PSS™E 31.0

USERS MANUAL

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PSS™E Overview

1.1 Introduction to the Users Manual

Welcome to the *Power System Simulator for Engineering (PSS™E) Users Manual*. The complete PSS™E package is comprised of a comprehensive suite of programs for studies of power system transmission network and generation performance in both steady-state and dynamic conditions. At present two primary simulators, one for steady-state analysis and one for dynamic simulation, facilitate calculations for a variety of analyses, including:

- Power flow and related network functions
- Optimal power flow
- Balanced and unbalanced faults
- Network equivalent construction
- Dