

3.1.3.2.2.3  Locomotive Dispatch

The Locomotive Dispatch screen is called by clicking the Locomotive Dispatch command button in the Locomotive Hauled frame of the Train Makeup Input screen.
The Locomotive Dispatch frame contains all of the procedures necessary to determine if a train has enough motive power. This determination is based on the dispatch rule of maintaining a fixed speed over a ruling grade and overcoming stiction on a starting grade. It is assumed that a Train file resides in the screens of the File Construction Module – Train Input screens.

This Train file could have been imported into these screens, or could have been built by the Build Train screen processes.

The purpose of this screen is to test this Train file for correct motive power according to the dispatch rules, and if the Train file passes the test, to determine if less motive power will do the same job. Likewise, if the Train file fails the test, to add motive power to just pass the test.

There are two Locomotive Dispatch Rules:

1. Speed to be maintained over Ruling Grade. Set the speed (mph or kph) to be maintained over the ruling grade (percent). Both speed and ruling grade are specified. The default values are shown in the speed and ruling grade text boxes, and should be changed to conform to the railroad and equipment available to that railroad. Change the speed and ruling grade if desired.
2. Stiction on Starting Grade. Stiction is defined here as the ratio (expressed as a fraction less than one) of the tractive effort once moving (at zero speed) to the tractive effort necessary to start. The starting grade (%) assumes that the whole train is on the grade. The default values are shown in the stiction and starting grade text boxes respectively, and should be changed to conform to the railroad and equipment available to that railroad. Change the speed and ruling grade if desired. For example, if there is enough play in the couplers, to effectively start one car at a time, the stiction value could be very high and approach 1.

The default values of all four parameters; namely, speed, ruling grade, stiction and starting grade can be changed by clicking the Set Default Dispatch Rules command button, which exposes another screen, in which the default values may be changed.

The Check Rule command button determines whether the rule is met with the motive power under consideration.

The total Tractive Effort of the train is computed along with its Train Resistance and Grade Resistance at the speed to be maintained over the ruling grade.

The total Tractive Effort of the train is again computed at 0 speed as well as the train resistance and starting grade resistance at zero speed. Multiplying it by the stiction modifies this total Tractive Effort. The smaller of the two tractive efforts is now named the Total Tractive Effort.

The Excess Tractive Effort (Total Tractive Effort less Resistance) is then determined. If the Excess Tractive Effort is positive the rule is met. If the Excess Tractive Effort is negative, the train fails the rule.

The rule, which dominated the dispatch, appears to the right of the Check Rule for Original (Modified) Train command button.

There are two options to be taken at this point: Change the dispatch rules or change the motive power.

By entering new values in the dispatch rule text boxes and clicking the Check Rule for Original (Modified) Train command button determines the effects of rule changes.

If motive power is to be changed, enter the new number of locomotives and again click the Check Rule for Original (Modified) Train command button.

It is generally prudent to select the number of locomotives, which just meets the rules. However, some railroads will add an extra locomotive in case one locomotive is out of service during the train run or for other unforeseen circumstances.

An example is shown in which the original train does not meet the rule.
Figure 3-46 Locomotive Dispatch Screen – Rule is Not Met

In this case, the train fails the rule. Add another locomotive by entering 3 into the Change the Number of Locomotives to: text box to obtain the next screen.
The rule is not met for 3, so enter 4 and check again.

Click the Check Rule for Modified Train command button to obtain the next screen.
The train now meets the dispatch rules, the dominant of which in this case is speed on ruling grade.

The Ruling Grade Check command button exposes the Ruling Grade Determination screen, shown next.

3.1.3.2.4 Ruling Grade Determination

The ruling grade determination procedure is designed to ascertain what areas of a track system a given train will be in a region which the average grade over the length of the train will exceed a preset limit (ruling grade). Thus the user is made aware of the chance that a train will violate a ruling grade rule.
The screen could also be called from two other screens, using the same Ruling Grade Check command button. These screens are: File Construction Module – Train File Input – Build Train screen, displayed in Figure 3-39 and the File Construction Module – Train File Input – Default Locomotive Dispatch Rules screen, which will be discussed and is shown in Figure 3-54.

The purpose of this screen is to produce a Ruling Grade file, from which the user can more prudently select the ruling grade rules, which were discussed in the previous Section 3.1.3.2.2.3.

The Ruling Grade Determination process begins with the selection of a Grade file.
Figure 3-50 File Construction Module – Ruling Grade Determination Screen – Grade File Selected

Complete the remainder of the screen according to the following steps:

Enter the Start and End Positions (miles for English units or kilometers for metric units). The Start Position must be greater than the File Start Position for the Grade file selected for building the Ruling Grade file. The End Position must be less than the File End Position for the Grade file selected for building the Ruling Grade file. Normal editing procedures can be used to enter and change values. Enter the Grade Limit (%), above which, the grade average is to be highlighted. The grade average is taken over the length of the train and the front of the train is the position at which the average grade will be specified in the Ruling Grade file. Normal editing procedures can be used to enter and change values.
Choose the train Running Direction. The choice can either be in increasing or decreasing values of position (or distance) with time. Click on entry to choose.

Enter the Position Increment. The train advances by the position increment for each position that the average grade is calculated. The average grade is displayed at that position, which represents the front of the train. The default value is 0.01.

Choose a Name for the Ruling Grade file. Since this file is both Grade dependent, Train dependent and Running Direction dependent, the file name should reflect these conditions. For example, if there was just one grade file, the file could be named after the train, with a + or – indicating direction. The default naming of a Ruling Grade file includes the Grade file name followed by an underscore followed by the length of the train in feet or meters followed by + or – to indicate direction of movement.

Enter an appropriate File Caption.

The next figure shows the completed screen.
Figure 3-51 File Construction Module – Ruling Grade Determination Screen – Completed Before File Creation

Click the Create File command button to create the file, then review the file.
Figure 3-52 Ruling Grade File – File Header

This section of the file shows the estimation parameters and the position of the front of train where the average grade over the train length exceeds the grade limit together with the average grade at that position.
Figure 3-53  Ruling Grade File – File Footer

The footer contains the range of the route where the average grade exceeds the grade limit and the length of each range.

This is followed by three distance numbers, the length of the route, the length of all portions of the route where the grade exceeds the limit, and the length of that portion of the route where the train, if stopped, cannot restart. The computed ratios in some sense represent a probability or risk of operating the train over the route.

3.1.3.2.2.5  Default Ruling Grade Rules

To set the default settings of the dispatch rules, click the Set Default Dispatch Rules command button on the Locomotive Dispatch screen, shown in Figure 3-45, to obtain the next screen.
Figure 3-54 Default Locomotive Dispatch Rules Screen

Change the rules in the text boxes provided and click the Modify Default File to save the results.

3.1.3.2.6 Train File Finalization

After all of these procedures are completed, go back to the original File Construction Module – Train File Input – Build Train to begin the process of Train file creation.
Figure 3-55 File Construction Module – Train File Input – Train Build Screen – Ready for Selection
Click the Select command button to obtain the next result.
Figure 3-56 Result of Train Build Selection
Click the OK command button to obtain the next screen.
Figure 3-57 Main Screen Ready for File Creation

The file may now be created.

This completes the Train Build process.

### 3.1.3.3 Propulsion Input Electric - Input Option

Selection of the Propulsion Input option in the Main Screen for the Train File for TPS Input of Figure 3-18 produces the following screen.
Figure 3-58 Propulsion Input Screen for the Train File for TPS Input, Electric - Input Selection — Propulsion Efficiency Input Option

Clicking the No Regeneration combo box and selecting the Regeneration option and clicking the DC Train combo box and selecting the AC Train option results in the following screen.
This screen will now provide the basis for the following discussions.

3.1.3.3.1 Efficiency Matrix Input Option

There are four option boxes on the upper left portion of the screen. These boxes are Real Power, Power Factor, Electric Brake and Brake Pwr Factor. The Power Factor option box is only available if the AC Train (rather than DC Train) selection is activated in the last combo box at the bottom left of the screen. The Electric Brake option can only be accessed if the Regeneration (rather than No Regeneration) selection is activated in the third from the bottom left combo box. The Brake Pwr Factor appears only if the AC Train and Regeneration selections are activated.

When the Real Power option is selected, the grid receives the points of the input curve for power. It represents the efficiency in converting power at the third rail, catenary or trolley to mechanical power at the rail. It is always less than or equal to 1.00. View or enter values for each speed and traction effort point in the spaces indicated. Traction effort may be specified directly or as a percentage of maximum traction effort at the designated speed, depending on the selection to the left, second box from bottom. When the selection Eff function of TE is made in the middle combo box, traction efficiency is entered as a function of traction effort and speed. This is explained with the help of the following illustration.
The efficiency is specified at every tractive effort and speed value. These values are shown as points covering the whole power and electrical braking effort region from zero to maximum speed. These efficiencies can either be provided by the supplier of the propulsion equipment or calculated using models within the FCM.

A second option is to choose Eff function of %Max TE. When this selection is made, traction efficiency is entered as a function of speed and the per cent (fraction) of maximum tractive effort at that speed. This is explained with the help of the following illustration.
The efficiency is specified at every speed value and at fixed percentages (fractions) of maximum tractive or electrical braking effort at the given speed value. These values are shown as points covering the whole power and electrical braking effort region from zero to maximum speed. These efficiencies can either be provided by the supplier of the propulsion equipment or calculated using models within the FCM.

Selection of the Power Factor option in Figure 3-59 produces a grid for input of power factor at each traction effort speed point. This input is also illustrated by the previous illustration, where the word efficiency is replaced by power factor. Likewise, selection of the Electric Brake option sets up the input for efficiencies in electric brake. These efficiencies represent the converting of mechanical power at the rail to electric power at the third rail, catenary or trolley. They are always less than or equal to 1.00. Selection of the Brake Pwr Factor option is the same as the Power Factor selection, but in electrical braking rather than power.

The Number of Spd Points entry in the screen sets the number of points on the speed axis of the efficiency and power factor curves. The range of entries lies between 2 and 25. The default value is 2. The speeds for the speed points are obtained by dividing the maximum speed by one less than the number of speed points and including zero and maximum speeds in the speeds.
The **Max Spd** entry is the maximum speed for propulsion and braking system input. It is the limiting speed for the efficiency curves as well as the limiting speed for the tractive and braking effort curves. (English units are mile per hour and metric units are kilometers per hour.) The default value is 80 mph for English units and 130 kph for Metric units.

The **Number of TE Points** entry is the number of points on the tractive effort axis of the efficiency and power factor curves. The range of entries lies between 2 and 25. The default value is 2. The traction efforts for the traction effort points are obtained by dividing the maximum traction effort by one less than the number of traction effort points and including zero and maximum traction effort in the traction efforts.

The **Max TE or EBE** entry is the maximum traction effort (Tractive Effort or Electrical Braking Effort) for propulsion and braking system input. It is the limiting traction effort for the efficiency curves as well as the limiting effort for the tractive and braking effort curves. (English units are mile per hour and metric units are kilometers per hour.)

The next three selections in Figure 3-59 are:

- **Regeneration** or **No Regeneration**. This selection determines whether the Electric Brake efficiency option is offered to the user. If the selection is **No Regeneration**, the option is not available.

- **Eff function of TE** or **Eff function of % Max TE**. This selection determines the method by which the efficiency and power factor curves are to be calculated or input. One of two methods can be selected. In both methods, the efficiencies are functions of speed. In the first case, the efficiency is a function of tractive effort as displayed in the first Efficiency vs. Traction Effort and Speed illustration of Figure 3-60, while in the second case, the efficiency is calculated as a function of a percentage of maximum tractive effort at the given speed, illustrated in Figure 3-61. The default is **Eff function of % Max TE**.

- **AC Train** or **DC Train**. This selection determines the power distribution system in which the train is running. Two choices are available AC or DC. If the AC distribution system is selected, the power factor curve must either be input or calculated from the model. If the choice is DC, the **Power Factor** entry option will not be offered to the user. At this stage, AC could mean either single or three phase.

Under the grid in the screen of Figure 3-59, there are three options: **Set Entry to Grid**, **TE vs. Spd Curve**, **EBE vs. Spd Curve** There is also a command button **Clear Grid**.

The **Set Entry to Grid** option is clicked whenever it is desired to set the following entries to the grid: **Number of Spd Points**, **Max Spd**, **Number of TE Points**, and **Max TE or EBE**. This has the effect of setting the new speeds or traction efforts to the entry grid.

Clicking the **Clear Grid** command button will clear the grids of all entries.

The **Text Transfer Option** is clicked when it is desired to input the Traction Curves and the Efficiency Matrices from either an external text file or a spreadsheet.

**3.1.3.3.2 Tractive Effort Input Option**

Selection of the **TE vs Spd Curve** option modifies the screen as follows.
Figure 3-62 Propulsion Input Screen for the Train File for TPS Input / Electric - Input Selection --- Propulsion System Tractive Effort vs Speed Curve

The Max Spd (maximum speed) entry is carried over from the previous screen. The grid in this screen is used for input of the tractive effort curve. (Tractive effort in English units is in pounds and in metric units is in newtons.) Normal editing procedures are used to enter or change the values. Instructions on the left of the screen provide additional editing hints.

The relation between the Traction Curves and the Propulsion Units in a Train of Cars or Vehicles is sometimes confusing to new users of the TOM. This document explains that relation in more detail with examples.

In most rail systems in the world, there are powered cars and non-powered cars. In rail transit, the most general configuration is trains of all powered cars. In mainline railroads, for passenger cars their may be trains of all powered cars as well as trains of locomotive (powered) hauled passenger coaches (non-powered) or locomotive hauled freight cars.

The Traction Curves (Tractive Effort vs Speed or Electrical Braking Effort vs Speed) are always entered on a Propulsion Unit basis.

The Traction Curves for the Train are computed internally in the TPS as follows.

Traction Effort per Train = Traction Effort per Propulsion Unit x Number of Propulsion Units per Train.

The Traction Effort per Propulsion Unit is entered into the Traction Effort vs Speed Grids of the File Construction Module – Train File Input – Propulsion Input screens.
The Number of Propulsion Units is entered in the # Prop entry in the Train Makeup Input grid of the File Construction Module – Train File Input – Train Makeup Input screen in Section 3.1.3.2.1.

Input tractive effort vs. speed. Normal editing procedures are used to enter or change the values. Use <ctrl>X to cut, <Ctrl>C to copy and <Ctrl>V to paste text. To copy using the mouse, click left mouse button on cell to be copied, hold down right mouse button, click left mouse button on cell to paste while still holding right mouse button down and then release right mouse button. Pay attention to the instructions on the left for additional editing hints.

Use the <Ctrl>F key to modify the effort by a fixed fraction. The factor used to multiply the efforts is entered in the box in the upper right hand corner. To multiply an effort by the factor, select the effort or contiguous range of efforts with the mouse and press <Ctrl> R

The screen is modified when <Ctrl>F key is pressed as follows.

![Figure 3-63 Propulsion Input Screen for the Train File for TPS Input / Electric - Input Selection --- Propulsion System Tractive Effort vs Speed Curve / <Ctrl> F Modification of Screen – With Dialog](image)

Clicking the OK button on the dialog produces the following screen.
3.1.3.3 Electrical Braking Effort Input Option

Selection of the EBE vs Spd Curve option, which can only be activated if the Regeneration option in the screen of Figure 3-59 is selected, results in the next screen.
The **Max Spd** (maximum speed) entry is carried over from the previous screen. The grid in this screen is used for input of the electrical braking effort curve. (Electrical Braking effort in English units is in pounds and in metric units is in newtons.) Normal editing procedures are used to enter or change the values. Instructions on the left of the screen provide additional editing hints.

The relation between the **Traction Curves** and the **Propulsion Units** in a **Train of Cars** or **Vehicles** is sometimes confusing to new users of the TOM. This document explains that relation in more detail with examples.

In most rail systems in the world, there are powered cars and non-powered cars. In rail transit, the most general configuration is trains of all powered cars. In mainline railroads, for passenger cars their may be trains of all powered cars as well as trains of locomotive (powered) hauled passenger coaches (non-powered) or locomotive hauled freight cars.

The **Traction Curves** (Tractive Effort vs Speed or Electrical Braking Effort vs Speed) are always entered on a **Propulsion Unit** basis.

The **Traction Curves** for the **Train** are computed internally in the **TPS** as follows.

**Traction Effort per Train** = **Traction Effort per Propulsion Unit** x **Number of Propulsion Units per Train**.

The **Traction Effort per Propulsion Unit** is entered into the **Traction Effort vs Speed Grids** of the File Construction Module – Train File Input – Propulsion Input screens.

---

**Figure 3-65 Propulsion Input Screen for the Train File for TPS Input / Electric - Input Selection --- Propulsion System Electrical Braking Effort vs Speed Curve**

![Propulsion System EBE vs Spd Curve](image)

The Max Spd (maximum speed) entry is carried over from the previous screen. The grid in this screen is used for input of the electrical braking effort curve. (Electrical Braking effort in English units is in pounds and in metric units is in newtons.) Normal editing procedures are used to enter or change the values. Instructions on the left of the screen provide additional editing hints.
The Number of Propulsion Units is entered in the # Prop entry in the Train Makeup Input grid of the File Construction Module – Train File Input – Train Makeup Input screen in Section 3.1.3.2.1.

In addition, there is an FBE vs Spd Curve option on the screen which allows friction braking effort to be input.

3.1.3.3.4 Friction Braking Effort Input Option

Selection of the Friction Brake Input option in the Main Screen for the Train File for TPS Input of Figure 3-18 or the FBE vs Spd Curve option on the previous screen produces the following screen.

![Friction Brake FBE vs Spd Curve Screen]

This is the friction brake curve. Input friction-braking effort vs. speed. (Braking effort in English units is in pounds and metric units are in newtons.)

The FBE (friction brake effort) vs speed is entered on a per car basis. The friction brake effort will supplement the electrical braking effort.

If a Normal Brake Rate is set in the File Construction Module – Control File Input – Main Screen, enough friction braking will be supplied to brake the train at this rate. Thus no entries or 0 entry in this grid is appropriate.
The Max Spd (maximum speed) entry is carried over from the previous screen. The grid in this screen is used for input of the friction braking effort curve. (Friction Braking effort in English units is in pounds and in metric units is in newtons.) Normal editing procedures are used to enter or change the values. Instructions on the left of the screen provide additional editing hints.

3.1.3.3.5 Train File Text to TOM Transfer

Clicking the Text Transfer command button shown in the screens of Figure 3-62 through Figure 3-66 produces the following Train FileText to TOM Transfer screen.

Figure 3-67 Train File Text to TOM Transfer Screen

The purpose of this screen is to input the Efficiency Matrices and Traction Effort Curves using a text format rather than grid format, which was discussed in the previous pages. The text can be input directly using a comma or space delimiter. It can also be input from a spreadsheet (EXCEL) or text files from WORD, WordPad or Notepad. This feature allows the user to calculate the traction characteristics using his model and then transfer the results by copying, cutting and pasting into this screen.

The Number of Spd Points entry in the screen sets the number of points on the speed axis of the efficiency and power factor curves. The range of entries lies between 2 and 25. The default value is 2. The speeds for the speed points are obtained by dividing the maximum speed by one less than the number of speed points and including zero and maximum speeds in the speeds.

The Max Spd entry is the maximum speed for propulsion and braking system input. It is the limiting speed for the efficiency curves as well as the limiting speed for the tractive and braking effort curves. (English units are mile per hour and metric units are kilometers per hour.) The default value is 80 in English units and 130 in Metric units.

The Number of TE Points entry is the number of points on the tractive effort axis of the efficiency and power factor curves. The range of entries lies between 2 and 25. The default value is 2. The traction efforts
for the traction effort points are obtained by dividing the maximum traction effort by one less than the number of traction effort points and including zero and maximum traction effort in the traction efforts.

The Max TE or EBE entry is the maximum traction effort (Tractive Effort or Electrical Braking Effort) for propulsion and braking system input. It is the limiting traction effort for the efficiency curves as well as the limiting effort for the tractive and braking effort curves. (English units are mile per hour and metric units are kilometers per hour.) The default value is 1., which represents the maximum tractive effort, when the Eff Function of % Max TE combo box in the Propulsion Input screen has the value Eff Function of % Max TE.

There are a number of selection options at the right hand side of the screen. The first three selections, TE vs Spd Curve, EBE vs. Spd Curve or the FBE vs. Spd Curve options prepare the screen to work with the traction curves. The last four selections, Real Power Efficiency, Power Factor, Electric Brake Efficiency or the Electric Brake Power Factor options prepare the screen to work with the efficiency matrices.

The screen in Figure 3-67 is set up for the Tractive Effort Curve (Tractive Effort vs Speed). The tractive effort and speed is entered in the following format:

```
Speed (delimiter) Traction Effort (carriage return)
Speed (delimiter) Traction Effort (carriage return)
```

etc.

It must finish with a carriage return. For example:

```
15400
15400
13600
Etc.
```

It may be copied directly from a text file or spreadsheet. The speeds must begin with zero and end with the maximum speed shown in the Max Spd text box at the left.

If the Maximum Tractive Effort, shown in the box on the left is greater than 1, the maximum of the tractive effort entries in this text box must be less than or equal to that value.

The delimiter may be a tab, a comma, or a space. The tab delimiter is recognized only when the text is pasted from another application such as EXCEL, WORD, Notepad, etc. or when the entries are imported from a train file using the Import Command Button. The current delimiter in use is shown at the left.

The next screen shows the Efficiency Matrix in real power for a train file, which has been imported into the model. It is a DC train with no regeneration.
Figure 3-68 Train File Text to TOM Transfer Screen with Imported Train File for DC Train with No Regeneration

The Speed Points for the efficiency matrix and the Traction Effort points are shown to the bottom and the right of the efficiency matrix, respectively. Since the points were imported from a train file, which is currently active in the model, the delimiters are tabs. The entries may be edited directly in the screen or they may be cut and pasted into a spreadsheet or some other program for editing.

When editing is finished, the Transfer command button is clicked to transfer the data into the grids of the model. This process has the same effect as entering the data directly into the grids.

Entries into the efficiency matrices can be made directly into the text boxes, as well.

The speed point values are entered as: speed (delimiter) speed (delimiter) speed (delimiter) speed

The traction effort values are entered as:
Traction Effort (carriage return)
Traction Effort (carriage return)
Traction Effort (carriage return)
(Carriage return)

The efficiency values are entered as:
Efficiency (delimiter) Efficiency (delimiter) Efficiency (delimiter) Efficiency (carriage return)
Efficiency (delimiter) Efficiency (delimiter) Efficiency (delimiter) Efficiency (carriage return)
Efficiency (delimiter) Efficiency (delimiter) Efficiency (delimiter) Efficiency (carriage return)
Efficiency (delimiter) Efficiency (delimiter) Efficiency (delimiter) Efficiency (carriage return)
(Carriage return)
The entries may be copied directly from a text file or spreadsheet. The speeds must begin with zero and end with the maximum speed.

If the Maximum Traction Effort, shown in the box on the left is greater than 1, the maximum of the traction effort entries in this text box must be less than or equal to that value.

The delimiter may be a tab, a comma, or a space. The tab delimiter is recognized only when the text is pasted from another application such as EXCEL, WORD, Notepad, etc. or when the entries are Imported from a train file using the Import Command button. The delimiter is shown at the left of the screen.

The use of mixed delimiters is not permitted.

3.1.3.4 Propulsion Input Electric - Model Option

Creating a Train File using the Electric – Model option results in saving that file in the Electric – Input option format. Thus the next time it is viewed, all information of the process of how it was created is not preserved in the Train File, but rather in an auxiliary file called the Propulsion Model Detailed Output File (TC-*.*)

Setting the Type of Propulsion System of the Propulsion Input Screen for the Train File for TPS of Figure 3-18 followed by clicking Propulsion Input produces the following screen.
Figure 3-69 Propulsion Input Screen for the Train File for TPS / Electric – Model Selection

Clicking the Compute from Model option produces the following screen.
This screen is used to input the information from which a propulsion system model computes the traction effort vs speed curves. The form of the screen will change depending upon the Motor Type and Type Control selected.

For the Motor Type selection, the DC series, DC Separately Excited and AC Induction motor-based models are available. The Type Control selections which are available depend on the Motor Type selected and whether the AC Train or DC Train option was selected in the Propulsion Input Screen for the Train File for TPS Input / Electric – Model Selection of Figure 3-69. A hierarchy is formed for the type of control, which can be used with the various combinations.

Control selection may be:

Figure 3-71 Motor Control Categories

Control models are presently not available for the *italicized* controls.
For DC Motors with the **DC Train** selection, the **CHOPPER** and **CAM** control options are available.

For DC Motors with the **AC Train** selection, the **PHASE** control is available.

For the AC Induction motor with the **DC Train** selection, Pulse-Width-Modulated Inverter (PWM_INV) control is available.

For the AC Induction motor with the **AC Train** selection, Four Quadrant (4_QUAD) control is available.

Once the **Motor Type** is selected, clicking on the **Motor Selection** list and selecting the motor can choose the actual motor file. Selection of the (NEW) option causes the screen with the Subsystem Model to appear so that a new model file can be produced.

Once the **Type Control** is selected, clicking on the Control Selection list and selecting the control can choose the actual control file. The **Control Selection** for the CAM control is not present, since the model is to insert resistors in series with the motor circuit as needed. Selection of the (NEW) option causes the screen with the Subsystem Model to appear so that a new model file can be produced.

As the model expands, more motor/control models will become available.

Beginning at the top left, there are three entries: **Nominal Voltage**, **Maximum Voltage** and **Minimum Voltage**. These are followed by the Use Standard Voltage Relations option. The nominal voltage is the open circuit voltage of the power distribution system with a default value of 750 v. If the Use Standard Voltage Relations option is set, the maximum and minimum voltages are set at (nominal + 10%) and (nominal - 25%), respectively. This is the default. If the option is not set, maximum and minimum power distribution system voltage may be set separately.

Creating a **Train File** using the Electric – Model option results in saving that file in the Electric – Input option format. Thus the next time it is viewed, all information of the process of how it was created is not preserved in the Train File, but rather in an auxiliary file called the Propulsion Model Detailed Output File (TC-*.*), which is created as part of the process.

The Propulsion Model Detailed Output File may be selected by editing the filename at the bottom left. This is the path and filename where the detailed results of the computation are saved and not the resulting train file. Clicking on a file in the list and clicking on the Delete button may also delete files. Note that the model output file can be viewed or deleted but not selected.

At the beginning of the middle column of selections in the screen is the entry **Power Control Modes**. This entry is the number of power control modes. A power control mode is one combination of a motor circuit with a specific value of field shunting. For example, a motor circuit with four motors could be 4 series/1 parallel, 2 series/2 parallel or 1 series/4 parallel. Field shunting refers to shunting current around the motor field. This refers principally to DC series motors. The default value is 1. The propulsion model algorithms are described from an operations standpoint in Section 3.6 and from a technical standpoint in Appendix 9.12.

The grid below the Power Control Modes entry in the previous screen accepts as input the definition of the motor circuit modes used in the model’s calculation. Enter the parameters for each of the Propulsion Control Modes. These parameters include the number of motors in series, the number of motors in parallel and the field strength. In the case of DC Series Motors, use the Power Field Strength selection below the grid to obtain a field strength for the particular motor selected.

The Number of Motors/ Car entry limits the possibilities of control mode definitions. The default value used here is 4.

The remaining selections at the bottom of the second column of the screen are; Motor Selection, Control Selection and Gear Unit Selection. The selections are determined by which model files exist in the Submodel Database. Building new motor (*.mot), control (*.con) or gear unit (*.gum) files is explained in Section 3.6.

Select the voltage at which the model will calculate the propulsion characteristics (traction and efficiency curves) by activating the Propulsion Calculation at: at the right on the screen. This voltage can be...
Nominal, Maximum, Minimum or Average. The Average voltage selection causes the voltage to vary inversely with the power drawn. In the power mode, maximum power draw implies minimum voltage and minimum power drawn implies nominal voltage. In the electric brake mode, maximum power output to the line implies maximum voltage and minimum power output means nominal voltage. The default value for this selection is Nominal voltage.

In the control section of the screen, selections are available for the Number of Controls/Car and the Control Selection.

The propulsion characteristics (traction effort and efficiency curves) are calculated on a per car basis. Thus the number of control units per car must be specified. The default value is 1.

Click on the Control Selection, which refers to a specific manufacturer's control unit for the application.

If the Regeneration selection is made on the Propulsion Input Screen for the Train File for TPS Input / Electric-Model Selection of Figure 3-69, the following screen becomes visible when the Compute from Model box is checked.

Since regeneration is to be activated with a chopper control, the electrical braking effort and efficiencies as a function of electrical braking effort and speed are also calculated. However, the user is required to enter parameters to aid these calculations.

Select the Electrical Braking EBE Criteria. Select the Maximum Deceleration (English units are mile per hour per second and metric units are meters per second squared.) and specify whether it is to be applied to a Crush Loaded Car (passenger load factor 100%) or an Empty Car. The electrical braking curve will be calculated to match the criteria selected. The default is a rate of 3.00 for a crush-loaded car.
The Brake Control Modes are similar to the Power Control Modes. These refer to the motor circuits and field strength combinations. Enter the parameters for each of the electric brake control modes. These parameters include the number of motors in series, the number of motors in parallel and the field strength. Use the Brake Field Strength selection below to obtain a field strength for the particular motor selected in electrical brake Figure 3-72 (DC Series Motors only).

The Select button at the bottom right of the screen is clicked when the selection of the output choices is completed. This incorporates those choices in the resulting file once the file is activated.

The Reset button completely resets the screen, starting from scratch. It is best used when problems arise and the user can no longer fix them. The Close button acts the same as the Reset button in this case.

Two examples of Train file creation are illustrated in the next two sections: DC Series Motors – Regeneration and AC Induction Motors – Regeneration.

3.1.3.4.1 DC Series Motors – Regeneration

Completion of all of the inputs in the screen of Figure 3-72, results in the following screen.

Figure 3-73 Propulsion Model Input Screen for the Train File for TPS Input with Regeneration Option – DC Series Motors – Completed Screen

Clicking the Select command bottom results in the following screen.
Figure 3-74 Propulsion Input Screen for the Train File for TPS / Electric – Model Selection – After Model Computation for DC Series Motors - Regeneration

Clicking the Select button on the screen will cause the following screen to appear.
Two tasks remain; namely, completion of the Train Makeup Input screen and completion of this screen. First, completion of the Train Makeup Input screen is shown in the next screen.
Figure 3-76 Completion of the Train Makeup Input Screen
Clicking the Select button will return to the screen in Figure 3-75.
Figure 3-77 Completed Main Screen for the Train File for TPS Input – With Electric – Model Type Propulsion System – (DC Series Motors – Regeneration)

Clicking the Create command button produces the following screen.
Figure 3-78 Completed Main Screen for the Train File for TPS Input – With Electric – Model Type Propulsion System – Creation of the Train File - (DC Series Motors – Regeneration)

The file may now be viewed in the TOM File Viewer by clicking the Yes button for Review File?. The result is shown as the following screen.
3.1.3.4.2 AC Induction Motors – Regeneration

A second example involves the AC Drive.

Selection **AC Ind** as the **Motor Type** and **PWM_INV** as the Control Type of Figure 3-72 produce the following screen.
Figure 3-80 Propulsion Model Input Screen for the Train File for TPS Input with Regeneration Option – AC Induction Motors with PWM Inverter Control

Only one **Power Mode** and one **Brake Control Mode** are possible for this configuration.

Clicking the **Gear Unit** option at the bottom right of the screen produces the following screen.
Figure 3-81 Gear Unit Model File Selection

A list of Gear Unit Model Data Files (*.gum) in the Applications directory is shown at the left and middle of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well. The Select One action will cause the gear unit mode filename to appear in the Name of File box.

The Select button at the bottom right of the screen is clicked when the selection of the output choices is completed. This incorporates those choices in the resulting file once the file is activated.

The Reset button completely resets the screen, starting from scratch. It is best used when problems arise and the user can no longer fix them. The Close button closes the screen.

A click on the Gear Unit Model button in the middle of the screen causes the screen with the Subsystem Model to appear so that a new model file can be produced.

A gear unit file selection is shown in the next screen.
The same process as just described for the case of DC Series Motors – Regeneration is used to create the train file. The steps are:

Select the gear unit by clicking the Select button in the screen of Figure 3-82.

Complete the Propulsion Model Input Screen for the Train File for TPS Input with Regeneration Option – AC Induction Motors with PWM Inverter Control of Figure 3-80.

Complete the Train Makeup input screen of Figure 3-76.

Complete the main screen for the Train File for TPS Input of Figure 3-75.

Create and Review the file.

The screens for these steps are now presented. Clicking the Select button in the screen of Figure 3-82 and completing the Propulsion Model Input Screen for the Train File for TPS Input with Regeneration Option – AC Induction Motors with PWM Inverter Control of Figure 3-80, produces the next screen.
Figure 3-83 Propulsion Model Input Screen for the Train File for TPS Input with Regeneration Option – AC Induction Motors with PWM Inverter Control – Completed Screen

Clicking the Select button produces the next screen.
Figure 3-84 Propulsion Input Screen for the Train File for TPS / Electric – Model Selection –After Model Computation for AC Induction Motors – Regeneration.

Clicking the Select button on this screen results in the screen of Figure 3-75. Clicking the Train Makeup Input check box and completing the Train Makeup Input screen results in the screen of Figure 3-76.

Clicking the Select button on this screen returns to the Train File Input – Main Screen, which when completed is the following screen.
Figure 3-85 Completed Main Screen for the Train File for TPS Input – With Electric – Model Type Propulsion System – (AC Induction Motors – Regeneration)

Clicking the Create File button produces the following screen.
Figure 3-86 Completed Main Screen for the Train File for TPS Input – With Electric – Model Type Propulsion System – Creation of the Train File - (AC Induction Motors – Regeneration)

The file may now be viewed in the TOM File Viewer by clicking the Yes button for Review File?. The result is shown as the following screen.
3.1.3.4.3 Re-creating an Electric – Model Type File

Creating a Train File using the Electric – Model option results in saving that file in the Electric – Input option format. Thus the next time it is viewed, all information of the process of how it was created is not preserved in the Train File, but rather in an auxiliary file called the Propulsion Model Detailed Output File (TC-*.*), which is created as part of the process.

First, import the Train file into the screens, by double-clicking on the train file. This is shown in the next screen.
Figure 3-88 File Construction Module – Train File Input – Main Screen File Imported Into Screen

Changing the setting of this combo box from Electric – Input to Electric - Model, will initiate a procedure, through which the original screens, which created the Train file was will appear. This procedure requires that the original Propulsion Model Detailed Output file (TC-*.* ) exists in the directory. All files which are created in this manner are stored as Train files with the Electric – Input format.

Change the Type Propulsion System from Electric – Input to Electric – Model.
Figure 3-89 File Construction Module – Train File Input – Main Screen File Imported Into Screen – Inquiry

Click the Yes command button to proceed.
Figure 3-90 File Construction Module – Train File Input – Main Screen File Imported Into Screen – Second Inquiry

Click the Yes command button to proceed.
This screen can be changed and the *Train* file can be created as a new file or the same file.

### 3.1.3.5 Propulsion Input *Fuel - Fuel Curves*

Selection of the *Fuel - Fuel Curves* Type of Propulsion System in Figure 3-18 followed by a click on the *Propulsion Input* option of that same screen produces the following screen.
On the left of the screen there are two entries: **Number of Fuel Curves** and **Number of Points per Curve**. The values of 8 for both of these entries are the default. The user can enter up to 10 curves and 10 points per curve.

Once these entries are made, click the **Set Entry to Grid** option to set up the grids for input of data. This action will produce the following screen.
The **Fuel Rate** for *Idle, Dynamic* braking and the train **Auxiliary** power is input using the grid on the bottom left side of the screen. The fuel rate is the rate of fuel consumption and is measured in gallons per hour for English unit input and imperial gallons per hour for metric input. The units are discussed further in Appendix 9.3.

The fuel curves are input using the grid in the center of the screen. Each curve is at a constant fuel rate. Enter the **Fuel Rate** (gallons per hour or imperial gallons per hour for English or metric units, respectively). For each Fuel Rate, enter the **Speed** and **TE or EBE** (tractive or electrical braking effort) for each point on the curve.

Click on the **TE vs Spd Curve** to get to the screen of Figure 3-62, the Tractive Effort vs. Speed Curve and **EBE vs Spd Curve** to get to the screen of Figure 3-65, the Electrical Braking Effort vs. Speed Curve.

An example of a completed or imported file screen is shown next.
The *Select* button is clicked when the selection of the output choices is completed. This incorporates those choices in the resulting file once the file is activated.

The *Reset* button completely resets the screen, starting from scratch. It is best used when problems arise and the user can no longer fix them. The *Close* button closes the screen and returns to the screen at the next highest level.

### 3.1.3.6 Propulsion Input Fuel - Straight Line

Selection of the *Fuel - Straight Line Type of Propulsion System* in Figure 3-18 followed by a click on the *Propulsion Input* option of that same screen produces the following screen.
Figure 3-95 Propulsion Input Fueled Trains / Straight Line Method

The Fuel Rate for Idle, Dynamic braking and the train Auxiliary power are input using the grid on the bottom left side of the screen. The fuel rate is the rate of fuel consumption and is measured in gallons per hour for English unit input and imperial gallons per hour for metric input. The units are discussed further in Appendix 9.3.

The Straight Line Method for computing fuel consumption uses the formula shown in the screen. Enter the Intercept and Slope of the straight line. The units for the Intercept are gallons/hour for English units and imperial gallons per hour for metric units. The units for the Slope are gallons per horsepower-hour for English units and imperial gallons per kilowatt-hour for metric units.

Click on the TE vs Spd Curve to get to the screen of Figure 3-62, the Tractive Effort vs. Speed Curve and EBE vs Spd Curve to get to the screen of Figure 3-65, the Electrical Braking Effort vs. Speed Curve.

An example of a completed or imported file screen is shown next.
The **Select** button is clicked when the selection of the output choices is completed. This incorporates those choices in the resulting file once the file is activated.

The **Reset** button completely resets the screen, starting from scratch. It is best used when problems arise and the user can no longer fix them. The **Close** button closes the screen and returns to the screen at the next highest level.

Click the **TE vs Spd Curve** checkbox to obtain the grid for entering the Tractive Effort vs. Speed curve.

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**Figure 3-96 Propulsion Input Fueled Trains / Straight Line Method (Completed or Imported File)**
Figure 3-97 Grid for entry of the Tractive Effort vs. Speed Curve

Entering the new maximum speed into the Max Spd text box and clicking the Size Grid to Speed command button may change the maximum speed. Thus for a maximum speed of 70, enter the speed followed by the click.
3.1.3.7 Onboard Storage Input Option

Selection of the Onboard Storage Input option in the Main Screen for the Train File for TPS Input in Figure 3-18 produces the following screen.
There are two models for decay of the storage device energy. Select the model for energy decay. The first model is *Exponential Decay* (default), with decay rate (fraction / sec) proportional to the amount of energy in the storage device. The second model is *Linear Decay* with a fixed rate (Wh / sec).

### Storage Devices/Car

The value of 0 or blank indicates no storage devices. Regeneration must be turned on for on-board energy storage. If the size of the storage device is inadequate, energy is returned to the line.

**Initial Energy/Device**

This is the initial stored energy in the device when the train starts at the terminal. Energy is expressed in watt-hrs.

**Min Stored Energy/Device**

This entry is the minimum stored energy that the device will hold. Energy flows out of the device are stopped when the storage decreases to this level. Energy is expressed in watt-hrs.

**Max Stored Energy/Device**

This entry is the maximum stored energy that the device can hold. Energy flows into the device are stopped when the storage increases to this level. Energy is expressed in watt-hrs.

**Max Power Output/Device**

This entry is the maximum power output that the device can produce. Additional power will come from the power distribution system. Power is expressed in watts.

**Max Power Input/Device**

This entry is the maximum power input that the device can accept. Additional power would be returned to the distribution system. Power is expressed in watts.
Output Efficiency

This entry is the ratio power output delivered from the storage device to the power output from storage. The remainder goes into heat. Efficiency is expressed as a fraction between 0 and 1.

Input Efficiency

This entry is the ratio power input into storage to the power delivered to the storage device. The remainder goes into heat. Efficiency is expressed as a fraction between 0 and 1.

SS Energy Loss/Device

This entry is the steady state energy loss of the device. It is expressed in fraction/sec or Wh/sec depending on the loss model selected. If the loss model is exponential, the loss is expressed in fraction per second. If the loss model is linear, the loss is expressed in Wh/sec.

The units of power are in watts (W) and of energy inputs are watt-hours (Wh). Efficiencies are expressed in fractions.

3.1.3.8 Metric/English Conversion Option

When an existing train file is imported into the model, an option exists to convert that file to English units, if the original file is in metric units, or to Metric units if the original file is in English units.
Figure 3-99 Imported Train File Illustrating the Possibility of Converting Units

A click on Convert to Metric command button will convert units and the file may then be created in the new units.

3.1.4 TPS Station Input

A DC Test System is used to illustrate entry of data into the remaining input files of the TPS. The track layout for this system follows.
Figure 3-100 Track Layout of DC Test System

Selection of Station in the TPS Input Selection screen Figure 3-3 produces the following screen.
Figure 3-101 Main Screen for the Station File for TPS Input

A list of station files in the database for the rail system selected is shown at the left and middle of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

Selection of the Name of File to be created or modified is at the left and bottom of the screen. This is edited in the usual window manner.

The station file can have input units, which are either English or metric, and output units, which are either English or metric. This is selected by checking the appropriate box at the left of the screen. A description for the kind of units expected is given in Appendix 9.3.

The input for the station records is accomplished in free format in the box designated by Station Name, Position, Dwell Time (sec), Passenger Load Factor (%). For each passenger station, enter the station
name (limit 12 characters) followed by a comma delimiter, followed by the position (English units feet or miles or metric units meters or kilometers depending on input units selection at left) of the station followed by a comma delimiter, followed by a dwell time (sec) followed by a comma delimiter, followed by a passenger load factor (%) followed by a carriage return. The passenger load factor at a particular station represents the load factor from that station to the next station (in the list) if the run is to be in the increasing position direction and from that station (in the list) to the previous station if the run is in the decreasing position direction. Use normal editing procedures to enter or change any values.

The position associated with a station is the stopping point of the front of the train at that station. To obtain the best accuracy, position values should be as low as possible. For example, rather than have the position of the right of way be between 1000. and 1007., it would be better to have the position of the right of way between 0. and 7. The reason for the latter selection is that computations are done with single precision, which involves six significant figures. Thus the digits 100 are not significant for computational purposes.

The passenger load factor is the ratio:

\[
\frac{\text{Train Weight} - \text{Train Empty Weight}}{\text{Train Crush Load Weight} - \text{Train Empty Weight}}
\]

Enter the station portion of the four characters ID that appears in the output power profile using the station file ID box. The other two characters come from the train file. The File Caption, which appears as a title script within the file, is a title, which is carried through the simulator or program and becomes part of the normal output. It is used to identify the run.

An example of a completed or imported file screen is shown next.
Clicking the **Invert** button reverses the increasing position direction. The invert process consists of multiplying all of the right of way positions by the value (-1) and reordering these positions in ascending value. The rights of way elements are also reordered so that the value between adjacent inverted values of position remains the same. **Note:** This option is rarely used. It would only be used when it was desired to change the direction of increasing position mileposts or kilometerposts. In this case, all right of way and station files would also be “inverted”.

The **Shift** button is activated when a value is entered into the **Shift Distance** box. Subsequent clicking of the **Shift** button is the equivalent of increasing or decreasing all of the positions in a right of way file by a constant amount which is the value in the box. The effect is to shift the zero position of the right of way. **Note:** This option is rarely used. It would only be used when it was desired to change the reference position of mileposts or kilometerposts. In this case, all right of way and station files would also be “shifted”.

Figure 3-102 Main Screen for the Station File for TPS Input (Completed or Imported File)
The final action to create the file is taken by clicking on the Create button. The file is created and the user is given the option of viewing the file with a Yes or No button. Clicking on Yes will produce a TOM File View of the file. Clicking on No will close the file.

There are two other buttons at the right of the screen Close and Reset. A click on Close will abort the screen and return to the TPS Input Selection screen of Figure 3-3. A click on Reset will create the same screen in the same manner as if it was called from the TPS Input Selection screen.

### 3.1.5 TPS Grade Input

Selection of Grade in the TPS Input Selection screen of Figure 3-3 produces the following screen.

![Figure 3-103 Main Screen for the Grade File for TPS Input](image)

A list of grade files in the database for the rail system selected is shown at the left and middle of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.
Selection of the Name of File to be created or modified is at the left and bottom of the screen. This is edited in the usual window manner.

The grade file can have input units, which are either English or Metric and output units, which are either English or metric. This is selected by checking the appropriate box at the left of the screen. A description for the kind of units expected is given in Appendix 9.3.

The grade records are input in free format in the box designated by Position, Grade. For each record, enter the position (English units feet or miles or metric units meters or kilometers depending on input units selection at left) followed by a comma delimiter, followed by grade (%) followed by a carriage return. Use normal editing procedures to enter or change any values.

The File Caption appears as a title script at the end of the file is not used as any portion of the run but simply identifies the file.

An example of completed or imported file version of the screen is shown next.

![Figure 3-104 Main Screen for the Grade File for TPS Input (Completed or Imported)](image)

Clicking the Invert button reverses the increasing position direction. The invert process consists of multiplying all of the right of way positions by the value (-1) and reordering these positions in ascending value. The rights of way elements are also reordered so that the value between adjacent inverted values
position remains the same. In the case of the grade right of way element, the sign of the grade is also reversed. Note: This option is rarely used. It would only be used when it was desired to change the direction of increasing position mileposts or kilometerposts. In this case, all right of way and station files would also be “inverted”.

The **Shift** button is activated when a value is entered into the **Shift Distance** box. Subsequent clicking of the **Shift** button is the equivalent of increasing or decreasing all of the positions in a right of way file by a constant amount, which is the value in the box. The effect is to shift the zero position of the right of way. Note: This option is rarely used. It would only be used when it was desired to change the reference position of mileposts or kilometerposts. In this case, all right of way and station files would also be “shifted”.

The final action to create the file is taken by clicking on the **Create** button. The file is created and the user is given the option of viewing the file with a **Yes** or **No** button. Clicking on **Yes** will produce a **TOM File View** of the file. Clicking on **No** will close the file.

There are two other buttons at the right of the screen **Close** and **Reset**. A click on **Close** will abort the screen and return to the previous screen. A click on **Reset** will create the same screen in the same manner as if it was called from the **TPS Input Selection** screen of Figure 3-3.

### 3.1.6 TPS Curve Input

Selection of **Curve** in the TPS Input Selection screen of Figure 3-3 produces the following screen.
A list of curve files in the database for the rail system selected is shown at the left and middle of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

Selection of the Name of File to be created or modified is at the left and bottom of the screen. This is edited in the usual window manner.

The grade file can have input units, which are either English or Metric and output units, which are either English or metric. This is selected by checking the appropriate box at the left of the screen. A description for the kind of units expected is given in Appendix 9.3.

The curve records are input in free format in the box designated by Position, Curvature. For each record, enter the position (English units feet or miles or metric units meters or kilometers depending on input units selection at left) followed by a comma delimiter, followed by curve (degrees) followed by a carriage return. Use normal editing procedures to enter or change any values.
The *File Caption* appears as a title script at the end of the file is not used as any portion of the run but simply identifies the file.

An example of completed or imported file version of the screen is shown next.

**Figure 3-106 Main Screen for the Curve File for TPS Input (Completed or Imported)**

Clicking the *Invert* button reverses the increasing position direction. The invert process consists of multiplying all of the right of way positions by the value (-1) and reordering these positions in ascending value. The rights of way elements are also reordered so that the value between adjacent inverted values of position remains the same. **Note: This option is rarely used. It would only be used when it was desired to change the direction of increasing position mileposts or kilometerposts. In this case, all right of way and station files would also be “inverted”.**

The *Shift* button is activated when a value is entered into the *Shift Distance* box. Subsequent clicking of the *Shift* button is the equivalent of increasing or decreasing all of the positions in a right of way file by a constant amount, which is the value in the box. The effect is to shift the zero position of the right of way. **Note: This option is rarely used. It would only be used when it was desired to change the reference position of mileposts or kilometerposts. In this case, all right of way and station files would also be “shifted”.**
The final action to create the file is taken by clicking on the Create button. The file is created and the user is given the option of viewing the file with a Yes or No button. Clicking on Yes will produce a TOM File View of the file. Clicking on No will close the file.

There are two other buttons at the right of the screen Close and Reset. A click on Close will abort the screen and return to the previous screen. A click on Reset will create the same screen in the same manner as if it was called from the TPS Input Selection screen of Figure 3-3.

3.1.7 TPS Speed Restriction Input

Selection of Spd Res in the TPS Input Selection screen Figure 3-3 produces the following screen.

A list of speed restriction files in the database for the transportation system selected is shown at the left and middle of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.
Selection of the **Name of File** to be created or modified is at the left and bottom of the screen. This is edited in the usual window manner. The speed restriction file can have input units, which are either English or Metric and output units, which are either English or metric. This is selected by checking the appropriate box at the left of the screen. A description for the kind of units expected is given in Appendix 9.3.

The input for the speed restriction records is accomplished in free format in the box designated by **Position, Speed Restriction**. For each record, enter the position (English units feet or miles or metric units meters or kilometers depending on input units selection at left) followed by a comma delimiter, followed by a speed restriction (English units mph or metric units kph depending on input units selection at left) followed by a carriage return. Use normal editing procedures to enter or change any values.

The **File Caption**, which appears as a title script at the end of the file, is not used as any portion of the run but simply identifies the file.

An example of a completed or imported file screen is shown next.

![Main Screen for the Speed Restriction File for TPS Input (Completed or Imported File)](image)

Clicking the **Invert** button reverses the increasing position direction. The invert process consists of multiplying all of the right of way positions by the value (-1) and reordering these positions in ascending value. The rights of way elements are also reordered in such a way so that the value between adjacent inverted values of position remains the same. **Note: This option is rarely used. It would only be used**
when it was desired to change the direction of increasing position mileposts or kilometerposts. In this case, all right of way and station files would also be “inverted”.

The Shift button is activated when a value is entered into the Shift Distance box. Subsequent clicking of the Shift button is the equivalent of increasing or decreasing all of the positions in a right of way file by a constant amount, which is the value in the box. The effect is to shift the zero position of the right of way. Note: This option is rarely used. It would only be used when it was desired to change the reference position of mileposts or kilometerposts. In this case, all right of way and station files would also be “shifted”.

The final action to create the file is taken by clicking on the Create button. The file is created and the user is given the option of viewing the file with a Yes or No button. Clicking on Yes will produce a TOM File View of the file. Clicking on No will close the file.

There are two other buttons at the right of the screen Close and Reset. A click on Close will abort the screen and return to the previous screen. A click on Reset will create the same screen in the same manner as if it was called from the TPS Input Selection screen of Figure 3-3.

3.1.8 TPS Speed Command Input

Selection of Spd Cmd in the TPS Input Selection screen of Figure 3-3 produces the following screen.
Figure 3-109 Main Screen for the Speed Command File for TPS Input

A list of speed command files in the database for the transportation system selected is shown at the left and middle of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

Selection of the Name of File to be created or modified is at the left and bottom of the screen. This is edited in the usual window manner. The Speed Command file can have input units, which are either English or Metric and output units, which are either English or metric. This is selected by checking the appropriate box at the left of the screen. A description for the kind of units expected is given in Appendix 9.3.

The input for the speed command records is accomplished in free format in the box designated by Position, Speed Command. For each record, enter the position (English units feet or miles or metric units meters or kilometers depending on input units selection at left) followed by a comma delimiter, followed by a speed command (English units mph or metric units kph depending on input units selection at left) followed by a carriage return. Use normal editing procedures to enter or change any values.

The File Caption, which appears as a title script at the end of the file, is not used as any portion of the run but simply identifies the file.

An example of a completed or imported file screen is shown next.
Figure 3-110 Main Screen for the Speed Command File for TPS Input (Completed or Imported File)

Clicking the Invert button reverses the increasing position direction. The invert process consists of multiplying all of the right of way positions by the value (-1) and reordering these positions in ascending value. The rights of way elements are also reordered in such a way so that the value between adjacent inverted values of position remains the same. Note: This option is rarely used. It would only be used when it was desired to change the direction of increasing position mileposts or kilometerposts. In this case, all right of way and station files would also be “inverted”.

The Shift button is activated when a value is entered into the Shift Distance box. Subsequent clicking of the Shift button is the equivalent of increasing or decreasing all of the positions in a right of way file by a constant amount, which is the value in the box. The effect is to shift the zero position of the right of way.

Note: This option is rarely used. It would only be used when it was desired to change the reference position of mileposts or kilometerposts. In this case, all right of way and station files would also be “shifted”.

The final action to create the file is taken by clicking on the Create button. The file is created and the user is given the option of viewing the file with a Yes or No button. Clicking on Yes will produce a TOM File View of the file. Clicking on No will close the file.
There are two other buttons at the right of the screen: Close and Reset. A click on Close will abort the screen and return to the screen. A click on Reset will create the same screen in the same manner as if it was called from the TPS Input Selection screen of Figure 3-3.

There is a second method by which speed commands can be created. Click on the Create Using Power Profile option to create a speed command file from an existing power profile. The speed command file is created from a TPS run. The output power profile is used as the basis for this construction. The resulting power profile is used to create the speed command file. As soon as the Create Using Power Profile option is selected, the Main Screen for the Speed Command File for TPS Input of Figure 3-110 is modified as follows.

![Figure 3-111 Main Screen for the Speed Command File for TPS Input / Create Using Power Profile Option](image)

Select a power profile from the list of p-files so that a speed command file can be constructed from it.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.
The Control file of the TPS run which generated the power profile should have a small **Calculation Time Interval** set (typically 1.0 sec) and the **Calculations per Display** set to 1. The power profile is selected by double clicking on the desired one or by clicking on the desired one and clicking on the **Select** button.

The **File Caption**, which appears as a title script at the end of the file, is not used as any portion of the run but simply identifies the file.

The next action to create the file is taken by clicking on the **Create** button. The file is created and the User is given the option of editing the file in the **Position, Speed Command** text box. If the User chooses not to edit, the file remains as is.

Edit the file in the text box and create the file by clicking on the **Create** button. The file is created and the user is given the option of viewing the file with a **Yes** or **No** button.

The file is created and the user is given the option of viewing the file with a **Yes** or **No** button. Clicking on **Yes** will produce a **TOM File View** of the file. Clicking on **No** will close the file.

**The Speed Command File is extremely important in taking the first cut at building a Track Layout File for the TMS.**

3.1.9 **TPS Route Input**

Selection of **Route** in the **TPS Input Selection** screen of Figure 3-3 produces the following screen.
Figure 3-112 Main Screen for the Route File for TPS Input

A list of route files in the database for the rail system selected is shown at the left and middle of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

Selection of the Name of File to be created or modified is at the left and bottom of the screen. This is edited in the usual window manner.

The route file can have input units, which are either English or Metric and output units, which are either English or metric. This is selected by checking the appropriate box at the left of the screen. A description for the kind of units expected is given in Appendix 9.3.

The input for the route records is accomplished in free format in the box designated by Position, Track Number. For each record, enter the position (English units feet or miles or metric units meters or kilometers depending on input units selection at left) followed by a comma delimiter, followed by track number followed by a carriage return. Track number is an integer from 1 to 99. Track numbers 1-49 are
used for main track and track numbers 50-99 are used for non-main or connecting tracks. Use normal editing procedures to enter or change any values.

The **File Caption**, which appears as a title script at the end of the file, is not used as any portion of the run but simply identifies the file.

An example of a completed or imported file screen is shown next.

![Figure 3-113 Main Screen for the Route File for TPS Input (Completed or Imported File)](image)

Clicking the **Invert** button reverses the increasing position direction. The invert process consists of multiplying all of the right of way positions by the value (-1) and reordering these positions in ascending value. The rights of way elements are also reordered in such a way so that the value between adjacent inverted values of position remains the same. **Note: This option is rarely used. It would only be used when it was desired to change the direction of increasing position mileposts or kilometerposts. In this case, all right of way and station files would also be “inverted”**.

The **Shift** button is activated when a value is entered into the **Shift Distance** box. Subsequent clicking of the **Shift** button is the equivalent of increasing or decreasing all of the positions in a right of way file by a constant amount, which is the value in the box. The effect is to shift the zero position of the right of way. **Note: This option is rarely used. It would only be used when it was desired to change the reference position.
position of mileposts or kilometerposts. In this case, all right of way and station files would also be “shifted”.

The final action to create the file is taken by clicking on the Create button. The file is created and the user is given the option of viewing the file with a Yes or No button. Clicking on Yes will produce a TOM File View of the file. Clicking on No will close the file.

There are two other buttons at the right of the screen Close and Reset. A click on Close will abort the screen and return to the screen. A click on Reset will create the same screen in the same manner as if it was called from the TPS Input Selection Screen of Figure 3-3.

3.2 INPUT FOR THE ENS or TMS

A click on the ENS Input check box of the FCM Main Screen of Figure 3-2 allows the user to select the construction of one of the following input files for the ENS as shown in the screen below.

![Figure 3-114 ENS Input Selection](image)
The following files may be selected:

- **Fnames** - ENS File of Filenames Input
- **Network** - ENS or TMS Network Input
- **Op Tim** - ENS or TMS Operating Time Input
- **Trn Loc** - ENS or TMS Train Location Input
- **Cur Meas** - ENS or TMS Current Measurement Input
- **Pri Cct** – ENS or TMS Primary Circuit Input (Version 3.4 and higher)
- **Rtn Cct** - ENS or TMS Primary Circuit Input (Version 3.4 and higher)

Note that with the exception of the first file, the file of filenames, all of the other files are used as input to the TMS as well as the ENS.

A double click on the appropriate file selection causes the selected filename to appear in the box above the choices and produces screens, which lead the user to create the appropriate file.

### 3.2.1 ENS File of Filenames Input

Selection of **Fnames** in the ENS Input Selection screen produces the following screen.
This screen is used to create the File of Filenames File for ENS input. Three buttons are visible in the center of the screen: View One, Select One and Delete One. A list of files of filenames already contained in the database of the rail system selected is above these buttons. A single click on one of the filenames in the selection list highlights that file. The file may then be viewed, selected or deleted.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

A click on a file name in the Input File Name list box followed by a short mouse movement over the list box causes the caption of the file to be displayed in the tool tip text. A click with the right mouse button causes the file to be displayed in the File Viewer from which it can be edited by clicking the Edit command button in the File Viewer.

The procedure used to create or modify existing file of filenames for the ENS is the same as described in the TPS File of Filenames Input of Section 3.1.1.

An example of a completed or imported file screen is shown next.
Figure 3-116 File of Filenames File for ENS Input (Completed or Imported File)

As in the case of the TPS File of Filenames Input screen, clicking on the ENS command button on this screen will immediately execute the file of filenames.

By clicking on the Check File of Filenames command button, the input files of File of Filenames residing in the List of Files file list box will be checked. Checking means that the Train ID, Train Direction and Train Departure Position will be compared between the Train Location input file and the power profiles to determine the consistency. This process is shown in the next screens.
Click the **Check File of Filenames** command button to produce the next screen.

Click the **Check File of Filenames** command button to cause the input files of File of Filenames residing in the **Input File Name** list box to be checked. Checking means that the Train ID, Train Direction and Train Departure Position will be compared between the Train Location input file and the Power Profiles to determine the consistency. Clicking with the right mouse button causes the **Electric Connectivity Test** command button to appear and the **Check File of Filenames** command button is hidden.

Click the **Check File of Filenames** command button to produce the next screen.
The next step is to check the electrical connectivity of the network, which means to assure that all trains on the system will obtain power as determined by the Network file and the Power Profiles specified in the Input Filenames list box. Click the Yes command button to expose the Electric Connectivity Test command button.
Figure 3-119 Screen Set Up for Electric Connectivity Test

Clicking the Electric Connectivity Test command button performs the test. The results are shown in the next screen.
Figure 3-120 Indication That All Electrical Connectivity Tests Are Given Passing Grades

Each of the Power Profiles has now been tested. It is important to complete the preceding check and tests in order to assure that the File of Filenames truly represents the user’s intentions.

The final action to create the file is taken by clicking on the Create button. The file is created and the user is given the option of viewing the file with a Yes or No button. Clicking on Yes will produce a TOM File View of the file. Clicking on No will close the file.

There are two other buttons at the right of the screen Close and Reset. A click on Close will abort the screen and return to the screen. A click on Reset will create the same screen in the same manner as if it was called from the ENS Input Selection screen of Figure 3-114.
3.2.2 ENS or TMS Network Input

The electric network refers to the complete wayside power distribution system under which the electric trains are running. Correct description of the network is crucial to successful ENS runs. For illustration purposes, the simple electric network of the TEST rail system is used in this section. A nodal diagram is shown.

![Nodal Diagram - Test System](image)

**Figure 3-121**
Selection of Network in the ENS Input Selection screen of Figure 3-114 produces the following screen.
A list of Network files in the database for the rail system selected is shown at the left and middle of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

Selection of the Name of File to be created or modified is at the left and bottom of the screen. This is edited in the usual windows manner.

The Network file can have input units, which are either English or Metric and output, units which are either English or Metric. This is selected by checking the appropriate box at the left of the screen. A description for the kind of units expected is given in Appendix 9.3.

There are two selections to be made, which are located at the top of the middle column of the screen. These are; Type Network and Regenerative Action.

The first of these selects the type of network for the application. Three choices are available; an AC Network Only, in which case the trains run under an AC catenary; a DC Network Only, in which case the trains collect DC power and metering is done on DC power; and, an AC & DC Network, in which case the trains pickup DC power and there are converters on the line which convert AC power into DC power. The last situation is the default.
The **Regenerative Action** choice selects the method for handling regeneration from the trains. Regeneration must be turned off if the regenerating train causes the voltage to rise above the maximum voltage tolerated by the line. The method for turning off regeneration is the selection that is made here. Three choices are available; **Turn Off for Snapshot**, **Turn Off for Brake Cycle**, which turns off regeneration completely for the braking cycle or **Power Limited by Max Voltage**, which reduces the power output at the line until the line voltage falls below the maximum voltage. The default is to reduce the regenerated power until voltage comes into tolerance and is typical of what is done in practice.

Following these two selections, there are several entries to be made. The first of these is the **Convergence Accuracy**. This entry sets the convergence accuracy for the iterations of voltage substitution. The ENS uses a **Gauss-Seidel** method for solving the load flow. It is a substitution method by which a new estimate of the voltages in the electric network is developed from the previous estimate. The absolute difference between the new voltage and the previous voltage, for all voltages in the network must be less than the convergence accuracy for the load flow to finish. The default is **0.0000001 (10^-7)**. Normal text editing is appropriate here to change the value.

The next entry specifies the **Max Number of Iterations** before declaring non-convergence of the load flow. Repetition of the step described in the previous paragraph is termed iteration. The default value is **39500**.

The next entry is the **Unit Power**. The default value is **5 MW** for **Type Networks: AC & DC Network** and **DC Network Only** selections, and **40 MW** for **Type Network: AC Network Only** selection. The unit power is normally selected as the power rating of a substation. Normal text editing is appropriate here to change the value.

The next entry is the **Unit Voltage**. This is the open circuit voltage. The default value is **750 V** for **Type Networks: AC & DC Network and DC Network Only** selections, and **27600 V** for **Type Network: AC Network Only** selection. It is taken as the unit value of voltage for the power distribution system. Normal text editing is appropriate here to change the value.

There is a note of caution on the choice of the **Unit Power** selection, especially if the user plans to do current analysis using the FMM. Since the **Unit Impedance** is expressed as the quantity \([\text{Unit Voltage}^2/\text{Unit Power}]\), the **Unit Power** must be selected in such a manner as not to make the **Unit Impedance** too large. In this case, the circuit impedances expressed in the units of **Unit Impedance** will be very small (~10^-4 or 10^-5). This will cause current analysis calculations to be inaccurate. All circuit impedances should be larger than ~10^-4.

Next is the **Maximum Line Voltage** entry. This value is used only for regeneration turnoff. The default value is **825 V** for **Type Networks: AC & DC Network and DC Network Only** selections, and **30360 V** for **Type Network: AC Network Only** selection. Normal text editing is appropriate here to change the value.

There have been some changes in the default values for **Version 3.3.4** of the TOM and higher, beginning with and including the **Convergence Accuracy**, **Max Number of Iterations**, **Unit Power**, **Unit Voltage** and **Maximum Line Voltage** entries.

Click on the **Convergence Accuracy** label for the text box on the screen. This action produces the next screen.
The Convergence Factor \( (c_f) \) is an integer, which indicates a cumulative average of actual accuracies achieved over that past number of iterations. This effects a second criteria for declaring convergence. If \( \text{Acc} \) is the set accuracy, and in the current snapshot the achieved accuracy is \( dx \), then the cumulative accuracy achieved is given by the expression

\[
\text{Cumdx} = \frac{dx + c_f \times \text{Cumdx}}{c_f + 1}
\]

The second convergence criteria is then

\[ dx > \text{Cumdx}. \]

This second convergence criteria, in addition to \( dx < \text{Acc} \), which is the first and main criterion, has the effect of squeezing the maximum accuracy out of the loadflow, even though the loadflow will not converge to the accuracy set by the user, \( \text{Acc} \). Any oscillations from snapshot to snapshot are not allowed to grow too large.

This feature remains hidden because it should rarely be used. Of course, if the user demands too high an accuracy, it may be required. Each problem has its maximum natural accuracy, which the second convergence criteria may be used to find.
The next three options: **AC Part of Nodal Diagram**, **DC Part of Nodal Diagram**, and **Converter Part of Nodal Diagram** are used to aid the user in the construction of the network line and node (buss) connections.

If the network contains only DC components, then begin by selecting the **DC Part of Nodal Diagram** option. If the network contains only AC components or is a mixed bag of AC and DC components, start by selecting **AC Part of Nodal Diagram**.

Check **Rail Voltage Output** if this network is to be used for a rail voltage estimate. The network must have two tracks only. This selection causes information important in estimating rail voltages to be output to the Current Measurement Output File (AO-*.*).

The **Include Return Circuit** checkbox and **Generate Network** command button is only present in Version 3.4 and higher. These features are discussed in **Section 3.2.2.8**

### 3.2.2.1 AC Part of Nodal Diagram

Selection of the **AC Part of Nodal Diagram** produces the following screen.
There is an option at the right and top of the screen: **Use Default Sequence**. If this option is selected, a default naming of the lines and nodes will help the user input the network. **This option can only be accessed when AC/DC networks are being constructed.**

The **Use Default Sequence** is discussed in Section 3.2.2.4.

On the left, upper screen there are two indicators: # of **AC Lines** and # of **AC Nodes**. These indicators, which cannot be modified by the user, keep track of the number of lines and nodes, which are entered. Below these indicators are three other options: **View AC Input**, **View DC Input**, and **View Converter Input**. These options allow the user to switch among the AC, DC and converter portions of the input.

The grids labeled **Line Input** and **Node Input** are the entries for the line and node information. **The Line Input must be completed before the node input is started.** Enter the data for the AC lines where indicated. The **Line Name**, the **Begn Node** (Beginning node of the line) and the **End Node** (End node of the line) are each limited to four characters. The **Trk #** (track number) is limited to an integer between 1 and 99. These track numbers must be the same as the designations for routing the trains in the TPS input. The **Impedance** of the line is expressed in the unit ohm, which is just the square of the unit voltage (open circuit voltage) divided by the unit power. In **AC/DC distribution systems**, the unit voltage is the open circuit DC voltage. Please note that the unit impedance expression involves the square of the ratio of the open circuit voltage on the line to the unit voltage (sometimes referred to as the turns ratio). For example, if the AC open circuit voltage is 69 kV and the unit voltage is 750 V, then the turns ratio (n) is 69000/750. The unit impedance is given by the expression:

$$ Z_{pu} = \frac{Z_{actual}}{((\text{Unit Voltage})^2/((\text{Unit Power}))^2)*n^2} $$

Enter both the **Real** and **Imag** (imaginary) part of the impedance. Enter the **Current Factor** of the AC line. This value refers only to AC/DC power systems. It is not used in the load flow calculations, and its primary purpose is for determination of line current in the AC portion of the power system. Thus to get the primary current, given the DC current, one uses the current factor rather than the primary voltage in the ratio:

$$ \text{DC Voltage} \times \frac{\text{Primary Current}}{\text{Current Factor}} $$

The units for the **Current Factor** are kV.

In **AC/DC power distribution** the **Current Factor** depends on the transformer-rectifier unit. The two most common are shown below.

**Typical 6-Pulse Rectifier (ANSI Circuit 25)**

A six-pulse rectifier is composed of six or multiple of six diodes configured to form a three-phase double-way bridge for AC to DC conversion. The output of this configuration has six pulses per ac cycle. If the secondary of the transformer is connected in wye, this would be **ANSI Circuit 26**. In both circuits, the **Current Factor** is:
A twelve-pulse rectifier is comprised of essentially two six-pulse bridges connected in parallel through an inter-phase transformer to insure proper current balance between the two bridges. The input to the two bridges is provided by two separate windings of the rectifier transformer. One of the windings is connected delta while the other is connected wye. This provides the necessary phase shift to produce the six phases. When these six phases are full wave rectified this produces the twelve-pulse output. The Current Factor is:

\[ 1.708 \times \text{(primary voltage)} \]
The node type options shown are **Load**, **Convr** (converter), **Meter**, **Source**, **CirElem** (circuit element) and **Storage**. Select the node from these choices. Each of these is explained.

**Load**

The load node has power associated with it, its voltage is determined by the solutions of the network equations. Typical load nodes are the trains, tie stations and connections between any parts of the network. In the case of tie stations and network connections the power is zero.

**Convr**

The converter node represents either the AC or DC side of a converter, which converts AC to DC or DC to AC. The line between these nodes is the converter representation. They are only present in AC/DC networks.

**Meter**

The meter node is a node of fixed voltage through which a variable amount of power is delivered to and from the network.

**Source**

Figure 3-125 Network File for ENS Input / AC Input / Select Node Type Options
A source node is a node of variable voltage where a fixed amount of power is delivered to or from the network.

**CirElem**
A circuit element node is a node, which is the end of a line, which is combinations of resistors, capacitors and/or inductors. The other end of the line is a load node and is attached to the network. The impedance of the line is the equivalent impedance of the combination of resistors capacitors and/or inductors. The voltage of the circuit element node is set near zero (generally 0.01 unit ohms).

**Storage**
A storage node is a node representing a wayside energy storage device (station). It is always at the end of the line to which it is attached. Parameters associated with this node are:

- **Set Voltage**, above which charging occurs and below which discharging occurs.
- **Power Out**, maximum discharging power
- **Power In**, maximum charging power
- **Maximum Energy**, maximum stored energy capability
- **Minimum Energy**, minimum stored energy capability
- **Initial Energy**, initial stored energy
- **Efficiency In**, ratio of electrical charge energy to additional stored energy upon charge.
- **Efficiency Out**, ratio of subtractional stored energy upon discharge to electrical discharge energy.
- **Decay Type**, may be linear or exponential
- **Decay Rate**, loss of energy with time. It is specified as stored energy per hour if linear and % per hour of stored energy.

The node is initially fixed voltage through which a variable amount of power is delivered to and from the network. If the power exceeds the limits of maximum charging and discharging power, the node is then converted to a **Source** node, with a fixed amount of power equal to the maximum charging or discharging power as the case may be.

Complete the entries by adding the **Cplx Volt** (complex voltages) both **Real** and **Imag** (imaginary), **Cplx Pwr** (complex powers) both **Real** and **Imag** (imaginary), and the **ROW Post** (right of way positions (for the nodes that are associated with the tracks on which trains will run)). Toggle the mouse on the elements under the **Trk Node** (track node) column to produce a **y** or blank, to represent a node that is part of the track or not part of the track. Use unit values for voltages and real power (kW) for power. The real part of the complex voltage remains a constant for meter nodes (usually 1.0), all other voltages are set to zero. Power remains constant for source (positive) and sink (negative) **Source** nodes. All other nodes have complex power equal to zero. Position is input in either English units (miles) or metric units (kilometers).

In the last column, enter the primary voltage (kV) for the **Voltage Factor**. Either Line-to-Line or Line-to Neutral Primary Voltage can be entered here. This number is not used in any of the calculations except voltage drops in the primary circuit.

The **Delete Row** button is used to delete one line in the line input grid. Click on the row to be deleted in the **Line Input** grid and then click on the **Delete Row** button. If the line to be deleted is a converter or has a converter node, which is not connected to any other line, the user will be informed, at which time he is given the opportunity to take the converter off line. Otherwise, the line cannot be deleted in this manner.

An example of a completed or imported file screen is shown next.
Use the options at the bottom left to go to the next screens. Otherwise, the Select button at the right of the screen is clicked when the selection of the output choices is completed. This incorporates those choices in the resulting network file.

The Reset button completely resets the screen, starting from scratch. It is best used when problems arise and the user can no longer fix them. The Close button closes the program and returns the user to the next higher level. In this case, the screen “remembers” its settings.

### 3.2.2.2 DC Part of Nodal Diagram

Selection of the DC Part of Nodal Diagram produces the following screen. If the network being constructed is AC/DC, clicking the View DC option in the screen or the DC Part of the Nodal Diagram option in the Network File for ENS Input screen of Figure 3-122, also leads to the following screen.
There is an option at the right and top of the screen: **Use Default Sequence**. If this option is selected, a default naming of the lines and nodes will help the user input the network. This option can only be accessed when AC/DC networks are being constructed.

On the left of the screen there are two indicators: # of DC Lines and # of DC Nodes. These indicators, which cannot be modified by the user, keep track of the number of lines and nodes, which are entered. Below these indicators are three other options: **View AC Input**, **View DC Input**, and **View Converter Input**. These options allow the user to switch among the AC, DC and converter portion of the input. The grids labeled **Line Input** and **Node Input** are the entries for the line and node information. The **Line Input** must be completed before the node input is started. Enter the data for the DC lines where indicated.

The **Line Name** and the **Begin Node** (begin node) and the **End Node** of the line are each limited to four characters. The **Trk #** (track number) is limited to an integer between 1 and 99. These track numbers must be the same as the designations for routing the trains in the **TPS** input. The **Resistance** of the line is expressed in the unit ohm, which is just the square of the unit voltage divided by the unit power. Click on a particular data entry to edit. Backspace deletes the entry one character at a time. A carriage return on the
last entry of the line brings up a new line. A carriage return on the first entry of a blank new line closes the entries. Reopen by clicking mouse on last column and last row.

Entry of the DC node data in the Node Input grid can begin only after the line data have been entered. After the Line Input grid has been closed (by a carriage return on a blank record) click on the first row and first column or the Node Input grid. This action will setup all of the nodes mentioned in the Line Input grid. Complete the entries by adding the Voltage, Pwr (power), and the ROW Pos [right of way positions (for the nodes that are associated with the tracks on which trains will run). Toggle the mouse on the elements under the Trk Node (track node) column to produce a y or blank, to represent a node that is part of the track or not part of the track. Use unit values for voltages and real power (kW) for power.

A click on one of the grid elements in the Node Type column of the Node Input grid followed by a click on the Select Node Type options has been described in Figure 3-125 and the text that follows.

The Delete Row button is used to delete one line in the Line Input grid. Click on the row to be deleted in the Line Input grid and then click on the Delete Row button.

Position is input in either English units (miles) or metric units (kilometers). A carriage return on the last entry of the line brings up the next line.

An example of a completed or imported file screen is shown next.
Use the options at the bottom left to go to the next screens. Otherwise, the Select button at the right of the screen is clicked when the selection of the output choices is completed. This incorporates those choices in the resulting network file.

The Reset button completely resets the screen, starting from scratch. It is best used when problems arise and the user can no longer fix them. The Close button closes the program and returns the user to the next higher level. In this case, the screen “remembers” its settings. If the default sequence is being used, the user is aided with line and node naming.

### 3.2.2.3 Converter Part of Nodal Diagram

Selection of the **Converter Part of Nodal Diagram** in Figure 3-122 produces the following screen. It is only exercised if the network being constructed is AC/DC. The input described is for **TOM Version 3.6** and later. Clicking the View Converter Input option in the previous screen also produces the following screen.
There is an option at the right and top of the screen: **Use Default Sequence**. If this option is selected, default naming of the lines and nodes will help input the network.

On the left of the screen there is an indicator: **# of Converters**. This indicator, which cannot be accessed by the user, keeps track of the number of converters which are entered. Below these indicators are three other options: **View AC Input**, **View DC Input**, and **View Converter Input**. These options allow the user to switch among the AC, DC and converter portion of the input.

Entry of the converter data should begin only after the AC and DC line and node data have been entered. The converter data are entered in the **Converter Input** grid. The AC side of the converters was already defined in the AC input screen of Figure 3-126. Complete the entries by adding the corresponding DC Node (name) and the following information:

**Substation Type.** The substation type can be either an inverter, a rectifier/inverter, controlled rectifier or controlled rectifier/inverter. The substation can consist of one or more units. The unit type can be a transformer-rectifier, a transformer-rectifier/inverter, a transformer-controlled rectifier or / transformer-controlled rectifier/inverter. If the substation contains more than one unit, they must be of the same unit type. To select the **Substation Type**, click the grid rectangle for the selection, followed by a click on the **Select Substation Type** combo box at the right of the screen.
Figure 3-130 Select Substation Type
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Impedance. The impedance is expressed in the fractional drop of the unit voltage through the substation at its rated load, expressed in terms of the unit power of the network.

Assume that the substation consists of \( n \) units (in parallel) each of power rating \( p \), the unit network voltage is \( v \), and \( z \) is the voltage drop through each unit at its rated load. In addition, the unit power of the network is \( P \). The impedance of the substation is given by the equation:

\[
Z = \left( \frac{P}{np} \right) \left( \frac{z}{v} \right)
\]

6/12 Pulse is the classification of the substation units whether they are 6 or 12 pulse. To select 6/12 Pulse (for the converter, whether it is six pulse or twelve pulse) click on the Select Unit Type at the right of the screen.

The Comm Ratio (ratio of the commutating to total reactance) is entered in this column. Commutation ratio has meaning only for 12 pulse units.

The next column of the grid is Cont Volt item. This is the converter voltage control. It is expressed in the voltage range of control in the unit voltage value.

The rectifier has no voltage control. The value is 0.

For the controlled rectifier, the voltage control can remain at zero or be set to a value greater or less than -1. If the voltage control is set to zero, the voltage control will maintain the voltage drop through the substation at zero until the rated load voltage drop is reached. This is the substation impedance at rated load. Thus, if it is set different from zero, voltage control will automatically maintain the dc voltage drop through the substation, at zero until the impedance plus the set level is reached, at which time thereafter, the drop will be the same as a rectifier. More information, including the model used to calculate the control is highlighted in Appendix 9.18.4.1.

For the inverter, the voltage for which the inverter portion of the circuit is activated is the control voltage. It is also referenced to the open circuit dc voltage. Thus, the inverter substation will block current from flowing in the reverse direction through the substation, until the open circuit plus voltage control (voltage) is reached. If the voltage control is 0, all current is returned to the line. Setting the voltage higher than 0 will block more current from flowing in the reverse direction. (Note: This control voltage is not the voltage control of the inverter. It’s the turn on voltage. If there is no desire to reduce the current going back to the line, leave the inverter voltage control at zero)

For the controlled rectifier inverter, the voltage control refers to the controlled rectifier portion. In this case, the inverter has no voltage control and will behave as if the voltage control were 0.

Conv Power. The value entered here is the rating of the substation expressed in the network unit power. From the equation above, it is the term \( (np/P) \).

Power Factor. This is the power factor of the substation. For 6 pulse the ideal value is \( \frac{3}{\pi} \) 0.955. For a 12 pulse unit the ideal value is 0.9886.

No Load Power Loss. This is the value of the no load power loss of the substation expressed in terms of the network unit power.

Rated Load Power Loss. This is the value of the rated load power loss of the substation expressed in terms of the network unit power.

In equation form, if \( p_0 \) is the no load loss of the unit and \( p_r \) is the rated load loss, then the no load and rated load losses of the substation consisting of \( n \) units is:

No Load Substation Losses: \( P_0 = p_0 (np/P) \)

Rated Load Substation Losses: \( P_R = p_r (np/P) \)

A more comprehensive discussion of the methodology appears in Appendix 9.18.
An example of a completed or imported file screen is shown next.

Figure 3-131 Network File for ENS Input Converter Input (Completed or Imported File)

Use the options at the bottom left to navigate to the other screens. Otherwise, the Select button at the right of the screen is clicked when the selection of the output choices is completed. This incorporates those choices in the resulting network file.

The Reset button completely resets the screen, starting from scratch. It is best used when problems arise and the user can no longer fix them. The Close button closes the program and returns the user to the next higher level. In this case, the screen “remembers” its settings. If the default sequence is being used, the user is aided with converter naming.

To complete the entries in the Network File for ENS Input screen of Figure 3-122, continue with the following.

The File Caption appears as a title script at the end of the file. There are two captions here. Both of the captions are used as part of the titles of the file and are incorporated into the ENS or TMS runs, which use the file.

An example of a completed or imported file screen is shown next.
The final action to create the file is taken by clicking on the **Create** button. The file is created and the user is given the option of viewing the file with a **Yes** or **No** button. Clicking on **Yes** will produce a TOM File View of the file. Clicking on **No** will close the file.

### 3.2.2.4 Use Default Sequence

The nodal diagram for the default sequence network is shown next.
The example of construction of a default sequence network using the TOM will use four substations.

Begin with the Network Nodal Diagram screen – AC Input.
Figure 3-134 Network Nodal Diagram Input Screen – AC Input

Click the Use Default Sequence checkbox to obtain the next screen.
Figure 3-135 Information Message With Instructions for Construction of the Default Network

Begin construction of the default network with the AC Lines by click on the row under the line name followed by a carriage return. Perform this action four times (for four substations). At the end hit another carriage return.
Figure 3-136 AC Line Construction Framework Complete

Next click on the Node Name column of the Node Input grid.
Figure 3-137 AC Node Input Framework Construction Complete

Click the View DC Input checkbox.
Figure 3-138 Network Nodal Diagram Input Screen – DC Input

On the DC Line Input grid, click the first row under Line Name.
Figure 3-139 DC Line Input Framework Construction Completed

Now click the first row of the Node Input grid under Node Name.
Figure 3-140 Node Input Framework Construction Completed

Click the View Converter Input checkbox.
Click the first row of the **Converter Input** grid under the **AC Node** column.
Figure 3-142 Converter Input Framework Construction Completed

All that remains to be done is to add or modify grid values in AC Line and Node grids, DC Line and Node grids and the Converter grid to conform to values of the actual network.

3.2.2.5 Text to TOM Transfer

Major portions of the network file can be transferred from or exported to text files, which may be created in EXCEL, WORD, Notepad, etc. directly into the nodal diagram input grids as shown in Figure 3-124 through Figure 3-131. This capability is shown in the next few screens.
Figure 3-143 Network File for ENS Input DC Nodal Input (Completed or Imported File)

Clicking on the **Text Transfer Command** button shown in the screen produces the following screen.
Any one of the five major areas of the nodal diagram can be input in the model using this feature. These areas are AC Lines, AC Nodes, DC Lines, DC Nodes and Converters. Selection of the proper option at the right of the screen determines which components will be input.

Selection of the **AC Line Option** produces the AC Line Component Text box. The components of the AC Line are:

Line Name (delimiter) Begin Node Name (delimiter) End Node Name (delimiter) Track or Line Number (delimiter) Real Part of the Impedance (delimiter) Reactive Part of the Impedance (carriage return).

There is one of these records for each line. At the end of all records, there must be a carriage return. Impedances are always in unit values. **Two or more lines between the same two nodes must always have the same line name but different track or line numbers.**
Selection of the **AC Node Option** produces AC Node Component Text box. The components of the AC Node are:

- Node Name (delimiter)
- Node Type (delimiter)
- Real Part of the Voltage (delimiter)
- Imaginary Part of the Voltage (delimiter)
- Real Part of the Power (delimiter)
- Imaginary Part of the Power (delimiter)
- Right of Way Position (delimiter)
- Track Association (carriage return).

There is one of these records for each node. At the end of all records, there must be a carriage return. Node positions are only necessary for track-associated nodes. The mile or kilometer post location of the node is entered. Voltages and powers are entered in unit values. **Track Association** simply refers to whether the node is on a track on which trains are running. **Track Association** is entered as a *y* or *n*.

Selection of the **DC Line Option** produces the DC Line Component Text box. The components of the DC Line are:

- Line Name (delimiter)
- Begin Node Name (delimiter)
- End Node Name (delimiter)
- Track or Line Number (delimiter)
- Resistance (carriage return).

There is one of these records for each line. At the end of all records, there must be a carriage return.

**Impedances are always in unit values. Two or more lines between the same two nodes must always have the same line name but different track or line numbers.**

Selection of the **DC Node Option** produces the DC Node Component Text box. The components of the DC Node are:

- Node Name (delimiter)
- Node Type (delimiter)
- Voltage (delimiter)
- Power (delimiter)
- Right of Way Position (delimiter)
- Track Association (carriage return).

There is one of these records for each node. At the end of all records, there must be a carriage return. Node positions are only necessary for track-associated nodes. The mile or kilometer post location of the node is entered. Voltages and powers are entered in unit values. **Track Association** simply refers to whether the node is on a track on which trains are running. **Track Association** is entered as a *y* or *n*.

Selection of the **Converter Option** produces the Converter Component Text box. The components of the Converter are:

- Converter AC Node (delimiter)
- Converter DC Node (delimiter)
- Inv/Rect (delimiter)
- Impedance (delimiter)
- 6/12 Pulse (delimiter)
- Commutation Ratio (carriage return).

There is one of these records for each converter. At the end of all records, there must be a carriage return. **Inv/Rect** indicates whether or not the converter is a rectifier (*Rect*) or an inverter (*Inv*). Impedance is the absolute magnitude of the impedance in unit value. **6/12 Pulse** indicates whether the Rectifier is six or twelve pulse. Enter 6 or 12. Commutation Ratio is the ratio of the commutating to total reactance.

The **delimiter** may be a **tab, space or comma**. The tab character cannot be used for direct input into the text box. It is reserved for importing from the grids of the **TOM** or for pasting from other text, such as **EXCEL**, **WORD** or **Notepad**.

The **Clear Text Command** button clears the text from the text box.

The **Import Command** button imports the information from the **Network File** currently resident in the **TOM** onto the screen. If no network file is currently resident in the **TOM**, there is an indication message. If there is any confusion on what entries to make in the text box, importing a resident network file generally will make things clearer.

The **Transfer Command** button transfers the information from the screen to the grids in the **TOM**. There are error indications if any of these data fail format or content tests.

An example of a screen just after clicking the **Import Command** button for the **DC Nodes** selection is shown in the next screen.
The Reset button completely resets the screen, starting from scratch. It is best used when problems arise and the user can no longer fix them. The Close button closes the program and returns the user to the next higher level. The Exit button closes the TOM toolbox.

An EXCEL spreadsheet is a convenient way of transferring all nodal and lineal information to the TOM via the TOM Transfer Screen. One begins by transferring a known example to the spreadsheet by successively using the Import function of the screen. The spreadsheet can then be used for calculations, such as impedances and distances between nodes to produce a new spreadsheet for the user’s network.
The spreadsheet for the Simple DC Network just entered into the TOM is shown next.

![Simple DC Network](image)

### DC Lines

<table>
<thead>
<tr>
<th>Line</th>
<th>Begin Node</th>
<th>End Node</th>
<th>Track</th>
<th>Resistance Per Unit</th>
<th>Internodal Distance</th>
<th>Unit Ohms per Mile</th>
</tr>
</thead>
<tbody>
<tr>
<td>L1</td>
<td>T1</td>
<td>T1</td>
<td>1</td>
<td>0.0002</td>
<td>1.000</td>
<td>0.172</td>
</tr>
<tr>
<td>L2</td>
<td>T2</td>
<td>T2</td>
<td>1</td>
<td>0.0002</td>
<td>1.000</td>
<td>0.172</td>
</tr>
<tr>
<td>L3</td>
<td>T3</td>
<td>T3</td>
<td>1</td>
<td>0.0002</td>
<td>1.000</td>
<td>0.172</td>
</tr>
</tbody>
</table>

### DC Nodes

<table>
<thead>
<tr>
<th>Node Name</th>
<th>Type</th>
<th>Unit Voltage</th>
<th>Unit Power</th>
<th>Position</th>
<th>Track Associated</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>Load</td>
<td>1</td>
<td>0</td>
<td>0.1</td>
<td>y</td>
</tr>
<tr>
<td>D1</td>
<td>Con</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>y</td>
</tr>
<tr>
<td>T2</td>
<td>Load</td>
<td>1</td>
<td>0</td>
<td>1.5</td>
<td>y</td>
</tr>
<tr>
<td>D2</td>
<td>Con</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>y</td>
</tr>
<tr>
<td>T3</td>
<td>Load</td>
<td>1</td>
<td>0</td>
<td>3.1</td>
<td>y</td>
</tr>
</tbody>
</table>

### AC Lines

<table>
<thead>
<tr>
<th>Line</th>
<th>Begin Node</th>
<th>End Node</th>
<th>Track</th>
<th>Resistance Per Unit</th>
<th>Reactance Per Unit</th>
<th>Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA1</td>
<td>N1</td>
<td>A1</td>
<td>1</td>
<td>0.001</td>
<td>21.845</td>
<td></td>
</tr>
<tr>
<td>LA2</td>
<td>N2</td>
<td>A2</td>
<td>1</td>
<td>0.001</td>
<td>21.845</td>
<td></td>
</tr>
<tr>
<td>LA3</td>
<td>A1</td>
<td>A2</td>
<td>1</td>
<td>0.001</td>
<td>21.845</td>
<td></td>
</tr>
</tbody>
</table>

### AC Nodes

<table>
<thead>
<tr>
<th>Node Name</th>
<th>Type</th>
<th>Complex Unit Voltage</th>
<th>Complex Unit Power</th>
<th>Position</th>
<th>Track Associated</th>
<th>Voltage Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>N1</td>
<td>Meter</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>n</td>
</tr>
<tr>
<td>N2</td>
<td>Meter</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>n</td>
</tr>
<tr>
<td>A1</td>
<td>Con</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>n</td>
</tr>
<tr>
<td>A2</td>
<td>Con</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>n</td>
</tr>
</tbody>
</table>

### Converters

<table>
<thead>
<tr>
<th>AC Node</th>
<th>DC Node</th>
<th>Type</th>
<th>Impedance</th>
<th>Pulse Ratio</th>
<th>Reactance Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>D1</td>
<td>Rect</td>
<td>0.36</td>
<td>0.065</td>
<td>0.065</td>
</tr>
<tr>
<td>A2</td>
<td>D2</td>
<td>Rect</td>
<td>0.36</td>
<td>0.065</td>
<td>0.065</td>
</tr>
</tbody>
</table>

Figure 3-146 EXCEL Spreadsheet With Simple DC Network Data Ready for TOM Transfer

Note that two types of calculations were made in the spreadsheet. The internodal distance was calculated first and added as a column to the DC Lines. This was necessary to compute the Unit Resistance of the DC Lines by multiplying the Internodal Distance by the Unit Ohms Per Mile.

### 3.2.2.6 Moving Nodes

Nodes associated with the tracks on which trains run can be moved. The only stipulation is that the node be moved only as far as the adjacent nodes to which it is connected. To initiate the movement of a node, click the **Move Node** command button in Figure 3-143. This action produces the following screen.
Figure 3-147 The Node Move Screen of the File Construction Module - Network File.

A list of all of the movable nodes is obtained by clicking on the Select Node to be Moved Combo box. This produces the following screen.
Figure 3-148 The Node Move Screen of the File Construction Module Network File. Click on Select Node to be Moved Combo box.

The node can be selected by clicking on the desired node, which produces the following screen.
Figure 3-149 The Node Move Screen of the File Construction Module Network File - After Selection of a Node to be Moved.

The Node Position Text box shows the present position of the selected node to be moved. The Adjacent Node Text box immediately below, shows all relevant information on the nodes directly connected to the selected node. This information includes the node name and position and the track number and impedance of the line connecting the adjacent node to the selected node. At this stage in the procedure, this text box can be edited. Lines can be deleted if it is desired to keep these lines out of the remaining of the procedure.

Instructions on node movement are given to the right of the Adjacent Node Text box.

The node can only be moved nearly to the position of the closest adjacent node. The new position of the node is entered into the New Position of Node box. After the position is inserted into the text box, the Estimate New Impedance Command button is clicked.

This action causes the impedances of the appropriate lines connecting the selected node to the adjacent nodes to be recalculated, taking into account the node’s new position. It is assumed that the impedances are proportional to the distances between the nodes. The following screen is produced.
Clicking the `Accept Revised Lines` button completes the Move Node procedure. All information is now transferred to the grids. The following screen is produced after clicking the command button.
Figure 3-151 The Node Move Screen of the File Construction Module Network File after clicking the Accept Revised Lines Command button.

This completes the move node procedure.

3.2.2.7 Changing Base Impedance

Selecting a network file in Figure 3-122 and importing it into the model produces the following screen.
A mechanism has been included for changing the impedance base on which all network line impedance are computed. Clicking the **Change Impedance Base Command** button produces the following file.

![Network File Screen for ENS Input](image)

**Figure 3-152 Network File Screen for ENS Input After Selection of a Network File**
Figure 3-153 Network File Screen for ENS Input After Clicking the Change Impedance Base Command Button

The new Unit Voltage and/or Unit Power are inserted into the appropriate text boxes and the Change Command button is clicked. The new impedance base is recalculated and the new line impedances are determined automatically.

3.2.2.8 Network with Return Circuit

3.2.2.8.1 Introduction

Previously, the Train Operations Model (TOM©) had used the loop method of load flow for calculating powers, voltages and currents in the power distribution of electrified rail systems. This means that the primary\(^2\) circuit is considered in the load flow and the return circuit is handled by lumping its impedance in series with the primary circuit impedance. So, for example when a catenary or third rail impedance is specified, the impedance of the running rail is added to that of the catenary or third rail and then the load flow is performed.

In many cases of rail systems, the return circuit impedance does not simply add in series to the primary circuit impedance. There is one case in which the answers would be very close; namely, the case where track bonds are very close together compared to the length of the trains, which are running on the system

\(^2\) Primary circuit in this context refers to the substations and the catenary or third rail. In DC systems, the positive circuit is the primary circuit and the negative circuit is the return circuit.
and there are no tie stations (breaker houses) between substations. These tie stations improve the conductivity of the primary circuit as well as provide isolation capability. In this case the bonded rails are considered in parallel. Where this condition is not met, it is not clear how or in what direction the circuit powers, voltages and currents vary from the case, for which the return circuit is accounted.

In order to clarify this question, it has been necessary to include the return circuit for all cases in the TOM. However, this inclusion also gives the TOM the full capability of doing both the primary and return circuits. In adding this capability to the TOM, a graphical method is used to construct both the primary and return circuits, giving the TOM an improved way of building the network, representing these circuits.

Construction of the Primary and Return Circuits are developed in Section 3.2.6.

3.2.8.2 Generate Network File

Version 3.4 of the TOM and later editions have the capability of generating a Network file from a Primary Circuit file or a Primary Circuit file together with a Return Circuit file.

In Versions 3.4 of higher, a click on the ENS Input check box of the FCM Main Screen of Figure 3-2 allows the user to select the construction of one of the following input files for the ENS as shown in the screen below.

![Figure 3-154 FCM Main Screen in Version 3.4 or Higher of the TOM](image)

Selection of Network in the ENS Input Selection screen produces the next screen.
Figure 3-155 Network File for ENS Input for Version 3.4 or Higher of the TOM.

In addition to the items on the screen of Figure 3-122, which are described under the figure, two items have been added in this screen: the Generate Network command button and the Include Return Circuit check box.

Clicking the Generate Network command button produces the next screen.
This action produces the screen shown in the figure. In this case, the **Include Return Circuit** check box on the previous screen was not checked and return circuit information is not included in the screen.

A **Primary Circuit** file is selected by clicking on the **Primary Circuit File** (file) list box.
Once selected, the View command button produces a TOM File View of the file selected and the Modify command button imports the file into the File Construction Module – Primary or Return Circuit Input – Main Screen, which is described in Section 3.2.6.

Once the Primary Circuit file is selected, click the Generate Network command button to build the Network file.

This action produces the next screen.
Figure 3-158 File Construction Module – Network File Input – Network Nodal Diagram Input – Converter Input Screen

This screen appears so that input items may be modified to reflect the system under consideration. Any of the items may be modified. When completed, click on the **Select** command button for the next screen.
Figure 3-159 Network File for ENS Input / AC & DC Network Input – Produced from Generate Network Command

This screen now contains the network that was generated. It can now be modified as desired according to the procedures described in Sections 3.2.2.1 to 3.2.2.7. To view the AC part of the nodal diagram, click the AC Part of Nodal Diagram check box. To view the DC part of the nodal diagram, click the DC Part of Nodal Diagram check box. To view the converter part of the nodal diagram, click the Converter Part of Nodal Diagram check box. The next three figures show the results of each action.
Figure 3-160 Network File for ENS Input / AC & DC Network Input – Produced from Generate Network Command – AC Part
Figure 3-161 Network File for ENS Input / AC & DC Network Input – Produced from Generate Network Command – DC Part
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Figure 3-162 Network File for ENS Input / AC & DC Network Input – Produced from Generate Network Command – Converter Part

Return to the File Construction Module – Network File Input – Main Screen.
Figure 3-163 File Construction Module – Network File Input – Main Screen – After Generation from a Primary Circuit File.

Click the Include Return Circuit check box.
The Substation Feeder Length Limit text box appears. This limit is set in either the Primary or Return Circuit construction procedure discussed in Section 3.2.6.1.1. It represents a limit on the feeder horizontal distance from the substation to the track connection.

Click the Generate Network command button.
In this case, three file list boxes are present on the screen: Primary Circuit File, Return Circuit File and Return Circuit Impedance File, respectively. Files from each of these file list boxes are selected by clicking on the appropriate file in the file list box.

Each of the selected files can be viewed using the View command button, which produces a TOM File View of the file selected.

In the case of a Primary or Return Circuit file, the Modify command button imports the file into the File Construction Module – Primary or Return Circuit Input – Main Screen, which is described in Section 3.2.6.
The Recalculate command button under the Return Circuit Impedance File (file) list box, will prepare the Return Circuit Impedance file selected for recalculation as described in Section 4.14. Normally, this action would not have to be taken, since the file was already calculated. The Return Circuit Impedance file contains the dynamic impedances, which when placed in series with the train, effectively provide the return circuit impedance. Details on constructing the Return Circuit Impedance file are given in Section 4.14, while the methodology is explained in more detail in the Appendix 9.17.

Click the Generate Network command button to build the Network file.

All three files, Primary Circuit, Return Circuit and Return Circuit Impedance files must be consistent before a Network file is generated. If they are not consistent, the Network will not be built. Diagnostic messages will inform the user of inconsistencies. These are selected in the next screen.

Figure 3-166 File Construction Module – Network File – Network Generator Input – Files Selected
After clicking the **Generate Network** command button, the following screen is displayed.

![Network Nodal Diagram Input](image)

**Figure 3-167 File Construction Module – Network File Input – Network Nodal Diagram Input – Converter Input Screen**

This screen appears so that input items may be modified to reflect the system under consideration. Any of the items may be modified. When completed, click on the **Select** command button for the next screen.
Figure 3-168 File Construction Module – Network File Input – Main Screen – Includes Information from Primary & Return Circuit Files and Return Circuit Impedance File.

The captions may be modified to represent the network more accurately. After this action is accomplished, provide the name of the network file in the **Name** text box, followed by clicking the **Create File** command button to create the file. The result is the following screen.
Figure 3-169 File Construction Module – Network File Input – Main Screen – Includes Information from Primary & Return Circuit Files and Return Circuit Impedance File – File Created

After the Network screens are modified and the Network file is saved, a TOM File View of the file shows the difference between a Network file constructed from just a primary circuit and a Network file constructed from a primary and return circuit. This is viewed by clicking the Yes command button. This difference is illustrated below.
Notice that there are four records before the `FILENAME` record. These records are:

- RETURN CIRCUIT IMPEDANCE
- PRIMARY CIRCUIT
- RETURN CIRCUIT
- SUBSTATION FEEDER LENGTH LIMIT

In a `Network` file constructed from just a primary circuit, these records are not present.

It should also be emphasized that when constructing a `Network` file using just a primary circuit, the return circuit impedances are lumped in series with the primary circuit impedances as was originally done in the `Network` file in the past. This is not the case when using the return circuit explicitly.

### 3.2.2.9 Wayside Energy Storage

Both Generic and Enhanced Generic wayside energy storage for AC/DC systems and generic wayside energy storage for AC systems are incorporated into the TOM.

One feature of generic energy storage is its use in substation or wayside resistors in order to absorb dynamic braking energy, when resistors are not placed onboard the train. Initiating this feature is also discussed in this section.

#### 3.2.2.9.1 Generic Storage Devices
Both AC and DC storage devices can be incorporated in the AC/DC network and AC storage devices can be incorporated into AC networks. For purpose of illustration, five storage stations were added to the TEST network of Figure 3-121 and the resulting nodal diagram is shown.

Figure 3-171 Test System Nodal Diagram with Five Storage Stations

Importing a network file which has storage stations, or building a network file, which contains a storage station, will cause the screen of Figure 3-126 to look slightly different for the AC and DC portions.
The command button **Wayside Storage** appears on the screen. Clicking this command button with the **View AC Input** box checked produces the following screen.
Clicking this Wayside Storage command button with the View DC Input box checked, produces the following screen.
Figure 3-174 DC Wayside Storage Station Input Screen

Enter the data for the wayside storage devices in the system.

- **Set Voltage**, above which charging occurs and below which discharging occurs.
- **Power Out**, maximum discharging power
- **Power In**, maximum charging power
- **Maximum Energy**, maximum stored energy capability
- **Minimum Energy**, minimum stored energy capability
- **Initial Energy**, initial stored energy
- **Efficiency In**, ratio of electrical charge energy to additional stored energy upon charge.
- **Efficiency Out**, ratio of subtractional stored energy upon discharge to electrical discharge energy.
- **Decay Type**, may be linear or exponential
- **Decay Rate**, loss of energy with time. It is specified as stored energy per hour if linear and % per hour of stored energy.
- **Turns Ratio**, (for AC storage devices) the ratio of the open circuit voltage at the storage node to the unit voltage.

**Voltage inputs are in unit voltage units. Power and Energy inputs are in unit power units.**

Click on a particular data entry to edit or enter. Backspace deletes the entry one character at a time.

Setting the Decay Type is accomplished by first clicking on the entry in the grid, proceed to the Energy Decay selection, and then select either linear or exponential by clicking the mouse.
3.2.2.9.2 Wayside Resistors for Absorption of Regenerated Braking Energy

One feature of generic energy storage is its use in substation or wayside resistors in order to absorb dynamic braking energy, when resistors are not placed onboard the train. Adding this capability to a substation is illustrated here.

A nodal diagram for the Resistor Substation is shown.

![Resistor Substation Nodal Diagram](image)

Figure 3-175 Resistor Substation Nodal Diagram

A typical Wayside Storage Input screen is shown next.
The **Set Volt** is at the value where the resistor is put into the circuit. The **Pwr Out** is set very low, which effectively does not allow power output from the storage device and the **Pwr In** is set very high, which allows maximum power input. The **Max Ener** is set very high to allow maximum energy to be stored in the device. These settings allow the storage device to act as a resistor.

### 3.2.2.9.3 Enhanced Generic Storage Devices

An **Enhanced Generic Energy Storage Device** based on a more sophisticated control has also been incorporated into the TOM. Input for this device can be accessed by clicking on the **Type of Storage Device** combo box of Figure 3-174. This action produces the following screen.
A second click on the Enhanced Generic selection produces the following screen.
Figure 3-178 DC Wayside Storage – Enhanced Generic Storage Parameter Input (First Set)

Enter the data for the Enhanced Generic wayside storage device in the system.

- **Mean Voltage**, the initial guess for the mean line voltage above which charging may occur and below which discharging may occur. This is only the initial guess, the mean voltage is continuously averaged as the flywheel operates.
- **Max Pwr DChg**, maximum discharging power
- **Max Pwr Chg**, maximum charging power
- **Max Energy**, maximum stored mechanical energy capability
- **Min Energy**, minimum stored mechanical energy capability below which discharging cannot occur.
- **Initial Energy**, initial stored energy at beginning of the run.
- **Eff Chg**, charging efficiency, which is the ratio of electrical charge energy to additional stored mechanical energy upon charge.
- **Eff DChg**, discharging efficiency, which is the ratio of subtractions of mechanical stored energy upon discharge to electrical discharge energy.
- **Decay Rate**, loss of energy with time. It is specified as % per hour of stored energy expressed as a fraction.

Additional parameters must be entered, which become visible by moving the slider to the left. These parameters are explained more fully, with the help of the diagram of Figure 3-179 shown next. This diagram can also be accessed by clicking on the **View Control Variables** command button on the screen of Figure 3-178.
Figure 3-179 Graphic Illustration of Control Scheme Parameters.
Moving the slider of Figure 3-178 to the left reveals the next set of parameters, which continue the entry data for the Enhanced Generic wayside storage devices in the system.
The second set or continuation of the entry data for the Enhanced Generic wayside storage devices in the system are described with reference to Figure 3-179 and the figure above.

**Volt Ofst Max Pwr DChg**, the voltage offset, referred to the Mean Voltage, below which maximum power is discharged to the line.

**Volt Ofst Min Pwr DChg**, the voltage offset, referred to the Mean Voltage, below which power is discharged to the line up to maximum power discharge in a linear fashion.

**Volt Ofst Max Pwr Chg**, the voltage offset, referred to the Mean Voltage, above which maximum power is charged from the line.

**Volt Ofst Min Pwr Chg**, the voltage offset, referred to the Mean Voltage, above which power is charged from the line up to maximum power in a linear fashion.

**Min Pwr DChg**, the power discharge when the line voltage equals (Mean Voltage - Volt Ofst Min Pwr DChg)

**Min Pwr Chg**, the power charge when the line voltage equals (Mean Voltage + Volt Ofst Min Pwr Chg).

The third set or continuation of the entry data for the Enhanced Generic wayside storage devices in the system is described with reference to Figure 3-179, by sliding the slider of the above figure all the way to the left as shown next.
These parameters are:

- **Rec Pwr DChg**, the amount of recovery power discharge, used to bring the flywheel back to its initial energy state, when the line voltage is between **Mean Voltage** and **(Mean Voltage - Volt Ofst Min Pwr DChg)**.

- **Rec Pwr Chg**, the amount of recovery power charge, used to bring the flywheel back to its initial energy state, when the line voltage is between **Mean Voltage** and **(Mean Voltage + Volt Ofst Min Pwr Chg)**.

- **Min Voltage**, the line voltage below which the flywheel stops discharging.

- **Max Voltage**, the line voltage above which the flywheel stops charging.

- **Coast Band**, a preset energy band, which is used in three ways. This is described further in Appendix 9.15.2.

- **Voltage Filter**, a set time in seconds over which the **Mean Voltage** is determined by averaging the line voltage over that time in the past.

- **Idle Energy**, a preset energy, which is the natural state of the flywheel. This is described further in Appendix 9.15.2.

**Voltage inputs are in unit voltage units. Power and Energy inputs are in unit power units.**

Click on a particular data entry to edit or enter. Backspace deletes the entry one character at a time.

Setting the Decay Type is accomplished by first clicking on the entry in the grid, proceed to the Energy Decay selection, and then select either linear or exponential by clicking the mouse.
Use <ctrl>-X to cut, <Ctrl>-C to copy and <Ctrl>-V to paste text, only one cell at a time. To copy using the mouse, click left mouse button on cell to be copied, hold down right mouse button, click left mouse button on cell to paste while still holding right mouse button down and then release right mouse button.

Otherwise, the Select button at the right of the screen is clicked when the selection of the output choices is completed. This incorporates those choices in the resulting network file.

The Reset button completely resets the screen, starting from scratch. It is best used when problems arise and the user can no longer fix them. The Close button closes the program and returns the user to the next higher level. In this case, the screen “remembers” its settings.

3.2.3 ENS or TMS Operating Time Input

Selection of Op Time in the ENS Input Selection screen of Figure 3-114 produces the following screen.
A list of operating time files in the database for the rail system selected is shown at the left and middle of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

Selection of the Name of File to be created or modified is at the left and bottom of the screen. This is edited in the usual window manner.

There are three time entries for this file: Simulation Start Time, Simulation End Time, and Time Interval Between Snapshots. Enter the Simulation Start Time and Simulation End Time in a 24-hour format. The entry must be of the form hh:mm:ss. For example, 4:10 p.m. would be entered as 16:10:00.
The **Time Calculator** could be useful if times are in other formats. The **Time Interval Between Snapshots** must be entered in seconds. (Note: The **Time Interval Between Snapshots** must be the same value as the display time used in the **TPS Control file** to generate the **Power Profiles** used as input to the **ENS**, for which this file is to be used as input.

The **File Caption**, which appears as a title script at the end of the file, is included as part of the output of the **ENS** or **TMS** output files.

An example of a completed or imported file screen is shown next.

![Operating Time File for ENS Input (Completed or Imported File)](image)

Figure 3-183 Operating Time File for ENS Input (Completed or Imported File)
The final action to create the file is taken by clicking on the Create button. The file is created and the user is given the option of viewing the file with a Yes or No button. Clicking on Yes will produce a TOM File View of the file. Clicking on No will close the file.

The Reset button completely resets the screen, starting from scratch. It is best used when problems arise and the user can no longer fix them. The Close button closes the program and returns the user to the next higher level.

3.2.4 ENS or TMS Train Location Input

Selection of Trn Loc in the ENS Input Selection screen of Figure 3-114 produces the following screen.

A list of train location files in the database for the rail system selected is shown at the left and middle of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.
Selection of the Name of File to be created or modified is at the left and bottom of the screen. This is edited in the usual window manner.

The train location file can have input units, which are either English or metric and output units, which are either English or metric. This is selected by checking the appropriate box at the left of the screen. A description for the kind of units expected is given in Appendix 9.3.

At the right of the screen, there are two options for selecting train location: Headway and Timetable.

3.2.4.1 Headway

The first option is Headway. Click here to specify train location by headway. The screen is modified as follows.

![Figure 3-185 Train Location File for ENS Input / Headway Option](image)

This method of specification can only be used with systems where trains run on a fixed headway. The following input is required: Headway (minutes), Schedule Offset (minutes), Start Time (hh:mm:ss), End Time (hh:mm:ss), Train ID + Direction (for positive direction running), Start Position (for positive direction running), Train ID - Direction (for negative direction running), Start Position (for negative direction running) and the Number of Cars Per Train. The Start Position is specified in miles or feet in...
Enter train **Headway** (minutes). For a two-track system, headway is the time between trains running on the same track past a fixed point in the same direction. Normal editing procedures can be used to enter and change values.

Enter train **Offset** (minutes). For a two-track system with trains operating on fixed headway, offset is the difference in time between two trains running past a fixed point in opposite directions on different tracks. The offset can vary from zero to one-headway value.

Enter the **Start Time** and **End Time** for the trains. The time must be entered in a 24-hour format. The entry must be of the form hh:mm:ss. For example, 4:10 p.m. would be entered as 16:10:00.

Enter the **Train ID + Direction** for trains running in the direction of increasing value of position and the **Start Position** for these trains. The **Train ID - Direction** follows this for trains running in the direction of decreasing value of position and the **Start Position** for these trains.

A single click on the **Power Profile** (P-File) in the **File List Box** at the right, followed by a short mouse movement over the **File List Box** causes the caption of the file to be displayed in the tool tip text.

Clicking the **View P-File** command button displays the file in the **File Viewer**.

A right click over the **File List Box** will also cause the **Power Profile** to be displayed in the **File Viewer**.

Refer to the **P-Files** for the **Train ID** as well as the **Train Start Position** and running **direction** (either + or -).

Choose one of the options **AC Trains** or **DC Trains** depending on whether the power distribution system is AC or DC.

The **File Caption**, which appears as a title script at the end of the file, is not used as any portion of the run but simply identifies the file. It is recommended that it be used.

An example of a completed file screen is shown next.
The final action to create the file is taken by clicking on the **Create** button. The file is created and the user is given the option of viewing the file with a **Yes** or **No** button. Clicking on **Yes** will produce a **TOM File View** of the file. Clicking on **No** will close the file.

There are two other buttons at the right of the screen **Close** and **Reset**. A click on **Close** will abort the screen and return to the previous screen. A click on **Reset** will create the same screen in the same manner as if it was called from the **ENS Input Selection** screen of **Figure 3-114**.

The **Train Location File** just created can be viewed in the **TOM File Viewer** by clicking the **Yes** button. The file is displayed in the next screen.
Figure 3-187 Display of Train Location File Created by the Headway Option.

This file is stored as if it were created by the Timetable option. In fact, if this file is imported into the Train Location File Input Screen, it will be a timetable as seen in the next screen.
Figure 3-188 Train Location File Created by Headway Option and Imported into the Train Location File Input Screen

The file appears as a Timetable Option type Train Location File.

3.2.4.2 Timetable

The second option for train location is Timetable. Click here to specify train location by timetable input. The screen is modified as follows.
Figure 3-189 Train Location File for ENS Input / Timetable Option

The entries are made in the box: Train ID, Departure Time, Departure Position, Direction of Travel, Number of Cars in Train.

Enter the following for each train on the system: train ID followed by a comma delimiter, followed by departure time (hh:mm:ss), followed by a comma delimiter, followed by departure position (feet or miles in English units and meters or kilometers in metric units), followed by a comma delimiter, followed by the number of cars per train followed by a carriage return. Normal editing procedures can be used to enter and change values. The Time Calculator could be useful if times are in other formats.

To quickly enter an initial entry, double click on the power profile (p-file) associated with the entry in the upper right hand corner of the screen. This can be duplicated several times to correspond to the number of timetable entries for the Power Profile or TPS run. Only the time (hh:mm:ss) needs to be changed from (00:00:00). The Time Calculator could be useful if times are in other formats.

A single click on the power profile in the File List Box followed by a short mouse movement over the File List Box causes the caption of the file to be displayed in the tooltip text.

A right click over the File List Box will cause the Power Profile to be displayed in the File Viewer.

Timetable entries may be ordered by train ID and by departure time by clicking on the Order command button.
All of the departure times of a sequential set of timetable entries may be shifted by a fixed number of seconds. First enter the number of seconds to shift the departure times (+ or -), select the successive records to be shifted by dragging the mouse, and click on the **Shift** command button. Complete records must be selected when shifting.

All of the departure times of trains moving in the (- direction) in the set of timetable entries may be offset by a fixed number of seconds relative to those moving in the (+ direction). First enter the number of seconds for the offset (+ or -) and click on the **Offset** command button.

Choose one of the options **AC Trains** or **DC Trains** depending on whether the power distribution system is AC or DC.

The **File Caption**, which appears as a title script at the end of the file, is not used as any portion of the run but simply identifies the file.

An example of a completed or imported file screen is shown next.
There are two other buttons at the right of the screen Close and Reset. A click on Close will abort the screen and return to the previous screen. A click on Reset will create the same screen in the same manner as if it was called from the ENS Input Selection screen of Figure 3-114.

The Power Profiles are listed to the right of the Train Location File Input screen of Figure 3-189 for a very good reason. Double-clicking on Power Profile imports much of the information to construct the timetable from the Power Profile itself. An example is shown in the next screen, where several power profiles of the form P-Ax.tes were clicked.

Figure 3-191 Train Location File for ENS Input / Timetable Option (Double-clicking on P-Files)

All that needs to be modified is the departure time in each of these entries.

3.2.5 ENS or TMS Current Measurement Input

Selection of Cur Meas option in the ENS or TMS Input Selection screen of Figure 3-114 produces the following screen.
Figure 3-192 Current Measurement File for ENS Input

The screens are different depending upon whether **AC Trains** or **DC Trains** are selected. AC and DC refer to the power distribution system under which the trains run. The default selection is **DC Trains**.

There are two other buttons at the right of the screen **Close** and **Reset**. A click on **Close** will abort the screen and return to the previous screen. A click on **Reset** will create the same screen in the same manner as if it was called from the **ENS Input Selection** screen of Figure 3-114.

**3.2.5.1 AC Trains**

Selection of **AC Trains** leads to the following screen.
A list of current measurement files in the database for the rail system selected is shown at the left and middle of the screen. These files may be viewed, selected or deleted using the **View One**, **Select One** or **Delete One** buttons, respectively. Double clicking on the selection in the box will select that file as well.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

Selection of the **Name of File** to be created or modified is at the left and bottom of the screen. This is edited in the usual windows manner.

The current measurement file can have input units, which are either English or metric and output units, which are either English or metric. This is selected by checking the appropriate box at the left of the screen. A description for the kind of units expected is given in Appendix 9.3.

### 3.2.5.1.1 Current Measurement Points Along the Track

The entries are made in the box **Position ID, Position, Track Number**.

Enter the following for each current measurement point on the track; position ID (4 characters), followed by a comma delimiter, followed by position (feet or miles for English units or meters or kilometers for metric units), followed by a comma delimiter, and track number followed by a carriage return. Normal editing procedures can be used to enter and change values.
3.2.5.1.2 AC Node Voltages Text Box
Entries can also be made for the AC Node Voltages.
Enter the information about the nodes for which AC voltage will be output to the current measurement file. Enter the name of the node followed by a comma (,) delimiter, followed by a number indicating on which side of the transformer the node is placed, followed by a carriage return. The indication for the side of the transformer is either unity (1.00) or the transformer turns ratio. Normal editing procedures can be used to enter and change values.

An additional requirement is necessary in TOM Version 3.4 or higher for the next two conditions:
The Current Measurement Input file is to be used for ENS or TMS runs, which contain a Network, which was generated using a Primary and Return Circuit or a Primary Circuit.
Current analysis is to be conducted on the Primary and/or Return Circuit.
If these conditions hold, then the AC Node Voltages text box must contain the node names of the main transformer secondary and only those names.
If these conditions do not hold, then there is no restriction on the node and line names to be placed in the text box.

3.2.5.1.3 AC Line Currents Text Box
Entries can also be made for the AC Line Currents.
Enter the information about the non-track related AC lines for which current will be measured. These lines cannot be associated with the tracks (catenary, trolley, third rails) upon which trains are running. Enter the name of the line followed by a comma (,) delimiter, followed by a number indicating on which side of the transformer the node is placed, followed by a carriage return. The indication for the side of the transformer is either unity (1.00) or the transformer turns ratio. Normal editing procedures can be used to enter and change values.

An additional requirement is necessary in TOM Version 3.4 or higher for the next two conditions:
The Current Measurement Input file is to be used for ENS or TMS runs, which contain a Network, which was generated using a Primary and Return Circuit or a Primary Circuit.
Current analysis is to be conducted on the Primary and/or Return Circuit.
If these conditions hold, then the AC Line Voltages text box must contain the line names of the main transformer and only those names.
If these conditions do not hold, then there is no restriction on the node and line names to be placed in the text box.

3.2.5.1.4 Completion of the Screen
The File Caption, which appears as a title script at the end of the file, is not used as any portion of the run but simply identifies the file.
An example of a completed or imported file screen is shown next.
The final action to create the file is taken by clicking on the **Create** button. The file is created and the user is given the option of viewing the file with a **Yes** or **No** button. Clicking on **Yes** will produce a **TOM File View** of the file. Clicking on **No** will close the file.

There are two other buttons at the right of the screen **Close** and **Reset**. A click on **Close** will abort the screen and return to the previous screen. A click on **Reset** will create the same screen in the same manner as if it was called from the **ENS Input Selection** screen of Figure 3-114.

### 3.2.5.2 DC Trains

Selection of **DC Trains** option in the screen of Figure 3-192 leads to the following screen.
A list of current measurement files in the database for the rail system selected is shown at the left and middle of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

Selection of the Name of File to be created or modified is at the left and bottom of the screen. This is edited in the usual window manner.

The current measurement file can have input units, which are either English or metric and output units, which are either English or metric. This is selected by checking the appropriate box at the left of the screen. A description for the kind of units expected is given in Appendix 9.3.

The entries are made in the box Position ID, Position, Track Number.

Enter the following for each current measurement point on the track: position ID (4 characters), followed by a comma delimiter, followed by position (feet or miles for English units or meters or kilometers for metric units), followed by a comma delimiter, and track number followed by a carriage return. Normal editing procedures can be used to enter and change values.

The File Caption, which appears as a title script at the end of the file, is not used as any portion of the run but simply identifies the file.
An example of a completed or imported file screen is shown next.

![Current Measurement File for ENS Input - DC Trains (Completed or Imported File)](image)

The final action to create the file is taken by clicking on the **Create** button. The file is created and the user is given the option of viewing the file with a **Yes** or **No** button. Clicking on **Yes** will produce a **TOM File View** of the file. Clicking on **No** will close the file.

There are two other buttons at the right of the screen **Close** and **Reset**. A click on **Close** will abort the screen and return to the previous screen. A click on **Reset** will create the same screen in the same manner as if it was called from the **ENS Input Selection** screen of Figure 3-114.

### 3.2.6 ENS or TMS Primary Or Return Circuit File

The construction of the **Primary Circuit** or **Return Circuit** files are handled using the same screens. Double clicking the **PriCct** or **RtnCct** item in the **ENS Input** list box shown in Figure 3-154, leads to the following screens.

Clicking the **PriCct** item reveals the screen:
Clicking the *RtnCct* item in the *ENS Input* list box shown in Figure 3-154 reveals the screen:
Figure 3-198 File Construction Module – Primary or Return Circuit Input – Return Circuit Option Selected

This screen and subsequent screens called from this screen are discussed using the Return Circuit option. Differences between the return circuit and the primary circuit will be pointed out when appropriate.

The objects on the screen are now discussed.

A list of return circuit (primary circuit) files in the database for the rail system selected is shown at the left and middle of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

Selection of the Name of File to be created or modified is at the left and bottom of the screen. This is edited in the usual window manner.

Although the methodology for creating the return circuit (primary circuit) will not involve entering data into the grids, a discussion of the grids is useful at this point. The user must be very careful when changing information directly in the grids.

On the upper part of the screen there are two indicators: # of Lines and # of Nodes. These indicators, which cannot be modified, keep track of the number of lines and nodes, which are entered. The grids labeled Line Input and Node Input are the mechanisms to show the line and node information.

The Line Input is the grid used for input of information for each line. It contains the Line Name (line name limited to 4 characters), Begn Node (the begin point of the line limited to 4 characters), End Node (the endpoint of the line limited to 4 characters), Trk # (the track number of the line) and complex impedance (Impedance Real and Impedance Imaginary, representing the real and imaginary parts of the impedance.) Of course in DC circuits, the imaginary impedance is always zero.
The Circuit Options frame contains two check boxes, Primary Circuit and Return Circuit. Click the Primary Circuit checkbox to select primary circuit input. Click the Return Circuit checkbox to select return circuit input.

The Train Type frame contains two options. The AC Train option is selected for AC distribution systems and the DC Trains option is selected for DC distribution systems. The train type information is stored in the primary and return circuit files. Note that when the AC Train option is selected, only a Primary Circuit can be built.

The Primary or Return Circuit Construction frame contains three command buttons, the Text Transfer, the Graphic Input and the Circuit Check command button. The Circuit Check command button remains invisible until a circuit is present in the grids. These construction tools are discussed later.

The Impedances command button leads to a screen which can calculate impedances for the lines in the grid and subsequently insert them in the grid. This screen is discussed later.

The Clear All Impedances command button removes all impedances from the line grid.

The Compute Y- Matrix command button leads to a screen in which the user may compute the admittance matrices for primary and return circuits. This feature will be discussed later.

The File Caption text boxes are used to identify the file. These captions appear at the end of the file.

The Create File command button causes the creation of the primary or return circuit file depending on the option selected in the options frame.

The Help, Reset, Close and Exit command buttons have their usual meanings.

The construction tools and impedance calculations and insertions are described in the next sections.

### 3.2.6.1 Construction Tools

The construction tools consist of the Graphic Input process and the Text Transfer process.

#### 3.2.6.1.1 Graphic Input

There is a graphics facility for constructing the primary or return circuits. This facility is described in two parts: Procedures and Rules.

#### 3.2.6.1.1.1 Procedures for Constructing Primary and Return Circuits

**Description of Graphic Method**

Click the Graphic Input command button on the File Construction Module – Primary or Return Circuit Input screen shown in Figure 3-198 to yield the next screen.
Figure 3-199 File Construction Module – Return (Primary) Circuit File Input – Return (Primary) Circuit by Graphics

Clicking the Open Grid command button will produce one of two screens depending on whether or not the Line Grid of the File Construction Module – Primary or Return Circuit Input screen shown in Figure 3-198 has entries. If the grid has no entries, such as is the case in the screen of Figure 3-198, then the following screen results.
The circuit layout graph space has two dimensions. The horizontal direction is called the position portion of the graph space and the vertical direction is the track number portion of the graph space.

The position of the nodes is referred to mileposts or kilometerposts in the horizontal direction. Track numbers are referenced to the black-dotted lines running horizontally across the layout graph space. The first black-dotted line at the top is track 0, the second is track 1, the third is track 2, etc. There are light color lines running horizontally between the black lines. These lines are dividing lines between tracks 1 and 0, tracks 2 and 1, tracks 3 and 2, etc. The dots on each of these lines are referred to as grid points.

Lines are added to the graph space in an operation which consists of a mouse click on the beginning node position, drawing a line with the free mouse, followed by a mouse click on the ending node position. The next screen shows the graph space after the mouse is clicked near position \(-0.1\) on Track 1 and extended to position \(3.1\) on Track 1.
Note that the position and track number of the cursor is always displayed at the top of the screen when the mouse lies in the graph space.

The line is shown as in green with the nodes at the end as yellow circles.

The minimum and maximum node positions have been adjusted to correspond to the node positions of the first track segment drawn in the graph space. Thus it is always a good idea to make the first track segment the distance from the beginning of the track system (minimum value milepost or kilometerpost) to the end of the track system (maximum value milepost or kilometerpost).

The begin node and end node positions and track numbers of the last line entered are stored in text boxes at the upper left of the screen. Since it is not always possible for the begin node and end node positions to lie exactly on a grid point, these positions can be corrected by editing these text boxes and clicking the Correct Position command button. Also notice that these positions are slightly different than the desired – 0.1 and 3.1. These will be corrected later.

In addition to the action just described, the second click of the mouse button also registers the track segment in the Line Grid and Node Grid of the File Construction Module – Return (Primary) Circuit Input – Main Screen as shown in the next figure.
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Figure 3-202 File Construction Module – Primary or Return Circuit Input – Main Screen – Line and Node Entry Illustration

All node and line names are automatically generated. For nodes on track 0, the node name is 0x, for nodes on track 1 the node names are Ax, for nodes on track 2, node names are Bx, etc. For lines on the same track number, line names are Ax for track 1, Bx for track 2, Cx for track 3, etc, while lines connecting nodes which lie on different tracks are 80x between track 0 and any track, 81x for track 1 to any track, etc. x is a number from 0 to 99 for lines and from 0 to 999 for nodes. Track numbers assigned to lines between nodes on different tracks are the same as the first two characters of the line name: 80, 81, 82, etc.

Track 0 is reserved for substation nodes on the low voltage side. No lines can be drawn between nodes on track 0. A single node cannot be inserted on track 0. A line can only be drawn between track 0 and some other track.

The positions of the beginning and end node will now be corrected.

In the Begin Node Position and End Node Position text boxes of the File Construction Module – Return (Primary) Circuit File Input – Return (Primary) Circuit by Graphics – Circuit Layout Graph Space – Line Drawing Illustration in Figure 3-201, enter the numbers –0.1 and 3.1 and then click the Correct Position command button. This action is demonstrated in the next screen.
Figure 3-203 File Construction Module – Return (Primary) Circuit File Input – Return (Primary)
Circuit by Graphics – Circuit Layout Graph Space – Line Drawing Illustration – Correction Made

When the action is carried out, the correction is transferred to the grids as shown in the next screen.
As mentioned previously, the line and node names are automatically generated.

**Insert Node Procedure**

Nodes can now be entered on the first line, simply by inserting them at the proper positions. To insert a node at position 0.0 on Track 1, simply click the mouse at position 0.0 on Track 1 and then click it again. (Note this is not a double mouse click but a click followed by a second click in about a second.) Correct the position if necessary. The action just described produces the following screen.
It is always good practice to add the horizontal lines, which may represent track or feeders (return circuit) or catenary, third rail or feeders (primary circuit) to the graph space first, followed by the vertical lines which may represent substation connections, bonds (return circuit) or ties (primary circuit). The next screen shows the graph space with two lines, which extend from −0.1 to 3.1 on tracks 1 and 2.
Figure 3-206 File Construction Module – Return (Primary) Circuit File Input – Return (Primary) Circuit by Graphics – Circuit Layout Graph Space – Two Horizontal Lines

The next step is to insert four substation connections (from track 0 to track 1) at positions 0, 0.8, 2.0 and 2.9.

To insert the first one, click on track 0 at position 0, then click on track 1 at position 0. Correct as necessary to obtain the next screen.
The remaining connections are illustrated in the next screen.
From time to time it is desirable to click the **Clear Garbage** command button, which refreshes the screen from the information in the grids.

The layout may be viewed in the grids and is shown in the next screen.
Figure 3-209 File Construction Module – Primary or Return Circuit Input – Main Screen – Two Horizontal Lines Plus Four Substation Connections

In DC systems, the nodes on Track 0 represent the negative input point of the rectifier (return circuit) or positive output point of the rectifier (primary circuit). In AC systems, the nodes on Track 0 represent the low voltage side of the transformer.

Track Bonds (return circuit) and Tie Stations (primary circuit) are now placed at each substation and at the ends of track. These are illustrated in the next screen.
Node Related Procedures

Clicking with the right mouse button on a line or a node generates a menu. In the case of a node, the menu is shown in the next screen.
Four options are available in the menu:

- Identify
- Move
- Remove
- Impedance

Click the Close menu item to close the menu.

Click the Identify item to identify the node.
The **Node Name** and **Node Position** are displayed.

**Move Node Procedure**
Clicking on the **Move** menu item produces the next screen.
Figure 3-213 File Construction Module – Return (Primary) Circuit File Input – Return (Primary) Circuit by Graphics – Circuit Layout Graph Space – Circuit Layout – Moving A Node

The Move Node Procedure screen sets up node movement.

The node selected is in the Select Node to be Moved combo box. This can be changed if desired,

The node position is shown in the Node Position combo box. This is for reference only.

The adjacent nodes are shown in the text box at the left. The node, track number and position are shown in the text box.

Although the paragraph in the middle allows movement of the node to any position greater than 0, since this is a substation related node, the movement is restricted to less than 0.005. So move the node to 8.003.
Figure 3-214 File Construction Module – Return (Primary) Circuit File Input – Return (Primary) Circuit by Graphics – Circuit Layout Graph Space – Circuit Layout – Node Movement Complete

Movement of the node is verified by observation of the next screen indicating B3 is now at .803.
The position of B3 is .803.

The remove node procedure is demonstrated next. Begin by inserting a node at position 1.5 on track 2. This action is accomplished by clicking on position 1.5 on track 2, twice. The insertion is shown on the next screen.
The **Node Removal Procedure** is a two or more step process, depending on the node to be removed. It may involve removing and replacing lines and other nodes. To remove the node just inserted, click on the **Remove** menu item in Figure 3-211. The following screen appears.

![Figure 3-216 File Construction Module – Return (Primary) Circuit File Input – Return (Primary) Circuit by Graphics – Circuit Layout Graph Space – Circuit Layout – Node Insertion](image)
Click the Yes command button and the lines will be removed as shown in the next screen.
Figure 3-218 File Construction Module – Return (Primary) Circuit File Input – Return (Primary) Circuit by Graphics – Circuit Layout Graph Space – Circuit Layout – Node Removal Procedure – Lines Removed

The line is now drawn to complete the procedure.
Figure 3-219 File Construction Module – Return (Primary) Circuit File Input – Return (Primary) Circuit by Graphics – Circuit Layout Graph Space – Circuit Layout – Node Removal Procedure - Completed

The **Impedance** item of the menu in Figure 3-211 will be discussed later.

**Line Related Procedures**

With the right mouse, click on the line indicated as shown in the next screen.
The line related procedures as menu items are:

- Identify
- Remove
- Impedance
- Change Impedance

The Close item eliminates the menu.

Clicking the Identify item produces the next screen.
The identification of a line displays the **Line ID** (or name), the **End (Begin) Node ID** and **Position** [first node], **End (Begin) Node ID** and **Position** [second node] and **Impedance**. No impedances have yet been added to the grids so nothing appears in the **Impedance** item.

Selection of the **Remove** item of the menu, removes the line. Again, depending on which line is removed, the process could be one or several steps.

Removing the line identified in the previous figure results in the next screen.
Impedance by Graphics

Two kinds of impedances may be calculated by selecting the Impedance menu after right clicking with the mouse on a line or on a node. The impedance of any line is available by identifying the line.

Dynamic impedance refers to the impedance that a train would see at the position of the cursor on a Track Line.

Static impedance refers to the impedance between two nodes.

Both are demonstrated.

Dynamic Impedance

Open the graph space with an existing file.
With the right mouse, click on a Track Line at some point.
Figure 3-224 File Construction Module – Return Circuit File Input – Return Circuit By Graphics – Existing File Imported Into Screen – Right Mouse Click

Click on the **Impedance** item in the menu.
Figure 3-225 File Construction Module – Return Circuit File Input – Return Circuit By Graphics – Existing File Imported Into Screen – Right Mouse Click – Selection of the Impedance Item

The dynamic impedance is calculated using the following procedure.

All substations are energized. The voltage at each substation is set to the unit value (1.0).

A sink node is placed at the position to be measured. The power drawn by the sink is the power setting value (Default = 0.5.). The voltage drop to and the current flow into the sink node is calculated using the Gauss-Seidel method. The impedance is then calculated as the voltage drop divided by the current.

This impedance is the impedance the train would realized if it were placed at the measuring point from the train to the all of the substations on either side. Thus, it is the effective return circuit impedance to be added to the primary circuit impedance to complete the circuit.

Static Impedance

The static impedance is measured from node to node.

In the screen of Figure 3-223 click on a node with the right mouse.
Figure 3-226 File Construction Module – Return Circuit File Input – Return Circuit By Graphics – Existing File Imported Into Screen – Right Mouse Click on Node

Click on the Impedance item in the menu.
Figure 3-227 File Construction Module – Return Circuit File Input – Return Circuit By Graphics – Existing File Imported Into Screen – Impedance Item Selected on First Node

Go to the next node, which is the substation on the right.
Figure 3-228 File Construction Module – Return Circuit File Input – Return Circuit By Graphics – Existing File Imported Into Screen – Impedance Item Selected on Second Node

The impedance between nodes is calculated in the following manner.

The second node is given a fixed voltage or 1. in unit value. All remaining nodes are load nodes with 0 power. A power of the power setting value is put at the first (sink) node and the current is measured. The impedance is the (voltage drop/current).

If convergence is not obtained, try a lower power setting. Accuracy of the impedance is achieved by the highest power setting for which convergence is obtained. The choice of 0.5 power setting, which is also the default has been obtained by trial and error on several systems. Different rail systems may have a better power setting. Trial and error by the user is required here.

Change Impedance by Graphics

With the right mouse button, click on any line. This action exposes the line menu. Click on the Change Impedance item of the line menu, which exposes the Add Impedance Procedure screen.
This screen is discussed fully in Section 3.2.6.2 Impedances. The screen has been set up with the appropriate line name (B2), which it obtained from the graphics screen. The user inserts the impedance (real and imaginary) into the text boxes of the Add Impedance frame (in real ohms or real ohms per unit distance as appropriate for the line element). This is followed by clicking on the Set Impedances To Grids command button, which adds the impedance to the Line Input grid of Figure 3-209.

Other Command Buttons, Text Boxes and Frames

The remaining command buttons, frames and text boxes on the circuit layout graphics screen are now discussed.

Open Grid Command Button

Clicking the Open Grid command button loads the nodes and lines which are stored in the grids of the File Construction Module – Primary or Return Circuit Input – Main Screen, into the graph space.

Import Full Layout
Click on this command button will import the circuit layout present in the grids of the Main screen into the graph space of this screen. The maximum and minimum node positions in the circuit layout will fix the Maximum and Minimum Node Position text boxes. This action is to be contrasted to clicking the Import Partial Layout command button, whose action causes the Maximum and Minimum Node Position text boxes to fix the maximum and minimum node positions.

**Import Partial Layout Command Button**

Click on this command button will import the circuit layout present in the grids of the Main screen into the graph space of this screen. The Maximum and Minimum Node Position text boxes will fix the maximum and minimum node positions. This action is to be contrasted to clicking the Import Full Layout command button, whose action fixes the maximum and minimum node positions in the circuit layout.

**Clean Garbage**

Click on this command button will refresh the circuit layout graph space and the layout presently contained therein, as is stored in the grids of the Main screen.

**Erase Layout**

Click on this command button to completely erase the circuit layout presently contained in the graph space. This command will also clear the grids and reset the Main screen to a new track layout. If Primary or Return Circuit file was imported into the screen, the file is not changed or erased.

**Feed Distance to Substations Frame**

This frame only applies to the Return Circuit and not the Primary Circuit.

The frame contains a text box and a command button. Set the feed distance to substation limit in the Limit text box. The feed distance to substation limit is the maximum horizontal distance that the feeders connect to the substation. This distance is measured along the right of way. It is expressed in Miles or Kilometers, depending on unit selection. This should be kept as small as possible. If the feeders connect to the track very far from the substation, use a connection to a higher track number line, with a tie or bond back to the active tracks (on which trains run).

The default value is 0.005. Click the Default command button in the frame to reestablish the default value.

**Impedance Calculational Parameters Frame**

These parameters are used to calculate static and dynamic impedances given line impedances. These parameters are discussed in more detail in Section 4.14.

Calculation of these impedances is accomplished using the Gauss-Seidel method, which is the same method used in the load flow of the ENS or TMS. This requires the user to specify a Power Setting (per unit), Maximum Iterations (maximum number of iterations before convergence is not achievable) and Convergence Accuracy (accuracy achieved before convergence is declared). If the user is uncertain about which values to use, they should be left at the default values. Click the Set Default command button in the frame to reestablish the default values of the model.
3.2.6.1.1.2 Rules for Constructing Primary and Return Circuits

The following are rules for adding lines and nodes to the track layout graph space. Terminology appears in the next figure.

![Line and Node Designation](image)

**Figure 3-229 Primary and Return Circuit Line and Node Terminology**

The begin node and end node of the first track line added to any new (empty) graph space must have the same track number.

No **Track Lines** can be added with track number 0.

Inserting **Substation Connection Lines**, **Bond Lines** and **Tie Lines** are added only after the **Track Lines** have been entered. A **Tie Line** refers to a **Primary Circuit** and a **Bond Line** to a **Return Circuit**.

It is good practice to add **Track Lines** first, followed by **Substation Connection**, **Bond** and **Tie Lines**.

If at anytime, the drawing of a legitimate line fails to register that line (the line does not appear on the graph), try again. If still not successful, try zooming in the position or track number graph space and retry.

Lines cannot be added between a **Track Line** and **Substation Connection Line**, a **Bond Line** or a **Tie Line**.

An attempt to add an illegal line may result in a message which informs the user. Sometimes the illegal line will be detected later.

The following are rules for removing lines and nodes to the circuit layout graph space.

Removing a **Substation Node**, removes the **Substation Connection Line** associated with that node. The **Substation Connection Node** is not removed. It becomes a **Track Line Node**.

**Track Line Nodes** can be removed in two steps. Use the **Remove Node** procedure for step 1. This procedure removes the adjacent lines as well. Step 2, reconnect the adjacent nodes that were not removed.

**Substation Connection Node** cannot be removed directly. It is better to remove the **Substation Connection Line**. Removal of a **Substation Connection Node** removes all lines associated with it.

**Tie** or **Bond Line Node** cannot be removed directly. It is better to remove the **Track** or **Bond Line** followed by removal of the **Track Line Nodes** associated with them.
3.2.6.1.2 Text Transfer

The Text Transfer procedure is a tool which allows the user to import the Line and Node Grids into an EXCEL spreadsheet or other text programs for modification. It works similar to the Text Transfer procedure in the Network file of the ENS or TMS or the Track Layout file of the TMS.

Import a Return Circuit file into the File Construction Module – Return or Primary Circuit File Input - Main screen by selecting a file in the Input File list box.

![Image of File Construction Module – Return or Primary Circuit File Input - Main Screen – Imported File]

Figure 3-230 File Construction Module – Return or Primary Circuit File Input - Main Screen – Imported File

Click the Text Transfer command button in the Return Circuit Construction frame.
Click the Import command button to transfer the information from the File Construction Module – Return or Primary Circuit File Input - Main Screen – Line Input grids to the Lines text box.
Figure 3-232 File Construction Module – Return or Primary Circuit File Input – Text to TOM Transfer Screen – Lines Text Box – Imported Information

Copy the information in the Lines text box and paste into a new EXCEL spreadsheet.
Figure 3-233 File Construction Module – Return or Primary Circuit File Input – Text to TOM Transfer Screen – Lines Text Box – Imported Information – Copied

Paste into spreadsheet.
Figure 3-234 EXCEL Spreadsheet Lines of the Return Circuit

Perform the same procedure with the nodes.
After some formatting and labeling, the spreadsheet takes on the form shown next.
The spreadsheet may now be used for modifications and the return circuit information, which results, can be pasted back into the Text to TOM Transfer screen, after which it may be transferred to the grids via the Transfer command button.

### 3.2.6.1.3 Circuit Check

The Circuit Check command button checks the circuit that was built and provides an analysis. If any problems are detected, the user is informed. If there are no problems, the user is also informed and given the option of reviewing the report.
Figure 3-237 File Construction Module – Primary or Return Circuit – Main Screen – Click on Circuit Check Command Button

Click the Yes command button to review the report.
Figure 3-238 File Viewer – Circuit Check Output Report – Top Portion

The bottom portion of the report is shown next.
Figure 3-239 File Viewer – Circuit Check Output Report – Bottom Portion

The file may be saved by clicking the Save File As command button to the file CctChkSRC-tes.tes.

There are several exceptions in the Circuit Check Output Report, which are worth highlighting, although none have appeared in this circuit check.

Node Classifications under the Circuit Check procedure determine exceptions:

Failed to Classify (FAILED TO CLASSIFY. THIS IS A MAJOR PROBLEM!)

Substation
Associated with substation, not end of track, within correct limits.
Associated with substation, not end of track, not within correct limits. (THIS MUST BE CORRECTED! NODE MUST BE BROUGHT WITHIN SUBSTATION FEEDER LENGTH LIMIT TO SUBSTATION!)
Associated with substation, end of track, within correct limits. (THIS MUST BE CORRECTED! END OF TRACK LINE MUST BE ADDED TO NODE!)
Associated with substation, end of track, not within correct limits. (THIS MUST BE CORRECTED! END OF TRACK LINE MUST BE ADDED TO NODE! NODE MUST ALSO BE BROUGHT WITHIN SUBSTATION FEEDER LENGTH LIMIT TO SUBSTATION!)
Track tie or bond not associated with substation, not end of track
Track tie or bond not associated with substation, end of track
Floating end of track
Floating not end of track. (THIS NODE IS NOT NECESSARY BUT WILL CAUSE NO PROBLEMS, BUT WILL EXTEND COMPUTATION TIME.)
Associated with substation, not end of track, within correct limits, track break.
Track tie or bond not associated with substation, not end of track, track break.
Feeder associated with substation.
Feeder not associated with substation
Items 3, 4 and 5 above must be corrected. Item 9 does not require correction. Item 4 has an exception. If the node associated with a substation is near or on a transition track between two track numbers, an extension to end of track must be added, even if the train cannot travel on this extension. Neglecting this could, but not necessarily will, cause problems in ENS or TMS.

The Substation Feeder Limit is the horizontal or position distance along the right of way, which the feeder can extend. The should be kept small <= .01. If feeder distances are larger than this on a rail system use a feeder track to make the connection.

A Floating Node can either be on a track line, in which case it is connects two track lines, or at the end of track without a tie or bond line connecting to it. It is legitimate at the end of track but not on a track line. If on a track line, all it does is add to the complexity of the computation.

3.2.6.2 Impedances
Impedances are a property of lines in the Primary and Return Circuits. All impedances are complex numbers, having a resistive (real) and reactive (imaginary) part. Of course, in DC Circuits, only the real part is present, the imaginary part set to zero. Impedances are different depending on whether AC or DC Circuits are considered. DC Circuits are handled first.

3.2.6.2.1 DC Circuits
Return to the return circuit layout, which was built in Section 3.2.6.1.1. The File Construction Module – Primary or Return Circuit – Main Screen is shown in the next screen, with node and line information on the return circuit layout.
There are two command buttons below the Return Circuit Construction frame: Impedances and Clear All Impedances.

The Clear All Impedances command button erases all impedances in the Line Input grid.

Clicking on the Impedances command button produces the next screen.
Figure 3-241 File Construction Module – Primary or Return Circuit – Add Impedance Procedure

There are five frames on this screen.

**English or Metric Units**

**Unit Values**

**Impedance Base Change**

**Impedance Specifications (Real Ohms)**

**Add Impedance (Real Ohms)**

**English or Metric Units Frame**

If the English option is selected (bullet), the units are English and if the Metric option is selected, the units are Metric.

**Unit Values**

The Unit Value frame is disabled and displays the unit values of **Power** (MW), **Voltage** (volts) and **Impedance** (ohms).

**Impedance Base Change**
The *Unit Values* of the impedance base by changing the unit power or unit voltage. Enter the new value of unit power in the *New Unit Power* text box and enter the new value of the unit voltage in the *New Unit Voltage* text box, and click the *Change* command button to obtain the next screen.

The new unit values are then used to recalculate calculate the unit impedances for the grids in the *Main* screen. This procedure is automatically completed.

**Impedance Specifications (Real Ohms) Frame**

The frame contains the following information on both the real and imaginary parts of the impedances:

- **Track Line** - Specified in ohms per unit distance
- **Track Bond Line** – Specified in ohms to the adjacent track
- **Substation Connection** – Specified in ohms to the substation
- **Return Feeder Line** – Specified in ohms per unit distance and represents a parallel feeder
- **Return Feeder Bond Line** – Specified in ohms of bond line and is the connection between the parallel feeder and the track line.
- **Line numbers Associated with Return Feeders** – A track number not associated with running trains but used as feeders for the purpose of improving circuit conductivity. If there is more than one feeder line, they are separated by semicolons (;).

If a primary circuit were specified, rather than a return circuit, the term tie would be substituted for bond and primary for return in the frame.
When Add Impedance Procedure screen first opens, the combo box is set to ALL, indicating that all impedances in the Line Input grid will be calculated using the values in the Impedance Specifications Frame.

The user can change any of the values of the impedances specified in the frame, by entering a different value into any of the text boxes. Clicking the Set Impedances to Grids command button will cause the computation of all of the impedances in the unit ohm and the insertion of those impedances into the Line Input grid. This insertion will only take place if the Line Input grid impedance cells are blank. (Please note: All Impedances in the text boxes of the Impedance Specifications Frame are in real ohms or real ohms per unit distances, whereas all impedances in the Line Input grid are in the unit ohm.)

Add Impedance Frame

The Add Impedance Frame becomes visible when a line name is selected in the Impedances for Line(s) combo box as shown.

Figure 3-243 Add Impedance Procedure Screen with Add Impedance Frame Visible

Adding impedance by filling in the text boxes in the Add Impedance Frame and clicking the Set Impedances to Grids command button will cause the computation of the appropriate impedance in the unit ohm followed by an insertion of the same into the Line Input grid for the line specified by the Impedance for Line(s) combo box.

Adding the impedance of a single line can also begin in the graphics screen. This was described in Section 3.2.6.1.1.1.5 and will not be repeated here.
There are five command buttons below the **Impedance Specifications** frame:

- **Set Impedances to Grids** – This command button sets the values of impedances to the Line Input grid performing all calculations on distances between nodes and unit values, with the current specifications in the Impedance Specifications frame. If the Add Impedance frame is visible because a line was selected in the Impedance for Line(s) combo box, impedance is added only for that line. The values thus set into the grids are in the unit ohm.
- **Set Default Impedances** – This command button sets the current default values for the Rail System under consideration into the text boxes of the frame.
- **Set Imported Impedances** – Values of the impedances used for the Set Impedances to Grids procedure are stored with the primary or return circuit file if the file is saved. If the file is re-imported into the grids using the Select command button on the Main screen, these values are imported directly into the Impedance Specification frame. If the frame values are changed, they can be reestablished to the imported file values using this command button.
- **Save Default Impedances** – This command button is used to save the impedances currently present in the Impedance Specification frame to the Rail System under consideration. Thus, every time the Set Default Impedances command button is clicked afterwards, the impedances in the frame will be the impedances just saved. In other words, the Rail System under consideration will have new default impedances.
- **Restore Original Default Impedances** – This command button restores the original default impedances of the TOM to the Impedance Specification frame.

Click the Set Impedances to Grids command button and return to the Main screen.

**Figure 3-244 File Construction Module – Primary or Return Circuit Input – Main Screen**

Note that these impedances are now in expressed in the unit ohm.
The file is now saved by adding file captions and a file name and then clicking on the Create File command button.

Figure 3-245 File Construction Module – Primary or Return Circuit – Main Screen – Return Circuit Information of the Layout Built in Section 3.2.6.1.1 – Saved File

Click the Yes command button to review the file. The top portion of the file is in the next screen.
Figure 3-246 File Viewer – Top Portion of Saved File

The bottom portion of the same file is shown in the next view of the screen.
Figure 3-247 File Viewer – Bottom Portion of Saved File

Note that the Unit information together with the Impedance specifications are stored with the file.

Primary Circuit files are built using the same procedures as the Return Circuit example just illustrated. There are very slight differences, which are now demonstrated.

Import a Primary Circuit file as shown in the next screen.
Figure 3-248 File Construction Module – Primary or Return Circuit – Main Screen – Primary Circuit

The only difference between a primary and return circuit is the selected option in the Circuit Option frame. It is now the Primary Circuit rather than the Return Circuit.

The only other differences are in the Add Impedance Procedure screen, shown next.
Figure 3-249 File Construction Module – Primary or Return Circuit – Add Impedance Procedure Screen – Primary Circuit

The only differences of course are the impedance specifications, the word “tie” replacing the word “bond” and the word “primary” replacing the word “return”.

3.2.6.2.2 AC Circuits

AC Primary Circuits are handled exactly like DC Primary and Return Circuits. In the case of AC, the substation node is the high or low voltage side of the transformer (Primary Circuits) depending on the nature or the AC distribution system, while, in the case of DC, the substation node is the negative end of the rectifier. A few screens are shown to illustrate the differences.

The Main screen is shown next, with an imported file.
The imported file is a 2 x 25 kV AC distribution system, with two substations and seven auto-transformers. On the main screen the AC Trains option is selected and there are now reactive or imaginary components of impedance present.

The system is displayed in the Primary Circuit by Graphics screen for illustrative purposes.
Figure 3-251 File Construction Module – Primary or Return Circuit – Primary Circuit By Graphics Screen – AC Distribution 2 x V kV System

There are three track lines. Track Line 3 is the primary feeder, which is connected via auto-transformer and main transformers to the running track lines one and two in series with the running rails. There are six auto-transformers and two substation transformers (center-tapped on the secondary). Two of the auto-transformers are at the same position (25) and thus are only visible as one in the graph space. Since the circuit to the right of position 25 and the circuit to the left of position 25 are separate circuits on the primary, they can be constructed with a gap at position 25 and then brought together using the Shift Nodes Procedure frame on the Main screen. This is discussed in more detail in Section 3.2.6.3.

Impedances for a 2xV kV system with auto transformers is also handle slightly different to accommodate the main transformers, the auto-transformers and the feeders.
Figure 3-252 Add Impedance Procedure for 2xV kV System with Auto-Transformers

The Substation Connection text boxes contain the complex impedance in ohms of the transformer on the secondary side.

The Primary Feeder Line text boxes contain the complex impedance of the feeder line. If there is more than one feeder line number, because of branching of the AC Train system, then these line numbers would be separated by semicolons;.
Figure 3-253 Add Impedance Procedure for 2xV kV System with Auto-Transformers. Three Feeder Line Numbers Showing Semicolon(;)-Separation.

The Auto Transformer Turns Ratio text box contains the value 2, which is the case for a 2xV kV distribution system. If this were a Direct Feed distribution system, which contained feeder lines, the value would be 1.

The Primary Feeder Tie Line text boxes contain the complex impedance of the auto-transformer in ohms for a 2xV kV distribution system and in the actual tie impedance in ohms for a Direct Feed distribution system.

3.2.6.3 Shift Nodes Procedure Frame

The Shift Nodes Procedure frame allows the construction of circuits, which are separated electrically, to be constructed with physical gaps, and to be brought together later, still remaining electrically disconnected. This occurs mostly on AC distribution systems with phase breaks or 2x25 kV distribution.
systems with auto-transformers in different circuits. It could also occur on DC distribution systems with circuit separation.

The example, which will be shown consists of two substations, with four auto-transformers. It is built with the physical gap between the circuit of 1 unit distance (mile or kilometers). Using the Shift Nodes Procedure, the system is then brought together physically but not electrically.

The physically separated circuits are shown in the next screen.
Figure 3-255  File Construction Module – Primary or Return Circuit – Main Screen – Physically Separated Circuits

There are three text boxes to be completed.

**Minimum Position** – Node position values less than this value will not be shifted.

**Maximum Position** – Node position values greater than this value will not be shifted.

**Shift Distance** – The amount that the position of each node in the range between minimum and maximum will be shifted.

After the text boxes are completed, a click on the Shift command button completes the procedure. Note that if the nodes which are separated physically, but not electrically are shifted so that no physical distance separates them, these nodes are still separated electrically and cannot be shifted again.

To bring the circuits together physically but not electrically, enter 16 in the **Minimum Position** text box and 31 in the **Maximum Position** text box and -1 in the **Shift Distance** text box, to yield the next screen.
The **Shift** command button will shift the nodes positions between 16 and 31 by –1, bringing the nodes together physically but not electrically as shown in the next screen.
Figure 3-257 File Construction Module – Primary or Return Circuit – Main Screen – Shift Procedure Executed
The circuits are no longer separated physically but are separated electrically.

Note that all nodes are shifted by the distance specified by the user, with the exception of substation nodes. Substations node positions will not be shifted.

3.2.6.4 Y-Matrix

The File Construction Module – Primary or Return Circuit – Main Screen with Imported File is shown next.
Click the Compute Y Matrix command button to prepare to display the admittance matrix.

Highlight the file to be selected and click the Select One command button to produce the admittance matrix for the circuit.
The View in File Viewer command button transfers the file to the TOM File Viewer in text format.

Figure 3-261 File Construction Module – Primary or Return Circuit – Y- Matrix Screen – Admittance Matrix Loaded
The file may be copied to the Clipboard or to Notepad for insertion into spreadsheets or other text handling programs.

By clicking the Save File As command button, the file will be saved in the filename indicated in the textbox.

### 3.2.6.5 File Creation

The screen shown below is the File Construction Module – Primary or Return Circuit File Input – Main Screen, which is ready for file creation.
Figure 3-263 File Construction Module – Primary or Return Circuit File Input – Main Screen – Ready for File Creation

Clicking the Create File command button produces the next screen.
Figure 3-264 File Creation with Line Name Translator Option

Clicking the Yes command button will build the Line Name Translator file, which can then be used to make some of the output processes more transparent.
Figure 3-265 File Creation with Line Name Translator Option Taken

Clicking the View Translator File command button produces displays it in the File Viewer.
Figure 3-266 Line Name Translator File
3.2.7 TMS Compatibility

If the TMS is to be run with the ENS (TMS with ENS) then non-main or connecting tracks must be given special consideration. These tracks are numbered from 50 to 99. However, in Primary and Return Circuits, circuit ties, bonds and substation connections have track or line numbers from 80 to 99. This leaves the range of numbers from 50 to 79, which can be used for non-main or connecting tracks.

If the Graphics procedure is to be used for circuit construction or reconstruction, these non-main tracks must be accommodated. Consider the following track layout.

Lazy Junction will require non-main tracks as shown in the Track Layout next.
Figure 3-268 DCEE Track Layout Showing Connecting Track #51

The connecting track directly above track 51 is track 50. Thus the numbers are larger than can be accommodated in the circuit graphics. Thus the circuit is constructed as follows.
A magnified view of the Lazy Junction area is shown in the next screen.
Figure 3-270 Return Circuit Layout - Compatibility With TMS – Junction Area Magnified

The connecting tracks are track 5 and track 6. They are electrically connected with a bond to track 2 and track 4, respectively. Tracks 5 and 6 are also electrically connected at each end. Although the switching nodes are at 3.95 and 4.05 in the Track Layout, in the Return Circuit Layout, the connections are placed at 3.94 and 4.06, respectively, to assure that the train gets power when passing through the switch. This screen is now closed. The Primary or Return Circuit – Main Screen is shown next.
These track numbers can now be converted to the original connecting track numbers of 50 and 51, by double clicking on the particular cells and typing in the new track numbers as shown in the next screen.
This file can now be created and it is now compatible with the TMS operating with the ENS.

By clicking the Graphic Input command button, an attempt can be made to open the Graphics Input screen. The problem is that it cannot work as is since the Graphic Input screen will not accept track numbers higher than 14. The number 14 is not magic, but is the number of tracks visible in the screen, which can easily be worked. So the track numbers should be converted to numbers less than or equal to 14. This is not a problem, since connecting tracks which are separated horizontally can have the same track numbers in the TMS, as long as they don’t overlap in horizontal positions. So the track numbers of connecting tracks can be converted manually or automatically. If done manually, and if the circuit is to be recreated, these track numbers are required to be converted again manually before clicking the Create File command button.

The second option is automatic conversion of the track numbers, which is the better way of accomplishing the TMS compatibility goal. It is a better method, because it keeps track of the conversion and upon recreation of the file will put the correct TMS compatibility track numbers in automatically as well, if so desired. However, these numbers may also be manually converted before recreation of the file. To demonstrate the procedure, click the Graphic Input command button to produce the next screen.
Figure 3-273 Return Circuit by Graphics Screen Before Clicking the Open Grid Command Button.

Clicking either the Open Grid, Import Partial Layout or Import Full Layout command buttons, produces the next screen.
Figure 3-274 Return Circuit by Graphics Screen After Clicking the Open Grid Command Button.

The dialog informs the user that a track number compatible with the TMS is being converted to a track number not compatible with the TMS but with the Return Circuit by Graphics screen.

This procedure is followed by a similar dialog for every track number which must be converted. It is only by clicking the Yes command button on the dialog that the number is converted. Clicking the No command button stops the procedure at any time. It is restarted again by clicking either the Open Grid, Import Partial Layout or Import Full Layout command buttons.

The procedure is remembered, so that on recreation of the file, the track numbers are reconverted to their original values. Thus clicking the Create File command button on the Main screen, produces the next screen.
Figure 3-275 The Main Screen on Clicking the Create File Command Button.

The dialog informs the user that this file, which was TMS compatible when created or imported into the screen went through the graphics process and should be converted back to its original condition. Clicking the Yes command button will convert the track numbers back to their original values before going through the graphics process.

Clicking the No command button will require the user to manually convert the track numbers.

Clicking the Yes command button produces the next screen.
Figure 3-276 The Main Screen with The Conversion Completion Dialog

Clicking the OK command button followed by the Create File command button creates the file.

For very complicated circuits and track layouts, more manual work may be required in both the Track Layout and Circuit Layout files to effect TMS compatibility. The rules are:

Connecting Track must have values higher than 49.

Circuit connects such as bonds, ties and substation connections must have track numbers higher than 79.

If Track Layouts and Circuit Layouts are to be TMS compatible, the Track Layout cannot have connecting track numbers higher then 79, so they must lie between 50 and 79. (Note connecting tracks which do not overlap in beginning and end positions can have the same track numbers.)

Circuit Layouts, which are TMS compatible, must have track numbers between 1 and 14 in order to be graphics compatible. This conversion occurs within the Primary or Return Circuit Input – Main Screen and the Primary or Return Circuit by Graphics Screen.
3.3 **INPUT FOR THE TMS**

A click on the TMS Input box of the FCM Main Screen of Figure 3-2 allows the user to select the construction of one of the following input files for the TMS as shown in the screen below.

![Figure 3-277 TMS Input Selection](image)

The following files may be selected:

- **Fnames** - TMS File of Filenames Input
- **TrkLayout** - TMS Track Layout File Input
- **Network** - TMS or ENS Network file Input
- **Op Tim** - ENS or TMS Operating Time Input
- **Trn Loc** - ENS or TMS Train Location Input
- **Cur Meas** - ENS or TMS Current Measurement Input
All of the files used as input to the ENS can also be input to the TMS, however constructing these files are discussed under Section 3.2. The Stop Distance File is not an input file to the TMS, but rather can be used as an aid to setting up track segments (blocks).

A double click on the appropriate file selection causes the selected filename to appear in the box above the choices and produces screens, which lead the user to create the file.

3.3.1 TMS File of Filenames Input

Selection of **Fnames** in the TMS Input Selection screen of Figure 3-277 produces the following screen.

![Figure 3-278 File of Filenames File for TMS Input](image-url)
This screen is used to create the File of Filenames File for TMS input. Three buttons are visible in the center of the screen: View One, Select One and Delete One. A list of files of filenames already contained in the database of the rail system selected is above these buttons. A single click on one of the filenames in the selection list highlights that file. The file may then be viewed, selected or deleted.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

A click on a file name in the Input File Name list box followed by a short mouse movement over the list box causes the caption of the file to be displayed in the tool tip text. A click with the right mouse button causes the file to be displayed in the File Viewer from which it can be edited by clicking the Edit command button in the File Viewer.

The procedure used to create or modify new and existing files of filenames for the TMS is the same as described in Section 3.1.1 for the TPS file of filenames and will not be repeated here.

An example of a completed or imported file screen is shown next.
Figure 3-279 File of Filenames File for TMS Input (Completed or Imported File)

Click under the Help command button to toggle the Check File of Filenames command button to become visible or invisible.

Click the Check File of Filenames command button to cause the input files of File of Filenames residing in the Input File Name list box to be checked. Checking means that the Train ID, Train Direction and Train Departure Position will be compared between the Train Location input file and the Power Profiles to determine the consistency. Clicking with the right mouse button causes the Electric Connectivity Test command button or the Track Connectivity Test command button to appear and the Check File of Filenames command button is hidden. Clicking with the right mouse button on the visible command button then toggles the command button between Electric Connectivity Test and Track Connectivity Test.

This process is shown in the next screens.

Figure 3-280 Screen Showing Check File of Filenames Command Button (To Expose Click Under Help)

A click on the Check File of Filenames produces the next screen if a consistency problem exists.
Figure 3-281 Action Resulting From Executing the Check File of Filenames Command

View the problems by clicking the Yes command button.
Figure 3-282 Problem Screen Shown in the File Viewer

Correct the problems by either changing the departure position and direction in the Train Location file or by rerunning the TPS, changing the Control file to represent increasing position direction. After correction, click the Check File of Filenames command button again to obtain the following screen.
Figure 3-283 Query Indicating Consistency of Train Location File and Power Profiles and Asking to Check Track Connectivity

Click the Yes command button to reveal the next screen.
Figure 3-284 File of Filenames Screen Showing the Track Connectivity Test Command Button

Click on the Track Connectivity Test command button. This procedure will assure that every position in every Power Profile is on the track number specified by the Track Layout file. If there were problems, the track connectivity test procedure must be rerun.
Figure 3-285 Track Connectivity Test for the File of Filenames Successful

Each of the Power Profiles has now been tested. **It is important to complete the preceding check and tests in order to assure that the File of Filenames truly represents the user’s intentions.**

If the File of Filenames had contained a Network file, indicating running the TMS while analyzing power, the user would have the opportunity to exercise the Electric Connectivity Test procedure, before the Track Connectivity Test procedure.

Clicking with the right mouse button toggles the command button between Electric Connectivity Test and Track Connectivity Test.

The final action to create the file is taken by clicking on the Create button. The file is created and the user is given the option of viewing the file with a Yes or No button. Clicking on Yes will produce a TOM File View of the file. Clicking on No will close the file.

Once the file is created, the user can execute it directly from this screen. Clicking the TMS command button will start the simulator.
There are two other buttons at the right of the screen Close and Reset. A click on Close will abort the screen and return to the previous screen. A click on Reset will create the same screen in the same manner as if it was called from the TMS Input Selection screen of Figure 3-277.
3.3.2 TMS Track Layout File Input

3.3.2.1 Track Layout Grids

Selection of TrkLayout in the TMS Input Selection screen of Figure 3-277 produces the following screen.

Figure 3-286 Track Layout File Input for TMS

A list of track layout files in the database for the rail system selected is shown at the left and middle of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

Selection of the Name of File to be created or modified is at the left and bottom of the screen. This is edited in the usual window manner.

No information can be entered into the grids directly. Construction of the track layout file will involve the use of two sub-sections of this section. The procedures of Subsection 3.3.2.2 will be used to develop the initial layout of the main track segments and the procedures in Subsection 3.3.2.4 will be used to modify the initial layout, until the final layout is achieved. The latter procedure is a graphic process.
On the upper part of the screen there are two indicators: **# of Track Segments** and **# of Nodes**. These indicators, which cannot be modified, keep track of the number of track segments (blocks) and nodes.

The **Track Segment Input** is a record of information for each track segment. It contains the **Sgmnt Name** (track segment name limited to 4 characters), **Begn Node** (the begin point of the track segment limited to 4 characters), **End Node** (the endpoint of the segment limited to 4 characters), **Track #** (the track number of the segment), **Grade %** (the average grade in % over the track segment), **Curve deg** (the average curve in degrees over the track segment) and **Speed Code 1… Speed Code 9** (speed codes: in mph [kph] 1 being the least restrictive to 9 being the most restrictive). Normally, the input for **Speed Code 1** would be the normal operation speed command. (At the present time, only Speed Code 1 is used, and that very restrictively. The speed code feature has been incorporated in the TOM for possible use in future upgrades.)

The **Track #** (the track number of the segment) is a number from 1 thru 49 for main track segments and from 50 thru 99 for non-main or connecting track segments. Main line and branch line tracks are made up of main track segments, while connections between main line and branch line tracks are accomplished using non-main track segments. These connections include switch turnouts, crossovers and transition track segments. It is suggested that Section 9.16 be read before proceeding with this section, in order to understand the philosophy used here for the track layout.

The **Node Input** is a record of information for the beginning or ending (**Begn Node** or **End Node**) of each track segment. It contains the **Node Name** and **Node Pos** (the node position).

Selection of the **Run Loadflow** option indicates that the **ENS** will be run simultaneously with the **TMS**. This will allow electric power flows to be calculated as the trains move on the track layout.

Selection of the **Fuel Consumption** option will set the **TMS** to calculate fuel used by a non-electric rail system.

As a train transits from one main track to another main track via a non-main or connecting track, detection of the train becomes a little fuzzy because of the averaging process in the power profile after it is imported into the **TMS**. As a consequence, the user sets a detection factor, which incorporates this “fuzziness” so that switch and crossover settings will be proper. The **TMS Detection Factor** is expressed as a percentage of the track segment lengths in the vicinity of the transition. It should be set as small as possible by a trial and error method, running the **TMS**. Typically, values between 0-5% should work. The right value will mean that all switches and crossover interlocks will change under ATC as required. If they do not, the value is too low. The default value is 0%, no fuzziness.

The **File Caption** appears as a title script at the end of the file. There are two captions here. Both of the captions are used as part of the titles of the file and are incorporated into the **TMS** runs, which use the file.

An example of a completed or imported file screen is shown next.
Figure 3-287 Track Layout File Input for TMS Input (Completed or Imported File)

The number –1 in the Speed Code columns Speed Code 2 thru Speed Code 9 are automatically inserted. If no entry is made in these columns, the file is saved with –1 in these columns. A –1 indicates a speed command of 0.

The final action to create the file is taken by clicking on the Create button. The file is created and the user is given the option of viewing the file with a Yes or No button. Clicking on Yes will produce a TOM File View of the file. Clicking on No will close the file. Speed codes of –1 are assigned to blank speed code entries.

There are two other buttons at the right of the screen Close and Reset. A click on Close will abort the screen and return to the previous screen. A click on Reset will create the same screen in the same manner as if it was called from the TMS Input Selection screen of Figure 3-277.

There are also aids for construction of and procedures for modifying track layouts. These are described in the next two sections.

3.3.2.2 Aids For Track Layout Construction

There are several aids available to construct the Track Layout Input File. These are listed below and described in the following sections.

Text Transfer
Generate Track Layouts
Add Profile Information
Graphic Input
3.3.2.2.1 Text Transfer

There is a capability to transfer the major portions of the track layout input file from text files, which may be created in EXCEL, WORD, NotePad, etc. directly into the track layout grids as shown in Figure 3-287. Clicking on the Text Transfer button in the figure will result in the next screen.

Each of the two major areas of the Track Layout grids can be input in the model using this feature. These areas are Track Segment Input and Node Input. Selection of the proper option at the right of the screen determines which components will be input.

Selection of the Track Segments option produces the Track Segments text box. The components of the Track Segment are:
- Track Segment Name (delimiter)
- Begin Node Name (delimiter)
- End Node Name (delimiter)
- Track Number (delimiter)
- Grade(%) (delimiter)
- Curvature (degree) (delimiter)
- Speed Code 1 (delimiter)
- Speed Code 2 (delimiter)
- ... Speed Code 8 (delimiter)
- Speed Code 9 (carriage return).

There is one of these records for each track segment. At the end of all records, there must be a carriage return.
Selection of the **Nodes** option produces the **Node** text box. The components of the DC Node are: Node Name (delimiter) Node Position (carriage return). There is one of these records for each node. At the end of all records, there must be a carriage return.

The **delimiter** may be a tab, space or comma. The tab character cannot be used for direct input into the text box. It is reserved for importing from the grids of the **TOM** or for pasting from other text, such as **EXCEL**, **WORD** or **NotePad**.

The **Clear Text** command button clears the text from the text box.

The **Import** command button imports the information from the **Track Layout** grids currently resident in the **TOM** onto the screen. If no track layout input file is currently resident in the **TOM**, there is an indication message. If there is any confusion on what entries to make in the text box, importing a resident train control file generally will make things clearer.

The **Transfer** command button transfers the information from the text box to the grids in the **TOM**. There are error indications if any of these data fail format or content tests.

The process used here is similar to the process used for **TOM to Text Transfer** in the **Network File Input**.

An example of a screen just after clicking the **Import** command button is shown.
Figure 3-289 File Construction Module – Track Layout File Input – Text to TOM Transfer Screen - After Import Command Button is Clicked

The **Reset** button completely resets the screen, starting from scratch. It is best used when problems arise and the user can no longer fix them. The **Close** button closes the program and returns the user to the next higher level. The **Exit** button closes the **TOM** toolbox.

Closing the **Text to TOM Transfer Screen** and selecting the input information resident in the previous screen results in the following screen.
This aid is useful for a user who desires to work with the track segments and nodes in an EXCEL spreadsheet for this purpose or other purposes. The final results can then be transferred to the TOM via this TOM to Text Transfer method.

### 3.3.2.2 Generate Track Layouts

This aid is extremely useful when starting a new track layout. Its purpose is to generate a layout consisting of all main parallel tracks (track numbers 1-49). Clicking the **Generate Track Layouts** command button of the screen in Figure 3-286 results in the following screen.
The track segments generally depend on the Speed Command file, which indicates where the signal blocks should be placed. Section 3.1.8 provides the procedures for creating Speed Command files.

This method will select the track segment positions based on the Speed Command file. Proceed as follows for each track number to be entered into the track layout.

Determine the extent of the track by entering the maximum and minimum node positions in the Enter Min Node Position and Enter Max Node Position text boxes.

Select a grade, curve and speed command file by clicking on the file name in the Grade Files, Curve Files and Spd Cmd Files list boxes, respectively. Selection of a speed command file is required, while selection of grade or curve files is not required. Clicking the View command button or double-clicking on the file name can view any of these files.

Select the track number by clicking on the track number in the Track Numbers combo box list.

A click on a file name in the any of the file list boxes followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text. This action is useful for identifying any of the files.

A typical selection would produce the following screen.
Figure 3-292 File Construction Module – Track Layout File Input – Generate Track Layouts Screen – After Selection

Click the **Generate Layout for Track 1** command button to generate the track segments and nodes for track 1, the track number, which was selected. The result is the following screen.
Track segments can be generated for several tracks. In this case, track layouts are generated for tracks 1, 4, 2 and 5, resulting in the following screen.
Figure 3-294 File Construction Module – Track Layout File Input – Generate Track Layouts Screen – Completion of Track Segment Generation For Track 1, 4, 2 and 5.

Track segments can be generated for any track number in any order. Clicking the Order Track Number command button will show the completed work by ascending track numbers.

Clicking the Perform Analysis command button will subject the track segments generated by the previous procedure to rigorous tests. These test will assure that the Track Layout File, currently residing in the Track Layout Track Segment Input and Node Input grids are in accordance with the rules outlined in Appendix 9.16.

These two actions result in the following screen.
At this point, clicking the Close command button will return to the previous screen, shown next, after a caption has been added and a temporary file name is given to the present track layout.
Figure 3-296 File Construction Module – Track Layout File Input Screen – After Generating Track Layouts for Tracks 1, 2, 4 and 5.

This screen shows a track layout consisting of four parallel main tracks; a first step in construction of a more complicated track layout. The results may be recorded in a temporary Track Layout file (TW-TEMP.tes), by clicking the Create File command button. This action results in the following screen.
Figure 3-297 File Construction Module – Track Layout File Input Screen – After Generating Track Layouts for Tracks 1, 2, 4 and 5 and In Process of Creating the Temporary Track Layout File.

Clicking the Yes command button on the Query produces the next screen.
Figure 3-298 File Construction Module – Track Layout File Input Screen – After Generating Track Layouts for Tracks 1, 2, 4 and 5 and Completion of the Temporary Track Layout File.

Clicking the Yes command button on the Query produces the following screen.
This Track Layout file (TW-TEMP.tes) can now be used as the basis for creating more complicated track layouts, with switches, crossovers and transition tracks. This process is discussed in more detail in Section 3.3.2.2.4, which follows the next section.

The first four menus on the screen are the same as those on the TMS Track and Train Display screen, which is displayed in Figure 2-20. Some of the menu items are grayed because these cannot be accessed on a static track display. No train movement will occur in this screen. The primary purpose of this screen is track layout construction verification.

3.3.2.2.3 Add Profile Information
In the previous section, profile information was added to the track layout during the generation process. This was not necessary, for it could have been done later using the Add Profile Information aid. Clicking the Add Profile Information command button of Figure 3-287 produces the following screen.
This screen is the same as that of Figure 3-291 with the exception of the Add Profile command button. All of the instructions discussed in the previous sections for Generating Track Layouts are pertinent here.

When the screen is completed, click the Add Profile command button. The result is to add profile information to an existing track layout.

### 3.3.2.2.4 Graphic Input

There is a facility for constructing the track layout by drawing the track segments. This facility is described in two parts: Procedures and Rules.

#### 3.3.2.2.4.1 Procedures for Adding and Removing Nodes and Track Segments

Clicking the Graphic Input command button of the screen in Figure 3-286 results in the following screen.
Figure 3-301 File Construction Module – Track Layout File Input – Track Layout By Graphics Screen

Clicking the Open Grid command button will produce one of two screens depending on whether or not the Track Grid of the Track Layout File Input for TMS screen has entries. If the grid has no entries, such as is the case in the screen of Figure 3-286, then the following screen results.
The layout graph space has two dimensions. The horizontal direction is called the position portion of the graph space and the vertical direction is the track number portion of the graph space.

The position of the nodes is referred to mileposts or kilometerposts in the horizontal direction. Track numbers are referenced to the black-dotted lines running horizontally across the layout graph space. The first black-dotted line at the top is track 1, the second is track 2, the third is track 3, etc. There are light color lines running horizontally between the main tracks. These are used for connection type tracks, which are non-main tracks. The dots on each of these lines are referred to as grid points.

Track segments are added to the graph space in an operation which consists of a mouse click on the beginning node position, drawing a line with the free mouse, followed by a mouse click on the ending node position. The next screen shows the graph space after the mouse is clicked on position 1.007 on Track 1 and extended to position 9.034 on Track 1.
Figure 3-303 File Construction Module – Track Layout File Input – Track Layout By Graphics Screen – Layout Graph Space – In Process Of Drawing First Line Segment

Note that the position and track number of the cursor is always displayed at the top of the screen.

A solid (but wiggley) black line extends from position 1.007 on Track 1 to position 9.034 on Track 1. Clicking the mouse on position 9.034 on Track 1 produces the following screen.
Figure 3-304 File Construction Module – Track Layout File Input – Track Layout By Graphics Screen – Layout Graph Space – Completion of Process Of Drawing First Line Segment

The track segment is shown as a green line with the nodes at the end as yellow circles.

The minimum and maximum node positions have been adjusted to correspond to the node positions of the first track segment drawn in the graph space. Thus it is always a good idea to make the first track segment the distance from the beginning of the track system (minimum value milepost or kilometerpost) to the end of the track system (maximum value milepost or kilometerpost).

The begin node and end node positions and track numbers of the last track segment entered are stored in text boxes at the upper left of the screen. Since it is not always possible for the begin node and end node positions to lie exactly on a grid point, these positions can be corrected by editing these text boxes and clicking the Correct Position command button.

In addition to the action just described, the second click of the mouse button also registers the track segment in the Track Grid and Node Grid of the File Construction Module – Track Layout File Input Screen as shown in the next figure.
The desired track segment was from position 1.00 to 9.00 and is now corrected using the correction method in the screen of Figure 3-304. This action results in the following screen.

Figure 3-305 File Construction Module – Track Layout File Input Screen – First Track Segment Registered
Although the minimum and maximum node positions remain the same, the track segment end points have changed as is seen in the next screen.
All node and track segment names are automatically generated. For main track segments, track segment names are Ax for track 1, Bx for track 2, Cx for track 3, etc, while non-main or connecting track segments are 50x for track 50, 51x for track 51, etc. x is a number from 0 to 99 for non-main track segments and from 0 to 999 for main track segments. Node names also have the same designation as line names, Ax, Bx, Cx for main track segments, track 1, track 2, track 3 (these take priority for nodes, i.e. nodes common to both main and non-main track segments are named for main track) and 50x, 51x, for track 50, track 51, etc.

To correct the layout graph space to display what is now registered in the grids, click the Import Full Layout button of Figure 3-306. This action results in the next screen.
Figure 3-308 File Construction Module – Track Layout File Input – Track Layout By Graphics Screen – Layout Graph Space Corrected

The track segment and node names are automatically generated. Nodes can now be entered on the first track segment, simply by inserting them at the proper positions. To insert a node at position 2.7 on Track 1, simply click the mouse at position 2.7 on Track 1 and then click it again. (Note this is not a double mouse click but a click followed by a second click in about a second.) The action just described produces the following screen.
Figure 3-309 File Construction Module – Track Layout File Input – Track Layout By Graphics Screen – Layout Graph Space – Completion of Process Of Inserting a Node

Again the position of the node is not exactly at 2.7 but at 2.706. The correction process (changing both the Begin Node Position and End Node Position in the text boxes followed by a click on the Correct Position command button.) produces the correct track segment. The result is the following screen.
The begin node and end node of the first track segment added to any new (empty) main track must have the same track number. Connecting track segments (i.e. segments between two different main tracks) can only be added after the main tracks already exist. It is good practice to add main track segments first, followed by non-main track segments.

A different version of the four tracks, which were previously generated by the Generate Track Layouts procedure and which are displayed in the screen of Figure 3-299, can be imported into the graph layout space. First, click the Close command button to close the Track Layout graph space. This action results in the following screen.
Figure 3-311 File Construction Module – Track Layout File Input Screen – After Closing the Track Layout by Graphics Screen

Import the file TW-temp.tes by clicking on the file in the TrkLayout Input File list box and then click the Select One command button or by double clicking on the file in the TrkLayout Input File list box. This action produces the following screen.
Clicking the Graphic Input button results in the next screen, after the Open Grid command button is clicked.
The procedure for adding a non-main track segment to the graph space is the same as for adding a main track segment. Clicking the mouse at position .856 on Track 1, drawing the line to position .938 on Track 2 and clicking the mouse again produces the following screen.
Figure 3-314  File Construction Module – Track Layout File Input – Track Layout By Graphics Screen – Layout Graph Space – Four Main Tracks With Associated Nodes – Adding a Non Main Track Segment

The resulting crossover from Track 1 to Track 2 is shown as a red line, as are all non main track segments. There is one non main track node and two main track nodes, one on track 1 and the other on track 2.

There are two separate zoom features, one for the position portion of the graph space and the other for the track number portion of the graph space.

The Position Zoom Feature allows the user to magnify the position portion of the graph space.

With the mouse, first click on the minimum node position in the Position Zoom Feature box. This action will define the left end of the magnification.

Click on the maximum node position in the Position Zoom Feature box. This action will define the right end of the magnification and refresh the screen to the desired magnification.

Notice that the position of the mouse is specified at the top of the screen.

Setting the minimum and maximum node positions at 0.476 and 1.34, respectively, using this procedure, produces the following screen.
Figure 3-315 File Construction Module – Track Layout File Input – Track Layout By Graphics Screen – Layout Graph Space – Four Main Tracks With Associated Nodes and Crossover – Position Zoom Feature Procedure (Magnification)

Notice that the minimum and maximum node positions appear in the Minimum Node Position text box and Maximum Node Position text box in the upper right of the screen.

Changing the positions in the Minimum and Maximum Node Position text boxes and then clicking the Import Partial Layout command button can also accomplish this magnification.

Changing the positions in the Minimum and Maximum Node Position text boxes and then clicking the Import Partial Layout command button is the only way to effect shrinking or condensation (rather than magnification) of the position graph space. This result of this procedure is shown in the next screen.
Figure 3-316 File Construction Module – Track Layout File Input – Track Layout By Graphics Screen – Layout Graph Space – Four Main Tracks With Associated Nodes and Crossover – Position Zoom Feature Procedure (Shrinking or Condensation)

A right click of the mouse on the Position Zoom Feature box will return the screen to its original condition. The result is shown in the next screen.
There is also a **Track Zoom Feature**, which operates in the vertical direction.

Selection of a percentage zoom in the **Track Zoom Feature** list box will magnify the vertical direction or the track number portion of the graph space. The track number portion of the layout space always begins with track number one, independent of the zoom selection.

Selection of the Track Zoom Feature to 200% produces the following screen.
Selection of a track zoom of 100% will return the screen to its normal condition as shown in Figure 3-317. Pointing the mouse cursor to an existing track segment or node and clicking the right mouse button will display a menu of actions.

In the case of a track segment, the actions are: For Track Segment ID /Identify, Remove/Close.

In the case of a node, the actions are For Node ID/Identify, Move, and Remove/Close.

Clicking on Close simply closes the menu with no other action.

Identify for a node lists its name and position. This action is shown in the following screen.
Figure 3-319 File Construction Module – Track Layout File Input – Track Layout By Graphics Screen – Layout Graph Space – Four Main Tracks With Associated Nodes and Crossover – Identify Node

This node is on track 2 of the crossover.

Identify for a track segment lists its name, its end nodes’ names and its end nodes’ positions. This procedure is shown in the next screen.
Figure 3-320 File Construction Module – Track Layout File Input – Track Layout By Graphics Screen – Layout Graph Space – Four Main Tracks With Associated Nodes and Crossover – Identify Track Segment

This track segment is on track 2 and has as its left end node, the crossover node.

The Remove procedure for nodes causes the following action, shown in the next screen.
Figure 3-321 File Construction Module – Track Layout File Input – Track Layout By Graphics Screen – Layout Graph Space – Four Main Tracks With Associated Nodes and Crossover – Remove Node Procedure

Clicking the No command button will leave the screen unchanged. Clicking the Yes command button will remove the node and the track segments as shown in the next screen.
Notice that the adjacent nodes of the track segments were not removed.

The `Remove` procedure for a track segment does not give a warning (unless it is illegal), such as in the `Remove` procedure for nodes. Removal of a track segment is shown in the next screen.
The Move procedure for nodes is accomplished manually rather than graphically. Right clicking of the mouse on the node identified in Figure 3-319 followed by a click on the Move menu item produces the following screen.
Figure 3-324 File Construction Module – Track Layout File Input – Track Layout By Graphics Screen – Layout Graph Space – Four Main Tracks With Associated Nodes and Crossover – Move Node Procedure

Inserting 0.89 into the New Position of Node text box followed by a click on the Move Node command button produces the following screen.
Figure 3-325 File Construction Module – Track Layout File Input – Track Layout By Graphics Screen – Layout Graph Space – Four Main Tracks With Associated Nodes and Crossover – Completion of Move Node Procedure

There are four command buttons on the right of the screen of Figure 3-325. The actions of these command buttons are described.

**Open Grid** - Click on this command button will open the track layout graph space. If a track layout is already present in the Track Layout Grids of the Track Layout Input screen, then this track layout will be imported into the graph space.

**Import Partial Layout** - Clicking on this command button will import the track layout present in the Track Layout Grids of the Track Layout Input screen into the track layout graph space of this screen. The Maximum and Minimum Node Position text boxes will fix the maximum and minimum node positions. This action is to be contrasted to clicking the Import Full Layout command button, whose action fixes the Maximum and Minimum Node Position text boxes to the maximum and minimum node positions in the track layout.

**Import Full Layout** – Clicking on this command button will import the track layout present in the Track Layout Grids of the Track Layout Input screen into the track layout graph space of this screen. The maximum and minimum node positions in the track layout will fix the Maximum and Minimum Node Position text boxes. This action is to be contrasted to clicking the Import Partial Layout command button, whose action causes the Maximum and Minimum Node Position text boxes to fix the maximum and minimum node positions.

**Clean Garbage** - Click on this command button will refresh the track layout graph space and clear the layout of extraneous lines and points presently contained therein.

3.3.2.2.4.2  **Rules for Adding and Removing Nodes and Track Segments**
The following are rules for adding track segments and nodes to the track layout graph space.

The begin node and end node of the first track segment added to any new (empty) main track must have the same track number. Connecting track segments (i.e. segments between two different main tracks) can only be added after the main tracks already exist.

It is good practice to add main track segments first, followed by non-main track segments.

When adding main track segments, it is best to begin with one a track segment which runs from the beginning to end of track for that main track number. This procedure is then followed by insertion of nodes on that track. A node may be inserted by one mouse click, a pause (about 1 second) and a second mouse click, all of which is done without moving the mouse.

If at anytime, the drawing of a legitimate track segment fails to register that track segment (the segment does not appear on the graph), try again. If still not successful, try zooming in the position or track number graph space.

Track segments cannot be added between a main and non-main track. All track segments are added between main tracks. The non-main track node is inserted automatically.

An attempt to add an illegal track segment results in a message which informs the user The following are illegal attempts:

- Addition of a track segment to any of the switches of a double crossover
- Addition of a track segment whose end nodes are adjacent to a switch or crossover.
- Addition of a track segment whose end node is a switch node in any direction except that of changing a switch into a crossover.
- Addition of a track segment to an existing crossover.
- Addition of a track segment, which results in a switch into an end of track node.
- Addition of a track segment to a transition node, through which, it would be impossible for trains to move.

Track segments cannot be added to double turnout switches and transition switches.

A non-main track, which makes a crossover with several main tracks, must be built in only one direction. If built in different directions, it will cause the non-main track segments to have different track numbers. This violates the rule that non-main connecting tracks must have the same track number.

The following are rules for removing track segments and nodes to the track layout graph space.

Removing a node, removes the two adjacent track segments. To remove a node, without removing the adjacent track segments on a main track, remove the node and add back a track segment between the adjacent nodes.

Non-main track segments cannot be removed separately. To remove both non-main track segments between main tracks remove the common node.

Track segments of a double crossover cannot be removed separately. The complete double crossover is removed by removing the common crossover node.

Switch, crossover and transition nodes cannot be removed directly. Generally, the adjacent non-main track node must be removed to effect the removal in a second step.
3.3.2.3 Manual Procedures for Modifying Track Layouts

There are several manual procedures available to modify the track layout. These procedures are carried out using separate screens rather than using the Graphics Input procedures just described. These are listed below and described in the following sections.

Move Node
Insert Node
Remove Node
Insert Track Segment
Remove Track Segment

3.3.2.3.1 Move Node

Nodes can be moved. The only stipulation is that the node be moved only as far as the adjacent nodes to which it is connected. To initiate the movement of a node, click the Move Node command button in the Track Layout File Input screen of Figure 3-287. This action produces the following screen.

![Move Node Procedure Input Screen](image)

Figure 3-326 File Construction Module – Track Layout File Input – Move Node Procedure Input Screen
A list of all of the movable nodes is obtained by clicking on the Select Node to be Moved combo box. This produces the following screen.

Figure 3-327 File Construction Module – Track Layout File Input – Move Node Procedure Input Screen - Click on Select Node to be Moved combo box

The node can be selected by clicking on the desired node, which produces the following screen.
Figure 3-328 File Construction Module – Track Layout File Input – Move Node Procedure Input Screen - After Selection of a Node to be Moved.

The Node Position text box shows the present position of the selected node to be moved. The Adjacent Node Name, Track Number, Adjacent Node Position text box immediately below, shows all relevant information on the nodes directly connected to the selected node. This information includes the node name, track number and position of the track segments connecting the adjacent nodes to the selected node.

Instructions on node movement are given to the right of the Adjacent Node Name, Track Number, Adjacent Node Position text box. The node can only be moved nearly to the position of the closest adjacent node. The new position of the node is entered into the New Position of Node text box. Clicking the Move Node command button will move the node, which means that its position in the Node Input grid of the File Construction Module – Track Layout File Input screen is now the new position. The following screen is produced.
Click the Move Node command button to move the node and complete the procedure.
Figure 3-330  File Construction Module – Track Layout File Input – Move Node Procedure Input Screen - After Node Has Been Moved.

Clicking the Close command button returns to the previous screen, which shows the moved node’s new position.
This completes the move node procedure.

3.3.2.3.2 Insert Node Procedure

Nodes can be inserted into the track layout. When a node is inserted, it will cause the creation of two track segments, in place of the track segment in which the node was inserted. This procedure allows the insertion of nodes in main track segments only. Clicking the Insert Node command button of the screen shown in Figure 3-331, results in the following screen.
To insert a node, select a track number from the Select Track Number combo box. Enter the new node name and its position in the New Node Name and New Node Position text boxes. By clicking the Select New Node Name command button, the name will be selected automatically, to assure there is no duplication.

The node and track segment names, which are presently in the track layout, can be accessed in the combo boxes. These are for reference only. Nothing will happen if any of them are selected.

The next screen shows the selection of track number, node name and node position.
Once the information has been entered and selected, click the **Register Node** command button to produce the next screen.
The node selected has been registered and the track segment [A10] on which it is located named. Select the name of the two new track segments generated by inserting the node. This can be done by entering the track segment name directly into the text boxes below or by clicking the [Select New Track Segment Names] command button below. If the latter method is used, the track segment name will be automatically generated. After the entry of the track segments names is completed, click the [Add New Track Segments] command button to add the new information to the grid. If an error was made in the previous procedure, exit the screen.

Figure 3-334 File Construction Module – Track Layout File Input – Insert Node Procedure Input Screen – Required Information Entered and Selected – Register Node command button Clicked.

The information on the new track segments appear in the New Track Segments list box, listing begin and end node names and positions. The new track segment names may now be entered into the appropriate text boxes or they may be selected automatically by clicking the [Select New Track Segment Names] command button.

The next screen shows the results to this point.
Figure 3-335 File Construction Module – Track Layout File Input – Insert Node Procedure Input Screen – All Required Information Entered and Selected.

Click the Add New Track Segments command button to complete the work. The following screen results.
3.3.2.3.3 Remove Node Procedure

Nodes can be removed from the track layout. Certain nodes cannot be removed. Nodes comprising switches, crossovers and transition from one main track to another cannot be removed directly; however the switches, crossovers and transitions can be removed indirectly, generally by removing adjacent nodes. Examples will be provided.

Clicking the Remove Node command button of Figure 3-286 results in the following screen.
Select the name of the node to be removed from the **Select Node to Be Removed** combo box, which results in the following screen.

Click the **Remove Node** command button to remove the node. This results in the following screen.
Clicking the Yes command button in the Inquiry message box will remove the node and the two track segments indicated. The track segment connecting the nodes adjacent to the removed node is not there. If it is desired to put in this track segment, it must be done with the Insert Track Segment procedure, which is discussed in the next Section.

Closing the Remove Node screen results in the previous screen with the node and track segments removed.

### 3.3.2.3.4 Insert Track Segment

Track segments may be inserted into the track layout. They can only be inserted between main tracks. Clicking the Insert Track Segment command button produces the next screen.

![Insert Track Segment Procedure](image)

- If the begin and/or end nodes already exist for the track segment to be added, they should be chosen from the Node Names in Layout combo box. They may also be entered in the begin or end Node Name text box. For a new begin and/or end node, not in the track layout, insert the name and position of the begin and/or end node in the text boxes to the left. (Note that the name of a new node can be generated automatically by clicking the Select Begin or End Node Name command buttons in the left.) Select the track number of the new begin or end node from the Begin or End Node Track Number combo box to the left. A list of current track segment names in the track layout is provided for convenience of lookup. When these actions are completed, click the Register Track Segment command button.

![Figure 3-340 File Construction Module – Track Layout File Input – Insert Track Segment Procedure Input Screen](image)
There are four ways to add the track segment to the track layout.

**Two Existing Nodes on Different Main Tracks** - From an existing node on a main track to an existing node on another main track

**One Existing Node and One Inserted Node on Different Main Tracks** - From an inserted node on a main track to an existing node on another main track

**Two Inserted Nodes on Different Main Tracks** - From an inserted node on a main track to an inserted node on another main track

**Two Existing Nodes on Same Main Track** - Between two existing nodes on the same main track

### 3.3.2.3.4.1 Two Existing Nodes on Different Main Tracks

To add the track segment from two existing nodes on different tracks, select the two nodes from the Node Names in Layout combo box, the first and then the second. This action results in the next screen.

![Image of the track layout and nodes]

If the beginning and/or end nodes already exist for the track segment to be added, they should be chosen from the Node Names in Layout combo box. They may also be entered in the Begin or End Node Name textboxes. For a new beginning and/or end node, not in the track layout, insert the name and position of the beginning and/or end node in the text boxes to the left. (Note that the name of a new node can be generated automatically by clicking the Select Begin or End Node button.)

Click the **Register Track Segment** command button to view the next screen.

Figure 3-341 File Construction Module – Track Layout File Input – Insert Track Segment Procedure

Input Screen – Selection of Two Existing Nodes for the Track Segment Ends
The connection between two different main tracks consists of two line segments with an intermediate node. Since a non-main track must connect the two different main tracks, a non-main track number is selected from the Non-Main Track Number combo box. At this point, entries for the Non-Main Track Node Position, the Non-Main Track Segment Name 1 and the Non-Main Track Segment Name 2 are added. These entries may be made manually in each of the appropriate text boxes, or by clicking the Automatically Make All Selections command button to produce the entries.

After the selections and entries are made, the following screen results.
The last step has been completed. Because of the selection of two existing main track nodes, a total of two non-main track segments must be added. Select the non-main track number from the Non-Main Track Number combo box and enter the non-main node name and position in the appropriate text boxes. Also enter the names for the two non-main track segments in the appropriate text boxes. All can be done automatically by clicking the Automatically Make All Selections command button. In this case the non-main track number must be selected in the combo box. After completion, click the Register All Track Segments command button.

Figure 3-343 File Construction Module – Track Layout File Input – Insert Track Segment Procedure
Input Screen – Selection of Two Existing Nodes for the Track Segment Ends – Completion of Entries and Selections

To complete the procedure, click the Register All Track Segments command button, to produce the following screen.
Clicking the Add All Track Segments to Grids command button will add the track segments and nodes to the appropriate grids.

Default values of no grade (0), no curve (0) and speed command (Speed Code 1) of 5 (mph or kph) are added to the grids for non-main track segments. New main track segments have the same grade, curve and speed command as the original track segment from which they were created by splitting it.

Profile information for the two new non-main track segments can be modified to reflect the actual track profile, rather than the default values shown in the screen. After modification is complete, click the Accept Entries command button to enter the information and return to the previous screen.
At this point, another track segment can be added by clicking the Insert Next Track Segment command button, or return to the previous screen by clicking the Close command button. Closing the screen returns the focus to the previous screen.

3.3.2.3.4.2 One Existing Node and One Inserted Node with Two Different Main Tracks

To add the track segment from one existing node and one new node on different tracks, select the existing node from the Node Names in Layout combo box. The new node can be inserted by selecting the track number, entering the node name and node position. The selection of the node name can also be done automatically by clicking Select Begin Node Name or Select End Node Name. This action results in the next screen.
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**Figure 3-346 File Construction Module – Track Layout File Input – Insert Track Segment Procedure Input Screen – One Existing Node and One New Node on Different Main Tracks**

Click the Register Track Segment command button to view the next screen.
The connection between two different main tracks consists of two line segments with an intermediate node. Since a non-main track must connect the two different main tracks, a non-main track number is selected from the Non-Main Track Number combo box. At this point, entries for the Non-Main Track Node Name and the Non-Main Track Position are added. These entries may be made manually in each of the appropriate text boxes, or by clicking the Automatically Make All Selections command button to produce the entries.

Because one of the nodes was inserted, two additional main track segments are generated as a result. Entries for the Main Track Segment 1 Name and the Main Track Segment 2 Name are added. These entries may be made manually in each of the appropriate text boxes, or by clicking the Automatically Make All Selections command button to produce the entries.

After a non-main track number is selected, clicking the Automatically Make All Selections command button will produce all of the entries.

After the selections and entries are made, the following screen results.
The first step has been completed. Because of the insertion of one new main track node and the selection on existing main track node, a total of four track segments must be added: two main track and two non-main track. A list of two (Main Track) of the four track segments with their associated nodes appear in the (Non Main Track Segments) box. Enter track names for these segments in the appropriate text boxes. Select the non-main track number and the non-main node name and position. Select the non-main track number from the (Non Main Track Number) combo box and enter the non-main node name and position in the appropriate text boxes. Also enter the names for the two non-main track segments in the appropriate text boxes. All can be done automatically by clicking the (Automatically Make All Selections) command button. In this case the non-main track number must be selected in the combo box. After completion, click the (Register All Track Segments) command button.

Figure 3-348 File Construction Module – Track Layout File Input – Insert Track Segment Procedure Input Screen – One Existing Node and One New Node on Different Main Tracks – Completion of Entries and Selections

To complete the procedure, click the Register All Track Segments command button, to produce the following screen.
Clicking the Add All Track Segments to Grids command button will add the track segments and nodes to the appropriate grids.

Default values of no grade(0), no curve(0) and speed command (Speed Code 1) of 5 (mph or kph) are added to the grids for non-main track segments. New main track segments have the same grade, curve and speed command as the original track segment from which they were created by splitting it.

Profile information for the two new non-main track segments can be modified to reflect the actual track profile, rather than the default values shown in the screen. After modification is complete, click the Accept Entries command button to enter the information and return to the previous screen.

### 3.3.2.3.4.3 Two Inserted Nodes with Two Different Main Tracks
To add the track segments from two inserted nodes on different tracks, new nodes can be inserted by selecting the track numbers and entering the node names and node positions. This action results in the next screen.

Click the **Register Track Segment** command button to view the next screen.
The connection between two different main tracks consists of two line segments with an intermediate node. Since a non-main track must connect the two different main tracks, a non-main track number is selected from the Non-Main Track Node combo box. At this point, entries for the Non-Main Track Node Name, the Non-Main Track Node Position, the Non-Main Track Segment 1 Name and the Non-Main Track Segment 2 Name are added. These entries may be made manually in each of the appropriate text boxes, or by clicking the Automatically Make All Selections command button to produce the entries.

Because two of the nodes were inserted four additional main track segments are generated as a result. Entries for the Main Track Segment 1 Name and the Main Track Segment 2 Name for both nodes. These entries may be made manually in each of the appropriate text boxes, or by clicking the Automatically Make All Selections command button to produce the entries.

After a non-main track number is selected, clicking the Automatically Make All Selections command button will produce all of the entries.

After the selections and entries are made, the following screen results.
Figure 3-352 File Construction Module – Track Layout File Input – Insert Track Segment Procedure

Input Screen – Two New Nodes on Different Main Tracks – Completion of Entries and Selections

To complete the procedure, click the Register All Track Segments command button, to produce the following screen.
Clicking the Add All Track Segments to Grids command button will add the track segments and nodes to the appropriate grids.

Default values of no grade(0), no curve(0) and speed command (Speed Code 1) of 5 (mph or kph) are added to the grids for non-main track segments. New main track segments have the same grade, curve and speed command as the original track segment from which they were created by splitting it.

Profile information for the two new non-main track segments can be modified to reflect the actual track profile, rather than the default values shown in the screen. After modification is complete, click the Accept Entries command button to enter the information and return to the previous screen.

3.3.2.3.4.4 Two Existing Nodes on Same Main Track
To add the track segments between existing nodes on the same main track, select the nodes from the **Node Names in Layout** combo box. This action results in the next screen.

If the begin and/or end nodes already exist for the track segment to be added, they should be chosen from the **Node Names in Layout** combo box. They may also be entered in the **Begin (or End) Node Name** text box. For a new begin and/or end node, not in the track layout, insert the name and position at the begin and/or end node in the text boxes to the left. (Note that the name of a new node can be generated automatically by clicking the **Select Begin Node Name** command button.)

Select the track number of the new begin or end node from the **Begin (or End) Node Track Number** combo box to the left. A list of current track segment names in the track layout is provided for convenience of selection. When these actions are completed, click the **Register Track Segment** command button.

Click the **Register Track Segment** command button to view the next screen.
The connection between two nodes on the same track can be made only if the nodes are end nodes, which result because of gaps in the track continuity. This is illustrated in the following figure.
Discontinuities occur in tracks 1 and 3 in the above illustration. Track segments can be added, which connect the end nodes of these discontinuities.

Enter the track name in the **Track Name** text box or click the **Select Track Name** command button to automatically choose a unique track name.

After the selection or entry is made, the following screen results.
The two nodes selected are both end of track nodes in adjacent disconnected track segments. This action will connect them. Enter the track name, or alternatively, click the Evented Track Name command button to automatically select the track name. When completed, click the Add Track Name to Grid command button to add the track segment to the Track Segment grid.

Figure 3-357 File Construction Module – Track Layout File Input – Insert Track Segment Procedure Input Screen – Two Existing Nodes on Same Main Track – Completion of Entries and Selections

Clicking the Add Track Name to Grid command button will add the track segment to the Track Segment Input grid. In this case, however there is a preliminary step as shown in the next screen.
Figure 3-358 File Construction Module – Track Layout File Input – Insert Track Segment Procedure Input Screen – Two Existing Nodes on Same Main Track – Completion of Entries and Selections – After Add Entry to Grid Button Is Clicked

Clicking the No button will add the entry to grid. Clicking the Yes button will produce the following screen.
Figure 3-359 File Construction Module – Track Layout File Input – Insert Track Segment Procedure Input Screen – Two Existing Nodes on Same Main Track – Completion of Entries and Selections – After Add Entry to Grid Button Is Clicked – Add Profile Information Screen

Profile information is added as per the next screen.
Figure 3-360 File Construction Module – Track Layout File Input – Insert Track Segment Procedure Input Screen – Two Existing Nodes on Same Main Track – Completion of Entries and Selections – After Add Entry to Grid Button Is Clicked – Add Profile Information Screen – Profile Information Added

Clicking the Accept Entries command button results in the screen of Figure 3-357. This screen can now be closed if no more additions are required or reset if additional work is to be done.

3.3.2.3.5 Remove Track Segment Procedure

The Remove Track Segment Procedure input screen is exposed by clicking the Remove Track Segment command button on the screen in Figure 3-287. It is shown in the next screen.
Figure 3-361 File Construction Module – Track Layout File Input – Remove Track Segment Screen
Select the name of the track segment to be removed from the Select Track Segment to Be Removed combo box, which results in the following screen.

Figure 3-362 File Construction Module – Track Layout File Input – Remove Track Segment Screen – Track Segment To Be Removed Selected.

Click the Remove Track Segment command button to remove the track segment and close the screen.

3.3.2.4 Creating And Viewing The Track Layout File
After all of the Aids and Procedures have been applied to construct the track layout file. The file selected is TW-A.tes, which was used extensively in the description of TMS operation in Section 2.3. This file is shown completed in the next screen.
The Layout Analysis check box (checked) will assure that any errors in the creation of the file will be highlighted, a summary will be provided and the user will be able to view the track layout immediately.

Clicking the Create File command button will create the train control file and result in the following screen.
Clicking the **Yes** command button in the **Query** box will produce the following screen.
Figure 3-365 File Construction Module – Track Layout File Input Screen – Query to view the track layout.

Clicking the Yes command button in the Query box produces the following screen.
Section 9.16 describes in detail, the features of the track layout.

Features important to the user are described in Section 2.3 TMS. These are the same when running the TMS or the Track Layout Viewer. In the Track Layout Viewer, only the features appropriate to the static track network can be accessed.

### 3.3.3 Station Description File

Selection of Sta Dscrp in the TMS Input Selection screen of Figure 3-277 produces the following screen.
A list of station description files in the database for the rail system selected is shown at the left of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

Selection of the Name of File to be created or modified is at the left and bottom of the screen. This is edited in the usual window manner.

The station description file can have input units, which are either English or metric, and output units, which are either English or metric. This is selected by checking the appropriate box at the left of the screen. A description for the kind of units expected is given in Appendix 9.3.

The input for the station description records is accomplished in free format in the box designated by Station Name, Position, Platform Length, and Track Number. For each passenger station or freight train track entry area, enter the station name (limit 12 characters) followed by a comma delimiter, followed by the position (English units feet or miles or metric units meters or kilometers depending on input units.
selection at left) of the station followed by a comma delimiter, followed by a platform length (English units feet or miles or metric units meters or kilometers) depending on input units selection at left followed by a comma delimiter, followed by a track number, followed by a carriage return. The position and platform length of the passenger station must be specified in the same units, i.e. if position is in miles so must the platform length be in miles. Use normal editing procedures to enter or change any values. The position is the center point of the platform.

The File Caption, which appears as a title script within the file, is not carried through any runs and is used just to describe the file.

An example of a completed or imported file screen is shown next.

![Figure 3-368 Main Screen for the Station Description File for TMS Input – Completed or Imported](image-url)
Note that in the TMS, the passenger station is located above the track. Thus for a center platform station between tracks 3 & 4, the station track number would be 4.

Clicking the Invert button reverses the increasing position direction. The invert process consists of multiplying all of the right of way positions by the value (-1) and reordering these positions in ascending value. The rights of way elements are also reordered so that the value between adjacent inverted values of position remains the same. **Note: This option is rarely used. It would only be used when it was desired to change the direction of increasing position mileposts or kilometerposts. In this case, all right of way and station files would also be “inverted.”**

The Shift button is activated when a value is entered into the Shift Distance box. Subsequent clicking of the Shift button is the equivalent of increasing or decreasing all of the positions in a right of way file by a constant amount which is the value in the box. The effect is to shift the zero position of the right of way.

**Note: This option is rarely used. It would only be used when it was desired to change the reference position of mileposts or kilometerposts. In this case, all right of way and station files would also be “shifted.”**

The final action to create the file is taken by clicking on the Create button. The file is created and the user is given the option of viewing the file with a Yes or No button. Clicking on Yes will produce a TOM File View of the file. Clicking on No will close the file.

There are two other buttons at the right of the screen Close and Reset. A click on Close will abort the screen and return to the TMS Input Selection screen of Figure 3-277. A click on Reset will create the same screen in the same manner as if it was called from the TMS Input Selection screen.

### 3.3.4 Stop Distance File

Selection of StopDist in the TMS Input Selection screen of Figure 3-277 produces the following screen.
The stop distance file is not an input file to the TMS, but can be used by the user in setting up blocks for Track Layout file input. 

A list of stop distance files in the database for the rail system selected is shown at the left and middle of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

A click on a file name in the any of the file list boxes followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text. This action is useful for identifying any of the files.

Selection of the Name of File to be created is at the left and bottom of the screen.
In the middle of the screen is the list of files, which contain the filenames of input files to the TPS. These files are used as the basis for the stop distance calculations and are contained in the RSDB that was selected. To select a file, click on a filename in the list and click on the Select One button or alternatively double click on the filename. To view a file of filenames, click on the filename and then click on the View One button.

Two selection options are available: Single Point or Table

If the option selected is Single Point, the screen presentation is in the above Figure 3-369. This option is discussed first.

In this case, a Stop Distance File or a TPS File of Filenames can be selected. The Stop Distance File is just a table of stop distances as a function of initial speed and position of the train. In the Single Point frame, enter the initial speed and position as well as the reaction time of the operator or train control equipment. A completed frame is shown next.

![Figure 3-369 Completed Screen for Calculation of Stopping Distance and Position in Single Point Option](image)

Click the Calculate command button to finish the procedure, results shown next.
Figure 3-371 Results of Calculation of Stopping Distance and Position in Single Point Option

Since an existing Stop Distance File was selected in this case, the process uses this table in this file to perform the calculation. Had a TPS File of Filenames been used as the starting point, a Stop Distance File would be created and used to perform the calculation.

The stop distance and positions units are miles for English units and kilometers for Metric units. The units of deceleration are miles per hour per second for English Units and meters per second squared for Metric units.

If the Table option is selected, the initial screen is shown next.

Figure 3-372 Calculation of Stopping Distance File in Table Option
In this case, the stop distance calculator creates a table of stop distances at each position along the right of
way incremented by the distance step and for every speed from zero to maximum, incremented by the
speed step.

In this calculation, speed restrictions are not obeyed, but full train capability and grades are taken into
account.

An example of a completed screen is shown next.

![Completed Screen for Table Option](image)

Figure 3-373 Completed Screen for Table Option

The final action to create the file is taken by clicking on the Create button. The file is created and the user
is given the option of viewing the file with a Yes or No button. Clicking on Yes will produce a TOM File
View of the file. Clicking on No will close the file. A click on the Create button followed by a click on the
Yes button produces a TOM File View.
The first record of the stop distance file contains the maximum speed, the speed step, the beginning position, the position increment and the end position. The beginning and ending positions are obtained from the station file of the TPS file of filenames used to create the stop distance file.

The second record contains the speeds incremented by the speed step.

The remaining records contain the position as the first entry followed by the stop distances at each of the speeds indicated in the second record. The table wraps to the next line.

**Figure 3-374 View of Stop Distance File**

The first record of the stop distance file contains the maximum speed, the speed step, the beginning position, the position increment and the end position. The beginning and ending positions are obtained from the station file of the TPS file of filenames used to create the stop distance file.

The second record contains the speeds incremented by the speed step.

The remaining records contain the position as the first entry followed by the stop distances at each of the speeds indicated in the second record. The table wraps to the next line.
3.4 INPUT FOR THE RVM

In TOM Version 3.5 and higher, there are two methods for computing rail voltage. The first method, referred to as the Old Method, uses a simplified model, in which rail voltage is calculated using a single train on the system. The second method, referred to as the New Method, uses the rail system as it runs. The latter method is more realistic for predicting actual rail voltage. However, the new method can only be applied to rail systems which run trains under a DC power distribution system. It is not yet available for AC power distribution.

A click on the RVM Input box of the FCM Main Screen of Figure 3-2 allows the user to select the construction of one of the following input files for the RVM as shown in the screen below.

The following files may be selected:

- Fnames - RVM File of Filenames Input (New and Old Method)
3.4.1 RVM File of Filenames Input

3.4.1.1 Old Method

Selection of Fnames in the RVM Input Selection screen of Figure 3-375 produces the following screen.

![Figure 3-376 File of Filenames File for RVM Input](image)

This screen is used to create the File of Filenames file for RVM input. Three command buttons are visible in the center of the screen: View One, Select One and Delete One. A list of files of filenames already contained in the database of the rail system selected is above these buttons. A single click on one of the filenames in the selection list highlights that file. The file may then be viewed, selected or deleted.
A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.
Notice there are three input files:
- Neg Network Input File (See Section 3.4.2)
- Rail Voltage Table (See Section 3.4.3)
- Cur Meas Output File – This is an output file from the ENS or TMS.

The procedure used to create or modify existing file of filenames for the RVM is the same as described in the TPS File of Filenames Input of Section 3.1.1.

An example of a completed or imported file screen is shown next.

The final action to create the file is taken by clicking on the Create button. The file is created and the user is given the option of viewing the file with a Yes or No button. Clicking on Yes will produce a TOM File View of the file. Clicking on No will close the file.

The New Rail Voltage Model checkbox toggles the screen between the Old Method and New Method for computing rail voltage. The New Method is discussed in the next section.
The Rail Voltage Model command button will run the RVM with the file RVM File of Filenames currently residing in the screen.

There are other buttons at the right of the screen Close and Reset. A click on Close will abort the screen and return to the screen. A click on Reset will create the same screen in the same manner as if it was called from the RVM Input Selection screen Figure 3-375.
3.4.1.2 New Method
Clicking the New Rail Voltage Model checkbox in the File of Filenames Input screen of Figure 3-376 produces the following screen.

![Diagram of File Construction Module - File of Filenames Input](image)

This screen is used to create the File of Filenames file for RVM input using the New Method. Three command buttons are visible in the center of the screen: View One, Select One and Delete One. A list of files of filenames already contained in the database of the rail system selected is above these buttons. A single click on one of the filenames in the selection list highlights that file. The file may then be viewed, selected or deleted.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.
Notice there are three input files:
- Return Circuit Rail Voltage Input File (See Section 3.4.4)
- Rail Voltage Table (See Section 3.4.3)
- Cur Analysis Output File – This is an output file from the Current Analysis program of the FMM.

The procedure used to create or modify existing file of filenames for the RVM is the same as described in the TPS File of Filenames Input of Section 3.1.1.

An example of a completed or imported file screen is shown next.

Figure 3-379 File of Filenames File for RVM Input (New Method) (Completed or Imported File)

The final action to create the file is taken by clicking on the Create button. The file is created and the user is given the option of viewing the file with a Yes or No button. Clicking on Yes will produce a TOM File View of the file. Clicking on No will close the file.
The Rail Voltage Model command button will run the RVM with the file RVM File of Filenames currently residing in the screen.

The New Rail Voltage Model checkbox toggles the screen between the Old Method and New Method for computing rail voltage.

There are other buttons at the right of the screen Close and Reset. A click on Close will abort the screen and return to the screen. A click on Reset will create the same screen in the same manner as if it was called from the RVM Input Selection screen Figure 3-375.

3.4.2  RVM Negative Network Input

Selection of Neg Network in the RVM Input Selection screen of Figure 3-375 produces the following screen.
A list of negative network files in the database for the rail system selected is shown at the left of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

Selection of the Name of File to be created or modified is at the left and bottom of the screen. This is edited in the usual windows manner.

A list of network files in the database for the rail system selected is shown in the middle of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well. The network file can be used as a starting point for creating the negative network file. Clicking Select One will load the network file into the text representation of the nodal diagram. Only the DC components will be selected.

Clicking the Show Nodal Diagram button will cause the following screen to appear.
On the left of the screen there are two indicators: # of DC Lines and # of DC Nodes. These indicators, which cannot be modified by the user, keep track of the number of lines and nodes, which are entered. The grids labeled Line Input and Node Input are the entries for the line and node information. The Line Input must be completed before the node input is started. Enter the data for the lines where indicated.

The Line Name, the Begin Node (begin node) and the End Node of the line are each limited to four characters.

The track number is limited to an integer between 1 and 99. If parallel tracks are cross bonded so that the return current from a train on one track is evenly shared among all of the tracks, indicate the cross bonded track numbers with a semicolon (;) between them. For example if parallel track numbers 3, 4, & 5 are cross bonded, then the track numbers in the entry should be 3;4;5. This will assure that a train traveling on any of the tracks will have return current shared equally by all of the tracks. Of course, the return track resistance then would be modified over that of a single track, because of the parallel condition of the return circuit.

The rail resistance of the return circuit is specified here in ohms per mile or ohms per kilometer, depending on whether distances are specified in English or metric units. The rail resistance is actually entered as the track resistance; namely two rails in parallel. Of course if the tracks are cross bonded, then the rail resistance would be entered as the parallel combination of the number of cross bonded tracks. Note that this entry is different from the entry used in the network used for the ENS or TMS, where resistance is specified in the unit ohm. In this case, the rail resistance is entered in ohms per unit length.
The leakage resistance is the resistance between the track and ground and is specified in ohms. If there are cross-bonded tracks, the leakage resistance is the parallel combinations of the individual tracks. **Note that this entry is different from the entry used in the network used for the ENS or TMS, where resistance is specified in the unit ohm. In this case, the leakage resistance is entered in ohms.**

The ground resistance of the return circuit is specified here in ohms per mile or ohms per kilometer, depending on whether distances are specified in English or metric units. Of course is the tracks are cross bonded, then the ground resistance is different than the ground resistance on non-cross bonded tracks. **Note that this entry is different from the entry used in the network used for the ENS or TMS, where resistance is specified in the unit ohm. In this case, the rail resistance is entered in ohms per unit length.**

Entry of the node data in the Node Input grid can begin only after the line data have been entered. After the Line Input grid has been closed (by a carriage return on a blank record) click on the first row and first column or the Node Input grid. This action will setup all of the nodes mentioned in the Line Input grid. Complete the entries by adding the ROW Pos [right of way positions]. A click on one of the grid elements in the Node Type column of the Node Input grid followed by a click on the Select Node Type options will select the type of node. Only Converter and Load nodes are acceptable here as entries.

The name and position of all of the nodes in the negative network must be the same as in the corresponding network. **Note that tie stations, which are represented as nodes in the network, are not tied on the return circuit side. So that, except when ties are used at the end of the electrified sections or as stub feeds, they would be eliminated from the positive network.**

In the frames at the right of the screen, are three entries: Rail Resistance per Unit Length, Rail to Ground Leakage Resistance and Ground Resistance per Unit Length. These entries provide the user with the means of entering each one of these quantities in each of the appropriate columns of the Line Input grid with one operation. Simply enter the quantity in the text box, and click on the adjacent Insert in Line Input Grid button. This action will insert the value in the text box in every row in the appropriate column.

The Delete Row button is used to delete one line in the Line Input grid. Click on the row to be deleted in the Line Input grid and then click on the Delete Row button.

After working with the Line Input grid, close the grid by clicking on the last row and last column followed by a double carriage return. After this action, click on the first row and first column of the Node Input grid. These actions will assure that the nodes are updated to any new information provide by line input.

An example of a completed or imported file screen is shown next.
The Select button at the upper right of the screen is clicked when the selection of the output choices is completed. This incorporates those choices in the resulting negative network file.

The Reset button completely resets the screen, starting from scratch. It is best used when problems arise and the user can no longer fix them. The Close button closes the program and returns the user to the next higher level. In this case, the screen “remembers” its settings.

The final action to create the file is taken by clicking on the Create button. The file is created and the user is given the option of viewing the file with a Yes or No button. Clicking on Yes will produce a TOM File View of the file. Clicking on No will close the file.

There is a capability to transfer the major portions of the negative network file from text files, which may be created in EXCEL, WORD, NotePad, etc. directly into the nodal diagram input grids as shown in Figure 3-382. Clicking on the Text Transfer button in the figure will result in the next screen.
Each of the two major areas of the nodal diagram can be input in the model using this feature. These areas are DC Lines and DC Nodes. Selection of the proper option at the right of the screen determines which components will be input.

Selection of the **DC Line Option** produces the **DC Lines** text box. The components of the **DC Lines** are:
- Line Name (delimiter)
- Begin Node Name (delimiter)
- End Node Name (delimiter)
- Track or Line Number (delimiter)
- Rail Resistance per Unit Length (delimiter)
- Rail to Ground Leakage Resistance (delimiter)
- Ground Resistance per Unit Length (carriage return).

There is one of these records for each line. At the end of all records, there must be a carriage return. Resistances are in ohms (not unit ohms). Resistances per unit
Selection of the **DC Node Option** produces the DC Nodes text box. The components of the DC Nodes are: Node Name (delimiter) (delimiter) Right of Way Position (carriage return). There is one of these records for each node. At the end of all records, there must be a carriage return. Only two types of nodes are permitted, the converter node and the load node. Load nodes are reserved for the beginning and end of the network.

The **delimiter** may be a tab, space or comma. The tab character cannot be used for direct input into the text box. It is reserved for importing from the grids of the **TOM** or for pasting from other text, such as **EXCEL**, **WORD** or **NotePad**.

The **Clear Text Command** button clears the text from the text box.

The **Import Command** button imports the information from the **Negative Network File** currently resident in the **TOM** onto the screen. If no network file is currently resident in the **TOM**, there is an indication message. If there is any confusion on what entries to make in the text box, importing a resident network file generally will make things clearer.

The **Transfer Command** button transfers the information from the screen to the grids in the **TOM**. There are error indications if any of these data fail format or content tests.

An example of a screen just after clicking the **Import Command** button is shown.
Figure 3-384 Negative Network File Text to TOM Transfer Screen After Import Command Button is Clicked

The Reset button completely resets the screen, starting from scratch. It is best used when problems arise and the user can no longer fix them. The Close button closes the program and returns the user to the next higher level. The Exit button closes the TOM toolbox.

Closing the Text to TOM Transfer screen and selecting the input information resident in the previous screen of Figure 3-382 results in the following screen.
The Maximum Internodal Distance is determined for any negative network file imported into the TOM. This value is important in constructing the Rail Voltage Table (RV Table), for it is the maximum distance for which it is necessary to calculate table values.

The final action to create the file is taken by clicking on the Create button. The file is created and the user is given the option of viewing the file with a Yes or No button. Clicking on Yes will produce a TOM File View of the file. Clicking on No will close the file.

The TOM File View of a negative network file is shown in the next screen.
3.4.3 RVM Rail Voltage Table Input

Clicking the RV Table selection of Figure 3-375 and clicking on the Select button produces the following screen.

![Figure 3-386 Negative Network File Shown in the TOM File Viewer](image)
A list of Rail Voltage Table files in the database for the rail system selected is shown at the left of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

Selection of the Name of File to be created or modified is at the left and bottom of the screen. This is edited in the usual windows manner.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.
The **Rail Voltage Table** is a 3-dimensional table of rail voltage factors, $X_{max}$, which are used to calculate the maximum rail to ground voltage for every train. The formula for the maximum rail to ground voltage occurs at the position of the train, and is related to the factor by the formula:

$$V_{max} = X_{max} \times R_D \times I,$$

Where, $R_D$, is the resistance per unit length (mi, km) of the running rails in parallel. The quantity, $I$, is the maximum value of the current drawn by the train either from the increasing milepost (kilometerpost) direction or the decreasing milepost (kilometerpost) direction. The sum of the currents drawn by the train from the increasing milepost (kilometerpost) direction and the decreasing milepost (kilometerpost) direction is the train current. Refer to Appendix 9.14 for the details on the estimates of $X_{max}$, which depends on the following three (thus, three dimensional table) parameters:

- The ratio, **Rail to Ground Leakage Resistance** at each tie/Rail Resistance per unit length
- The ratio, **Ground Resistance /Rail Resistance**
- The distance from the train to the substation

The mesh size is the number of inter-tie distances, which is the basic unit of series/parallel resistances. The mesh size multiplied by the inter-tie distance is the distance between lattice points in the **RV** model.

The **Rail Voltage Table** is used in order to interpolate and extrapolate values of $X_{max}$ other than those values listed in the table. The entries necessary to construct the **RV Table** are:

- The range (minimum, maximum) of the ratio, rail to ground leakage resistance at each tie/rail resistance per unit length. Also, enter the number of points including the minimum and maximum for which the values will be calculated.
- The range (minimum, maximum) of the ratio, ground resistance /rail. Also, enter the number of points including the minimum and maximum for which the values will be calculated.
- The maximum distance and step size for which the values of the table will be calculated. The values will be calculated for each distance from the step size to the maximum distance with intervals of the step size.
- The inter-tie distance. This is the distance between track ties expressed in inches or centimeters, depending on the choice of English or metric units.
- Mesh size as an integer, which represents the number of inter-tie spacings to select as the lattice distance. A small value will produce a more accurate solution, however, it will take more computer time.

The model used to compute the **RV Table** is outlined in Appendix 9.13.

Select **English** or **Metric** units as appropriate.

The **New Method**, which uses the **Return Circuit**, rather than the **Negative Network** as in the **Old Method**, is more efficient. It uses the actual **Return Circuit Rail Voltage** file, to be discussed in Section 3.4.4 as the basis for its construction. The **Choose Return Circuit RV File** combo box is used to choose the file which will be used with the **Rail Voltage Table** in the rail voltage calculation. It will set up the extremes of the parameters for the **Rail Voltage Table** tailored for use in the calculation, so that all parameters lie between the extremes (maximum and minimum).
Sometimes these calculations can be very time consuming. Checking the Activate Monitor check box on the RV Table screen causes the following Notepad screen to appear. This feature is useful when creating an RV Table with a large number of points and/or where large maximum distances and small mesh sizes are involved. It allows one to check the progress.

![Notepad screenshot](image)

**Figure 3-388 Instructions for Accessing the RV Table Creation Monitor File**

### 3.4.3.1 Old Method

In the Old Method, the parameters all parameters are selected to cover the resistances (Rail, Ground, Rail to Ground Leakage) and the ratio extremes are computed by hand and input to the text boxes.

The final action to create the file is taken by clicking on the Create button. The file is created and the user is given the option of viewing the file with a Yes or No button. Clicking on Yes will produce a TOM File View of the file. Clicking on No will close the file. An example is shown in the next screen.
The E-Variable is the Ratio of the Average Value of Ground Resistance to the Rail Resistance. The F-Variable is the Ratio of the Average Leakage Resistance to the Rail Resistance per Unit Length. These are clearly defined in terms of the model in Appendix 9.14.1.

3.4.3.2 New Method

Choosing a Return Circuit Rail Voltage file using the Choose Return Circuit RV File combo box of Figure 3-387, results in the next screen.
Figure 3-390 Rail Voltage Table Screen – Parameters Set by Return Circuit Rail Voltage File.

Since this Return Circuit Rail Voltage file will be used as input into the Rail Voltage calculation, the parameter ranges cover only those to be realized during the calculation process.
3.4.4 Return Circuit Rail Voltage File

In Figure 3-375, a click on the Rtn Cct RV item in the RVM Input list box followed by a click on the Select command button below (or alternatively, a double click on the Rtn Cct RV item) exposes the next screen.

The process of constructing a Return Circuit Rail Voltage file begins with importing a Return Circuit file into the screen. However, only Return Circuits for rail systems which run trains under a DC power distribution system can be imported here. The Old Method or New Method is not yet available for AC power distribution.

The second list box from the left contains a list of Return Circuit files in the Rail System directory for the rail system selected.

Double click on a file in the list selects and imports it into the screen.

Alternatively, click on the file and on the Select One button and the file is also selected and imported into the screen.

To view any file, click on the file and then on the View One button.

To delete a file, click on the file and click on the Delete One button. Clicking on the file and pressing the delete key as well can delete a file.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.
Double click on a file name in the list box to obtain the next screen.

![Diagram of the File Construction Module – Return Circuit Rail Voltage File – Return Circuit File Selected]

The **Line Input** grid holds information for each line of the **Return Circuit for Rail Voltage**. It contains the **Line Name**, the **Begin Node** (begn node) of the line, the **End Node** of the line, the **Track Number**, **Ground Resistance** and Rail to Ground Leakage Resistance (**Leakage Resistance**).

Only **Return Circuit Rail Voltage Ground Resistance** and **Leakage Resistance** can be entered or modified in the grid. If more modifications or additions are required, the **Return Circuit**, from which this grid was originally generated, must be changed and subsequently imported to this grid.

This grid holds information for each **Node** (Nodes are the endpoints of Lines) for the **Return Circuit for Rail Voltage**. It contains the **Node Name**, **Node Position** (Pos) and whether the **Node** is grounded.

To change any information in this grid, the **Return Circuit**, from which this grid was originally generated, must be changed and subsequently imported to this grid.

The first list box on the left contains a list of **Return Circuit Rail Voltage** files in the **Rail System** directory for the rail system selected.

Double click on a file in the list selects and imports it into the screen.

Alternatively, click on the file and on the **Select One** button and the file is also selected and imported into the screen.

To view any file, click on the file and then on the **View One** button.
To delete a file, click on the file and click on the **Delete One** button. Clicking on the file and pressing the delete key as well can delete a file.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

Double click on a file name in this list box to obtain the next screen.

In contrast to importing a **Return Circuit** file as shown in Figure 3-392, this screen shows **Ground Resistances** and **Rail to Ground Leakage Resistances** present in the **Line Input** grid.

Click the **Resistances** command button in Figure 3-392 to continue the process of building a **Return Circuit Rail Voltage** file from a **Return Circuit** file. The next screen is exposed.
The Resistances Specifications (Real Ohms) frame contains the following information on resistances:

- **Ground Resistance** - Specified in ohms per unit distance
- **Rail to Ground Leakage Resistance** – Specified in ohms

Any of the values of the resistances specified in the frame can be changed by the user, by entering a different value into any of the text boxes.

The Base Resistances (Real Ohms) frame contains the following information on resistances:

- **Ground Resistance** - Specified in ohms per unit distance
- **Rail to Ground Leakage Resistance** – Specified in ohms

These resistances cannot be changed directly by the user. These are the resistances carried along with the Return Circuit Rail Voltage file. They represent the base or possibly majority of resistance values to be used for the circuit.

In contrast to the resistance in the Resistances Specifications frame, these resistances are held and can be exchanged with the Resistances Specification frame. Most of the time, the resistances are the same.
The other command buttons on the screen have the following meanings:

**Set Resistances to Grids** – This command button sets the values of resistances in the Resistances Specifications frame to the Line Input grid after performing all calculations on distances between nodes, when required.

**Set Resistances from Base** - The Base Resistances are the ground resistance and rail to ground leakage resistance, which are used for most of the lines. If there are no resistances in the Line Input grids, it would be the Base Resistances which would be inserted; however, they must first be set into the Resistances Specifications frame. The command Set Resistance from Base will insert the resistances from the text boxes in the Base Resistances frame into the text boxes of the Resistances Specifications frame.

**Set Resistances to Base** - The Base Resistances are the ground resistance and rail to ground leakage resistance, which are used for most of the lines. If there are no resistances in the Line Input grids, it would be the Base Resistances which would be inserted; however, they must first be set into the Resistances Specifications frame. The command Set Resistance to Base will insert the resistances from the Resistances Specifications frame text boxes into the text boxes of the Base Resistances frame in order to preserve them.

**Set Default as Base** – This command button is used to set the resistances currently present in the Rail System under consideration to the Base Resistances.

**Save Base as Default** – This command button is used to save the resistances currently present in the Base Resistances frame to the Rail System under consideration. Thus, every time the Set Default as Base command button is clicked afterwards, the impedances in the frame will be the impedances just saved. In other words, the Rail System under consideration will have new default impedances.

**Restore Original Default Resistances** – This command button restores the original default resistances of the TOM to the Base Resistances frame.

Although this may sound complicated at first, the reason behind the complication will become apparent, when dealing with the insertion of impedances in individual lines by graphics.

Click the Set Resistances to Grid command button to produce the next screen.
Resistances may now be changed manually, in the Line Input grid, or they may be modified in the graphics procedure to be outlined next. Modifications would be required if different Ground Resistances or Rail to Ground Resistances are different for some lines. If this is carried out manually, Ground Resistance dependence on distance between nodes must be accounted for manually. In the graphics procedure, this accounting is done automatically.

The Clear All Resistances command button eliminates all resistance entries.

Click the Graphic Input command button to produce the next screen.
Click the **Open Grid** command button to display the next screen.
The circuit layout graph space has two dimensions. The horizontal direction is called the position portion of the graph space and the vertical direction is the track number portion of the graph space.

The position of the nodes is referred to mileposts or kilometerposts in the horizontal direction. Track numbers are referenced to the black-dotted lines running horizontally across the layout graph space. The first black-dotted line at the top is track 0, the second is track 1, the third is track 2, etc. There are light color lines running horizontally between the black lines. These lines are dividing lines between tracks 1 and 0, tracks 2 and 1, tracks 3 and 2, etc. The dots on each of these lines are referred to as grid points.

Note that the position and track number of the cursor is always displayed at the top of the screen when the mouse lies in the graph space.

Track lines of the Return Circuit for Rail Voltage are shown in green with yellow dots representing the nodes. Red lines are rail bonds.

The minimum and maximum node positions correspond to the node positions of the furthest nodes to the left and right, respectively.

The Return Circuit for Rail voltage cannot be modified in this screen. Modification of the Return Circuit for Rail Voltage can only be accomplished through the procedures discussed in Section 3.2.6.1.1.

This graph space is reserved for Identification of Lines and Nodes and modification of resistances of the Return Circuit Rail Voltage file. This is demonstrated in the next few screens.
3.4.4.1 Node Identification

A node in the graph space is identified by clicking on it with the right mouse button as demonstrated in the next screen.

Figure 3-398 Node Menu
Click the Identify menu item to obtain the next screen.
Figure 3-399 Node Identification

The Node Name and Node Position are presented.

The second menu item, Ground, of Figure 3-398, will ground the node at that point. This feature will ground the node so that the rail voltage is zero at that point.

3.4.4.2 Line Identification

A line in the graph space is identified by clicking on it with the right mouse button as demonstrated in the next screen.
Figure 3-400 Line Menu

Click the **Identify** menu item to obtain the next screen.
Figure 3-401 Line Identification

The Line Name, Line Number, End Nodes (Names, Positions), Average Ground Resistance and Average Leakage Resistance are presented.

3.4.4.3 Setting Resistances

Clicking the Set Resistances menu item in the Line menu of Figure 3-400 produces the following screen.
Figure 3-402 Resistance Procedure Screen – Single Line Resistances To Be Modified

Enter the modified resistances into the Resistance Specifications frame and click the Set Resistances to Grid command button. This action returns the graphics screen.

This feature allows the user to use the Base Resistances over the circuit and then modify specific areas as required.
Figure 3-403 Return to Graphics Screen.
This completes the procedure for creating a Return Circuit Rail Voltage file.

3.4.5 Procedure for Determining Rail Voltage

Several steps are required in order to determine rail voltage.

Build the Return Circuit in accordance with the Return Circuit Rail Voltage requirements. (See Section 3.2.6). These requirements are described last.
Build a Return Circuit Impedance file for the Return Circuit (See Section 4.14.).
Build a Network file using the Return Circuit together with a Primary Circuit and the Return Circuit Impedance file. (See Section 3.2.2.8.).
Build the ENS or TMS File of Filenames, which contains the Network file just built (See Section 3.2.1 or 3.3.1 as appropriate.).
Run the ENS or TMS (See Section 2.2 or 2.3.2 as appropriate.).
Run the FMM Current Analysis program to obtain the Return Circuit Current Analysis Output file using the Current Measurement Output file from the ENS or TMS run (See Section 4.18.1.).
Build the Return Circuit Rail Voltage file (See Section 3.4.4.)
Build a matching Rail Voltage Table (See Section 3.4.3.2.).
Build a RVM File of Filenames file using as input the Return Circuit Rail Voltage file, the Rail Voltage Table file and the Return Circuit Current Analysis Output file. (See Section 3.4.1.2.).
Run the RVM. (See Section 8.2.).
The requirements for the Return Circuit Rail Voltage Circuit must be incorporated into the Return Circuit. Both circuits must look the same, so that if nodes are placed on lines without any connecting lines, this generally means that the Ground Resistance per Unit Length or Rail to Ground Leakage Resistance has a different value on either side of the node. It can also mean that the Rail Resistance per Unit Length is also different.

An example is shown in the next screen.

![Example of Return Circuit – Return Circuit By Graphics Screen Showing a Node Common to Two Lines](image)

The Return Circuit Rail Voltage Circuit must be the same and is shown in the next screen.
The node common to only two lines could also represent a ground point of the circuit.
3.5 **INPUT FOR THE ECM**

A click on the ECM Input box of the FCM Main Screen of Figure 3-2 allows the user to select the construction of the following input file for the ECM as shown in the screen below.

![ECM Input Selection Screen](image)

Only the meter consolidation file construction is available here. This is used by the programs in the ECM described in more detail in Section 5 of this manual. A double click on Mtr Cons or a click on Mtr Cons followed by a click on the Select button produces the next screen.
A list of meter consolidation files in the database for the rail system selected is shown at the left and middle of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

Selection of the Name of File to be created or modified is at the left and bottom of the screen. This is edited in the usual window manner.

In the middle column of the top half of the screen is a list of network files in the RSDB for the rail system selected. The meter consolidation file can be built from a list of meters contained in these files.

Double click on a file in the lists selects it. Alternatively, click on the file and on the Select button and the file is also selected. Selections of the file places the entire list of meter names in the file into the List of Meters to be Consolidated box below. To view any file, click on the file and then on the View One button.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

The List of Meters to be Consolidated is a list of meter names, which will be incorporated into the meter consolidation file. A double click on a meter eliminates it from the list. Enter a new meter name in the Add Meter Name box and click on the Add button to add it to the list. Double click on the meter name in the Add Meter Name box also adds it to the list. Bring in other network files to build the consolidation if necessary. The Number of Meters box keeps track of the number of meters in the list.
Enter the ID for the consolidated meters in the Consolidate Meters ID box. Up to four characters is acceptable.

An example of a completed or imported file screen is shown next.

Figure 3-408 ECM Input Selection - Meter Consolidation File (Completed or Imported File)

The final action to create the file is taken by clicking on the Create button. The file is created and the user is given the option of viewing the file with a Yes or No button. Clicking on Yes will produce a TOM File View of the file. Clicking on No will close the file.

There are two other buttons at the right of the screen Close and Reset. A click on Close will abort the screen and return to the previous screen. A click on Reset will create the same screen in the same manner as if it was called from the ECM Input Selection screen of Figure 3-406.

3.6 **SUB SYSTEM MODELS FOR THE TOM**

A click on the Subsystem Models button of the FCM Main Screen of Figure 3-1 produces the next screen.
This screen is used to activate the subsystem fundamental models of the TOM, including at present the Propulsion Subsystem consisting of motors, controls and gears. These models are used to develop the performance characteristics of the components. These characteristics are then stored in files, which can be called by the FCM to complete the input files. The files are kept in the Applications directory (default ../tom). Files for motors, controls and gear units have the extensions (ext) mot, con & gum, respectively. These files can be viewed using the TOM File Viewer. Viewing these files is explained further in Section 6.1.3.

3.6.1 DC Series Motor
Clicking on the DC Series Motor button of the Subsystem Models Activation Screen of Figure 3-409 produces the following screen.
A list of DC Series Motor Data Files (*.mot) in the Applications directory is shown at the left and middle of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

Selection of the Name of File to be created or modified is at the left and bottom of the screen. This is edited in the usual window manner.

All entries to the motor model files must be in English units.

Enter the field strengths for the DC Series motor shunted fields in the Enter Field Strengths boxes. The first field strength must be 100%. The remaining field strengths must be entered in descending order (Enter 90% field strength as 0.90). After the field strength is entered, click the Data Entry button to access the screen, where the Amp-RPM-Torque table will be completed at the particular field strength. This screen will be shown after the present screen is completed.

Enter a numeric designation into the Manufacturer Motor Type or Designation box. It must be all numeric, four numbers followed by a decimal point.

Enter a value in volts in the Motor Voltage for Data box. This value is the voltage at which all of the Amp-RPM-Torque tables are constructed at the particular field strengths in the Enter Field Strengths boxes.

Enter a value in amps in the Maximum Armature Current box. This value is the maximum value of armature current, not to be exceeded in any of the Amp-RPM-Torque tables.
Enter a value in revolutions per minute (RPM) in the Motor Maximum Speed box. This value is the maximum speed of the motor armature, not to be exceeded in any of the Amp-RPM-Torque tables.

Enter values in volts in the Maximum Motor Voltage Power and Brake boxes.

Enter values in ohms in the Resistance Field and Armature boxes.

Enter the parameters, which define the Dynamic Brake Taper. Three points define the taper. Specify the motor voltage and current at each of the points indicated by the graph. Enter the voltage in the Volts boxes to the right of the graph and the currents in the Amps boxes immediately below the graph. Use normal editing procedures.

The File Caption, which appears as a title script at the end of the file, is not used as any portion of the run but simply identifies the file.

An example of a completed or imported file screen is shown next.

Figure 3-411 DC Series Motor Model Main Screen (Completed or Imported File)

Clicking on a Data Entry button immediately to the right of the Enter Field Strengths boxes, for example the one representing 1. (100%) field strength produces the following completed screen.
When the Amp-RPM-Torque tables are completed use the Select button to return to the previous screen with the values intact. The Close button also returns to the previous screen with the values intact. The Reset button will erase all of the tables.

The final action to create the file is taken by clicking on the Create button on the DC Series Motor Model Main Screen (Completed or Imported File) Figure 3-411. The file is produced and the user is given the option of viewing the file with a Yes or No button. Clicking on Yes will produce a TOM File View of the file. Clicking on No will close the file.

There are two other buttons at the right of the completed screen of Figure 3-411. These buttons are Close and Reset. A click on Close will abort the screen and return to the previous screen. A click on Reset will create the same screen in the same manner as if it was called from the Subsystem Models Activation Screen of

3.6.2 DC Separately Excited Motor

Clicking on the DC Sep Ex Motor button of the Subsystem Models Activation Screen of

produces the following screen.
Figure 3-413 DC Separately Excited Motor Model

A list of DC Sep Ex Motor Data Files (*.mot) in the Applications directory is shown at the left and middle of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

Selection of the Name of File to be created or modified is at the left and bottom of the screen. This is edited in the usual window manner.

All entries to the motor model files must be in English units.

There are five entries of motor characteristics above the diagram. New entries should be made in the appropriate boxes. The defaults are shown.

The equation for the motor model is shown in the diagram. All of the symbols are defined in the diagram or the equivalent circuit.

The Saturation Curve table shows the flux $\Phi$ for each field current $IF$. The default values may be replaced by new values.

The File Caption, which appears as a title script at the end of the file is not used as any portion of the run but simply identifies the file.

An example of a completed or imported file screen is shown next.
Figure 3-414 DC Separately Excited Motor Model (Completed or Imported File)

The final action to create the file is taken by clicking on the Create button. The file is created and the user is given the option of viewing the file with a Yes or No button. Clicking on Yes will produce a TOM File View of the file. Clicking on No will close the file.

There are two other buttons at the right of the screen Close and Reset. A click on Close will abort the screen and return to the previous screen. A click on Reset will create the same screen in the same manner as if it was called from the Subsystem Models Activation Screen.

3.6.3 AC Induction Motor
Clicking on the AC Induction Motor button of the Subsystem Models Activation Screen of Figure 3-409 produces the following screen.

Figure 3-409 produces the following screen.

Figure 3-415 AC Induction Motor Model Input Screen
A list of AC Ind Motor Data Files (*.mot) in the Applications directory is shown at the left and middle of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

Selection of the Name of File to be created or modified is at the left and bottom of the screen. This is edited in the usual window manner.

All entries to the motor model files must be in English units.

The diagram shows six entries of motor electrical characteristics in the center of the screen. Entries should be made in the appropriate boxes. The defaults are shown. These entries are Stator (Primary) Resistance \([R_1]\), Stator (Primary) Inductance \([L_1]\), Core or Magnetizing Inductance \([L_m]\), Core or Magnetizing Resistance \([R_m]\), Secondary (Rotor) Inductance \([L_2]\) and Secondary (Rotor) Resistance \([R_2]\).

The equivalent circuit for the induction motor can be viewed by clicking on the Show Equivalent Circuit button and is shown in the following figure.

![AC Induction Motor Equivalent Circuit Screen](image.png)

**Figure 3-416 AC Induction Motor Equivalent Circuit Screen**

Enter the value in revolutions per minute (RPM) in the Maximum Motor Speed box of Figure 3-415. The motor cannot exceed this speed in all computations.

Enter the value of line to line volts in the Maximum Motor Voltage box. Applied voltages to the motor are always less than this value in all computations.

Enter the value in amps in the Maximum Stator Current box of Figure 3-415. Currents in the primary are limited to this value or less in all computations.

Enter the frequency in hertz to be used at maximum motor voltage in the Frequency at Max Voltage box of Figure 3-415. The control keeps the ratio of voltage to frequency constant. The frequency is the primary frequency.

Enter the value in the Number of Pole Pairs box of Figure 3-415. Since the motor is symmetric, the number of poles is 2x number of pole pairs.

Enter a value in the Coefficient1 and Coefficient2 boxes of Figure 3-415. The formula defining friction loss is:

\[
\text{Friction Loss} = \text{Coefficient1} \times \text{RPM} + \text{Coefficient2} \times \text{RPM}^2
\]

Enter a value for the Coefficient box of Figure 3-415. The formula defining windage loss is:

\[
\text{Windage Loss} = 10^{-9} \times \text{Coefficient} \times \text{RPM}^3
\]

Where the motor speed, RPM is measured in revolutions per minute, and the loss in watts.

Enter a value in the Stray Loss Coefficient box. The stray loss coefficient is defined by the formula:

\[
\text{Stray Loss} = \text{Stray Loss Coefficient} \times \text{Motor Power Input}
\]

Where the power input to the motor and the stray losses are measured in watts.

The File Caption, which appears as a title script at the end of the file, is not used as any portion of the run but simply identifies the file.
An example of a completed or imported file screen is shown next.

Figure 3-417 AC Induction Motor Model (Completed or Imported File)

The final action to create the file is taken by clicking on the Create button. The file is created and the user is given the option of viewing the file with a Yes or No button. Clicking on Yes will produce a TOM File View of the file. Clicking on No will close the file.

There are two other buttons at the right of the screen Close and Reset. A click on Close will abort the screen and return to the previous screen. A click on Reset will create the same screen in the same manner as if it was called from the Subsystem Models Activation Screen of...
3.6.4 Gear Unit

Clicking on the Gear Unit button of the Subsystem Models Activation Screen of

![Subsystem Model Activation](image)

Figure 3-409 produces the following screen.

![Gear Unit Model](image)

\[\tau_l = a_g n_c^{-1} + b_g + c_g \tau_m + d_g n_c^2 + e_g n_c + f_g n_c^2 \quad \text{for} \quad n_c > 0\]

\[\tau_l = b_g + c_g \tau_m \quad \text{for} \quad n_c = 0\]
Figure 3-418 Gear Unit Model

A list of Gear Unit Model Data Files (*.gum) in the Applications directory is shown at the left and middle of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

Selection of the Name of File to be created or modified is at the left and bottom of the screen. This is edited in the usual window manner.

All entries to the gear unit model files must be in English units.

The equation for the generalized gear unit is shown in the screen together with default values of the coefficients.

The File Caption, which appears as a title script at the end of the file, is not used as any portion of the run but simply identifies the file.

An example of a completed or imported file screen is shown next.

Figure 3-419 Gear Unit Model (Completed or Imported File)

The final action to create the file is taken by clicking on the Create button. The file is created and the user is given the option of viewing the file with a Yes or No button. Clicking on Yes will produce a TOM File View of the file. Clicking on No will close the file.

There are two other buttons at the right of the screen Close and Reset. A click on Close will abort the screen and return to the previous screen. A click on Reset will create the same screen in the same manner as if it was called from the Subsystem Models Activation Screen of
3.6.5 Chopper Control

Clicking on the Chopper Control button of the Subsystem Models Activation Screen of Figure 3-409 produces the following screen.

Figure 3-409 produces the following screen.
A list of Chopper Control Files (*.con) in the Applications directory is shown at the left and middle of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

Selection of the Name of File to be created or modified is at the left and bottom of the screen. This is edited in the usual window manner.

The five main circuit components of the chopper control are shown above and below the diagram and in relation to the component symbols on the diagram. The default entries can be replaced by new values.

On the right side of the screen are two other entries. Enter a value in watts in the Constant Losses box. These represent the relatively constant losses such as control power supplies, gating, blowers … etc.

Enter a value in the Ratio of Commutation Time to Period box. This is generally a very small value.

The File Caption, which appears as a title script at the end of the file, is not used as any portion of the run but simply identifies the file.

An example of a completed or imported file screen is shown next.

The final action to create the file is taken by clicking on the Create button. The file is created and the user is given the option of viewing the file with a Yes or No button. Clicking on Yes will produce a TOM File View of the file. Clicking on No will close the file.

There are two other buttons at the right of the screen Close and Reset. A click on Close will abort the screen and return to the previous screen. A click on Reset will create the same screen in the same manner as if it was called from the Subsystem Models Activation Screen of
3.6.6 Phase Control

Clicking on the Phase Control button of the Subsystem Models Activation Screen produces the following screen.

Figure 3-409 produces the following screen.
Figure 3-422 Phase Control Model

A list of Phase Control Files (*.con) in the Applications directory is shown at the left and middle of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

Selection of the Name of File to be created or modified is at the left and bottom of the screen. This is edited in the usual window manner.

There are four phase control sub models imbedded in this model. These are the four combinations of three phase and single phase together with full bridge and midpoint. These are selected by setting the following boxes: Single Phase vs. Three Phase and Full Bridge vs. Midpoint on the right side of the screen.

An expanded version of the TOM will later allow for Full Control, Half Control or No Control. Full control allows controlled devices (Thyristors, Transistors, etc.) in both legs while half control allows uncontrolled devices (diodes) in one leg and controlled devices in the other. No control is simply a rectifier with uncontrolled devices in both legs. At present, only full control is allowed.

Future expansion of the model will also allow permanent rectifiers to be inserted into the circuit as the speed of the train increase. At present no permanent rectifiers are permitted.

Enter new values in place of the default values in the remaining boxes. If there is no transformer, enter a Transformer Turns Ratio of 1 plus zero Transformer Resistance and Transformer Reactance. Transformer Reactance is measured at line frequency.

The File Caption, which appears as a title script at the end of the file, is not used as any portion of the run but simply identifies the file.

An example of a completed or imported file screen is shown next.
The final action to create the file is taken by clicking on the **Create** button. The file is created and the user is given the option of viewing the file with a **Yes** or **No** button. Clicking on **Yes** will produce a TOM File View of the file. Clicking on **No** will close the file.

There are two other buttons at the right of the screen **Close** and **Reset**. A click on **Close** will abort the screen and return to the previous screen. A click on **Reset** will create the same screen in the same manner as if it was called from the Subsystem Models Activation Screen of  

3.6.7 PWM Inverter
Clicking on the PWM Inverter Control button of the Subsystem Models Activation Screen of Figure 3-409 produces the following screen.

Figure 3-409 produces the following screen.
A list of **PWM Inverter Data Files** (*.con) in the Applications directory is shown at the left and middle of the screen. These files may be viewed, selected or deleted using the **View One**, **Select One** or **Delete One** buttons, respectively. Double clicking on the selection in the box will select that file as well.

Selection of the **Name of File** to be created or modified is at the left and bottom of the screen. This is edited in the usual window manner.

The five main circuit components of the PWM inverter control are shown above and below the diagram and in relation to the component symbols on the diagram. The default entries can be replaced by new values.

On the right side of the screen are three other entries. Enter a value in watts in the **Constant Losses** box. These represent the relatively constant losses such as control power supplies, gating, blowers … etc.

Enter a value in the **Modulation Frequency** box. This value represents the maximum frequency at which the devices are turned on and then off.

Enter a value in amps for the **Maximum Current** box. This is the maximum DC of the line.

The **File Caption**, which appears as a title script at the end of the file, is not used as any portion of the run but simply identifies the file.

An example of a completed or imported file screen is shown next.

![PWM Inverter Control Model (Completed or Imported File)](image)

The final action to create the file is taken by clicking on the **Create** button. The file is created and the user is given the option of viewing the file with a **Yes** or **No** button. Clicking on **Yes** will produce a **TOM File View** of the file. Clicking on **No** will close the file.

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There are two other buttons at the right of the screen Close and Reset. A click on Close will abort the screen and return to the previous screen. A click on Reset will create the same screen in the same manner as if it was called from the Subsystem Models Activation Screen.

3.6.8 Four Quadrant Controller

The Four Quadrant Controller is a control which takes single phase, high voltage AC, which is the usual power distribution in main line railroad electrification and controls three phase AC induction motors. These controllers produce unity power factor on the AC distribution system and are fully capable of regeneration. Clicking on the Four Quadrant Control button of the Subsystem Models Activation Screen of Figure 3-409 produces the following screen.
Figure 3-426 Four Quadrant Control Model

A list of Four Quadrant Controller Data Files (*.con) in the Applications directory is shown at the left and middle of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

Selection of the Name of File to be created or modified is at the left and bottom of the screen. This is edited in the usual window manner.

The three main circuit components of the Four Quadrant Controller are shown in the diagram.

There are essentially two PWM Inverters operating back to back and a Main Transformer. Both inverters operate between DC and AC. In the case of the PWM Inverter on the right of the diagram, it operates between a DC link and three phase AC, while the one on the left operates between a DC link and single phase AC at the secondary of the Main Transformer. Both inverters operate in both directions and are able to control in four quadrants (± real current and ± reactive current).

All parameters in the text boxes of the diagram can be changed and the default values are shown.

The name of the file is placed in the Name of File text box.

The File Caption, which appears as a title script at the end of the file, is not used as any portion of the run but simply identifies the file.

An example of a completed or imported file screen is shown next.
The final action to create the file is taken by clicking on the Create button. The file is created and the user is given the option of viewing the file with a Yes or No button. Clicking on Yes will produce a TOM File View of the file. Clicking on No will close the file.

There are two other buttons at the right of the screen Close and Reset. A click on Close will abort the screen and return to the previous screen. A click on Reset will create the same screen in the same manner as if it was called from the Subsystem Models Activation Screen of Figure 3-409.
4 FILE MANIPULATION MODULE

The File Manipulation Module (FMM) is a series of computer programs, which interact with the user to manipulate the various files, which are both inputs to and outputs from the simulators. This manipulation is used for several purposes, which are described in this section. The module is called by clicking on the FMM button of the TOM Main Screen of Figure 1-2. The following screen is the result.
Figure 4-1 FMM Main Screen

A rail system is selected by double clicking on the desired system or by a single click on the system mnemonic followed by a click on select. This results in the following screen.
Pre-selection of the rail system TEST on the TOM main screen will result in this screen upon opening of the FMM main screen.

The options of the FMM are now listed in the screen and can be selected by the user by clicking the appropriate command button.
A brief description of the functions of each of the command buttons is now presented.

**Create Elevation File** – The function is to develop and Elevation file from a Grade file. A Grade file is integrated over position along the right-of-way. The resulting Elevation file checks the accuracy of the Grade file.

**Grade Separation Computer** – This function compares the difference in Elevation files of parallel tracks at any position along the right of way and determines the elevation difference between the two tracks.

**Propulsion Eff Conversion** - This function converts a Train file which contains propulsion efficiencies as a function of maximum traction effort and speed to one which contains propulsion efficiencies as a function of percent maximum tractive effort and speed.

**Traction Curve Fitter** – This process fits a portion of the traction curve (either Tractive Effort vs Speed or Electrical Braking Effort vs Speed) to a sum of terms consisting of powers of the reciprocal of speed. The input is a Train file.

**Average Power Profiles** - An average power profile given two or more power profiles (TPS output) from different trains. For example, a train made up cars with of mixed propulsion systems and with identical performance characteristics (tractive effort vs, speed values) could be simulated by running several trains, each of them with all of the same propulsion system and then developing a train with the mixed propulsion systems using a weighted average process.

**Append Power Profiles** – This function appends several power profiles, which are output from the TPS and combines them into one power profile. This utility is exercised when it is convenient to run train performance on several connected track segments separately, and later combine the results for input into the ENS or TMS or other programs.

**Clip Power Profiles** – This function removes records from the beginning and end of a power profile, which are output from the TPS and creates another power profile, which is shorter than the original. This utility can be conveniently used for trains, which are fuel powered in non-electrified territory and electric powered in electrified territory. It can also be used when the user desires to only study portions of the system under electric power. The new power profile can be used as input into the ENS or TMS or other programs.

**Motion Characteristics** - This process (MC) allows the user to view three areas of the Detailed Output file of the TPS. These areas are the Traction and Motion Characteristics area (Traction, Acceleration and Train Resistance Curves); Train Run Summary area (Distance, Time, Average Speed, Maximum Speed and Acceleration, etc.) and Energy End Use region (How energy is used.).

**Extend Load Curve** – This function expands meter load curve cycles over time, when it is known that the original load curve is cyclic in nature. Such would be the case for a rail system operating with constant headway between identical trains or one operating with several such constant headway patterns.

**Meter Reader** - This function copies meter readings and pastes them in other applications, such as Microsoft EXCEL or other spreadsheets. The resulting sheet can form the basis for energy cost computations.

**Occupancy Checker** – This function highlights trains, which are running on the same track and are within a certain set distance from each other. This program is useful when checking for potential conflicts.

**Route Checker** – This function analyzes a power profile to determine the train’s route through the track network. It lists the beginning position and track number, the positions of all track number changes made by the train and the end position and track number. A listing is made of all TPS input files, which were used to construct the power profile. These TPS input files can be viewed and then modified directly.

**Line Name Translator** - The TOM assigns the names of lines to circuits in the power system. The assignment results in a one to four alpha-numeric characters names. The Line Name Translator process results in a translation of these four character names into translated names which refers to line location and track numbers. This file, in the form of a table, provides a translation for reports and more transparent meaning to the line.

**Impedance Calculator** – This function calculates the dynamic impedances of a return circuit, given the return circuit.

**Minimum Train Voltage Finder** – This feature is only found in Version 3.4.2 or higher. This function scans the Current Measurement Output files from the ENS or TMS to find the lowest train voltages. It ranks these voltages from lowest to highest and specifies the position, track number and train ID for each voltage.

**Mean Useful Voltage Finder** – This feature is found in Version 3.7 or higher. The process finds the average train voltage of a region of an electric network under constraints of minimum and maximum
voltage and power settings. It works on both AC and DC systems and is tailored to provide different Mean Useful Voltages in accordance with International Standards EN 50388 (2012) or IEC62313.

**Maximum Train Current Finder** - This feature is only found in Version 3.4.2 or higher. This function scans the **Current Measurement Output** files from the ENS or TMS to find the highest train currents. It ranks these currents from highest to lowest and specifies the position, track number and train ID for each voltage.

**Current Analyzer** - This function develops the current as a function of time and the RMS current for all of the lines in the primary or return circuits from output from the ENS or TMS.

**Voltage Averager** - This feature is only found in Version 3.4.2 or higher. The **Voltage Average Process** is a way of making the running of the TPS and ENS dependent on each other. Through a voltage averaging process, voltages for traction are made dependent on minimum voltage seen in the distribution network. Thus the voltage seen y the train is dependent on the power drawn by that train. This is a method which simulates reality better than making train voltage independent of power drawn. However, it is a less conservative approach to power system evaluation.

The **Auto Offset Process** allows the user to automatically change the offset (point where trains moving in opposite directions pass each other) in fixed headway two track systems. This process is extremely useful for finding points of low voltage, where trains run differently than their advertised schedule. It is also useful for finding schedules which tend to save more energy when trains regenerate.

The **Auto Sub Out Process** allows the user to automatically determine whether low voltage problems exist when substations are taken out of service for maintenance. The process will take substations out of service one at a time and summarize the results on performance.

The **Auto Rail Voltage Process** permits the user to calculate maximum values of rail voltage for a given run scenario by variation of rail to ground leakage resistance and ground resistance over a range of values. This process will inform the user how sensitive the system under study is to the selection of these resistances.

A click on the **Close** button closes the module and returns the user to the previous screen.

A click on the **Exit** button closes the **TOM**.

Each of the options is discussed in the following sections.
4.1 CREATE AN ELEVATION FILE

A click on the Create an Elevation File command button in the FMM Main screen after rail system selection Figure 4-2 allows the user to build an elevation file using the grade file as the basis as can be seen in the next screen.

Figure 4-3 FMM Option Create Elevation File
The elevation file can have input units, which are either English or metric and output units, which are either English or metric. This is selected by checking the appropriate box at the top left of the screen. A description for the kind of units expected is given in Appendix 9.3.

A list of elevation files in the database for the rail system selected is shown at the left of the screen. These files may be viewed or deleted using the View One or Delete One buttons, respectively. Double clicking on the selection in the box will view that file.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

Selection of the Name of File to be created or modified is at the left and bottom of the screen. This is edited in the usual window manner.

In the middle of the screen is a list of grade files in the RSDB for the rail system selected. These are the files available from which to create elevation files. To view any file, click on the file and then on the View One button. To select a file, click on the file and click on the Select One button. Alternatively, double click on the file to select it. Selection of the file means that the elevation file will be computed using it as the basis.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

Enter the start position (miles for English units or kilometers for metric units) in the Elevation Start Position box. The start position must be greater than the Start Position for the grade file selected for building the elevation file.

Enter the end position (miles for English units or kilometers for metric units) Elevation End Position box. The end position must be less than the End Position for the grade file selected for building the elevation file.

Enter the altitude (feet in English units or meters in metric units) of the start position of the elevation file in the Elevation Start Altitude box. If some other position in the elevation file specifies the altitude, take an initial guess of the start position altitude. Create the file. Find the difference between the altitude of the specified position and its altitude in the elevation file. Finally, add the difference to the altitude of the start position on a second elevation file creation. The best guess for the initial file is an altitude of 0.

Normal editing procedures can be used to enter and change values for the entries.

An example of a completed screen is shown next.
The final action to create the file is taken by clicking on the Create button. The file is created and the user is given the option of viewing the file with a Yes or No button. Clicking on Yes will produce a TOM File View of the file. Clicking on No will close the file.

The Reset button completely resets the screen, starting from scratch. It is best used when problems arise and the user can no longer fix them. The Close button closes the program and returns the user to the FMM Main Screen after Rail System Selection of Figure 4-2.
4.2 GRADE SEPARATION COMPUTER

Given one or more parallel tracks along the right of way, this program computes the difference in elevation at any position between any two tracks. The elevation difference between any two tracks can only occur if the Grade files for the tracks are different. This difference is referred as grade separation. It is specified in meters or feet depending on whether Metric or English units are active.

A click on the Grade Separation Computer command button in the FMM Main screen after rail system selection of Figure 4-2 exposes the next screen.

Figure 4-5 Grade Separation Calculator (Computer) Opening Screen

There are two list boxes containing the same Elevation files in the Rail System Directory. These are designated Elevation File 1 and Elevation File 2.

These files may be viewed or selected by clicking on the file name followed by a click on the View One or Select One command buttons, respectively. Double-clicking on the file name selects the file as well. Two different files must be selected, one from each list box. These files must represent elevations for parallel tracks for the procedure to make any sense. For example, track 1 & 2 or track 2 & 3, etc. After selection, the following screen appears.
There are two paths that the user may take here. 
Single Position Computation  
Select Station File

**Single Position Computation**

Enter a common position in the Position text box, followed by a click on the Compute command button. This produces the next screen.
The elevation at the selected position is computed for both elevation files and displayed in the Elev 1 and Elev 2 text boxes, respectively. The Grade Separation is also displayed (Elev 2 – Elev 1). Metric units are meters and English units are feet.

This can be repeated for as many positions desired.

**Select Station File**

The second path is to click on the Station file follow by a click on the Select button. Double clicking on the file produces the same result shown in the next screen.
Two additional objects are shown on the screen. The **Choose a Station** combo box, in which the user selects the station name and the position of the stopping point of the front of the train is automatically selected as the position at which **Grade Separation** is calculated.

A click on the **Choose a Station** combo box, produces the next screen.
Choosing a station name produces the next screen.
Figure 4-10 Grade Separation Calculator – Station Name Choice Made

The numbers displayed in the results are for the stopping point of the front of the train in the chosen station.

The Auto Station Table command button conducts a process by which the Grade Separation information is produced for the stopping point of the front of the train in every station represented by the Station file.

Clicking the command button produces the following results,
Figure 4-11 Grade Separation Calculator – Auto Station Table Process – EXCEL Information Ready

Opening an EXCEL Spreadsheet and pasting the results is shown in the display.
Figure 4-12 Grade Separation Calculator – EXCEL Results Display

These results may be formatted for presentation purposes as shown next.

<table>
<thead>
<tr>
<th>Station</th>
<th>Position</th>
<th>Elevation</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bethesda</td>
<td>1.9464</td>
<td>321.75</td>
<td>-0.01</td>
</tr>
<tr>
<td>ChevyChase Lk</td>
<td>3.2989</td>
<td>276.85</td>
<td>0.05</td>
</tr>
<tr>
<td>Lyttonsville</td>
<td>4.6854</td>
<td>284.7</td>
<td>0.15</td>
</tr>
<tr>
<td>Westside/16th</td>
<td>5.7276</td>
<td>323.41</td>
<td>-0.42</td>
</tr>
<tr>
<td>SilverSprTC</td>
<td>6.2898</td>
<td>348.38</td>
<td>-0.93</td>
</tr>
<tr>
<td>SilverSprLib</td>
<td>6.6305</td>
<td>340.53</td>
<td>0.4</td>
</tr>
<tr>
<td>Dale Drive</td>
<td>7.1877</td>
<td>266.71</td>
<td>0.14</td>
</tr>
<tr>
<td>ManchesterPl</td>
<td>7.7479</td>
<td>259.49</td>
<td>0.21</td>
</tr>
<tr>
<td>Long Branch</td>
<td>8.1528</td>
<td>274.77</td>
<td>-0.19</td>
</tr>
<tr>
<td>PinyBranchRd</td>
<td>8.5674</td>
<td>256.08</td>
<td>1.56</td>
</tr>
<tr>
<td>Tak/LingleyTC</td>
<td>9.3163</td>
<td>191.11</td>
<td>1.52</td>
</tr>
<tr>
<td>Riggs Road</td>
<td>9.9034</td>
<td>152.53</td>
<td>1.54</td>
</tr>
<tr>
<td>Arpt/IntlCmp</td>
<td>11.2799</td>
<td>143.76</td>
<td>1.13</td>
</tr>
<tr>
<td>CampusCenter</td>
<td>11.8487</td>
<td>178.79</td>
<td>1.04</td>
</tr>
<tr>
<td>EastCampus</td>
<td>12.4006</td>
<td>76.55</td>
<td>1.37</td>
</tr>
<tr>
<td>CollegePkMe</td>
<td>13.3116</td>
<td>59.95</td>
<td>4.32</td>
</tr>
<tr>
<td>M Square</td>
<td>14.0695</td>
<td>38.3</td>
<td>4.22</td>
</tr>
<tr>
<td>RiverdalePk</td>
<td>14.9292</td>
<td>77.2</td>
<td>4.21</td>
</tr>
<tr>
<td>Beacon Hts</td>
<td>15.8653</td>
<td>116.85</td>
<td>4.23</td>
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<tr>
<td>AngleRd/Gnr</td>
<td>17.1468</td>
<td>196.05</td>
<td>3.51</td>
</tr>
<tr>
<td>NewCarrolltn</td>
<td>18.1089</td>
<td>119.68</td>
<td>4.95</td>
</tr>
<tr>
<td>Station File</td>
<td>ST-0.ppt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Directory</td>
<td>C:sim\Cmpnt\pp</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date/Time of Run</td>
<td>8/10/2018 11:47:39 AM</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Station Name</td>
<td>Position</td>
<td>EL-file 1</td>
<td>EL-file 2</td>
</tr>
<tr>
<td>-------------------</td>
<td>----------</td>
<td>-----------</td>
<td>-----------</td>
</tr>
<tr>
<td>Bethesda</td>
<td>1.9464</td>
<td>321.75</td>
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<tr>
<td>ChevyChaseLk</td>
<td>3.2989</td>
<td>276.85</td>
<td>276.9</td>
</tr>
<tr>
<td>Lyttonsville</td>
<td>4.6854</td>
<td>284.7</td>
<td>284.85</td>
</tr>
<tr>
<td>Westside 16th</td>
<td>5.7275</td>
<td>323.41</td>
<td>322.99</td>
</tr>
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<td>SilverSprTC</td>
<td>6.2898</td>
<td>348.38</td>
<td>347.44</td>
</tr>
<tr>
<td>SilverSprLib</td>
<td>6.8305</td>
<td>340.53</td>
<td>340.92</td>
</tr>
<tr>
<td>Dale Drive</td>
<td>7.1877</td>
<td>265.71</td>
<td>265.85</td>
</tr>
<tr>
<td>ManchesterPl</td>
<td>7.7479</td>
<td>259.49</td>
<td>259.7</td>
</tr>
<tr>
<td>Long Branch</td>
<td>8.1529</td>
<td>274.77</td>
<td>274.59</td>
</tr>
<tr>
<td>Pny/BranchRd</td>
<td>8.6574</td>
<td>256.08</td>
<td>257.64</td>
</tr>
<tr>
<td>Tch/LcnglyTC</td>
<td>9.3153</td>
<td>191.11</td>
<td>192.63</td>
</tr>
<tr>
<td>Riggs Road</td>
<td>9.9034</td>
<td>152.53</td>
<td>154.07</td>
</tr>
<tr>
<td>Adp/Rd/WstCmp</td>
<td>11.2799</td>
<td>143.78</td>
<td>144.91</td>
</tr>
<tr>
<td>CampusCenter</td>
<td>11.5487</td>
<td>178.79</td>
<td>179.83</td>
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<td>EastCampus</td>
<td>12.4086</td>
<td>76.55</td>
<td>77.92</td>
</tr>
<tr>
<td>CollegePkt/Mc</td>
<td>13.3116</td>
<td>59.96</td>
<td>61.28</td>
</tr>
<tr>
<td>M Square</td>
<td>14.0695</td>
<td>38.3</td>
<td>42.62</td>
</tr>
<tr>
<td>RiverdaleFk</td>
<td>14.9292</td>
<td>77.2</td>
<td>81.41</td>
</tr>
<tr>
<td>Beacon Hts</td>
<td>15.8653</td>
<td>115.85</td>
<td>120.08</td>
</tr>
<tr>
<td>Anple/Rd/Glnr</td>
<td>17.1468</td>
<td>196.05</td>
<td>199.56</td>
</tr>
<tr>
<td>NewCarroltn</td>
<td>18.1089</td>
<td>119.68</td>
<td>124.63</td>
</tr>
</tbody>
</table>

Station File = ST-0.prp
Directory = C:\vorm\tomdak\prp
Date/Time of Run = 8/10/2018 11:47:39 AM
4.3 **PROPULSION EFFICIENCY CONVERSION**

A click on the Propulsion Eff Conversion command button in the FMM Main screen after rail system selection of Figure 4-2 allows the user to convert a train file which contains propulsion efficiencies as a function of maximum traction effort and speed to one which contains propulsion efficiencies as a function of percent maximum tractive effort and speed. The next screen is produced.

![Figure 4-14 FMM Propulsion Efficiency Converter](image)

A list of train files in the database for the rail system selected is shown at the left and middle of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.
Selection of the Name of File to be created or modified is at the left and bottom of the screen. This is edited in the usual window manner.

In the middle of the screen is a list of train files in the RSDB for the rail system selected. These are the Train Files Available from which to effect the conversion. To view any file, click on the file and then on the View One button. To select a file, click on the file and click on the Select One button. Alternatively, double click on the file to select it.

An example of a completed screen is shown next.

Figure 4-15 FMM Propulsion Efficiency Converter (Completed)

Selection of the file means that the new train file will be computed using the one just selected as the basis. The final action to create the file is taken by clicking on the Create button. The file is created and the user is given the option of viewing the file with a Yes or No button. Clicking on Yes will produce a TOM File View of the file. Clicking on No will close the file.
The Reset button completely resets the screen, starting from scratch. It is best used when problems arise and the user can no longer fix them. The Close button closes the program and returns the user to the FMM Main Screen after Rail System Selection of Figure 4-2.

4.4 TRACTION CURVE FITTER

The Traction Curve Fitter process fits a portion of the traction curve (either Tractive Effort vs Speed or Electrical Braking Effort vs Speed) to a sum of terms consisting of powers of the reciprocal of speed. The input is a Train file.

A click on the Traction Curve Fitter command button of Figure 4-2 produces the next screen.

Figure 4-16 Main Screen of the Traction Curve Fitter
A list of train files in the database for the rail system selected is shown at the left and middle of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

The Name of File selected is at the left and bottom of the screen.

The Reset button completely resets the screen, starting from scratch. It is best used when problems arise and the user can no longer fix them. The Close button closes the program and returns the user to the FMM Main Screen after Rail System Selection of Figure 4-2.

A click on the Train file to be used, followed by a click on the Select One command button or alternatively a double click on the Train file exposes the next screen.
The Select One frame contains two options: Tractive Effort Curve and Electric Brake Curve. Either one may be selected by clicking the option. The default option is the Tractive Effort Curve.

The Speed – Traction Effort text box contains the Traction Effort vs Speed values for the curve obtained from the Train File selected. Whether the Traction Effort is Tractive or Electric Brake depends on the option selected.

The Traction Effort – Speed values to be used in the curve fitting are obtained by highlighting them in the Speed-Traction Effort text box as shown in the next screen.

![Traction Curve Fitter Screen](image)

Figure 4-18 The Traction Curve Fitter Screen After Selection of a Train File with Traction Effort – Speed Points Highlighted

The highlighting is accomplished by executing the mouse down to the left of the speed value of the first record and sliding the mouse down the left side of the text box until it is located one record past the last record to be selected at which time a mouse up movement is executed.
The Number of Coefficients text box contains the number of terms in the equation to be fit to the Traction Effort-Speed Points selected. The equation has the form

\[ E = C(0) + C(1)\left(\frac{v_s}{v}\right) + C(2)\left(\frac{v_s}{v}\right)^2 + \ldots + C(M-1)\left(\frac{v_s}{v}\right)^{M-1} \]

Where \( E \) is the Traction Effort, \( v \) is the Speed, \( v_s \) is the Speed at the beginning of the range of points, and \( M \) is the number of coefficients for the text box. The coefficients are \( C(0), C(1), C(2) \ldots C(M-1) \).

Click the Conduct Fit command button to finish the procedure, which produces the next screen.
Figure 4-20 Traction Curve Fit Results

The **Overall Goodness of the Fit** is just the average of the absolute values of the percent difference between calculated and actual values of the **Traction Effort**.

By clicking the **Save File As** command button, the **Traction Effort Curve Fit** results are saved to the file designated in the **Save File As** text box. The user has no control over the name of the file, which has the form:

```
TCFM-mP$T-*.*
```

Where $m$ is the number of coefficients, $P$ for tractive effort and $B$ for electrical braking effort and $T$-$*$. $*$ represents the **Train** file from which the fit was produced.
4.5 AVERAGE POWER PROFILES

A click on the Average Power Profile command button in the FMM Main screen after rail system selection of Figure 4-2 allows the user to develop an average power profile given two or more power profiles (TPS Output) from different trains. For example, a train made up of mixed chopper and cam control cars with identical performance characteristics could be simulated by running two trains, one of them with all chopper cars and the other with all cam control cars. Using this program, the mixed train power profile is developed from the other two power profiles.

A click on this option produces the following screen.

![Figure 4-21 FMM Option Average Power Profiles](image)

A list of power profiles in the database for the rail system selected is shown at the left and middle of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

Selection of the Name of File to be created or modified is at the left and bottom of the screen. This is edited in the usual windows manner.

In the upper middle of the screen is a list of power profiles in the RSDB for the rail system selected. These files are the Power Profiles Available from which the average power profile may be developed. To view
any file, click on the file and then on the View One button. To select a file, click on the file and click on the Select One button. Alternatively, double click on the file to select it. Selection of the file means that the average power profile will be computed using the ones just selected.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

Below the list of power profiles to be selected is a List of Power Profiles to be Averaged. To select a power profile for the list double click on the file in the list above. Then enter the number of cars in the new train, which have that power profile. To delete a power profile from the list, double click on it. This action will delete the profile and the associated number of cars. The Base Power Profile (i.e. the base train) must be the first one in the list.

Enter the ID for the train represented by the averaged power profile in the Train ID for Averaged Files box. Four characters can be used for the ID.

An example of a completed screen is shown next.

![Figure 4-22 FMM Option Average Power Profiles (Completed)](image)

Enter a file caption, which is placed at the end of the file. It will not appear in any of the output and it is used only to identify the file. The file caption can contain any alphanumeric character except the comma (,).

Click on the box and enter the caption. Change caption by dragging mouse and typing over.

The final action to create the file is taken by clicking on the Create button.
The file is created and the user is given the option of viewing the file with a Yes or No button. Clicking on Yes will produce a TOM File View of the file. Clicking on No will close the file.

No Caption was entered into the screen before the Create File command button was clicked. A default caption was shown as shown. This may be edited and the file may be recreated.

The Reset button completely resets the screen, starting from scratch. It is best used when problems arise and the user can no longer fix them. The Close button closes the program and returns the user to the FMM Main Screen after Rail System Selection Figure 4-2.
4.6 **APPEND POWER PROFILES**

A click on the **Append Power Profile** command button in the **FMM Main** screen after rail system selection of Figure 4-2 allows the user to append several power profiles, which are output from the **TPS** and combine them into one power profile. This utility is exercised when it is convenient to run train performance on several connected track segments separately, and later combine the results for input into the **ENS** or **TMS** or other programs.

One example of such an application is when two tracks separate for some distance and then join. If the distance along one track is longer than that of the other, the **TPS** can be run in two segments for one of the tracks; along the track from the separation to the merger, and then, from the merger on.

A click on this option produces the next screen.

![Figure 4-24 FMM Option Append Power Profiles](image)

A list of power profiles in the database for the rail system selected is shown at the left and middle of the screen. These files may be viewed, selected or deleted using the **View One**, **Select One** or **Delete One** buttons, respectively. Double clicking on the selection in the box will select that file as well.
A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

Selection of the Name of File to be created or modified is at the left and bottom of the screen. This is edited in the usual window manner.

In the upper middle of the screen is a list of power profiles files in the RSDB for the rail system selected. These files are the Power Profiles Available from which the appended power profile may be developed. To view any file, click on the file and then on the View One button. To select a file, click on the file and click on the Select One button. Alternatively, double click on the file to select it.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

Below the list of Power Profiles Available is a List of Power Profiles to be Appended. To select a power profile for the list double click on the file in the list above. To delete a power profile from the appended list, double click on it. The Base Power Profile (i.e. the first train) should be the first one in the list.

Enter the ID for the train represented by the appended power profile in the Train ID for Appended Files box. Four characters can be used for the ID.

An example of a completed screen is shown next.
Figure 4-25 FMM Option Append Power Profiles (Completed)

Enter a file caption, which is placed at the end of the file. It will not appear in any of the output and it is used only to identify the file. The file caption can contain any alphanumeric character except the comma (,).

Click on the box and enter the caption. Change caption by dragging mouse and typing over.

The final action to create the file is taken by clicking on the Create button.
Figure 4-26 Option Append Power Profiles (Completed) After the Create File Command Button Clicked

The file is created and the user is given the option of viewing the file with a Yes or No button. Clicking on Yes will produce a TOM File View of the file. Clicking on No will close the file.

No Caption was entered into the screen before the Create File command button was clicked. A default caption was entered as shown. This may be edited and the file may be recreated.

The Reset button completely resets the screen, starting from scratch. It is best used when problems arise and the user can no longer fix them. The Close button closes the program and returns the user to the FMM Main Screen after Rail System Selection of Figure 4-2.

4.7 POWER PROFILE CLIPPER

A click on the Power Profile Clipper command button in the FMM Main screen after rail system selection of Figure 4-2 allows the user to remove records from the beginning and end of a power profile, which are output from the TPS and create another power profile, which is shorter than the original. This utility can be conveniently used for trains, which are fuel powered in non-electrified territory and electric powered in electrified territory. It can also be used when the user desires to only
study portions of the system under electric power. The new power profile can be used as input into the ENS or TMS or other programs.

A click on this option produces the next screen.

![Figure 4-27 FMM Option Power Profile Clipper](image)

A list of power profiles in the database for the rail system selected is shown at the left and middle of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

Selection of the Name of Clipped File to be created is at the left and bottom of the screen. This is edited in the usual window manner.

In the upper middle of the screen is a list of power profiles files in the RSDB for the rail system selected. These files are the Power Profiles Available from which a clipped power profile may be developed. To view any file, click on the file and then on the View One button. To select a file, click on the file and click on the Select One button. Alternatively, double click on the file to select it. Once the file is selected, a new screen appears.
The power profile selected is clipped by selecting the train position for the last clipped record from the beginning of the original file and by selecting the train position for the last record to be excluded from the clipped file. The train positions of the first and last record of the original file are shown. The user then selects the train positions for the clipped file. The train positions for the clipped file must lie within the range of train positions in the original file and must be in the same order. Thus the first selected train position must be less than the last selected train position for increasing train position files and the reverse for decreasing train position files.

An example of a completed screen is shown next.
Figure 4-29 FMM Option Power Profile Clipper (Completed)

The caption for the original power profile is placed in the **Clipped File Caption** text box. A caption is automatically added as **Clipped from pos x to y**, where x and y are the train positions of the first and last clipped records. This caption can be edited after selection of these positions.

The final action to create the file is taken by clicking on the **Create** button. This action produces the following screen.
Because the clipped power profile may have a different train starting position than the original power profile, there is a time difference, called the **time offset**, representing the records clipped from the beginning of the file. This **time offset** is the time necessary for the train to move from the train position of the first record in the original file to the train position of the first record in the clipped file. The **time offset** can be used to adjust timetables, when clipped files are used.

The file is created and the user is given the option of viewing the file with a **Yes** or **No** button. Clicking on **Yes** will produce a **TOM File View** of the file. Clicking on **No** will close the file.

The **Reset** button completely resets the screen, starting from scratch. It is best used when problems arise and the user can no longer fix them. The **Close** button closes the program and returns the user to the **FMM Main Screen after Rail System Selection** of Figure 4-2.
4.8 MOTION CHARACTERISTICS

A click on the Motion Characteristics command button in the FMM Main screen after rail system selection of Figure 4-2 allows the user to view various results of a single train run using the TPS Detailed Output file. These results include traction and motion items, run summary information and energy end uses.

A click on this option produces the following screen.
Figure 4-31 TPS Motion Characteristics Screen

Double clicking on a TPS Detailed Output file or alternatively clicking on a TPS Detailed Output file followed by a click on the select button, results in the next screen.

There are three command buttons corresponding to functions to be performed by each of them.

Traction and Motion Characteristics focuses on that portion of the TPS Detailed Output file, which presents the traction effort curves, the applied acceleration and deceleration, the actual acceleration and
deceleration and the train resistance curve. All are functions of speed and all are computed on level, tangent track.

**Train Run Summary** focuses on that portion of the TPS Detailed Output file, which presents summary information on the terminal to terminal train run. Information such as trip time, average speed, run distance, maximum speed, acceleration and deceleration and information on energy and power consumption.

**Energy End Uses** presents that portion of the TPS Detailed Output file, showing summary information on energy end uses such as net input gross input and regeneration recovery and auxiliaries, traction losses and friction losses.

Results of each of the command button clicks are shown in the next three screens.

---

Figure 4-33 Traction and Motion Characteristics Result
Figure 4-34 Train Run Summary Result

Figure 4-35 Energy End Uses Result
4.9 **EXTEND LOAD CURVE**

A click on the *Extend Load Curve* command button in the *FMM Main* screen after rail system selection of Figure 4-2 allows the user to expand meter load curve cycles over time, when it is known that the original load curve is cyclic in nature. Such would be the case for a rail system operating with constant headway between identical trains.

A click on this option produces the following screen.

![Figure 4-36 FMM Option Load Curve Extender](image)

A list of load curve files in the database for the rail system selected is shown at the left and middle of the screen. These files may be viewed, selected or deleted using the *View One*, *Select One* or *Delete One* buttons, respectively. Double clicking on the selection in the box will select that file as well.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

Selection of the **Name of File** to be created or modified is at the left and bottom of the screen. This is edited in the usual window manner.
In the upper middle of the screen is a list of load curve files in the RSDB for the rail system selected. These files are the Load Curves Available from which the extended load curve may be developed. To view any file, click on the file and then on the View One button. To select a file, click on the file and click on the Select One button. Alternatively, double click on the file to select it.

Below the list of load curves is the Duration of Load Curve. Both the curve To be Extended and the Extended curve are shown. The user can only enter a time in hh:mm:ss format, to which the load curve is to be extended. The Time Calculator could be useful if times are in other formats.

An example of a completed screen is shown next.

![Extended Load Curve Extender](image)

The caption for the extended load curve is imported from original load curve. A suggested caption of Extended to HH:MM:SS is automatically added to the caption of the original load curve. Editing of this caption is possible after the extended time is selected.

The final action to create the file is taken by clicking on the Create button. The file is created and the user is given the option of viewing the file with a Yes or No button. Clicking on Yes will produce a TOM File View of the file. Clicking on No will close the file.

The Reset button completely resets the screen, starting from scratch. It is best used when problems arise and the user can no longer fix them. The Close button closes the program and returns the user to the FMM Main Screen after Rail System Selection of Figure 4-2.
4.10 METER READER

A click on the Meter Reader command button in the FMM Main screen after rail system selection of Figure 4-2 allows the user to copy meter readings and paste them in other applications, such as Microsoft EXCEL. Clicking this option produces the following screen.

Figure 4-38 Meter Reader Screen

A list of meter files in the database for the rail system selected is shown at the left and middle of the screen. A meter file is created in the EDC Module Energy-Demand computer. See Section 5.1.

These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

There are two options available for choice: Load Curve and Demand. Selecting the Load Curve option and double clicking on a meter file produces the following screen.
This screen shows the integration of the load curve over each demand interval for the meter file selected. There are as many entries as there are demand intervals and meters, including the coincident demand meter (ALL) as well. The entries are in kW.

The energy used in each demand interval recorded by each meter is just the entry multiplied by the demand interval.

The load curve may be copied and pasted into an EXCEL or other spread sheet.

Selection of the Demand option produces the following screen.
In this case, the maximum demand for each meter in all of the demand intervals is shown. These demands may be copied and pasted into an EXCEL or similar spread sheet.
4.11 OCCUPANCY CHECKER

The Occupancy Checker program allows the user to highlight trains, which are running on the same track and are within a certain set distance from each other. This program is useful when checking for potential conflicts.

A click on the Occupancy Checker command button in the FMM Main screen after rail system selection of Figure 4-2 allows the user to check if there are two or more trains within a fixed distance of each other on the same track as determined from outputs from the ENS or TMS. Clicking this option produces the following screen.
Figure 4-41 The Occupancy Checker screen.

Selection of the Current Measurement Output File from an ENS or TMS run provides the basis for determining any occupancy conflicts. This produces the next screen.

A click on a file name in the current measurement output files list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

Figure 4-42 The Occupancy Checker Screen After Selection of a Current Measurement Output File
Entering the **Position Difference**, which may either be in miles or kilometers, will determine the criterion. Two or more trains within this fixed distance will appear in the **Occupancy File** created by the procedure. Filling in **Position Difference**.

The caption for the occupancy file is imported from original current measurement output file. A suggested caption of `pos dif x` is automatically added to the caption of the original load curve. `X` is just the position difference entered into the **Position Difference** text box. Editing of this caption is possible after the position difference is selected is selected.

Figure 4-43 Completed Screen for Occupancy Checker
Clicking the Create Command button produces the following screen.

Figure 4-44 Completed Creation of the Occupancy File

The occupancy file thus created can be viewed in the TOM File Viewer shown in the following screen.
Figure 4-45 View of the Occupancy File

This demonstrates that in the TMS or ENS run that created the Current Measurement Output File (AO-*.*), no train was within 3 miles or kilometers of each other on the same track.
4.12 ROUTE CHECKER

A click on the Route Checker command button in the FMM Main screen after rail system selection of Figure 4-2 allows the user to analyze a power profile, which can be selected in the next screen.

Figure 4-46 File Manipulation Module – Route Checker Screen

A list of power profiles in the database for the rail system selected is shown at the left of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

Clicking on a power profile followed by a click on the Select One command button produces the following screen.
The routing information is shown in the *Routing Information* text box. It includes begin and end positions and the positions and track numbers of all of the track number change points along the route.

The text boxes beneath the *Routing Information* text box are:

- **Selected Train ID** - The text box contains the 4-alphanumeric ID of the train represented by the power profile.
- **Selected Train Direction** – The text box contains + dir for trains moving in the direction of increasing position or – dir for trains moving in the direction of decreasing position. If the train runs in two directions, such as may be the case for appended power profiles, the designation is both.
- **Selected Train Run Duration** – The duration of the TPS run specified by the power profile is given in the text box. This item may be copied and pasted in another screen or application. The format is hh:mm:ss.
- **Selected Train Energy from Power Profile** – The text box contains the total energy expended over the run as represented by the power profile. It is the integral of power over time. If the train is electric, the value is kWh. If the train is non-electric, using fuel, the value is gallons in English units or imperial gallons in Metric units.
- **Selected Train Energy from Averaged Power Profile** – The text box contains the total energy expended over the run as represented by the averaged power profile. The power profile used by the ENS and TMS to locate trains, determine their speeds and power requirements and determine their track number is not the original power profile but one, which is equalized or averaged so that the time increments between the snapshots are all the same. Linear interpolation is used to do the equalizing. The energy is the integral of averaged power over time. If the train is electric, the value is kWh. If the train is non-electric, using fuel, the value is gallons in English units or imperial gallons in Metric units.
- **Selected Train Snapshot Time Interval** – The time interval between power profile records.
The **Input Files** frame contains all of the TPS input files that generated the power profile.

A click on the **Route** file produces a **TOM File Viewer** view of the file as seen in the next screen.

**Figure 4-48 File Viewer View of the Route File selected**

Notice that the track change points in the route file are slightly different than the track change points of the routing information listing of the previous screen in Figure 4-47. The routing information of the previous screen contains the average position of the power profile record immediately before and immediately after the track change point, while the route file contains the exact track change point.

To view the pertinent parts of the averaged power profile, click on the **View Averaged Power Profile** command button on the screen in Figure 4-47. This action produces the following screen.
Figure 4-49 View of Averaged Power Profile Created By the Route Checker
This file is useful when investigating conflicts at switches and crossovers.

A click on the **Time Calculator** command button produces the **Time Calculator** screen, with the run duration already present in the screen.

![Time Calculator Screen](image)

**Figure 4-50 Time Calculator Screen with Run Duration Present in Five Time Formats.**

Times may be added or subtracted in any or all of the five formats.
4.13 LINE NAME TRANSLATOR

A click on the Line Name Translator command button in the FMM Main screen after rail system selection of Figure 4-2 allows the user to develop a table, which can be used for translation of TOM line names to more useful descriptive names.

The process develops a table which shows an equivalency between the TOM Line Name and a Translated Line Name in Primary and Return Circuit files and Return Circuit Rail Voltage files. The TOM Line Name is just a four alphanumeric code, which is assigned to circuit lines automatically by the TOM. The Translated Line Name specifies where the line is located in the circuit.

Track Lines are specified by beginning and end positions and track number.

Substation Connection Lines are specified by the track number to which the connection is made and its position on that track.

Bond or Tie Lines are specified by connection track numbers and the position of the connection.

If desired, this table can be used in output to make it much more transparent and thus more user friendly.

The user is also queried on file creation if a file name translation is required.

The File Name Translator screen is shown next.
Figure 4-51 Line Name Translator

Click on the Choose Type Circuit combo box to produce the next screen.
Figure 4-52 Line Name Translator – Choose Type Circuit

Choosing the Return Circuit produces the next screen.
Figure 4-53 Line Name Translator – Return Circuits

Choose a Return Circuit file from the list box, by clicking on it and clicking the Select One command button or by double-clicking on it. The file can be viewed by clicking the View One command button.
Click the Create File command button to produce the output.
In addition, when the Create File command button is clicked, the following sequence is put onto the Clipboard:

- B1: Trk Line from Pos = .25 to Pos = 0.50 Trk # 2
- A0: Trk Line from Pos = .25 to Pos = 0.50 Trk # 1
- B5: Trk Line from Pos = 0.50 to Pos = .75 Trk # 2
- B7: Trk Line from Pos = .75 to Pos = 1.00 Trk # 2
- A5: Trk Line from Pos = 0.50 to Pos = .75 Trk # 1

...etc.
This sequence is an EXCEL compatible text, where the fields are separated by the tab character, so the sequence can be pasted directly into an EXCEL Spreadsheet.

The user is informed that the Clipboard now has this information which can be pasted into a table in an EXCEL Spreadsheet. This table has a useful format to be especially used in reports, which the user develops. More detail on the table formats are presented in Appendix 9.21, and specific information on this file is in Appendix 9.21.2.1.

Click the OK command button to delete the message. The next screen appears.

Figure 4-56 Line Name Translator File in the File Viewer

If it is desired to save the output, click the Save File As command button. The file will be saved as a Summary file of the type shown in the text box (TRANSRC-*.rt).

4.14 IMPEDANCE CALCULATOR

A click on the Impedance Calculator command button in the FMM Main screen after rail system selection of Figure 4-2 allows the user to calculate the dynamic impedances of a return circuit, given the return circuit.
The file list box to the left of the screen contains the names of the Return Circuit Impedance files in the directory of the rail system selected. These may be viewed by clicking the View One command button. Any may be deleted after confirmation by clicking the Delete One command button next to the file list box.

The middle of the screen shows a file list box containing the Return Circuit files. These may be viewed and selected by clicking the View One and Select One command buttons respectively. Selection means that the file name is transferred to the Circuit Input File Selected: text box below the file list box. This selected file will be the circuit for which the static and dynamic impedances will be calculated.

The term “Dynamic Impedance” refers to the effective impedance of the return circuit between the substations and the train. In contrast, the term “Static Impedance” refers to the impedances between any two nodes of a fixed circuit.

There are two frames on the right of the screen:

**Run Progress**

**Calculation Parameters**

The impedance calculations use an iterative Gauss-Seidel method, which take time. As a consequence, the user is kept informed of the progress of the run via the Run Progress frame. Items such as number of
Positions to Calculate, number of Positions Calculated, computer Present Time and estimated Time of Completion are displayed.

The Calculation Parameters frame hold the parameters for the calculation, which may be changed by the user. The default parameters are shown in the entries for the:

**Position difference** – The step size for calculations of the dynamic impedances along the right of way.

**Power Setting** – Expressed in unit power, this setting represents the power a train will draw as it moves along the right of way in order to estimate impedance. In practice, the impedance does not depend on this power setting but the convergence and accuracy of the solution is affected.

**Maximum Iterations** – The number of iterations to be carried out before giving up on convergence to the accuracy chosen.

**Convergence Accuracy** – Accuracy achieved before convergence is declared.

The Create File command button initiates the process.

It is suggested that the user retain the default values of all parameters except the Position Difference. For right of ways which are very long, a distance step is probably too small and will cause undue long running of the process. It will be a matter of trial and error for a rail system.

The next screen shows the process in progress for a small return circuit file for the dynamic impedances.
Figure 4-58 File Manipulation Module – Impedance Calculator – Calculation in Progress for Dynamic Impedances

The next screen shows the run after completion.

Figure 4-59 File Manipulation Module – Impedance Calculator – Calculation Complete

Click the **Yes** command button to review the file.
Figure 4-60 File Viewer Showing Return Circuit Impedance File – Header Records

The header records of the impedance file are shown. These records include the **Calculational Parameters**, the **Unit Values** and other information. The next screen shows the dynamic impedance records.
Figure 4-61 File Viewer Showing Return Circuit Impedance File – Dynamic Impedance Records

Each record includes the following information:

<table>
<thead>
<tr>
<th>Record #</th>
<th>Track #</th>
<th>Position</th>
<th>Complex Impedance</th>
<th>Actual Iterations to Convergence</th>
<th>Actual Convergence</th>
</tr>
</thead>
<tbody>
<tr>
<td>312</td>
<td>1.02</td>
<td>0.34817</td>
<td>1.0</td>
<td>298</td>
<td>0.00000000499</td>
</tr>
<tr>
<td>313</td>
<td>1.03</td>
<td>0.34819</td>
<td>1.0</td>
<td>294</td>
<td>0.00000000494</td>
</tr>
<tr>
<td>314</td>
<td>1.04</td>
<td>0.34819</td>
<td>1.0</td>
<td>294</td>
<td>0.00000000494</td>
</tr>
<tr>
<td>315</td>
<td>1.05</td>
<td>0.34819</td>
<td>1.0</td>
<td>294</td>
<td>0.00000000494</td>
</tr>
<tr>
<td>316</td>
<td>1.06</td>
<td>0.34819</td>
<td>1.0</td>
<td>294</td>
<td>0.00000000494</td>
</tr>
<tr>
<td>317</td>
<td>1.07</td>
<td>0.34819</td>
<td>1.0</td>
<td>294</td>
<td>0.00000000494</td>
</tr>
<tr>
<td>318</td>
<td>1.08</td>
<td>0.34819</td>
<td>1.0</td>
<td>294</td>
<td>0.00000000494</td>
</tr>
<tr>
<td>319</td>
<td>1.09</td>
<td>0.34819</td>
<td>1.0</td>
<td>294</td>
<td>0.00000000494</td>
</tr>
<tr>
<td>320</td>
<td>1.10</td>
<td>0.34819</td>
<td>1.0</td>
<td>294</td>
<td>0.00000000494</td>
</tr>
<tr>
<td>321</td>
<td>1.11</td>
<td>0.34819</td>
<td>1.0</td>
<td>294</td>
<td>0.00000000494</td>
</tr>
<tr>
<td>322</td>
<td>1.12</td>
<td>0.34819</td>
<td>1.0</td>
<td>294</td>
<td>0.00000000494</td>
</tr>
<tr>
<td>323</td>
<td>1.13</td>
<td>0.34819</td>
<td>1.0</td>
<td>294</td>
<td>0.00000000494</td>
</tr>
<tr>
<td>324</td>
<td>1.14</td>
<td>0.34819</td>
<td>1.0</td>
<td>294</td>
<td>0.00000000494</td>
</tr>
<tr>
<td>325</td>
<td>1.15</td>
<td>0.34819</td>
<td>1.0</td>
<td>294</td>
<td>0.00000000494</td>
</tr>
<tr>
<td>326</td>
<td>1.16</td>
<td>0.34819</td>
<td>1.0</td>
<td>294</td>
<td>0.00000000494</td>
</tr>
<tr>
<td>327</td>
<td>1.17</td>
<td>0.34819</td>
<td>1.0</td>
<td>294</td>
<td>0.00000000494</td>
</tr>
<tr>
<td>328</td>
<td>1.18</td>
<td>0.34819</td>
<td>1.0</td>
<td>294</td>
<td>0.00000000494</td>
</tr>
<tr>
<td>329</td>
<td>1.19</td>
<td>0.34819</td>
<td>1.0</td>
<td>294</td>
<td>0.00000000494</td>
</tr>
<tr>
<td>330</td>
<td>1.20</td>
<td>0.34819</td>
<td>1.0</td>
<td>294</td>
<td>0.00000000494</td>
</tr>
<tr>
<td>331</td>
<td>1.21</td>
<td>0.34819</td>
<td>1.0</td>
<td>294</td>
<td>0.00000000494</td>
</tr>
<tr>
<td>332</td>
<td>1.22</td>
<td>0.34819</td>
<td>1.0</td>
<td>294</td>
<td>0.00000000494</td>
</tr>
<tr>
<td>333</td>
<td>1.23</td>
<td>0.34819</td>
<td>1.0</td>
<td>294</td>
<td>0.00000000494</td>
</tr>
<tr>
<td>334</td>
<td>1.24</td>
<td>0.34819</td>
<td>1.0</td>
<td>294</td>
<td>0.00000000494</td>
</tr>
<tr>
<td>335</td>
<td>1.25</td>
<td>0.34819</td>
<td>1.0</td>
<td>294</td>
<td>0.00000000494</td>
</tr>
<tr>
<td>336</td>
<td>1.26</td>
<td>0.34819</td>
<td>1.0</td>
<td>294</td>
<td>0.00000000494</td>
</tr>
<tr>
<td>337</td>
<td>1.27</td>
<td>0.34819</td>
<td>1.0</td>
<td>294</td>
<td>0.00000000494</td>
</tr>
<tr>
<td>338</td>
<td>1.28</td>
<td>0.34819</td>
<td>1.0</td>
<td>294</td>
<td>0.00000000494</td>
</tr>
</tbody>
</table>
4.15 MINIMUM TRAIN VOLTAGE FINDER

A click on the Minimum Train Voltage Finder command button in the FMM Main screen after rail system selection of Figure 4-2 allows the user to determine the lowest train voltages on the line, their positions and track numbers and the ID of the train causing the low voltage.

Figure 4-62 Minimum Train Voltage Finder
Click on the Current Measurement Output file, for which minimum train voltages are to be summarized. The View One command button displays the file in the File Viewer. The Select One command button selects the file for which the minimum voltages are to be found. Double clicking on the file selects it as well.

Choose the number of lowest voltages desired from the Number of Minima combo box. A number from 1 to 10 can be chosen from the combo box or a number may be entered into text area. The default value is 1.
Figure 4-64 Number of Minima Chosen

Click the Create File command button to produce the output.
Figure 4-65 Lowest Train Voltages Are Displayed

In addition, when the Create File command button is clicked, the following sequence is put onto the Clipboard:

```
ENS4n.tes  DC Test Pri wo Ties Rtn wo Bonds NReg 608.6  0.463  2  R1E1
```

This sequence is an EXCEL compatible text, where the fields are separated by the tab character, so the sequence can be pasted directly into an EXCEL Spreadsheet.

The user is informed that the Clipboard now has this information which can be pasted into a table in an EXCEL Spreadsheet. This table has a useful format to be especially used in reports, which the user develops. More detail on the table formats are presented in Appendix 9.21, and specific information on this file is in Appendix 9.21.2.2.

Click the OK command button to delete the message.

If it is desired to save the output, click the Save File As command button. The file will be saved as a Summary file of the type shown in the text box (SUMVSAO.*,).
4.16 MEAN USEFUL VOLTAGE FINDER

A click on the Mean Useful Voltage Finder command button in the FMM Main screen after rail system selection of Figure 4-2 allows the user to calculate the mean useful voltage as defined in International Standards EN 50388 (2012) or IEC 62313.

![Mean Useful Voltage Calculator](image)

Click on the Current Measurement Output file, from which mean useful voltages are to be calculated. The View One command button displays the file in the File Viewer. The Select One command button
selects the file for which the mean useful voltages are to be found. Double clicking on the file selects it as well.

Figure 4-67 Mean Useful Voltage Calculator Screen – Current Measurement Output File Selected

The mean useful voltage displayed is for the entire network. Also shown in the Calculational Parameters frame are the Train ID combo box and the minimum and maximum for position, voltage and power for the total network and the ENS or TMS run.

The mean useful voltage can now be calculated for any train on the network as well as all trains (ALL+), for any conditions of the choice of parameters.
Minimum and Maximum Position defines the region or zone within the network. Minimum and Maximum Voltage defines the range of trains whose voltages are to be included. Finally, Minimum and Maximum Power defines a range of train powers. The voltages of trains which lie in the power range would be included.

As an example, suppose it is desired to calculate the mean useful voltage of the train with ID R1E1, in the region between position 1.5 and 2.25 and not include trains which are regenerating, coasting or are stationary. These trains will be taking power for traction only. Thus the range of powers would include trains taking auxiliary power (180 kW) as well as negative power (regeneration). Thus the next screen would have the following information.

![Mean Useful Voltage Calculator Screen](image)

Figure 4-68 Mean Useful Voltage Calculator Screen – Parameters of Sample Selected
At this point, click the **Re-Calculate** command button to obtain the mean useful voltage for these conditions.

![Mean Useful Voltage Calculator Screen – Re-Calculated With Parameters of Sample](image)

**4.17 MAXIMUM TRAIN CURRENT FINDER**
A click on the Maximum Train Current Finder command button in the FMM Main screen after rail system selection of Figure 4-2 allows the user to determine the highest train currents on the line, their positions and track numbers and the ID of the train causing the highest current.

![File Manipulation Module - Maximum Train Current Finder](image)

Figure 4-70 Maximum Train Current Finder

Click on the Current Measurement Output file, for which maximum train currents are to be summarized. The View One command button displays the file in the File Viewer. The Select One command button selects the file for which the minimum voltages are to be found. Double clicking on the file selects it as well.
Choose the number of lowest voltages desired from the Number of Maxima combo box. A number from 1 to 10 can be chosen from the combo box or a number may be entered into text area. The default value is 1.
Figure 4-72 Number of Maxima Chosen
Click the Create File command button to produce the output.
In addition, when the Create File command button is clicked, the following sequence is put onto the Clipboard:

```
ENS4n.tes DC Test Pri wo Ties Rtn wo Bonds NReg 8691.6 0.463 2 R1E1
```

This sequence is an EXCEL compatible text, where the fields are separated by the tab character, so the sequence can be pasted directly into an EXCEL Spreadsheet.

The user is informed that the Clipboard now has this information which can be pasted into a table in an EXCEL Spreadsheet. This table has a useful format to be especially used in reports, which the user develops. More detail on the table formats are presented in Appendix 9.21, and specific information on this file is in Appendix 9.21.2.3.

Click the OK command button to delete the message.

If it is desired to save the output, click the Save File As command button. The file will be saved as a Summary file of the type shown in the text box (SUMASAO*.*)
4.18 CURRENT ANALYZER

The full capability for circuit analysis exists in Version 3.6.1 and higher although some capability existed in Version 3.4.2 and higher. It is connected with the Primary and Return Circuits used in Network file construction and subsequent running in the electric network analysis of the ENS or TMS. The main objective of the Circuit Analysis program of the FMM is to determine electric current flows and RMS currents in either the Primary or Return Circuit. In Version 3.6.1 and higher, the Circuit Analysis program can also determine current flows and RMS currents in simple loop networks, where no circuits were involved in constructing the network. A Return Circuit cannot be constructed for an AC Train System.

For a DC system, there are three possible ENS or TMS load flow methods. These methods are the Return Circuit Method, the Loop Method and the Simplified Loop Method. These have the following meaning.

**Return Circuit Method**

The Network file is constructed from both a Primary and Return Circuit.

**Loop Method**

The Network file is constructed from a Primary Circuit where the return circuit impedances are lumped into the circuit.

**Simplified Loop Method**

The Network file is constructed manually without a circuit where the return impedances are lumped into the network.

Since AC systems are required to have only a Primary Circuit, only two possible ENS or TMS load flow methods are used, the Loop Method and the Simplified Loop Method.

There are two methods of Current Analysis in TOM Version 3.6.1 and higher. One is the AO- Method and the other is the END Method.

**AO- Method**

This method is applied only to ENS or TMS load flows by the Return Circuit Method. This means only DC systems. This method of Current Analysis uses the ENS or TMS Current Measurement Output file (AO-*.*) and repeats the load flows using current sources and sinks, where the current sources and sinks are substation currents and train currents, respectively, obtained from the output file of the ENS or TMS.

**END Method**

This method is applied to all other cases of ENS or TMS load flows (DC and AC systems by either the Loop Method or Simplified Loop Method. This method of Current Analysis uses the ENS or TMS Detailed Output file (END*.*) and uses the original the load flows of the ENS or TMS.

Before a Primary or Return Circuit can be analyzed, it is necessary to conduct some preliminary steps:

Construct both the Primary and Return Circuit (or a single Primary Circuit file) for a rail network using the construction tools of Section 3.2.6, ENS or TMS Primary Or Return Circuit File construction of the FCM.
Using the Impedance Calculator of the FMM, develop the Return Circuit Impedance file. This procedure is explained in Section 4.14 (Impedance Calculator). This step is not necessary if just a single Primary Circuit file is used without a Return Circuit.

Construct the Network file using the Network with Return Circuit Option described in Section 3.2.2.8. If a single Primary Circuit file is used, the Return Circuit Option is not selected. If the Primary Circuit file represents an AC distribution circuit, then the Current Measurement Input file must have the node names of the main transformer primaries and the line names of the main transformers specified. These must be the only node names and line names specified in that file.

Run the ENS or TMS to complete the electric network analysis. The Current Measurement Output file must be selected as an output choice.

Once these steps have been completed, either the Return or Primary Circuit can be analyzed.

Note, selection of a single Primary Circuit file for construction of the Network file assumes the Loop Method (Primary and Return Circuit Impedances are in series and the series combination is contained in the Primary Circuit). Prior to Version 3.4, this was the only method available. Construction of the Network file prior to Version 3.4, and subsequent running of the ENS or TMS was the Simplified Loop Method.

In Version 3.6.1 and higher, the current flows through the network can also be determined, when either a Simplified Loop Method was used for network construction or a Loop Method using the Primary Circuit (where the impedances of the return circuit are incorporated). Both of these processes involve the Detailed Output file or in the case of a Network constructed from a Primary Circuit file without a Return Circuit file (Loop Method). A Detailed Output (END*,.*) must be produced to effect current analysis, which uses this file, rather than the Current Measurement Output (AO=*.*,*) file. However, the Detailed Output file must be developed using Version 3.6.1 or higher as output from the ENS or TMS.

In AC Networks, only Primary Circuit can be generated or the Network can be developed manually. Since the Reactive portion of the Impedance is roughly 4-5 times that of the Real portion, the return must be incorporated into the primary. Thus, only the Loop Method or Simplified Loop Method of the ENS or TMS is possible with the TOM.

Using the Detailed Output file is referred to as the END Method of Current Analysis and using the Current Measurement Output file together with a Primary Circuit or Return Circuit is called the AO-Method of Current Analysis. The AO-Method of Current Analysis cannot be used when just a Primary Circuit exists alone, which has used the Loop Method, since it does not make sense to repeat the loadflow. Thus the only use of the AO-Method of Current Analysis is for DC distribution systems with a separate Primary and Return Circuit, which was run under the ENS or TMS Return Circuit Method.

The next screen shows the main screen of the FMM, obtained by clicking the FMM command button on the TOM main screen. The TEST rail system has been selected.
Figure 4-74 Main Screen of the FMM with the TEST Rail System Selected
Click the Current Analyzer command button to produce the next screen.
The Current Measurement and Converters command buttons are discussed in Section 4.18.6. These buttons are connected with a quick analysis of converter current and current measurement points on the system.

A list of Current Measurement Output files in the Rail System Database for the rail system selected is shown in the combo box.

Double click on a file in the list selects it and places it in the Current Measurement Output File Name text box below.

Alternatively, click on the file and on the Select One command button and the file is also selected and placed in the Current Measurement Output File Name text box below.

To view any file, click on the file and then on the View One button.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

All of the information necessary to analyze the circuit is contained in the Current Measurement Output file.

Selecting a file results in the following screen.
The Choose Circuit combo box presents the user with the choice of either a Return Circuit (RC-) or a Primary Circuit (PC-), which was specified in the Current Measurement Output file selected. These two files were used to create the Network file, which was part of the ENS or TMS run, which produced the Current Measurement Output file.

The Network file is also shown in the text box below the combo box.

Current analysis will proceed for the circuit file chosen in the combo box. The choice mechanism is shown in the next screen.
Figure 4-77 Screen Showing Choices of Primary or Return Circuit Available

A choice is made, which produces the following screen.
Figure 4-78 Screen After Primary or Return Circuit File Choice

On the left part of the screen is a list of Current Analysis Output files in the Rail System Database for the rail system selected. The file names have the following designation:

RCA refers to Return Circuit Analysis Output files.
PACA refers to Primary Circuit Analysis Output files.

These files contain the results of the circuit analysis.

To view any file, click on the file and then on the View One command button. The file may also be viewed by double clicking it.

The file may be deleted after confirmation by clicking on the file, followed by a click on the Delete One command button or by simply hitting the delete key.

The Analyze One command button summarizes the Circuit Current Output file selected in the list box to the left. For each snapshot, the Snapshot Time, Number of Iterations, Actual Accuracy, $I^2R$ Losses and the Currents (Input, Output and Balance in amps and percent) are presented. The summary, at the end of this file, is the same as the output file analyzed.

The Translate One command button translates the line names of the RMS portion of the Circuit Current Output file selected in the list box to the left. It produces an output file of the form RMSCURSRCA*. or RMSCURSPCA*. depending on whether the Circuit Current Output file is from a Return or Primary Circuit.
A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

The circuit analysis is performed for each snapshot in the ENS or TMS run from which the Current Measurement Output file was the product.

Circuit analysis is performed using the Gauss-Seidel method, which is the same method used in the load flow of the ENS or TMS. This requires the user to specify the Maximum Iterations (maximum number of iterations before convergence is not achievable) and Convergence Accuracy (accuracy achieved before convergence is declared).

The Convergence Factor (cf) is an integer, which indicates how large of an iteration span a cumulative average of accuracies is taken. The cumulative average is a moving average, which averages the last cf of accuracies with the current accuracy. This choice effects a second criteria for declaring convergence. If Acc is the set accuracy, and in the current snapshot the achieved accuracy is dx, then the cumulative accuracy achieved is given by the expression

\[ \text{Cumdx} = \frac{dx + cf \times \text{Cumdx}}{cf + 1} \]

The second convergence criteria is then

\[ dx > \text{Cumdx}. \]

This second convergence criteria, in addition to \( dx < \text{Acc} \), which is the first and main criterion, has the effect of squeezing the maximum accuracy out of the loadflow, even though the loadflow will not converge to the accuracy set by the user, Acc. Any oscillations from snapshot to snapshot are not allowed to grow too large.

Setting \( cf = 0 \) has the effect of not including the second convergence criteria. Setting \( cf = \text{Maximum Iterations} \) has the same effect. Cf = 0 is the default value.

The Minimum Convergence Accuracy is the minimum accuracy that is acceptable, and if,

\[ dx > \text{MinAcc} \]

the iteration procedure ceases and the user then is given options of changing the procedure for completing the analysis. At this point, the user may eliminate the result of the snapshot, set or reduce a Convergence Factor and rerun the analysis or stop. Normally, the Convergence Factor would remain zero. It is only in rare, extreme cases, where it should be used, and after its use, the answers should be examined carefully.

The Save As Default command button saves the parameters currently in the Calculational Parameters frame to the default for the Rail Transit System. It is saved to the file DefCalPar.ext, where ext is the file extension appropriate to the Rail Transit System.

The Restore Default command button imports the Calculational parameters used for the TOM and stored in the Application directory into the text boxes in the Calculational Parameters frame.

Accuracy is a function of whether regeneration is on or off and other factors. The higher the required accuracy implies longer the running time of the analysis.

If the user is uncertain about which values to use, they should be left at the default values, until experience is gained.

Clicking on the Create File command button begins the analysis process, as shown in the next screen.
The **Run Progress** frame informs the user of the progress of the analysis. The method selected for the current analysis can be very time-consuming, especially if there are many nodes involved.

An estimate is made of the positions to be calculated and the time to complete the calculations. Progress is shown indicating the positions already calculated and the present time. This calculation is upgraded often as the program proceeds.

The end of the run is shown in the next screen.
The **Average Accuracy** is the value of accuracy achieved during the analysis. It is the average value the accuracy achieved for each of the snapshots.

The **Maximum Accuracy** is the maximum value of the accuracy achieved in all of the snapshots.

By viewing the output file by clicking the **Yes** command button, the snapshot time where the **Maximum Accuracy** occurred is displayed. The display is at the bottom of the output file.

The **Find Extremum** command button exposes the **Extremumizer Screen**, which is discussed in Section 8.7. This tool is extremely useful when it is necessary to use a **Convergence Factor** for a second convergence criterion. The value of the **Convergence Factor** can be optimized to give the best accuracy for the analysis.

Clicking on the **Yes** command button to review the output file, produces the following screen.
The Current Analysis Output file presents information on the results of the circuit analysis. The material presented is different for AC and DC circuits.

The View RMS Currents command button is present in the File Viewer whenever it contains a file which summarizes RMS currents. These include the Current Analysis Output Files for both Primary (PCA*.*) and Return (RCA*.*) Circuits as well as the Current Measurement Output File (AO-*.*)

These are described in screens on this page and the following pages. Methodologies used are described in Section 9.17 of the Appendix.

For each snapshot, a header appears followed by three separate tables:

**CURRENT ANALYSIS LINE RESULTS FIXED CIRCUIT**
**CURRENT ANALYSIS LINE RESULTS ACTIVE CIRCUIT**
**CURRENT ANALYSIS NODAL RESULTS ACTIVE CIRCUIT**

The header provides the snapshot time, the accuracy achieved and the number of iterations needed to obtain the accuracy.

The fixed circuit represents the lines and nodes of the circuit without the trains being shown as lines and nodes. However the trains are present. The active circuit represents the lines and nodes with the trains present as well as the trains shown as lines and nodes as well.

Line results are the displays by lines and nodal results are the displays by nodes. In the case of lines, currents are tabulated, while in the case of nodes, complex voltages, currents and powers are tabulated. In the latter case, the current represents the injected current into the node, while in the former case, the current is the flow of current in the line between the nodes, which are the endpoints of the line. This is better described by the next illustration.
In the illustration, the line name is \( L \), with the begin node \( b \) and the end node \( e \). The positive direction is defined as either increasing position or increasing track number.

- **Real**: This current shows both direction and magnitude. Direction is indicated as positive for the increasing milepost or track number direction or as negative for the decreasing milepost or track number direction.

- **Reactive**: This current is appropriate for AC distribution systems (It is zero for DC distribution systems.) and shows both direction and magnitude. Direction is indicated as positive for the increasing milepost or track number direction or as negative for the decreasing milepost or track number direction.

- **Magnitude**: This current is appropriate for AC and DC distribution systems. In the case of AC or DC distribution, this current is the complex absolute value of real and reactive current, given by the formula: \( \sqrt{\text{Real}^2 + \text{Reactive}^2} \). However for DC distribution, the reactive current is zero. This type of current is always positive.

- **Heating**: This current represents the heating effect in a line on which trains run. It differs from the **Magnitude** type current in that it captures the heating effect of the train presence on the line. The **RMS** (Root-Mean-Square) current used for calculating heating effects.

The difference between **Heating** and **Magnitude** type currents is explained below, by considering a line with three nodes, one of which is a train (**T**).
Thus, the Heating current takes into account the passage of the trains through the network. The real, reactive and magnitude of current don’t have any meaning for lines (tracks) with trains on them.

4.18.1 Current Analysis Results DC Circuits (AO- Method)

4.18.1.1 Current Analysis Results Fixed DC Circuit (AO- Method)

Three currents are displayed for each line, which shows the line name, begin node and end node as well.

There are four types of current; namely, Real, Reactive, Magnitude and Heating.
The number of trains currently positioned in the line is shown as $n_T$, where $n$ is the number of trains in that line. In this case it is one.

**4.18.1.2 Current Analysis Line Results Active DC Circuit (AO- Method)**

The Current Analysis Line Results Active Circuit is shown for the same snapshot in the next screen view.
The Begin and End Node of the active lines are shown in the table along with the Real Current and Current Magnitude together with the \( I^2 R \) Losses.

The node labeled Trn \( n \) is the node associated with the \( n \)th train.

Real train current, which is input to the train and output from the network, is negative by convention, so that in the case of a regenerating train, the real current is output by the train and input to the network and is designated positive.

Likewise, substation current input into the network is designated as positive and output from the network as negative. This convention is further discussed in Section 9.17.

At the end of the table, not visible in this screen, are the losses and current balance, shown in the next screen.
Figure 4-86 Current Analysis Output Screen View 3: Line Results Active DC Circuit Losses and Current Balance

The I–Square R Losses (kW) is the sum of all the line losses.

The Current Balance (Amps) is the difference between Network Input Current and Network Output Current, and is a measure of the accuracy of the analysis. The Network Input Current and Network Output Currents are also displayed.

Line Current Balance (%) represents the Current Balance (Amps)/Absolute Value of Input and Output Current in percent. Smaller is better. However, in some cases, where the trains are not drawing much current, or in networks where regeneration is turned on, both input and output current of the network are small, thus the Line Current Balance (%) could be very large. This should be examined on an individual snapshot basis.

*The real, reactive and magnitude of current don’t have any meaning for lines (tracks) with trains on them in the fixed DC circuit.*

4.18.1.3 Current Analysis Nodal Results Active DC Circuit (AO-Method)

The next screen shows the nodal results.
Figure 4-87 Current Analysis Output Screen View 4: Nodal Results Active DC Circuit

This table shows the Voltage (Drop), Current and Power associated with each node.

Voltage is the Node Voltage.

Current is the current injected into the node, positive for substation input and negative for train output for the Primary Circuit and the reverse for the Return Circuit.

Power is power injected into the node, positive for substation input and negative for train output, independent of Primary or Return Circuit. Note that if a train is regenerating, the power output from the train is positive.

An analysis is considered accurate, whenever the injected current into all of the nodes except the substation nodes and train nodes is zero. The amount of current actually present in the non-substation and non-train nodes is a measure of the accuracy achieved.

4.18.1.4 RMS Current Summaries DC Circuit (AO- Method)

At the end of the Current Analysis Output file are the RMS Current Summaries. These are shown in the next screen. They can be quickly reached by clicking the View RMS Currents command button.
The RMS Current is computed for the lines of the fixed circuit.

The I – Square R Energy is also displayed in this screen. This represents the cumulative DC Network losses due to the Primary or Return Circuit. Converter or Substation losses are not present here.

The RMS current is the heating current.

Thus, for the total network, the DC Network losses are just the sum of Primary and Return Circuit losses.

Finally, the last part of the output file is shown in the next screen.
The following information is provided at the end of the Current Analysis Output file for DC circuits:

**Maximum Real Line Current Balance (%)** and the **Snapshot of Occurrence**.

**Maximum Reactive Line Current Balance (%)** and the **Snapshot of Occurrence**. This is always zero for DC circuits.

**Maximum Number of Iterations** and the **Snapshot of Occurrence**.

**Non-Convergences**. The number of snapshots for which the accuracy achieved exceeded the set accuracy.

**The Set Maximum Number of Iterations**

**Maximum Accuracy**. The average accuracy for all of the snapshots.

**The Set Accuracy** for convergence.

**The Set Minimum Accuracy** for convergence.

**The Convergence Factor**.

**The Return Circuit Impedance** file name.

**The Substation Feeder Length Limit**. This quantity represents a limit on the feeder horizontal distance (along the right of way) from the substation to the track connection.

**Return Circuit** file name.

Output from **ENS** or **TMS**. Whether the file was generated as a consequence of **TMS** or **ENS**.

**The Current Measurement Output** file name on which the analysis was based as well as when it was generated.

**The Circuit Analysis Output file Caption**.

**The Circuit Analysis Output** file name, information on when it was run and the run time on the computer on which it was run.
Clicking the **EXCEL Ready** command button produces the next screen.

![Figure 4-90 Results of Executing the EXCEL Ready command button](image)

The **Clipboard** now has information, which can be pasted into an **EXCEL Spreadsheet**.

This sequence is an **EXCEL** compatible text, where the tab character separates the fields, so the sequence can be pasted directly into an **EXCEL Spreadsheet**.

The user is informed that the **Clipboard** now has this information, which can be pasted into a table in an **EXCEL Spreadsheet**. This table has a useful format to be especially used in reports, which the user develops. More detail on the table formats are presented in Appendix 9.21, and specific information on this file is contained in Appendix 9.21.1.4.

Click the **OK** command button to delete the message.
4.18.2 Current Analysis Results AC Circuits (END Method)

The AC Circuit is more difficult to analyze since the currents, powers and voltages are complex numbers. AC Circuits are always Primary Circuits and the ENS or TMS are run in either the Simplified Loop Method or the Loop Method. This means that the Rail Impedance is considered as part of the Primary Network. The Loop Method is used when a Primary Circuit is used to generate the Network and the Simplified Loop Method is used when the Network is constructed by hand.

There is another complication for AC Circuits, which have a feeder line, such as the Primary Circuit for a 2x25 kV With AutoTransformers network.

The FMM – Current Analyzer screen for a network with these characteristics is shown next.

![Figure 4-91 FMM - Current Analyzer Screen for a 2x25 kV w AutoTransformers Network](image-url)

Selection of the Primary Circuit for this network results in the next screen.
Figure 4-92 FMM - Current Analyzer Screen for a 2x25 kV w AutoTransformers Network – Before Circuit Selection

Clicking on the Choose Circuit combo box produces the next screen.
Only one choice is available since AC networks allow only Primary Circuits. Making the choice results in the next screen.
Figure 4-94 FMM - Current Analyzer Screen for a 2x25 kV w AutoTransformers Network – Choice Made

Note what has happened. The Detailed Output file from the ENS or TMS will be used for Current Analysis. If such a file doesn’t exist or if the file were generated under a version of the TOM before 3.6.1, the user is informed to rerun the ENS or TMS under the current version to produce a proper Detailed Output file.

The Turns Ratio combo box is required if an AC Primary Circuit has a feeder line. It expresses the turns ratio or the voltage ratio of the feeder line to the track line. In the case of a 2x25 kV With AutoTransformers network, the ratio is 2; namely 2x25/25. If the feeder line is at the same voltage as the track line, then the turns ratio is 1. Select the Turns Ratio.

4.18.2.1 Current Analysis Results Fixed AC Circuit (END Method)

Four currents are displayed for each line, which shows the line name, begin node and end node as well. These currents are the real current (includes direction), reactive current (includes direction), the magnitude and the heating current. The sample case is shown below.
The number of trains currently positioned in the line is shown as $n_T$, where $n$ is the number of trains in that line. In this case it varies from 0 - 2.

Since the END Method of Current Analysis is used, Iterations and Accuracy are set to zero.

The real, reactive and magnitude of current don’t have any meaning for lines (tracks) with trains on them in the fixed circuit.

4.18.2.2 Current Analysis Line Results Active AC Circuit (END Method)

The Current Analysis Line Results Active Circuit is shown for the same snapshot in the next screen view.
The Begin and End Node of the active lines are shown in the table along with the Real Current and Current Magnitude together with the $I^2R$ Losses.

The nodes labeled Trn $n$ represent the node associated with the $n$’th train.

The second part of the screen is shown next.
The I – Square R Losses (kW) is the sum of all the line losses.
4.18.2.3 Current Analysis Nodal Results Active AC Circuit (END Method)

The next screen shows the nodal results.

This table shows the complex (real and reactive) Voltage (Drop), Current and Power associated with each node of the AC circuit.

Voltage (Drop) is the Node Voltage.
Current is the current injected into the node, positive for substation input and negative for train output.
Power is power injected into the node, positive for substation input and negative for train output.

Ideally, the current and power for all non-substation and non-train nodes should be zero; that they are non-zero is a measure of the accuracy.

The remainder of the table is shown in the next screen.
The real and reactive voltage at the \( n \text{th} \) train is at the node \( \text{Trn}_n \). In this case all feeder nodes have voltage of \( 2x \) because of the turns ratio. Currents into feeder nodes (substations) are also modified by the turns ratio.
4.18.2.4 RMS Current Summaries AC Circuit (END Method)

At the end of the Current Analysis Output file are the RMS Current Summaries. Clicking on the View RMS Currents command button on the File Viewer can easily get these. These are shown in the next screen.

![Current Analysis Output Screen View 5a: RMS Current Summaries Fixed AC Circuit](image)

The RMS Current is computed for the lines of the fixed circuit.
The $I^2R$ Energy is also displayed in this screen. This represents the cumulative AC Network losses due to the Primary or Return Circuit. Main Substation losses are not present here.

Clicking the EXCEL Ready command button produces the next screen.
Figure 4-102 Results of Executing the EXCEL Ready command button

The Clipboard now has information which can be pasted into an EXCEL Spreadsheet.

This sequence is an EXCEL compatible text, where the fields are separated by the tab character, so the sequence can be pasted directly into an EXCEL Spreadsheet.

The user is informed that the Clipboard now has this information which can be pasted into a table in an EXCEL Spreadsheet. This table has a useful format to be especially used in reports, which the user develops. More detail on the table formats are presented in Appendix 9.21, and specific information on this file is contained in Appendix 9.21.1.4.

Click the OK command button to delete the message.

4.18.3 Summary Current Analysis DC and AC Systems

In summary, DC Current Analysis uses the AO-Method when both a Primary and Return Circuit are present. In this method, the substations and trains act as current generators, the currents being determined by the Current Measurement Output file (AO-*.* ) of the ENS or TMS.

In all other cases for DC Current Analysis and all AC Current Analysis the END Method is used since the ENS or TMS runs use the Loop Method or the Simplified Loop Method.

There is one caution when using the END Method for Current Analysis. The END-file (Detailed Output file) must be obtained by running TOM Version 3.6.1 and higher. If this is not the case, the User is informed.
4.18.4 Circuit Current Analyzer Summary

The FMM Circuit Current Analyzer Summary is an output file, which produces summary material for each snapshot in either the Primary or Return Circuit Current Analysis Output file.

For each snapshot, the summary contains the following items.

**Snapshot Time**  hh:mm:ss.ss format

**Number of Iterations**  Actual number of iterations to convergence.

**Actual Accuracy**  The actual convergence accuracy achieved for the snapshot.

**I Square R Losses**  The sum of line losses for the active circuit for the snapshot.

**Real Current Items**
- Input into the circuit whether from substations or trains.
- Output from the circuit whether to substations or trains
- Current Balance in Amps ([Output] - [Input])
- Current Balance in (%) \{Current Balance/[.5*(|Output| + |Input|)]\}

**Reactive Current Items**
- Input into the circuit whether from substations or trains.
- Output from the circuit whether to substations or trains
- Current Balance in Amps ([Output] - [Input])
- Current Balance in (%) \{Current Balance/[.5*(|Output| + |Input|)]\}

On the FMM – Current Analyzer screen, select a Current Analysis Output file from the Current Analysis Output file list box.
Click the **Analyze One** command button to obtain the next screen of the **File Viewer**.
Scrolling to the bottom of the screen presents the next view.

This is the same material that appears at the end of the Circuit Current Analysis Output file.
4.18.5 Line Name Translated RMS Current Summary

The **Translate One** command button translates the line names of the RMS portion of the **Circuit Current Output** file selected in the list box to the left. It produces an output file of the form `RMSCUR$RCA*.*` or `RMSCUR$PCA*.*` depending on whether the **Circuit Current Output** file is from a Return or Primary Circuit.

![Figure 4-106 Current Analyzer Screen with Selections Made](image)

Clicking the **Translate One** command button produces the next screen in the **TOM File Viewer**.
4.18.6 Converter Current and Current Measurement Analyzers

The Converter Current Analyzer and the Current Measurement Analyzer use the same screen to accomplish their tasks. In one case, the maximum and minimum absolute currents and the times of occurrence as well as the average and RMS absolute currents are determined for the converters on the system, while in the second case, these same currents are determined for the current measurement points on the system.

Begin with the Current Analyzer screen of the FMM.
Figure 4-108 File Manipulation Module – Current Analyzer.

The **Current Measurement** command button provides a summary analysis for the fixed current measurement points on the system. The **Converters** command button provides the gate for the summary analysis of converter currents.

The **Line Current** command button is used to provide a summary analysis of all line currents on the system. This is discussed in the next section.

Click on the **Current Measurement** command button to expose the next screen.
Figure 4-109 File Manipulation Model – Current Measurement Analyzer

The command button Converter Current Analyzer will expose the Converter Current Analyzer screen. Thus, the function of the command button is to toggle between the two screens. Thus clicking on the button exposes the next screen.
Although this screen is called the **Converter Current Analyzer** screen, three options are provided; namely, **Current Summary**, **Power Summary** and **Voltage Summary**. Any of these options may be selected.

Double clicking on a filename in the **Current Measurement Output** file list box on the left, or alternatively, clicking on the filename in the list box followed by a click on the **Select One** command button exposes the next screen.
Figure 4-111 File Manipulation Model – Converter Current Analyzer – After file Selection

Clicking the Create File command button results in the next screen.
In addition, when the Create File command button is clicked, the following sequence is put onto the Clipboard:

<table>
<thead>
<tr>
<th>Y0</th>
<th>00</th>
<th>5401.6</th>
<th>8:00:12</th>
<th>0.1</th>
<th>8:05:00</th>
<th>1127.2</th>
<th>1746.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y1</td>
<td>01</td>
<td>4306.6</td>
<td>8:02:33</td>
<td>0</td>
<td>8:05:00</td>
<td>1225.8</td>
<td>1659.1</td>
</tr>
<tr>
<td>Y2</td>
<td>02</td>
<td>6242.7</td>
<td>8:02:33</td>
<td>0</td>
<td>8:05:00</td>
<td>1397.9</td>
<td>2116.8</td>
</tr>
<tr>
<td>Y3</td>
<td>03</td>
<td>5369</td>
<td>8:00:12</td>
<td>0.1</td>
<td>8:05:00</td>
<td>894.1</td>
<td>1343.5</td>
</tr>
</tbody>
</table>
This sequence is an EXCEL compatible text, where the fields are separated by the tab character, so the sequence can be pasted directly into an EXCEL Spreadsheet.

The user is informed that the Clipboard now has this information which can be pasted into a table in an EXCEL Spreadsheet. This table has a useful format to be especially used in reports, which the user develops. More detail on the table formats are presented in Appendix 9.21, and specific information on this file is in Appendix 9.21.2.4.

Click the OK command button to delete the message.

4.18.6.1 Current Summary Option
If the Current Summary option was selected, the next screen follows:

```
<table>
<thead>
<tr>
<th>CONVERTER</th>
<th>RECOMMENDED CURRENT</th>
<th>MAXIMUM CURRENT</th>
<th>MINIMUM CURRENT</th>
<th>TIME</th>
<th>VALUE</th>
<th>CURRENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>C1</td>
<td>5.0E+01</td>
<td>5.0E+01</td>
<td>0.1</td>
<td>0.85</td>
<td>0.00</td>
<td>12.7</td>
</tr>
<tr>
<td>C2</td>
<td>6.5E+02</td>
<td>6.5E+02</td>
<td>6.5E+02</td>
<td>0.85</td>
<td>0.00</td>
<td>15.9</td>
</tr>
<tr>
<td>C3</td>
<td>5.0E+01</td>
<td>5.0E+01</td>
<td>5.0E+01</td>
<td>0.85</td>
<td>0.00</td>
<td>15.9</td>
</tr>
</tbody>
</table>

Figure 4-113 Results of Converter Current Analysis – Current Summary Option

The converter name, maximum and minimum current values and time of occurrence, and the average and RMS currents are shown. The values are for the DC side of the converter.

If it is desired to save the output, click the Save File As command button. The file will be saved as a Summary file of the type shown in the text box (SUMCASA0*,*).

4.18.6.2 Power Summary Option

If the Power Summary option was selected, the next screen follows:
737

4.18.6.3 Voltage Summary Option

If the **Voltage Summary** option was selected, the next screen follows:
Figure 4-115 Results of Converter Current Analysis – Voltage Summary Option

The converter name, maximum and minimum voltage value and time of occurrence, and the average and RMS voltages are shown. Note that RMS voltage doesn’t have any meaning, but has been included for completeness. The values are for the DC side of the converter.

If it is desired to save the output, click the Save File As command button. The file will be saved as a Summary file of the type shown in the text box (SUMVASAO*.*).

Clicking the Current Measurement Analyzer command button in the screen of Figure 4-110 or by clicking the Current Measurement command button in the screen of Figure 4-108 produces the next screen, which then can be used to do the current measurement analysis.
Figure 4-116 File Manipulation Model – Converter Current Analyzer – After file Selection
Clicking the Create File command button produces the next screen.
In addition, when the Create File command button is clicked, the following sequence is put onto the Clipboard:

<table>
<thead>
<tr>
<th>Test</th>
<th>Time</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
<th>Value 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>11</td>
<td>8:00:12</td>
<td>281.2</td>
<td>805:00</td>
<td>37.4</td>
<td>73</td>
</tr>
<tr>
<td>12</td>
<td>8:00:12</td>
<td>281.3</td>
<td>805:00</td>
<td>37.4</td>
<td>73.1</td>
</tr>
<tr>
<td>13</td>
<td>8:04:02</td>
<td>4287.1</td>
<td>805:00</td>
<td>453</td>
<td>863</td>
</tr>
<tr>
<td>14</td>
<td>8:00:58</td>
<td>4289.6</td>
<td>805:00</td>
<td>654.6</td>
<td>1214.9</td>
</tr>
<tr>
<td>15</td>
<td>8:02:29</td>
<td>6491.8</td>
<td>805:00</td>
<td>631.4</td>
<td>1436.5</td>
</tr>
<tr>
<td>16</td>
<td>8:02:33</td>
<td>5928.9</td>
<td>805:00</td>
<td>576.9</td>
<td>1331.6</td>
</tr>
<tr>
<td>17</td>
<td>8:00:13</td>
<td>7118.6</td>
<td>805:00</td>
<td>637.5</td>
<td>1262</td>
</tr>
</tbody>
</table>

This sequence is an EXCEL compatible text, where the fields are separated by the tab character, so the sequence can be pasted directly into an EXCEL Spreadsheet.

The user is informed that the Clipboard now has this information which can be pasted into a table in an EXCEL Spreadsheet. This table has a useful format to be especially used in reports, which the user develops. More detail on the table formats are presented in Appendix 9.21, and specific information on this file is in Appendix 9.21.2.5.
Click the OK command button to delete the message.

Figure 4-118 Results of Current Measurement Analysis

The current measurement position name, maximum and minimum current value and time of occurrence, and the average and RMS currents are shown.

If it is desired to save the output, click the Save File As command button. The file will be saved as a Summary file of the type shown in the text box (SUMM$AO*.*).

4.18.7 Line Current Analyzer

The Line Current Analyzer provides a summary analysis of current through every fixed line on the system. The maximum and minimum heating currents and the times of occurrence as well as the average and RMS heating currents are determined.

Heating current is used and represents the magnitude of the current on all lines on which trains do not run, including substation connections, bonds and feeders. On fixed lines on which trains do run, the heating current represents the heating effect and is not equal to the magnitude of the current. More information on current definitions appears here (click).

Begin with the Current Analyzer screen of the FMM.
Figure 4-119 File Manipulation Module – Current Analyzer.

The **Current Measurement** command button provides a summary analysis for the fixed current measurement points on the system. The **Converters** command button provides the gate for the summary analysis of converter currents.

The **Line Current** command button is used to provide a summary analysis of all line currents on the system.

Click on the **Line Current** command button to expose the next screen.
Figure 4-120 File Manipulation Model – Line Current Analyzer

Choose the type circuit in the Circuit Choice combo box. It can either be Return or Primary. Choosing results in the next screen.
Select a Return Circuit Current Analysis Output file by double-clicking on it or by clicking on it followed by clicking on the Select One command button. The file may be viewed by clicking on it and clicking the View One command button.

Selecting the file produces the next screen.
Figure 4-122 File Manipulation Model – Line Current Analyzer – Return Circuit Choice – Selecting a Current Analysis Output File

Click the Create File command button to produce the next screen
Figure 4-123 Query on Using TOM Assigned Line Names or Translated Line Names
Click the No command button to use the TOM Assigned Line Names.
In addition, when the Create File command button is clicked, the following sequence is put onto the Clipboard:

<table>
<thead>
<tr>
<th>Letter</th>
<th>Time</th>
<th>Current</th>
<th>Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>A0</td>
<td>8:00:12</td>
<td>14.9</td>
<td>29.1</td>
</tr>
<tr>
<td>B1</td>
<td>8:00:12</td>
<td>15.1</td>
<td>29.6</td>
</tr>
<tr>
<td>A1</td>
<td>8:04:02</td>
<td>438.9</td>
<td>843.5</td>
</tr>
<tr>
<td>B0</td>
<td>8:00:57</td>
<td>624.6</td>
<td>1139.6</td>
</tr>
<tr>
<td>A2</td>
<td>8:02:27</td>
<td>410.6</td>
<td>783.3</td>
</tr>
<tr>
<td>B2</td>
<td>8:02:33</td>
<td>410.6</td>
<td>783.3</td>
</tr>
<tr>
<td>A3</td>
<td>8:01:03</td>
<td>487.6</td>
<td>833.4</td>
</tr>
<tr>
<td>A5</td>
<td>8:03:24</td>
<td>6.5</td>
<td>11.1</td>
</tr>
<tr>
<td>B3</td>
<td>8:03:24</td>
<td>411.2</td>
<td>806.9</td>
</tr>
<tr>
<td>B5</td>
<td>8:03:24</td>
<td>6.9</td>
<td>11.7</td>
</tr>
<tr>
<td>S10</td>
<td>8:00:12</td>
<td>1150</td>
<td>1782.4</td>
</tr>
<tr>
<td>S00</td>
<td>8:00:12</td>
<td>1150</td>
<td>1782.4</td>
</tr>
<tr>
<td>S11</td>
<td>8:00:12</td>
<td>822.5</td>
<td>1617.1</td>
</tr>
<tr>
<td>S01</td>
<td>8:02:33</td>
<td>1255.3</td>
<td>1704.6</td>
</tr>
</tbody>
</table>

This sequence is an EXCEL compatible text, where the fields are separated by the tab character, so the sequence can be pasted directly into an EXCEL Spreadsheet.
The user is informed that the Clipboard now has this information which can be pasted into a table in an EXCEL Spreadsheet. This table has a useful format to be especially used in reports, which the user develops. More detail on the table formats are presented in Appendix 9.21, and specific information on this file is in Appendix 9.21.2.6.

Figure 4-125 Line Current Analysis Summary File With TOM Assigned Line Names

These files may be saved by clicking the Save File As command button.

The saved files have the form (SUMLSRC\*.*s) or (SUMLS\*\*.*), depending on whether the analyzed file was a return or primary circuit.
The second branch is to click the Yes command button in the Query of Figure 4-123.

In addition, when the **Create File** command button is clicked, the following sequence is put onto the **Clipboard**:
<table>
<thead>
<tr>
<th>Trk Line from Pos = -.1 to Pos = 0</th>
<th>Trk #</th>
<th>8:00:12</th>
<th>8:05:00</th>
<th>14.9</th>
<th>29.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trk Line from Pos = -.1 to Pos = 0</td>
<td>Trk # 2</td>
<td>8:00:12</td>
<td>8:05:00</td>
<td>15.1</td>
<td>29.6</td>
</tr>
<tr>
<td>Trk Line from Pos = 0 to Pos = 1</td>
<td>Trk # 1</td>
<td>8:04:02</td>
<td>8:05:00</td>
<td>438.9</td>
<td>843.5</td>
</tr>
<tr>
<td>Trk Line from Pos = 0 to Pos = 1</td>
<td>Trk # 2</td>
<td>8:00:57</td>
<td>8:05:00</td>
<td>624.6</td>
<td>1139.6</td>
</tr>
<tr>
<td>Trk Line from Pos = 1 to Pos = 2</td>
<td>Trk # 1</td>
<td>8:02:27</td>
<td>8:05:00</td>
<td>528.3</td>
<td>1025.7</td>
</tr>
<tr>
<td>Trk Line from Pos = 1 to Pos = 2</td>
<td>Trk # 2</td>
<td>8:02:33</td>
<td>8:05:00</td>
<td>410.6</td>
<td>783.3</td>
</tr>
<tr>
<td>Trk Line from Pos = 2 to Pos = 3</td>
<td>Trk # 1</td>
<td>8:01:03</td>
<td>8:05:00</td>
<td>487.6</td>
<td>833.4</td>
</tr>
<tr>
<td>Trk Line from Pos = 2 to Pos = 3</td>
<td>Trk # 2</td>
<td>8:02:33</td>
<td>8:05:00</td>
<td>698.5</td>
<td>1170.4</td>
</tr>
<tr>
<td>Trk Line from Pos = 3 to Pos = 3.1</td>
<td>Trk # 1</td>
<td>8:03:24</td>
<td>8:05:00</td>
<td>6.5</td>
<td>11.1</td>
</tr>
<tr>
<td>Trk Line from Pos = 3 to Pos = 3.1</td>
<td>Trk # 2</td>
<td>8:03:24</td>
<td>8:05:00</td>
<td>6.9</td>
<td>11.7</td>
</tr>
<tr>
<td>Bond Line from Trk # 1 to Trk # 2 Pos = -.1</td>
<td>113</td>
<td>8:00:12</td>
<td>8:05:00</td>
<td>14.9</td>
<td>29.3</td>
</tr>
<tr>
<td>Bond Line from Trk # 1 to Trk # 2 Pos = 0</td>
<td>5427</td>
<td>8:00:12</td>
<td>8:05:00</td>
<td>1150</td>
<td>1782.4</td>
</tr>
<tr>
<td>Bond Line from Trk # 1 to Trk # 2 Pos = 0</td>
<td>6247</td>
<td>8:00:12</td>
<td>8:05:00</td>
<td>822.5</td>
<td>1617.1</td>
</tr>
<tr>
<td>Bond Line from Trk # 1 to Trk # 2 Pos = 1</td>
<td>4472</td>
<td>8:02:33</td>
<td>8:05:00</td>
<td>1255.3</td>
<td>1704.6</td>
</tr>
<tr>
<td>Bond Line from Trk # 1 to Trk # 2 Pos = 1</td>
<td>3705</td>
<td>8:00:58</td>
<td>8:05:00</td>
<td>698.5</td>
<td>1170.4</td>
</tr>
<tr>
<td>Bond Line from Trk # 1 to Trk # 2 Pos = 2</td>
<td>6486</td>
<td>8:02:33</td>
<td>8:05:00</td>
<td>1423.8</td>
<td>2161.9</td>
</tr>
<tr>
<td>Bond Line from Trk # 1 to Trk # 2 Pos = 2</td>
<td>5065</td>
<td>8:03:24</td>
<td>8:05:00</td>
<td>771.2</td>
<td>1446.4</td>
</tr>
<tr>
<td>Bond Line from Trk # 1 to Trk # 2 Pos = 3</td>
<td>5390</td>
<td>8:00:12</td>
<td>8:05:00</td>
<td>906.5</td>
<td>1362.9</td>
</tr>
<tr>
<td>Bond Line from Trk # 1 to Trk # 2 Pos = 3</td>
<td>2494</td>
<td>8:03:24</td>
<td>8:05:00</td>
<td>369.3</td>
<td>626.3</td>
</tr>
<tr>
<td>Bond Line from Trk # 1 to Trk # 2 Pos = 3.1</td>
<td>45</td>
<td>8:03:24</td>
<td>8:05:00</td>
<td>6.8</td>
<td>11.4</td>
</tr>
</tbody>
</table>

This sequence is an **EXCEL** compatible text, where the fields are separated by the tab character, so the sequence can be pasted directly into an **EXCEL Spreadsheet**.

The user is informed that the **Clipboard** now has this information which can be pasted into a table in an **EXCEL Spreadsheet**. This table has a useful format to be especially used in reports, which the user develops. More detail on the table formats are presented in Appendix 9.21, and specific information on this file is in Appendix 9.21.2.6. This information in the **Translated Line Names** is more transparent to the user.

The next screen shows the **File Viewer** with the same information:
Figure 4-127 Line Current Analysis Summary File With Translated Line Names

These line names are more transparent, since they place the line on the circuit.
4.19 VOLTAGE AVERAGER

The Voltage Averager Process is a way of making the running of the TPS and ENS dependent on each other. Through a voltage averaging process, voltages for traction are made dependent on minimum voltage seen in the distribution network. Thus the voltage seen by the train is dependent on the power drawn by that train. This is a method which simulates reality better than making train voltage independent of power drawn. However, it is a less conservative approach to power system evaluation. The average voltage, which results from this process is termed a self-consistent average voltage.

At the present time, the TOM does not have the capability of using the actual line voltage to determine the performance of the train. Computationally, this is an iterative procedure in which the train performance is adjusted with the line voltage until the line voltage and voltage at which the performance is calculated are the same.

As mentioned previously, this is a time consuming procedure. It must begin when the first train leaves the terminal according to the timetable, since the positions of all trains on the line cannot be determined beforehand as is presently done with the TOM. The procedure proceeds as follows:
Initially guess that all trains on the line have open circuit voltage.
Run a partial TPS on every train on the system given their voltage, position and speed, determine the traction effort necessary to advance them one increment in time, subject to the wayside conditions (grade, curve, speed restriction or command, route).
Use traction efficiencies for each train to determine the power at the line.
Run a partial ENS to determine voltages at all of the trains.
Do these voltages agree with the previous voltages used for the TPS.
If all voltages agree, within some level of accuracy go to 7, if not go to 2.
Determine all salient powers, currents and voltages.
Increase time by one increment.
If the end time is reached go to 9, if not go to 1.
Summarize and quit.

Since the procedure is extremely time consuming, many scenarios cannot be tried for a fixed time interval. As computer speed increases in the future, this will become less true.

The alternate way around this is to use the present method of running the TPS and ENS separately, and making the assumption that the major portion of the voltage drop on the line comes from the train drawing the power. This assumption will allow the use of performance in which the line voltage varies inversely as the power drawn or given to the line. This capability is built into the propulsion model of the TOM.

The Voltage Averager procedure proceeds as follows. Initially
Guess that all trains on the line have a nominal voltage.
Build a Train file using the Electric Propulsion Model built into the TOM. (In the FCM - Train File Input – Main Screen, choose Propulsion System Type as Electric – Model)(Note: More detail about the procedure is given in Section 3.1.3.4.)
Build the remaining input files for TPS input for all trains on the system and then run a full TPS on every train on the system
The output Power Profiles (P-Files) are added to the remaining input files in the ENS File of Filenames and the ENS is conducted.

The next part of the procedure is taken up by the Voltage Averager and the following steps are conducted in the procedure.
Iteration = 0.
Using the ENS File of Filenames file, determine the Train file and Detailed Propulsion Output file, which was generated by the initial part of the procedure.

Re-compute a new Train file, where the Nominal Voltage entry is the Unit Voltage (Open Circuit Voltage) entry in the Network file of the ENS File of Filenames file.

Using the TPS File of Filenames files, generated in the initial portion, re-run the TPS for all trains on the system.

Using the same ENS File of Filenames file, rerun the ENS.

Find the Minimum Voltage on System using the FMM – Minimum Voltage Finder procedure.

Create a new Train file, where Nominal Voltage is still the Open Circuit Voltage, and the Minimum Voltage is the Minimum Voltage on System.

Check that Previous Minimum Voltage on System = Present Minimum Voltage on System.

If 12. is true then quit the process. Convergence was obtained.

If 12. is false then Iteration = Iteration + 1 and go to 8.

Note that in this process, files will be overwritten. The user is given a chance to preserve them, either by archiving the whole directory ahead of the ongoing procedure or by otherwise restoring them later.

Begin with the Voltage Averager screen of the FMM.
The first step in the process is to select an ENS File of Filenames file.
Figure 4-129 FMM – Voltage Averager Screen – After Selection

The overwrite warning appears warning the user so that he may take precautions.

Assuming precautions were taken, click the **Yes** command button.
Figure 4-130 FMM – Voltage Averager Screen – Selection Made

To complete the iteration process one step at a time click the **Process** command button. To do the complete iteration process, click the **Auto Process** command button. For illustrative purposes, the **Process** command button is clicked.
This text box shows the results of Average Voltage processing by displaying the appropriate voltages for each step. Convergence is obtained when all voltages of two successive steps are equal. These voltages are:

- **Open Circuit Voltage** – Determined from the Network file in the ENS File of Filenames file.
- **Train Minimum Voltage** – Minimum train voltage determined after performing ENS with the new Power Profiles (P-Files).


Clicking the Continue Process command button will complete Iteration 1.

Figure 4-132 FMM Voltage Averager – Iteration 1
The process may be competed at any time by clicking the **Quit Process** command button. This produces the next screen.

![Voltage Averager](image)

**Figure 4-133 Information Message – EXCEL Type Information on Clipboard from Voltage Averager**

In addition, when the **Create File** command button is clicked, the following sequence is put onto the **Clipboard**:

```
0  750  562  750  541  
1  750  541  750  574  
```

This sequence is an EXCEL compatible text, where the fields are separated by the tab character, so the sequence can be pasted directly into an **EXCEL Spreadsheet**.
The user is informed that the **Clipboard** now has this information which can be pasted into a table in an **EXCEL Spreadsheet**. This table has a useful format to be especially used in reports, which the user develops. More detail on the table formats are presented in Appendix 9.21, and specific information on this file is in Appendix 9.21.2.7.

![Figure 4-134 Voltage Averager Results in File Viewer](image)

The full convergence process is initiated by clicking the **Auto Process** command button. Reset the screen first.
Figure 4-135 Voltage Averager – Full Convergence Process Running After Iteration 2

After convergence is complete, the next screen is shown.
Figure 4-136 Information Message – EXCEL Type Information on Clipboard from Voltage Averager Using Auto-Processing

Clicking the OK command button results in the next screen.
What is important here is the new minimum voltage.

4.20 AUTO OFFSET PROCESS

The Auto Offset Process allows the user to automatically change the offset (point where trains moving in opposite directions pass each other) in two track systems. This process is extremely useful for finding points of low voltage, where trains run differently than their advertised schedule. It is also useful for finding schedules which tend to save more energy when trains regenerate.

In order to perform this automatic process with the TOM, the following conditions must be met:

It must be a two track system, one track for trains moving in the positive direction and the other for trains moving in the negative direction.
There must be two and only two types of trains, one moving in the positive direction and the other in the negative direction. [The process will work for more than a two track system with more than two type trains. It offsets the trains moving in the negative direction from those in the positive direction.]
The trains must be on a headway, which is the same in both directions. The headway may be an average headway rather than a fixed headway. The cycle time is the time in which the sequence of headways, which constitute the average, completes. For a two track system on fixed headway, the cycle time is the fixed headway.
It is recommended that the timetable be set up so that the system is fully loaded with trains during twice the cycle time. The process does work during transients, but the interpretation of the results could be misleading.

A click on the Auto Offset Process command button in the FMM Main screen after rail system selection of Figure 4-2 displays the Auto Offset Process screen.

* For example, trains running in the headway sequence (1 min, 1 min, 9 min, 9 min) have an average headway of 5 min with a cycle time of 20 min. The symbol used for this designation is [1x2/9x2 Stagger].
Figure 4-138 Initial Configuration of Auto Offset Process Screen

Select an ENS File of Filenames by a double click or by a single click on the file list box followed by a click on the Select command button.
Figure 4-139 Auto Offset Process Screen - Selection of File of filenames

The Parameters frame contains the following items, some of which are grayed, indicating that they cannot be changed.

Run Time (sec) of both trains, from terminal to terminal.
Cycle Time (sec) – Time to repeat a given headway sequence. If the system has fixed headway, the cycle time is equivalent to the fixed headway. (This is the case in the above screen.)
Offset (sec) – Time between trains passing a fixed point and moving in opposing directions. This is the offset as the original ENS File of Filenames was executed by the ENS.
Simulation Time (sec) – The time from the start to end of the simulation as specified by the Operating Time (OP-) file. This must be equal to the cycle time if results are to be meaningful.
In addition, the Parameter frame provides the instructions for conducting the offset process. It constitutes:

**Offset Begin (sec)** – The beginning point of the process. (Default 0)

**Offset Step (sec)** – The step size. (Default 1 sec)

**Offset End (sec)** – The end point of the process (Default 1 HW)

The user can select these numbers.

Figure 4-140 Auto Offset Process Screen – Completion of Input Parameters

After all of the parameters have been entered, click the **Begin Process** command button to initiate the offset process.
The Run Monitor frame keeps track of the progress of the run, since some of these can be very long.

It contains the following items:

- **Present Offset (sec)** – The offset being presently calculated.
- **Number to Calculate** – The total number of offsets to be calculated.
- **Number Calculated** – The number already calculated.
- **Present Time** – Computer time at beginning of present calculation.
- **Completion Time** – Prediction of the completion time.

Click the Yes command button:
Click the **OK** command button on the dialogue to produce the next screen.
Figure 4-143 Results for the Auto Offset Process

This report consists of the following items.

For each offset point

- Metered kW, kVAR and KVA
- Power Factor (Overall)
- Losses AC, DC, Converter and Total
- Energy Balance
- Number of non-convergent snapshots in ENS run
- Minimum Train Voltage information (Value, Position, Track Number and Train ID)

Summary Information

- Maximum Voltage, kW, kVAR, kVA
- Minimum Voltage, kW, kVAR, kVA
- Average Voltage, kW, kVAR, kVA

This report can be saved with the file name in the Save File As text box.

The report resides on the clipboard and can be pasted directly into EXCEL.

Since the ENS runs had non-convergent snapshots, no information is available on these snapshots. The user should go back to run the ENS at this offset value to determine the problem. The Train ID NCON indicates that the ENS run was non-convergent and the number of non-convergent snapshots is given.

The Merge Offset Runs command button of Figure 4-140 produces the next screen.
The purpose of the **Merged Auto Offset Process Results Files** process is to combine the **Auto Offset Process Results Files** into one file, which is also an **Auto Offset Process Results File**. There are two reasons for this process.

Because the **Auto Offset Process** can take a long time on larger rail systems, it is sometimes convenient to apply it partially and then combine the results into one file.

It is sometimes desirable to carry out a process on a rail system in large time steps, examine the results of these steps and pick small ranges where a desired parameter (**Minimum Voltage** or **Minimum kWh**) is suspected in order to do a reduced time step in these ranges.

The file list box at the left of the screen contains the file names of **Auto Offset Process Results Files**. Click on the file name and then click on the **View One** command button to view the file in the **File Viewer**. Click on the **Delete One** command button to delete the highlighted file after verification of the desire to delete.

The file list box in the center of the screen contains the file names of **Auto Offset Process Results Files Available**. Click on the file name and then click on the **View One** command button to view the file in the **File Viewer**. Click on the **Select One** command button to select the highlighted file. Double clicking on the file also selects it. This results in the following screen:

---

**Figure 4-144 Merged Auto Offset Process Results Screen**

The purpose of the **Merged Auto Offset Process Results Files** process is to combine the **Auto Offset Process Results Files** into one file, which is also an **Auto Offset Process Results File**. There are two reasons for this process.

Because the **Auto Offset Process** can take a long time on larger rail systems, it is sometimes convenient to apply it partially and then combine the results into one file.

It is sometimes desirable to carry out a process on a rail system in large time steps, examine the results of these steps and pick small ranges where a desired parameter (**Minimum Voltage** or **Minimum kWh**) is suspected in order to do a reduced time step in these ranges.

The file list box at the left of the screen contains the file names of **Auto Offset Process Results Files**. Click on the file name and then click on the **View One** command button to view the file in the **File Viewer**. Click on the **Delete One** command button to delete the highlighted file after verification of the desire to delete.

The file list box in the center of the screen contains the file names of **Auto Offset Process Results Files Available**. Click on the file name and then click on the **View One** command button to view the file in the **File Viewer**. Click on the **Select One** command button to select the highlighted file. Double clicking on the file also selects it. This results in the following screen:
Double clicking subsequent files in the Auto Offset Process Results Files Available file list box, will place that file into the Auto Offset Process Results Files to Merge list box. These are the files, which will be merged, with a click on the Create File command button.

The Minimum, Step and Maximum text boxes in the frame keep track of the range, which will be incorporated into the new merged Auto Offset Process Results file, when it is created.

Double clicking on a file name in the Auto Offset Process Results Files to Merge list box will remove it from the box and readjust the range.

The next screen shows a completed (ready for merger) Auto Offset Process Results Files to Merge list box.
Figure 4-146 Merged Auto Offset Process Results Screen – Ready for Merging

The Merged File Caption is automatically created and revised as file names are added to the Auto Offset Process Results Files to Merge list box. It accomplishes this task by adding

;OFFSET[Min:Value;Step:Value;Max:Value]

to the end of the basic file caption (without the offset). Value can either take on the actual offsets in seconds or in case of the Step, VARIABLE, if there is no common step size. It is recommended that the user accept this caption.

Click the Create File command button to effect the merger process, resulting in the next screen.
Click the Yes command button to review the file.

Figure 4-147 Merged Auto Offset Process Results Screen – Merged

Figure 4-148 Merged Auto Offset Process Results Screen – Merged – Paste to EXCEL Information Message
Clicking the OK command button, shows the next screen.

Figure 4-149 File View of the Merged File Scroll Top
And scrolling down to the bottom:

Figure 4-150 File View of the Merged File Scroll Bottom
4.21 **AUTO SUB OUT PROCESS**

The **Auto Sub Out Process** allows the user to remove substations from service, one at a time, for as many substations he wishes to remove. This process is only valid for **DC Distribution** systems, where substations are converters.

A click on the **Auto Sub Out Process** command button in the **FMM Main** screen after rail system selection of Figure 4-2 displays the **Auto Substation Out Process** screen.

![Figure 4-151 Initial Configuration of the Auto Substation Out (of Service) Screen](image)

Select an **ENS File of Filenames** by a double click or by a single click on the file list box followed by a click on the **Select** command button.
At this point, highlight the substations to be included in the process using the mouse.
Figure 4-153 Auto Substation Out Screen Substations Highlighted

Click the Begin Process command button to initiate the process. After the process has completed, the following screen appears.
During the process, which could take a long time, the Run Monitor frame keeps track of progress. It displays and updates the following information:

**Present Substation Out** – The present substation out of service.

**Number to Calculate** – Number of ENS runs to be conducted with each substation out of service including the run with all substations in service.

**Number Calculated** – Number of ENS runs already conducted.

**Present Time** – Present computer clock time.

**Completion Time** – Predicted completion time.

Click the Yes command button to display the results.
Figure 4-155 Summary of Results for the Auto Sub Out Process

This report consists of the following items.

For each substation out of service (including none)

- Metered kW, kVAR and KVA
- Power Factor (Overall)
- Losses AC, DC, Converter and Total
- Energy Balance
- Number of non-convergent snapshots in ENS run
- Minimum Train Voltage information (Value, Position, Track Number and Train ID)

Summary Information

- Maximum Voltage, kW, kVAR, kVA
- Minimum Voltage, kW, kVAR, kVA
- Average Voltage, kW, kVAR, kVA

The report resides on the clipboard and can be pasted directly into EXCEL.
4.22 AUTO RAIL VOLTAGE PROCESS

The Auto Rail Voltage Process permits the user to calculate maximum values of rail voltage for a given run scenario by variation of rail to ground leakage resistance and ground resistance over a range of values. This process will inform the user how sensitive the system under study is to the selection of these resistances.

A click on the Auto Rail Voltage Process command button in the FMM Main screen after rail system selection of Figure 4-2 displays the Auto Rail Voltage Process screen.

Figure 4-156 FMM Auto Rail Voltage Process Screen

A click on the RVM File of Filenames list box followed by a click on the View One command button displays the file in the File Viewer. A click on the Select One command button or a double click on the file in the list box leads to the next screen.
The **File of Filenames Files** frame contains the names of the three input files in the **RVM File of Filenames** file. These files will be used as input to the process.

The **Parameters** frame contains two text boxes: **Leakage Resistance** and **Ground Resistance**. The text boxes are shown with the default values of leakage resistances and ground resistances that will be used during the automated process. These will be varied by ground resistance by leakage resistance, which means that for each leakage resistance, the sequence of ground resistances will be calculated and displayed in that order. The maximum voltage is then a function of both variables and will be displayed in a table at the end of the process.

The user can enter a different sequence of values for these parameters in any order as shown in the next screen.
Click the Begin Process command button to initiate the run.
The Run Monitor frame keeps track of the progress of the run. Clicking the Yes command button produces the next screen.
Clicking the OK command button produces the next screen.
Figure 4-161 FMM Auto Rail Voltage Process Screen - File Viewer Display of Results

An example of a paste to EXCEL may look like the next screen.
## AUTO RAIL VOLTAGE PROCESS SUMMARY

<table>
<thead>
<tr>
<th>Leakage Resistance</th>
<th>Ground Resistance</th>
<th>Maximum Voltage</th>
<th>Occurrence Position</th>
<th>Track Number</th>
<th>Snapshot Time</th>
<th>Node</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>10</td>
<td>87.9</td>
<td>1</td>
<td>1</td>
<td>8:23:36</td>
<td>A3</td>
</tr>
<tr>
<td>1000</td>
<td>15</td>
<td>72</td>
<td>1</td>
<td>1</td>
<td>8:23:36</td>
<td>A3</td>
</tr>
<tr>
<td>1000</td>
<td>20</td>
<td>62.3</td>
<td>1</td>
<td>1</td>
<td>8:23:36</td>
<td>A3</td>
</tr>
<tr>
<td>1000</td>
<td>25</td>
<td>55.7</td>
<td>1</td>
<td>1</td>
<td>8:23:36</td>
<td>A3</td>
</tr>
<tr>
<td>1000</td>
<td>30</td>
<td>50.8</td>
<td>1</td>
<td>1</td>
<td>8:23:36</td>
<td>A3</td>
</tr>
<tr>
<td>1000</td>
<td>35</td>
<td>46.9</td>
<td>1</td>
<td>1</td>
<td>8:23:36</td>
<td>A3</td>
</tr>
<tr>
<td>500</td>
<td>10</td>
<td>63</td>
<td>1</td>
<td>1</td>
<td>8:23:35</td>
<td>A3</td>
</tr>
<tr>
<td>500</td>
<td>15</td>
<td>51.3</td>
<td>1</td>
<td>1</td>
<td>8:23:35</td>
<td>A3</td>
</tr>
<tr>
<td>500</td>
<td>20</td>
<td>44.4</td>
<td>1</td>
<td>1</td>
<td>8:23:35</td>
<td>A3</td>
</tr>
<tr>
<td>500</td>
<td>25</td>
<td>39.6</td>
<td>1</td>
<td>1</td>
<td>8:23:35</td>
<td>A3</td>
</tr>
<tr>
<td>500</td>
<td>30</td>
<td>36.1</td>
<td>1</td>
<td>1</td>
<td>8:23:35</td>
<td>A3</td>
</tr>
<tr>
<td>500</td>
<td>35</td>
<td>33.3</td>
<td>1</td>
<td>1</td>
<td>8:23:35</td>
<td>A3</td>
</tr>
<tr>
<td>200</td>
<td>10</td>
<td>40.3</td>
<td>1</td>
<td>1</td>
<td>8:23:33</td>
<td>A3</td>
</tr>
<tr>
<td>200</td>
<td>15</td>
<td>32.7</td>
<td>1</td>
<td>1</td>
<td>8:23:33</td>
<td>A3</td>
</tr>
<tr>
<td>200</td>
<td>20</td>
<td>28.2</td>
<td>1</td>
<td>1</td>
<td>8:23:33</td>
<td>A3</td>
</tr>
<tr>
<td>200</td>
<td>25</td>
<td>25.2</td>
<td>1</td>
<td>1</td>
<td>8:23:33</td>
<td>A3</td>
</tr>
<tr>
<td>200</td>
<td>30</td>
<td>22.9</td>
<td>1</td>
<td>1</td>
<td>8:23:33</td>
<td>A3</td>
</tr>
<tr>
<td>200</td>
<td>35</td>
<td>21.1</td>
<td>1</td>
<td>1</td>
<td>8:23:33</td>
<td>A3</td>
</tr>
</tbody>
</table>

Figure 4-162 FMM Auto Rail Voltage Process Screen - Paste into EXCEL Template
5 ENERGY COST MODULE

The Energy Cost Module (ECM) is a series of computer programs, which interact with the user to summarize and manipulate the meter load curves into the energy and power demand components of the energy use pattern. The energy use pattern and the power rate structure of a specific electric rail authority is the basis for the energy cost computation. The module is called by clicking on the ECM button of the TOM Main Screen in Figure 1-2. The following screen is the result.

![Energy Cost Module Main Screen](image)

Figure 5-1 ECM Main Screen

The Close button closes the screen. The Exit button closes the TOM.

A rail system is selected by double clicking on the desired system or by a single click on the system designator followed by a click on select. This results in the following screen.
Figure 5-2 ECM Main Screen After Rail System Selection

Pre-selection of the rail system TEST on the TOM main screen will result in this screen upon opening of the ECM main screen.

The two options of the ECM are now listed in the screen and can be selected by the user by checking the appropriate option.

Each of the options is discussed in the following sections.

5.1 COMPUTE ENERGY - DEMAND OPTION

A click on the Compute Energy - Demand option ECM Main Screen After Rail System Selection of Figure 5-1 allows the user to input a set of coincident meter load curves and summarize the meter readings over the stated demand intervals. The following screen is the result.
A list of energy-demand consolidation files in the database for the rail system selected is shown at the left, middle of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

Selection of the Name of File to be created or modified is at the left and bottom of the screen. This is edited in the usual window manner.

In the upper middle of the screen is a list of load curve files in the RSDB for the rail system selected. These are the Load Curves Available from which the energy - demand consolidation files are computed. To view any file, click on the file and then on the View One button. To select a file, click on the file and click on the Select One button. Alternatively, double click on the file to select it.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

To the right of the list of load curve files, there is a list of Meter Files Available for the rail system selected. The meter files are obtained from an integration of the load curves. The meter files contains a summary of the demands by meter. Note that the Meter file is an OUTPUT file of this procedure.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.
Double click on a file in the list selects it. Alternatively, click on the file and on the Select One button and the file is also selected. To view any file, click on the file and then on the View One button. The name of the file selected appears in the box below. This file will be output together with the energy-demand consolidation file.

Enter the demand interval (min.) in the Demand Interval box at the bottom left of the screen. This is the time interval over which the energy will be averaged to determine the demand. Values can vary from 15 – 60 minutes.

The File Caption is entered in the bottom two boxes. This caption is carried through the simulator or program and becomes part of the normal output. It is used to identify the run. An example of a completed screen is shown next.

The final action to create the file is taken by clicking on the Create button. The file is created and the user is given the option of viewing the file with a Yes or No button. Clicking on Yes will produce a TOM File View of the file. Clicking on No will close the file.

The Reset button completely resets the screen, starting from scratch. It is best used when problems arise and the user can no longer fix them. The Close button closes the program and returns the user to the ECM Main Screen after Rail System Selection of Figure 5-2.

5.2 CONSOLIDATE LOAD CURVES OPTION
A click on the Consolidate Load Curves option ECM Main Screen After Rail System Selection of Figure 5-2 allows the user to append load curves and consolidate them by only selecting those meters which are designated for consolidation (i.e., they belong to the same power company or some other reason for consolidation). The time span of the resulting appended coincident load curve is the union of the set of time spans from the individual load curves.

A click on this option produces the following screen.

![Figure 5-5 ECM Consolidate Load Curves Option](image)

A list of load curve files in the database for the rail system selected is shown at the left, middle of the screen. These files may be viewed, selected or deleted using the View One, Select One or Delete One buttons, respectively. Double clicking on the selection in the box will select that file as well.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

Selection of the Name of File to be created or modified is at the left and bottom of the screen. This is edited in the usual window manner.

In the upper middle of the screen is a list of load curve files in the RSDB for the rail system selected. These are the Load Curves Available from which the consolidated load curve file is computed. To view any file, click on the file and then on the View One button. To select a file, click on the file and click on the Select One button. Alternatively, double click on the file to select it.
A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

Below and to the right of the list of load curve files, there is a list of **Meter Consolidation Files Available** for the rail system selected. Double click on a file in the list selects it. Alternatively, click on the file and on the **Select One** button and the file is also selected. To view any file, click on the file and then on the **View One** button. The name of the file selected appears in the box below.

A click on a file name in the file list box followed by a short mouse movement over the file list box causes the caption of the file to be displayed in the tool tip text.

An example of a completed screen is shown next.

![Figure 5-6 ECM Consolidate Load Curves Option (Completed)](image)

**Figure 5-6 ECM Consolidate Load Curves Option (Completed)**

A **Caption** is automatically entered. This caption is the caption of the **Meter Consolidation** file. The caption may be edited in the usual manner.

The final action to create the file is taken by clicking on the **Create** button.
The file is created and the user is given the option of viewing the file with a Yes or No button. Clicking on Yes will produce a TOM File View of the file. Clicking on No will close the file.

The Reset button completely resets the screen, starting from scratch. It is best used when problems arise and the user can no longer fix them. The Close button closes the program and returns the user to the ECM Main Screen after Rail System Selection of Figure 5-2.
6 DATABASE UTILITY (DB)

The Database Utility (DB) is a series of computer programs, which interact with the user to access all of the files, which are readable by the modules and the simulators of the TOM. The utility is called by clicking on the DB button in the TOM Main Screen of Figure 1-2. The following screen is the result.

![DB Main Screen](image)

The user now has four choices: Select, Add, Delete, Re-create or View of Submodel Database.

Click on a rail system and the following screen appears.
Pre-selection of the rail system TEST on the TOM main screen will result in this screen upon opening of the DB main screen.

Briefly stated now, but to be discussed in more detail later, the functions of the four command buttons under the Rail System list box are as follows.

Select – The function is to select the directory and database for the highlighted Rail System.
Delete – The function is to delete the database and the files in the directory for the highlighted Rail System.
Add – The function is to add a new Rail System database and directory.
Re-Create – The function is to delete the files in the directory but keeping the database for the highlighted Rail System.
To display the screen of Figure 6-1 and thus access the **Submodel Database**, select “None” for the rail system on the TOM main screen in **Figure 1-2**.

The user is given additional choices; namely, **View Database** as well as **Review**: with five checkboxes.

The choices are now discussed in the following order:

- **View Database**
- **View Submodel Database**
- **Select**
- **Add**
- **Delete**
- **Review**

### 6.1 VIEW DATABASE CHOICE

A click on the **View Database** button in the **DB Main Screen After Rail System Selection** of Figure 6-2 produces the following screen.

![Figure 6-3 DB Table View Screen](image-url)
The filename and the path of the database are shown at the top left of the screen. Rail system databases for the TOM are always of the form `def-ext.mdb`, where `ext` is the file extension designated for the rail system. This database can also be viewed and manipulated with Microsoft Access™.

The bottom portion of the screen shows the table view of the database. Each record has three entries: **File Name**, **File Type** and **File Description**. The **File Name** refers to the name of a particular input or output file of the simulators and modules of the TOM, with their standard designations (i.e. `CU-*`.ext for curve files, `GR-*`.ext for grade files, etc.). The **File Type** refers to the standard TOM category for the file. The **File Description** is the **File Caption**, which was entered on the creation of the file.

The columns of the table can be varied in size by dragging the cursor over the top frame of the table, where the two vertical lines are. A particular record in the database is selected by clicking on it. A display of the **File Name** of the record selected appears in the box at the upper right label **File Name in Focus**.

The **Search File** text box at the top right of the screen is used for fast scrolling to the type of filenames in the database. Enter the first three characters of a filename in the database to activate a scroll to the area of theses files. The letters must be entered slowly, so that the scroll completes for each letter entered. This tool is a way to quickly find the area where the files, beginning with these characters are located in the database. Entering more than three characters will show a warning, followed by a resetting of the screen.

There are four buttons above the **File Name in Focus** box. These are **Help**, **Record View**, **Close** and **Exit**. A click on **Close** returns to the previous screen. A click on **Exit** closes the TOM. The **Help** and **Record View** buttons are discussed later.

Below the **File Name in Focus** box are four other buttons. These are **View File**, **Delete File**, **Modify File** and **DB Reconciler**. If the file selected in the table view is a file of filenames for input into one of the three simulators, there is an additional button, which appears in the grouping below the **File Name in Focus** box as is seen in the next screen.
Figure 6-4 DB Table View Screen / File of Filenames Selected

The additional button is the Run Simulator.

The following functional buttons will be discussed in the following sections.

Help
Record View
View File
Delete File
Modify File
Trace File
Run Simulator
DB Reconciler

6.1.1 Help

A click on the Help button of the DB Table View Screen of Figure 6-3 produces the following screen.
Figure 6-5 TOM File Viewer Screen of the Help File: help01.txt

This TOM File Viewer screen of the help file: help01.txt is different from the normal TOM File Viewer screens for other files. It provides an access to the on-line version of this Program Manual.

6.1.2 Record View

A click on the Record View button of the DB Table View Screen of Figure 6-3 produces the following screen.
This screen presents the database in a single record at a time mode. The Record View Control is used to navigate through the database.

|< Go to the beginning of the database.
|< Go to the previous record.
|> Go to the next record.
|> Go to the end of the database.

A click on Table View returns to the DB Table View Screen.

6.1.3 View File

A click on the View File button in the screens DB Single Record View Screen of Figure 6-6 or DB Table View Screen of Figure 6-3 produces the follow screen.
6.1.4 Delete File

Any of the files in the database can be deleted by clicking the **Delete** button for the **File Name in Focus**. A confirmation of the delete request is required.

6.1.5 Modify File

Several of the files, which have been created by the **FCM**, can be modified. Generally, if the **Modify File** button is present when the file is selected in the **DB Table View Screen** of Figure 6-3, the file can be modified. The process of modification leads back to the original screen from which the file was created, prompting an import of the file into that screen in which it can be modified.

An example of file modification can be seen by clicking on **Modify File** in the **DB Table View Screen** of Figure 6-3. As an example, the file **am-2x.tes** is the **File Name in Focus**. Clicking on the **Modify File** button leads to the next screen, which has an explanation of how to proceed with the modification.
Figure 6-8 Screen after Selection of Modify File for AM-2x.wma

The file has been imported into its creation screen and can be modified by editing.

6.1.6 Trace File

If an output file from one of the simulators (TPS, ENS or TMS) or the Rail Voltage Model is selected in the DB Table View Screen, the Modify File command button is replaced with a Trace File command button as shown in the next screen.
Figure 6-9 DB Table View Screen Selection of Output File with Trace File Command Button

A click on the Trace File command button will produce the following screen.
Figure 6-10 DB Table View Screen Selection of Output File After Click on Trace File Command Button

A click on the Yes command button in the File Result query produces the following screen.
Figure 6-11 File of Filenames Screen with the Selected File as Output File

In this case the output file selected was generated by a simulator, and in fact the ENS. If this current measurement file were generated by the TMS, the TMS File of Filenames screen would have appeared.

Power Profiles and Load Curves can both be outputs from simulators; namely, the TPS for Power Profiles and the ENS or TMS for Load Curves. But these files can also be generated from other processes.

Power Profiles can be generated by averaging, appending or clipping power profiles, while Load Curves can be generated by extending or consolidating load curves. Clicking the Trace File command button, while highlighting a file generated in these manners is illustrated.
Figure 6-12 DB Table View Screen Selection of Extended Load Curve File

Clicking the Trace File command button produces the following screen.
Thus, additional information is provided on the source of the extended load curve.

6.1.7 Run Simulator

A click on the Run Simulator button of the DB Table View Screen of Figure 6-4 when a file of filenames for a simulator has the focus runs the simulator. An example of a TPS run is shown in the next two screens.
Figure 6-14 DB Table View Screen / TPS File of Filenames Selected

A click on the Run Simulator button produces the following screen.
Thus any simulator (TPS, ENS or TMS) and Rail Voltage Model (RVM) can be run from the DB Table View Screen of Figure 6-3 by selecting the appropriate file of filenames for the simulator.

6.1.8 DB Reconciler

A click on the DB Reconciler button of the DB Table View Screen of Figure 6-3 shows a comparison of files that are in the table view of the database to files actually in the rail system database. If all of the files are created or modified using the modules of the TOM, they will exist in the database as well as the directory. If the files were imported into the directory by some other means or if the files are deleted using...
the Windows Explorer® or some other program external to the TOM, there will be a difference between directory and database.

Normally, a click on the DB Reconciler button produces something similar to the following screen.

![Figure 6-16 TOM File Viewer / Showing Normal DB Reconciler Results](image)

Since no files are listed, the database and the directory both display the same files and are in synchronization.

However, if some of the files in the directory are not in the database and some files in the database are not in the directory, clicking the DB Reconciler button produces the following screen.
In this case, there are four files in the directory (Dir) that are not accounted for in the database (DB). Likewise, there are five files accounted for in the DB that are not in the Dir.

Two command buttons, Reconcile and Auto Reconcile are also visible on the screen, with brief instructions.

Clicking one of these command buttons, either Reconcile or Auto Reconcile, will start a process, which will reconcile the Dir with the DB and visa versa. The Reconcile command button will conduct the process on one file at a time, whereas the Auto Reconcile command button executes the process on all of the files, which exist in either the Dir or the DB.

Files that are in the DB and not in the Dir may only be deleted from the DB. These cannot be added to the Dir, since they don’t exist. If the files are in an archive, they may be put into the Dir. They also can be re-created, if the process for re-creation is known.

Files that are in the Dir but not in the DB can be either added to the Dir or deleted from the Dir if no longer needed.

As mentioned, the process initiated by the Reconcile command button will work on only one of the files at a time. The process initiated by the Auto Reconcile button will work on the whole group of files in the category (Dir or DB).

The Auto Reconcile process is generally used when a group of files is dumped in the Dir from another location (either another computer or archive).

Examples of the processes are demonstrated in the next two sections.
6.1.8.1 Files in Dir but not in DB

If a file exists in the Dir but not in the DB, there are two options:

Add file to the DB.
Delete file from Dir.

Highlight the file and click the Reconcile command button to display the next screen.

Figure 6-18 Data Base Utility – Data Base and Directory Reconciler – File in Directory

If the file is no longer wanted, click the Delete command button, if the file is to be kept, click the Add to Database command button.

Performing either process produces the next screen.
Files in DB but not in Dir

Highlighting one of the files in the DB but not in the Dir and clicking the Reconcile command button produces the next screen.
In this case, the file is accounted for in the DB but does not exist in the Dir. Either the file can be removed from the DB or if the file is archived, it can be added to the Dir. Either action reconciles the DB and Dir. Clicking the Delete command button results in the following screen.

Figure 6-21 File Viewer Indication of Process Completion – Deleted File from Database

Note that the same result would appear if the DB Reconciler button of the DB Table View Screen of Figure 6-3 were clicked after an archived version of the missing file were placed in the Dir.
6.1.8.3 Auto Reconcile Command Button

A click on the Auto Reconcile command button, produces the following screen.

Figure 6-22 Auto Reconcile Process – Delete or Add Screen
Clicking the following command buttons and process produces the following results:

- **Delete from Directory** – Deletes all the files in the (Dir but not in DB)
- **Add to Database** – Adds all the files in the (Dir but not in DB) to DB
- **Delete from Database** – Deletes all the files in the (DB but not in the Dir) from DB.
- **Restore from Archive** – Adds all files to Dir, which are in DB.

In the end, the DB and Dir are reconciled.
6.2 **VIEW SUBMODEL DATABASE CHOICE**

A click on the View SubModel Database button of the DB Main screen of Figure 6-1 produces the next screen, which is a main screen.

6.2.1 DB Utility – Table View – Sub Model Database

![Figure 6-23 DB Main Screen / View SubModel Database Selection](image)

The Database Filename is **def-tom.mdb**. This file is in the Application directory, which defaults to ..\tom. All of the files contained in the database are also located in the Application directory.

The files listed in the database are of four general types:

- **TOM Reference Text** – This type of file can only be viewed. It cannot be modified or deleted from the directory. It can be deleted from the database, but not on this screen.
- **Model** - This type of file can be viewed, modified or deleted.
- **Car Library** - This type of file can only be viewed. It cannot be modified or deleted from the directory. It can be deleted from the database, but not on this screen.

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Screen Instruction Text - This type of file can only be viewed or deleted from the directory. It can be deleted from the database, but not on this screen. This file is modified in Notepad only, and can be done by viewing it and issuing the Copy to Notepad command in the TOM File Viewer.

Impedance Default – The impedance default permanent file, ImpDefPerm.txt, can only be viewed. It can be deleted from the database but not in this screen.

The naming convention is discussed in Appendix 9.2

A click on a file in the DB Main Screen / View Submodel Database Selection screen of Figure 6-23 produces the following screen.

In addition to being viewed, this file of the Model Type can be deleted or modified. A click on the Modify button produces the following screen.
Clicking OK to the note results in the next screen.

Since the motor is DC Series, a click on the **DC Series Motor** button will expose the motor model to be modified. This was illustrated in Section 3.6.

Similar procedures are used to modify the other **Model Type** files.
6.2.2 Database Utility – Sub Model Database File Adder

Clicking the Add File command button on the DB Utility - Table View screen, with the Sub Model Database loaded, as shown in Figure 6-23, exposes the next screen.

The File Type list box on the screen shows the four general types of files, previously discussed; namely, TOM Reference Text, Car Library, Screen Instruction Text, Model (Motor, Motor Control, Gear Unit) and Impedance Default. A click on one of the items in the list box produces the next screen.
The files in the Sub Model Database list box on the left of the screen lists the files of the type selected in the File Type list box on the right.

Select one of the files in the Sub Model Database list box by clicking on the file.
The following command buttons are described:

View File – The file is viewed in the TOM File Viewer. Double clicking on a file in the Model Database list box produces the same result.

Add File to Database – The file is added to the Sub Model Database.

Delete File in Database – The file is deleted from the Sub Model Database. Pressing the <Delete> key will also delete the file from the database. Note that the file is not deleted from the directory.

The remain command buttons on the screen have their usual meaning. These include Help, Reset, Close and Exit.
6.3 **SELECT CHOICE**

A click on one of the rail systems in the DB Main screen of Figure 6-1 followed by a click on the Select button or alternatively a double click on the rail system produces the following screen.

The following options are available to the user: TPS Files, ENS Files, TMS Files, ECM or RVM Files. The user selects one of the options by clicking on it.
TPS Files Option

Clicking on the TPS Files option produces the following screen.

![Database Utility - Main Screen](image)

Any of the choices of TPS input or output file selections are available to be viewed by the user.

The TPS input file types are: File of Filenames (Fnames), Control (Control), Train (Train), Station (Station), Grade (Grade), Curve (Curve), Speed Restriction (Spd Res), Speed Command (Spd Cmd), and Route (Route).
The TPS output file types are: Summary Output (Sum Out), Detailed Output (Det Out) and Power Profile (Pwr Pro).

Other file types associated with the TPS or its input files include:

**Propulsion Detail (Prop Det)**, which is produced as output when creating a Train file, with an Electric – Model Type Propulsion System (Section 3.1.3.4).

**Elevation (Elevation)**, which is constructed from a Grade file. (Section 4.1).

**Train Resistance (Trn Res)**, which is a table calculated in the Train Resistance Calculator and Converter. The Train Resistance Calculator and Converter can be accessed by clicking under the Help command button on the File Construction Module – Train Input File – Main Screen, which exposes the Train Resistor Calculator command button. A click on this button will expose the Train Resistance Calculator and Converter screen. (Section 3.1.3.1).

**Traction Curve (Trac Curve)**, which is the result of a process that fits a portion of the traction curve (either Tractive Effort vs Speed or Electrical Braking Effort vs Speed) to a sum of terms consisting of powers of the reciprocal of speed. The input is a Train file. (Section 4.4)

Double click on file type to select or alternatively click on file type to select followed by a click on the corresponding Select command button, under the selection. Selection of the file type is placed in the TPS Input text box above the list box.

Selection of one of these choices (Grade) gives the user the options shown on the following screen.
The files in the database are displayed in the box. The grade file is used as an example, however any of the input or output files of the TPS could have been selected here. The user has three choices at this point: View One, Copy Filenames or Delete One.

A click on one of the files followed by a click on View One produces the TOM File View of the file.
A click on the Copy Filenames command button will copy the list of filenames to the Clipboard to be pasted into some other application.

Likewise, a click on Delete One deletes the file. A warning is given to the user if a file is to be deleted so that the user may confirm deletion.

Clicking the Edit button, imports the file into the screen that originally created it. The file can then be modified.

Copying them to the Clipboard or to Notepad and editing them there can also modify files. This alternate procedure is provided for users, which have worked with earlier versions of the TOM [then known as the Energy Management Model (EMM)] and are more comfortable doing the FORTRAN format editing.

If this method of creating, modifying and deleting files is used, the database cannot be updated. Thus it is strongly advised to use the procedures in Sections 6.1.4, 6.1.5 and 6.2 or the particular modules FCM, FMM or ECM for file creation, editing and deleting. Clicking the Edit button will also result in the database being updated. These latter methods will always keep the database current with the directories.
Remaining Options

The remaining options of the DB Main Screen / Select Choice of Figure 6-32; namely, ENS Files, TMS Files, ECM Files and RVM Files are handled in the same manner as the TPS Files option. Only the main screen and the definition of the files are shown for each of the choices.

ENS Files

![ENS Files](Image)

Figure 6-34  DB Main Screen / Select Choice / ENS Option
The ENS input file types are: File of Filenames (Fnames), Network (Network), Operating Time (Op Time), and Current Measurement (Cur Meas). The power profiles associated with each train are also input files but these are generated by the TPS.

The Primary Circuit (Pri Cct) and Return Circuit (Rtn Cct) file types are not direct input into the ENS. These files are indirect input in the sense that they are used to generate the Network file, which is input to the ENS.

The ENS output file types are: Summary Output (Sum Out), Detailed Output (Det Out), Load Curve (Load Crv) and Current Measurement Output (Cur Out).

Other file types associated with the ENS or its input files include:

- Line Name Translator file (Line Name Trans), which is created building Circuit files and via the FMM Line Name Translator.
- Return Circuit Impedance file (Rtn Cct Imp), which is created using a Return Circuit file (Rtn Cct).
- Return Circuit Analysis Output file (Rtn Cur An Out), which is created using the FMM Current Analyzer.
- Primary Circuit Analysis Output file (Pri Cur An Out), which is created using the FMM Current Analyzer.
- Circuit Check file (Cct Chk), which is created from either a Primary or Return Circuit file (Pri Cct or Rtn Cct).
- Circuit Analysis Summary file (Cct An Sum Out), which is created using the FMM Current Analyzer.
- Admittance Matrix file (Adm Matrix), which is created from either a Primary or Return Circuit file (Pri Cct or Rtn Cct).
- Occupancy file (Occupancy), which is generated from a Current Measurement Output file (Cur Out).
- Converter Current Analysis Summary file (Conv Cur Sum), which is generated by the FMM Converter Current Analyzer.
- Current Measurement Analysis Summary file (Meas Cur Sum), which is generated by the FMM Current Measurement Analyzer.
- Line Current Analysis Summary file (Line Cur Sum), which is generated by the FMM Line Current Analyzer.
- Minimum Train Voltage Summary file (Min Trn Volt Sum), which is generated by the FMM Minimum Voltage Finder.
- Maximum Train Current Summary file (Max Trn Cur Sum), which is generated by the FMM Maximum Train Current Finder.
- Average Voltage Process Summary (Ave Volt Sum), which is generated by the FMM Voltage Averager.
- Auto Offset Process Results (Auto Ofst Proc), which is generated by the FMM Auto Offset Process.
- Auto Substation Out Process Results (Auto Sub Out Proc), which is generated by the FMM Auto Substation Out Process.

Double click on file type to select or alternatively click on file type to select followed by a click on the corresponding Select command button, under the selection. Selection of the file type is placed in the ENS Input text box above the list box.
TMS Files

![TMS File Types](image)

Figure 6-35 DB Main Screen / Select Choice / TMS Option

The TMS input file types are: File of Filenames (Fnames), Track Layout (TrkLayout), Network (Network), Operating Time (Op Time), Current Measurement (Cur Meas) and Station Description (Sta Dscrp).

The Primary Circuit (Pri Cct) and Return Circuit (Rtn Cct) file types are not direct input into the TMS. These files are indirect input in the sense that they are used to generate the Network file, which is input to the TMS.

The TMS output file types are: Summary Output (Sum Out), Detailed Output (Det Out), Load Curve (Load Crv), Current Measurement Output (Cur Out) and Alarm Output (Alarm Out).

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Other file types associated with the TMS or its input files include:

- **Line Name Translator** file (Line Name Trans), which is created building Circuit files and via the FMM Line Name Translator.
- **Return Circuit Impedance** file (Rtn Cct Imp), which is created using a Return Circuit file (Rtn Cct) Return Circuit Analysis Output file (Rtn Cur An Out), which is created using the FMM Current Analyzer.
- **Primary Circuit Analysis Output** file (Pri Cur An Out), which is created using the FMM Current Analyzer.
- **Circuit Check** file (Cct Chk), which is created from either a Primary or Return Circuit file (Pri Cct or Rtn Cct).
- **Circuit Analysis Summary** file (Cct An Sum Out), which is created using the FMM Current Analyzer. Admittance Matrix file (Adm Matrix), which is created from either a Primary or Return Circuit file (Pri Cct or Rtn Cct).
- **Occupancy** file (Occupancy), which is generated from a Current Measurement Output file (Cur Out).
- **Converter Current Analysis Summary** file (Conv Cur Sum), which is generated by the FMM Converter Current Analyzer.
- **Current Measurement Analysis Summary** file (Meas Cur Sum), which is generated by the FMM Current Measurement Analyzer.
- **Line Current Analysis Summary** file (Line Cur Sum), which is generated by the FMM Line Current Analyzer.
- **Minimum Train Voltage Summary** file (Min Trn Volt Sum), which is generated by the FMM Minimum Voltage Finder.
- **Maximum Train Current Summary** file (Max Trn Cur Sum), which is generated by the FMM Maximum Train Current Finder.
- **Average Voltage Process Summary** (Ave Volt Sum), which is generated by the FMM Voltage Averager.

Double click on file type to select or alternatively click on file type to select followed by a click on the corresponding Select command button, under the selection. Selection of the file type is placed in the TMS Input text box above the list box.
ECM Files

The ECM input file is just the Meter Consolidation (Mtr Cons). Output files are the Summary Output (Sum Out), the Meter Demand Output (Mtr Out) and the Load Curve (Load Crv).

Double click on file to be built or alternatively click on file to be built followed by a click on the corresponding Select button under the selection.
RVM Files

The RVM input file types are: File of Filenames (Fnames), Negative or Return Network (Neg Network), Return Circuit Rail Voltage (Rtn Cct RV) and Rail Voltage Table (RV Table).

The Current Measurement Output (Cur Out) file associated with the running of a single train is also an input file but is generated by the ENS or TMS. The Return Current Analysis Output (Rtn Cur An Out) file is also an input file, which is generated by the Current Analyzer program of the File Manipulation Module (FMM).
The RVM output file types are: Summary Output (Sum Out) and Detailed Output (Det Out).

There is more discussion of the use of all of these files in Section 8.2.

Other files associated with the RVM are:
- **Line Name Translator (Line Name Trans)**, which is generated by the FCM - Return Circuit Rail Voltage screen.
- **Auto Rail Voltage Process Results (Auto RV Process)**, which is generated by the FMM - Auto Rail Voltage Process.

Double click on file type to select or alternatively click on file type to select followed by a click on the corresponding Select command button, under the selection.

Selection of the file type is placed in the RVM Input text box above the list box.
6.4 **ADD CHOICE**

A click on the **Add** button of Figure 6-1 DB Main Screen produces the following screen.

![Figure 6-38 DB Main Screen / Add Choice](image)

Add the rail system mnemonic for the directory that is to be created in the **Add Mnemonic here**. The mnemonic is limited to **5 characters**. Add the rail system file extension identification for the directory that is to be created in the **Add File Extension** box. The file extension is limited to **3 characters**. Normal editing procedures can be used for both of these boxes.
The final action needed to add the rail system to the database is to click on the **Add Selection** button. An example is shown in the next screen.

![Database Utility - Main Screen](image)

**Figure 6-39 DB Main Screen / Add Choice / Add FAKE (mnemonic)**

Clicking the **Add Selection** command button produces the next screen.
Figure 6-40 Information Request on Unit Selection

There are three possibilities in selecting the units:

- Yes command button selects Metric
- No command button selects English
- Cancel command button selects both Metric and English

The only effect of a selection here is to allow automatic selection of units on the TOM Main Screen in Figure 1-2. So that selecting the Rail System on the main screen will automatically set the default units if the Yes or No command button was selected here.
The new directory as well as a database is added as soon as the Add Selection button is clicked. The database is the file def-fke.mdb, which resides in the new directory \tom\tomdat\fke. The result is the next screen.
Figure 6-41 DB Main Screen / Add Choice / FAKE Added
6.5 **DELETE CHOICE**

A click on a rail system results in the following screen.

A click on the **Delete** button produces the following screen.

Figure 6-42 DB Main Screen / FAKE Rail System Selected

A click on the **Delete** button produces the following screen.
Selection of the Yes button deletes the rail system. *Be Careful. It cannot be recovered at this point.* The next screen shows the result.
6.6 RE-CREATE CHOICE

The Re-Create choice will delete all of the files in the directory of the Rail System selected, but will not delete the database (Note that it will delete the filenames in the database). This is particularly useful when unzipping a previously zipped file containing different files related to the same Rail System.

Begin with the next screen.
A click on the **Re-Create** command button, produces the following screen.
Selection of the Yes button does not delete the rail system but it does delete the directory. Be Careful. It cannot be recovered at this point. The next screen shows the result.
The files have been deleted in the directory but the directory and the database (less the filenames) remains.
6.7 RAIL SYSTEM DIRECTORY

The Rail System Directory contains all of the files associated with the TOM. Another approach to viewing and deleting files in directory is shown in this section. Begin with the Database Utility - Main Screen.

![Database Utility - Main Screen](image)

The five checkboxes labeled TPS Files, ENS Files, TMS Files, ECM Files and RVM Files are gateways to the directory editor from the file perspective. Clicking on any of the checkboxes will expose list boxes which show the types of files associated with the simulators or modules. All procedures described for TPS
are repeated in all five of the gateway. The TPS is done in some detail, while the others are just highlighted.

6.7.1 TPS Files

Clicking on the TPS Files checkbox of Figure 6-48, leads to the next screen.

![Database Utility - Main Screen – TPS Checkbox Activated](image)

Any of the choices of TPS input or output file selections are available to be viewed by the user.
The **TPS** input file types are: File of Filenames (Fnames), Control (Control), Train (Train), Station (Station), Grade (Grade), Curve (Curve), Speed Restriction (Spd Res), Speed Command (Spd Cmd), and Route (Route).

The **TPS** output file types are: Summary Output (Sum Out), Detailed Output (Det Out) and Power Profile (Pwr Pro).

Other file types associated with the **TPS** or its input files include:

- **Propulsion Detail (Prop Det)**, which is produced as output when creating a **Train** file, with an **Electric – Model Type Propulsion System**. See Section 3.1.3.4.
- **Traction Curve Fit Results (Trac Curv)**, which is produced from a **Train** file, whose traction effort is fitted to a sum of powers of reciprocals of the speed. See Section 4.4.
- **Train Build (Trn Build)**, which is produced in the train building process. This file has the same name as the **Train** file created using the process, but instead of the leader T-, the leader is TB-. See Sections 3.1.3.2 and 3.1.3.2.2.1
- **Elevation (Elevation)**, which is constructed from a **Grade** file. See Section 4.1.
- **Train Resistance table (Trn Res)**, which is calculated from the **Train Resistance Calculator** and Converter. See Sections 3.1.3.1 and 3.1.3.1.6.
- **Ruling Grade (Rul Grd)**, which is output from the **Ruling Grade Determination** process. See Section 3.1.3.2.2.4.

Double click on file type to select or alternatively click on file type to select followed by a click on the corresponding Select command button, under the selection. Selection of the file type is placed in the **TPS** Input text box above the list box.

Double-click on **Grade** to produce the next screen.
Figure 6-50 Database Utility – File Viewer – Grade Files

This is a list of files of the type selected in the rail system selected in the database. Click on file to select it. To view a selected file, click on View. Double click on file also views the file. To delete a selected file, click on Delete.

This Copy Filenames command will copy the list of files in the box above and paste them on the clipboard. The list may be transferred to another application by executing the paste command in that application.
These procedures are valid for all directory files.

6.7.2 ENS Files

Clicking on the ENS Files checkbox of Figure 6-48, leads to the next screen.

![Figure 6-51 Database Utility - Main Screen – ENS Checkbox Activated](image)

The ENS input file types are: File of Filenames (Fnames), Network (Network), Operating Time (Op Time), and Current Measurement (Cur Meas). The power profiles associated with each train are also input files but these are generated by the TPS.
The Primary Circuit (Pri Cct), Return Circuit (Rtn Cct) and Return Circuit Impedance (Rtn Cct Imp) file types are not direct input into the ENS. These files are indirect input in the sense that they are used to generate the Network file, which is input to the ENS. See Section

The ENS output file types are: Summary Output (Sum Out), Detailed Output (Det Out), Load Curve (Load Crv) and Current Measurement Output (Cur Out).

Other file types associated with the ENS or its input files include:

- **Line Name Translator** file (Line Name Trans), which is created building Circuit files and via the FMM Line Name Translator.
- **Return Circuit Impedance** file (Rtn Cct Imp), which is created using a Return Circuit file (Rtn Cct).
- **Return Circuit Analysis Output** file (Rtn Cur An Out), which is created using the FMM Current Analyzer.
- **Primary Circuit Analysis Output** file (Pri Cur An Out), which is created using the FMM Current Analyzer.
- **Circuit Check** file (Cct Chk), which is created from either a Primary or Return Circuit file (Pri Cct or Rtn Cct).
- **Circuit Analysis Summary** file (Cct An Sum Out), which is created using the FMM Current Analyzer.
- **Admittance Matrix** file (Adm Matrix), which is created from either a Primary or Return Circuit file (Pri Cct or Rtn Cct).
- **Occupancy** file (Occupancy), which is generated from a Current Measurement Output file (Cur Out).
- **Converter Current Analysis Summary** file (Conv Cur Sum), which is generated by the FMM Converter Current Analyzer – Current Option.
- **Converter Power Analysis Summary** file (Conv Pwr Sum), which is generated by the FMM Converter Current Analyzer – Power Option.
- **Converter Voltage Analysis Summary** file (Conv Volt Sum), which is generated by the FMM Converter Current Analyzer – Voltage Option.
- **Current Measurement Analysis Summary** file (Meas Cur Sum), which is generated by the FMM Current Measurement Analyzer.
- **Line Current Analysis Summary** file (Line Cur Sum), which is generated by the FMM Line Current Analyzer.
- **Line Name Translated RMS Current Summary** file (Line Tran RMS Cur), which is generated by the Translate One command of the FMM Line Current Analyzer.
- **Minimum Train Voltage Summary** file (Min Trn Volt Sum), which is generated by the FMM Minimum Voltage Finder.
- **Maximum Train Current Summary** file (Max Trn Cur Sum), which is generated by the FMM Maximum Train Current Finder.
- **Average Voltage Process Summary** (Ave Volt Sum), which is generated by the FMM Voltage Averager.
- **Auto Offset Process Results** (Auto Ofst Proc), which is generated by the FMM Auto Offset Process.
- **Auto Substation Out Process Results** (Auto Sub Out Proc), which is generated by the FMM Auto Sub Out Process.

Double click on file type to select or alternatively click on file type to select followed by a click on the corresponding Select command button, under the selection. Selection of the file type is placed in the ENS Input text box above the list box.

The same procedures apply to the files here as previously indicated for TPS Files.
6.7.3 TMS Files

Clicking on the TMS Files checkbox of Figure 6-48, leads to the next screen.

The TMS input file types are: File of Filenames (Fnames), Track Layout (TrkLayout), Network (Network), Operating Time (Op Time), Current Measurement (Cur Meas) and Station Description (Sta Dscrp).
The Primary Circuit (Pri Cct) and Return Circuit (Rtn Cct) file types are not direct input into the TMS. These files are indirect input in the sense that they are used to generate the Network file, which is input to the TMS.

The TMS output file types are: Summary Output (Sum Out), Detailed Output (Det Out), Load Curve (Load Crv), Current Measurement Output (Cur Out) and Alarm Output (Alarm Out).

Other file types associated with the TMS or its input files include:

- **Line Name Translator** file (Line Name Trans), which is created building Circuit files and via the FMM Line Name Translator.
- **Return Circuit Impedance** file (Rtn Cct Imp), which is created using a Return Circuit file (Rtn Cct) Return Circuit Analysis Output file (Rtn Cur An Out), which is created using the FMM Current Analyzer.
- **Primary Circuit Analysis Output** file (Pri Cur An Out), which is created using the FMM Current Analyzer.
- **Circuit Check** file (Cct Chk), which is created from either a Primary or Return Circuit file (Pri Cct or Rtn Cct).
- **Circuit Analysis Summary** file (Cct An Sum Out), which is created using the FMM Current Analyzer.
- **Admittance Matrix** file (Adm Matrix), which is created from either a Primary or Return Circuit file (Pri Cct or Rtn Cct).
- **Occupancy** file (Occupancy), which is generated from a Current Measurement Output file (Cur Out).
- **Converter Current Analysis Summary** file (Conv Cur Sum), which is generated by the FMM Converter Current Analyzer – Current Option.
- **Converter Power Analysis Summary** file (Conv Pwr Sum), which is generated by the FMM Converter Current Analyzer – Power Option.
- **Converter Voltage Analysis Summary** file (Conv Cur Sum), which is generated by the FMM Converter Current Analyzer – Voltage Option.
- **Current Measurement Analysis Summary** file (Meas Cur Sum), which is generated by the FMM Current Measurement Analyzer.
- **Line Current Analysis Summary** file (Line Cur Sum), which is generated by the FMM Line Current Analyzer.
- **Line Name Translated RMS Current Summary** file (Line Tran RMS Cur), which is generated by the FMM Line Current Analyzer.
- **Minimum Train Voltage Summary** file (Min Trn Volt Sum), which is generated by the FMM Minimum Voltage Finder.
- **Maximum Train Current Summary** file (Max Trn Cur Sum), which is generated by the FMM Maximum Train Current Finder.
- **Average Voltage Process Summary** (Ave Volt Sum), which is generated by the FMM Voltage Averager.

Double click on file type to select or alternatively click on file type to select followed by a click on the corresponding Select command button, under the selection. Selection of the file type is placed in the TMS Input text box above the list box.

The same procedures apply to the files here as previously indicated for TPS Files.
6.7.4 ECM Files

Clicking on the ECM Files checkbox of Figure 6-48, leads to the next screen.

Figure 6-53 Database Utility - Main Screen – ECM Checkbox Activated

The ECM input file is just the Meter Consolidation (Mtr Cons). Output files are the Summary Output (Sum Out), the Meter Demand Output (Mtr Out) and the Load Curve (Load Crv).

Double click on file to be built or alternatively click on file to be built followed by a click on the corresponding Select button under the selection.
The same procedures apply to the files here as previously indicated for TPS Files.

6.7.5 RVM Files

Clicking on the RVM Files checkbox of Figure 6-48, leads to the next screen.

![Figure 6-54 Database Utility - Main Screen – RVM Checkbox Activated]

The RVM input file types are: File of Filenames (Fnames), Negative or Return Network (Neg Network), Return Circuit Rail Voltage (Rtn Cct RV) and Rail Voltage Table (RV Table).
Other files, which are output files from other processes, are used as input to or are associated with the RVM. Depending on whether the Old Method or New Method (See Section 3.4) for the RVM calculation, the following files are input.

**Old Method.** The Current Measurement Output (Cur Out) file associated with the running of a single train is also an input file but is generated by the ENS or TMS.

**New Method.** The Return Circuit Analysis Output file (Rtn Cur An Out), which is created using the FMM Current Analyzer.

**Line Name Translator** file (Line Name Trans), which is created building Circuit files and via the FMM Line Name Translator.

The RVM output file types are: Summary Output (Sum Out) and Detailed Output (Det Out).

In addition, the FMM Auto Rail Voltage Process, has an output file, which can be displayed by clicking the Auto RV Proc menu item.

Double click on file type to select or alternatively click on file type to select followed by a click on the corresponding Select command button, under the selection.

The same procedures apply to the files here as previously indicated for TPS Files.
7 GRAPHICS UTILITY (GRAPH)

The graphics utility (GRAPH) is a computer program, which interacts with the user to produce visual displays of inputs and outputs to the simulators and modules of the TOM. It is initiated by clicking on the GRAPH button of the TOM Main Screen shown in Figure 1-2 TOM Main Screen. The following screen appears.

A rail system is selected by double clicking on the desired system or by a single click on the system designator followed by a click on select. It could have also been set on the TOM Main Screen. This results in the following screen.
Pre-selection of the rail system TEST on the TOM Main Screen will result in this screen upon opening of the GRF main screen.

The graphics utility contains several types of graph categories as can be seen in the screen. Select one of the curves by clicking the mouse. There are several features of the graphics screen that can be explained once. This is done in the discussion of the Elevation option, which is next.

7.1 ELEVATION

An elevation curve is a plot of elevation as a function of position along the right of way. Clicking the mouse on the Elevation option in the GRAPH Main Screen after Rail System Selection of Figure 7-2 produces the following screen.
Figure 7-3 GRAPH Main Screen / Elevation Option

The user selects an elevation file from the Choose Elevation File list and a station file from the Choose Station File list. After these files are chosen, the following screen results.
Figure 7-4 GRAPH Main Screen / Elevation Option (Completed)

Graph scales can be set manually or automatically.

The user can set the coordinates of any of the graphs manually by specifying the minimum and maximum of the x and y-axes and the step size between tic marks for both axes. This is accomplished by clicking the **Set Scale** check box. The manual setting will be described later.

Automatic setting of the scales chooses the maximum and minimum of the (x, y) coordinates of the graph to set the scale. Step size is always one-tenth of the difference between maximum and minimum for each axis. Proceed with the automatic scale setting.

Clicking the **Complete Graph** command button produces the following screen.
Figure 7-5 Plot Screen Showing Elevation Plot with Automatic Scaling

The **Plot Screen** contains several menus, which include **File, Edit, View, State, Window** and **Help**. These menu items serve a variety of functions, which are now described.

- **File** - Includes the following items and functions related to peripherals:
  - **Exit** - Exits the program to the parent screen.

- **Edit** - Includes the standard windows editing functions of **Select All** and **Copy**.

- **View** - Includes the standard windows type views of **Size to Fit** and **Full Screen**, both of which are self-explanatory.

- **State, Window** and **Help** are grayed and have no function.

This graph can be copied to word using the following procedure. Click the **View** menu followed by a click on **Full Screen** item. The same procedure can be conducted by pressing the **<alt> Enter** key on the keyboard. Copy the screen and paste in **WORD** or any word processing program, adding a border format on the picture. The result can be something like the following.
There is also a zoom feature to the plot. Simply place the mouse at a desired initial position on the plot. Press the left mouse button down and holding it move the mouse to some final position releasing the mouse button. The mouse must always move from top to bottom and from left to right in tracing the track. The result is a zoomed version of the graph, which lies in the rectangle whose diagonal is determined by the initial and final points of the mouse. This plot is shown next.
Figure 7-7 Sample of Elevation Plot Zoom Feature

The printing and zooming features are just illustrated for the **Elevation** option, although they may be done for all of the plots. A second diagonal drag of the mouse across the screen results in the original graph, before it was zoomed.

The next demonstration is the manual setting of the graph scale. Begin with the Graphic Utility – Main Screen as shown in Figure 7-4. Click the **Set Scale** check box.
Figure 7-8 Graphics Utility – Set Graph Scale screen

The Graphic Utility – Set Graph Scale screen specifies the graph type. This is usually specified as the Y-Axis title and the X-Axis title. For example one specification may be Elevation (Y-Axis) vs. Position (X-Axis). There are other specifications.

The Y-Axis title or name in this case is Elevation. The X-Axis title or name in this case is Position.

There are six text boxes, to which the user can make entries. These entries refer to the minimum, step size and maximum for the x and y-axes.

There is a requirement that the step size divides the maximum less the minimum of the scale. In other words, the value \([\text{maximum of the scale} - \text{minimum of the scale}] / \text{step size}\) is an integer.

A Supplementary Title can also be added or modified here. The plotting routine names the graph and then adds this information along with the name to the graph.

Add the entries to the screen.
Click the \textit{Select} command button to obtain the next screen.

Click the \textit{Complete Graph} command button to obtain the next screen.
Figure 7-11 Plot Screen Showing Elevation Plot with Manual Scaling

This plot may also be tailored to produce the next figure.
Figure 7-12 Elevation Plot with Manual Scaling

All of the plots, which are now demonstrated, have the ability to be scaled automatically or manually.

7.2 **PROPULSION CURVES**

Four types of propulsion curves are provided by the graphics utility. Click on the Propulsion Curves option or the GRAPH Main Screen after Rail System Selection of Figure 7-2. These plots include those illustrated in the next screen.
The user selects one of the propulsion curves, which may be Tractive Effort Curves (tractive effort vs. speed), E. Braking Effort Curves (electrical braking effort vs. speed), Eff Curves in Power (propulsion efficiency in power) or Eff Curves in E. Brake (propulsion efficiency in electrical braking). He then selects a train file from which these curves will be determined and inputs a Supplementary Title for the plot.

Click the Complete Graph button and the graph is produced. Samples of the curves are shown in the following plots.
7.2.1 Tractive Effort Curve
A tractive effort curve is shown.

Figure 7-14 Tractive Effort Plot
The same printing and zoom procedure as outlined in Section 7.1 can be used here.

7.2.2 Electrical Braking Effort Curve
The electrical braking effort curve is shown next.
Figure 7-15 Electrical Braking Effort Plot

The same zoom procedure as outlined in Section 7.1 can be used here as well and in all of the graphs.
7.2.3 Power Efficiency Curves

The propulsion efficiency curves in power are shown next.

![Figure 7-16 Power Efficiency Curves Plot](image)

There are five lines in the plot. Each of the lines represents the efficiency as a certain fraction of full tractive effort.

The same zoom procedure as outlined in Section 7.1 can be used here as well.

7.2.4 Electrical Braking Efficiency Curves

The electrical braking efficiency curves are shown next.
There are five lines in the plot. Each of the lines represents the efficiency as a certain fraction of full electrical braking effort.

The same zoom procedure as outlined in Section 7.1 can be used here as well. Manual rather than automatic scaling may also be used.

### 7.3 TRAIN RESISTANCE CURVES

A train resistance curve is provided by the graphics utility. Click on the Trn Res Curve option on the GRAPH Main Screen after Rail System Selection of Figure 7-2. The resulting screen is shown next.
Choose a Train Resistance Table file by clicking on the file in the file text box in the middle of the screen. The result is the next screen.

Figure 7-18 Graphics Utility - Main Screen Train Resistance Curve Option

Figure 7-19 Graphics Utility - Main Screen Train Resistance Curve Option – File Chosen
Click the **Complete Graph** command button to complete the procedure and present it in a desirable format.

![Figure 7-20 Train Resistance Curve](image)

**7.4 TRAIN RUN RESULTS**

Five types of train running result curves are provided by the graphics utility. Click on the **Train Run Results** option or the **GRAPH Main Screen after Rail System Selection** of Figure 7-1.
These curves include Speed vs. Position, Power vs. Position, Acceleration vs. Position, Speed vs. Time, Position vs. Time, Power vs. Time and Acceleration vs. Time. The first three of these curves include plots of the passenger station or stop positions. The speed vs. position curve also shows the speed restrictions or commands depending on what was used in the simulation.

Click on one of the five curves, enter the name of the file of filenames for the TPS run and enter a Supplementary Title. The Complete Graph button is then clicked to complete the plot. Samples of the different plots are shown on the next five plots.

Use the same zoom procedure as described in Section 7.1 to obtain finer resolution on the plots. Printing is accomplished using the same procedure suggested in Section 7.1.
7.4.1 Speed vs. Position

The speed vs. position plot is shown next.

Figure 7-22 Speed vs. Position Plot

The speed restrictions or speed commands have also been added to this plot.
7.4.2 Power vs. Position

The power vs. position plot is shown next.

Figure 7-23 Power vs. Position Plot

Regenerated power is shown in a different color.
7.4.3 Acceleration vs. Position

The acceleration vs. position plot is shown next.

Figure 7-24 Acceleration vs. Position Plot

Deceleration is shown in a different color.
7.4.4 Speed vs. Time

The speed vs. time plot is shown next.

Figure 7-25 Speed vs. Time Plot
7.4.5 Position vs. Time

The position vs. time plot is shown next.

![Position vs. Time Plot]

**Figure 7-26 Position vs. Time Plot**

7.4.6 Power vs. Time

The power vs. time plot is shown next.
Figure 7-27 Power vs. Time Plot

Regenerated power is shown in a different color.

7.4.7 Acceleration vs. Time

The acceleration vs. time plot is shown next.
Figure 7-28 Position vs. Time Plot

Deceleration is shown in a different color.

7.5 METER LOAD CURVE

The meter load curve is a measure of the instantaneous power flowing through a meter or a conjunctive set of meters as a function of time. Click on the Meter Load Curve option in the GRAPH Main Screen After Rail System Selection of Figure 7-2 to view the screen.
Selection of a load curve automatically makes a list of meters, which are represented in that load curve. This is shown in the next screen.
The user may select a single meter or a set of meters from the list. Selection is accomplished by clicking on the meter name. To delete a meter from the set, just click on the meter in the selected meter box. The completed screen is shown next with all meters selected.

Figure 7-31 GRAPH Main Screen / Meter Load Curve (Completed)

A sample of a load curve for the meter selected in the list is shown next.
Figure 7-32 Load Curve Plot

This curve may be zoomed by using a procedure similar to that of Section 7.1. Manual scaling could also be done for this graph as well as for all others.
7.6 TRAIN GRAPH

A train graph is a plot of the running of a system of trains on a two-track system. The position of each train is plotted vs. time. Generally, the position is the abscissa and the time is the ordinate of the graph. Click on the Train Graphs option in the GRAPH Main Screen after Rail System Selection of Figure 7-2 to view the screen.

Figure 7-33 GRAPH Main Screen / Train Graphs / TMS Runs Option (Default)

The user selects a name of the file of filenames for a TMS run. A station file is also selected along the right of way.

An alternative is to select the name of the file of filenames for an ENS run, which can be viewed by clicking the ENS Runs option in the figure. The result is shown in the next screen.
Figure 7-34 GRAPH Main Screen / Train Graphs / ENS Runs Option

The completed screen of Figure 7-33 is shown next.
Figure 7-35 GRAPH Main Screen / Train Graphs (Completed)

A sample train graph is shown next.
Trains, which are accelerating, are shown in green, trains in braking are shown red and trains, which are moving at constant speed, are shown in black.

### 7.7 ELECTRICAL GRAPHS

The electrical graph category is a series of graphs of electrical measurements from the:

- Current Measurement Output file (AO-*.*), of the ENS or TMS
- Return or Primary Circuit Current Analysis Output files of the FMM Current Analyzer
- Rail Voltage Detailed Output file of the RVM

Click on the Electrical Graphs option in the GRAPH Main Screen After Rail System Selection of Figure 7-2 to view the screen.
Figure 7-37 GRAPH Main Screen / Electrical Graphs

Either the AC Trains or DC Trains option is selected for trains running under AC or DC power distribution. Selection of AC Trains produces the next screen.
Figure 7-38 GRAPH Main Screen / Electrical Graphs / AC Trains Option

The electrical graphs are shown in the preceding screen.

7.7.1 Measured Current vs. Time

Selection of the Measured Current vs. Time option produces the next screen.
Figure 7-39 Electrical Graphs / AC Trains Option / Measured Current vs. Time

The choice of the file produces the next screen.
Figure 7-40 Electrical Graphs / AC Trains Option / Measured Current vs. Time / Position Choices

Up to five current measurement positions can be selected. In this example, there are many measurement positions to select from. Positions are selected by clicking on them in the Choose up to 5 Measurement Position Names box. They are deselected by clicking on them in the Chosen Names box.

Choosing B21+, B22+ and B31- and providing the Supplementary Title completes the screen shown next.
Figure 7-41 Electrical Graphs / AC Trains Option / Measured Current vs Time (Completed)

Clicking on Complete Graph produces the following plot.
Figure 7-42 Measured Current vs. Time Plot

Zooming, printing and manual scaling is accomplished in the manner explained in Section 7.1.

7.7.2 Train Current vs. Position
Clicking on the Train Voltage vs. Position option of GRAPH Main Screen / Electrical Graphs / AC Trains of Figure 7-38 option produces the next screen.
Figure 7-43 Electrical Graphs / AC Trains Option / Train Current vs Position

The current vs position of a single train may be selected by entering the 4 Alphanumeric Train ID into the text box shown. Entering the alphanumeric ALL+, which is the default, will cause the current versus position of all of the trains to be plotted.

Choice of a Current Measurement Output file (AO.*) and a Station file (ST-.*.) together with a supplementary title completes the screen and is shown below.
Figure 7-44 Electrical Graphs / AC Trains Option / Train Current vs. Position (Completed)

Clicking on Complete Graph produces the following plot.
Figure 7-45 Train Current vs. Position Plot

This graph is important in the analysis of power distribution system maximum current draw. If there were a desire to see this plot with the substations rather than passenger stations shown on it, just create a station file (ST-*) with substation names and locations and select it in previous screen. Of course both passenger stations and substations could be shown together with the appropriate (ST-*) file.

Zooming, printing and manual scaling is accomplished in the manner explained in Section 7.1.

7.7.3 Train Voltage vs. Position

Clicking on the Train Voltage vs. Position option of GRAPH Main Screen / Electrical Graphs / AC Trains of Figure 7-38 option produces the next screen.
Figure 7-46 Electrical Graphs / AC Trains Option / Train Voltage vs Position

The voltage vs position of a single train may be selected by entering the 4 Alphanumeric Train ID into the text box shown. Entering the alphanumerics ALL+, which is the default, will cause the voltage versus position of all of the trains to be plotted.

Choice of a Current Measurement Output file (AO*.*) and a Station file (ST-*.* ) together with a supplementary title completes the screen and is shown below.
The Mean Useful Voltage for a train is the average of all voltages for that train for every snapshot. The Mean Useful Voltage for the system is the average of all train voltages on the system for every snapshot. To obtain the former, enter the train ID in the Train ID textbox and to obtain the latter, enter ALL+ in the Train ID textbox.

Clicking on Complete Graph produces the following plot.
Figure 7-48 Train Voltage vs. Position Plot

This graph is important in the analysis of power distribution system voltage regulation. If there were a desire to see this plot with the substations rather than passenger stations shown on it, just create a station file (ST-*.) with substation names and locations and select it in previous screen. Of course both passenger stations and substations could be shown together with the appropriate (ST-*.) file.

Zooming, printing and manual scaling is accomplished in the manner explained in Section 7.1.

7.7.4 Train Current vs. Voltage

Clicking on the Train Current vs. Voltage option of GRAPH Main Screen / Electrical Graphs / AC Trains of Figure 7-38 option produces the next screen.
Figure 7-49 Electrical Graphs / AC Trains Option / Train Current vs Voltage

The current vs voltage of a single train may be selected by entering the 4 Alphanumeric Train ID into the text box shown. Entering the alphanumerics ALL+, which is the default, will cause the current versus voltage of all of the trains to be plotted.

Choice of a Current Measurement Output file (AO,*) with a supplementary title completes the screen and is shown below.
Figure 7-50 Electrical Graphs / AC Trains Option / Train Current vs Voltage (Completed)

Clicking on **Complete Graph** produces the following plot.
Figure 7-51 Train Current vs Voltage Plot

This graph is important in the analysis of power distribution system where the propulsion system has the capability of limiting the current as a function of voltage. Since the ENS and TMS are not capable of limiting current on the fly, modification of the Traction Effort vs Speed Curves can effect current limiting manually. This graph shows how successful the modifications are. In particular, it can be used with the 4.19 Voltage Averager for current limitation.

Zooming, printing and manual scaling is accomplished in the manner explained in Section 7.1.

7.7.5 Node Voltage vs. Time

AC Trains Option

Clicking on the Node Voltage vs. Time option of GRAPH Main Screen / Electrical Graphs / AC Trains option of Figure 7-38 produces the next screen.
Figure 7-52 Electrical Graphs / AC Trains Option / Node Voltage vs. Time

Selection of a Current Measurement Output file results in the next screen.
Figure 7-53 Electrical Graphs / AC Trains Option / Node Voltage vs. Time / Node Selection

Up to five nodes can be selected. In this example, there are six node names. Nodes are selected by clicking on them in the Choose up to 5 Node Names box. They are deselected by clicking on them in the Chosen Names box.

Choosing SA1 and SB1 and providing the Supplementary Title completes the screen shown next.
Figure 7-54 Electrical Graphs / AC Trains Option / Node Voltage vs Time (Completed)

Clicking on **Complete Graph** produces the following graph.
Zooming and printing is accomplished in the manner explained in Section 7.1.

**DC Trains Option**

Begin with the **DC Trains** option selected on the screen.
Figure 7-56 Graphics Utility – Electrical Graphs Screen – DC Train Option Selected

Clicking on the Node Voltage vs. Time option of GRAPH Main Screen / Electrical Graphs / DC Trains option produces the next screen.
Selection of a Current Measurement Output file results in the next screen.

Figure 7-58 Electrical Graphs / DC Trains Option / Node Voltage vs. Time / Node Selection
Clicking the Yes command button of the query results in the next screen, while clicking the No command button exposes the AC Nodes for voltage plotting, similar to that discussed in the previous section.

Figure 7-59 Electrical Graphs / DC Trains Option / Node Voltage vs. Time / Node Selection / Current Measurement File Chosen/ Converter Nodes Displayed in List Box

Up to five nodes can be selected. In this example, there are four node names. Nodes are selected by clicking on them in the **Choose up to 5 Node Names** list box. They are deselected by clicking on them in the **Chosen Names** box.

Choosing **01** and **02** and possibly modifying the **Supplementary Title** completes the screen shown next.
Clicking on **Complete Graph** produces the following graph.

![Graph](image)

**Figure 7-61 DC Converter Node Voltage vs. Time Plot**

Zooming and printing is accomplished in the manner explained in Section 7.1.
7.7.6 Line Current vs. Time

Clicking on the **Line Current vs. Time** option of **GRAPH Main Screen / Electrical Graphs / AC Trains** option of Figure 7-38 produces the next screen.

![Figure 7-62 Electrical Graphs / AC Trains Option / Line Current vs. Time](image)

The Choose Source Information combo box has the following choices, shown in the next screen.
Figure 7-63 Electrical Graphs / AC Trains Option / Line Current vs. Time/Combo Box Choice

These choices are available in TOM Version 3.4 and higher. Previous versions have only one choice; namely, Current Measurement Output.

Choosing the Current Measurement Output choice, leads to the next screen.
Figure 7-64 Electrical Graphs / AC Trains Option / Line Current vs. Time/Current Measurement Output Choice

Up to five lines can be selected. In this example, there are six line names. Lines are selected by clicking on them in the Choose up to 5 Line Names box. They are deselected by clicking on them in the Chosen Names box.

Choosing FA1 and FB1 and providing the Supplementary Title completes the screen. Clicking on Complete Graph provides the plot shown next.
Figure 7-65 Line Current vs Time Plot

Choice of the Primary Circuit Current Analysis Output combo box option, produces the next screen.
A Choose Type Current combo box appears on the screen as well as a list of Return Circuit Analysis Output files. The next screen show the choices afforded by the combo box.
The Choose Type Current combo box refers to the type of line current. This combo box appears when either the Return Circuit Current Analysis Output or Primary Circuit Current Analysis Output choice is made with the Choose Source Information combo box. There are four choices for the type of current:

- **Real** – This current shows both direction and magnitude. Direction is indicated as positive for the increasing milepost direction or as negative for the decreasing milepost direction.

- **Reactive** – This current is appropriate for AC distribution systems (It is zero for DC distribution systems.) and shows both direction and magnitude. Direction is indicated as positive for the increasing milepost direction or as negative for the decreasing milepost direction.

- **Magnitude** – This current is appropriate for AC and DC distribution systems. In the case of AC or DC distribution, this current is the complex absolute value of real and reactive current, given by the formula: \[ \text{Magnitude} = \sqrt{\text{Real}^2 + \text{Reactive}^2} \]. However for DC distribution, the reactive current is zero. This type of current is always positive.

- **Heating** – This current represents the heating effect in a line in which trains run. It differs from the Magnitude type current in that it captures the heating effect of the train presence on the line. The RMS current used for calculating heating effects.

The difference between Heating and Magnitude type currents is explained below, by considering a line with three nodes, one of which is a train (T).
Figure 7-68 Explanation of Currents

Choice of the **Heating Current and the Return Circuit Output file RCAap1rn.tes**, with selection of the lines A3 and B3 produces the next screen.

Figure 7-69 Electrical Graphs / AC Trains Option / Line Current vs. Time/ Primary Circuit Current Analysis Output Choice / Heating Current Choice
Click the **Complete Graph** command button to finish the plot.

![Graph](image)

**Figure 7-70** Electrical Graphs / AC Trains Option / Line Current vs. Time / Primary Circuit Current Analysis Output Choice / Heating Current Choice - Plot
7.7.7 Converter Current vs. Time

Clicking on the DC Trains option in the GRAPH Main Screen / Electrical Graphs of Figure 7-37 produces the following screen.

![Converter Current vs. Time Graph](image)

Figure 7-71 GRAPH Main Screen / Electrical Graphs / DC Trains Option

In addition to the four options covered in the GRAPH Main Screen / Electrical Graphs / AC Trains option of Figure 7-38, there are two additional options for the DC Trains selection. These options are Converter Current vs. Time and Rail Voltage vs Position.

Clicking on the Converter Current vs. Time option produces the next screen.
Selection of the **Current Measurement Output** file results in the following screen.
Up to five converters can be selected. In this example, there are only two converters A1-D1 and A2-D2. Converter names are selected by clicking on them in the Choose up to 5 Converter Names box. They are deselected by clicking on them in the Chosen Names box.

Choosing A2-D2 and providing the Supplementary Title completes the screen shown next.
Figure 7-74 Electrical Graphs / DC Trains Option / Converter Current vs. Time (Completed)

Clicking on **Complete Graph** command button produces the following plot.
Figure 7-75 Converter Current vs Time Plot

7.7.8 Rail Voltage

The second option of GRAPH Main Screen / Electrical Graphs / DC Trains Option of Figure 7-71 is the Rail Voltage Position / Time graph. Clicking on this option produces the following screen.
The next few screen depends on whether the RVM Detailed Output file was created under the **Old Method** or the **New Method**.

**Old Method**

The selections are shown on the next screen.
Clicking on **Complete Graph** produces the following plot.
Figure 7-78 Rail Voltage vs Position Plot (Old Method)

**New Method**

The New Method is much more accurate and has more capabilities and features. In fact, users are discouraged from using the old method, since it’s predictive capabilities are very limited.

If produced by the New Method, the Rail Voltage Detailed Output file will trigger the following screen.
Figure 7-79 Selection Of A Rail Voltage Detailed Output File (New Method)
Under these circumstances, the screen contains a Rail Voltage Graphs frame. This frame has three options for graphing rail voltage in the Rail Voltage Detailed Output file selected.

The Options are:
Max Rail Voltage vs Position - This graph is similar to that of the Old Method, except that for every snapshot, the maximum rail voltage is obtained and its position is plotted.
Rail Voltage vs Position – At any snapshot, selected by the user, the rail voltage profile of the track is displayed. This profile is referred the Position Based Rail Voltage Profile.
Rail Voltage vs Time – At a fixed position, the rail voltage is plotted for every snapshot. This profile is referred the Time Based Rail Voltage Profile.

In addition, the snapshot time, the position, track number, node name and value of the maximum rail voltage is indicated in the text boxes at the bottom of the frame.

Each of these features is illustrated further in the following subsections.

7.7.8.1.1 Max Rail Voltage vs Position
This graph is similar to that of the Old Method, except that for every snapshot, the maximum rail voltage is obtained and its position is plotted. In contrast, the Old Method output the rail voltage at the position of the train, when a single train, and no other trains, was on the system.

This option is the default option. Clicking the Complete Graph command button produces the following plot.
The **Global Maximum Rail Voltage** is just the maximum of all of the **Local Maximum Rail Voltages** displayed in this graph.

### 7.7.8.1.2 Rail Voltage vs Position

Clicking the **Rail Voltage vs Position** option of Figure 7-79 produces the next screen.
Figure 7-81 Rail Voltage vs Position Option Selected

The **Track Number** may be selected using the items in the **Track Number** combo box. Its default value is the number of the track on which the maximum rail voltage occurred.

The **Position Increment** is the distance between successive sampling of rail voltage. Its default value is 0.01 mi. (km.).

The snapshot may be selected using the snapshots in the **Choose Snapshot** combo box. Its default value is the snapshot at which the maximum rail voltage occurred.

Click the **Complete Graph** command button to complete the plot.
7.7.8.1.3 Rail Voltage vs Time

Click the Rail Voltage vs Time option of Figure 7-79 to produce the next screen.

Figure 7-83 Rail Voltage vs Time Option Selected
The Track Number may be selected using the items in the Track Number combo box. Its default value is the number of the track on which the maximum rail voltage occurred.

The Position is the point at which rail voltage is to be measured as a function of time. Its default value is position at which the maximum rail voltage has occurred.

Clicking the Complete Graph command button produces the next plot.

Figure 7-84 Plot of Rail Voltage vs Time at Fixed Position on Track 2.
7.8 STORAGE GRAPHS

Click on the Storage Graphs option in the GRAPH Main Screen After Rail System Selection of Figure 7-2 to view the screen.

Figure 7-85 Storage Graphs Screen

There are five possible graphs, which include test voltage vs. time, storage voltage vs. time, mean voltage vs. time, storage power vs. time and stored energy vs. time. A storage graph uses the current measurement output file (AO-*.* ) from the ENS or TMS to develop the graph.

The test voltage and mean voltage have meaning only with a Enhanced Generic Storage Device. The test voltage is the voltage at the storage device with the device disconnected, i.e. not charging or discharging. The storage voltage is the voltage at the device when it is operating, either charging or discharging. The mean voltage is the voltage averaged over a time interval called the voltage filter. The mean voltage
determines whether charging or discharging will occur. If the test voltage is below the mean voltage, the
device discharges, if the test voltage is above the mean voltage the device charges.
The generic storage device has a set voltage. For the generic device, when the storage voltage is above the
set voltage the device, charging occurs and when below, discharging occurs.

7.8.1 Test Voltage vs. Time
The test voltage for an Enhanced Generic Storage Device is the line voltage at the device with no charge
or no discharge.

A click on the Test Voltage vs. Time check box produces the following screen.

![Figure 7-86 Storage Graphs – Test Voltage vs. Time](image)

Selection of an AO*-tes file, the Device Name and inclusion of a Supplementary Title for the graph
leads to the following screen.
Figure 7-87 Storage Graphs – Test Voltage vs. Time (Completed)

Clicking the Complete Graph command button leads to the following graph.
7.8.2 Storage Voltage vs. Time

The storage voltage is the line voltage at the storage device as it is charging or discharging.

A click on the Storage Voltage vs Time command button produces the following screen.
Selection of an AO-*tes file, the Device Name and inclusion of a Supplementary Title for the graph leads to the following screen.

Figure 7-89 Storage Graphs – Storage Voltage vs. Time
Figure 7-90 Storage Graphs – Storage Voltage vs. Time (Completed)
Clicking the Complete Graph button produces the following screen.
7.8.3 Mean Voltage vs. Time

The mean voltage is the voltage averaged over a time interval called the voltage filter. The mean voltage determines whether charging or discharging will occur. If the test voltage is below the mean voltage, the device discharges, if the test voltage is above the mean voltage the device charges.

A click on the Mean Voltage vs Time command button produces the following screen.
Selection of an AO-*tes file, the Device Name and inclusion of a Supplementary Title for the graph leads to the following screen.

Figure 7-92 Storage Graphs – Mean Voltage vs. Time
Clicking the **Complete Graph** button produces the following screen.

Figure 7-93 Storage Graphs – Mean Voltage vs. Time (Completed)
7.8.4 Power vs. Time

A click on the **Storage Power vs. Time** check box in Figure 7-85 produces the following screen.
Figure 7-94 Storage Graphs – Storage Power vs Time

Selecting the AO-*.*tes file, followed by selection of the Storage Device and providing a Supplementary Title produces the following screen.
Figure 7-95 Storage Graphs – Storage Power vs Time (Completed)
Clicking the Complete Graph button produces the graph.
Figure 7-96 Graph of Storage Power vs Time

7.8.5 Stored Energy vs. Time

A click on the Storage Energy vs. Time check box produces the following screen.
Figure 7-97 Storage Graphs - Storage Energy vs. Time

Selecting the AO-*.*tes file, followed by selection of the Storage Device and providing a Supplementary Title produces the following screen.
Figure 7-98 Storage Graphs - Energy vs. Time (Completed)

Clicking the Complete Graph command button leads to the following graph.
Figure 7-99 Wayside Storage Device Graph of Energy vs. Time

7.9 AUTO OFFSET PROCESS RESULTS GRAPHS
Click on the Offset Graphs option in the GRAPH Main Screen after Rail System Selection of Figure 7-2 to view the screen.
There are four graphs of interest, which result from the *Auto Offset Process* (4.20).

- Minimum Voltage vs Offset
- Metered kW vs Offset
- Metered kVAR vs Offset
- Metered kVA vs Offset

Selection of the appropriate option will produce the associated graph. Examples of each are shown.

### 7.9.1 Minimum Voltage vs Offset
Figure 7-101 Minimum Voltage vs Offset Example

7.9.2 Metered kW vs Offset
Figure 7-102 Metered kW vs Offset Example

7.9.3 Metered kVAR vs Offset
Figure 7-103 Metered kVAR vs Offset Example

7.9.4 Metered kVA vs Offset
Figure 7-104 Metered kVA vs Offset Example
7.10 Auto Rail Voltage Process Results Graphs

The results of the Auto Rail Voltage Process described in Section 4.22 can be graphed. In this situation Rail Voltage is a function of two variables: rail to ground Leakage Resistance and Ground Resistance. Leakage Resistance has the units of ohms and Ground Resistance has the units of ohms per unit distance.

Figure 7-105 Auto Rail Voltage Process Result Graphs Selected

7.10.1 Rail Voltage vs Ground Resistance Graph

Selecting an Auto Rail Voltage Results file produces the next screen.
The Leakage Resistance to Choose list box contains the leakage resistances for which graphs of rail voltage vs ground resistance are available. Choose up to five of them.

Click the **Complete Graph** command button to complete the graph.
Figure 7-108 Graph of Rail voltage vs Ground Resistance for Several Leakage Resistances

7.10.2 Rail Voltage vs Leakage Resistance

The next screen shows the setup for rail voltage vs leakage resistance at various ground resistances.
Figure 7-109 Setup for Rail Voltage vs Leakage Resistance at Several Ground Resistances

The graph is shown next.
Figure 7-110 Rail Voltage vs Leakage Resistance for Several Ground Resistances
7.11 MANUAL VS. AUTOMATIC SCALING OF GRAPHS

In Version 3.2 and all previous versions, the graph scale was set automatically, using the maximum and minimum of the (x, y) coordinates and ten divisions on both the x and y-axes to set the scale. This is good for engineering work because together with the zoom feature it allows the user to detail specific areas of the graph space in his or her work.

Several clients requested a manual setting feature for presentation purposes to their clients or management. This has now been added in Version 3.3 and higher.

Take as an example the train voltage vs. position on the WMATA Red Line. The automatic setting produces the following graph.

![Voltage vs. Position Graph Using Automatic Scaling](image)

Figure 7-111 Voltage vs. Position Graph Using Automatic Scaling

The manual setting allows this next presentation of the same graph.
Figure 7-112 Voltage vs. Position Graph Using Manual Scaling

All graphs supported by the TOM have this feature in the Version 3.3 and higher.

An example of manual scaling is shown next, generating the graph depicted in the above plot.

Begin with the Graphics Utility - Main Screen, with the WMATA rail system selected.
Click on the **Electrical Graphs** check box.
Figure 7-114 Graphics Utility – Electrical Graphs Screen

Click the DC Trains check box.
Figure 7-115 Graphics Utility – Electrical Graphs Screen – DC Trains Selected

Click the Train Voltage vs Position check box.

Select the appropriate AO- and ST- file names.
Click the Set Scale check box.

Complete the screen entries.
Figure 7-118 Graphics Utility – Set Graph Scale Screen

Click the Select command button.

Figure 7-119 Graphics Utility – Electrical Graphs Screen – Selections Made (Return from Scale)
Insert the Supplementary Title in the text box and click the Complete Graph to produce the plot of Figure 7-106.
8 SUPPLEMENTARY PROGRAMS

There are supplementary programs, which have been added to the TOM, to provide the user with tools to improve efficiency of operation and tools to do supplementary calculations.

8.1 FILE VIEWER

The File Viewer is a program which is used to view any text file in the database or in the application directory of the TOM.

8.1.1 Original Functions

8.1.1.1 Help Function

Clicking on the Help command button of Figure 1-2 produces the following screen.

![Figure 8-1 File Viewer Display of the help01.txt File in the Applications directory (C:\tom)](image)

8.1.1.2 Copy to Clipboard and Copy to Notepad Functions

Two functions, which are useful, are Copy to Notepad and Copy to Clipboard.

The Copy to Notepad button will display the file present in the File Viewer in Notepad. For example, in the File Viewer of Figure 8-1, clicking the Copy to Notepad command button produces the next screen.
Likewise, in the File Viewer of Figure 8-1, clicking the Copy to Clipboard command button, opening WORD and pasting produces the next screen.

Since all files of the TOM are text files, this procedure always works.
8.1.1.3 Set Print Function

A click on the Set Print command button results in the next screen.

Figure 8-3 Setting the Print Font Size.

The print font size is the only option available to change in the printing of files. Enter a new font size and click the Set button changes the font size of the printer.

The Print command uses WORD to print the file. When it works, it produces high quality print outs. It may fail however, because of any of the following circumstances.

- WORD is not present on the computer.
- The WORD Version is earlier then 2000.
- A large WORD document is open.
- Virus scanning software is present. (Thinks it detects a malicious script.)

There are two alternatives to a No Print situation.

Click the Copy to Notepad command button and print the Notepad file.
Click Copy to Clipboard command button and then paste into WORD or some other word processing program to print.

8.1.1.4 Help Program Manual Viewer

Clicking the Help Program Manual command button produces the following screen.
A double click on the WORD Version picture screen will open this manual in Microsoft WORD. A double click on the PDF Version picture will open this manual in Adobe Acrobat. Please follow the instructions, selecting the read-only option and enabling all macros. The latter may require a lower security setting on the computer.

8.1.1.5 Edit Function

Clicking the Edit command button has no effect on the screen with the help01.txt file present. However, if the file is an input file to one of the simulators or supplementary models or processes, the edit function will load the file that is present in the File Viewer and load it into the screen which created it, so that it can be modified. To illustrate this use, consider the next screen, which is the TPS File of Filenames screen.
It has been found in running the TMS, the route taken by the train TPSA2.tes was not as intended. The file TPSA2.tes is imported into the screen by double-clicking on the filename to produce the following screen.
Figure 8-6 TOM File Viewer Edit Function Illustration – TPS File of Filenames Screen – File TPSA2.tes

Clicking the Route Input File in the Input File Type list box produces the next screen.
There are two ways to accomplish the next procedure.

A click on the Route file RU-A2.tes (which is the route file of TPSA2.tes) in the List of Files list box, followed by a click on the View One command button.

A click on the Route file RU-A2.tes (which is the route file of TPSA2.tes) in the Input File Name list box, followed by a click on the Right Mouse button.

Both methods lead to the next screen.
Figure 8-8 TOM File Viewer – File RU-A2.tes

Clicking the Edit command button causes the following screen to appear.
The file can now be modified.

**8.1.1.6 File Properties Function**

The **File Properties** command button displays the properties of the file currently in the **File Viewer** and displayed in the **File Name** text box. Clicking the command button produces the next screen.
8.1.1.7 Other Original Buttons

Other buttons present in the TOM File Viewer of Figure 8-8 include the GRAPH command button, which is a direct link to the graphics package, the DB command button, which is a direct link to the database, the Close button, which closes the screen and returns to the previous screen and the Exit command button, which closes the TOM.

8.1.2 Added Functions

There are several functions which have been added to the File Viewer in later versions of the TOM, especially TOM Version 3.4 and higher. These are discussed next.

8.1.2.1 Search Function

Another feature of the File Viewer is the search capability, which is present in Version 3.4 and higher. Consider the file displayed in the File Viewer.
Figure 8-11 File Imported into File Viewer in Preparation for Search
Enter a search text into the Search Box text box.

Figure 8-12 File Imported into File Viewer in Preparation for Search. Text Entered.
Click the Search command button.
Figure 8-13 File Imported into File Viewer in Preparation for Search. Text Entered. Search Command Button Clicked.

If more instances of the Search Box text box is desired, click the Search Again command button. A second instance was found. Clicking the Search Again button again produces the result.
8.1.2.2 Save File As

Outputs of several processes, normally not saved, are viewed in the file viewer by clicking the YES command button on the screen. The information resides in a temporary file. The Save File As command will allow the process to be saved, should the user desire. However, the TOM assigns the permanent file name, which identifies the file. The user has no control of the summary output filename.

For example, the ENS Summary Output can be saved by clicking the Save File As command button. The file name has the prefix SUM$ on the File of Filenames that generated the summary output for the ENS. Thus if the File of filenames was ENS*.*, the summary output file would be SUMSENS*.*

The next screen shows such a file, summary output from the ENS.
Figure 8-15 Summary Output From The ENS

Clicking the Save File As command button will save the file with the name designated in the Save File As text box. The user has no control over the file name. The result is the next screen.

Figure 8-16 Executing the Save File As Command
8.1.2.3 View Summary Function

Clicking the View Summary command button on the previous File Viewer or importing an ENS or TMS Summary Output file into the File Viewer results in the next screen.

Figure 8-17 File Viewer With View Summary Command Button Visible

Clicking the View Summary command button results in the following screen.
Figure 8-18 File Viewer After View Summary Command Button Clicked

Importing a Current Measurement Output file, a Primary Circuit Current Analysis Output file or a Return Circuit Current Analysis Output file into the File Viewer results in the next screen.

Figure 8-19 File Viewer With View RMS Currents Command Button Visible
Clicking the View RMS Current command button results in the following screen.

Figure 8-20 File Viewer After View RMS Currents Command Button Clicked

8.1.2.4 EXCEL Ready Function

Certain features have been incorporated into the output of some TOM procedures to allow ease of transfer to EXCEL Spreadsheets, for ease of constructing tables in reports.

Some of these actions are automatic, in the sense that the information is pasted on the Clipboard, when the process to compute the information is complete. In other cases, the user is asked to execute a command button, which effects the pasting of the information on the Clipboard.

A tutorial of these processes appears in Appendix 9.21. It is not repeated here, since plenty of examples are presented there.
8.2 RAIL VOLTAGE MODEL

The Rail Voltage Model (RVM) has been designed to estimate maximum rail to ground voltage in train networks with DC Power Distribution. There are two methods by which this estimate can be made. These methods are termed the Old Method and the New Method. The terms are applied to versions of the model lower than 3.5 (Old Method) and 3.5 and higher (New Method). Both methods can be used with version 3.5 and higher.

Old Method
This method can estimate maximum rail to ground voltage in very simple two track networks and with a single train running on the network.

Rail voltage estimates can be made on more complicated networks by separating them into pieces, where each piece is a simple network described above.

New Method
This method can estimate maximum rail to ground voltage in any train network with no limits on the number of trains running. It utilizes the return circuit to make the estimate and depends on the line currents moving through the rails.

The RVM is initiated by clicking the Rail Voltage Model button of the TOM screen shown in Figure 1-2. This will cause a screen similar to the following to appear:
A rail system is selected from the list either by double clicking on the rail system designation or by clicking once on the designation followed by one click on the Select command button. This modifies the screen as follows:
Pre-selection of the rail system **TEST** on the **TOM** main screen will result in this screen upon opening of the **TPS** main screen.

![RVM Main Screen After Rail System Selection](image)

Figure 8-22 RVM Main Screen After Rail System Selection
A file of filenames is selected by double clicking on it (or a click on the filename followed by a click on the select button). This leads to the following screen:

Figure 8-23 RVM Main Screen after File of Filenames is Selected

After the RVM runs, the output file can immediately be viewed by clicking on the Yes command button on the final screen. This results in viewing the summary file in the TOM File Viewer. The outputs are different depending on whether the File of Filenames selected is of the Old Method or the New Method.
8.2.1 Old Method

The Summary Output file for the Old Method is shown next.

![Figure 8-24 TOM File View of Summary Output File of RVM Old Method](image-url)
The **Rail Voltage** is listed for every position.

### 8.2.2 New Method

The **Summary Output** file is now shown for the **New Method**.
The Detailed Output file for the New Method is divided into three parts:

Header
Line and Node Rail Voltages
Maximum Rail Voltage for Each Snapshot

The Header section is shown next.
The **Header** provides a complete identification of the **RVM** run including the input files and the **Return Circuit** file from which the **Return Circuit Current Analysis Output** file and **Return Circuit Rail Voltage** file was obtained.

It also displays the **Maximum Rail Voltage**, its **Position**, **Track Number** and **Snapshot Time**.

The next section is the **Line and Node Rail Voltages** shown for one snapshot in the next screen.
In the Ends of Line Voltages subsection, the beginning and ending nodes of the line are shown together with the line (track) number and relative voltages of the beginning and ending nodes.

In the Node Voltages subsection, the node name, position, track number and voltage are shown, using the minimum position node of each track as reference. Discussion of the method used to compute lineal and nodal rail voltages is discussed in Appendix 9.14.

The Maximum Rail Voltage for Each Snapshot section is shown in the next screen.
8.3 Time Calculator

The Time Calculator tool will convert time expressed in various ways to times expressed in different ways. It will also add two times or subtract one time from another. In case of addition and subtraction, the time is also expressed in different ways. The minimum time unit is one second. Time can be expressed in one of five ways and likewise is displayed in all five ways. The five ways are:

- Decimal, using hours i.e. 1.2686 hrs
- Decimal, using minutes i.e. 76.117 min.
- Integer, using seconds i.e. 4567 sec.
- Symbolic, using hours:minutes i.e. 01:16.117
- Symbolic, using hours:minutes:seconds i.e. 01:16:07

The Time Calculator bases all of its calculations rounded to the nearest second. If any entry is made other than seconds, the number of seconds of that entry is rounded to the nearest second, and the remainder of the calculations and conversions are based on that number of seconds.

The Time Calculator is a tool for constructing timetables and start and end times for ENS and TMS runs.

The time calculator is accessed from several screens within the TOM. The following screen appears.
An entry is placed in one of the boxes according to the format indicated for that box. An example is shown in the next screen.

Clicking on the Convert button produces the following screen.
Figure 8-32 Time Calculator – Convert Feature Complete
Results are accurate to the nearest second. Choosing the Subtract feature and making an entry for the Subtrahend produces the following screen.

Figure 8-33 Time Calculator – Illustration of the Subtract Feature
Clicking the Subtract button produces the following screen.
In the **Subtract** process, the **Subtrahend** must always be less than the **Minuend**. An error will occur if it is not.

The **Clear** button will empty all of the boxes.

There are two other buttons on the screen **Close** and **Reset**. A click on **Close** will abort the screen and return to the previous screen. A click on **Reset** will create the same screen as when the **Time Calculator** was first called.

### 8.4 **METRIC ENGLISH CONVERTER**

The **Metric English Converter** screen provides a mechanism to convert English units to Metric units and visa versa for all of the physical units used by the **TOM**. Click on the **Metric English Converter** command button of Figure 3-1 produces the following screen.
An option may be selected on the left side of the screen in the figure. Once the option is selected, type in the value for either the English (Metric) unit to be converted and the result will appear in the corresponding converted Metric (English) unit position. An example is shown with the choice of acceleration in the following screen.

<table>
<thead>
<tr>
<th>Item</th>
<th>English Unit</th>
<th>Metric Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance or Position</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Speed</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acceleration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Force</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Energy</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel Flow</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fuel Flow per Unit Power</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Area</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vehicle Length</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wheel Diameter</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

This Metric to English/English to Metric converter is used to convert the units of physical quantities used in the Train Operations Model. Simply select the option on the left for the item to be converted and type in the appropriate quantity either in the Metric or English unit text box.
8.5 COMPLEX NUMBER CALCULATOR

The Complex Number Calculator screen provides a way to produce complex number operations and functions which may be useful in circuit calculations. A click on the Complex Number Calculator command button of Figure 3-1 produces the following screen.
The purpose of the Complex Number Calculator is to provide a quick method to operate with complex numbers. Operations include arithmetic, computation of general functions and trigonometric and hyperbolic functions.

Accuracy of computation is provided to 14 decimal places. Number smaller than $10^{-15}$ are considered zero. Numbers larger than 14 digits, whether positive or negative are rounded off to 14 digits.

The calculator uses the standard formulas and definitions for things associated with complex numbers. Details of its operation are described in Appendix 9.20.

**8.6 LINEAR INTERPOLATION**

On the main screen of the FCM, shown in Figure 3-1, click on the Linear Interpolation command button to expose the Linear Interpolator.
The purpose of this tool is to use the equation $Y = a \times X + b$ to find the $Y$ value corresponding to a value for $X$, given the points $(X1, Y1)$ and $(X2, Y2)$. Inputs are $X1$, $X2$, $X$, $Y1$ and $Y2$ and the result is $Y$.

An example is shown on the next screen.

Clicking the Solve command button results in the next screen.
The Help command button produces a brief help dialog, which informs the user. The Close command button exits the interpolator.

8.7 EXTREMUMIZER

Click the Find Extremum command button on the File Command Module – Main Screen in Figure 3-1 to expose the Extremumizer.
Enter or paste values for \(X_1, X_2, X_3, Y_1, Y_2,\) and \(Y_3\) in the space provided. Click the Solve command button to obtain the value of \(X\) (ext) and \(Y\) (ext), the extremum. The program uses a parabolic interpretation to find the extremum, either a maximum or minimum. The coefficients \(a, b\) and \(c\) of the parabolic equation \(y = ax^2 + bx + c\) are also displayed.

An example is shown next.

![Extremumizer Main Screen - Values Entered](image)

Clicking the Solve command button produces the next screen.

![Extremumizer Main Screen – Solution](image)

The Clear All command button clears all text boxes. The Help command button relates instructions on how to use the Extremumizer. The Close command button closes the screen.

This tool is very useful for making quick estimates of best values of parameters.
8.8 **TOM EXTRA DATA**

The **TOM Extra Data** screen provides a way to access all of the other data files that are present in the **Rail Systems Data Base** and are not used directly by the **TOM** for input and output. A click on the **TOM Extra Data** command button of Figure 3-1 produces the following screen.

![Figure 8-44 TOM Extra Data Main Screen](image)

Selection of a **Rail System** followed by the selection of a **File Type** option (EXCEL Document) produces the following screen.
Figure 8-45 TOM Extra Data Selection of Rail system and EXCEL file Option

Selection of a file in the List of Files list box produces the following screen.
The other file type options will produce similar results. For Microsoft Windows type files such as bitmaps and text files, the files can be opened directly by selecting them. For Microsoft Office type files the file must be opened by the user, with a similar procedure given in the instructions.

In particular, there are two files, which are automatically provided with every new rail system, which is added to the TOM. One file is a WORD document and the other is an EXCEL document. The filenames of these files are: WORDCompanion-Mnemonic-ext.doc and EXCELCompanion-Mnemonic-ext.xls. (Mnemonic is the Rail System designation and ext is the Rail System file extension. These companion documents are provide so that the user may keep all raw technical data (EXCEL) and procedures and results(WORD) within the directory of the Rail System under consideration. These files are not in the Rail System Database. Examples of such files are available with the sample Rail Systems provided with the model.

For a new Rail System, following the procedure indicated in Figure 8-46 result in the following EXCEL workbook.
Figure 8-47 EXCEL Workbook for New Rail System
9 APPENDICES

9.1 RAIL SYSTEM FILE NAMING CONVENTION

The file naming convention for the TOM has been carefully selected to present the user with the bookkeeping features of the model together with the power of its tools. The data files for all of the rail systems are expected to reside in the directory ..\tomdat which is further subdivided into directories \ext, which hold the actual input and output files. A list of the conventions used for the TOM is shown below.
## Table 9-1 File Naming Convention for the TOM

<table>
<thead>
<tr>
<th>Rail System</th>
<th>Acronym</th>
<th>Mnemonic</th>
<th>City</th>
<th>State</th>
<th>ext</th>
</tr>
</thead>
<tbody>
<tr>
<td>BI-State Development Agency</td>
<td>BIDA</td>
<td>BIDA</td>
<td>St Louis</td>
<td>MO</td>
<td>bid</td>
</tr>
<tr>
<td>British Columbia Rapid Trans. Co.</td>
<td>BC RAIL</td>
<td>BCTRN</td>
<td>Vancouver</td>
<td>BC</td>
<td>vnc</td>
</tr>
<tr>
<td>Calgary Transit</td>
<td>CT</td>
<td>CT</td>
<td>Calgary</td>
<td>AL</td>
<td>cts</td>
</tr>
<tr>
<td>Chicago Transit Authority</td>
<td>CTA</td>
<td>CTA</td>
<td>Chicago</td>
<td>IL</td>
<td>cta</td>
</tr>
<tr>
<td>City of Detroit Dept. of Transp.</td>
<td>DDOT</td>
<td>DDOT</td>
<td>Detroit</td>
<td>MI</td>
<td>det</td>
</tr>
<tr>
<td>Dallas Area Rapid Transit</td>
<td>DART</td>
<td>DART</td>
<td>Dallas</td>
<td>TX</td>
<td>dar</td>
</tr>
<tr>
<td>Edmonton Transit</td>
<td>ET</td>
<td>ET</td>
<td>Edmonton</td>
<td>AB</td>
<td>edm</td>
</tr>
<tr>
<td>Government of Ontario Transit</td>
<td>GO RAIL</td>
<td>GOTRN</td>
<td>Toronto</td>
<td>ON</td>
<td>gor</td>
</tr>
<tr>
<td>Gr. Cleveland Reg. Trans. Auth.</td>
<td>GCRTA</td>
<td>GCRTA</td>
<td>Cleveland</td>
<td>OH</td>
<td>rta</td>
</tr>
<tr>
<td>Houston Metro</td>
<td>OTAHC</td>
<td>HOUS</td>
<td>Houston</td>
<td>TX</td>
<td>hou</td>
</tr>
<tr>
<td>Long Island Railroad</td>
<td>LIRR</td>
<td>LIRR</td>
<td>New York</td>
<td>NY</td>
<td>lir</td>
</tr>
<tr>
<td>Los Angeles Co. Metro. Transp.</td>
<td>LACMT</td>
<td>LACMT</td>
<td>Los Angeles</td>
<td>CA</td>
<td>lac</td>
</tr>
<tr>
<td>MA Bay Transportation Auth.</td>
<td>MBTA</td>
<td>MBTA</td>
<td>Boston</td>
<td>MA</td>
<td>mta</td>
</tr>
<tr>
<td>Mass Transit Administration of MD</td>
<td>MTAM</td>
<td>MTAMD</td>
<td>Baltimore</td>
<td>MD</td>
<td>mta</td>
</tr>
<tr>
<td>Metro-Dade Transit Agency</td>
<td>MDTA</td>
<td>MDTA</td>
<td>Miami</td>
<td>FL</td>
<td>mia</td>
</tr>
<tr>
<td>Metro-North Commuter Railroad</td>
<td>MNCR</td>
<td>MNCR</td>
<td>New York</td>
<td>NY</td>
<td>mnc</td>
</tr>
<tr>
<td>Metro. Atlanta Rapid Trans. Auth.</td>
<td>MARTA</td>
<td>MARTA</td>
<td>Atlanta</td>
<td>GA</td>
<td>mar</td>
</tr>
<tr>
<td>Metro. Trans. Auth. Of Harris Co.</td>
<td>MTA</td>
<td>MTAHHR</td>
<td>Houston</td>
<td>TX</td>
<td>mtn</td>
</tr>
<tr>
<td>Metropolitan Transit</td>
<td>METRA</td>
<td>METRA</td>
<td>Chicago</td>
<td>IL</td>
<td>mtr</td>
</tr>
<tr>
<td>Miami Valley Reg. Transit Auth.</td>
<td>MVRTA</td>
<td>MVRTA</td>
<td>Dayton</td>
<td>OH</td>
<td>mva</td>
</tr>
<tr>
<td>Montreal Urban Conn. Trans. Corp.</td>
<td>MUCTC</td>
<td>MUCTC</td>
<td>Montreal</td>
<td>PO</td>
<td>muc</td>
</tr>
<tr>
<td>Municipality of Metro. Seattle</td>
<td>MMS</td>
<td>MMS</td>
<td>Seattle</td>
<td>WA</td>
<td>mms</td>
</tr>
<tr>
<td>N. IN Commuter Transp. District</td>
<td>NICTD</td>
<td>NICTD</td>
<td>Chicago</td>
<td>IN</td>
<td>ssh</td>
</tr>
<tr>
<td>New Jersey Transit Corporation</td>
<td>NJT</td>
<td>NJT</td>
<td>Newark</td>
<td>NJ</td>
<td>njt</td>
</tr>
<tr>
<td>New York City Trans. Authority</td>
<td>NYCTA</td>
<td>NYCTA</td>
<td>New York</td>
<td>NY</td>
<td>nyc</td>
</tr>
<tr>
<td>Niagara Frontier Transp. Auth.</td>
<td>NFTA</td>
<td>NFTA</td>
<td>Buffalo</td>
<td>NY</td>
<td>nft</td>
</tr>
<tr>
<td>Port Auth. Trans-Hudson Corp.</td>
<td>PATH</td>
<td>PATH</td>
<td>New York</td>
<td>NY</td>
<td>pth</td>
</tr>
<tr>
<td>Port Authority of Allegheny Co.</td>
<td>PAT</td>
<td>PAT</td>
<td>Pittsburgh</td>
<td>PA</td>
<td>pat</td>
</tr>
<tr>
<td>Port Authority Transit Corp.</td>
<td>PATCO</td>
<td>PATCO</td>
<td>Lindenwood</td>
<td>NJ</td>
<td>ptc</td>
</tr>
<tr>
<td>Regional Transit Authority</td>
<td>NORTA</td>
<td>NORTA</td>
<td>New Orleans</td>
<td>LA</td>
<td>nor</td>
</tr>
<tr>
<td>Regional Transportation District</td>
<td>DRTD</td>
<td>DRTD</td>
<td>Denver</td>
<td>CO</td>
<td>dnv</td>
</tr>
<tr>
<td>S.E. PA Transportation Auth.</td>
<td>SEPTA</td>
<td>SEPTA</td>
<td>Philadelphia</td>
<td>PA</td>
<td>sep</td>
</tr>
<tr>
<td>Sacramento Reg. Transit District</td>
<td>SRTD</td>
<td>SRTD</td>
<td>Sacramento</td>
<td>CA</td>
<td>srt</td>
</tr>
<tr>
<td>San Diego Trolley, Inc.</td>
<td>SDTI</td>
<td>SDTI</td>
<td>San Diego</td>
<td>CA</td>
<td>sdt</td>
</tr>
<tr>
<td>San Francisco Municipal Railway</td>
<td>MUNI</td>
<td>MUNI</td>
<td>San Francisco</td>
<td>CA</td>
<td>mun</td>
</tr>
<tr>
<td>San Francisco Bay Area Rapid</td>
<td>BART</td>
<td>BART</td>
<td>San Francisco</td>
<td>CA</td>
<td>bar</td>
</tr>
<tr>
<td>Santa Clara Co. Transp. Agency</td>
<td>SCCTA</td>
<td>SCCTA</td>
<td>San Jose</td>
<td>CA</td>
<td>scc</td>
</tr>
<tr>
<td>The Hamilton Street Railway Co.</td>
<td>HSRC</td>
<td>HSRC</td>
<td>Hamilton</td>
<td>ON</td>
<td>ham</td>
</tr>
<tr>
<td>Toronto Transit Commission</td>
<td>TTC</td>
<td>TTC</td>
<td>Toronto</td>
<td>ON</td>
<td>ttc</td>
</tr>
<tr>
<td>Tri-Co. Met. Transp. Dist. Of OR</td>
<td>TRIMET</td>
<td>TRIMET</td>
<td>Portland</td>
<td>OR</td>
<td>tri</td>
</tr>
<tr>
<td>Wash Metro. Area Trans. Auth.</td>
<td>WMATA</td>
<td>WMATA</td>
<td>Washington</td>
<td>DC</td>
<td>wma</td>
</tr>
</tbody>
</table>

The sub directory `ext` used for each rail authority is the same as the TOM file extension (.ext) used in the last column of the above table.

A tabulation of the input and output files connected with the simulators and modules are shown below. The file format and purpose are summarized in the table.
<table>
<thead>
<tr>
<th>Filename Format</th>
<th>File Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADM$PC*.ext</td>
<td>FCM Admittance Matrix (Primary Circuit)</td>
</tr>
<tr>
<td>ADM$RC*.ext</td>
<td>FCM Admittance Matrix (Return Circuit)</td>
</tr>
<tr>
<td>AO*.ext</td>
<td>ENS &amp; TMS Current Measurement Input</td>
</tr>
<tr>
<td>CAO$PC*.ext or CAO$RC*.ext</td>
<td>FMM Circuit Current Analyzer Output (Primary or Return)</td>
</tr>
<tr>
<td>CCT$PC*.ext</td>
<td>FCM Check Circuit File (Primary Circuit)</td>
</tr>
<tr>
<td>CCT$RC*.ext</td>
<td>FCM Check Circuit File (Return Circuit)</td>
</tr>
<tr>
<td>CL*.ext</td>
<td>TPS Control Input</td>
</tr>
<tr>
<td>CU*.ext</td>
<td>TPS Curve Input</td>
</tr>
<tr>
<td>DC*.ext</td>
<td>TPS Max Deceleration Modification Input (Bombardier Proprietary)</td>
</tr>
<tr>
<td>DefCalPar.ext</td>
<td>Rail System Default Calculational Parameters for Circuit Current Analysis</td>
</tr>
<tr>
<td>DR*.ext</td>
<td>TPS Aero Drag Modification Input (Bombardier Proprietary)</td>
</tr>
<tr>
<td>EDC*.ext</td>
<td>EDC Energy Demand Summary</td>
</tr>
<tr>
<td>EL*.ext</td>
<td>Elevation</td>
</tr>
<tr>
<td>END*.ext</td>
<td>ENS &amp; TMS Detailed Output</td>
</tr>
<tr>
<td>ENS*.ext</td>
<td>ENS File of Filenames Input</td>
</tr>
<tr>
<td>QR*.ext</td>
<td>TPS Grade Input</td>
</tr>
<tr>
<td>ImpedancesDefault.ext</td>
<td>Rail System Impedance Default</td>
</tr>
<tr>
<td>L*.ext</td>
<td>ENS &amp; TMS Load Curve Output</td>
</tr>
<tr>
<td>MC*.ext</td>
<td>Meter Consolidation Input</td>
</tr>
<tr>
<td>N*.ext</td>
<td>ENS &amp; TMS Network Input</td>
</tr>
<tr>
<td>NN*.ext</td>
<td>RVM Negative Network Input</td>
</tr>
<tr>
<td>OC*.ext</td>
<td>Occupancy</td>
</tr>
<tr>
<td>OP*.ext</td>
<td>ENS &amp; TMS Operating Time Input</td>
</tr>
<tr>
<td>P*.ext</td>
<td>Power Profile</td>
</tr>
<tr>
<td>PC*.ext</td>
<td>ENS &amp; TMS Primary Circuit Input</td>
</tr>
<tr>
<td>PCA*.ext</td>
<td>Primary Circuit Current Analysis Output</td>
</tr>
<tr>
<td>RC*.ext</td>
<td>ENS &amp; TMS Return Circuit Input</td>
</tr>
<tr>
<td>RCA*.ext</td>
<td>Return Circuit Current Analysis Output</td>
</tr>
<tr>
<td>RU*.ext</td>
<td>TPS Route Input</td>
</tr>
<tr>
<td>RMDCURS*.ext</td>
<td>Line Name Translated RMS Current Summary</td>
</tr>
<tr>
<td>RV*.ext</td>
<td>RVM Detailed Output</td>
</tr>
<tr>
<td>RV*.ext</td>
<td>RVM File of Filenames Input</td>
</tr>
<tr>
<td>RVV*.ext</td>
<td>RVM Summary Output</td>
</tr>
<tr>
<td>RXY*.ext</td>
<td>RVM Rail Voltage Table</td>
</tr>
<tr>
<td>RX*.ext</td>
<td>Return Circuit Rail Voltage</td>
</tr>
<tr>
<td>SC*.ext</td>
<td>TPS Speed Command Input</td>
</tr>
<tr>
<td>SD*.ext</td>
<td>TMS Station Description Input</td>
</tr>
<tr>
<td>SP*.ext</td>
<td>TPS Speed Restriction Input</td>
</tr>
<tr>
<td>ST*.ext</td>
<td>TPS Station Input</td>
</tr>
<tr>
<td>SUM$ENS*.ext</td>
<td>ENS Summary Output</td>
</tr>
<tr>
<td>SUM$TMS*.ext</td>
<td>TMS Summary Output</td>
</tr>
<tr>
<td>SUM$CAO*.ext</td>
<td>Converter Current Analysis Summary</td>
</tr>
<tr>
<td>SUM$MAO*.ext</td>
<td>Current Measurement Analysis Summary</td>
</tr>
<tr>
<td>T*.ext</td>
<td>TPS Train Input</td>
</tr>
<tr>
<td>TC*.ext</td>
<td>Propulsion Model Detailed Output</td>
</tr>
<tr>
<td>TL*.ext</td>
<td>ENS &amp; TMS Train Location Input</td>
</tr>
<tr>
<td>TMA*.ext</td>
<td>TMS Alarm Output</td>
</tr>
<tr>
<td>TMS*.ext</td>
<td>TMS File of Filenames Input</td>
</tr>
<tr>
<td>TPS*.ext</td>
<td>TPS File of Filenames Input</td>
</tr>
<tr>
<td>TRAN*.ext</td>
<td>Circuit Line Name Translator</td>
</tr>
<tr>
<td>TSD*.ext</td>
<td>TPS Detailed Output</td>
</tr>
<tr>
<td>TSS*.ext</td>
<td>TMS Summary Output</td>
</tr>
<tr>
<td>TW*.ext</td>
<td>TMS Track Layout</td>
</tr>
<tr>
<td>XR*.ext</td>
<td>Return Circuit Impedance</td>
</tr>
</tbody>
</table>
9.2 SUB MODEL FILE NAMING CONVENTION

The naming convention for the Sub Model Database is shown in the next table.

<table>
<thead>
<tr>
<th>Filename Format</th>
<th>File Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>*.txt</td>
<td>TOM Reference Text</td>
</tr>
<tr>
<td>SI*.txt</td>
<td>Screen Instruction Text</td>
</tr>
<tr>
<td>ImpDefPerm.txt</td>
<td>Impedance Default</td>
</tr>
<tr>
<td>DefCalPerm.txt</td>
<td>Default Calculational Parameters for Circuit Current Analysis</td>
</tr>
<tr>
<td>*.lib</td>
<td>Car Library</td>
</tr>
<tr>
<td>*.mot</td>
<td>Motor Model</td>
</tr>
<tr>
<td>*.con</td>
<td>Motor Control Model</td>
</tr>
<tr>
<td>*.gum</td>
<td>Gear Unit Model</td>
</tr>
</tbody>
</table>

9.3 METRIC/ENGLISH UNIT CONVENTION FOR MODEL

Both English and Metric unit capability is available for the TOM. Some restrictions must be observed when using it, however, since all internal calculations are done using English units.

Observe the rules listed below for English and Metric input:

<table>
<thead>
<tr>
<th>MEASURE</th>
<th>ENGLISH unit</th>
<th>METRIC unit</th>
<th>CONVERSION FACTOR English to metric</th>
</tr>
</thead>
<tbody>
<tr>
<td>DISTANCE</td>
<td>miles</td>
<td>kilometers</td>
<td>1.60934</td>
</tr>
<tr>
<td>SPEED</td>
<td>mph</td>
<td>kph</td>
<td>1.60934</td>
</tr>
<tr>
<td>ACCELERATION</td>
<td>mphps</td>
<td>kphps</td>
<td>0.44704</td>
</tr>
<tr>
<td>FORCE</td>
<td>lb</td>
<td>newton</td>
<td>4.4482</td>
</tr>
<tr>
<td>WEIGHT</td>
<td>ton</td>
<td>tonne</td>
<td>0.90719</td>
</tr>
<tr>
<td>VOLUME</td>
<td>gal</td>
<td>imp gal</td>
<td>0.83267</td>
</tr>
<tr>
<td>LENGTH</td>
<td>ft</td>
<td>meter</td>
<td>0.30490</td>
</tr>
<tr>
<td>AREA</td>
<td>sq ft</td>
<td>sq meter</td>
<td>0.09294</td>
</tr>
</tbody>
</table>

In the Davis Equation train resistance formula

<table>
<thead>
<tr>
<th>FLANGE COEFF</th>
<th>lb/ton/mph</th>
<th>nt/tonne/kph</th>
<th>3.04676</th>
</tr>
</thead>
<tbody>
<tr>
<td>AERODY COEFF</td>
<td>lb/sq ft/sq mph</td>
<td>nt/sq m/sq kph</td>
<td>18.47996</td>
</tr>
</tbody>
</table>

Figure 9-1 TOM English and Metric Units

The Metric English Converter, which can be accessed through the Metric English Converter command button of the FCM Main screen, shown in Figure 3-1, provides conversion for all units used in the TOM.
9.4 DYNAMIC LINK LIBRARY(DLL) LISTING

A dynamic link library (DLL) is used in conjunction with the Visual Basic Programs to run the simulators and finish creating and modifying files. A list of the DLL programs and their purpose is listed below.
Table 9-4 Dynamic Link Libraries Used in the TOM

<table>
<thead>
<tr>
<th>Filename of DLL</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>tomaplvb.dll</td>
<td>ECM Load Curve Consolidator</td>
</tr>
<tr>
<td>tomcflv3.dll</td>
<td>FCM Control File for the TPS</td>
</tr>
<tr>
<td>tomcmfvb.dll</td>
<td>FCM Current Measurement Input for the ENS and</td>
</tr>
<tr>
<td>tomedcvb.dll</td>
<td>ECM Energy - Demand Computer</td>
</tr>
<tr>
<td>tome1vb.dll</td>
<td>FMM Elevation</td>
</tr>
<tr>
<td>tomensv3.dll</td>
<td>ENS</td>
</tr>
<tr>
<td>tomfelvb.dll</td>
<td>FCM File of Filenames for the ENS</td>
</tr>
<tr>
<td>tomfnvb.dll</td>
<td>FCM File of Filenames for the TMS</td>
</tr>
<tr>
<td>tomfrvb.dll</td>
<td>FCM File of Filenames for the RVM</td>
</tr>
<tr>
<td>tomftvb.dll</td>
<td>FCM File of Filenames for the TPS</td>
</tr>
<tr>
<td>tomgrfvb.exe</td>
<td>GRAPH Utility (not a DLL but an executable)</td>
</tr>
<tr>
<td>tomicpb.dll</td>
<td>FMM Load Curve Extender</td>
</tr>
<tr>
<td>tommnfb.dll</td>
<td>FCM Network for the ENS and TMS</td>
</tr>
<tr>
<td>tomoffs.dll</td>
<td>FCM Operating Time for the ENS and TMS</td>
</tr>
<tr>
<td>tompavvb.dll</td>
<td>FMM Power Profile Averager</td>
</tr>
<tr>
<td>tompavvb.dll</td>
<td>FCM Train TE vs Speed Curve Power Limit (not used)</td>
</tr>
<tr>
<td>tompavvb.dll</td>
<td>FMM Power Profile Appender</td>
</tr>
<tr>
<td>tompavvb.dll</td>
<td>FMM Power Profile Clipper</td>
</tr>
<tr>
<td>tomrowvb.dll</td>
<td>FCM Right of Way for the TPS</td>
</tr>
<tr>
<td>tomrvmvb.dll</td>
<td>RVM</td>
</tr>
<tr>
<td>tomrvtvfb.dll</td>
<td>FCM Rail Voltage Table for the RVM</td>
</tr>
<tr>
<td>tomsttvb.dll</td>
<td>FCM Stop Distance</td>
</tr>
<tr>
<td>tomtlrvb.dll</td>
<td>FCM Train Location for the ENS and TMS</td>
</tr>
<tr>
<td>tomtmsvb.exe</td>
<td>TMS (not a DLL but an executable)</td>
</tr>
<tr>
<td>tomtmvb.dll</td>
<td>FCM Track Layout for the TMS</td>
</tr>
<tr>
<td>tomtmvb.dll</td>
<td>FCM Train for the TPS</td>
</tr>
<tr>
<td>tomtspv3.dll</td>
<td>TPS</td>
</tr>
<tr>
<td>TomTrackLayout Viewer.exe</td>
<td>FCM Track Layout (not a DLL but an executable)</td>
</tr>
</tbody>
</table>

The *.dll files and the *.exe files are located in the Application directory (default: ..\tom)

9.5 VISUAL BASIC OBJECTS USED IN THE TOM

9.5.1 Introduction
Throughout this manual and throughout the help screens of the TOM itself, certain terminology is used which refer to the object programming of Visual Basic. Such expressions as “click a command button” or “select an item from a combo box” are used throughout. The purpose of this section of the appendix is to present the objects used in the TOM and define the terminology used to refer to them.

9.5.2 Objects Used in the TOM
An object is a combination of code and data that can be treated as a unit.

A Form object is a window or dialog box that makes up part of an application's user interface.

The following screen shows examples of the objects used in the TOM.
A Screen is a particular view of a form. Several screens may be produced at runtime from a single form. An example of a screen which is a different view of the above form is shown next.
The following additional objects are used in the TOM, examples of which are shown on the form:

A Check Box control displays an X when selected; the X disappears when the Check Box is cleared. This control is used to give a True/False or Yes/No option.

A Label control is a graphical control used to display text that a user can't change directly. In the TOM, many labels are used to name other objects.

A Command Button control is used to begin, interrupt, or end a process or procedure.

A Text Box control, sometimes called an edit field or edit control, displays information entered at design time, entered by the user, or assigned to the control in code at run time.

A List Box control displays a list of items from which the user can select one or more. If the number of items exceeds the number that can be displayed, a scroll bar is automatically added to the control.

A Combo Box control combines the features of a Text Box control and a List Box control—Information can be entered in the text box portion or an item may be selected from the list box portion of the control.
A File List Box control locates and lists files in the directory specified by the Path property at run time. Use this control to display a list of files selected by file type.

A Grid control allows the displaying of information in cells, which have a row number and column number.

A Picture Box control can display a graphic from a bitmap, icon, or metafile, as well as enhanced metafile, JPEG or GIF files.

A Frame control provides an identifiable grouping for controls. A Frame control can be used to subdivide a form functionally.

Objects have properties, are able to recognize events and are able to react to methods.

A property is an object’s setting or attribute. Examples: size, color

A partial listing of the Command Button Properties is shown next.

<table>
<thead>
<tr>
<th>Properties - Command1</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Command1 CommandButton</td>
<td></td>
</tr>
<tr>
<td>Name</td>
<td>Command1</td>
</tr>
<tr>
<td>Appearance</td>
<td>1 - 3D</td>
</tr>
<tr>
<td>BackColor</td>
<td>30H-E0000000</td>
</tr>
<tr>
<td>Cancel</td>
<td>False</td>
</tr>
<tr>
<td>Caption</td>
<td>Command Button</td>
</tr>
<tr>
<td>Default</td>
<td>False</td>
</tr>
<tr>
<td>DisabledPicture</td>
<td>(none)</td>
</tr>
<tr>
<td>DownPicture</td>
<td>(none)</td>
</tr>
<tr>
<td>DragIcon</td>
<td>(none)</td>
</tr>
<tr>
<td>DragMode</td>
<td>0 - Manual</td>
</tr>
<tr>
<td>Enabled</td>
<td>True</td>
</tr>
<tr>
<td>Font</td>
<td>MS Sans Serif</td>
</tr>
<tr>
<td>Height</td>
<td>372</td>
</tr>
<tr>
<td>HelpContextID</td>
<td>0</td>
</tr>
<tr>
<td>Index</td>
<td></td>
</tr>
</tbody>
</table>

Figure 9-4 Command Button Properties

An event is an action recognized by an object. Example: Click of a Mouse button

A partial listing of the Command Button Events is shown next.
A method is a procedure which can operate on an object.
Example: dialing a telephone

A partial listing of the Command Button Methods is shown next.
9.6 VISUAL BASIC FORM AND MODULE LISTING

The TOM programs operate using forms and modules. The forms and modules are defined below:
## Table 9-5 Forms Used in the TOM (not provided to the User)

<table>
<thead>
<tr>
<th>Form Filename</th>
<th>Form Name</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>ComplexArithmetic.frm</td>
<td>ComplexArithmetic</td>
<td>TOM Complex Number Calculator</td>
</tr>
<tr>
<td>Date Time Calculator.frm</td>
<td>Date Time Calculator</td>
<td>Date Time Difference (Not Used in TOM)</td>
</tr>
<tr>
<td>extremumizer.frm</td>
<td>extremumizer</td>
<td>Extremumizer</td>
</tr>
<tr>
<td>tsdxbx03.frm</td>
<td>frmDatabase</td>
<td>DB Record View</td>
</tr>
<tr>
<td>tsdxbx04.frm</td>
<td>frmDatabaseT</td>
<td>DB Table View</td>
</tr>
<tr>
<td>frmDbandDirReconciler.frm</td>
<td>frmDbandDirReconciler</td>
<td>DB Database and Directory Reconciler</td>
</tr>
<tr>
<td>frmDeletorAdd.frm</td>
<td>frmDeletorAdd</td>
<td>DB Delete or Add</td>
</tr>
<tr>
<td>ecmvbxx03.frm</td>
<td>frmECMAplvbx</td>
<td>ECM Load Curve Consolidator</td>
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<tr>
<td>ecmvbxx02.frm</td>
<td>frmECMEdcvbx</td>
<td>ECM Energy - Demand</td>
</tr>
<tr>
<td>ecmvbxx01.frm</td>
<td>frmECMVbx</td>
<td>ECM Main</td>
</tr>
<tr>
<td>ensvbxx01.frm</td>
<td>frmENSvbx</td>
<td>ENS Main</td>
</tr>
<tr>
<td>fcmvbxx05.frm</td>
<td>frmFCMAddProvbx</td>
<td>FCM Track Layout - Add Profile for TMS</td>
</tr>
<tr>
<td>fcmvbxx07.frm</td>
<td>frmFCMAMcvbx</td>
<td>FCM Current Measurement Input for ENS &amp; TMS</td>
</tr>
<tr>
<td>fcmvbxx10.frm</td>
<td>frmFCMClcSub1vbx</td>
<td>FCM Control File form for TPS - Detailed Input</td>
</tr>
<tr>
<td>fcmvbxx11.frm</td>
<td>frmFCMClcSub2vbx</td>
<td>FCM Control File form for TPS - Brake Taper</td>
</tr>
<tr>
<td>Fcmvb3x09.frm</td>
<td>FmmFCMClcVbx</td>
<td>FCM Control for TPS – Main ( ≥ Ver 3.0 )</td>
</tr>
<tr>
<td>fcmvbxx09.frm</td>
<td>frmFCMClcVbx</td>
<td>FCM Control File form for TPS – Main ( &lt; Ver 3.0 ) (Obsolete)</td>
</tr>
<tr>
<td>frmFCMDCMFS1.frm</td>
<td>frmFCMDCMFS1</td>
<td>FCM Submodel DC Series Motor Field Strength 1</td>
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<td>frmFCMDCMFS2</td>
<td>FCM Submodel DC Series Motor Field Strength 2</td>
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<td>frmFCMDCMFS5</td>
<td>FCM Submodel DC Series Motor Field Strength 5</td>
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<td>frmFCMDCMFS6.lrm</td>
<td>frmFCMDCMFS6</td>
<td>FCM Submodel DC Series Motor Field Strength 6</td>
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<td>FCM File of Filenames for ENS, RVM, TPS &amp; TMS</td>
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<td>frmFCMMccvbx</td>
<td>FCM Meter consolidation</td>
</tr>
<tr>
<td>fcmvbxx27.frm</td>
<td>frmFCMModelsvbx</td>
<td>FCM Submodel - Main</td>
</tr>
<tr>
<td>fcmvbxx38.frm</td>
<td>frmFCMNegNwSub1vbx</td>
<td>FCM Negative Network for RVM - Nodal Diagram</td>
</tr>
<tr>
<td>fcmvbxx39.frm</td>
<td>frmFCMNegNwSub2vbx</td>
<td>FCM Negative Network for RVM – Text to TOM Transfer</td>
</tr>
<tr>
<td>fcmvbxx37.frm</td>
<td>frmFCMNegNwvx</td>
<td>FCM Negative Network for RVM - Main</td>
</tr>
<tr>
<td>fcmvbxx19.frm</td>
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<td>FCM Network for ENS &amp; TMS - Nodal Diagram</td>
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<td>fcmvbxx34.frm</td>
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<td>FCM Network for ENS &amp; TMS – Text to TOM Transfer</td>
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<tr>
<td>fcmvbxx35.frm</td>
<td>frmFCMNetSub3vbx</td>
<td>FCM Network for ENS &amp; TMS – Move Node</td>
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<tr>
<td>fcmWaysideStorage.frmmm</td>
<td>FmmFCMNetSub4vbx</td>
<td>FCM Waseside Storage for ENS &amp; TMS</td>
</tr>
<tr>
<td>fcmvbxx73.frm</td>
<td>frmFCMNetSub5vbx</td>
<td>FCM Network – Network Generator</td>
</tr>
<tr>
<td>fcmvbxx18.frm</td>
<td>frmFCMNetwvbx</td>
<td>FCM Network for ENS &amp; TMS - Main</td>
</tr>
<tr>
<td>fcmvbxx08.frm</td>
<td>frmFCMOpcvbx</td>
<td>FCM Operating Time for ENS &amp; TMS</td>
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<tr>
<td>fcmvbxx65.frm</td>
<td>frmFCMReturnCircuitGrf</td>
<td>FCM Primary or Return Circuit by Graphics for ENS &amp; TMS</td>
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<tr>
<td>fcmvbxx77.frm</td>
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<td>FCM Return Circuit Rail Voltage File Input - Return Circuit for Rail Voltage by Graphics</td>
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<td>fcmvbxx80.frm</td>
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<td>FCM Return Circuit Rail Voltage File Input - Text to TOM Transfer</td>
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<td>Description</td>
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<td>------------------------------------------------------------------------------</td>
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<td>FcmReturnCircuitRailVoltvbx FCM Return Circuit Rail Voltage File Input - Main Screen</td>
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<td>FcmReturnCircuitSub1vbx FCM Primary or Return Circuit Text to TOM Transfer for ENS &amp; TMS</td>
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<td>FcmReturnCircuitSub2vbx FCM Primary or Return Circuit Text to TOM Transfer for ENS &amp; TMS</td>
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<td>FcmReturnCircuitSub3vbx FCM Primary or Return Circuit Text to TOM Transfer for ENS &amp; TMS</td>
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<td>Fcmvbx69.frm</td>
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<tr>
<td>Fcmvbx74.frm</td>
<td>FcmReturnCircuitSub6vbx FCM Primary or Return Circuit Y Matrix for ENS &amp; TMS</td>
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<tr>
<td>Fcmvbx64.frm</td>
<td>FcmRowvbx FCM Right of Way File for TPS</td>
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<tr>
<td>Fcmvbx59.frm</td>
<td>FcmStavbx FCM Station File for TPS</td>
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</tr>
<tr>
<td>Fcmvbx43.frm</td>
<td>FcmStdbx FCM Station Description for TMS</td>
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</tr>
<tr>
<td>Fcmvbx20.frm</td>
<td>FcmStpdx FCM Stop Distance Calculator for TMS</td>
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</tr>
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<td>Fcmvbx40.frm</td>
<td>FcmCtisub1vbx FCM Track Layout File Input - Text to TOM Transfer</td>
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</tr>
<tr>
<td>Fcmvbx51.frm</td>
<td>FcmCtisub2vbx FCM Track Layout File Input - Insert Node Procedure</td>
<td></td>
</tr>
<tr>
<td>Fcmvbx53.frm</td>
<td>FcmCtisub3vbx FCM Track Layout File Input - Move Node Procedure</td>
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<td>FcmCtisub4vbx FCM Track Layout File Input - Insert Track Segment Procedure</td>
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<td>FcmCtisub5vbx FCM Track Layout File Input - Insert Track Segment Procedure - Add Profile Information</td>
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<td>FcmCttx FCM Track Layout for TMS</td>
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<td>Fcmvbx64.frm</td>
<td>FcmCtlocoLocoDispatchvbx FCM Train File Input - Default Locomotive Dispatch Rules</td>
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<td>Fcmvbx63.frm</td>
<td>FcmCtlocoHauledvbx FCM Train – Build Train for TPS</td>
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<tr>
<td>Fcmvbx59.frm</td>
<td>FcmCtlocoLibvbx FCM Train – Manage Car Library for TPS</td>
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<td>Fcmvbx77.frm</td>
<td>FcmCtlocoRulingGradevbx FCM Ruling Grade Determination</td>
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<td>FcmCtlocoSub10vbx FCM Submodel PWM Inverter Control</td>
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<td>FcmCtlocoSub11vbx FCM Submodel Phase Control</td>
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<td>FcmCtlocoSub3vbx FCM Train for TPS - Propulsion Efficiency</td>
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<td>Fcmvbx16.frm</td>
<td>FcmCtlocoSub4vbx FCM Train for TPS - Fuel Propulsion Model</td>
<td></td>
</tr>
<tr>
<td>Fcmvbx17.frm</td>
<td>FcmCtlocoSub5vbx FCM Train for TPS - Electric Propulsion Model</td>
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<td>Fcmvbx23.frm</td>
<td>FcmCtlocoSub6vbx FCM Submodel DC Series Moto</td>
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<td>FcmCtlocoSub7vbx FCM Submodel AC Induction Motor</td>
<td></td>
</tr>
<tr>
<td>Fcmvbx25.frm</td>
<td>FcmCtlocoSub8vbx FCM Submodel Gear Unit (not used)</td>
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<td>Fcmvbx26.frm</td>
<td>FcmCtlocoSub9vbx FCM Submodel DC Chopper Control</td>
<td></td>
</tr>
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<td>Fcmvbx61.frm</td>
<td>FcmCtlocoTrainResistanceConverter FCM Train – Train Resistance Converter &amp; Calculator for TPS</td>
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<td>Fcmvbx75.frm</td>
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<td>FcmCtlocoTrainResistanceTable FCM Train Resistance Table</td>
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<td>Form Name</td>
<td>Description</td>
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<td>fcmvbx12.frm</td>
<td>frmFCMTFcvbx</td>
<td>FCM Train for TPS - Main</td>
</tr>
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<td>fcmvbx06.frm</td>
<td>frmFCMTlcvbx</td>
<td>FCM Train Location for ENS &amp; TMS</td>
</tr>
<tr>
<td>fcmvbx52.frm</td>
<td>frmFCMTnctiGrf</td>
<td>FCM Track Layout – Layout by Graphics</td>
</tr>
<tr>
<td>fcmvbx01.frm</td>
<td>frmFCMvbx</td>
<td>FCM Main</td>
</tr>
<tr>
<td>fcmvbx14.frm</td>
<td>frmFMMCAOAvbx</td>
<td>FMM Circuit Analyser Output Analyzer</td>
</tr>
<tr>
<td>fcmvbx16.frm</td>
<td>frmFMMCASMLvbx</td>
<td>FMM Line Current Analyzer</td>
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<td>fcmvbx15.frm</td>
<td>frmFMMCASMMvbx</td>
<td>FMM Converter Current Analyzer</td>
</tr>
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<td>frmFMMCAvbx</td>
<td>FMM Current Analyzer - Main</td>
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<td>fmmvbx07.frm</td>
<td>frmFMMCmivbx</td>
<td>FMM Car Distance Calculator - Main</td>
</tr>
<tr>
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<td>frmFMMElivbx</td>
<td>FMM Elevation - Main</td>
</tr>
<tr>
<td>fmmvbx154.frm</td>
<td>frmFMMPavvbx</td>
<td>FMM Power Profile Averager - Main</td>
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<td>frmFMMPavvbx</td>
<td>FMM Power Profile Appender - Main</td>
</tr>
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<td>fmmvbx11.frm</td>
<td>frmFMMPbcvbx</td>
<td>FMM Power Profile Clipper - Main</td>
</tr>
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<td>fmmvbx10.frm</td>
<td>frmFMMPbcvbx</td>
<td>FMM Power Profile Clipper - Main</td>
</tr>
<tr>
<td>fmmvbx17.frm</td>
<td>FrmFMMPROCOffvbx</td>
<td>FMM ENS Offset Process</td>
</tr>
<tr>
<td>fmmvbx172.frm</td>
<td>frmFMMProcSubOutvbx</td>
<td>FMM Auto Substation Out Process</td>
</tr>
<tr>
<td>fmmvbx22.frm</td>
<td>frmFMMRcvbx</td>
<td>FMM Route Checker - Main</td>
</tr>
<tr>
<td>fmmvbx21.frm</td>
<td>frmFMMTncvbx</td>
<td>FMM Propulsion Efficiency Conversion - Main</td>
</tr>
<tr>
<td>fmmvbx20.frm</td>
<td>frmFMMuvvbx</td>
<td>FMM Useful Train Voltage Finder</td>
</tr>
<tr>
<td>fmmvbx18.frm</td>
<td>FrmFMMAVvbx</td>
<td>FMM Voltage Averager</td>
</tr>
<tr>
<td>fmmvbx01.frm</td>
<td>frmFMMvbx</td>
<td>FCM Main</td>
</tr>
<tr>
<td>grfvbx02.frm</td>
<td>frmGRFAMcvbx</td>
<td>GRAPH Electrical</td>
</tr>
<tr>
<td>grfvbx04.frm</td>
<td>frmGRFScalevbx</td>
<td>GRAPH Set Scale</td>
</tr>
<tr>
<td>grfvbx03.frm</td>
<td>frmGRFStcvbx</td>
<td>GRAPH Storage</td>
</tr>
<tr>
<td>grfvbx01.frm</td>
<td>frmGRFvbx</td>
<td>GRAPH Main</td>
</tr>
<tr>
<td>frmMetricEnglishConverter.frm</td>
<td>frmMetricEnglishConverter</td>
<td>TOM Metric English Converter</td>
</tr>
<tr>
<td>frmOptions.frm</td>
<td>frmOptions</td>
<td>Not used</td>
</tr>
<tr>
<td>tomvbx03.frm</td>
<td>frmPrint</td>
<td>TOM File Printer</td>
</tr>
<tr>
<td>tomvbx04.frm</td>
<td>frmProgManViewer</td>
<td>TOM Manual Viewer</td>
</tr>
<tr>
<td>fcmvbx56.frm</td>
<td>frmRemoveNode</td>
<td>FCM Track Layout – Remove Node for TMS</td>
</tr>
<tr>
<td>fcmvbx70.frm</td>
<td>FrmRemoveReturnCircuitLine</td>
<td>FCM Primary or Return Circuit Remove Circuit Line for ENS &amp; TMS</td>
</tr>
</tbody>
</table>
Table 9-6 Modules Used in the TOM (not provided to the User)

<table>
<thead>
<tr>
<th>Module Filename</th>
<th>Module Name</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auxiliary.bas</td>
<td>Auxiliary Codes</td>
<td>TOM Auxiliary Function Subroutines</td>
</tr>
<tr>
<td>ComplexArithmeticAdd.bs</td>
<td>ComplexArithmeticAdd</td>
<td>TOM Complex Arithmetic Calculator</td>
</tr>
<tr>
<td>EXCELModules.bas</td>
<td>EXCELModule</td>
<td>TOM EXCEL Interface</td>
</tr>
<tr>
<td>ImpedanceCalculator.bas</td>
<td>ImpedanceCalculator</td>
<td>TOM Impedance Related Subroutines</td>
</tr>
<tr>
<td>TrainContrlo.bas</td>
<td>TrainControl</td>
<td>TMS Train Control &amp; Movement Subroutines</td>
</tr>
<tr>
<td>Readjustment.bas</td>
<td>TrainFileMods</td>
<td>FCM Train Associated</td>
</tr>
</tbody>
</table>
9.7 RAIL SYSTEM FILE DEFINITION

Several rail system data files have been provided as samples of input and output data for the model. The definitions of these files are contained in this Appendix 9.1. These include a Test Rail System (TEST), Washington Metro (WMATA), Baltimore heavy rail (MTAMD), Miami (MIAMI), Atlanta (MARTA), BiState (St. Louis) (BIDA) Light Rail and Houston metro (HOUS).

9.8 TECHNICAL DETAILS - TRAIN PERFORMANCE SIMULATOR

The TPS is a program, which accepts input data describing the characteristics of a train and information about stations, grades, curvatures, speed restrictions and/or speed commands along the right of way. These data are used to simulate the motion of the train along the right of way in order to obtain the trajectory of the train (speed, time, and power vs. distance along the right of way).

9.8.1 Input Data

Input data for the TPS are divided into four major categories: file definition, simulation or control parameters, train data and right of way data. The first category includes the names of files to be used as input data to the TPS and the names of files for output data. The second category includes selections for output display, input/output controls and general rail system parameters such as acceleration, deceleration, top speed and starting position. The third category includes train makeup, on-board energy storage capability, propulsion and braking characteristics. The fourth category includes station mileposts, dwell times and load factors, speed restrictions and or commands, grade and alignment profiles and routing information.
9.8.1.1 Input File Definition

The file definition is contained in the File of Filenames, the format of which is shown below.

<table>
<thead>
<tr>
<th># of Records</th>
<th>Format</th>
<th>Contents of Record</th>
<th>Expected File Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A42</td>
<td>Filename of Control File</td>
<td>CL-<em>.</em></td>
</tr>
<tr>
<td>1</td>
<td>A42</td>
<td>Filename of Train File</td>
<td>T-<em>.</em></td>
</tr>
<tr>
<td>1</td>
<td>A42</td>
<td>Filename of Station File</td>
<td>ST-<em>.</em></td>
</tr>
<tr>
<td>1</td>
<td>A42</td>
<td>Filename of Grade File</td>
<td>GR-<em>.</em></td>
</tr>
<tr>
<td>1</td>
<td>A42</td>
<td>Filename of Curve File</td>
<td>CU-<em>.</em></td>
</tr>
<tr>
<td>1</td>
<td>A42,1X,A2</td>
<td>Filename of Speed Restriction File</td>
<td>SP-<em>.</em></td>
</tr>
<tr>
<td>1</td>
<td>A42</td>
<td>Filename of Speed Command</td>
<td>SC-<em>.</em></td>
</tr>
<tr>
<td>1</td>
<td>A1,1X,A42</td>
<td>Route File?(Y or N) if Y, then</td>
<td>RU-<em>.</em></td>
</tr>
<tr>
<td>1</td>
<td>A1,1X,A42</td>
<td>Filename of Route File</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>A1,1X,A42</td>
<td>Power Profile?(Y or N) if Y, then</td>
<td>P-<em>.</em></td>
</tr>
<tr>
<td>1</td>
<td>A1,1X,A42</td>
<td>Filename of Power Profile File</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>A1,1X,A42</td>
<td>Detailed Output File?(Y or N) if Y,</td>
<td>TSD*-.*</td>
</tr>
<tr>
<td>1</td>
<td>A1,1X,A42</td>
<td>Filename of Detailed Output File</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>A1,1X,A42</td>
<td>Summary Output File?(Y OR N) if Y,</td>
<td>TSS*-.*</td>
</tr>
<tr>
<td></td>
<td></td>
<td>name of Summary Output File</td>
<td></td>
</tr>
</tbody>
</table>

The remaining records have: FORMAT(A1,1X,A45)

The first eight records are input filenames. The first record contains the name of the control file, which contains the system and control parameters. The second record is the name of the train file, which contains information on the makeup of the train, including the propulsion and braking system. The next five records contain the names of the station, grade, curve, speed restriction, speed command and route files, all of which comprise the right of way data.

The last three records contain the output filenames: The first record contains the name of the power profile; the second, the name of the detailed output file and; the third, the name of the summary output file.

If a ‘/C’ appears in position 44 and 45 of the speed restriction filename record, a speed command file is expected as record 7. If no such indicator appears, then there is no speed command file and the speed restriction file governs the train motion.

For the last four records, a ‘Y’ or ‘y’ is required in position 1 of the record if the file is named. Otherwise no file is expected.

9.8.1.2 Control File Definition

The format of the control file is shown next.

The first record of the file lists the parameters for display of the output. Ten display choices can be selected from thirty nine available selections, which are listed on the following page.
## FORMAT OF CONTROL FILE (CL, *, *)

<table>
<thead>
<tr>
<th># OF RECORDS</th>
<th>VARIABLE AND DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>[FORMAT(10I2, 10X, 10I2)]</td>
</tr>
<tr>
<td></td>
<td>DISP(I)(I=1,10) The output display choices are elected by inserting the appropriate two-digit number in the DISPLAY CHOICES. Only ten displays may be selected and any ordering is acceptable. The default is no display.</td>
</tr>
<tr>
<td></td>
<td>MET The metric unit indicator</td>
</tr>
<tr>
<td></td>
<td>0 - All English units</td>
</tr>
<tr>
<td></td>
<td>1 - English input, metric output</td>
</tr>
<tr>
<td></td>
<td>2 - All metric units</td>
</tr>
<tr>
<td></td>
<td>IPAVE The power average indicator</td>
</tr>
<tr>
<td></td>
<td>0 - Only the instantaneous value of the power is displayed each display interval.</td>
</tr>
<tr>
<td></td>
<td>1 - The average power is displayed each display interval.</td>
</tr>
<tr>
<td>1</td>
<td>[FORMAT(2I2, 2I2, F8.0, 16X, F8.0, 5X)]</td>
</tr>
<tr>
<td></td>
<td>INOUT Regulates input data to be displayed. (0=no data, 1=train data, 2=corridor plus train data; default=0)</td>
</tr>
<tr>
<td></td>
<td>DT1 Specifies the number of time increments between successive displays. Default=05</td>
</tr>
<tr>
<td></td>
<td>DELTD Specifies distance increment for graph choices. Default=.5(miles)</td>
</tr>
<tr>
<td></td>
<td>DT Specifies run time increment. Default=1.0(sec)</td>
</tr>
<tr>
<td></td>
<td>CLTL Specifies whether title record will be used. (1=yes, 0=no, default=0)</td>
</tr>
<tr>
<td></td>
<td>CSTMOD Specifies whether saw tooth coasting will be used. (0=no, 1=yes with coast from designated speed, 2=yes, with coast from speed restriction, default=0)</td>
</tr>
<tr>
<td>1</td>
<td>[FORMAT(2I2, 0F8.0, 6F8.0)]</td>
</tr>
<tr>
<td></td>
<td>D1 Direction of train travel. (+1=increasing position, -1=decreasing position, default=+1)</td>
</tr>
<tr>
<td></td>
<td>ACCMAX and DCCMAX Specifies the maximum acceleration and deceleration of the train. Default is the maximum permitted by the tractive and braking curves. [Units: mph/s/mph/s²]</td>
</tr>
<tr>
<td></td>
<td>START Specifies the starting position, the point at which the train originates. The default is the position of the originating station in the Station File (i.e. the first station if D1.EQ. +1 and the last station if D1.EQ. -1).</td>
</tr>
<tr>
<td></td>
<td>V Specifies the starting speed. Default value is 0. [Units:mph/kph]</td>
</tr>
<tr>
<td></td>
<td>TOPSPE Specifies the maximum speed that the train will run. The default is the maximum speed as determined by the Speed Restriction File. In no event does the train speed exceed the speed restriction at any point. [Units:mph/kph]</td>
</tr>
<tr>
<td></td>
<td>PLOADC Specifies the passenger load factor at the beginning of a run only if the run does not begin at the originating station. Default value is 0%.</td>
</tr>
<tr>
<td></td>
<td>BRAKER and ACELR Specifies the braking and accelerating rate for the train. The default value is the tractive or braking curves. These inputs simulate load weighing by the traction and braking equipment. If BRAKER.LT.0, a brake taper is called. [Units:mph/s/mph]</td>
</tr>
<tr>
<td></td>
<td>CSPD The coast speed for anticipatory coasting. The braking effort above this speed is set to the coast drag CPCT, defined below. [Units:mph/kph]</td>
</tr>
<tr>
<td></td>
<td>CPCT The coast drag for anticipatory coasting. This drag is specified as a fraction of full braking effort. (If CPCT.EQ.0.90 then drag = 0.90 * full braking effort)</td>
</tr>
<tr>
<td></td>
<td>ACJERK The jerk rate limit for acceleration. This limits the rate of change of acceleration from stations and from the present speed restriction of the train. The default is 0., indicating no jerk limit. [Units: mph/s³/mph/s²]</td>
</tr>
<tr>
<td></td>
<td>BRJERK The jerk rate limit for deceleration. This limits the rate of change of deceleration into stations and to the next speed restriction of the train. The default is 0., indicating no jerk limit. [Units: mph/s³/mph/s²]</td>
</tr>
<tr>
<td></td>
<td>WNDSPD The value of the headwind speed. The default is 0. [Units: mph/kph]</td>
</tr>
</tbody>
</table>
CONTROL FILE DISPLAY CHOICES

01 - Power to storage to replace losses
02 - Power delivered from storage device to propulsion unit
03 - Power delivered from propulsion unit to storage.
04 - Energy in storage
05 - Input electrical power
06 - Power output through wheels
07 - Power lost to heat in power conditioner
08 - Power lost to heat in motor
09 - Power lost to heat in gears
10 - Power used to overcome rolling train resistance
11 - Power used to overcome aerodynamic train resistance
12 - Power used to accelerate the train
13 - Power used to climb grades
14 - Power used for auxiliaries
15 - Grade
16 - Acceleration
17 - Curve
18 - Speed
19 - Speed Restriction
20 - Milepost
21 - Power lost to heat in storage device
22 - Power lost to heat in friction braking
23 - Power lost to resistors during electrical braking
24 - Power lost in curving
25 - Conversion efficiency(6/5)
26 - Energy used to replace storage losses
27 - Electrical energy input to train
28 - Mechanical energy output through wheels
29 - Energy lost in power conditioner
30 - Energy lost in motors
31 - Energy lost in gears
32 - Energy used to overcome rolling train resistance
33 - Energy used to overcome aerodynamic train resistance
34 - Energy used during acceleration(train kinetic energy)
35 - Energy used in climbing grades(train potential energy)
36 - Energy used by auxiliaries
37 - Energy lost in friction braking
38 - Energy lost in resistors during braking
39 - Energy lost in curving

note: All power terms are in watts, all energy terms are in watt-hours, and all energy terms are accumulated from the start of the run.
The second record of the file controls output and the computational parameters. Most of the entries are self-explanatory. The variables CLTL and CSTMOD may cause the TPS to expect more than three records in the file. If CLTL.EQ.1., then a title record is added to the file, as the fourth record. This title appears on the summary output of the TPS along with the title from the second record of the Train File and the second record of the Station File. If CSTMOD.NE.0, then the TPS expects to read a fourth (fifth) record depending on whether CLTL.EQ.0.(1.). This fourth (fifth) record contains the coast speed band and the drag. If CSTMOD.EQ.1, then TOPSPE (coast speed) in the next record must be set. If CSTMOD.EQ.2, the present speed restriction along the right of way is taken as the coast speed.

The third record of the Control File contains information appropriate to train performance. The variables ACCMAX and DCCMAX, place a limit on the acceleration and deceleration of the train independent of speed and grade. The variable TOPSPE can be interpreted as the maximum speed of the train if CSTMOD.EQ.0 in the previous record or the coast speed, if CSTMOD.EQ.1, indicating saw tooth coasting is enabled. The variable BRAKER sets the maximum braking effort of the train on level track. Retardation on positive grade sections will exceed this braking effort. If BRAKER.LT.0., then two additional records are added after the saw tooth coasting record indicating brake taper points.

The variable ACELR in the third record sets the maximum acceleration (MPHPS) or maximum tractive effort (on a per powered vehicle basis) at start (zero speed) on level track. Its value is recognized as acceleration if ACELR.LT.10. and tractive effort for ACELR.GT.10. The next two variables, CSPD and CPCT define the coast speed and drag for anticipatory coasting (If CSPD.EQ.0. then no anticipatory coasting). The braking effort in the TPS is set to (CPCT*FULL BRAKING EFFORT) above the coast speed.

The braking taper records (2) contain the speed points (record 1) and the braking rates (record 2) at the speed points. The TPS finds a brake rate value between two successive speed points by linear interpolation.

9.8.1.3 Train File Definition

The TPS expects train data to reside in a single file. The variables are grouped in parts:

Part 1: Weights and Dimensions
Part 2: On-Board Energy Storage
Part 3a: Propulsion Model (Diesel Propulsion)
Part 3b: Propulsion Model (Electric Propulsion)
Part 4: Traction and Braking

Part 1 provides weight and dimensional type information, train resistance data and control information, which key other inputs for the Train File. It is shown next.
### FORMAT OF TRAIN FILE (T-*.* *)

#### PART I WEIGHTS AND DIMENSIONS

<table>
<thead>
<tr>
<th># OF RECORDS</th>
<th>VARIABLE AND DEFINITION</th>
</tr>
</thead>
</table>
| 1            | [FORMAT(78A1)]  
TITL(I)(I=1,78): Descriptive title of train which appears in output. |
| 1            | [FORMAT(A2,I5,F5.0,10X,F10.0,3I2)]  
TNAME: The train portion of the four character ID which appears in the output power profile. The other two characters come from the second record of the station file. |
|              | NCART: The number of different type cars in the train. A car may be different because of weight, power vs non-power, train resistance parameters, auxiliary power, or any other of the variables in the next NCART records. |
|              | AREA: Frontal area (sq. ft.) of the train for purposes of the aerodynamic train resistance. |
|              | BTUGAL: The BTU content of a gallon of fuel. A value is 134000. It has no meaning unless the variable TTYPE.EQ.2.OR.TTYPE.EQ.3, in this record. |
|              | FLANGE: The flange coefficient used in a Davis type formula for train resistance. Normally, a value of .045 is used for self-propelled cars and locomotives and a value of .03 for coaches. Measured values should be entered when available. |
|              | TTYPE: The propulsion system model type.  
1 - Diesel propulsion with fuel curves.  
2 - Diesel propulsion with constant conversion efficiency.  
3 - Electric propulsion with efficiency curves representing conversion of line power to rail power. |
|              | NHS: High Speed Train Indicator  
>175 MPH Set to 1  
0 otherwise |
|              | METTRN: Units used (0-English, 3-Metric) |
|              | [FORMAT(4I5,4F5.0,F10.0,6F8.0)]  
NCART: The number of cars of type I. |
|              | NMOTR(I)(I=1,NCART): The number of motors on the car of type I. In the case of a non-powered car the value is set to 0. In the case of electric propulsion with efficiency curves (TTYPE.EQ.3), this value is set to 1. The correct number of motors is used only for fuel propelled engines (TTYPE.EQ.1.OR.TTYPE.EQ.2). |
|              | NXL(I)(I=1,NCART): The number of axles on the car of type I. This value is used for the Davis type train resistance computations. |
|              | NSEAT(I)(I=1,NCART): The number of seats or passenger spaces on the car. This value is used to calculate the number of gallons of fuel per seat-mile for diesel or turbine propelled passenger trains. |
|              | AUX(I)(I=1,NCART): The average auxiliary power requirements of the car of type I. The units are KW. |
|              | CARLEN(I)(I=1,NCART): The length of the car of type I. This value is used to determine train length in order to correct speed restrictions for the effect and for later use in the TMS. |
|              | WTE(I)(I=1,NCART): The empty weight of the car of type I. |
|              | WTF(I)(I=1,NCART): The full weight of the car of type I. This is the weight of the car at maximum load. Use of the passenger load factor in the station file will vary the weight between empty and full as the load factor varies between 0 and 100%. |
|              | DRAG(I)(I=1,NCART): The aerodynamic drag coefficient for the car of type I. Typical values are .0024 for lead cars and .00034 for trailing cars. This value is used for the Davis type train resistance calculation. |
|              | EDRW(I)(I=1,NCART): The equivalent rotational weight of the I'th car. If the value is 0., the equivalent rotational weight is assumed to be 10% of car weight. |

If the train resistance coefficients of a Davis type formula is not used, the train resistance will be calculated using single car train resistance coefficients. These are of the form:

- For rolling resistance for the I'th type vehicle: $C(1,I) + C(2,I)*WT + [C(3,I) + C(4,I)*WT]^*V$  
- For aerodynamic resistance for the I'th type vehicle: $C(5,I)*V^2$  
- For all other resistances for the I'th type vehicle: $C(6,I)*V^3$
Specific details of Part 1 input, which may prove beneficial, are:

1. The variable TNAME, which identifies the train, is a combination of two user-selected alpha-numerics. The TPS combines them with the two user-selected alpha-numerics from the station file to form the Train Type ID for the Power Profile output of the TPS, which is used as input to ENS.

2. The number of different vehicles (represented by the integer variable NCART) is defined on user discretion. A vehicle can be different because of its weight, number of engines or motors, its auxiliary power, its length, number of axles, number of seats or its aerodynamic drag coefficient.

3. Train resistance is computed internally in the TPS by using a Davis type formula. By clever selection of the variables AREA, FLANGE, NXL (I) and DRAG (I) together with different types of vehicles increasing NCART, the train resistance of the train to be simulated can be matched easily to its experimental value obtained in a coast-down test. Note that AREA, FLANGE, NXL (I) and DRAG (I) are used only for computation of train resistance.

4. One of four types of propulsion inputs can be selected by choosing the value of TTYPE:
   
   a. TTYPE.EQ.0: Uses the electric propulsion model internal to the TPS to relate power at the rail to power at the catenary, trolley or third rail.
   
   b. TTYPE.EQ.1: Indicates that a diesel propulsion model with fuel consumption curves will be used. For diesel-electric locomotives, throttle positions are usually specified, which are positions of constant fuel flow (gal/hr) at which a tractive effort/speed curve is given. Note that the heat value of the fuel can be specified in the variable BTUGAL.
   
   c. TTYPE.EQ.2: A diesel propulsion model with a linear relation between fuel flow and horsepower at the rail will be used. This relation is of the form:

   \[
   \text{Fuel Flow} = \text{Constant} + \text{Coeff} \times \text{Rail HP}
   \]

   The user selects the coefficient (Coeff) and Constant. Note that the fuel heat value can be specified in the variable BTUGAL.

   TTYPE.EQ.3: Indicates that a general propulsion efficiency model will be used. The efficiency of the propulsion system from rail to energy source on the vehicle is specified in both power and braking at several (tractive effort, speed) points. In this circumstance, a propulsion model external to the TPS can be used to compute power at the energy source given power at the rail. For AC electric trains, power factor at line must be specified as well. This will be zero for DC trains.
<table>
<thead>
<tr>
<th># OF RECORDS</th>
<th>VARIABLE AND DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>[FORMAT(2.5F10.0,2F5.0,F10.0,I2)]</td>
</tr>
</tbody>
</table>

**NSTOPR**  The number of on-board energy storage devices per powered car. The value of 0 indicates no storage devices. If there is no on-board storage then a blank record is required here. Regeneration must be turned on for on-board energy storage (NREG.EQ.0). If the size of the storage device is inadequate, energy is returned to the line.

**WHSTAR**  The initial stored energy (wh) per device.

**WHLOW**  The lower limit of stored energy (wh) per device.

**WHHIGH**  The upper limit of stored energy (wh) per device.

**PMAXO**  The maximum output power (w) per device.

**PMAXI**  The maximum input power (w) per device.

**EFFOUT**  The output power conversion efficiency of the device. Enter as decimal fraction.

**EFFIN**  The input power conversion efficiency of the device. Enter as decimal fraction.

**WHLOSS**  The steady state energy loss of the device. It may be expressed in wh/s or %/s depending on the variable LOSS. Enter %/s as decimal fraction/s.

**LOSS**  The steady state energy loss computation code:

1 - Exponential decay

\[ E_o = E_e \times (1 - DT \times WHLOSS) \quad [WHLOSS \ %/s] \]

2 - Linear decay

\[ E_o = E_e - DT \times WHLOSS \quad [WHLOSS \ wh/s] \]
### FORMAT OF TRAIN FILE (T-*.*)

**PART 3 PROPULSION MODEL**

#### A. DIESEL PROPULSION

<table>
<thead>
<tr>
<th># OF RECORDS</th>
<th>VARIABLE AND DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>DIESEL PROPULSION WITH FUEL CONSUMPTION CURVES</strong></td>
</tr>
<tr>
<td></td>
<td>if TTYPE.EQ.1, THEN THIS PART IS READ:</td>
</tr>
<tr>
<td></td>
<td>1 [FORMAT(2I5)]</td>
</tr>
<tr>
<td></td>
<td><strong>NCRV</strong> The number of fuel consumption curves. Limit is 10.</td>
</tr>
<tr>
<td></td>
<td><strong>NPNT</strong> The number of points to be selected on each curve. The limit is 10.</td>
</tr>
<tr>
<td></td>
<td>1 [FORMAT(3F8.0)]</td>
</tr>
<tr>
<td></td>
<td><strong>FIDLE</strong> Fuel consumption rate (per engine) at idle.</td>
</tr>
<tr>
<td></td>
<td><strong>DYNAM</strong> Fuel consumption rate (per engine) during dynamic braking.</td>
</tr>
<tr>
<td></td>
<td><strong>FAUX</strong> Fuel consumption rate (per engine) due to auxiliaries.</td>
</tr>
<tr>
<td></td>
<td>1 [FORMAT(10F8.0)]</td>
</tr>
<tr>
<td></td>
<td><strong>FC(I)(I=1,NCRV)</strong> Fuel consumption rate (per engine) for each of the curves in ascending order of rate.</td>
</tr>
<tr>
<td></td>
<td><strong>NCRV</strong> [FORMAT(10F8.0)]</td>
</tr>
<tr>
<td></td>
<td><strong>VEL(I,J)(I=1,NCRV)</strong> For the I'th fuel consumption curve, the speed at the J'th selected point, in ascending order of speed.</td>
</tr>
<tr>
<td></td>
<td><strong>NCRV</strong> [FORMAT(10F8.0)]</td>
</tr>
<tr>
<td></td>
<td><strong>TEF(I,J)(I=1,NCRV)</strong> For the I'th fuel consumption curve, the tractive effort (per engine) at the J'th selected point, in ascending order of speed.</td>
</tr>
<tr>
<td></td>
<td><strong>DIESEL PROPULSION WITH CONSTANT EFFICIENCY</strong></td>
</tr>
<tr>
<td></td>
<td>if TTYPE.EQ.2, THEN THIS PART IS READ:</td>
</tr>
<tr>
<td></td>
<td>1 [FORMAT(5F8.0)]</td>
</tr>
<tr>
<td></td>
<td><strong>FIDLE</strong> Fuel consumption rate at idle (per engine).</td>
</tr>
<tr>
<td></td>
<td><strong>DYNAM</strong> Fuel consumption rate during dynamic braking (per engine).</td>
</tr>
<tr>
<td></td>
<td><strong>GALH00</strong> The intercept of the fuel consumption vs rail horsepower line (per engine).</td>
</tr>
<tr>
<td></td>
<td><strong>GALHP</strong> The slope of the fuel consumption vs rail horsepower line (per engine).</td>
</tr>
<tr>
<td></td>
<td><strong>FAUX</strong> Fuel consumption rate due to auxiliaries (per engine).</td>
</tr>
</tbody>
</table>
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#### FORMAT OF TRAIN FILE (T-*,*)

PART 3 PROPULSION MODEL

**B. ELECTRIC PROPULSION**

<table>
<thead>
<tr>
<th># OF RECORDS</th>
<th>VARIABLE AND DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELECTRIC PROPULSION</td>
<td>IF TTYPE.EQ.3, THEN THIS PART IS READ:</td>
</tr>
<tr>
<td>1</td>
<td>[FORMAT(20,2)]</td>
</tr>
<tr>
<td>NROWS</td>
<td>The number of points on the speed axis.</td>
</tr>
<tr>
<td>NCOLS</td>
<td>The number of points on the tractive effort axis.</td>
</tr>
<tr>
<td>NRE0</td>
<td>Regenerative braking selection (0 - yes, 1 - no).</td>
</tr>
<tr>
<td>NROWS/10</td>
<td>[FORMAT(10F8.0)]</td>
</tr>
<tr>
<td>ROW(I)(I=1,NROWS)</td>
<td>Values of speed along the speed axis beginning with 0.</td>
</tr>
<tr>
<td>NCOLS/10</td>
<td>[FORMAT(108.0)]</td>
</tr>
<tr>
<td>COL(I)(I=1,NCOLS)</td>
<td>Values of tractive effort (per powered car) along the tractive effort axis starting at 0.</td>
</tr>
<tr>
<td>NROWS</td>
<td>[FORMAT(108.0)]</td>
</tr>
<tr>
<td>MC(I,J,1)(I=1,NCOLS)</td>
<td>Traction efficiency at the I'th speed point on the speed axis and the J'th tractive effort point on the tractive effort axis. Enter as decimal fraction.</td>
</tr>
<tr>
<td>NROWS</td>
<td>[FORMAT(10F8.0)]</td>
</tr>
<tr>
<td>MC(I,J,2)(I=1,NCOLS)</td>
<td>Power factor at the I'th speed point on the speed axis and the J'th tractive effort point on the tractive effort axis. Enter as decimal.</td>
</tr>
<tr>
<td>NROWS</td>
<td>[FORMAT(10F8.0)]</td>
</tr>
<tr>
<td>MCB(I,J,1)(I=1,NCOLS)</td>
<td>Regenerative braking efficiency at the I'th speed point on the speed axis and the J'th electrical braking effort point on the electrical braking effort axis. Enter as decimal.</td>
</tr>
<tr>
<td>NROWS</td>
<td>[FORMAT(10F8.0)]</td>
</tr>
<tr>
<td>MCB(I,J,2)(I=1,NCOLS)</td>
<td>Regenerative braking power factor at I'th speed point on the speed axis and the J'th electrical braking effort point on the electrical braking effort axis. Enter as decimal.</td>
</tr>
</tbody>
</table>
### 9.8.1.4 Right of Way File Definition

The description of the right of way is shared among the Station, Grade, Curve, Speed Restriction, Speed Command and Route files, which are read by the TPS in that order. In each file, an integer variable indicates the number of records in the file. The principal purpose of routing is to distinguish between tracks on different routes that a train may take through a complex network.

With the exception of the Station File, all of the right of way related files have the form (position, right of way parameter). The right of way parameter is in force from the previous position to the present position.

<table>
<thead>
<tr>
<th># OF RECORDS</th>
<th>VARIABLE AND DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>[FORMAT(9F8.0)] TE(I)(I=1,NHL) Maximum tractive effort capability (per powered car) in order of increasing speed, beginning at 0. and incrementing by 5 mph to maximum speed.</td>
</tr>
<tr>
<td>4</td>
<td>[FORMAT(9F8.0)] EBE(I)(I=1,NHL) Maximum electrical braking effort capability (per powered car) in order of increasing speed beginning at 0. and incrementing by 5 mph.</td>
</tr>
<tr>
<td>4</td>
<td>[FORMAT(9F8.0)] FBE(I)(I=1,NHL) Maximum friction braking effort (per powered car) in order of increasing speed, beginning at 0. and incrementing by 5 mph. These last four records must not be present if BRAKER.NE.0. Where NHL = 36 IF NHS = 0 70 IF NHS = 1</td>
</tr>
</tbody>
</table>
# FORMAT OF RIGHT OF WAY RELATED FILES

## Station File (ST-*.*)

<table>
<thead>
<tr>
<th># OF RECORDS</th>
<th>VARIABLE AND DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Station File (ST-<em>.</em>))</td>
</tr>
<tr>
<td>1</td>
<td>[FORMAT(80A1)]</td>
</tr>
<tr>
<td></td>
<td>TITLEC(I)=1,80) Descriptive title to appear in output.</td>
</tr>
<tr>
<td>1</td>
<td>[FORMAT(A2)]</td>
</tr>
<tr>
<td></td>
<td>SSTPE: Station type. These two characters are combined with the two characters from the second record of the Train File and together form the train ID for the Power Profile.</td>
</tr>
<tr>
<td>1</td>
<td>[FORMAT(15s)]</td>
</tr>
<tr>
<td></td>
<td>NSTOP: The number of stations.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NSTOP</th>
<th>[FORMAT(F10.0,3A4,2F10.0)]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FOR I=1,NSTOP</td>
</tr>
<tr>
<td></td>
<td>STM(I) The position of the Ith station.</td>
</tr>
<tr>
<td></td>
<td>STNM(I,J)=1,3 The name of the Ith station.</td>
</tr>
<tr>
<td></td>
<td>STOP(I) The dwell time at the Ith station. The first and last station have no dwell time.</td>
</tr>
<tr>
<td></td>
<td>STLOAD(I) The passenger load factor between the Ith station and the previous station, defined by the direction of the train motion. Between station I and station [I - (-1)**D1] except for I.NE.1 if D1.EQ.+1 and I.NE.NSTOP if D1.EQ.-1.</td>
</tr>
</tbody>
</table>

## Grade File (GR-*.*)

<table>
<thead>
<tr>
<th># OF RECORDS</th>
<th>VARIABLE AND DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Grade File (GR-<em>.</em>))</td>
</tr>
<tr>
<td>1</td>
<td>[FORMAT(15s)]</td>
</tr>
<tr>
<td></td>
<td>NGC: The number of grade change points in file.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NGC</th>
<th>[FORMAT(2F10.0)]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FOR I=1,NGC</td>
</tr>
<tr>
<td></td>
<td>GM(I) Position of Ith grade change point.</td>
</tr>
<tr>
<td></td>
<td>G(I) Percent grade between (I-1)th grade change point and Ith point.</td>
</tr>
</tbody>
</table>

## Curve File (CU-*.*)

<table>
<thead>
<tr>
<th># OF RECORDS</th>
<th>VARIABLE AND DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Curve File (CU-<em>.</em>))</td>
</tr>
<tr>
<td>1</td>
<td>[FORMAT(15s)]</td>
</tr>
<tr>
<td></td>
<td>NCC: The number of curve change points in file.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NCC</th>
<th>[FORMAT(2F10.0)]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FOR I=1,NCC</td>
</tr>
<tr>
<td></td>
<td>CM(I) The position of the Ith curve change point.</td>
</tr>
<tr>
<td></td>
<td>C(I) Degree of track curvature between the (I-1)th curve change point and the Ith point.</td>
</tr>
</tbody>
</table>
FORMAT OF RIGHT OF WAY RELATED FILES (continued)

<table>
<thead>
<tr>
<th># OF RECORDS</th>
<th>VARIABLE AND DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Speed Restriction File(SP-<em>.</em>))</td>
</tr>
<tr>
<td>1</td>
<td>[FORMAT(I5)]</td>
</tr>
<tr>
<td>NSC</td>
<td>The number of speed restriction change points.</td>
</tr>
<tr>
<td></td>
<td>[FORMAT(2F10.0)]</td>
</tr>
<tr>
<td>FOR I=1,NSC</td>
<td>SM(I) The position of speed restriction change point.</td>
</tr>
<tr>
<td></td>
<td>SP(I) The speed restriction (mph) between the (I-1)th speed restriction change point and the Ith point.</td>
</tr>
<tr>
<td></td>
<td>CAUTION: Two successive speed restrictions must be different. The speed restriction file must cover the whole range of mileposts which the train will run.</td>
</tr>
<tr>
<td></td>
<td>Speed Command File(SC-*.**))</td>
</tr>
<tr>
<td>1</td>
<td>[FORMAT(I5)]</td>
</tr>
<tr>
<td>NSCC</td>
<td>The number of speed restriction change points.</td>
</tr>
<tr>
<td></td>
<td>[FORMAT(2F10.0)]</td>
</tr>
<tr>
<td>FOR I=1,NSCC</td>
<td>SMC(I) The position of the speed command change point.</td>
</tr>
<tr>
<td></td>
<td>SCP(I) The speed command between the (I-1)th speed command change point and the Ith point.</td>
</tr>
<tr>
<td></td>
<td>Route File(RU-*.**))</td>
</tr>
<tr>
<td>1</td>
<td>[FORMAT(I5)]</td>
</tr>
<tr>
<td>NRDTE</td>
<td>The number of track change points.</td>
</tr>
<tr>
<td></td>
<td>[FORMAT(F10.0,I2)]</td>
</tr>
<tr>
<td>FOR I=1,NRDTE</td>
<td>ROUTE(I) The position of the Ith track change point.</td>
</tr>
<tr>
<td></td>
<td>NROUTE(I) The track number (1-99) between the (I-1)th and the Ith track change point.</td>
</tr>
<tr>
<td>note:</td>
<td>The grade, curve, speed restriction, speed command and route profiles must extend about .1 mi beyond both the starting and ending points of the run. The TPS modifies the speed restriction file by adding zero speed at the station stops and by accounting for train length.</td>
</tr>
</tbody>
</table>
9.8.2 Main Program Description

A diagram of the trajectory calculation for a train is shown next.

The calculation of the trajectory begins at zero speed and at the position designated in the input files. It proceeds in time steps whose duration is specified by the Control File entry Calculational Time Interval.

It proceeds forward until the first speed restriction is encountered at which time a backward calculation in time is started beginning at the speed restriction position and the speed restriction speed. When the trajectory represented by the forward calculation is intersected by the trajectory represented by the backward calculation, the remaining part of the forward trajectory from the intersection point to the speed restriction encountered is eliminated and the piece of the backward calculation from the speed restriction to the intersection point is added to the remaining part of the forward trajectory. Time is adjusted to compensate.

If the position is in the range of the speed restriction, the speed is set to the speed restriction and the remainder of the trajectory through the speed restriction is added to the existing trajectory.

If the next speed restriction is higher, the calculation proceeds in the forward direction until the next lower speed restriction is encountered, at which time, the same process is repeated.
If the next speed restriction is lower, the same process is repeated.

This procedure continues until a stop is encountered, at which time the trajectory is used to determine the records of the power profile.

The program flowchart is shown next.
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TPS Flow Diagram

Subroutine Backup places the train at the new speed restriction and proceeds to compute a new trajectory in the backward direction.
The program begins by initializing the variables, reading the input data and determining the train's initial conditions. It then outputs the input data using the subroutine OUTINP. The main loop begins with statement 1.

Time is incremented by the calculation time interval. If the train has arrived at the next station, the subroutine STATIO is called. Its purpose is to write the detailed output on the run from the previous station via subroutine OUTPUT and to set up the train conditions for the run to the next station. If the present station is the last station, the program develops the summary output and produces the Power Profile, which can be subsequently used as input to the ENS.

If the train is in between stations, the subroutines TCP, CURVE, GRADE, SPEED, FORWARD, and SPEED are called. Each of the subroutines has the following functions.

TCP - This is the train capability routine. It determines the train resistance as well as the maximum tractive and braking effort capability of the train at its operational speed and weight.

CURVE - This is the curve lookup table. The routine looks up the curvature of the right of way at the present position of the train.

GRADE - This is the grade lookup table. The routine looks up the grade of the right of way at the present position of the train.

SPEED - This routine has two functions. The first function is a speed restriction lookup along the right of way at the present position of the train. This function is utilized in the first call to speed. The second function is a determination of whether or not a new speed restriction has been encountered in the present step. This function is exercised in the second call to the routine in the above sequence.

FORWARD - this routine selects the acceleration mode for the next time interval. The modes are acceleration, deceleration, coasting, or cruising. The mode is selected based on the relationship between the current speed and the speed restriction, as well as on other parameters. After the mode is selected, the appropriate routine is called to calculate the acceleration and tractive effort in the interval. The speed and distance are integrated to find the values at the end of the time interval. If the lower bound of the coast band has been crossed, the speed, time and location of the exact intercept point are calculated and stored in the storage arrays.

The new speed is compared with the speed restriction or speed command. If the speed is less than the value, the calculation is repeated for the next time increment. If the speed exceeds the value, and a speed command is in effect, the speed is set equal to the speed command and the time and distance are readjusted to match. Storage of the trajectory is updated using the routine STOFO. If no speed command is in effect and if a new speed restriction has been encountered which is less than the previous speed restriction, the subroutine BACKUP is called which calculates a backward trajectory until the forward trajectory is intersected. At that point the storage via routine STOFO is updated to allow the extended forward trajectory to be the backward trajectory just calculated by routine BACKUP. If no speed command is in effect and there has been no change in the speed restriction in the last step, then storage is updated using the routine STOFO. The calculation then proceeds to the new time interval.

The subroutine OUTPUT, which is called from STATIO, calls the routines, which calculate the real and reactive components of the power or the fuel consumption at every point along the trajectory.
9.8.3 Output Data

There are three separately selected outputs from the TPS. These are the Detailed, Summary, and Power Profile outputs.

9.8.3.1 TPS Detailed Output File

The Detailed Output File (TSD-*.* ) has five parts.

The first part summarizes the input data concerning the train. Information concerning the number of vehicles, (powered and not powered), vehicle empty and full weights as well as passenger load factor to start and train weight; number of motors, vehicle lengths and cross sectional areas; wheel diameter, and operating voltage are printed out when selected. The traction curves are also presented as a function of speed together with the acceleration, deceleration and train resistance appropriate to an empty train (no passengers).

Examples of Part 1 are shown in Figure 9-7 to Figure 9-10.

Figure 9-7 TPS Detailed Output File Part 1a

Information in this screen contains the content of the File of Filenames file for the TPS run. All of the files shown are either input to or output from the TPS.
Figure 9-8 TPS Detailed Output File Part 1b
Information in this screen describes more detail about the run itself. The items described are contained in the Control file (CL-) specified in the File of Filenames file.
Figure 9-9 TPS Detailed Output File Part 1c

Information at the top this screen is still contained in the Control file (CL-) specified in the File of Filenames file. The next items represent the specification of the Train file (T-) specified in the File of Filenames file.
Figure 9-10 TPS Detailed Output File Part 1d

Information at the top this screen is still contained in the Train file (T-) specified in the File of Filenames file.

The Traction and Motion Characteristics (Level Tangent Track) are shown in a table, which lists as a function of speed the Traction Characteristics: Tractive Effort (TE), Electrical Braking Effort (EBE), Friction Braking Effort (FBE) and Total Braking Effort (BE) and the Motion Characteristics: Applied and Actual Acceleration and Deceleration on level-tangent track. Applied means no train resistance and actual includes train resistance. Train Resistance is shown in the last column.
Figure 9-11  TPS Detailed Output File Part 2

Part 2 lists the right of way profiles and station information. All grades, curves, speed restrictions, speed commands and route segments are displayed versus position. Station names, mileposts, dwell times and passenger load factors are all displayed. These are continued in the Right of Way [Grade (GR-)], Curve (CU-), Speed Restriction (SR-) and Route (RU-) files in the File of Filenames file.
Figure 9-12 TPS Detailed Output File Part 3

Part 3 reports on the output during the run of user’s selection of ten variables at selected time increments during the calculation. There are thirty-nine variables from which to choose including speed, distance, acceleration, all of the various power variables, and all of the associated energy variables. Time is always displayed. For the most part, the time increment is the Display Time Interval selected in the Control file (CL-).

Part 4 summarizes the results of the run in two sections Part 4a and Part 4b.
Figure 9-13 TPS Detailed Output File Part 4a

Part 4a, the first section, lists **the Train ID**, distance traveled, run time, average and maximum speeds and maximum acceleration and braking obtained during the run. In addition several energy and power related items are output in summary form such as kilowatt-hours per car mile and per ton-mile, average and peak power.
Figure 9-14 TPS Detailed Output File Part 4b

Part 4b shows a summary the energy end use of the train for the entire run. The actual energy consumption is also displayed, as are all of its constituent parts (Energy Components) such as energy going to rolling friction losses, propulsion energy etc.

Potential Energy is work against gravity. The first computation is made as the train moves against or with the grade force (proportional to force x speed) and the second is due to the elevation differences between starting and ending points (proportional to weight x elevation change). Positive (negative) means the difference between start and end elevations is positive (negative).

An energy flow diagram can be developed from this section of the output, which graphically shows how much energy is lost to the environment and where these losses occur.
Figure 9-15 Rail Vehicle Energy Flow Diagram
Part 5 provides information on the energy and power performance of a train with on-board energy storage. Since the storage device has in and out losses, a maximum energy storage capability and maximum input and output power limitations, a report is presented containing a summary of each of these parameters for the TPS run. Energy units are kilowatt-hours and power units are kilowatts.
9.8.3.2 TPS Summary Output File

The Summary Output File (TSS-*.*), provides a station-by-station summary of the run. The station-to-station names, distances, time (including dwell), average speeds, energies and energies per car-distance are displayed as well as a summary of these same quantities for the entire run.

Figure 9-17 TPS Summary Output File Electric Powered Trains

In the case of fuel powered trains, a sample of the Summary Output file is shown next.
Figure 9-18 TPS Summary Output File Fuel Powered Trains
9.8.3.3 TPS Power Profile Output File

The TPS program creates a Power Profile File (P-*.*), containing information for the ENS and TMS. This file lists the train position, speed, real and reactive power demand, acceleration, and traction effort, speed command and train weight as a function of time. The user specifies the time increment between successive points in this output by selecting the number of calculation time intervals in one display interval. The output for this file is repeated every display interval.

Figure 9-19 TPS Power Profile Output File Part 1

The first record contains: Number of Power Profile Records, Number of Cars in Train, Train Driven by Fuel (1) or Electric Power (0), Train Length (mi. or km.), Reaction Time of Driver or On-Board Train Control (sec.).

For each Power Profile Record, the following information is displayed: Time (sec.), Train ID, Speed (mph or kph), Position (mi. or km.), Real Power (watts), Reactive Power (volt-ampere-reactive), Track Number, Acceleration (mphps or mpsps), Traction Effort (lbs. or newtons), Speed Command (mph or kph), Train Weight (tons or tonnes).

If the train has fuel as its energy source, then Real Power (gallons per hour or imperial gallons per hour) reflects rate of fuel use.

At the end of the file, a list of all of the input files to the TPS for this particular run is produced. This list is used by the TMS.
### Figure 9-20 TPS Power Profile Output File Part 2

Part 2 shows a listing of the input files for the run in a format readable by the TMS.
9.8.4 Verification, Limitations and Performance

9.8.4.1 Verification

Verification has two aspects; namely, that the TPS does what is intended and that what is intended conforms to reality.

Each of the modules in the TPS has been carefully examined and verified that it indeed does what was intended. The entire TPS has been subjected to close scrutiny and most of the options, which can be selected by the user have been verified. As in the case of all large computer programs with many input option selections, some combinations were not tested, so that under rare circumstances it is possible that a coding error may be discovered.

That the TPS conforms to reality has been verified in many ways. The first way was the comparison of its performance to that of other computer programs that have found acceptance in the Transportation Industry.

The second way was to compare actual test data with TPS runs. The TPS has been in actual use since 1981. It has been compared with many runs on many rail systems including rail systems of the:

- Washington Metropolitan Area Rail Authority (WMATA)
- Metropolitan Atlanta Rapid Rail Authority (MARTA)
- Maryland Mass Rail Administration (MTAMD) (Baltimore)
- New Jersey Rail (NJT) (Morris-Essex Line)
- Port Authority of Allegheny County (PAT) (Pittsburgh)
- Miami Dade County (MIAMI)

It has also been verified on many other systems by several consultants and rail authorities.

9.8.4.2 Dimensional and Size Restriction

In present day PC with 32-bit architecture, no problems are encountered because of program size. The main storage array dimensions for time, distance, speed, acceleration and tractive effort can easily be changed with a text editor. This dimension limits the inter station travel time or the time step size so that the inter station travel time is that dimension multiplied by the time step size.

The grade, speed restriction, curve and route changes as well as number of stations are adequately handled by the dimension of those variables. If larger profile requirements are encountered, this storage could be expanded with a text editor.
9.8.4.3 Inherent Computational Errors

Euler's numerical integration method results in some error when calculating speed from acceleration. The error is larger when the acceleration or deceleration is being limited by the availability of tractive force or braking force. Since both tractive force and braking force available decrease with speed, and since the integration step always starts with the lower speed (since the deceleration is integrated with a reverse Euler's Method), the program will tend to apply more tractive force or more braking force than is actually available. The magnitude of the error depends upon the tapering of available tractive force and braking force with speed as well as the length of the time step.

Larger calculation time intervals produce larger errors. For commuter, heavy light rail and people movers, one-second time intervals seem to be appropriate. Computational error for this case is less than 1%. For inter city trains, whether freight or passenger, two-second time intervals can be used with less than 1% error. Within a reasonable limit (>0.1 second) reducing the time interval reduces the computational error.

Of less significance is the fact that a set tractive effort will not result in a set acceleration over a fixed time interval. The rolling friction and the air friction are speed dependent. Consequently, a set tractive effort will result in a steadily decreasing acceleration until a balancing point is reached. This error depends primarily upon the time step chosen and, with short time steps, is of no real significance.

The integration of speed to find distance uses the trapezoidal rule and consequently has less discretization error. It assumes a linear change in speed, an assumption subject to the above errors. The error generated by this approximation is not of great concern.

Power, at any given instant, is dependent upon force and speed or volts and amps. Energy is found by integrating power with a forward Euler Method for the entire run. Since speed and force as well as volts and amps are continuously changing, this leads to a small error. Since at the time of calculation of both power and energy all of the speed, force, amp, and volt values for each instant in time are known, it would be easy to raise the order of the integration if this were ever necessary.

9.8.5 Methodology

9.8.5.1 General

The TPS generates a speed, distance, and real and reactive power table as a function of time. This is referred to as a trajectory or power profile. It uses discrete time steps to integrate the equations of motion. Speed and distance are determined by integrating the equation of motion. Real and reactive power are determined by converting mechanical power at the rail to real and reactive electrical power at the line using conversion efficiencies which are also functions of tractive effort and speed. Fuel consumption for non-electric trains is determined either by using a linear mechanical horsepower relationship or by using the actual fuel curves specified by the engine supplier.
Three procedures consisting of several subroutines are used to generate the output just described:

**TRAIN CAPABILITY PROCEDURE**

Given the speed and position of the train, this procedure determines the maximum acceleration and deceleration capability of the train to continue the trajectory.

**INTEGRATION PROCEDURE**

Given the acceleration/deceleration to be maintained over the next time interval and the train's speed and position at the present time interval, the procedure calculates the train's speed and position at the end of the time interval.

**POWER DEMAND PROCEDURE**

Given the speed and tractive effort of the train at any instant of time, this module determines the real and reactive power supplied to or generated by the train. Likewise, fuel consumption for trains which consume fuel.

The train capability and integration procedures are used to generate the speed-position-time portion of trajectory of the train subject to the speed restrictions, speed commands, grade and curve conditions and station stop requirements. There are several basic steps involved in this procedure:

1. Begin at a point of known position, speed and time.
2. Select a time step (interval).
3. Determine the range of tractive and braking effort that the propulsion and braking system can deliver.
4. Select a tractive and braking effort that lies within the range consistent with trajectory objectives and requirements.

Determine the resulting speed change and compute the train speed and position at the end of the time step.

Repeat steps (3-6) to advance the trajectory in time and position to meet the trajectory objective. If a station stop is encountered, calculate the power consumption or fuel consumption for each point on the train trajectory just generated.

Integrate the power or fuel consumption over the whole trajectory. When the last station stop is encountered, repeat step 7 and summarize the run.
9.8.5.2 Equations of Motion

The equation of motion is illustrated next.

\[ F_A - T_{RR} - T_{RA} - G - C = M_e \cdot \frac{dV}{dT} \]

- \( F_A \) - Applied Traction Effort
- \( T_{RR} \) - Train Rolling Resistance
- \( T_{RA} \) - Train Aerodynamic Resistance
- \( G \) - Grade Resistance
- \( C \) - Curve Resistance
- \( M_e \) - Equivalent Mass
- \( \frac{dV}{dT} \) - Acceleration

**Figure 9-21 Equation of Motion**

The grade and curve resistance terms in the equation of motion are illustrated next.
Figure 9-22 Grade and Curve Resistance

The TPS uses 0.8 lbs/ton/degree of curvature in English units for the value of the coefficient \( C_0 \). Note that grade resistance can be either positive or negative while the curve resistance always is negative, opposing the motion.

The train resistance always opposes the motion. There are two terms in the train resistance formula, the rolling resistance (RR) and the aerodynamic resistance (RA). The TPS uses two methods to calculate train resistance. The standard Davis equation can be used or the coefficient method. Both of these are illustrated next.
Train Resistance

**Davis Formula:**

\[ T_{EF} = 1.3 \times (6.37 \times W + 29 \times (129) \times a + f \times W + v \]

\[ T_{RE} = \frac{C_A}{A} + C_g \times (C-1) \times A \times v^2 \]

where in English (Metric) units:

- W: weight of train (tons/tonne)
- v: Speed of train (mph/kph)
- a: number of axes/axle
- f: friction coefficient (lbs/ton/mph/ks/tonne/kph)
- C: Number of cars/trains
- A: frontal area (m²)
- \( T_{RR} \): Train Rolling Resistance (lbs/axle)

Aerodynamic coefficients

- \( C_A \): Front car (lbs/ft²/m²/mph², kgs/m²/mph²)
- \( C_g \): Tail cars (lbs/ft²/m²/mph², kgs/m²/mph²)
- \( T_{RA} \): Train Aerodynamic Resistance (lbs/axle)

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Figure 9-23 Davis Equation

Train Resistance

**The Coefficient Method for each car:**

For rolling resistance for the Ith type car —

\[ T_{Rm} = C(1,I) + C(2,I) \times W + [C(3,1) + C(4,1) \times W] \times v \]

For aerodynamic resistance for the Ith type car —

\[ T_{RA} = C(5,1) \times v^2 \]

The coefficients have the following units in English (Metric):

- \( C(1,I) \): lbs (nts)
- \( C(2,I) \): lbs/ton (nts/tonne)
- \( C(3,I) \): lbs/mph (nts/kph)
- \( C(4,I) \): lbs/ton/mph (nts/tonne/kph)
- \( C(5,I) \): lbs/mph² (nts/kph²)

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Figure 9-24 Single Vehicle Coefficients
The equivalent rotational weight is also included.

**Equivalent Rotational Weight**

In English (Metric) Units, the equation of motion is written:

\[ M_E \cdot \frac{dV}{dt} = 91.1 \cdot (1016) \cdot (W + W_E) \cdot a \]

where:
- \( a \) = the acceleration (mph/ps) (mps^2)
- \( W \) = weight (tons) (tonnes), and
- \( W_E \) = the equivalent rotational weight (tons) (tonnes)

If no value is included for equivalent rotational weight, the TPS uses the equation:

\[ W_E = 0.1 \cdot W \]

**Figure 9-25 Equivalent Rotational Weight Effects**

Once the entire trajectory between two adjacent stops is computed, the power demand procedure is called at each time increment to determine the power flow to the train.
In English (Metric) Units, the mechanical power at the wheel/rail interface is written:

\[ P = 1.99 \times 0.278 \times F_A \times v \]

where:
- \( P \) = Power (watts)
- \( v \) = Speed (mph) (kph)
- \( F_A \) = Applied Traction Effort (lbs) (nt)

Figure 9-26 Mechanical Power Developed at Wheel/Rail Interface

Electrical power at the line is just the efficiency multiplied by the mechanical power.

9.8.5.3 Integration Formula

The integration formulae are shown in the next illustration.
Acceleration is integrated using Euler's Method to find speed at each step in time, in the forward calculation. In the backward calculation a reverse Euler's Method is employed, as the index is decremented (for negative time steps).

The trapezoidal rule is employed to integrate speed and determine distance. This method yields identical results for the forward and backward calculations though the form is slightly different.

When calculating energy from the instantaneous values of power, Euler's Method is again used. There is no need to have a forward and a backward calculation at this point since the entire integration is in the forward direction using Euler's Method.

9.9 TECHNICAL DETAILS - ELECTRIC NETWORK SIMULATOR

The Electric Network Simulator (ENS) is a computer program which determines the overall power flow in an electrified rail system under the dynamic conditions of train movement.

9.9.1 Input Data

Input data for the ENS are divided into six basic areas: file definition, electric network description, operating parameters, train location, current calculation designation, and TPS train performance power profiles. The first area includes the names of files to be used as input data to the ENS and the names of files to capture the generated output. The second area provides a description of the electric network, which is feeding the moving trains. The third category provides the operating parameters for simulation. The fourth area deals with the specification of the location of trains and their movement in time. The fifth defines positions along the track or guideway where instantaneous and RMS values of third rail, catenary or trolley current will be computed. And finally, the sixth category includes a sequence of power profiles, which have been generated by the TPS for each type train running on the system.
9.9.1.1 Input File Definition

The format of the File of Filenames for the ENS is below. The first four records are the input filenames. The first record the electric network description file, the second record contains the name of the operating time file, the third record has the name of the train locator file, and the fourth record shows the name of the current measurement input file.

The next three records in the file are output files, which the user may or may not specify. These files include the detailed output file, the load curve file, and the current measurement output file. This latter file can only be requested when a current measurement input file is named. If a particular file is not specified, then an N is required in the first column of the record.

The remaining records in the file specify the names of the power profiles for each of the trains, which will be running on the system. An ‘N’ or ‘n’ is put in the first column of the record following the last power profile to signal the end of the power profile filenames.

<table>
<thead>
<tr>
<th># of Records</th>
<th>Format</th>
<th>Contents of Record</th>
<th>Expected File Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A42</td>
<td>Filename of Network File</td>
<td>N-<em>.</em></td>
</tr>
<tr>
<td>1</td>
<td>A42</td>
<td>Filename of Operating Time File</td>
<td>OP-<em>.</em></td>
</tr>
<tr>
<td>1</td>
<td>A42</td>
<td>Filename of Train Locator File</td>
<td>TL-<em>.</em></td>
</tr>
<tr>
<td>1</td>
<td>A1,1X,A42</td>
<td>Current Measurement(Y or N) if Y, then Filename of Current Position File</td>
<td>AM-<em>.</em></td>
</tr>
<tr>
<td>1</td>
<td>A1,1X,A42</td>
<td>Detailed Output(Y or N) if Y, then Filename of Detailed Output File</td>
<td>END*.*</td>
</tr>
<tr>
<td>1</td>
<td>A1,1X,A42</td>
<td>Load Curve?(Y or N) if Y, then Filename of Load Curve File</td>
<td>L-<em>.</em></td>
</tr>
<tr>
<td>1</td>
<td>A1,1X,A42</td>
<td>Current Measurement Output(Y OR N) if Y, then Filename of Current Measurement Output File</td>
<td>AO-<em>.</em></td>
</tr>
<tr>
<td>N</td>
<td>A42</td>
<td>Filename of Power Profile(Input)</td>
<td>P-<em>.</em></td>
</tr>
<tr>
<td>0</td>
<td></td>
<td>N(for no more) after N Power Profiles have been listed.</td>
<td></td>
</tr>
</tbody>
</table>
9.9.1.2 Network Description File

The format for the network description file is shown next. This network is a representation of the electric distribution system under which the trains are receiving power.

The network description consists of a general portion, definition of the AC part of the network, definition of the DC part of the network, and definition of the converter portion, which is the interface between AC and DC sections.
### FORMAT OF NETWORK FILE

<table>
<thead>
<tr>
<th># OF RECORDS</th>
<th>VARIABLE AND DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>[FORMAT(70A1)]</td>
</tr>
<tr>
<td></td>
<td>TITLE(I)(I=1,70)</td>
</tr>
<tr>
<td>1</td>
<td>[FORMAT(70A1)]</td>
</tr>
<tr>
<td></td>
<td>TITLE(I)(I=1,70)</td>
</tr>
</tbody>
</table>

**THE GENERAL SYSTEM PARAMETERS ARE READ:**

1. [FORMAT(2I10)]
   - INPTAC  Specifies the existence of an AC portion of the network (0 - no, 1 - yes).
   - INPTDC  Specifies the existence of a DC portion of the network (0 - no, 1 - yes).

1. [FORMAT(4I10)]
   - IACCYC and IDCCYC  These two variables select the turn off mode for regenerating AC and DC trains, respectively, when the line voltage exceeds the maximum (DV) under conditions of regeneration. (0 - turn off regeneration for snapshot, 1 - turn off regeneration for present braking cycle, 2 - regenerate enough power to keep line voltage from exceeding the maximum.)

1. [FORMAT(4I10)]
   - IPRTNX Normally, this variable is set to zero. If it is set to one, the subroutine PRNTX will be called to print additional output for investigation purposes.

1. [FORMAT(2I10,10X,3F10.0)]
   - PUNIT  The unit power of the system. Units are watts.
   - DV  Maximum tolerable voltage increase in line(unit).
   - PVOLT  The unit voltage(volts).
   - TURNS  The transformer turns ratio. The ratio of primary voltage to secondary voltage.
   - ACC  The accuracy of the convergence. Default ACC= .0000001

1. [FORMAT(4I10)]
   - NB  The number of nodes in the AC portion. A node is a point of constant voltage and is sometimes referred to as a bus.
   - NG  The number of AC nodes less the number of AC substations and tie stations. If there are no AC trains running on the system, then NG = EQ. NH.
   - NL  The number of lines in the AC portion. A line is a current path between two nodes.
   - NCVT  The number of AC - DC converters.

1. BLANK RECORD

### THE AC PORTION OF THE NETWORK PARAMETERS ARE READ:

1. [FORMAT(4I10)]
   - NB  The number of nodes in the AC portion. A node is a point of constant voltage and is sometimes referred to as a bus.
   - NG  The number of AC nodes less the number of AC substations and tie stations. If there are no AC trains running on the system, then NG = EQ. NH.
   - NL  The number of lines in the AC portion. A line is a current path between two nodes.
   - NCVT  The number of AC - DC converters.
There are several points worth noting on the input format to the network description file.

1. Two titles of seventy characters each can be used to describe the electric network. These titles will appear on both the summary and detailed output.

2. In general the electric rail in North America has both an AC and DC part to the network. In many cases the AC portion consists of just a meter node and an AC converter node for each substation. There are cases, however, where more extensive AC distribution and transmission does occur.

The meter node is considered an infinite bus, and as such the voltage will remain fixed. For all other nodes in the system the voltage will vary according to the solution of the network equations. These are the points where the load curves are calculated.

The remainder of the input is self-explanatory.
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#### FORMAT OF NETWORK FILE (continued)

<table>
<thead>
<tr>
<th># OF RECORDS</th>
<th>VARIABLE AND DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>NL</td>
<td>[FORMAT(3(A4,2X),I6,2F10.0)]</td>
</tr>
<tr>
<td></td>
<td>FOR I=1,NL</td>
</tr>
<tr>
<td></td>
<td>TKN(I)</td>
</tr>
<tr>
<td></td>
<td>The name of the I’th AC line.</td>
</tr>
<tr>
<td></td>
<td>SB(I)</td>
</tr>
<tr>
<td></td>
<td>The name of the starting node for the I’th AC line.</td>
</tr>
<tr>
<td></td>
<td>EB(I)</td>
</tr>
<tr>
<td></td>
<td>The name of the ending node for the I’th AC line. Note that 'starting' and 'ending' are arbitrary.</td>
</tr>
<tr>
<td></td>
<td>TRK(I)</td>
</tr>
<tr>
<td></td>
<td>The line or track number (1-99) of the I’th AC line. If the line is associated with tracks on which trains are running, multiple tracks between two fixed nodes must have the same line name and are distinguished by line number. If the line is not associated with tracks on which trains are running, multiple lines between two fixed nodes must have different line names and are assigned line number (1-99).</td>
</tr>
<tr>
<td></td>
<td>ZSER(I)</td>
</tr>
<tr>
<td></td>
<td>The complex impedance associated with the I’th AC line.</td>
</tr>
<tr>
<td>NB</td>
<td>[FORMAT(A4,2X,I6,4F5.0,15X,F10.0)]</td>
</tr>
<tr>
<td></td>
<td>FOR I=1,NB</td>
</tr>
<tr>
<td></td>
<td>BBN(I)</td>
</tr>
<tr>
<td></td>
<td>The name of the I’th AC node.</td>
</tr>
<tr>
<td></td>
<td>TYPE(I)</td>
</tr>
<tr>
<td></td>
<td>The type of AC node(1 - load, 3 - meter, 4 - AC side of converter, 9 power source or sink.)</td>
</tr>
<tr>
<td></td>
<td>VT(I)</td>
</tr>
<tr>
<td></td>
<td>The complex voltage(unit) initially associated with the AC node I. Meter nodes retain initial value of voltage.</td>
</tr>
<tr>
<td></td>
<td>PM(I)</td>
</tr>
<tr>
<td></td>
<td>The real unit power associated with AC node I. - Indicates power sink. + Indicates power source.</td>
</tr>
<tr>
<td></td>
<td>Q1(I)</td>
</tr>
<tr>
<td></td>
<td>The reactive unit power associated with AC node I.</td>
</tr>
<tr>
<td></td>
<td>SMPT(I)</td>
</tr>
<tr>
<td></td>
<td>The milepost at which AC node I is located. This value is used only if the node is an AC substation or tie station.</td>
</tr>
</tbody>
</table>

#### THE DC PORTION OF THE NETWORK PARAMETERS ARE READ:

<table>
<thead>
<tr>
<th>1</th>
<th>[FORMAT(3I10)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>NB1</td>
<td></td>
</tr>
<tr>
<td>The number of DC nodes in the DC portion. A node is a point of constant voltage and is sometimes referred to as a bus.</td>
<td></td>
</tr>
<tr>
<td>NG1</td>
<td></td>
</tr>
<tr>
<td>The number of DC nodes less the number of DC substations and tie stations. If there are no DC trains on the system, then NG1.EQ.NB1.</td>
<td></td>
</tr>
<tr>
<td>NL1</td>
<td></td>
</tr>
<tr>
<td>The number of lines in the DC portion. A line is a current path between two nodes.</td>
<td></td>
</tr>
</tbody>
</table>
# OF RECORDS | VARIABLE AND DEFINITION
---|---
NL1 | [FORMAT(3(A4,2X),I6,F10.0)]
FOR I=1,NL1
TKN1(I) | The name of the I'th DC line.
SB1(I) | The name of the starting node for the I'th DC line.
EB1(I) | The name of the ending node for the I'th DC line.
TRK1(I) | The line or track number (1-99) of the I'th DC line. If the line is associated with tracks on which trains are running, multiple tracks between two fixed nodes must have the same line name and are distinguished by line number. If the line is not associated with tracks on which trains are running, multiple lines between two fixed modes must have different line names and are assigned line number 1-99.
ZSER1(I) | The resistance associated with the I'th DC line.

NB1 | [FORMAT(A4,2X,I6,2F5.0,F10.0)]
FOR I=1,NB1
BBN1(I) | The name of the I'th DC node.
TYPE1(I) | The type of DC node(5 - load, 7 - meter, 8 - DC side of converter, 13  power source or sink.)
ET(I) | The voltage(unit) initially associated with the DC node I. Meter nodes retain the initial value of voltage.
PM1(I) | The real unit power associated with DC node I. - Means power sink. + Means power source.
SMPT1(I) | The milepost at which DC node I is located. This value is used only if the node is a DC substation or tie station.

THE CONVERTER PARAMETERS ARE READ:

NCVT | [FORMAT(2(A4,2X),3F5.0,2I5,F10.0)]
FOR I=1,NCVT
ACSIDE(I) | The name of the AC side node of the I'th converter.
DCSIDE(I) | The name of the DC side node of the I'th converter.
ALPU(I) | A switch which determines whether or not, if the I'th converter is a rectifier, it is six pulse(ALPU(I).EQ.0.) or twelve pulse (ALPU(I).EQ.1.).
XCTT(I) | The effective impedance, expressed as resistance of converter I at no load.
DADT(I) | If the I'th converter is a twelve pulse rectifier, this variable is the ratio of the common to total commutating reactance. This is based on the total substations, which includes rectifiers in parallel.
INVERT(I) | The type of converter (0 - rectifier, 1 - inverter).
9.9.1.3 Operating Time File Definition

The Operating Time File controls the time interval over which the simulation takes place plus the snapshot interval, or the time between snapshots. The format required for this file is shown below. Both the beginning and ending point of simulation time are input as hh:mm:ss.

### FORMAT OF OPERATING TIME FILE

<table>
<thead>
<tr>
<th># OF RECORDS</th>
<th>VARIABLE AND DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>{FORMAT(70A1)}</td>
</tr>
<tr>
<td></td>
<td>T3TLE(I)(I=1,70)</td>
</tr>
<tr>
<td></td>
<td>The title of the operating file. This title appears in the output.</td>
</tr>
<tr>
<td>1</td>
<td>{FORMAT(6(I2,1X),F10.0)}</td>
</tr>
<tr>
<td></td>
<td>I1,I2,I3</td>
</tr>
<tr>
<td></td>
<td>The hour(HH), minute(MM) and second(SS) associated with the start of simulation time.</td>
</tr>
<tr>
<td></td>
<td>J1,J2,J3</td>
</tr>
<tr>
<td></td>
<td>The hour(HH), minute(MM) and second(SS) associated with the end of simulation time.</td>
</tr>
<tr>
<td></td>
<td>TBTWEN</td>
</tr>
<tr>
<td></td>
<td>The time between snapshots associated with the movement of trains. This time must be an integral multiple of the time between successive records in the power profiles.</td>
</tr>
</tbody>
</table>

9.9.1.4 Train Locator File Definition

The format for the train locator file is shown next.

FORMAT OF TRAIN LOCATOR FILE

# OF RECORDS VARIABLE AND DEFINITION
1 [FORMAT(2I10)]
   IACTAB  An index which defines the method by which AC trains will be located for a given time, T
   (0 - from their previous positions, 1 - based on a headway and offset, 2 - based on a timetable, 3
   - no AC trains in system.)

   IDCTAB  An index which defines the method by which DC trains will be located for a given time, T
   (0 - from their previous positions, 1 - based on a headway and offset, 2 - based on a timetable, 3
   - no DC trains in system.)

AC TRAIN LOCATION BY POSITION

IF IACTAB.EQ.0 THEN READ:
1 [FORMAT(I10)]
   NV  The number of AC trains on the system.

   [FORMAT(A4,6X,F10.0,I4)]
   FOR I=1,NV
   TACNM(I)  The ID for the I'th AC train. This ID is matched against that in the power profile to pick
   out correct performance characteristics.
   SPOST(I)  The milepost of the I'th AC train's initial position.
   AUP(I)  The direction of travel for the I'th AC train (1 - increasing milepost direction, -1 -

DC TRAIN LOCATION BY POSITION

IF IDCTAB.EQ.0 THEN READ:
1 [FORMAT(I10)]
   NV1  The number of DC trains on the system.

   [FORMAT(A4,6X,F10.0,I4)]
   FOR I=1,NV
   TDCNM(I)  The ID for the I'th DC train. This ID is matched against that in the power profile to pick
   out correct performance characteristics.
   SPOST1(I)  The milepost of the I'th DC train's initial position.
   DUP(I)  The direction of travel for the I'th DC train (1 - increasing milepost direction, -1 -

AC TRAIN LOCATION BY HEADWAY AND OFFSET

IF IACTAB.EQ.1 THEN READ:
1 [FORMAT(2F10.0)]
   HW  The headway(seconds) for the AC trains on the system. The value is the separation of trains in
   time.
   OFFSET The offset for AC trains on the system. This variable represents the separation in time for
   trains leaving one terminal relative to the other. The units are seconds and the variable can range
   from zero to one headway.

DC TRAIN LOCATION BY HEADWAY AND OFFSET

IF IDCTAB.EQ.1 THEN READ:
1 [FORMAT(2F10.0)]
   HW1 The headway(seconds) for the DC trains on the system. The value is the separation of trains in
   time.
   OFFSET1 The offset for DC trains on the system. This variable represents the separation in time for
   trains leaving one terminal relative to the other. The units are seconds and the variable can range
   from zero to one headway.
### Format of Train Locator File (continued)

<table>
<thead>
<tr>
<th># of Records</th>
<th>Variable and Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AC Train Location by Timetable</td>
</tr>
<tr>
<td></td>
<td><em><strong>IF IACTAB.EQ.2 THEN READ:</strong></em></td>
</tr>
<tr>
<td>1</td>
<td>[FORMAT(I10)] NCARD The number of entries in the timetable for AC trains.</td>
</tr>
<tr>
<td></td>
<td>[FORMAT(A4,2(F2.0,1X),F2.0,F10.0,3X,2I5)] FOR I=1,NCARD</td>
</tr>
<tr>
<td></td>
<td>TTYPE(I) The ID for the I'th train entry in the timetable. This ID is matched against train ID in the power profile to determine performance.</td>
</tr>
<tr>
<td></td>
<td>DPTIME(I) The departure time(seconds) of the I'th train entry in the timetable. The value is read as (HH:MM:SS) and internally converted to seconds.</td>
</tr>
<tr>
<td></td>
<td>DPOST(I) The departing milepost for the I'th train entry in the timetable.</td>
</tr>
<tr>
<td></td>
<td>TDIR(I) The direction of travel for the I'th train entry in the timetable (1 - direction of increasing milepost, -1 - direction of decreasing milepost).</td>
</tr>
<tr>
<td></td>
<td>NCPT(I) The number of cars per train for the I'th train entry in the timetable.</td>
</tr>
<tr>
<td></td>
<td>DC Train Location by Timetable</td>
</tr>
<tr>
<td></td>
<td><em><strong>IF IDCTAB.EQ.2 THEN READ:</strong></em></td>
</tr>
<tr>
<td>1</td>
<td>[FORMAT(I10)] NCARD The number of entries in the timetable for DC trains.</td>
</tr>
<tr>
<td></td>
<td>[FORMAT(A4,2(F2.0,1X),F2.0,F10.0,3X,2I5)] FOR I=1,NCD</td>
</tr>
<tr>
<td></td>
<td>TTYP(I) The ID for the I'th train entry in the timetable. This ID is matched against train ID in the power profile to determine performance.</td>
</tr>
<tr>
<td></td>
<td>DPTIM1(I) The departure time(seconds) of the I'th train entry in the timetable. The value is read as (HH:MM:SS) and internally converted to seconds.</td>
</tr>
<tr>
<td></td>
<td>DPOST(I) The departing milepost for the I'th train entry in the timetable.</td>
</tr>
<tr>
<td></td>
<td>TDIR(I) The direction of travel for the I'th train entry in the timetable (1 - direction of increasing milepost, -1 - direction of decreasing milepost).</td>
</tr>
<tr>
<td></td>
<td>NCPT(I) The number of cars per train for the I'th train entry in the timetable.</td>
</tr>
</tbody>
</table>
The method for locating trains on the electric network and the parameters for execution of that method are
determined using the train locator file. The user may specify both AC or DC trains, that is, trains, which
obtain their power from a line, which carries AC or DC, and the method for locating the trains which may
be by POSITION, TIMETABLE, or HEADWAY AND OFFSET.

Locating trains by specifying their POSITION means that the trains are placed on the network at particular
locations. As the simulation advances in time, the trains will move according to their power profiles. No
new trains are added to the system after the beginning of the simulation. This method for locating the
trains is useful when only one or two snapshots of the system are taken at special train positions to
determine instantaneous currents and voltage drop. Any more than one or two snapshots will cause the
program to become unstable, especially if the trains are removed from the system because they have
reached their terminals

The TIMETABLE method for train location is the usual way to effect the process. A schedule is specified,
and the ENS places the trains on the network following that schedule. Departure times are considered the
beginning point of the power profile. As the simulation proceeds trains are added and removed from the
network as specified by the schedule.

The HEADWAY AND OFFSET method for locating trains is used in limited circumstances. The
condition for specifying the method is a double track system between two terminus points with a regular
schedule. The headway, which is the separation between trains running on the same track, is given as a
time interval (seconds). The offset, which is the difference in the time when the trains leave one terminal
relative to the second terminal, is also input as a time interval (seconds). The offset can vary between zero,
in which the trains leave each of the terminals simultaneously to one headway.

**9.9.1.5 Current Position File Definition**

This file specifies the position at which line current will be computed and displayed, for each snapshot and
in summary form as a RMS current. The position is specified as both a milepost and track number. The
actual current calculated at that position will be flowing through the third rail, or alternatively, the trolley or
catenary. The format for the current position file is listed next.
### 9.9.1.6 Train Power Profile File Definition

The format for the train power profile is shown next.

<table>
<thead>
<tr>
<th># OF RECORDS</th>
<th>VARIABLE AND DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>For AC Distribution:</td>
<td></td>
</tr>
<tr>
<td>1  [FORMAT(I10)]</td>
<td>NFP  The number of entries in the current position table.</td>
</tr>
<tr>
<td>NFP  [FORMAT(A4,1X,F10.0,1X,I2)]</td>
<td>FOR I=1,IPOWER</td>
</tr>
<tr>
<td>NAPOS(I)  The name of the I'th position at which current will be calculated at each snapshot and the RMS value of it will be determined for the run.</td>
<td></td>
</tr>
<tr>
<td>POSLO(I)  The milepost of the I'th position.</td>
<td></td>
</tr>
<tr>
<td>NUTRK(I)  The track number associated with the I'th position.</td>
<td></td>
</tr>
<tr>
<td>For DC Distribution:</td>
<td></td>
</tr>
<tr>
<td>1  [FORMAT(I10)]</td>
<td>IPOwer  The number of entries in the current position table.</td>
</tr>
<tr>
<td>IPOwer  [FORMAT(A4,1X,F10.0,1X,I2)]</td>
<td>FOR I=1,IPOWER</td>
</tr>
<tr>
<td>NAPOS1(I)  The name of the I'th position at which current will be calculated at each snapshot and the RMS value of it will be determined for the run.</td>
<td></td>
</tr>
<tr>
<td>POSLO1(I)  The milepost of the I'th position.</td>
<td></td>
</tr>
<tr>
<td>NUTRK1(I)  The track number associated with the I'th position.</td>
<td></td>
</tr>
</tbody>
</table>
# FORMAT OF TRAIN POWER PROFILES

## AC TRAINS

**IF IACTAB.NE.3 THEN READ:**

1  

<table>
<thead>
<tr>
<th># OF RECORDS</th>
<th>VARIABLE AND DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>The number of power profile records for the train.</td>
</tr>
<tr>
<td>NACF</td>
<td>The number of cars per train. Used only for headway and offset train location input</td>
</tr>
<tr>
<td>FOR I=1,M</td>
<td></td>
</tr>
<tr>
<td>H(I)</td>
<td>The time associated with the I'th record.</td>
</tr>
<tr>
<td>TRAC(I)</td>
<td>The train ID associated with the I'th record. All of the IDs are the same for all of the records.</td>
</tr>
<tr>
<td>SMILE(I)</td>
<td>The milepost associated with the I'th record.</td>
</tr>
<tr>
<td>TP(I)</td>
<td>The real power associated with the I'th record.</td>
</tr>
<tr>
<td>TQ(I)</td>
<td>The reactive power associated with the I'th record.</td>
</tr>
<tr>
<td>TAUP(I)</td>
<td>The track number associated with the I'th record. If the train is moving in the direction of increasing milepost the entry is positive and in the direction of decreasing milepost the entry is negative.</td>
</tr>
<tr>
<td>VDC(I)</td>
<td>The speed command associated with the I'th record. This variable is used for input to the TMS only.</td>
</tr>
<tr>
<td>TRNWT(I)</td>
<td>The train weight associated with the I'th record. This variable is used for input into the TMS only.</td>
</tr>
</tbody>
</table>

## DC TRAINS

**IF IDCTAB.NE.3 THEN READ:**

1  

<table>
<thead>
<tr>
<th># OF RECORDS</th>
<th>VARIABLE AND DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td>MD</td>
<td>The number of power profile records for the train</td>
</tr>
<tr>
<td>NDCF</td>
<td>The number of cars per train. Used only for headway and offset train location input</td>
</tr>
<tr>
<td>FOR I=1,M</td>
<td></td>
</tr>
<tr>
<td>HDC(I)</td>
<td>The time associated with the I'th record.</td>
</tr>
<tr>
<td>TRDC(I)</td>
<td>The train ID associated with the I'th record. All of the IDs are the same for all of the records.</td>
</tr>
<tr>
<td>DMILE(I)</td>
<td>The milepost associated with the I'th record.</td>
</tr>
<tr>
<td>DP(I)</td>
<td>The power associated with the I'th record.</td>
</tr>
<tr>
<td>TDUP(I)</td>
<td>The track number associated with the I'th record. If the train is moving in the direction of increasing milepost the entry is positive and in the direction of decreasing milepost the entry is negative.</td>
</tr>
<tr>
<td>VDC(I)</td>
<td>The speed command associated with the I'th record. This variable is used for input to the TMS only.</td>
</tr>
<tr>
<td>TRNWT(I)</td>
<td>The train weight associated with the I'th record. This variable is used for input into the TMS only.</td>
</tr>
</tbody>
</table>
The train power profile is a direct output from the TPS. It is the specification of how a particular train will run through the network as the simulation advances in time. The actual power used or regenerated by the train is also contained in the records of this file.

9.9.2 Main Program Description

This program accepts single train power and time profiles as functions of location along the right of way, timetables for movement of multiple trains, power rail, catenary or trolley impedance, running rail impedance, substation locations and characteristics, operating voltages-nominal, maximum and minimum, characteristics of the distribution network, the substation feeders, and metering point locations as input.

It simulates the movement of the trains by taking snapshots of the entire system at fixed intervals in time.

The output gives a complete electrical picture of the system including power flows, voltages, currents and losses at all salient points. In particular, power through metering points (forward and reverse), third rail propulsion system and substation losses and energy given to the environment (train resistance, auxiliary loads, friction or dissipative braking) are computed. Capability for regeneration to other trains and through regenerative substations (even through metering points) is also included.

The ENS flow diagram is shown next. After initializing and reading the input data files, the ENS sets up the stationary network, which consists of all of the non-moving nodes. It then proceeds to the main loop. After incrementing time by one unit, the program sets up the active network, which includes the present position of all of the trains as moving nodes on the network. Thus the active network contains both moving and stationary nodes.

For AC trains, the active network is solved and the simulator moves on to the next increment of time or snapshot. If the trains run under a DC distribution network, the problem is now non-linear since current cannot flow in the reverse direction (negative current) through the substations. The network is converted to an all AC network, and if negative currents are detected at a substation, the substation impedance is substantially increased to block the current flow, and the network is resolved until such negative current is reduced to zero. If the voltage at any regenerating train exceeds the maximum, the regenerated power is reduced, the substation resistance is reset to normal and the loop is repeated. Once overall convergence is met, the detailed output for the snapshot is recorded and the program goes on to the next snapshot.

The process continues until the end time for simulation is reached.

The Gauss-Siedel method is used to solve the active network. This is a substitution method by which the new node voltages are recalculated from the old node voltages by using the admittance matrices. The procedure is iterated until the convergence criteria is met; namely, that the difference between the absolute magnitudes of the new and old voltages is less than some small value. The basic equation used in the method is illustrated next.
Figure 9-28 Gauss-Siedel Equations

The flow diagram for the ENS process is shown next.
Program Manual for Train Operations Model / Rail Systems Center / 1/1/2019

Start
- Initialize Read Input
  - Set Output Files
  - Set Up Stationary Network

1
- Initialize Read Input
  - Set Output Files
  - Set Up Stationary Network

2
- Solve Network
  - DC Trains?
    - Negative Current thru Substation?
      - Yes
        - Substantially Increase Substation Impedance
      - No

3
- Max Train Voltage Exceeded?
  - Yes
    - Reduce Train Power Output
    - Reset Substation Impedances to Normal
  - No

- Detailed Output
- Time Output

ENS Flow Diagram
9.9.3 Output Data

There are three output files generated by the ENS, which are also generated by the TMS when it is running with ENS. Each may or may not be selected by the user. The files are detailed output, load curves and current measurement output.

9.9.3.1 ENS or TMS Detailed Output

The Detailed Output File (END*.*) consists of a description of the input parameters (Part 1), a detailed output of the appropriate electrical values at each node and other data concerning the run at each snapshot (Part 2), and a summary page (Part 3), which summarized energy at the end of the run.

The listing of the input parameters consists of a line listing, which details all of the lines on the systems including their begin and end nodes and their complex impedance. A node listing is also presented which contains a description of each node, its position on the right of way (where appropriate), its type, and complex voltages and powers associated with the node. This is Part 1, which is shown in sub parts a, b and c.

9.9.3.1.1 Part 1 Network Input

![Figure 9-29 ENS or TMS Detailed Output File Line Listing Part 1a (AC/DC Type Network)](image)

Part 1a displays the following information: Title of Run, Type Network (AC only, DC Only or AC/DC).

In this case, the Type Network is AC/DC.

If the Type Network is AC only, then the next figure would be the output.
Figure 9-30 ENS or TMS Detailed Output File Line Listing Part 1a (AC only Type Network)

Part 1b displays the AC portion of the Network input. It is different for the AC/DC Type Network and AC only Type Network.
Figure 9-31 ENS or TMS Detailed Output Part 1b: AC Portion of Network AC/DC Type Network

Displayed are the Number of Substations, the Number of Meters, Meter Names and the Line Listing, which includes Line Number, Starting Node Name, Ending Node Name and the Impedance (Real, Reactive).

For the AC Type Network only,
Figure 9-32 ENS or TMS Detailed Output Part 1b: AC Portion of Network AC only Type Network
Displayed are the Number of Substations, Substation Listing (Node Name, Node Type and Location), the Number of Meters, Meter Names and the Line Listing, which includes Line Number, Starting Node Name, Ending Node Name and the Impedance (Real, Reactive).

Note: Node Type=1 is a Load Node.
Figure 9-33  ENS or TMS Detailed Output File DC Portion of Network Part 1c (AC/DC Type Network)

Displayed are the Number of Substations and Tiestations, Substation and Tie Station Listing (Node Name, Node Type and Location), the Number of Meters and the Line Listing, which includes Line Number, Starting Node Name, Ending Node Name, Track or Line Number and the Impedance (Real, Reactive). In this case reactive impedance=0.

Note: Node Type=5 is a Load Node and Node Type=8 is a Converter Node.

9.9.3.1.2 Part 2 Dynamic Output at Each Snapshot

For each snapshot, the complex voltage and power is presented for each of the fixed nodes on the system. Likewise for each train on the system, the complex voltage and power as well as the train location is listed. In addition the power flow by energy end use for that snapshot is given. Energy end use includes power regenerated by trains, power consumed by trains and network losses. These are different for AC/DC Type Network and AC Only Type Network.
AC/DC Type Network

Figure 9-34 ENS or TMS Detailed Output File Part 2a Snapshot Listing Power AC/DC Type Network

The Snapshot Time is given.

The SUMMARY DATA provides the following lines for the columns labeled KW (Kilo-Watt), KVAR (Kilo-Volt-Ampere-Reactive) METERING POINT POWER (The sum of all metered power. It does not include power provided by other sources in the network.) POWER DELIVERED TO VEHICLES (The sum of all power used by the trains as obtained through the network.) POWER REGENERATED BY VEHICLES (The sum of all power regenerated by the trains to the network.) AC NETWORK LOSSES [All I-Square * R losses (kW only) in the AC Network] CONVERTER LOSSES [All losses (kW only) in the Converters (Substations) including the Transformers] DC NETWORK LOSSES [All I-Square * R losses (kW only) in the DC Network] TOTAL NETWORK LOSSES [Sum of AC, DC and Converter Losses (kW only)]

The POWER BALANCE FOR NETWORK is the difference between the METERING POINT POWER and the (POWER DELIVERED TO VEHICLES + POWER REGENERATED BY VEHICLES + TOTAL NETWORK LOSSES). It does not include the power of any sources or sinks in the network, although the losses created by these sources or sinks are included in the balance. If there are no sources or sinks, the deviation of this number from zero is an indication of the accuracy achieved.
For each Bus or Node, the Type is given, the Complex Voltage (unit values) and the Complex Power (unit values) are presented for the snapshot. The Train Number, Train Type (ID), Location and Track Number, Voltage and Power are listed in unit values.

The Bus or Node Type numbers mean:
AC Side: 1-Load; 3-Meter; 4-Converter; 9-Source or Sink; 10-Circuit Element; 11-Storage
DC Side: 5-Load; 7-Meter; 8-Converter; 13-Source or Sink; 14-Circuit Element; 15-Storage

At the end of the run, a summary of energies by network end use is given. This summary is similar to the power summary just described.
The **SUMMARY** provides the following lines for the columns labeled **KWH** (Kilo-Watt-Hours), **KVARH** (Kilo-Volt-Ampere-Reactive-Hours), **KWHPCD** (Kilo-Watt-Hours per Car-Distance) and **KVARHPCD** (Kilo-Volt-Ampere-Reactive-Hours per Car-Distance):

- **ENERGY DELIVERED TO VEHICLES** (The sum of all energy used by the trains as obtained through the network.)
- **ENERGY REGENERATED BY VEHICLES** (The sum of all energy regenerated by the trains to the network.)
- **AC NETWORK LOSSES** [All I-Square * R losses (kW only) in the AC Network]
- **CONVERTER LOSSES** [All losses (kW only) in the Converters (Substations) including the Transformers,]
- **DC NETWORK LOSSES** [All I-Square * R losses (kW only) in the DC Network]
- **TOTAL NETWORK LOSSES** [Sum of AC, DC and Converter Losses (kW only)]

The **ENERGY BALANCE FOR NETWORK** is the difference between the **METERING POINT ENERGY** and the (**ENERGY DELIVERED TO VEHICLES** + **ENERGY REGENERATED BY VEHICLES** + **TOTAL NETWORK LOSSES**). It does not include the energy of any sources or sinks in the network, although the losses created by these sources or sinks are included in the balance. If there are no sources or sinks, the deviation of this number from zero is an indication of the accuracy achieved.

The **ACCUMULATED CAR-DISTANCE** is the sum of each car times the distance that it has moved during the simulation period.

The **NUMBER OF NON-CONVERGENT SNAPSHOTS** is the number of snapshots for which convergence was not achieved. Sometimes increasing the number of iterations reduces this number.
Figure 9-37 ENS or TMS Detailed Output File Part 2a Snapshot Listing Power AC Only Type Network

The Snapshot Time is given.

The SUMMARY DATA provides the following lines for the columns labeled KW (Kilo-Watt), KVAR (Kilo-Volt-Ampere-Reactive)

METERING POINT POWER (The sum of all metered power. It does not include power provided by other sources in the network.)

POWER DELIVERED TO VEHICLES (The sum of all power used by the trains as obtained through the network.)

POWER REGENERATED BY VEHICLES (The sum of all power regenerated by the trains to the network.)

AC NETWORK LOSSES [All I-Square * R losses (kW only) in the AC Network]

CONVERTER LOSSES [All losses (kW only) in the Converters (Substations) including the Transformers.

DC NETWORK LOSSES [All I-Square * R losses (kW only) in the DC Network]

TOTAL NETWORK LOSSES [Sum of AC, DC and Converter Losses (kW only)]

The POWER BALANCE FOR NETWORK is the difference between the METERING POINT POWER and the (POWER DELIVERED TO VEHICLES + POWER REGENERATED BY VEHICLES + TOTAL NETWORK LOSSES). It does not include the power of any sources or sinks in the network, although the losses created by these sources or sinks are included in the balance. If there are no sources or sinks, the deviation of this number from zero is an indication of the accuracy achieved.
For each Bus or Node, the Type is given, the Complex Voltage (unit values), Complex Power (unit values) and Power Factor are presented for the snapshot. The Train Number, Train Type (ID), Location and Track Number, Voltage and Power are listed in unit values.

The Bus or Node Type numbers mean:
AC Side: 1-Load; 3-Meter; 4-Converter; 9-Source or Sink; 10-Circuit Element; 11-Storage
At the end of the run, a summary of energies by network end use is given. This summary is similar to the power summary just described.

The **SUMMARY** provides the following lines for the columns labeled **KWH** (Kilo-Watt-Hours), **KVARH** (Kilo-Volt-Ampere-Reactive-Hours), **KWHPCD** (Kilo-Watt-Hours per Car-Distance) and **KVARHPCD** (Kilo-Volt-Ampere-Reactive-Hours per Car-Distance):

- **METERING POINT ENERGY** (The sum of all metered energy. It does not include energy provided by other sources in the network.)
- **ENERGY DELIVERED TO VEHICLES** (The sum of all energy used by the trains as obtained through the network.)
- **ENERGY REGENERATED BY VEHICLES** (The sum of all energy regenerated by the trains to the network.)
- **AC NETWORK LOSSES** [All I-Square * R losses (kW only) in the AC Network]
- **CONVERTER LOSSES** [All losses (kW only) in the Converters (Substations) including the Transformers.]
- **DC NETWORK LOSSES** [All I-Square * R losses (kW only) in the DC Network]
- **TOTAL NETWORK LOSSES** [Sum of AC, DC and Converter Losses (kW only)]

The **ENERGY BALANCE FOR NETWORK** is the difference between the **METERING POINT ENERGY** and the (**ENERGY DELIVERED TO VEHICLES + ENERGY REGENERATED BY VEHICLES + TOTAL NETWORK LOSSES**). It does not include the energy of any sources or sinks in the network, although the losses created by these sources or sinks are included in the balance. If there are no sources or sinks, the deviation of this number from zero is an indication of the accuracy achieved.

The **ACCUMULATED CAR-DISTANCE** is the sum of each car times the distance that it has moved during the simulation period.
The NUMBER OF NON-CONVERGENT SNAPSHOTS is the number of snapshots for which convergence was not achieved. Sometimes increasing the number of iterations reduces this number.

9.9.3.2 ENS or TMS Load Curve Output

The load curves are listings of complex power for each snapshot taken during the run. These are contained in the Load Curve File (L-*.*). These listings are made for every meter type node on the system. The load curves are subsequently used to estimate the energy cost parameters of demand and energy use.

![Figure 9-40 ENS or TMS Load Curve Output File](image)

The first record contains the Number of Snapshots, Number of Meters, Simulation Start Time (Seconds), Simulation End Time (Seconds), Car-Distance Accumulated.

For each meter, the Real and Reactive Power is displayed in pairs for each snapshot in succession.
9.9.3.3 ENS or TMS Current Measurement Output

The Current Measurement Output File (AO-*.*.*) consists of the voltage at all salient points in the network and the current at the points on the track which were selected in the Current Measurement Input File (AM-*.*.*). These are displayed in the file at every snapshot. The display is different for AC/DC Type Networks and AC Only Type Networks.

9.9.3.3.1 AC/DC Type Networks

**Figure 9-41 ENS or TMS Current Measurement Output File AC/DC Type Network (AC and Converter Portion)**

For each snapshot, the following information is output:

**AC Portion of the Network**

- **Line Name**, **Begin Node Name**, **End Node Name**, **Begin Node Voltage**, **End Node Voltage**, **Voltage Drop** between begin node and end node, **Real** and **Reactive Current** in the **Line**.

**Converter Portion of the Network**

- **AC Node Name**, **DC Node Name**, **AC Node Voltage**, **DC Node Voltage**, **Voltage Drop** (Unit Volts), **Unit Impedance**, **Current on DC Side**.
Figure 9-42 ENS or TMS Current Measurement Output File AC/DC Type Network (Current at Fixed Position on DC Track)

For each snapshot and for every measuring device (Ammeter), the following information is provided.

**Name, Position, Track Number** and **Current**. Positive values of current indicate the flow is in the increasing position direction and negative values of current indicate the flow is in the decreasing position direction.
For each snapshot and for each train on the network, **Type (ID)**, **Position**, **Track Number**, **Line Voltage**, **Line Current** and **Line Power** are listed. In addition, the **Position** and **Current** flow to the adjacent nodes are also listed.

![Figure 9-43 ENS or TMS Current Measurement Output File AC/DC Type Network (Train Information)](image_url)
A summary of **RMS Current** at the measurement points is produced at the end of the run.

Figure 9-44  ENS or TMS Current Measurement Output File AC/DC Systems (RMS Currents)
9.9.3.3.2 AC Only Type Networks

Figure 9-45 ENS or TMS Current Measurement Output File AC Only Systems [Fixed Node Voltage, Fixed Line Voltage]

For the fixed nodes, the Complex Voltage and its Magnitude is listed.

For the fixed lines, the Complex Current and its Magnitude is listed.
Figure 9-46 ENS or TMS Current Measurement Output File AC Only Systems (Train Information)
A summary of RMS Current at the measurement points is produced at the end of the run.

Figure 9-47 ENS or TMS Current Measurement Output File AC Only Systems (RMS Currents)
9.9.3.4 ENS or TMS Summary Output

There is a summary output produced of each snapshot. However, this output can be kept or discarded. It consists of the total real and reactive power produced at each snapshot as well as a summary at the end of the run.

If the summary of an ENS run is kept, it is the file SUMSENS*.*, where ENS*.* is the File of Filenames for the run. If the summary of a TMS run is kept, it is the file SUMTMS*.*, where TMS*.* is the File of Filenames for the run.

Figure 9-48 ENS or TMS Summary Output File (Snapshot Output)

Note: The columns titled **KW** and **KVAR** contain the sum of the Kilowatts and Kilo-Volt-Amperes-Reactive of the meters, respectively. The columns labeled **ITERATIONS** and **ACCURACY** are the number of iterations and accuracy achieved at the final iteration, respectively.
The **SUMMARY** provides the following lines for the columns labeled **KWH** (Kilo-Watt-Hours), **KVARH** (Kilo-Volt-Ampere-Reactive-Hours), **KWHPCD** (Kilo-Watt-Hours per Car-Distance) and **KVARHPCD** (Kilo-Volt-Ampere-Reactive-Hours per Car-Distance):

- **METERING POINT ENERGY** (The sum of all metered energy. It does not include energy provided by other sources in the network.)
- **ENERGY DELIVERED TO VEHICLES** (The sum of all energy used by the trains as obtained through the network.)
- **ENERGY REGENERATED BY VEHICLES** (The sum of all energy regenerated by the trains to the network.)
- **AC NETWORK LOSSES** [All I-Square * R losses (kW only) in the AC Network]
- **CONVERTER LOSSES** [All losses (kW only) in the Converters (Substations) including the Transformers.
- **DC NETWORK LOSSES** [All I-Square * R losses (kW only) in the DC Network]
- **TOTAL NETWORK LOSSES** [Sum of AC, DC and Converter Losses (kW only)]

The **ENERGY BALANCE FOR NETWORK** is the difference between the **METERING POINT ENERGY** and the (**ENERGY DELIVERED TO VEHICLES + ENERGY REGENERATED BY VEHICLES + TOTAL NETWORK LOSSES**). It does not include the energy of any sources or sinks in the network, although the losses created by these sources or sinks are included in the balance. If there are no sources or sinks, the deviation of this number from zero is an indication of the accuracy achieved.

The **ACCUMULATED CAR-DISTANCE** is the sum of each car times the distance that it has moved during the simulation period.

The **NUMBER OF NON-CONVERGENT SNAPSHOTs** is the number of snapshots for which convergence was not achieved. Sometimes increasing the number of iterations reduces this number.

The **MAXIMUM ACCURACY ACHIEVED** is the worst accuracy (lower is better) obtained during any iteration. It reflects accuracy of each snapshot, whereas **ENERGY BALANCE FOR NETWORK**
represents accuracy for the simulation.
9.9.4 Verification, Limitations and Performance

9.9.4.1 Verification

Each of the subroutines of the ENS has been carefully examined and verified. The entire program was also been subjected to close scrutiny. Two methods have been used to check the performance of the simulator.

Method 1.
1. Inject power into the node
2. Perform Load Flow calculation
3. After convergence is achieved, recalculate all the nodes’ injected power using the admittance matrices and voltages.
4. Compare these results with the original node injected powers.

This check has been performed on both the AC and DC networks. All of these tests verified that the program was operating correctly.

Method 2.
1. Inject power into the node
2. Perform Load Flow calculation
3. Calculate line current and the losses in the system, including the AC network losses, DC network losses, and converter losses.
4. Add the system losses to the power required by the load. This should equal the total power delivered to the system

All of these tests also showed that the program was operating correctly.

Both the TPS and ENS were used to predict the energy consumption of sections of the rail system of several rail authorities. These predictions were then compared with energy audits taken under nearly the same conditions as the simulations. The results are shown below. The largest differences seem to occur in rail systems, which are regenerating, however in no case as the difference been larger than 10%.
### Predicted vs Audited Energy Consumption

<table>
<thead>
<tr>
<th>Transit Authority/Rail System</th>
<th>Kilowatt Hours per Car Mile</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Actual</td>
<td>Simulated</td>
<td>Difference</td>
</tr>
<tr>
<td>Washington Metro (1980)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red Line</td>
<td>6.87</td>
<td>6.63</td>
<td>-4%</td>
</tr>
<tr>
<td>Blue/Orange Line</td>
<td>5.73</td>
<td>6.16</td>
<td>+7%</td>
</tr>
<tr>
<td>Metropolitan Atlanta (1983-84)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1983 Operating Period</td>
<td>5.01</td>
<td>4.54</td>
<td>-9%</td>
</tr>
<tr>
<td>1984 Operating Period</td>
<td>5.67</td>
<td>5.44</td>
<td>-4%</td>
</tr>
<tr>
<td>Baltimore Metro (1986,1988)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1986 Operating Period</td>
<td>5.67</td>
<td>5.44</td>
<td>-4%</td>
</tr>
<tr>
<td>1988 Operating Period</td>
<td>4.60</td>
<td>4.70</td>
<td>+2%</td>
</tr>
<tr>
<td>New Jersey Transit (1987)</td>
<td>6.74</td>
<td>6.75</td>
<td>+0.1%</td>
</tr>
<tr>
<td>Port Authority of Allegheny County (1989)</td>
<td>6.66</td>
<td>6.66</td>
<td>0.0%</td>
</tr>
</tbody>
</table>
9.9.4.2 Program Failure Conditions

Non-convergence is the condition wherein the solution to the network equations cannot be achieved within the number of iterations and accuracy specified. This condition occurs when the voltage drop is too large or equivalently impedances are too high.

There are two types of non-convergences:

The non-convergence can be removed by increasing the number of iterations or lowering the accuracy.

The non-convergence cannot be removed by increasing the number of iterations or lowering the accuracy.

Rail systems function well, if the power distribution systems have very low impedance. If convergence problems arise, it is usually because the power system is too weak. The program has been designed to output the non-convergence condition when it occurs.

Failure conditions occur principally in two areas.

Bad input
Locating trains in areas where power cannot reach them (also bad input).

9.9.4.3 Inherent Computational Errors

The major source of errors comes from the load flow iterative method itself. The convergence criteria can be set by the user both in accuracy and the number of iterations before calling it quits and declaring non-convergence. Decreasing convergence criteria is not recommended unless increasing accuracy is important, even the computer accuracy will be the lower boundary of precision of this calculation.

9.9.4.4 Program Running Time

The ENS running time depends on the size of the network to be solved, timetable or headway input, natural or assured receptivity, and number of entries in the power profiles of the trains on the network.

The program running time becomes strongly dependent on the number of nodes, including vehicles, when the network is large. This time increases with the square of the number of nodes. In a regenerative system with natural receptivity (only the trains on the system accept the regenerated power), the running time will be high, because of the method used to block the current from flowing in the reverse direction through a rectifier.

The rapid increase in speed of PC type computers over the last ten years have made present computers more tolerant of long running programs. Problems that were run in the eighties on large mainframes are now run on PC with higher speed and thus, shorter times. Parallel processing also helps decrease this running time. The running time for the ENS is expected to become shorter in the future.

9.9.5 METHODOLOGY
The load flow calculation uses the Gauss-Siedel iterative method. This module differs from conventional load flow calculations. It has the capability to handle AC, DC or composite networks.

The basic steps are:

1. Convert the system to an all AC network keeping a record of the DC part and the converters.

2. Perform the load flow calculation on the AC network.

3. Check the current flows through all the converters. If the converter is an inverter, the current can flow both ways. If the converter is a rectifier and current tries to flow in the blocked direction, increase the impedance of the rectifier in a large step. If the current is flowing in the conducting direction set the rectifier impedance in accordance with the rectifier model.

4. Repeat procedure 2 and 3 until convergence is obtained. After convergence is obtained, the voltage for each vehicle is checked in the system. If there is any vehicle with its voltage exceeding maximum allowable then its regeneration power is reduced by 10%.

Repeat procedure 4 and 5 until convergence is obtained. Continue with the next snapshot and then go to procedure 1.

When snapshots are finished formalize output.

9.10 TECHNICAL DETAILS - TRAIN MOVEMENT SIMULATOR

The Train Movement Simulator (TMS) is a computer program, which runs multiple trains under the commands of the train control system, which is controlling the rail network and under the dynamic conditions experienced by the network.

9.10.1 Input Data

Input data for the train movement simulator is nearly the same as that of the ENS, except that the track layout and passenger station data are specified as well. Input for the TMS is divided into eight basic areas: file definition, track layout description, electric network description, operating parameters, train location, current calculation designation, passenger station description and TPS train performance power profiles. The first area includes the names of files to be used as input data to the TMS and the names of files to capture the generated output. The second area provides a description of the track layout, which defines the tracks used and the location of switches and crossovers. The third area provides a description of the electric network, which is feeding power to the moving trains. The fourth category provides the operating parameters for simulation. The fifth area deals with the specification of the location of trains and their movement in time. The sixth defines positions along the track or guide way where instantaneous and RMS values of third rail, catenary or trolley current will be computed. The seventh provides a description of the passenger stations, their locations and platform lengths. Finally, the eighth category includes a sequence of power profiles, which have been generated by the TPS for each type train running on the system.

9.10.1.1 Input file Definition

The format of the File of Filenames for the TMS is shown below. The first six records are the input filenames. The first record contains the name of the track layout file, the second record contains the
electric network description file, the third record contains the name of the operating time file, the fourth
record has the name of the train locator file, the fifth record shows the name of the current measurement
input file and the sixth record is the name of the station description file.

<table>
<thead>
<tr>
<th># of Records</th>
<th>Format</th>
<th>Contents of Record</th>
<th>Expected File Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A42</td>
<td>Track Layout File</td>
<td>TW-.*</td>
</tr>
<tr>
<td>1</td>
<td>A42</td>
<td>Filename of Network File</td>
<td>N-.*</td>
</tr>
<tr>
<td>1</td>
<td>A42</td>
<td>Filename of Operating Time File</td>
<td>OP-.*</td>
</tr>
<tr>
<td>1</td>
<td>A42</td>
<td>Filename of Train Locator File</td>
<td>TL-.*</td>
</tr>
<tr>
<td>1</td>
<td>A1,1X,A42</td>
<td>Current Measurement(Y or N) if Y, then Filename of Current Position File</td>
<td>AM-.*</td>
</tr>
<tr>
<td>1</td>
<td>A1,1X,A42</td>
<td>Station Description(Y or N) if Y, then Filename of Station Description File</td>
<td>SD-.*</td>
</tr>
<tr>
<td>1</td>
<td>A1,1X,A42</td>
<td>Detailed Output(Y or N) if Y, then Filename of Detailed Output File</td>
<td>END-.*</td>
</tr>
<tr>
<td>1</td>
<td>A1,1X,A42</td>
<td>Load Curve?(Y or N) if Y, then Filename of Load Curve File</td>
<td>L-.*</td>
</tr>
<tr>
<td>1</td>
<td>A1,1X,A42</td>
<td>Current Measurement Output(Y OR N) if Y, then Filename of Current Measurement Output File</td>
<td>AO-.*</td>
</tr>
<tr>
<td>N*</td>
<td>A2</td>
<td>Filename of Power Profile(Input)</td>
<td>P-.*</td>
</tr>
<tr>
<td>1</td>
<td>A42</td>
<td>N(for no more) after N* Power Profiles have been listed.</td>
<td></td>
</tr>
</tbody>
</table>

The next four records in the file are output files, which the user may or may not specify. These files
include the detailed output file, the load curve file, the current measurement output file and the alarm
output file. This current measurement output file can only be requested when a current measurement input
file is named. If a particular file is not specified, then an N is required in the first column of the record.

### 9.10.1.2 Track Layout File

The next page shows the format for the track layout file.

The first two records are title records. The third record is a count of the number of track segments and
nodes, which lie at the beginning and end of each track segment. The third record also contains a
designation of whether or not the load flow of the electric network simulator will be turned on or off. It also
contains a detection designation for detecting blocks or other trains.

The next group of records contains one record for each track segment or block. Each record contains the
block id, the beginning point (node), the ending point (node), the track number, the grade, the curve and the
speed codes for that segment.

The next group of records is pertinent to the beginning and ending points of the blocks. Their id, position
and track number describes these nodes. A node is identified as a switch point automatically as the
endpoints of a switch track.
# OF RECORDS | VARIABLE AND DEFINITION
---|---
1 | TWTIT1 A title or train control description. This title will appear in the output.
1 | TWTIT2 A title or train control description. This title will appear in the output.
1 | NLN The number of track segments or fixed blocks in the system.
NND | The number of nodes on the track network. In the context of train control a node is beginning or ending of a block or a detection point in the case of moving block
NTW | A variable if 0, then no power calculation, if 1 power calculation.
ERFRC | Detection fuzziness factor, expressed as a percent of block length (generally 0-5 range)
NLN | FOR I=1, NLN
TWLNID(I) | The name of the I'th track segment.
TWBNID(I) | The name of the beginning node for the I'th track segment.
TWENID(I) | The name of the ending node for the I'th track segment. Note that 'starting' and 'ending' are arbitrary.
TWLNTN(I) | The track number of the I'th track segment. The main line is designated as track 1. Thus if the system is a single track with passing sidings, track 1 is the thru track. If the track is a switch, track numbers are designated beyond 100.
TWLNG(I) | The grade associated with the I'th track segment.
TWLNC(I) | The curvature associated with the I’th track segment.
TWLNSC(J,I), J=1,11 | Speed commands associated with the I’th track segment. The index J=1, indicates unrestricted speed command.
NND | FOR I=1, NND
TWNDID(I) | The name of the I’h node.
TWNDMP(I) | The position if the I’h node.
TWNDTN(I) | The track number of the I’h node.
9.10.1.3 Station Description File

The station description file contains data for all the passenger stations; namely their name, position, platform length and track number.

<table>
<thead>
<tr>
<th># OF RECORDS</th>
<th>VARIABLE AND DEFINITION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Station File (ST-<em>.</em>):</td>
</tr>
<tr>
<td>1</td>
<td>[FORMAT(80A1)] TITLEC(I)(I=1,80) Descriptive title.</td>
</tr>
<tr>
<td>1</td>
<td>[FORMAT(A2)] 00 – Has no meaning. Done to conform to format of Station File for TPS</td>
</tr>
<tr>
<td>1</td>
<td>[FORMAT(I5)] ISTADSCRIP The number of station description records.</td>
</tr>
<tr>
<td></td>
<td>[FORMAT(F10.0,A12,2F10.0)] FOR I=1,NSTOP</td>
</tr>
<tr>
<td></td>
<td>STAPOS(I) The position of the I'th station.</td>
</tr>
<tr>
<td></td>
<td>STANAME(I) The name of the I'th station.</td>
</tr>
<tr>
<td></td>
<td>STAPLT(I) The platform length at the I'th station.</td>
</tr>
<tr>
<td></td>
<td>STATRKNO(I) The track number associated with the I’th station.</td>
</tr>
</tbody>
</table>

9.10.1.4 Remaining Input Files

The remaining input are the same as the input files of the ENS and have been described in Section Error! Reference source not found..

9.10.2 Main Program Description

The program accepts as input all of the same files used in the ENS and described in the previous section. In addition, it accepts a track layout input file which contains information on the layout of the tracks, including switches and crossovers, and a passenger station description file, which contains data on the passenger stations.

The program executes in a manner similar to the ENS, and with the exception of the train control portion, which has user interaction. A flow diagram is shown on the next page.

The variables are initialized and all of the input files are loaded. The track layout is setup is set up according to the track layout file. All track segments(blocks) and track segment endpoints (nodes) are identified together with endpoint positions, average grades and curves within a block and the block speed codes.

Time is then incremented by one snapshot and the trains are located on the network according to the specifications in the train locator file, i.e. they are by timetable. If the variable is set to compute power, a Loadflow is completed as shown in the ENS flow diagram. At this point all of the output of the results of the snapshot is written to the output file.

The state of the train control system is determined and presented in graphical format on a Track and Train Display screen which the user can interact with in several ways. The user may set blocks, which are not
occupied, to red, set interlockings and switches and query the graph for physical information on trains and blocks. The user indicates completion and the program will then advance to the next snapshot.

If the next snapshot is beyond the end time as specified in the operating time file, the program will write all summary output information and stop execution.

The simplified flow diagram is shown next.
9.10.3 Output Data
9.10.3.1 TMS Alarm Output File
The alarm output file (TMA*.*\) is an additional output file used in the TMS, which is not used in the ENS. It provides a record of all conflicts and user interaction with the trains under manual train control (MTC) and all conflicts and automatic resolution of conflicts under automatic train control (ATC). These are displayed at every snapshot.

9.10.3.2 Remaining Output Files
The remaining output files, which are all selected by the user are the same as the output files of the ENS and are described in Section Error! Reference source not found.

9.11 TOM TROUBLESHOOTING
A user will have problems interacting with a model of this complexity. The requirement to keep track of a large number of files, used for different purposes, will cause problems. Even experienced users of the TOM will experience problems.

At this stage of development, most of the problems will be input. It’s the old saying with computer models: Garbage In = Garbage Out. It is probable that the user may find a problem that is not an input problem, but a program fault. Any problem of this nature should be reported the author of the model. This can be accomplished by e-mail Richard A. Uher uricharda@comcast.net. The report should contain a concise description of the problem, with attached input files, suspected of causing the problem.

Although many checks have been built into the TOM to catch common user errors, it is not possible to catch all of the errors. The type of problem that is the hardest to diagnose is the one shown in the following screen, upon running the TPS.
Figure 9-50 A Problem Has Been Encountered in a TPS Run Under Windows XP

For operating systems which are less sophisticated than Windows XP, such as Windows 9x or Windows 2000, the operating system may not report the error, but may simply cause the TOM to close without explanation or even worse, lock up the computer.

In the situation just described, the only alternative is to double-check all of the input data. Examples have been provided with the TOM of seven rail systems. Compare the input data with that of the seven rail systems to determine significant differences. If none of this works, e-mail Richard A. Uher uricharda@comcast.net, concisely describing the problem, with as much file backup as is possible. Of course, the problem must be reproducible, otherwise the error cannot be found.
9.12 PROPULSION SYSTEM MODEL DETAILS

Several propulsion models are available with the TOM.

The propulsion unit circuit is divided into two portions: the motor control unit and the motor circuit.

![Propulsion Unit Circuit](image)

Figure 9-51 Model of the Propulsion Unit Circuit Used for the TOM

The motor control unit controls the voltage to the motor circuit. It is fed back control information, usually current and speed of the motor. A motor circuit is one of the combinations shown.

![Motor Circuit Examples](image)

Figure 9-52 Examples of the Motor Circuit
In the case of the DC Series motor, a **Power Control Mode** or a **Electric Brake Control Mode** is defined as a combination of the motor circuit with some step of field shunting.

In terms of losses, the gear unit is lumped in with the motor.

In the case of a DC separately excited motor or an AC induction motor, a Power Control Mode or a Brake Control Mode is defined as one of the motor circuits.

Switching motor circuits from one combination to another is simply another way of controlling the voltage to the motor.

**9.12.1 Traction Efficiency**

The TOM uses the efficiency method to relate **Traction Effort** and **Speed** at the rail to **Power** at the line. **Traction Effort** could mean either **Tractive Effort** or **Electrical Braking Effort**.

**Traction Efficiency** is usually computed on a per car basis, that is, the propulsion system is defined on the basis of the powered car or locomotive and is considered one propulsion unit. This configuration, shown in the sketch below.

A full energy diagram of a transit vehicle or train of transit vehicles is shown below.
Figure 9-53 Rail Vehicle Energy Flow Diagram

Traction or Propulsion Unit Efficiencies are shown next, with reference to power conversion.
Figure 9-54 Power Conversion Efficiency

Thus all efficiencies are computed in this manner. Once they are computed, they are entered as described in Section 3.1.3.3.1
9.12.2 DC Series Motors

In the case of DC series motors, the motor consists of a field, armature, and field shunt. The basic equations for the motor are:

\[ V_A = I_A \cdot R_A + (1-f) \cdot I_A \cdot R_F \]

- \( R_A = \text{Armature Resistance} \)
- \( R_F = \text{Field Resistance} \)

\[ V_A = \frac{V_M}{N_S} \quad I_A = \frac{I_M}{N_P} \]

- \( N_S = \text{Number of Motors in Series} \)
- \( N_P = \text{Number of Motors in Parallel} \)

\[ I_S = I_A \cdot f \]

- \( f = \text{Fraction Field Shunted} \)

A single combination of a motor circuit configuration and field shunt fraction for a DC series motor is termed a Control Mode. The following diagram illustrates the tractive effort speed curves, which correspond to 4 control modes of a DC series motor circuit. The modes are composed of the four combinations obtained by mixing 4S/1P and 2S/2P with full field (\( f = 1.0 \)) and short field (\( f = s \)).
The actual tractive effort vs. speed curve will be the envelope of the curve shown. Efficiency points are calculated in all of the regions accessible by the propulsion control. The method of calculation is dependent on the region in which the efficiency point is located. If it is in the region where the motor circuit voltage must be varied, the control is used to vary the voltage. If the point lies in the mode control area, the motor circuit voltage is set to maximum and the mode control is used.
9.12.3 DC Separately Excited Motors

The model for the DC Separately excited motor is shown in the figure below.

![Figure 9-57 DC Separately Excited Motor Model](image)

The symbols used in the figure have the following meanings.

- **VA** – Armature Voltage
- **RA** – Armature Resistance
- **BR** – Brush Resistance
- **BD** – Brush Voltage Drop
- **IA** – Armature Current
- **IF** – Field Current
- **RF** – Field Resistance
- **KA** – Armature Resistance
- **CF** – Counter EMF
- **VF** – Field Voltage
- **RPM** – Motor Speed
- **BR** – Brush Resistance
- **Φ** – Flux
- **K1** – Torque Constant
- **K2** – Speed Constant

The equations for the motor are as follows.

**Armature Circuit**

\[
VA - IA^2RA - BR^2IA - BD = CEMF
\]

in the power mode.

\[
VA + IA^2RA + BR^2IA + BD = CEMF
\]

in the electrical brake mode.

**Field Circuit**

\[
VF = RF * IF
\]

**Motor Electrical Losses**

These losses include the field resistance, the brush resistance, the armature resistance, brush drop, hysteresis and eddy current.

\[
IA^2 * (RA + BR) + IA^2 * BD + IF^2 * RF + C1 * RPM + C3 * (CEMF)^2 / RPM
\]

**Motor Mechanical Losses**

These losses include friction and windage.

\[
C1 * RPM + C2 * (RPM)^2
\]
The motor flux $\Phi$ is a function of the field current, $IF$. The flux vs field current is referred to as the saturation curve of the motor. Except for small residual flux, it is zero at zero field current and begins to increase linearly with field current until it becomes constant at very high field currents (saturation).

9.12.4 AC Induction Motors

The equivalent circuit for a single phase of a 3-phase AC Induction motor under balanced load conditions is shown in the figure.

![Figure 9-58 AC Induction Motor Equivalent Circuit](image)

Definition of terms and symbols used in the analysis follows:

- $U_1$: Nominal Stator Voltage per Phase
- $I_1$: Primary or Stator Current
- $I_2$: Secondary or Rotor Current
- $L_2$: Secondary or Rotor Inductance
- $R_2$: Secondary or Rotor Resistance
- $L_1$: Primary or Stator Inductance
- $R_1$: Primary or Stator Resistance
- $L_m$: Magnetizing Inductance
- $R_m$: Magnetizing Resistance
- $s$: Slip

The slip, $s$, is defined by the equation:

$$s = \frac{\omega_2}{\omega_1}$$

Error! Bookmark not defined.

where

$$\omega_1 = 2 \pi f_1$$ is the angular frequency, where $f_1$ is the primary frequency, and

$$\omega_2 = 2 \pi f_2$$ is the angular frequency of the induced rotor current, where $f_2$ is the frequency of the induced rotor current.

The quantity, $\omega_1 - \omega_2$, is the angular speed of the rotor.

The stator, rotor and core reactance are defined in terms of their inductance:

- $X_1 = \omega_1 L_1$
- $X_2 = \omega_1 L_2$
- $X_m = \omega_1 L_m$

3 The normal definition of slip is $s=(\omega_1 - \omega_2)/\omega_1$. However, for equation convenience, it is defined here as $\omega_2/\omega_1$. 

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The stator, rotor and core impedance is just:

\[ Z_1 = R_1 + jX_1 \quad Z_2 = R_2 / s + jX_2 \quad Z_m = R_m + jX_m \]

where \( j = (-1)^{1/2} \).

### 9.12.4.1 Basic Electrical Equations

The loop equations can be written in matrix form:

\[
\begin{pmatrix}
U_1 \\
0
\end{pmatrix}
= \begin{pmatrix}
Z_1 + Z_m & Z_m \\
Z_m & -(Z_2 + Z_m)
\end{pmatrix}
\begin{pmatrix}
I_1 \\
I_2
\end{pmatrix}
\]

Thus the stator current is just:

\[ I_1 = \left( Z_1 + \frac{Z_m}{Z_2 + Z_m} \right) U_1 \]

The rotor current is just:

\[ I_2 = \left( Z_1 + \frac{Z_m}{Z_2 + Z_m} \right) \frac{Z_m}{Z_2 + Z_m} U_1 \]

If the assumption is made that the core or magnetizing resistance, \( R_m \), is much smaller than the core or magnetizing reactance, \( \omega_1 L_m \), then the primary current can be rewritten as:

\[ I_1 = \left( \frac{U_1}{R_1} \right) \frac{1 + jT_1}{(1 - S_g T_1 T_2) + j(T_1 + T_2)} \]

with its absolute value:

\[ |I_1| = \left( \frac{U_1}{R_1} \right) \frac{1 + T_1^2}{(1 - S_g T_1 T_2)^2 + (T_1 + T_2)^2} \]

where the stator power factor, \( T_1 \), the rotor power factor, \( T_2 \), and the leakage factor, \( S_g \), are defined:

\[ T_1 = \frac{\omega_1 (L_1 + L_m)}{R_1} \quad T_2 = \frac{\omega_2 (L_2 + L_m)}{R_2} \quad S_g = 1 - \frac{L_m^2}{(L_1 + L_m)(L_2 + L_m)} \]
The rotor current can then be written as:

\[ I_2 = j \left( \frac{L_m}{L_2 + L_m} \right) \left( \frac{T_2}{1 + jT_2} \right) \cdot I_1 \]

with its absolute value:

\[ |I_2| = \left( \frac{L_m}{L_2 + L_m} \right) \left( \frac{T_2}{1 + T_2^2} \right) \cdot |I_1| \]

The magnetization current can be written as:

\[ I_m = I_1 - I_2 \]

or:

\[ I_m = \left[ 1 - j \left( \frac{L_m}{L_2 + L_m} \right) \left( \frac{T_2}{1 + jT_2} \right) \right] \cdot I_1 \]

with its absolute value:

\[ |I_m| = \sqrt{1 - \left( \frac{L_m}{L_2 + L_m} \right)^2 \frac{T_2^2}{1 + T_2^2}} \cdot |I_1| \]

### 9.12.4.2 Motor Operation

The angular frequency, \( \omega = 2\pi f_1 \), is a variable quantity, which can be set to any value within the capability of the inverter feeding the motor. The majority of variable frequency, variable voltage inverter applications have been at constant V/f output, although other modes of operation are possible. With constant V/f output, the motor exhibits a constant torque capability, which is the desired characteristic. Under this mode of operation, the motor operates at fixed flux density, which allows economy of design.

Because of the constant volts/hertz relationship, nearly a constant flux density in the machine is maintained, however, for low frequencies and thus low applied voltage, this relationship does not hold, and a voltage boost is required to keep the flux constant.
This boost is given by the expression:

\[ U_i = \frac{f_1}{f_m} V_m + \sqrt{3} V_i \quad \text{for} \quad f_1 < f_m \]

\[ U_i = \frac{f_1}{f_m} V_m \quad \text{for} \quad f_1 \geq f_m. \]

The boost voltage compensates for the voltage drop in the stator windings, which is the stator current multiplied by the stator impedance, and is only important at low frequencies.

9.12.4.3 Torque, Power and Power Factor

The air gap power generated in the motor is just

\[ P_e = 3p R_s \left| i_1 \right|^2 \]

where the quantity, \( p \), is the number of pole pairs.

The mechanical torque is related to the air-gap power:

\[ \tau = \frac{P_e}{\omega_1} \]

where the quantity, \( \omega_1 \), is the primary angular frequency.
The mechanical power output of the motor, at any slip, $s$, is just:

$$ P_m = (1 - s) \frac{R_2}{s} |I_2|^2 $$

This power does not include the effects of friction, windage and stray losses, which are handled separately.

The power factor angle, $\theta$, is the angle whose tangent is the ratio of the imaginary to real parts of the primary current:

$$ \tan \theta = \frac{\text{Im}(I_1)}{\text{Re}(I_1)} $$

This can be rewritten as:

$$ \tan \theta = \left[ \frac{T_2 - \frac{T_1 + T_2}{1 - S_2 T_1 T_2}}{1 + \frac{T_1 + T_2}{1 - S_2 T_1 T_2}} \right] $$

### 9.12.4.4 Pull Out Torque

For a fixed primary frequency and voltage, the Torque vs Slip curve for a motor has the shape shown in the plot below:

**Figure 9-59 Torque vs Slip for an AC Induction Motor**

The pull out torque can be obtained by setting the derivative of the torque with respect to the slip, $s$, to zero.

$$ \frac{\partial \tau}{\partial s} = 0 $$
With the same assumption of $R_m << \omega_1 L_m$

$$\omega_2 = \frac{R_2}{(L_2 + L_m)\sqrt{1 + T_2^2}}\sqrt{1 + S_2^2 T_2^2}$$

9.12.4.5 Motor Losses

In addition to the stator, rotor and core losses represented by resistances in the equivalent circuit, there are three other losses generally considered in induction motor models. These losses are:

- Friction
- Windage
- Stray

Since the core losses were not accounted because of the assumption $R_m << \omega_1 L_m$, they must be handled separately when considering output torque.

All harmonic losses are neglected in this model.

9.12.4.5.1 Friction Losses

Friction losses are modeled by the equation:

$$W_f = W_{f1} \cdot (\text{RPM}) + W_{f2} \cdot (\text{RPM})^2$$

where the motor rotational speed, RPM, is just:

$$\text{RPM} = 120 \pi (\omega_1 - \omega_2)$$

9.12.4.5.2 Windage Losses

The windage losses vary as the cube of the motor rotational speed:

$$W_w = W_{w0} \cdot (\text{RPM})^3$$
9.12.4.5.3 Stray Losses

Stray losses are assumed to vary with the input power:

\[ W_{SL} = W_{SL,d} I_1 U_1 \cos \theta \]

9.12.4.5.4 Core Losses

The core losses are just given by the equation:

\[ W_C = 3R_m I_m^2 \]

9.12.4.6 Power and Torque Output

The actual power output (input) of the motor in the power (brake) mode is just:

\[ P_a = P_m \pm W_f \pm W_w \pm W_{SL} \pm W_C \]

and the output (input) torque is

\[ \tau_a = \frac{P_a}{\omega_1 - \omega_2} \]
9.12.5 Gear Unit

The gear unit may be thought of as a converter of the motor torque and rotational speed to wheel/axel torque and rotational speed. Finally, the wheels, through their interaction with the track, convert the wheel’s torque and rotational speed to traction effort and translational speed. The equations are:

**Traction Effort per Car:**

\[ TE = K \tau * NM*GR * \tau / D \]

**Speed:**

\[ V = K \omega * D * \omega / GR \]

Where:

- \( D \) = Wheel Diameter [inches (meters)]
- \( GR \) = Gear Ratio
- \( NM \) = Number of Motors per Car
- \( \omega \) = Rotational Speed [rpm]
- \( \tau \) = Motor Torque [foot-lbs (meter-newtons)]
- \( K \tau \) = Torque Constant = \([24(2)]\)
- \( K \omega \) = Speed Constant = \([\text{mph/rpm-inch (kph/rpm-meter)} [0.00298 (0.189)]\)

The gear unit losses are determined by the equation:

\[
\tau_l = a_g n_r^{-1} + b_g + c_g \tau_r n_r + d_g \tau_r^2 n_r + e_g n_r^2 + f_g n_r^3 \quad \text{for } n_r > 0
\]

\[
\tau_u = b_g + c_g n_r \quad \text{for } n_r = 0
\]

- \( \tau_u \): Gear Torque Loss
- \( \tau_u \): Motor Torque
- \( n_r \): Motor rpm
- \( a_g \): Constant Power Term (ft-lb-rpm)
- \( b_g \): Constant Torque Term (ft-lb)
- \( c_g \): Torque Term (~)
- \( d_g \): Power Term (ft-lb-rpm)
- \( e_g \): Speed Term (ft-lb-rpm)
- \( f_g \): Speed Squares Term (ft-lb-rpm^2)

*Figure 9-60 Gear Unit Torque Loss*

The torque to use in the conversion formula given above is the motor torque less the gear loss torque in power and the motor torque plus the gear loss torque in electric brake.
9.12.6 Resistor Control

The equivalent circuit for the resistor control, which is sometimes called CAM control is:

![Equivalent Circuit](image-url)

Figure 9-61 Equivalent Circuit for CAM or Resistor Control

The following symbols are defined:

- **IL** – Line Current
- **R** – Variable Resistor
- **VL** – Line Voltage
- **VM** – Motor Circuit Voltage

### 9.12.6.1 Resistor Control in Power

The equations for the resistor control in power are:

#### Maximum Voltage on Motor

The maximum voltage on the motor circuit is:

\[ V_M = V_L \]

#### Power Loss and Line Current

The power lost in the resistor at any time is given by the expression:

\[ P_L = (V_L - V_M) \times I_L \]

and the line current is the same as the motor circuit current.
9.12.6.2 Resistor Control in Brake

The equations for the resistor control in electrical braking are:

**Voltage Drop with No Resistance**

The line voltage is just equal to the motor circuit voltage.

\[ V_M = V_L \]

**Power Loss and Line Current**

For the case where \( V_M > V_L \), the resistor drops the voltage to the line. Thus:

\[ P_L = I_L (V_M - V_L) \]

And the resistor losses are just:

For the case where \( V_M < V_L \), there is no regeneration:

\[ P_L = 0 \]
9.12.7 Chopper Control
The equivalent circuit used to model the chopper control is shown below:

![Equivalent Circuit Chopper Model](image)

**Figure 9-62 Equivalent Circuit Chopper Model**

The following symbols are defined:

- **LR** – Line Reactor
- **MT** – Main Device
- **MR** – Motor Reactor
- **FC** – Filter Capacitor
- **FWD** – Free Wheeling Diode
- **R** – Braking Resistor
- **IL** – Line Current
- **IM** – Motor Circuit Current
- **VL** – Line Voltage
- **VM** – Motor Circuit Voltage
- **RLR** – Line Reactor Resistance
- **RMR** – Motor Reactor Resistance
- **RFC** – Filter Capacitor Resistance
- **VMT** – Voltage Drop Main Device
- **VFWD** – FWD Voltage Drop
- **PC** – Chopper Constant Losses
- **rt** – Ratio of Commutation Time to Chopper Period

Other circuit parameters to be used in the equations, which follow are:

- **RLR** – Line Reactor Resistance
- **RMR** – Motor Reactor Resistance
- **RFC** – Filter Capacitor Resistance
- **VMT** – Voltage Drop Main Device
- **VFWD** – FWD Voltage Drop
- **PC** – Chopper Constant Losses
- **rt** – Ratio of Commutation Time to Chopper Period

### 9.12.7.1 Chopper Control in Power

The equations for the chopper control in power are:

**Maximum Voltage on Motor**

The voltage drop from the line to the motor circuit for maximum voltage on the motor (with device MT fully conducting) and the motor circuit current in this condition is:

\[
V_M = V_L - I_M (R_{LR} + R_{MR}) - V_{MT} - r_t V_L
\]

\[
I_M = I_L
\]
Chopper Power Loss and Line Current

The power lost in the chopper at any time is given by the expression:

\[ P_L = I_M^2 \left[ R_{LR} + R_{MR} \right] + I_M \left[ V_{MT} + (1-r)V_{FWD} + r(1-r)I_M R_{FC} \right] + P_C \]

where:

\[ r = \frac{V_M}{V_L} \]

Thus the line current is just:

\[ I_L = \frac{P_L + I_M V_M}{V_L} \]

9.12.7.2 Chopper Control in Brake

The equations for the chopper control in electrical braking are:

Voltage Drop with No Resistance

The voltage drop from the motor (generator) circuit to the line at the line voltage with no resistance \((R=0)\) in the circuit and the associated line current are just:

\[ V_M = V_L + I_M (R_{LR} + R_{MR}) + V_{FWD} + r_1 V_L \]
\[ I_L = I_M \]
Chopper Power Loss and Line Current

For the case where $V_M > V_L$, the main device is turned off, so that the line current and motor circuit current are the same. The resistor drops the voltage to the line. Thus:

$$I_L = I_M$$

And the chopper losses are just:

$$P_L = I_M(V_M - V_L)$$

For the case where $V_M < V_L$, the main device is used to boost the voltage, so that the resistor value is set to zero ($R=0$). Thus, the chopper losses are:

$$P_L = I_M^2(\frac{1}{2}R_{LR} + R_{MR}) + I_M[fV_{FWD} + (1-r)V_{MT} + r(1-r)I_MR_{FC} + P_C]$$

The associated line current is then:

$$I_L = \frac{I_MV_M - P_L}{V_L}$$

Motor Circuit Voltage at No Line Current

The motor circuit voltage at zero line current (with the main device fully conducting) is given by the expressions:

$$I_L = 0$$

$$V_M = I_MR_{MR} + V_{MT} + \frac{P_C}{I_M} + rTV_L$$

This point represents the complete loss of electrical brake.
9.12.8 Phase Control

9.12.8.1 Full Bridge, Full Control

The equivalent circuit used to model the full bridge, full control phase control is shown below:

Figure 9-63 Equivalent Circuit Phase Control Model (Full Bridge, Full Control)

The following symbols are defined:

- $T$: Device
- $MR$: Motor Reactor
- $I_L$: Total Line Current
- $I_{LR}$: Reactive Line Current
- $I_M$: Motor Circuit Current
- $V_M$: Motor Circuit Voltage
- $V_L$: Line Voltage
- $R_{MR}$: Motor Reactor Resistance
- $R_{TR}$: Transformer Resistance
- $V_T$: Thyristor Voltage Drop
- $n$: Transformer Turns Ratio

Other circuit parameters to be used in the equations, which follow are:

- $R_{TR}$: Transformer Resistance
- $n$: Transformer Turns Ratio
9.12.8.1.1 Full Bridge - Full Control in Power

The equations for the full bridge – full control in power are:

9.12.8.1.1.1 Single Phase AC

**Maximum Voltage on Motor**

The voltage drop from the line to the motor circuit for maximum voltage on the motor (with device MT fully conducting) and the motor circuit current in this condition is:

\[ I_L = \frac{1}{n\sqrt{2}} I_M \]
\[ V_M = \frac{2\sqrt{2}}{n\pi} V_L - I_L \sqrt{R_{TR}^2 + X_{TR}^2} - V_T - I_M R_{MR} \]

**Conduction Angle, Power Factor, Losses, Line Current**

The conduction angle is given by the expression:

\[ \alpha = \cos^{-1}\left( \frac{n\pi}{2\sqrt{2}} \frac{V_M}{V_L} \right) \]

The power factor can be expressed as:

\[ PF = \frac{nV_M}{V_L} \]

The RMS line current is just:

\[ I_{L\text{RMS}} = \frac{I_M}{n} \sqrt{1 - \frac{\alpha}{\pi}} \]

The losses are given by the equation:

\[ P_L = R_{TR} I_{L\text{RMS}}^2 + R_{MB} I_M^2 + V_T I_M \sqrt{1 - \frac{\alpha}{\pi}} + V_I I_M \]

The real part of the line current is:

\[ \text{RE}(I_L) = \frac{V_M I_M + P_L}{V_L} \]
The magnitude of the line current is:

\[ |I_L| = \frac{\text{RE}(I_L)}{PF} \]

### 9.12.8.1.1.2 Three Phase AC

#### Maximum Voltage on Motor

The voltage drop from the line to the motor circuit for maximum voltage on the motor (with device MT fully conducting) and the motor circuit current in this condition is:

\[ I_L = \frac{\sqrt{3} I_M}{2n} \]

\[ V_M = \frac{3\sqrt{6}}{n\pi} V_L - I_L \sqrt{R_{TR}^2 + X_{TR}^2} - V_T - I_M R_{MR} \]

#### Conduction Angle, Power Factor, Losses, Line Current

The conduction angle is given by the expression:

\[ \alpha = \cos^{-1}\left(\frac{n\pi}{3\sqrt{6}} \frac{V_M}{V_L}\right) \]

The power factor can be expressed as:

\[ PF = \frac{nV_M}{\sqrt{6}V_L} \]

The RMS line current is just:

\[ I_{LRMS} = I_M \sqrt{\frac{1 - 3\alpha}{4\pi}} \]

The losses are given by the equation:

\[ P_L = R_{TR} I_{LRMS}^2 + R_{MH} I_M^2 + V_T I_M \sqrt{1 - \frac{3\alpha}{4\pi}} + V_I I_M \]

The real part of the line current is:

\[ \text{RE}(I_L) = \frac{V_M I_M + P_L}{V_L} \]
The magnitude of the line current is:

$$|I_L| = \text{RE} \left( \frac{I_L}{PF} \right)$$

9.12.8.1.2 Full Bridge - Full Control in Brake

The equations for the full bridge – full control in brake are:

9.12.8.1.2.1 Single Phase AC

**Maximum Voltage on Motor**

The voltage drop from the line to the motor circuit for maximum voltage on the motor (with device MT fully conducting) and the motor circuit current in this condition is:

$$I_L = \frac{n}{\sqrt{2}} I_M$$

$$V_M = \frac{2\sqrt{2}}{\pi} V_L + I_L \sqrt{R_{TR}^2 + X_{TR}^2} + V_T + I_M R_{MR}$$

**Conduction Angle, Power Factor, Losses, Line Current**

The conduction angle is given by the expression:

$$\alpha = \cos^{-1} \left( \frac{n \sqrt{2}}{2 \sqrt{2}} \frac{V_M}{V_L} \right)$$

The power factor can be expressed as:

$$\text{PF} = \frac{n V_M}{V_L}$$

The RMS line current is just:

$$I_{L\text{RMS}} = \frac{I_M}{n} \sqrt{1 - \frac{\alpha}{\pi}}$$

The losses are given by the equation:

$$P_L = R_{TR} I_{L\text{RMS}}^2 + R_{MR} I_M^2 + V_T I_M \sqrt{1 - \frac{\alpha}{\pi}} + V_I I_M$$
The real part of the line current is:

\[ \text{RE}(I_L) = \frac{V_M I_M - P_L}{V_L} \]

The magnitude of the line current is:

\[ |I_L| = \frac{\text{RE}(I_L)}{PF} \]

9.12.8.1.2.2 Three Phase AC

Maximum Voltage on Motor

The voltage drop from the line to the motor circuit for maximum voltage on the motor (with device MT fully conducting) and the motor circuit current in this condition is:

\[ I_L = \frac{\sqrt{3}}{2n} I_M \]

\[ V_M = 3\sqrt{6} \left( \frac{V_L}{n} \right) + I_L \sqrt{R_{TM}^2 + X_{TM}^2} + V_T + I_M R_{MR} \]

Conduction Angle, Power Factor, Losses, Line Current

The conduction angle is given by the expression:

\[ \alpha = \cos^{-1} \left( -\frac{n\pi}{3\sqrt{6}} \cdot \frac{V_M}{V_L} \right) \]

The power factor can be expressed as:

\[ PF = \frac{nV_M}{\sqrt{6}V_L} \]

The RMS line current is just:

\[ I_{LRMS} = \frac{I_M}{n} \sqrt{1 - \left( \frac{3\alpha}{4\pi} \right)} \]

The losses are given by the equation:

\[ P_L = R_{TM} I_{LRMS}^2 + R_{MR} I_M^2 + V_T I_M \sqrt{1 - \left( \frac{3\alpha}{4\pi} \right)} + V_T I_M \]
The real part of the line current is:

$$\text{RE}(I_L) = \frac{V_M I_M - P_L}{V_L}$$

The magnitude of the line current is:

$$|I_L| = \frac{\text{RE}(I_L)}{PF}$$

### 9.12.8.2 Midpoint, Full Control

The equivalent circuit used to model the midpoint, full control phase control is shown below:

![Figure 9-64 Equivalent Circuit Phase Control Model (Midpoint, Full Control)](image)

The following symbols are defined:

- T – Device
- MR – Motor Reactor
- I_L – Total Line Current
- I_LR – Reactive Line Current
- I_M – Motor Circuit Current
- V_M – Motor Circuit Voltage
- V_L – Line Voltage
- R_MR – Line Reactor Resistance
- R_TR – Transformer Resistance
- V_T – Thyristor Voltage Drop
- n – Transformer Turns Ratio

### 9.12.8.2.1 Midpoint - Full Control in Power

The equations for the full bridge – full control in power are presented.

#### 9.12.8.2.1.1 Single Phase AC

The equations are the same as for the Full Bridge – Full Control. These have been described in Section 9.12.8.1.1.1
9.12.8.2.1.2 Three Phase AC

Maximum Voltage on Motor

The voltage drop from the line to the motor circuit for maximum voltage on the motor (with device MT fully conducting) and the motor circuit current in this condition is:

\[ I_L = \frac{\sqrt{3}}{2n} I_M \]
\[ V_M = \frac{3\sqrt{2}}{n\pi} V_L - I_L \sqrt{R_{TR}^2 + X_{TR}^2} - V_T - I_M R_{MR} \]

Conduction Angle, Power Factor, Losses, Line Current

The conduction angle is given by the expression:

\[ \alpha = \cos^{-1} \left( \frac{n\pi}{3\sqrt{2}} \frac{V_M}{V_L} \right) \]

The power factor can be expressed as:

\[ PF = \frac{nV_M}{\sqrt{6}V_L} \]

The RMS line current is just:

\[ I_{L,RMS} = \frac{I_M}{n} \sqrt{1 - \frac{3\alpha}{4\pi}} \]

The losses are given by the equation:

\[ P_L = R_{TR} I_{L,RMS}^2 + R_{MR} I_M^2 + V_T I_M \sqrt{1 - \frac{3\alpha}{4\pi}} + V_T I_M \]

The real part of the line current is:

\[ \text{RE}(I_L) = \frac{V_M I_M + P_L}{V_L} \]
The magnitude of the line current is:

\[ |I_L| = \frac{RE(I_L)}{PF} \]

9.12.8.2.2 Full Bridge - Full Control in Brake

The equations for the full bridge – full control in brake are:

9.12.8.2.2.1 Single Phase AC

**Maximum Voltage on Motor**

The voltage drop from the line to the motor circuit for maximum voltage on the motor (with device MT fully conducting) and the motor circuit current in this condition is:

\[
I_L = \frac{1}{n\sqrt{2}} I_M
\]

\[
V_M = \frac{2\sqrt{2}}{n\pi} V_L + I_L \sqrt{\frac{R_{TR}^2 + X_{TR}^2}{R_{TR}}} + V_T + I_M R_{MR}
\]

**Conduction Angle, Power Factor, Losses, Line Current**

The conduction angle is given by the expression:

\[
\alpha = \cos^{-1}\left( -\frac{n\pi}{2\sqrt{2}} \frac{V_M}{V_L} \right)
\]

The power factor can be expressed as:

\[
PF = \frac{nV_M}{V_L}
\]

The RMS line current is just:

\[
I_{LRMS} = \frac{I_M}{n} \sqrt{1 - \frac{\alpha}{\pi}}
\]

The losses are given by the equation:

\[
P_L = R_{TR} I_{LRMS}^2 + R_{MR} I_M^2 + V_T I_M \sqrt{1 - \frac{\alpha}{\pi}} + V_T I_M
\]
The real part of the line current is:

$$\text{RE}(I_L) = \frac{V_M I_M - P_L}{V_L}$$

The magnitude of the line current is:

$$|I_L| = \frac{\text{RE}(I_L)}{PF}$$

9.12.8.2.2.2 *Three Phase AC*

**Maximum Voltage on Motor**

The voltage drop from the line to the motor circuit for maximum voltage on the motor (with device MT fully conducting) and the motor circuit current in this condition is:

$$I_L = \frac{\sqrt{3}}{2n} I_M$$

$$V_M = \frac{3\sqrt{6}}{n\pi} V_L + I_L \sqrt{R^2_{TR} + X^2_{TR} + V_T + I_M R_{MR}}$$

**Conduction Angle, Power Factor, Losses, Line Current**

The conduction angle is given by the expression:

$$\alpha = \cos^{-1}\left(-\frac{n\pi}{3\sqrt{6}} \cdot \frac{V_M}{V_L}\right)$$

The power factor can be expressed as:

$$PF = \frac{nV_M}{\sqrt{6}V_L}$$

The RMS line current is just:

$$I_{L\text{RMS}} = \frac{I_M}{n} \sqrt{1 - \frac{3\alpha}{4\pi}}$$

The losses are given by the equation:

$$P_L = R_{TR} I_{L\text{RMS}}^2 + R_{MR} I_M^2 + V_T I_M \sqrt{1 - \frac{3\alpha}{4\pi} + V_T I_M}$$
The real part of the line current is:

\[ \text{RE}(I_L) = \frac{V_L I_M - P_L}{V_L} \]

The magnitude of the line current is:

\[ |I_L| = \frac{\text{RE}(I_L)}{PF} \]
9.12.9 PWM Inverter Control

The per phase equivalent circuit for the PWM Inverter Control is shown in the figure below:

Figure 9-65 Equivalent Circuit PWM Inverter

The following symbols are defined:

- **LR** – Line Reactor
- **MT** – Main Device
- **MR** – Motor Reactor
- **FC** – Filter Capacitor
- **FWD** – Free Wheeling Diode
- **IL** – Line Current
- **IM** – Motor Circuit Current
- **VL** – Line Voltage
- **VM** – Motor Circuit Voltage
- **RLR** – Line Reactor Resistance
- **RMR** – Motor Reactor Resistance
- **RFC** – Filter Capacitor Resistance
- **V_FWD** – FWD Voltage Drop
- **V_M** – Voltage Drop Main Device
- **PC** – Inverter Constant Losses
- **f_1** – Inverter output frequency
- **θ** – Power factor angle of the motor

Other circuit parameters to be used in the equations, which follow are:

The equations developed for power and brake for the inverter circuit neglect all harmonic losses and all losses associated with boosting devices, which bring the motor circuit voltage above line voltage. The resistances of such devices can generally be lumped into the motor or line reactor resistances.
9.12.9.1 PWM Inverter Control in Power

The equations for the PWM Inverter Control in power are:

**Maximum Voltage on Motor**

The voltage drop from the line to the motor circuit for maximum voltage on the motor (with device MT fully conducting) and the motor circuit current in this condition is:

\[
V_M = \frac{\sqrt{3} V_L}{\pi} - I_M (R_{LR} + R_{MR}) - 2V_{MT}
\]

\[
I_M = \sqrt{3}I_L
\]

**Inverter Power Loss and Line Current**

The power lost in the inverter at any time is given by the expression:

\[
P_L = MDL + DL + LRL + MRL + FCL + P_C
\]

where:

MDL and DL are the main device and free wheeling diode losses, respectively, given by the expressions:

\[
MDL = \frac{3\sqrt{2} I_M V_{MT}}{\pi} (1 + r \cos \theta)
\]

\[
DL = \frac{3\sqrt{2} I_M V_{FWD}}{\pi} (1 - r \cos \theta)
\]

where the quantity, \( r \), is given by the expression:

\[
r = \frac{f_1}{f_{MAX}} + \frac{I_M R_s}{V_{M(MAX)}}
\]

The quantity, \( f_{MAX} \), is the inverter output frequency at maximum output voltage, \( V_{M(MAX)} \).

The line reactor loss, LRL, is given by the expression:

\[
LRL = R_{LR} I_M^2
\]

The motor reactor loss, MRL, is given by the expression:

\[
MRL = R_{MR} I_M^2
\]
The filter capacitor loss, FCL, is given by the expression:

\[ FCL = R_{FC} I_{FC}^2 \]

Where the quantity, \( I_{FC} \), is the rms current through the filter capacitor, given by the expression:

for \( r < 1 \):

\[ I_{FC} = 1.1L_{M} \sqrt{(1 - r \cos \theta)(r \cos \theta)} \]

for \( r = 1 \):

\[ I_{FC} = \frac{3L_{M}}{\pi} \sqrt{(0.965 - 0.926(2 \cos^2 \theta - 1))} \]

Thus the line current is just:

\[ I_L = \frac{P_L + \sqrt{3}I_{M}V_{M\cos \theta}}{V_L} \]

The equations are solved by an iterative procedure.

### 9.12.9.2 PWM Inverter Control in Brake

The equations for the PWM inverter control in electrical braking are:

**Voltage Drop**

The voltage drop from the motor (generator) circuit to the line at the line voltage and the associated line current are just:

\[ V_M = \frac{\sqrt{3}}{\pi} V_L + I_M (R_{LR} + R_{MR}) + 2V_{MT} \]

\[ I_M = \sqrt{3}I_L \]

**Inverter Power Loss and Line Current**

The power loss of the Inverter is given by the same expression in brake as in the power mode.

The associated line current is in the opposite direction and is given by the expression:

\[ I_L = \frac{\sqrt{3}I_M V_{M\cos \theta} - P_L}{V_L} \]
9.12.10  FQC - PWM Inverter Control

The Four Quadrant Control plus the per phase equivalent circuit for the PWM Inverter Control is shown in the figure below:

![Figure 9-66 Equivalent Circuit FQC - PWM Inverter Control](image)

The following symbols are defined:

- **LR** – Line Reactor
- **MD** – Main Device
- **MR** – Motor Reactor
- **FC** – Filter Capacitor
- **FWD** – Free Wheeling Diode
- **IC** – Intermediate Capacitor
- **IL** – Line Current
- **IM** – Motor Circuit Current
- **VL** – Line Voltage
- **VM** – Motor Circuit Voltage
- **MT** – Main Transformer

Other circuit parameters to be used in the equations, which follow are:

- **RLR** – Line Reactor Resistance
- **RMR** – Motor Reactor Resistance
- **RFC** – Filter Capacitor Resistance
- **VMD** – Voltage Drop Main Device
- **XMT** – Main Transformer Reactance (HV Equivalent)
- **RMT** – Main Transformer Resistance
- **RIC** – Intermediate Capacitor Resistance
- **VFWD** – FWD Voltage Drop
- **Pc** – Inverter Constant Losses
- **f1** – Inverter output frequency
- **θ** – Power factor angle of the motor
- **nT** – Main Transformer Turns Ratio

The equations developed for power and brake for the Four Quadrant – PWM Inverter circuit neglect all harmonic losses and all losses associated with boosting devices, which bring the motor circuit voltage above line voltage and correct the power factor to unity. The resistances of such devices can generally be lumped into the motor or line reactor resistances for the inverter portion and into the main transformer resistance for the four quadrant control portion.

The four quadrant control portion of the circuit maintains a constant voltage at the intermediate capacitor and corrects the power factor from 90% to 100%.
9.12.10.1 FQC - PWM Inverter Control in Power

The equations for the FQC - PWM Inverter Control in power are:

**Maximum Voltage on Motor**

The voltage drop from the line to the motor circuit for maximum voltage on the motor (with devices MD fully conducting) and the motor circuit current in this condition is given by two expressions:

\[ V_i = \frac{2\sqrt{2}}{\pi} \cdot \frac{V_L}{nT} - I_i \left( X_{MT}^2 + R_{MT}^2 \right)^{1/2} - V_{MD} \]

\[ I_i = \frac{2\sqrt{2}}{\pi} \cdot I_L \cdot nT \]

\[ V_M = \frac{\sqrt{6}}{\pi} \cdot V_i - I_i R_{LR} + I_M R_{MR} - 2 \cdot V_{MD} \]

\[ I_M = \sqrt{3} \cdot I_L \]

Thus given the line voltage and the maximum motor current, the line current and motor voltage can be obtained at maximum voltage on the motor.

**Four Quadrant - Inverter Controller Power Loss and Line Current**

The power lost in the controller at any time is given by the expression:

\[ P_L = MDL + DL + LRL + MRL + FCL + MTL + ICL + P_C \]

where:

MDL and DL are the main device and free wheeling diode losses, respectively, given by the expressions:

\[ MDL = \frac{3\sqrt{2} I_M V_{MT}}{\pi} (1 + r \cos \theta) \]

\[ DL = \frac{3\sqrt{2} I_M V_{FWD}}{\pi} (1 - r \cos \theta) \]

where the quantity, r, is given by the expression:
The quantity, $f_{\text{MAX}}$, is the inverter output frequency at maximum output voltage, $V_{\text{M(MAX)}}$.

The quantity, $R_s$, is the stator resistance of the induction motor.

The line reactor loss, $L_{RL}$, is given by the expression:

$$L_{RL} = R_{ls} I_f^2$$

The motor reactor loss, $M_{RL}$, is given by the expression:

$$M_{RL} = R_{mr} I_M^2$$

The filter capacitor loss, $F_{CL}$, is given by the expression:

$$F_{CL} = R_{FC} I_{FC}^2$$

Where the quantity, $I_{FC}$, is the rms current through the filter capacitor, given by the expression:

for $r<1$:

$$I_{FC} = 1.1 I_M \sqrt{\left[1 - r \cos \theta \right]}$$

for $r=1$:

$$I_{FC} = \frac{3}{\pi} I_M \sqrt{\left[0.0965 - 0.0926 \left(2 \cos^2 \theta - 1\right)\right]}$$

The intermediate capacitor loss, $I_{CL}$, is given by the expression:

$$I_{CL} = R_{IC} I_{IC}^2$$

Where the quantity, $I_{IC}$, is the rms current through the intermediate capacitor, given by the expression:

$$I_{IC} = \left(1 - \frac{2\sqrt{2}}{\pi}\right) I_f$$

Thus the intermediate current is just:

$$I_f = \frac{P_L + \sqrt{3} I_M V_M \cos \theta}{V_f}$$

The equations are solved by an iterative procedure.
9.12.10.2 FQC - PWM Inverter Control in Brake

The equations for the Four Quadrant - PWM Inverter controller in electrical braking are:

**Voltage Drop**

The voltage drop from the motor (generator) circuit to the line at the line voltage and the associated line current is determined by the following equations:

\[
V_I = \frac{2\sqrt{2}}{\pi} V_L \cdot \frac{I_I}{nT} + I_I (X_{MT}^2 + R_{MT}^2)^{1/2} + V_{MD}
\]

\[
I_I = \frac{2\sqrt{2}}{\pi} I_I \cdot nT
\]

\[
V_M = \frac{\sqrt{6}}{\pi} V_I + I_I R_{IR} + I_M R_{IR} + 2V_{MD}
\]

\[
I_M = \sqrt{3} I_I
\]

**Inverter Power Loss and Line Current**

The power loss of the Four Quadrant – PWM Inverter is given by the same expression in brake as in the power mode.

The associated intermediate current is in the opposite direction and is given by the expression:

\[
I_I = \frac{\sqrt{3} I_M V_M \cos \theta - P_L}{V_I}
\]

The equations again are solved by an iterative method.

9.13 TRACTION EFFORT CURVE FITTING

Traction curves (Effort vs Speed) have a dependence, in which the effort decreases with increasing speed beyond the cornering point. The cornering point of a traction curve is a point where the effort below the speed of the cornering point varies slowly or exhibits no variation for lower speed and varies rapidly for higher speed. The concept is illustrated below:
The purpose of this exercise is to set out a formalism, through which, using a least squares fitting technique, the effort for speeds larger than the cornering point speed may be expressed as

\[ E = \sum_{j=0}^{M} \frac{C_j}{v^j} \]

where \( E \) is the traction effort, \( v \) is the speed and \( C_j \) is a coefficient of the \( j \)th power of \( v \).

Normally, only two or three terms of the summation are used in practice.

The set of points to which the effort and speed are fitted are expressed as \((E_i, v_i)\). There are \( N \) of these points taken from the traction curve.

By the method of least squares, the quantity to be minimized is

\[ X^2 = \sum_{i=1}^{N} \left[ E_j - \sum_{j=0}^{M} \frac{C_j}{v_i^j} \right]^2 \]

Setting the derivatives of \( X^2 \) with respect to \( C_j \) equal to zero gives the following set of linear equations, written in matrix form

\[ V C = T \]
Where $C$ is the column vector with $M$ rows of coefficients $C_j$, the unknowns to be determined;

$T$ is the column vector of coefficients $T(j)$, defined by the expression

$$ T(j) = \sum_{i=1}^{N} \frac{E_i}{v_i^j}; $$

and, $V$ is the matrix, whose matrix element, $V_{jk}$, is given by the expression

$$ V_{jk} = \sum_{i=0}^{N} \frac{1}{v_i^{j+k+2}}; $$

The matrix, $V$ is $(M+1) \times (M+1)$ and a real symmetric matrix, which means it always has an inverse. To be fully determined, the relation, $N \geq M+1$, must be satisfied.

The solution is given by the expression

$$ C = V^{-1}T $$

The goodness of the fit, $G$ is given by the expression

$$ G = \frac{\sum_{i=1}^{N} |E_i - \sum_{j=0}^{M} \frac{C_j}{v_i^j}|}{N} $$

Which can be computed once the coefficients, $C_j$, are determined.

Without any loss of generality, the equations can be rewritten in the form:

$$ E = \sum_{j=0}^{M} C(j) \cdot \frac{v_s^j}{v_i^j} $$

where

$$ C(j) = \frac{C_j}{v_s^j} $$

And the quantity $v_s$ is the speed at the beginning of the range of Traction Effort-Speed points to be selected.

9.14 RAIL VOLTAGE MODEL

9.14.1 Basic Model and Equations
The schematic shown below is the model used for calculation of rail to ground voltage.

Definitions:

- $R_n$: The resistance of the parallel running rails in the circuit divided by the number of lattice elements ($n$)
- $R_{gn}$: The ground resistance in the circuit divided by the number of lattice elements ($n$)
- $R_L$: The average leakage resistance from rail to ground in each of the lattice elements.
- $I_g = \sum I_j$
The ground leakage currents, $I_j$, are the solutions of the set of simultaneous linear equations:

$$\sum R_{ij} I_j = R_n I$$

This can be written in matrix notation as

$$R I = R_n B I$$

Where $I = \{I_j\}$

Where, the matrix of resistances $R$ is of the form:

\[
\begin{array}{cccccc}
R_{1,i} + R_n + R_{gn} & R_{L} & 0 & 0 & 0 & 0 \\
R_{n} + R_{gn} & R_{L} + R_{n} + R_{gn} & -R_{L} & 0 & 0 & 0 \\
R_{n} + R_{gn} & R_{n} + R_{gn} & R_{L} + R_{n} + R_{gn} & -R_{L} & 0 & 0 \\
R_{n} + R_{gn} & R_{n} + R_{gn} & R_{n} + R_{gn} & R_{L} + R_{n} + R_{gn} & -R_{L} & 0 \\
R_{n} + R_{gn} & R_{n} + R_{gn} & R_{n} + R_{gn} & R_{n} + R_{gn} & R_{L} + R_{n} + R_{gn} & 2R_{L} + R_{n} + R_{gn} \\
\end{array}
\]

Matrix elements of $R$ can be expressed by the following algorithm:

$$R_{ij} = \begin{cases} 
R_{L} + R_{n} + R_{gn} & \text{for } j = i, i < n, \text{ for } j = n, i < n \\
2R_{L} + R_{n} + R_{gn} & \text{for } i = j = n \\
R_{n} + R_{gn} & \text{for } i < j \text{ and for } j < n \\
-R_{L} & \text{for } j = i + 1, i < n - 1 \\
0 & \text{for } j > i + 1, i < n - 2 
\end{cases}$$

The matrix, $B$, has the form:

\[
\begin{bmatrix}
1 \\
1 \\
1 \\
1 \\
1 \\
\end{bmatrix}
\]

Thus the rail voltages along the lattice are simply:

$$V_i = I_i R_{L}$$
9.14.2 Application of the Model

Let $R$ be the rail resistance between the load and the source and $R_g$ be the ground resistance between load and source. Express $R_g$ in terms of $R$ leads to the following expressions:

$$R_g = f \cdot R$$

$$R_n = R/n$$

$$R_{gn} = R_g/n = f \cdot R/n$$

Express the leakage resistance from rail to ground in terms of $R$

$$R_l = e \cdot R$$

With the above definitions, the matrix elements of the matrix elements of $R$ can be expressed by the following algorithm:

Expressing

$$R = R \cdot M$$

Then the value for the $M$ matrix elements are:

$$M_{ij} = \begin{cases} 
  e+1/n+f/n & \text{for } j = i < n, \text{ for } j = n, i < n \\
  2e+1/n+f/n & \text{for } i = j = n \\
  1/n+f/n & \text{for } i < j \text{ and for } j < n \\
  -e & \text{for } j = i + 1, i < n - 1 \\
  0 & \text{for } j > i + 1, i < n - 2 
\end{cases}$$

Under the above circumstances, the voltages are floating the end of the lattice. For establishing solid grounds at the endpoint, the matrix elements are

$$M_{ij} = \begin{cases} 
  e+1/n+f/n & \text{for } j = i < n, \text{ for } j = n, i < n \\
  1/n+f/n & \text{for } i = n, j < n \\
  e+1/n+f/n & \text{for } i = j = n \\
  1/n+f/n & \text{for } i < j \text{ and for } j < n \\
  -e & \text{for } j = i + 1, i < n - 1 \\
  0 & \text{for } j > i + 1, i < n - 2 
\end{cases}$$

The first circumstance will be called a Floating circuit, while the second will be called a Grounded circuit.

The set of simultaneous linear equations to be solved can be written in the form:

$$M \cdot I = 1/n \cdot B$$

where $I = I / I = \{I / I \}$
Solving this equation, compute the inverse of \( M \); namely, \( M^{-1} \).

\[
I = \frac{1}{n} \cdot M^{-1} \cdot B
\]

\[
I_i/I = \frac{1}{n} \cdot \sum M^{-1}_{ij}
\]

Assume that the rails are connected to the ground through the ties, which are a fixed distance apart. The number of lattice points, \( n \), is the ratio of the distance between source and load, \( D \), to the inter-tie distance, \( d \).

\[
n = \text{integer}(D/d)
\]

The common practice is to take the inter-tie distance as 21 inches, in which case the value of \( n \) would be 3017 per mile of source to load distance.

All currents, voltages, and resistances will be expressed in terms of the unit voltage and unit power.

The voltage between the rail and the ground at all lattice points can then be expressed as:

\[
V_i = I_i \cdot e \cdot R
\]

Or re-expressing in terms of the distance \( D \):

\[
V_i = I_i \cdot e \cdot D \cdot R_D
\]

Where \( R_D \) is the resistance per unit distance of the rail or track.

Letting \( k \) be the index

\[
X(e,f,D,n) = \sum (I_i/I) \cdot e \cdot D = [(1/n) \cdot e \cdot D \cdot \sum M^{-1}_{ij}]
\]

The final expression for the voltage is

\[
V = X(e,f,D,n) \cdot R_D \cdot I
\]

The quantity, \( X \) is only a function of \( e, f, D, \) and \( n \), and can be computed for a range of values of these variables ahead of the main rail voltage calculation. The table of values of \( X \) will be called the Rail Voltage Table.

Two types of circuits were considered. In the first case, in the first case of the Floating circuit, the Rail Voltages vary from a positive value at the current generator to a negative value at the opposing end. In the second case of a grounded circuit, the Rail Voltages vary from a positive value at the current generator to zero at the opposing end. In both cases, the Rail Voltages are monotonically decreasing with increasing lattice points.

Consider the next sketch of the track system, showing both lines and nodes.
Figure 9-67 Nodal and Lineal Voltage Relationships

Between nodes $N_x$ and $N_{x-1}$, there is a lattice for which $V_1$ to $V_n$ was computed. Since these functions are monotonically decreasing, $VP(L_x) = V_1$ and $VM(L_x) = V_n$. The formulae in the figure above relate the Nodal Voltages to the Lineal Voltages.

### 9.15 WAYSIDE ENERGY STORAGE MODEL

#### 9.15.1 Generic Model

A wayside energy storage model is generic, in the sense that it can represent different types of storage devices such as batteries and flywheels. The storage station is defined in the model by several parameters:

- **Set Voltage**, above which charging occurs and below which discharging occurs.
- **Power Out**, maximum discharging power
- **Power In**, maximum charging power
- **Maximum Energy**, maximum stored energy capability
- **Minimum Energy**, minimum stored energy capability
- **Initial Energy**, initial stored energy
- **Efficiency In**, ratio of electrical charge energy to additional stored energy upon charge.
- **Efficiency Out**, ratio of subtractional stored energy upon discharge to electrical discharge energy.
- **Decay Type**, may be linear or exponential
- **Decay Rate**, loss of energy with time. It is specified as stored energy per hour if linear and % per hour of stored energy (expressed as fraction).
- **Turns Ratio**, (for AC storage devices) the ratio of the open circuit voltage at the storage node to the unit voltage.

The algorithm is a step algorithm, which is as follows:

For each snapshot in the ENS or TMS run.
The storage node is initially a fixed voltage through which a variable amount of power is delivered to and from the network. If the power exceeds the limits of maximum charging and discharging power, the node is then converted to a Source node, with a fixed amount of power equal to the maximum charging or discharging power as the case may be.

If Node Voltage > Set Voltage then charge at Power between 0 and Power In, treating the storage station as a source node at the Power value.

If Node Voltage < Set Voltage then discharge at Power between 0 and Power Out, treating the storage station as a source node at the Power value.

Charge until the stored energy >= maximum stored energy capability. Discharge until the stored energy <= minimum stored energy capability.

If node voltage = Set Voltage, no charge or discharge by setting storage node to Load node with zero power.

On charging, Stored Energy = Stored Energy + Power x Efficiency In x dt – Decay Energy
On discharging, Stored Energy = Stored Energy - Power x EfficiencyOut x dt – Decay Energy
Where dt is the snapshot time interval, and
Decay Energy = Decay Rate x stored energy x dt for Decay Type = “exponential”
Decay Energy = Decay Rate x stored energy x dt for Decay Type = “linear”

9.15.2 Enhanced Generic Energy Storage Model

Treatment of the Enhanced Generic Wayside Storage Device is slightly different than the Generic Device just described. The Enhanced Generic wayside energy storage station is defined in the model by several parameters. Some of these parameters are illustrated in the control diagram presented below.
Mean Voltage, the initial guess for the mean line voltage above which charging may occur and below which discharging may occur. This is only the initial guess, the mean voltage is continuously averaged as the flywheel operates.

Max Energy, maximum stored mechanical energy capability

Min Energy, minimum stored mechanical energy capability below which discharging cannot occur.

Initial Energy, initial stored energy.

Eff Chg, charging efficiency, which is the ratio of electrical charge energy to additional stored mechanical energy upon charge.

Eff DChg, discharging efficiency which is the ratio of subtractional mechanical stored energy upon discharge to electrical discharge energy.

Decay Rate, loss of energy with time. It is specified as % per hour of stored energy expressed as a fraction.

Volt Ofst Max Pwr DChg, the voltage off set, referred to the Mean Voltage, below which maximum power is discharged to the line.

Volt Ofst Min Pwr DChg, the voltage off set, referred to the Mean Voltage, below which power is discharged to the line up to maximum power discharge in a linear fashion.
Volt Ofst Max Pwr Chg, the voltage offset, referred to the Mean Voltage, above which maximum power is charged from the line.

Volt Ofst Min Pwr Chg, the voltage offset, referred to the Mean Voltage, above which power is charged from the line up to maximum power in a linear fashion.

Max Pwr DChg, maximum discharging power
Max Pwr Chg, maximum charging power
Min Pwr DChg, the power discharge when the line voltage equals (Mean Voltage - Volt Ofst Min Pwr DChg)
Min Pwr Chg, the power charge when the line voltage equals (Mean Voltage + Volt Ofst Min Pwr Chg).
Rec Pwr DChg, the amount of recovery power discharge, used to bring the flywheel back to its initial energy state, when the line voltage is between Mean Voltage and (Mean Voltage - Volt Ofst Min Pwr DChg)
Rec Pwr Chg, the amount of recovery power charge, used to bring the flywheel back to its initial energy state, when the line voltage is between Mean Voltage and (Mean Voltage + Volt Ofst Min Pwr Chg)

Min Voltage, the line voltage below which the flywheel stops discharging.
Max Voltage, the line voltage above which the flywheel stops charging.
Coast Band, a preset energy band, which is used in three ways.

Voltage Filter, a set time in seconds over which the Mean Voltage is determined by averaging the line voltage over that time in the past.
Idle Energy, a preset energy, which represents the natural state of the flywheel. It is the state toward which the flywheel gravitates or recovers.

The algorithm used to simulate the flywheel operation in the TOM is now described.

For each snapshot in the ENS or TMS run.

All of the parameters described above are input.

The storage stations are initially Storage Nodes whose fixed power discharge (Power) is 0. Begin.

For each Storage Node:

Point A.
Solve the network. Obtain the Line Voltage at Storage Nodes.
Comment: Initialize variables
Set Vo = Vt the Test Line Voltage of previous snapshot
Let V = Line Voltage
Let Vt = (V + Vo) / 2, the new Test Line Voltage
LetVm = Mean Voltage
Let Ts = Time between snapshots in seconds.
Let Th = Time between snapshots in hours, Th = Ts/3600
Comment: Max or minimum voltages not exceeded
If Vt > Max Voltage or Vt < Min Voltage set Power=0 then GoTo C.
Comment: Max energy not exceeded test
If Stored Energy > (Max Energy - Coast Band) set Power = 0 then GoTo C.
Comment: Begin with charge region.
Comment: Set voltages, powers and efficiency
Let Vf = Volt Ofst Min Pwr Chg
Let Vg = Volt Ofst Max Pwr Chg
Let Pemax = - Max Pwr Chg
Let Pemin = - Min Pwr Chg
Let Perc = - Rec Pwr Chg
Let Pdrec = Rec Pwr DChg
If Vt  >= (Vm + Vg) set Power = Pcmax then GoTo B.
If Vt  > (Vm + Vf) set Power  = SingleInterpolation(Vm+Vg, Pemax,Vm+Vf, Pemin,Vt) then GoTo B.
Comment: Enter the charge recovery region
If Vt  > Vm then
Let E = Stored Energy
Let EI = Idle Energy
If E >= EI set Power = Pdrec then GoTo B.
If E <= EI set Power = Perc then GoTo B.
Comment: Minimum energy limit not exceeded
If Stored Energy < (Min Energy + Coast Band) set Power = 0 then GoTo C.
Comment: Enter discharge region
Comment: Set voltages, powers and efficiency
Let Vc = Volt Ofst Min Pwr DChg
Let Vb = Volt Ofst Max Pwr DChg
Let Pdmax = Max Pwr DChg
Let Pdmin = Min Pwr DChg
If Vt  <= (Vm - Vb) set Power = Pcmax then GoTo B.
If Vt  < (Vm - Vc) set Power  = SingleInterpolation(Vm-Vb,Pdmax,Vm-Vc,Pdmin,V) then GoTo B.
Comment: Enter the discharge recovery region
If Vt  < Vm then
Let E = Stored Energy
Let EI = Idle Energy
If E >= EI set Power = Pdrec then GoTo B.
If E <= EI set Power = Perc then GoTo B.
Comment: Region neither charge nor discharge
If Vt  = Vm set Power = 0 then GoTo C.

Point B
Comment: Assure that maximum or minimum stored energy is not exceeded
Let EFC = Eff Chg
Let EFD = Eff DChg
Set Decay Energy = Decay Rate * Stored Energy * Th
Comment: For charging and discharging , respectively
If Power < 0 set Energy Increment = Power * EFC * Th
If Power >= 0 set Energy Increment = Power * Th / EFD
Comment: Maximum energy exceeded
If (Stored Energy – Decay Energy – Energy Increment) > Max Energy then
If Power > 0 set Power = (Max Energy - Decay Energy – Energy Increment) * EFD/Th
If Power < 0 set Power = (Max Energy - Decay Energy – Energy Increment) / EFC/Th
Comment: Minimum energy exceeded
If (Stored Energy – Decay Energy – Energy Increment) < Min Energy then
If Power > 0 set Power = (Min Energy - Decay Energy – Energy Increment) * EFD/Th
If Power < 0 set Power = (Min Energy - Decay Energy – Energy Increment) / EFC/Th
Comment: End Assurance

Point C.
Resolve the network. Obtain the Line Voltage at Storage Nodes.
Comment: Initialize variables
Let V = Storage Voltage
Let Vm = Mean Voltage
Let Ts = Time between snapshots in seconds.
Let Th = Time between snapshots in hours; Th = Ts/3600
Let EFC = Eff Chg
Let EFD = Eff DChg
Comment: Recompute the mean voltage
Set Mean Voltage = [Vm * (Voltage Filter – Ts) + V * Ts] / Voltage Filter
Let Th = Time between snapshots in hours; Th = Ts/3600
Set Decay Energy = Decay Rate * Stored Energy * Th
Set Stored Energy = Stored Energy – Decay Energy
Comment: For charging and discharging, respectively
If Power < 0 set Stored Energy = Stored Energy – Power * EFC * Th
If Power > 0 set Stored Energy = Stored Energy – Power * Th / EFD
If Power < 0 set Power Loss = - Power * EFC
If Power > 0 set Power Loss = Power * (1 – EFD) / EFD
Comment: Save various power components for later integration
Let t = time at which present snapshot was taken
Set Storage Power (t) = Power
Set Storage Energy (t) = Stored Energy
Set Storage Power Loss (t) = Power Loss
Set Storage Decay Energy Loss (t) = Decay Energy
Set Storage Mean Voltage (t) = Vm
Set Storage Line Voltage (t) = V
GoTo A. until all snapshots are completed then GoTo C.

Point D.
Comment: Integration and Summation. These results appear in summary output.
Set INITIAL ENERGY IN STORAGE = Init Energy
Set FINAL ENERGY IN STORAGE = Stored Energy
Set GROSS ENERGY FROM STORAGE = Init Energy - Stored Energy
Set STORAGE DECAY LOSSES = Σ Storage Decay Energy Loss (t)
Set STORAGE IN AND OUT LOSSES = Σ Storage Power Loss (t) * Th
Set NET ENERGY FROM STORAGE = GROSS ENERGY FROM STORAGE - STORAGE DECAY LOSSES - STORAGE IN AND OUT LOSSES
Set ENERGY BALANCE FOR STORAGE = INITIAL ENERGY IN STORAGE – FINAL ENERGY IN STORAGE - STORAGE DECAY LOSSES - STORAGE IN AND OUT LOSSES - NET ENERGY FROM STORAGE
End

Definition: SingleInterpolation (x2,y2,x1,y1,x) = [(y2-y1)/(x2-x1)]*x  + (x2*y1-x1*y2)/(x2-x1)
9.16 TRACK LAYOUT

9.16.1 Introduction

The **Track Layout** is a map, which shows the geography of the tracks in relation to distance from a fixed point on the terrain and the basic elements of the signaling systems including blocks, switches and crossovers. The layout is in a two dimensional space, the x-direction representing the distances from a fixed point and the y-direction representing the track numbers of main and branch line tracks.

Construction of the track layout requires that certain rules be followed. These rules, together with the terms used for **TMS** purposes are described in the next section.

9.16.2 Track Objects

9.16.2.1 Basic Elements

The layout consists of track segments and nodes. A track segment is a section of track between two nodes. A track segment can be either a main or a non-main or connecting track segment. Main track segments can lie on either main line tracks or branch line tracks, while non-main track segments provide the connections between main line and/or branch line tracks.

Track segments have the following properties:
- **Name** – Limited to four alphanumeric characters
- **Begin Node Name** – The node name of one of the end nodes.
- **End Node Name** – The node name of the other end node.
- **Track Number** – The number of the track. Main tracks have numbers from 1-49, while non-main tracks have numbers from 50-99.
- **Grade** – The average grade between the end nodes on the designated track number.
- **Curve** – The average curve between the end nodes on the designated track number.
- **Speed Codes** – A set of speed commands for the track segment beginning with the least restrictive through the most restrictive.

Nodes have the following properties:
- **Name** – Limited to four alphanumeric characters.
- **Position** – The position along the right of way measured from a fixed position. Increasing position in the track layout of Figure 9-68.

There are several different types of track segments.
- **Block** – The track segment with no other type designation.
- **Switch Approach** – The track segment containing a switch node such that an approaching train can access the switch turnout track segment.
- **Switch Thru** - The track segment containing a switch node such that an approaching train cannot access the switch turnout track segment.
- **Switch Turnout** - The track segment containing a switch node, which is neither a switch approach nor switch thru track segment.
- **Crossover** – One of four track segments, which contains a crossover node.
- **Transition** – A track segment on a non-main track connecting to a track segment on a main track. The track segment on the main track must be the first or last track segment for the section of main track.

There are several different types of nodes.
Track End – A node common to only one track segment. This node appears at the beginning and end of sections of main tracks. Transition nodes also appear at the beginning and end of sections of main tracks.

Transition – A node common to only two track segments, one of which is a main track and the other is a non-main track. These nodes also appear at the beginning and end of sections of main tracks but provide a connection to non-main tracks.

Block End – A node common to only two track segments, which has no other designation of type.

Switch - A node common to only three track segments.

Crossover – A node common to only four track segments.

A typical layout for a ten main track rail system is shown in the illustration.

![Figure 9-68 The Track Layout](image-url)
9.16.2.2 Switches

A switch is an object, which contains three track segments and four nodes. There are three types of switches: single turnout, double turnout and transition.

Figure 9-69 Illustration of Switch Types
A single turnout switch is a switch whose approach and thru track segments are main track segments and whose turnout segment is a non-main track segment. A single turnout switch has the following properties:
The common node is called the switch node.
The three non-common nodes are block nodes.
Two track segments, switch approach and switch thru are main track segments.
The switch turnout track segment is a non-main track segment.

A double turnout switch is a switch whose approach is a main track segment and whose two turnouts both are non-main track segments. A double turnout switch has the following properties:
Consists of three track segments and four nodes.
The common node is called the switch node.
The three non-common nodes are block nodes.
The switch approach track segment is a main track segment.
The switch turnout track segments are non-main track segments.

The double turnout switch has no thru track segment.

A transition switch is a switch whose approach and thru track segments are non-main track segments and whose turnout is a main track segment. A transition switch has the following properties:
Consists of three track segments and four nodes.
The common node is called the switch node.
The three non-common nodes are block nodes.
The switch approach and thru track segments are non-main track segments.
The switch turnout track segment is a main track segment.

9.16.2.3 Crossovers
A crossover is an object which contains four track segments and five nodes.

![Crossover Diagram]

Figure 9-70 Crossover
The crossover has the following properties:
Consists of four track segments and five nodes.
The common node is called the crossover node.
The four non-common nodes are block nodes.
There are two main track segments, which must have the same track number.
There are two non-main track segments, which must have the same track number.
### 9.16.2.4 Double Crossovers

The double crossover is a crossover, which consists of four switches and one crossover node. The switch turnout track segments are the four track segments of the crossover.

![Double Crossover Diagram](image)

**Figure 9-71 Double Crossover**

The double crossover has the following properties:
- Consists of four switch nodes, one crossover node and eight block nodes.
- Consists of four switch turnout track segments, four switch approach track segments and four switch thru track segments and two block track segments.
- The switch turnout track segments are the four crossover track segments.
- All switches are single turnout.
9.16.2.5 Transitions
A transition is the connection of a main track segment to a non-main track segment at a terminal point of a section of main track.

![Transition Diagram]

**Figure 9-72 Transition**

The transition has the following properties:
- Consists of two nodes and one track segment.
- The transition track segment is a non-main track segment, which is connected to a switch turnout or crossover track segment at one end and a main track segment at the other end.
- The transition track segment must have the same track number as the switch turnout or crossover track segment.
- The transition node is the terminus of the main track.

9.16.2.6 Main Track Connections
Main track connections may be made in several ways.
- Double Crossover between adjacent main tracks. (Previously discussed)
- Direct Connection between adjacent main tracks.
- Direct Connection between non-adjacent main tracks.

These main track connections are described by referring to Figure 9-68.

**Direct Connection between adjacent main tracks**

The direct connection between adjacent main tracks consists of two switches on the adjacent main tracks. The turnout track segments of these switches share a common node.

**Direct Connection between non-adjacent main tracks**

The direct connection between non-adjacent main tracks can be made using two switches and either crossovers and/or over or under tracks. The over or under tracks can utilize bridges or underpasses to cross the main track, without using a physical crossover. Simple illustrations of each method are provided in Figure 9-68.
9.16.3 Interlocking
Interlocking is the linking of events such that causing one event will result in other events occurring.

9.16.3.1 Switch – Single Turnout
A single turnout switch is interlocked between its thru and turnout positions. This is illustrated in the following figure.

![Figure 9-73 Illustration of Single Sided Switch Interlocking](image)

The switch can be in only two positions: thru and turnout. The normal position is the thru position.

9.16.3.2 Switch – Double Turnout
The interlocking of the double turnout switch is more complicated than that of a single turnout switch. The interlocking is explained with the help of the following illustration.
Figure 9-74 Illustration of Double Turnout Switch Interlocking

The switch point of the double turnout switch is on Track 2. The two blocked positions are obtained by changing the position of the double turnout switch on Track 2. This action prevents trains from entering or leaving Track 2 from Tracks 1 and 3. The thru positions are also shown in the figure. Throwing the switch on Track 1(3) allows trains to move between Tracks 1(3) and Track 2, but prevents train movement between Track 3(1) and Track 2. The normal position is one of the blocked positions.

9.16.3.3 Switch – Transition

The interlocking of the transition switch is shown in the following figure.
The transition switch has two positions: thru and turnout. These positions are seen in the figure. The normal position is the thru position.

**9.16.3.4 Crossover**

Crossover interlocking is shown with the help of the following figure.
There are two positions: thru and turnout. The thru position blocks the non-main track, while the turnout position blocks the main track. The normal position is the thru position.

9.16.3.5 Double Crossover
The interlocking of the double crossover is explained using the following diagram.
Double Crossover Interlocking

Thru Position

Turnout Positions

Figure 9-77 Illustration of Double Crossover Interlocking

Double crossover interlocking has two types of positions: thru and turnout. The thru position allows trains to pass freely on the main tracks, while the turnout positions allow the train to crossover from one track to the other using the non-main track. Choosing one turnout position automatically blocks the second turnout position until it is changed back to the thru position.

9.16.3.6 Direct Connection – Adjacent Main Tracks
The interlocking of the direct connection between adjacent main tracks can be viewed in the following figure.
The direct connection between adjacent tracks interlocking has two types of positions: thru and turnout. The thru position allows trains to pass freely on the main tracks, while the turnout positions allow the train to crossover from one track to the other using the non-main track. The normal position is the thru position.

9.16.3.7 Direct Connection – Non-Adjacent Main Track with Crossover

The direct connection between non-adjacent main tracks using crossovers is explained with the help of the following figure.
This interlocking has two positions: thru and turnout. The thru position allows trains to move freely along the main tracks (1,2,3). The turnout position allows trains to crossover from track 1 to track 2, blocking the movement of trains on track 2. The normal position is the thru position.

**9.16.3.8 Direct Connection – Non-Adjacent Main Tracks with Over and/or Under Pass Tracks**

The direct connection between non-adjacent main tracks using overpasses or underpasses is explained with the help of the next figure.
Figure 9-80 Illustration of the Direct Connection – Non-Adjacent Tracks With Over And/Or Under Track Interlocking

The non-main track passes either under or over the main tracks 2-6. There are two positions for this interlocking: thru and turnout. In the thru position trains move freely on all tracks (1-7), while in the turnout position, trains on tracks 1 and 7 crossover to tracks 7 and 1, respectively. Trains still run freely on tracks 2-7. The normal position is thru.

9.16.3.9 Other Interlocking

There are many other types of interlocking, which are combinations of the interlocking previously discussed. It is not possible to illustrate all of them. An example is illustrated in the following figure.
Figure 9-81 Example of Compound Interlockings

In this example, track 1 is connected to tracks 8 and 9 via an over and/or under track, a crossover and a transition switch. It has two interlocked positions: thru and turnout. The thru position is normal and allows free train running on tracks 1-7 and 9, while blocking train movement on track 8. The normal turnout position allows trains on track 1 (9) to crossover to track 9 (1), with free train movement on tracks 2–6. Track 8 is still blocked. By manually setting the switch on tracks 8 and 9, a second turnout position is obtained, which allows a crossover from track 1 (8) to track 8 (1), and free movement of trains on tracks 2-6 and track 9.

9.17 PRIMARY AND RETURN CIRCUIT METHODOLOGIES

9.17.1 Introduction

Previously, the Train Operations Model (TOM©) had used the loop method of load flow for calculating powers, voltages and currents in the power distribution of electrified rail systems. This means that the primary circuit is considered in the load flow and the return circuit is handled by lumping its impedance in series with the primary circuit impedance. So, for example when a catenary or third rail impedance is

*Primary Circuit* in this context refers to the substations and the catenary or third rail. In DC systems, the positive circuit is the Primary Circuit and the negative circuit is the Return Circuit.
specified, the impedance of the running rail is added to that of the catenary or third rail and then the load flow is performed.

In many cases of rail systems, especially DC Train systems, the return circuit impedance does not simply add in series to the primary circuit impedance. There is one case in which the answers would be very close; namely, the case where track bonds are very close together compared to the length of the trains, which are running on the system and there are no tie stations (breaker houses) between substations. These tie stations improve the conductivity of the primary circuit as well as provide isolation capability. In this case the bonded rails are considered in parallel. Where this condition is not met, it is not clear how or in what direction the circuit powers, voltages and currents vary from the case, for which the return circuit is accounted.

In order to clarify this question, it has been necessary to include the return circuit for all cases in the TOM. However, this inclusion also gives the TOM the full capability of doing both the primary and return circuits. In adding this capability to the TOM, a graphical method is used to construct both the primary and return circuits, giving the TOM an improved way of building the network, representing these circuits.

This purpose of this Appendix is to develop that capability. This section of the Appendix is constructed along this line.

Section 9.17.2 presents the development of the algorithms, which were added to the model in words and illustrations.

In Section 9.17.3, the procedure used is described working with the TOM. This is a step by step procedure, which illustrates the features of the TOM, which have been added to effect return circuit inclusion.
9.17.2 Algorithm Development

9.17.2.1 General Approach

Because of all of the previous work on the ENS of the TOM, the methodology used to include the return circuit was a modified approach to the load flow. Previously, the return circuit was included by adding the return circuit impedance to the primary circuit impedance at all the fixed lines of the network. As previously mentioned, this approach is the correct one, whenever there are no ties between substations in the primary circuit, there are ties and rail bonds at the same location between substations and there are no rail bonds or a large number of rail bonds between substations. In the first case of no rail bonds in the return circuit, a single running rail or track (two running rails) impedance is added to the primary circuit impedance, while in the latter case of a large number of rail bonds between substations, the multiple track impedance of the return circuit is added to that of the primary circuit.

The figure below illustrates the new approach as compared with the old approach or loop method.

![Figure 9-82 Comparison of Primary Circuit Only vs Primary Plus Return Circuit Methodologies](image)

The **Primary Circuit Only** or **Loop Method** is shown on the left of the figure. This was the old (previous to Version 3.4) TOM method of computation. This method is still valid if a rail bond is at the position of the tie or there are no ties between substations.

The **Primary and Return Circuit Method** is shown on the right of the figure. Version 3.4 and higher of the TOM has the capability of both computational methods.
An explanation of the difference between these two methods is effected by reference to the figure. The difference is illustrated in the very simple DC circuit shown in the figure.

The distance between the substations $S1$ and $S2$ is $D$. A Tie Station (Breaker House), lies between the two substations at a distance of $fD$ from the substation $S1$. A train $T$ is located at a distance $e\cdot f\cdot D$ from the substation $S1$. (Note that the use of the fractions $e$ and $f$ generalize the mathematics of the resistance computations. The quantity $f$ can vary between 0 and 1 and without loss of generality, the quantity $e$ can also vary between 0 and 1.

The resistance of the primary circuit between the two substations is 1 and the resistance of the return circuit between the two substations is $r$. So that, if the true resistance of the primary circuit was $R$, the true resistance of the return circuit would be $r\cdot R$. This again simplifies computation without loss of generality.

The Resistance $R1$ and $R2$ are the effective resistance between the train and substations $S1$ and $S2$, respectively. As seen in the circuit diagrams of the figure, $R1$ and $R2$ are different depending on the method used to analyze the circuits; namely, Primary Circuit Only Method or Primary Plus Return Circuit Method. They are different parallel combinations of the resistances.

Consider now the general case of tie stations in the primary circuit and rail bonds spuriously located in the return circuit.

Figure 9-83 Four Substation – Three Track Network Showing Primary and Return circuits
The figure illustrates a three-track rail system fed by four substations. The primary circuit network is shown along with the return circuit network.

There are ties in the primary circuit, indicated by (T), at the ends of track and between two of the substations.
In the return circuit, there are rail bonds located at the substations as well as many locations between the substations and the end of tracks.

Two trains are shown on the rail system, thus the path of the current is between the primary and return circuits as illustrated.

The present approach to ENS could be of two types, depending on the analysis. A more conservative take would be to consider one running rail or track to be in series with the primary circuit, by adding the impedances in series. A less conservative approach, would be to consider all the running rails in parallel and then add it as a series impedance with the primary circuit.

However, the correct approach is to consider the train imbedded in both the primary and return networks and compute the impedances on the fly, so to speak.

In fact, this approach should also consider the train to consist of several moving nodes, each of which is a current collector on the primary circuit side, and several moving nodes, each of which is a wheel touching the running rails on the return circuit side.

If, for example, each train had ten cars, each with a length of 80 ft. and each car had two current collectors and four axles, there would be 20 nodes on the primary circuit and 40 nodes on the return circuit. Obviously a problem like this would get out of hand very quickly, so a simplifying assumption is made that one train can be represented by a single node in the primary circuit network and one node in the return circuit network. It is also assumed that these nodes are located at the front of the train.

The approach to solving the network will be to estimate the return circuit impedance for each train on the network, and add this impedance to the impedance of the primary circuit on a dynamic basis, as the trains move through the networks.

9.17.2.2 Impedances

Define the Return Circuit Dynamic Impedances as the impedances which move along with the train. The computation of these impedances is explained with the help of the next figure.
Consider the return circuit as a network itself, where the vertical lines are the track bonds and the horizontal lines are the track segments between the bonds. The connecting points as well as the train and substation are considered as nodes.

All substations are assumed to be energized as shown in the above figure. The voltage of the substations is set to 1.0 per unit. The loadflow is then performed by setting all remaining nodes to load nodes with zero power and the moving train to a load node with power \( p \). Once convergence is obtained the current \( I \), is computed and the voltage at the train node, \( V(p) \). The impedance is then calculated using the formula in the figure.

The dynamic impedances for the return circuit are calculated in the same manner for every position and track number in the return circuit. These are then stored in a table, so that whenever a train is moving on the network, the dynamic impedances for the correct return circuit follow the train.

As previously discussed, Return Circuit Dynamic Impedances are incorporated into the primary circuit on a dynamic basis. At each snapshot in the ENS, all impedances will be recalculated by adding the appropriate return circuit impedance to a train line, once the trains have been put into their correct position. The train line consists of two load nodes. One load node is on the track at the position of the train and has zero power. The second load node has power, \( p \), namely the power of the train. The line between these nodes has impedance \( Z \), the dynamic impedance.

As the trains move according to the running plan in the ENS run, the Network file, which now represents the primary circuit, will be modified as shown in the next figure.

![Figure 9-85 Modification of Primary Circuit to Accommodate Return Circuit Impedance](image)

The figure shows the primary network for the four substation, three track rail system.
The train node is positioned between the tie station and substation, which is shown as purple circles. The Return Circuit Dynamic Impedance $Z$ is incorporated by adding a temporary train node (in green) (load node with complex power input or output (taking power or regenerating). The original train node (red) now has zero power and the line between the original train node and the temporary node has the Return Circuit Dynamic Impedance $Z$.

**Figure 9-86 Computation of Final Circuit Impedance With Train Positioning**

Let the impedance of the line between nodes in the primary circuit be expressed with the following symbol:

$$Z_p(T, p_i, p_j)$$

Where $T$ is the track number, $p_i$ is the position of the node $i$ and $p_j$ is the position of the node $j$.

Thus, for track 1, the impedance between $p_1$ and $p_2$ is $Z(1, p_1, p_2)$ and the impedance between $p_2$ and $p_3$ is $Z(1, p_2, p_3)$. These are the impedances of the primary circuit only, at this stage.

When the train is included in the network, the primary impedance between $p1$ and the train and $p2$ and the train is computed as proportional to the distances. So that

$$Z_p(1, p_1, p_t) = \frac{(p_t - p_1) \times Z_p(1, p_1, p_2)}{p_2 - p_1}$$
And
\[ Z_p (1, p_1, p_2) = (p_2 - p_1) * Z_p (1, p_1, p_2) / (p_2 - p_1) \]

These adjustments have made a loop calculation of impedances again possible in the network, with the return circuit impedances dynamically changing to account for the return circuit.

9.17.3 Procedure

The procedure for inclusion of the return circuit in the TOM proceeds in the following steps.

Construct both the Primary and Return Circuit for a rail network using the construction tools of Section 3.2.6 ENS or TMS Primary Or Return Circuit File construction of the FCM.

1. Layout the primary circuit using a graphical procedure and calculate the line (node to node) impedances.
2. Layout the corresponding return circuit using a graphical procedure and calculate the line (node to node) impedances.
3. Estimate the dynamic impedances of the return circuit as a function of right of way position of the train and track number on which the train is running. Using the Impedance Calculator of the FMM, develop the Return Circuit Impedance file. This procedure is explained in Section 4.14 (Impedance Calculator). This step is not necessary if just a single Primary Circuit file is used.
4. Construct the Network file using the Network with Return Circuit Option described in Section 3.2.2.8. If a single Primary Circuit file is used, the Return Circuit Option is not selected.
5. Run the ENS or TMS to complete the load flow. The Current Measurement Output file must be selected as an output choice.
6. Use the Circuit Analyzer of the FMM to obtain the currents in both the Primary and Return Circuit. This procedure is outlined in Section 4.18.
7. Graph the circuit currents as desired to present the results. The graphing procedure is explained in Section 7.7.6.

The next few sections outline the procedure described here, showing only the major, rather than detailed features of the steps. The reference to the more detailed procedures are listed in each section.

9.17.3.1 Construction of the Primary Circuit File

Reference Section 3.2.6

A new file type has been defined for the primary circuit layout. This file has the leader PC-.

The PC- file contains primary circuit layout information and line impedances.

The construction of the Primary Circuit or Return Circuit files are handled using the same screens. Double clicking the PriCct or RtnCct item in the ENS Input list box shown in Figure 3-154, leads to the following screen, which is shown completed.
Figure 9-87 File Construction Module – Primary or Return Circuit Input – Primary Circuit Option Selected – Screen Completed

A click on the Graphic Input command button reveals the graphic approach to constructing the circuit.
Figure 9-88 File Construction Module – Primary Circuit File Input – Primary Circuit by Graphics – Circuit Layout Graph Space – Circuit Layout Completed

The file is then created and the final screen after creation is next.
Figure 9-89 FCM Primary Circuit File PC-4.tes Created

The file can now be checked by clicking the Check Circuit command button.

Figure 9-90 Circuit Check Complete on Primary Circuit File PC-4.tes
9.17.3.2 Construction of the Return Circuit File

Reference Section 3.2.6

Two new file types have been defined for the return circuit layout and impedance calculations. These files have the leaders RC- and ZR-.

The RC- file contains return circuit layout information and line impedances. The ZR- file type contains the dynamic impedances of the return circuit.

Three definitions are in order at this point.

The line impedances in the RC- file are of three general types: track line impedance [impedance of a single running rail or two running rails (track) in parallel], track bond line impedance [the impedance of the bond between running rail(s)], or substation connection impedance [the impedance of the connection between the running rail(s) and the return circuit end of substations].

Dynamic impedances are impedances associated with the moving train. These impedances are computed using the Impedance Calculator of the File Manipulation Module (FMM) and are deposited in the ZR-file.

The Return Circuit file is constructed using the same procedure as the Primary Circuit file. The graphics are shown next.
Figure 9-91 Graphics Screen for Return Circuit File RC-4b.tes
9.17.3.3 Construction of the Return Circuit Impedance File

Reference Section 4.14

The next step, after creating a Primary and a Return Circuit file is the creation of the Return Circuit Impedance file, which includes the Return Circuit Dynamic Impedances to be incorporated into a Network.

Computation of these impedances is accomplished using the same load flow methodology used in the ENS or TMS; namely, the Gauss-Seidel method. The algorithm to accomplish this computation is shown in the next figure.

![Figure 9-92 Algorithm to Compute Dynamic Impedance](image)

The algorithm works in unit values. All node voltages are initially set to 1.0. Since the substation voltage is at the infinite bus, all substation voltages will remain at 1.0 throughout the computation. All of the line impedances are set to their circuit values. The power node is set to p and the default setting of p = 0.5.

The steps are then shown in the table.

The screen of the FMM, for which this is accomplished is shown next.
Figure 9-93 Screen of the FMM for Creating the Return Circuit Impedance File ZR-4b.tes From the Return Circuit File RC-4b.tes.
9.17.3.4 Construction of the Network File

Reference Section 3.2.2.8.2.
The Network file N-4b.tes was created from the Return Circuit file RC-4b.tes, the Primary Circuit file PC-4.tes and the Return Circuit Impedance file ZR-4b.tes, all previously created.

The Network screen is shown next.

![Network File Screen](image)

Figure 9-94 Network File Necessary to Create the File N-4b.tes

Click the Generate Network command button to produce the next screen.
Click the Generate Network command button to complete the task. This leads to the screen just shown in the previous figure.
9.17.3.5 Construction of the Current Measurement Output File

Reference Sections
Construction ENS or TMS File of Filenames file. Sections 3.2.1 or 3.3.1
Running the ENS or TMS. Sections 2.2 or 2.3.2.

Running of the ENS or TMS must be set to produce a Current Measurement Output file. An example of a File of Filenames, which will produce the file, upon running the Simulator, is shown in the next screen.

![Figure 9-96 ENS File of Filename Screen Set Up to Produce the Current Measurement Output File AO-4b.tes Upon Running the ENS.](image)
9.17.3.6 Current Analysis Output Files
Reference Section 4.18

The main objective of the Circuit Analysis program of the FMM is to determine electric current flows and RMS currents in either the Primary or Return Circuit. The next screen show the setup.

![Figure 9-97 FMM Circuit Analyzer Set Up to Analyze the Current Flows from the Current Measurement Output File AO-4b.tes](image)

A click of the Create File command button will initiate the analysis and place the result in the output file RCA4b.tes, shown next.
Another view, showing the end of the file is shown next.

Figure 9-99 File View of the Current Analyzer Output File RCA4b.tes (Near End of File) Showing RMS Current Summaries
A similar file can be made for the primary circuit. These output files contain all of the information on the performance of these circuits (both primary and secondary) during the simulation period.

9.17.3.7 Results Presentation in Graphical Form

Reference Section 7.7.6.

Once the Current Analysis Output files are produced, these are used as the basis for plotting line currents as a function of time and summarizes RMS Currents in all of the lines of the Primary and Return Circuits. An example of such a graph is shown next.

Figure 9-100 Example of Heating Line Current in a DC Return Circuit Ready for Graphing

Click the Complete Graph command button to finish the plot.
Figure 9-101 Heating Current vs Time for a DC Return Circuit Lines A2 and B2
9.18 CONVERTER MODEL AND METHODOLOGY

This converter model is used in TOM Version 3.6 and higher. For purposes of illustration, the substations and converters considered in the model are shown in the figure below.

![Substations and Converters Diagram]

Figure 9-102 Substation and Converter Types Considered in the Model.

The substation is a parallel combination of like converter units. Thus if each unit has power rating, \( p \), then the parallel combination has power rating \( np \).

The Rectifier Unit is the simplest. There is no voltage control and current can only be passed in one direction; namely, from the AC side to the DC side.

The Controlled Rectifier Unit has limited voltage control. Like the Rectifier Unit, it can pass current only in one direction but can control the voltage through the unit so as to effectively cause no voltage drop on the DC side of the substation within the limit of the control.

The Rectifier Inverter Unit consists of a rectifier for current passing from the AC to DC side and an inverter for passing current from the DC to AC side. The inverter portion has limited voltage control, in that it can raise the blocking voltage above the open circuit DC voltage.

The Controlled Rectifier Inverter Unit consists of a controlled rectifier for current passing from the AC to DC side and an inverter for passing current from the DC to AC side. The controlled rectifier portion has limited voltage control, in that it can control the voltage through the unit so as to effectively cause no voltage drop on the DC side of the substation within the limit of the control. The inverter has no control, it will pass DC to AC current when the DC voltage exceeds the open circuit voltage.

Each one of these units, has associated with it, up to five additional parameters, one of which is the control voltage, \( v \), which is zero for the rectifier. The other parameters include its power rating, \( R \), its no load losses, \( P_0 \), and its rated load losses, \( P_r \).
The power factor of the unit on the AC side is also an input parameter. For the Rectifier and the Rectifier Inverter Unit, it is kept at its no load value, independent of load so that the reactive power on the AC side, will increase in proportion to the power on the DC side as the load increases.

For the Controlled Rectifier and the Controlled Rectifier Inverter Unit, the power factor, depends on the load through the unit and the phase angle of the controlled rectifier. Thus the reactive power on the AC side will be a larger portion of the real DC power at small loads and keep decreasing until the drop through the substation can no longer be maintained near zero. At this point, it behaves as a rectifier.

The algorithms used are described next.

The new converter model adds four new features to the TOM.

Better estimate of substation losses.
Blocking voltage control of the inverter
Correction of Reactive Power on the AC Side to account for the effects of the converter.
The ability to handle controlled rectifiers.

9.18.1 Estimate of Converter Losses
In the new model, substation losses are expressed as a linear relation, depending on the power load delivered through the converter. The no load and rated load losses are input. The load flow in the ENS determines the power \( P \) through the substation. If it is assumed that \( P_0 \) and \( P_r \) are the no load and rated load losses, then the substation losses given the Power Rating, \( R \), of the substation are

\[
P_0 + (P_r - P_0)(P/R)
\]

This equation is valid independent of substation type (Rectifier, Controlled Rectifier or Inverter).

9.18.2 Rectifier Substation
The rectifier substation has no control capability. If current attempts to flow back toward the AC side, it is blocked by substantially increasing the impedance of the circuit.

9.18.3 Inverter Substation
The inverter substation is actually a rectifier/controlled inverter substation. Current can flow in both directions through the substation. The blocking voltage, called the control voltage for the inverter can increase from open circuit voltage until it reaches the point of no current flow to the AC side.

9.18.4 Controlled Rectifier and Controlled Rectifier/Inverter Model

9.18.4.1 Controlled Rectifier
The controlled rectifier requires special consideration, because the power factor will change as the load through the substation changes. The controlled rectifier will deliver power at open circuit voltage, when the load is less than some designated substation load.

In the case of the controlled rectifier substation, the transformer secondary voltage in the unit voltage is raised by the control voltage \( V_c/N \), so that if the unit voltage is \( V \), then the transformer secondary voltage is:

\[
V(1 + V_c/N)
\]
Control of the substation is effected using the following algorithm, which is essentially, varying the substation impedance as a function of the power through the substation. The algorithm is stated as follows:

Let $Z_0$ be the impedance of the substation, expressed as a percentage of fraction of the substation rated load. This is in effect the voltage drop at rated load in unit value, $V$. In the TOM, $V$ is the open circuit voltage.

Let $Z_b = 0.1 * Z_0$ represent a small base impedance, representing the voltage drop through the controlled rectifier alone and its small impedance, since roughly most of the drop is in the transformers, then the model varies the impedance of the substation as a function of load in the following way:

Let $X = P/R - (V_c/V)$

$$Z = Z_b \quad \text{for} \quad X \leq 1$$

$$Z = Z_b + (X - 1) * [Z_0 * (l - V_c/V) - Z_b] \quad \text{for} \quad 1 < X \leq 2$$

$$Z = Z_0 * (l - V_c/V) \quad \text{for} \quad X > 2.$$  

$V_c/V$ is termed the Control Voltage (CV).

The illustration below displays the scheme:

Figure 9-103 Controlled Rectifier Control Scheme
As the power, \( (P/R) \), through the substation increases, there are three distinct regions. The first region is the base impedance, where the controlled converter firing angle of delay remains constant >0, the second region, where the firing angle varies so that the effective impedance varies from the base impedance to the quantity \( X \) on the x-axis and the third region, where the firing angle is 0.

Thus by varying the impedance, the effective voltage drop through the substation is controlled.

The default voltage control, sets the \( V_c / V = 0 \). This setting maintains the voltage drop through the substation at open circuit voltage on the DC side until the rated load is reached. If it is desired to change the load point at which DC voltage is maintained at open circuit, the quantity, \( V_c / V \) is given by the formula:

\[
V_c / V = [(L/R) - 1]
\]

Where \( L/R \) is the load point.

Since everything is expressed in unit values in the input to the controlled rectifier in the Network screen, if it is desired to set the load point to 130% of rated load, then the control voltage is 0.3. The control voltage must have values which lie between zero and one, but cannot be equal to one.

\[ 0 \leq V_c / V < 1 \]

### 9.18.4.2 Controlled Rectifier/Controlled inverter
The controlled rectifier/controlled inverter substation is just the matching of a controlled converter and controlled inverter in one substation.

### 9.18.5 Reactive Power on the AC Side

#### 9.18.5.1 Rectifier and Inverter

All of the following analysis assumes that the overlap angle is small, which implies a very small commutating reactance.

If \( PF \) is the power factor on the AC side, the reactive power, \( Q \), is given by the following:

\[
Q = P \cdot \tan[\cos^{-1} (PF)]
\]

For 6-pulse substation :

\[
PF = 0.955 \Rightarrow Q = 0.2925 \cdot P
\]

For 12-pulse substation :

\[
PF = 0.989 \Rightarrow Q = 0.1474 \cdot P
\]
9.18.5.2 Controlled Rectifier

The reactive power is given by:

\[ Q = P \cdot \tan(\cos^{-1}(\text{PF})) \]

and the effective voltage drop is \( Z \) (defined by the Expression Above), so that the power factor is:

For a 6-pulse substation:

\[ PF = 0.955 \cdot [1 - (Z_0 - Z) \cdot (1 - V_c/V)] \]

For a 12-pulse substation:

\[ PF = 0.989 \cdot [1 - (Z_0 - Z) \cdot (1 - V_c/V)] \]

All of this analysis assumes that the overlap angle is small, which implies a very small commutating reactance for the converter.
9.19 EXTREMUMIZER

The Extremumizer uses a parabolic estimation of the extremum \([ X(\text{ext}), Y(\text{ext}) ] \) given three points \((X_1, Y_1), (X_2, Y_2)\) and \((X_3, Y_3)\).

The equation is

\[
Y = r \ X^2 + s \ x + t
\]

The extremum will occur where

\[
X = -2r/s
\]

If \( r > 0 \) the extremum is a minimum and if \( r < 0 \), the extremum is a maximum.

The technique used is a 3 x 3 matrix inversion.

A computationally efficient 3x3 matrix inversion is given by

\[
A^{-1} = \begin{bmatrix} a & b & c \\ d & e & f \\ g & h & k \end{bmatrix}^{-1} = \frac{1}{\det(A)} \begin{bmatrix} A & B & C \\ D & E & F \\ G & H & K \end{bmatrix}^T = \frac{1}{\det(A)} \begin{bmatrix} A & D & G \\ B & E & H \\ C & F & K \end{bmatrix}
\]

where the determinant of \( A \) can be computed by applying the rule of Sarrus as follows:

\[
\det(A) = a(eh - fd) + b(fg - kd) + c(dh - eg).
\]

If the determinant is non-zero, the matrix is invertible, with the elements of the above matrix on the right side given by

\[
\begin{align*}
A &= (ek - fh) \\
B &= (fg - dk) \\
C &= (dh - eg)
\end{align*} \quad \begin{align*}
D &= (ch - bk) \\
E &= (ak - cg) \\
F &= (gh - ad)
\end{align*} \quad \begin{align*}
G &= (hf - ce) \\
H &= (cd - af) \\
K &= (ae - bd)
\end{align*}
\]

In the case under consideration

\[
\begin{align*}
a &= X_1 \times X_1 \\
b &= X_1 \\
c &= 1 \\
d &= X_2 \times X_2 \\
e &= X_2 \\
f &= 1
\end{align*}
\]
Since

\[
\begin{align*}
Y_1 & = r X_1^2 + s X_1 + t \\
Y_2 & = r X_2^2 + s X_2 + t \\
Y_3 & = r X_3^2 + s X_3 + t
\end{align*}
\]

Solving for the variables \(r, s, t\) is just

\[
\begin{align*}
r & = A Y_1 + D Y_2 + G Y_3 \\
s & = B Y_1 + E Y_2 + H Y_3 \\
t & = C Y_1 + F Y_2 + K Y_3
\end{align*}
\]

\[
\begin{align*}
X (\text{ext}) & = -2 r/s \\
Y (\text{ext}) & = r X^2 + s X + t
\end{align*}
\]

The Extremizer is only useful where maxima and minima approaches are parabolic.

### 9.20 COMPLEX NUMBER CALCULATOR

Version 3.4 or higher has a built in Complex Number Calculator.

#### 9.20.1 Introduction

The purpose of the Complex Number Calculator is to provide a quick method to operate with complex numbers. Operations include arithmetic, computation of general functions and trigonometric and hyperbolic functions.

Accuracy of computation is provided to 14 decimal places. Number smaller than 10-15 are considered zero. Numbers larger than 14 digits, whether positive or negative are rounded off to 14 digits.

The calculator uses the standard formulas and definitions for things associated with complex numbers.

Section 2 shows the layout of the calculator and quickly describes the terminoloy used in these topics.

Section 3 presents a discussion of the Arithmetic Operations and presents the formulae used for the operations.

Section 4 details the General Functions, which can be computed by the calculator as well as their formulae.
Section 5 describes the Trigonometric Functions, which can be evaluated by the calculator as well as the formulae for achieving the results.

Section 6 highlights the Hyperbolic Functions, which are calculated using this tool and their formulae.

Section 7 describes the Manipulation Keys, which are useful to provide sequences of complex number operations.

Section 8 points out the Erasure Keys and finally, Section 9 highlights some miscellaneous key, useful to the user.

9.20.2 Screen Layout

The screen layout is shown next.

Figure 9-104 Complex Number Calculator Layout

Each of the areas of the screen are described in remainder of this section, with reference to this layout.

9.20.2.1 Complex Number Area

The Complex Number area on the screen is discussed in two parts: Text Boxes and Command Buttons or Keys.

9.20.2.1.1 Text Boxes

There are a total of twelve text boxes in the area, which are divided into three rows and four columns. The columns are divided according to the Real, Imaginary, Magnitude and Argument of the complex numbers in the rows, which are referred as U, V and Result.
The relations are next described.

If $Z$ is a complex number, the Cartesian expression of the number is

$$Z = x + j \ y$$

Where $j = (-1)^{1/2}$.

The Polar expression of $Z$, is

$$Z = |Z| e^{i \ \varphi}$$

Where $|Z| = (x^2 + y^2)^{1/2}$

And $\varphi = \text{arg}(Z)$

The function, $\text{arg}(Z)$, is defined as follows:

$$\varphi = \text{arg}(z) = \begin{cases} \arctan \left( \frac{y}{x} \right) & \text{if } x > 0 \\ \arctan \left( \frac{y}{x} \right) + \pi & \text{if } x < 0 \text{ and } y \geq 0 \\ \arctan \left( \frac{y}{x} \right) - \pi & \text{if } x < 0 \text{ and } y < 0 \\ \frac{\pi}{2} & \text{if } x = 0 \text{ and } y > 0 \\ \frac{-\pi}{2} & \text{if } x = 0 \text{ and } y < 0 \\ \text{indeterminate} & \text{if } x = 0 \text{ and } y = 0. \end{cases}$$

In terms of this notation, the real or \textit{x} is in the first column, the imaginary or \textit{y} is in the second column, the magnitude or $|Z|$ is in the third column and the argument or $\text{arg}(Z)$ is in the fourth column.

The complex numbers $U$ and $V$ are both used for addition, subtraction, multiplication, division and exponentiation, while only $U$ is used for all other operations. The result of all operations is shown in Result.

\textbf{9.20.2.1.2 Command Buttons or Keys}

There are two command buttons or keys in the \textbf{Complex Number} area of the screen. These are \texttt{e} and \texttt{Pi}.

A click on the \texttt{e} command button, places the base of the natural logarithm in the \textbf{Real} text box of the complex number \texttt{U} or \texttt{V}, depending on the key clicked. The value is:
A click on the Pi command button, places π in the Real text box of the complex number U or V, depending on the key clicked. The value is:

3.141592653589793

All of the remaining command buttons on the screen will be discussed in their appropriate categories and are discussed in the following sections.

9.20.2.2 Arithmetic Area
The arithmetic grouping involves both complex numbers U and V, and includes:
Addition U + V
Subtraction U – V
Multiplication U * V
Division U / V
Exponentiation U ^ V

9.20.2.3 General Functions Area
The general functions grouping involves only the complex number U, and includes:
Conjugate Conjugate U
Reciprocal 1 / U
Square U ^ 2
Square Root U ^ ½
Natural Logarithm Ln U
Natural Exponential e ^ U

9.20.2.4 Trigonometric Functions Area
The trigonometric functions grouping involves only the complex number U, and includes:
Sine Sin U
Cosine Cos U
Tangent Tan U
Inverse Sine or Arc Sine ASin U
Inverse Cosine or Arc Cosine ACos U
Inverse Tangent or Arc Tangent ATan U
9.20.2.5 Hyperbolic Functions Area
The hyperbolic functions grouping involves only the complex number U, and includes:
- Hyperbolic Sine: \( \text{Sinh} \ U \)
- Hyperbolic Cosine: \( \text{Cosh} \ U \)
- Hyperbolic Tangent: \( \text{Tanh} \ U \)
- Inverse Hyperbolic Sine or Hyperbolic Arc Sine: \( \text{ASinh} \ U \)
- Inverse Hyperbolic Cosine or Hyperbolic Arc Cosine: \( \text{ACosh} \ U \)
- Inverse Hyperbolic Tangent or Hyperbolic Arc Tangent: \( \text{ATan} \ U \)

9.20.2.6 Manipulation Keys Area
There are several manipulation command buttons or keys. These are:
- Copy Result to U
- Copy Result to V
- Store Result
- Clear Storage
- Recover to U
- Recover to V

9.20.2.7 Erasure Keys Area
Erasure command buttons or keys erase the several or all of the text boxes:
- Clear Result
- Clear All
- Reset
- Exit

9.20.2.8 Miscellaneous Keys
The miscellaneous command buttons or keys
- Real < --- > Imaginary
- Convert
- Toggle Trigonometric to Hyperbolic Functions
- Toggle Polar to Cartesian Entry
9.20.3 Arithmetic

The following representation will be used in describing operation formulae:

Given the complex numbers \( U \), \( V \) and \( R \), for the Result:

\[
U = U_r + j U_i \\
V = V_r + j V_i \\
R = R_r + j R_i
\]

9.20.3.1 Addition

The addition operation uses the following formulae:

\[
R = U + V \\
R_r = U_r + V_r \\
R_i = U_i + V_i
\]

9.20.3.2 Subtraction

\[
R = U - V \\
R_r = U_r - V_r \\
R_i = U_i - V_i
\]

9.20.3.3 Multiplication

\[
R = U \times V \\
R_r = U_r \times V_r - U_i \times V_i \\
R_i = U_r \times V_i + U_i \times V_r
\]
9.20.3.4 Division

\[ R = \frac{U}{V} \]

\[ R_r = \frac{U_r \cdot V_r + U_i \cdot V_i}{|V|^2} \]

\[ R_i = \frac{U_i \cdot V_r - U_r \cdot V_i}{|V|^2} \]

\[ |V| = \sqrt{V_r \cdot V_r + V_i \cdot V_i} \]

9.20.3.5 Exponentiation

\[ R = U^V \]

\[ R = e^{V \cdot \ln U} \]

Evaluation of \( \ln U \) is handled in Section 9.20.4.5. Evaluation of \( e^Z \), where in this case \( Z = V \cdot \ln U \) is discussed in Section 9.20.4.6.

9.20.4 General Functions

General functions include the conjugate, reciprocal, square, square root, natural logarithm and natural exponential.

9.20.4.1 Conjugate

The conjugate of the complex number

\[ R = U_r + j \cdot U_i \]

Is

\[ R = \text{Conj} \ (U) = U_r - j \cdot U_i \]

\[ R_r = U_r \]

\[ R_i = U_i \]
9.20.4.2 Reciprocal
The reciprocal of the complex number $U$ is:

$$ R = \frac{1}{U} = \frac{U_r}{|U|} - j \frac{U_i}{|U|} $$

$$ R_r = \frac{U_r}{|U|} \quad \quad R_i = -\frac{U_i}{|U|} $$

9.20.4.3 Square
The square of the complex number $U$ is:

$$ R = U^2 = U_r^2 - U_i^2 + j 2 U_r U_i $$

$$ R_r = U_r^2 - U_i^2 \quad \quad R_i = 2 U_r U_i $$

9.20.4.4 Square Root
The square root of the complex number $U$ is:

$$ U^{1/2} = e^{\text{Ln} U / 2} $$

Evaluation of $\text{Ln} U$ is handled in Section 9.20.4.5. Evaluation of $e^Z$, where in this case $Z = \text{Ln} U / 2$ is discussed in Section 9.20.4.6.

9.20.4.5 Natural Logarithm
The natural logarithm of the complex number $U$ is:

$$ R = \text{Ln} U = \text{Ln} |U| + j \text{Arg} (U) $$

$$ R_r = \text{Ln} |U| \quad \quad R_i = \text{Arg} (U) $$

The real function $\text{Arg} (Z)$ is discussed in Section 9.20.2.1.1.
9.20.4.6 Natural Exponential

The natural logarithm of the complex number \( U \) is:

\[
R = e^U = e^{Ur} \cos U_i + j e^{Ur} \sin U_i
\]

\[
R_r = e^{Ur} \cos U_i
\]

\[
R_i = e^{Ur} \sin U_i
\]

9.20.5 Trigonometric Functions

The formulae for trigonometric functions involves the hyperbolic functions, which are defined here.

\[
\sinh x = (e^x - e^{-x}) / 2
\]

\[
\cosh x = (e^x + e^{-x}) / 2
\]

\[
\tanh x = \sinh x / \cosh x
\]

These definitions are used in the formulae, which follow.

9.20.5.1 Sine

The sine of the complex number \( U \) is:

\[
R = \sin U = \sin Ur \cosh U_i + j \cos Ur \sinh U_i
\]

\[
R_r = \sin Ur \cosh U_i
\]

\[
R_i = \cos Ur \sinh U_i
\]

9.20.5.2 Cosine

The cosine of the complex number \( U \) is:

\[
R = \cos U = \cos Ur \cosh U_i - j \sin Ur \sinh U_i
\]

\[
R_r = \cos Ur \cosh U_i
\]

\[
R_i = - \sin Ur \sinh U_i
\]
9.20.5.3  Tangent

The tangent of the complex number \( U \) is:

\[
R = \tan U = \frac{\sin U}{\cos U}
\]

Calculation of the \( \sin U \) is in Section 9.20.5.1 and that of the \( \cos U \) is in Section 9.20.5.2.

9.20.5.4  Inverse Sine

The inverse sine or arc sine of the complex number \( U \) is:

\[
\text{ASin } U = - j \ln \left( j U + \left( 1 - U^2 \right)^{1/2} \right)
\]

Where the evaluation of the \( \ln (Z) \) is discussed in Section 9.20.4.5 and \( Z^{1/2} \) and \( Z^2 \) are discussed in Sections 9.20.4.3 and 9.20.4.4, respectively.

9.20.5.5  Inverse Cosine

The inverse cosine or arc cosine of the complex number \( U \) is:

\[
\text{ACos } U = - j \ln \left( U + \left( U^2 - 1 \right)^{1/2} \right)
\]

Where the evaluation of the \( \ln (Z) \) is discussed in Section 9.20.4.5 and \( Z^{1/2} \) and \( Z^2 \) are discussed in Sections 9.20.4.3 and 9.20.4.4, respectively.

9.20.5.6  Inverse Tangent

The inverse tangent or arc tangent of the complex number \( U \) is:

\[
\text{ATan } U = \frac{j}{2} * \ln \left( \frac{1 - j U}{1 + j U} \right)
\]

Where the evaluation of the \( \ln (Z) \) is discussed in Section 9.20.4.5.
9.20.6 Hyperbolic Functions

The hyperbolic functions are discussed next. The formulae for the hyperbolic functions are given here.

\[
\sinh x = \frac{e^x - e^{-x}}{2} \\
\cosh x = \frac{e^x + e^{-x}}{2} \\
\tanh x = \frac{\sinh x}{\cosh x}
\]

9.20.6.1 Hyperbolic Sine

The hyperbolic sine of the complex number \( U \) is:

\[
\sinh U = \sinh U_r \cdot \cos U_i + j \cosh U_r \cdot \sin U_i
\]

9.20.6.2 Hyperbolic Cosine

The hyperbolic cosine of the complex number \( U \) is:

\[
\cosh U = \cosh U_r \cdot \cos U_i + j \sinh U_r \cdot \sin U_i
\]

9.20.6.3 Hyperbolic Tangent

The hyperbolic tangent of the complex number \( U \) is:

\[
\tanh U = \frac{\sinh U}{\cosh U}
\]

9.20.6.4 Inverse Hyperbolic Sine

The inverse hyperbolic sine or hyperbolic arc sine of the complex number \( U \) is:

\[
\text{ASinh } U = \ln \left[ U + \sqrt{1 + U^2} \right]
\]

Where the evaluation of the \( \ln ( Z ) \) is discussed in Section 9.20.4.5 and \( Z^{1/2} \) and \( Z^2 \) are discussed in Sections 9.20.4.3 and 9.20.4.4, respectively.
9.20.5 Inverse Hyperbolic Cosine
The inverse hyperbolic cosine or hyperbolic arc cosine of the complex number \( U \) is:

\[
\text{ACosh } U = \ln \left[ U + \left( U^2 - 1 \right)^{1/2} \right]
\]

Where the evaluation of the \( \ln ( Z ) \) is discussed in Section 9.20.4.5 and \( Z^{1/2} \) and \( Z^2 \) are discussed in Sections 9.20.4.3 and 9.20.4.4, respectively.

9.20.6 Inverse Hyperbolic Tangent
The inverse hyperbolic tangent or hyperbolic arc tangent of the complex number \( U \) is:

\[
\text{ATanh } U = \frac{1}{2} \ln \left[ \frac{1 + U}{1 - U} \right]
\]

Where the evaluation of the \( \ln ( Z ) \) is discussed in Section 9.20.4.5.

9.20.7 Manipulation Keys
The following command buttons or keys are used to manipulate results so that it may be part on an ongoing computation process.

9.20.7.1 Copy to U or V
The \text{Copy to U} and \text{Copy to V} command buttons copy the complex number \text{Result} into the complex number \( U \) and \( V \), respectively.

9.20.7.2 Store Result
The \text{Store Result} command button causes the complex number \text{Result} to be stored in the complex number storage register for later recovery.

9.20.7.3 Clear Storage
The \text{Clear Storage} command button erases the complex number storage register.

9.20.7.4 Recover to U or V
The \text{Recover to U} or \text{Recover to V} command buttons places the content of the complex number storage register in the complex number \( U \) or \( V \), respectively.
9.20.8 Erasure Keys
The erasure command buttons or keys erase contents of the text boxes holding the components of the complex numbers.

9.20.8.1 Clear Result
The Clear Result command button initializes the Result complex number to zero or null.

9.20.8.2 Clear All
The Clear All command button erases or initializes all text boxes for the complex numbers U, V and Result. The complex number storage register is not affected.

9.20.8.3 Reset
The Reset command button initializes the calculator. All text boxes and storage registers are initialized.

9.20.8.4 Close
The Close command button closes the calculator. To open it, click on either its icon or a command button which opens it.

9.20.9 Miscellaneous Keys
The functions of the miscellaneous command buttons or keys are discussed next.

9.20.9.1 Real < --- > Imaginary
The Real < --- > Imaginary command button interchanges the Real and Imaginary parts of the complex number. The Argument is adjusted accordingly and the Magnitude does not change.

9.20.9.2 Convert
The Convert Rad to Deg and Convert Deg to Rad command button converts and sets the Argument of the complex number to be read or interpreted as radians or degrees. The default position is radians.

9.20.9.3 Toggle Trigonometric to Hyperbolic Function
The command buttons Hyperbolic Functions and Trigonometric Functions exposes the Hyperbolic and Trigonometric function command buttons, respectively. They toggle.

9.21 EXCEL FORMATTING FOR REPORTS
Certain features have been incorporated into the output of some TOM procedures to allow ease of transfer to EXCEL Spreadsheets, for ease of constructing tables in reports.
Some of these actions are automatic, in the sense that the information is pasted on the Clipboard, when the process to compute the information is complete. In other cases, the user is asked to execute a command button, which effects the pasting of the information on the Clipboard.

The topics covered in this section are:

**User Actuated Processes**
- TPS Summary Output (TSS*.*)[Section 9.21.1.1]
- ENS Summary Output (SUMSENS*,.*)[Section 9.21.1.2]
- TMS Summary Output (SUMSTMS*,.*)[Section 9.21.1.3]
- Return or Primary Circuit Current Analysis Output (RCA*,.*) or (PCA*,.*)[Section 9.21.1.4]
- RVM Summary or Detailed Output (RVM*,. or RVD*,.)*[Section

**Automatic Processes**
- Minimum Train Voltage[Section 9.21.2.2]
- Maximum Train Current[Section 9.21.2.3]
- Substation Loading[Section 9.21.2.4]
- Current Measurement[Section 9.21.2.5]
- Circuit Line Currents
  - Return Circuit Line Currents[Section 9.21.2.6.1]
  - Primary Circuit Line Currents[Section 9.21.2.6.2]
- Average Voltage Determination[Section 9.21.2.7]

9.21.1 User Actuated Processes

The **User Actuated Processes** begin with the importation certain types of summary output files into the **Train Operations Model – File Viewer** screen.

Only the summary output files of the TPS, ENS, TMS and Circuit Current Analysis Output files, which are output from the FMM – Current Analyzer fall into this category. This summary output may be accessed either from the database or by clicking the Yes command button to review the summary output file after one of these simulators or processes has run. The effect of clicking the Yes command button imports the file into the **Train Operations Model – File Viewer** screen.

In the case of access via the database, the pertinent files are TSS*,.*, SUMSENS*,. and SUMSTMS*,.* as the summary output files from the TPS, ENS, TMS and RCA*,.* and PCA*,.* as the outputs from the FMM – Current Analyzer. In the database, clicking the View command button imports the file into the **Train Operations Model – File Viewer** screen.

When any of these types of files are imported into the screen, the result is shown next.
Click on the **EXCEL Ready** command button to paste an EXCEL paste capable format of information on the Clipboard.
Figure 9-106 Train Operations Model – File Viewer – TPS Summary Output Table Information on Clipboard

The summary line in the file can be placed in a table in EXCEL, which has the proper format. This table would be set up to accept the paste without further actions. Tab characters are used between data fields on the Clipboard contents.

These EXCEL tables are required to have a special format, which is designed to accept the paste from the Clipboard. These formats are now illustrated for the various User Actuated Process files.
9.21.1.1 TPS Summary Output (TSS*.*)

The Clipboard contains the Run Summary Information. To illustrate, the EXCEL table is shown next.

<table>
<thead>
<tr>
<th>File of Filenames</th>
<th>Caption</th>
<th>Distance (mi)</th>
<th>Time (min)</th>
<th>Speed (mph)</th>
<th>Energy (kWh)</th>
<th>Energy (kWh/kpcm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPSdc+.TES</td>
<td>DC Test Line (-dir) AC/DC EB Trk 2 Regen</td>
<td>3.00</td>
<td>4.56</td>
<td>39.49</td>
<td>49.15</td>
<td>2.73</td>
</tr>
<tr>
<td>TPSdc+.TES</td>
<td>DC Test Line (-dir) AC/DC EB Trk 1 Regen</td>
<td>3.00</td>
<td>4.56</td>
<td>39.31</td>
<td>68.82</td>
<td>3.18</td>
</tr>
<tr>
<td>TPSdc+.TES</td>
<td>DC Test Line (-dir) Cam/Control EB Trk 2 No Regen</td>
<td>3.00</td>
<td>4.56</td>
<td>39.26</td>
<td>131.65</td>
<td>7.31</td>
</tr>
<tr>
<td>TPSdc+.TES</td>
<td>DC Test Line (+dir) Cam/Control WB Trk 1 No Regen</td>
<td>3.00</td>
<td>3.56</td>
<td>39.45</td>
<td>144.98</td>
<td>9.63</td>
</tr>
<tr>
<td>TPSdc+.TES</td>
<td>DC Test Line (+dir) Cam/Control Eastbound Track 3</td>
<td>3.00</td>
<td>4.58</td>
<td>35.06</td>
<td>137.65</td>
<td>7.26</td>
</tr>
<tr>
<td>TPSdc+.TES</td>
<td>DC Test Line (+dir) ChopperControl</td>
<td>3.00</td>
<td>4.56</td>
<td>39.26</td>
<td>63.67</td>
<td>3.65</td>
</tr>
<tr>
<td>TPSdc+.TES</td>
<td>DC Test Line (+dir) ChopperControl</td>
<td>3.00</td>
<td>4.56</td>
<td>39.33</td>
<td>71.89</td>
<td>3.59</td>
</tr>
<tr>
<td>TPSct+.TES</td>
<td>Coast Test - Anticipatory - Coast Speed 80 - Dir 0</td>
<td>20.00</td>
<td>17.42</td>
<td>68.89</td>
<td>332.36</td>
<td>2.77</td>
</tr>
<tr>
<td>TPSct+.TES</td>
<td>Coast Test - Anticipatory - Coast Speed 60 - Dir 0</td>
<td>20.00</td>
<td>19.56</td>
<td>61.34</td>
<td>265.88</td>
<td>2.22</td>
</tr>
<tr>
<td>TPSct+.TES</td>
<td>Coast Test - Anticipatory - Coast Speed 80 - Dir 0</td>
<td>20.00</td>
<td>22.04</td>
<td>54.45</td>
<td>252.69</td>
<td>2.11</td>
</tr>
<tr>
<td>TPSct+.TES</td>
<td>Coast Test - Anticipatory - Coast Speed 60 - Dir 0</td>
<td>20.00</td>
<td>22.04</td>
<td>54.45</td>
<td>252.69</td>
<td>2.11</td>
</tr>
<tr>
<td>TPSct+.TES</td>
<td>Coast Test - Anticipatory - Coast Speed 80 - Dir 0</td>
<td>20.00</td>
<td>17.50</td>
<td>68.47</td>
<td>320.12</td>
<td>2.67</td>
</tr>
<tr>
<td>TPSct+.TES</td>
<td>Coast Test - Anticipatory - Coast Speed 60 - Dir 0</td>
<td>20.00</td>
<td>17.50</td>
<td>68.47</td>
<td>320.12</td>
<td>2.67</td>
</tr>
<tr>
<td>TPSct+.TES</td>
<td>Coast Test - S Awareness - From Spd Res - Bnd 3 - Dir 0</td>
<td>20.00</td>
<td>17.00</td>
<td>67.61</td>
<td>264.42</td>
<td>3.24</td>
</tr>
<tr>
<td>TPSct+.TES</td>
<td>Coast Test - S Awareness - From Spd Res - Bnd 2 - Dir 0</td>
<td>20.00</td>
<td>16.73</td>
<td>60.82</td>
<td>259.43</td>
<td>2.66</td>
</tr>
<tr>
<td>TPSct+.TES</td>
<td>Coast Test - S Awareness - From Spd Res - Bnd 2 - Dir 0</td>
<td>20.00</td>
<td>30.08</td>
<td>39.89</td>
<td>223.56</td>
<td>1.86</td>
</tr>
<tr>
<td>TPSct+.TES</td>
<td>Coast Test - S Awareness - From Spd Res - Bnd 2 - Dir 0</td>
<td>20.00</td>
<td>43.63</td>
<td>31.87</td>
<td>241.93</td>
<td>2.02</td>
</tr>
<tr>
<td>TPSct+.TES</td>
<td>Coast Test - S Awareness - From Spd Res - Bnd 3 - Dir 0</td>
<td>20.00</td>
<td>17.42</td>
<td>68.89</td>
<td>332.36</td>
<td>2.77</td>
</tr>
</tbody>
</table>

Figure 9-107 EXCEL Table of TPS Summary Output

The focus is put on the cell in the white areas, one at a time and the <ctrl> V key is pressed. This action copies the Run Summary information from the TPS run to the table in EXCEL. This must be repeated for each white area. As an example of an EXCEL table row entry is shown next for TPSdc+.TES:

TPSdc+.TES  DC Test Line (+dir) Cam/Control EB Trk 2 No Regen  3.00  4.58  39.26  131.65  7.31
9.21.1.2 ENS Summary Output (SUMSENS*.*)

The Clipboard contains the Run Summary Information. To illustrate, the EXCEL table is shown next.

```
<table>
<thead>
<tr>
<th>File of Printname</th>
<th>Clipboard</th>
<th>DC Test System ENS Run (Base Case Rectifier Substations)</th>
<th>What</th>
<th>What</th>
<th>What</th>
<th>What</th>
<th>What</th>
<th>What</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENSr3.TES</td>
<td>DC Test Line Rect Reg - HW: .3 min</td>
<td>316.2 48.9 320 0.988 .0 6.74 34.41 41.15 .1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
```

Figure 9-108 EXCEL Table of ENS Summary Output

The focus is put on the cell in the white areas, one at a time and the <ctrl> V key is pressed. This action copies the Run Summary information from the ENS run to the table in EXCEL. This must be repeated for each white area. As an example of an EXCEL table row entry is shown next for ENSr3.tes:

```
ENSr3.TES 316.2 48.9 320 0.988 .0 6.74
```
9.21.1.3 TMS Summary Output (SUM$TMS.*)

This procedure works the same as in the previous section.
9.21.1.4 Return or Primary Circuit Current Analysis Output (RCA\*.*\*) or (PCA\*.*\*)

Figure 9-109 EXCEL Table of Return or Primary Circuit Current Analysis Output

The focus is put on the cell in the white area and the <ctrl> V key is pressed. This copy and paste can be done immediately after a run of the FMM – Current Analyzer process or by importing a Return or Primary Circuit Current Analysis Output file into the TOM – File Viewer and then clicking the EXCEL Ready command button.
9.21.1.5 RVM Summary or Detailed Output (RVM*.* or RVD*.*)

The Clipboard contains the Run Summary or Run Detailed Output Information for Maximum Rail Voltage. To illustrate, the EXCEL table is shown next.

<table>
<thead>
<tr>
<th>Output File</th>
<th>Conditions</th>
<th>Maximum Rail Voltage Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>RVM*.*</td>
<td>DC Test Run 1 Test Run 1 Brand X Gen</td>
<td>3.24 1.800 2 0.2300 0.50</td>
</tr>
<tr>
<td>RVM*.*</td>
<td>DC Test Run 2 Test Run 2 Brand Y Gen</td>
<td>2.03 1.800 2 0.2300 0.50</td>
</tr>
<tr>
<td>RVM*.*</td>
<td>DC Test Run 3 Test Run 3 Brand Z Gen</td>
<td>3.24 1.800 2 0.2300 0.50</td>
</tr>
<tr>
<td>RVD*.*</td>
<td>DC Test Run 1 Test Run 1 Brand X Gen</td>
<td>3.24 1.800 2 0.2300 0.50</td>
</tr>
<tr>
<td>RVD*.*</td>
<td>DC Test Run 2 Test Run 2 Brand Y Gen</td>
<td>2.03 1.800 2 0.2300 0.50</td>
</tr>
<tr>
<td>RVD*.*</td>
<td>DC Test Run 3 Test Run 3 Brand Z Gen</td>
<td>3.24 1.800 2 0.2300 0.50</td>
</tr>
</tbody>
</table>

Figure 9-110 Maximum Rail Voltage Table

The focus is put on the cell in the white area and the <ctrl> V key is pressed. This copy and paste can be done immediately after a run of the Rail Voltage Model process (by clicking the Yes command button) or by importing a Rail Voltage Model Detailed or Summary Output file into the TOM – File Viewer and then clicking the EXCEL Ready command button.

9.21.2 Automatic Processes

When computing these quantities in the FMM, the process stores the results in spreadsheet form on the Clipboard, so that they may be directly pasted in an EXCEL Spreadsheet table. The formats for these tables are shown in the following sections, with the paste cell in white. No action is required of the user, the paste on the Clipboard is automatic. The user is also informed of the paste.

9.21.2.1 Line Name Translation
9.21.2.2 Minimum Train Voltage

The focus is put on a cell in the white area and the <ctrl>V key is pressed. These can only be done one cell at a time after a run of the FMM – Minimum Train Voltage Finder process.
9.21.2.3 Maximum Train Current

Figure 9-113 EXCEL Table of Maximum Train Current Data
The focus is put on a cell in the white area and the <ctrl> V key is pressed. These can only be done one cell at a time immediately after a run of the FMM – Maximum Train Current Finder process.

9.21.2.4 Substation Loading

Figure 9-114 EXCEL Table of Substation Loading Data
The focus is put on the cell in the white area and the <ctrl> V key is pressed. These can only be done after a run of the FMM – Converter Current Analyzer process.
### 9.21.2.5 Current Measurement

#### Figure 9-115 EXCEL Table of Current Measurement Data

<table>
<thead>
<tr>
<th>Name of Point of Measurement</th>
<th>Maximum Current</th>
<th>Time of Max Current</th>
<th>Minimum Current</th>
<th>Time of Min Current</th>
<th>Average Current</th>
<th>RMS Current</th>
</tr>
</thead>
<tbody>
<tr>
<td>I1-</td>
<td>281.2</td>
<td>8:00:12</td>
<td>0.0</td>
<td>8:05:00</td>
<td>37.4</td>
<td>73.0</td>
</tr>
<tr>
<td>I2-</td>
<td>281.3</td>
<td>8:00:12</td>
<td>0.0</td>
<td>8:05:00</td>
<td>37.4</td>
<td>73.1</td>
</tr>
<tr>
<td>I3-</td>
<td>4207.1</td>
<td>8:04:02</td>
<td>0.0</td>
<td>8:05:00</td>
<td>453.0</td>
<td>863.0</td>
</tr>
<tr>
<td>I4-</td>
<td>4399.6</td>
<td>8:00:56</td>
<td>0.0</td>
<td>8:05:00</td>
<td>664.6</td>
<td>1214.9</td>
</tr>
<tr>
<td>I5-</td>
<td>6491.8</td>
<td>8:02:29</td>
<td>0.0</td>
<td>8:05:00</td>
<td>631.4</td>
<td>1436.5</td>
</tr>
<tr>
<td>I6-</td>
<td>5928.9</td>
<td>8:02:33</td>
<td>0.0</td>
<td>8:05:00</td>
<td>576.9</td>
<td>1331.6</td>
</tr>
<tr>
<td>I7-</td>
<td>7118.6</td>
<td>8:00:13</td>
<td>0.0</td>
<td>8:05:00</td>
<td>637.5</td>
<td>1262.0</td>
</tr>
<tr>
<td>I8-</td>
<td>2498.6</td>
<td>8:03:24</td>
<td>0.0</td>
<td>8:05:00</td>
<td>396.7</td>
<td>655.5</td>
</tr>
<tr>
<td>I9-</td>
<td>110.6</td>
<td>8:03:24</td>
<td>0.0</td>
<td>8:05:00</td>
<td>12.2</td>
<td>29.0</td>
</tr>
<tr>
<td>I10-</td>
<td>110.6</td>
<td>8:03:24</td>
<td>0.0</td>
<td>8:05:00</td>
<td>12.2</td>
<td>29.0</td>
</tr>
<tr>
<td>A0+</td>
<td>6927.0</td>
<td>8:04:03</td>
<td>0.0</td>
<td>8:05:00</td>
<td>552.4</td>
<td>1281.9</td>
</tr>
<tr>
<td>B2+</td>
<td>6365.4</td>
<td>8:00:12</td>
<td>0.0</td>
<td>8:05:00</td>
<td>845.6</td>
<td>1650.5</td>
</tr>
<tr>
<td>A3+</td>
<td>8229.9</td>
<td>8:02:29</td>
<td>0.0</td>
<td>8:05:00</td>
<td>576.1</td>
<td>1169.4</td>
</tr>
<tr>
<td>B3+</td>
<td>2697.9</td>
<td>8:02:33</td>
<td>0.0</td>
<td>8:05:00</td>
<td>436.3</td>
<td>743.1</td>
</tr>
<tr>
<td>A4+</td>
<td>8180.9</td>
<td>8:01:39</td>
<td>0.0</td>
<td>8:05:00</td>
<td>737.7</td>
<td>1750.7</td>
</tr>
<tr>
<td>B4+</td>
<td>5729.6</td>
<td>8:03:24</td>
<td>0.0</td>
<td>8:05:00</td>
<td>516.6</td>
<td>1164.5</td>
</tr>
<tr>
<td>A5+</td>
<td>110.6</td>
<td>8:03:24</td>
<td>0.0</td>
<td>8:05:00</td>
<td>12.2</td>
<td>29.0</td>
</tr>
<tr>
<td>B5+</td>
<td>110.6</td>
<td>8:03:24</td>
<td>0.0</td>
<td>8:05:00</td>
<td>12.2</td>
<td>29.0</td>
</tr>
</tbody>
</table>

The focus is put on the cell in the white area and the <ctrl> V key is pressed. These can only be done only once immediately after a run of the FMM – Current Measurement Analyzer process.

### 9.21.2.6 Circuit Line Currents

#### 9.21.2.6.1 Return Circuit Line Currents
Figure 9-116 EXCEL Table of Return Circuit Line Current Data

The focus is put on the cell in the white area and the `<ctrl>` V key is pressed. These can only be done only once immediately after a run of the FMM – Circuit Line Current Analyzer process.
9.21.2.6.2 Primary Circuit Line Currents

Figure 9-117 EXCEL Table of Primary Circuit Line Current Data

The focus is put on the cell in the white area and the <ctrl> V key is pressed. These can only be done only once immediately after a run of the FMM – Circuit Line Current Analyzer process.
9.21.2.7 Average Voltage Determination

Average Voltage Determination is accomplished using a voltage convergence procedure.

![Average Voltage Determination Process Table]

Figure 9-118 EXCEL Table of Average Voltage Determination Data

The focus is put on the cell in the white area and the <ctrl>V key is pressed. These can only be done only once immediately after a run of the FMM – Voltage Averager process.

9.21.2.8 Auto Offset Process Result

The Auto Offset Process Result (4.20) is set up for a direct paste into EXCEL. However the spread sheet will have to be reformatted somewhat.

An example is shown.
## OFFSET STUDY FOR FILENAME: ENSDAC TES CAPTION: DC Test Line AC Drive - 8:00-8:05

<table>
<thead>
<tr>
<th>Offset (sec)</th>
<th>Mbl kW</th>
<th>Mbr kW</th>
<th>Pow Factor</th>
<th>AC Current Loss</th>
<th>DC Current Loss</th>
<th>Volt</th>
<th>Past Trig</th>
<th>Trig ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>354</td>
<td>40.5</td>
<td>0.907</td>
<td>5.93</td>
<td>36.97</td>
<td>33.66</td>
<td>0</td>
<td>P1023</td>
</tr>
<tr>
<td>10</td>
<td>262.7</td>
<td>39.9</td>
<td>0.907</td>
<td>5.47</td>
<td>30.78</td>
<td>32.25</td>
<td>0</td>
<td>P1023</td>
</tr>
<tr>
<td>20</td>
<td>214.5</td>
<td>33.7</td>
<td>0.908</td>
<td>5.11</td>
<td>27.56</td>
<td>32.66</td>
<td>0</td>
<td>P1023</td>
</tr>
<tr>
<td>30</td>
<td>267.7</td>
<td>32.4</td>
<td>0.908</td>
<td>5.04</td>
<td>36.04</td>
<td>30.07</td>
<td>0</td>
<td>P1023</td>
</tr>
<tr>
<td>40</td>
<td>230.0</td>
<td>36.6</td>
<td>0.906</td>
<td>5.29</td>
<td>24.71</td>
<td>30</td>
<td>0</td>
<td>P1023</td>
</tr>
<tr>
<td>50</td>
<td>246.1</td>
<td>39.5</td>
<td>0.907</td>
<td>5.54</td>
<td>23.37</td>
<td>28.81</td>
<td>0</td>
<td>P1023</td>
</tr>
<tr>
<td>60</td>
<td>230.0</td>
<td>41</td>
<td>0.904</td>
<td>5.53</td>
<td>49.22</td>
<td>54.76</td>
<td>-23.7</td>
<td>P1023</td>
</tr>
<tr>
<td>70</td>
<td>235.0</td>
<td>40.8</td>
<td>0.905</td>
<td>6.36</td>
<td>71.54</td>
<td>71.43</td>
<td>-12.3</td>
<td>P1023</td>
</tr>
<tr>
<td>80</td>
<td>235.7</td>
<td>36</td>
<td>0.906</td>
<td>6.36</td>
<td>53.62</td>
<td>36.21</td>
<td>-18.6</td>
<td>P1023</td>
</tr>
<tr>
<td>90</td>
<td>234.0</td>
<td>31.7</td>
<td>0.907</td>
<td>4.97</td>
<td>32.26</td>
<td>30.27</td>
<td>0</td>
<td>P1023</td>
</tr>
<tr>
<td>100</td>
<td>223.1</td>
<td>36.5</td>
<td>0.907</td>
<td>5.19</td>
<td>36.68</td>
<td>30.77</td>
<td>0</td>
<td>P1023</td>
</tr>
<tr>
<td>110</td>
<td>209.0</td>
<td>39.9</td>
<td>0.906</td>
<td>5.39</td>
<td>61.61</td>
<td>67.17</td>
<td>-0.6</td>
<td>P1023</td>
</tr>
<tr>
<td>120</td>
<td>241.0</td>
<td>39.9</td>
<td>0.907</td>
<td>5.39</td>
<td>51.97</td>
<td>57.37</td>
<td>-0.6</td>
<td>P1023</td>
</tr>
<tr>
<td>130</td>
<td>218.0</td>
<td>38.4</td>
<td>0.905</td>
<td>5.39</td>
<td>29.7</td>
<td>34.1</td>
<td>0</td>
<td>P1023</td>
</tr>
<tr>
<td>140</td>
<td>244.7</td>
<td>39</td>
<td>0.906</td>
<td>5.42</td>
<td>66.15</td>
<td>33.66</td>
<td>0</td>
<td>P1023</td>
</tr>
<tr>
<td>150</td>
<td>235.5</td>
<td>30.1</td>
<td>0.907</td>
<td>5.37</td>
<td>27.74</td>
<td>33.11</td>
<td>0</td>
<td>P1023</td>
</tr>
<tr>
<td>160</td>
<td>235.5</td>
<td>37.4</td>
<td>0.905</td>
<td>5.33</td>
<td>30.44</td>
<td>31.77</td>
<td>0</td>
<td>P1023</td>
</tr>
<tr>
<td>170</td>
<td>233.7</td>
<td>57</td>
<td>0.904</td>
<td>5.31</td>
<td>36.23</td>
<td>31.54</td>
<td>0</td>
<td>P1023</td>
</tr>
<tr>
<td>180</td>
<td>222.9</td>
<td>35</td>
<td>0.906</td>
<td>5.2</td>
<td>27.77</td>
<td>32.10</td>
<td>0</td>
<td>P1023</td>
</tr>
<tr>
<td>190</td>
<td>255.9</td>
<td>94.1</td>
<td>0.905</td>
<td>5.13</td>
<td>30.14</td>
<td>39.26</td>
<td>2.3</td>
<td>P1023</td>
</tr>
<tr>
<td>200</td>
<td>252.3</td>
<td>37.3</td>
<td>0.907</td>
<td>5.23</td>
<td>44.23</td>
<td>49.63</td>
<td>3.5</td>
<td>P1023</td>
</tr>
<tr>
<td>210</td>
<td>235</td>
<td>41.5</td>
<td>0.907</td>
<td>5.58</td>
<td>39.86</td>
<td>31.52</td>
<td>0.1</td>
<td>P1023</td>
</tr>
<tr>
<td>220</td>
<td>262.3</td>
<td>40.3</td>
<td>0.907</td>
<td>5.55</td>
<td>36.41</td>
<td>31.91</td>
<td>0</td>
<td>P1023</td>
</tr>
<tr>
<td>230</td>
<td>234.5</td>
<td>33.7</td>
<td>0.906</td>
<td>5.11</td>
<td>36.69</td>
<td>34</td>
<td>0</td>
<td>P1023</td>
</tr>
<tr>
<td>240</td>
<td>194.4</td>
<td>32.5</td>
<td>0.906</td>
<td>4.89</td>
<td>31.26</td>
<td>36.12</td>
<td>0</td>
<td>P1023</td>
</tr>
<tr>
<td>250</td>
<td>216.9</td>
<td>94.1</td>
<td>0.906</td>
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Figure 9-119 Auto Offset Process Results EXCEL Sample

### 9.21.2.9 Auto Rail Voltage Process Results
## AUTO RAIL VOLTAGE PROCESS SUMMARY

**FILE: RVM4r.tes**  
**CAPTION: DC Test Pri wo Ties Rtn wo Bonds Reg**

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<th>Ground Voltage</th>
<th>Maximum Occurrence Position</th>
<th>Track Number</th>
<th>Snapshot Time</th>
<th>Node Name</th>
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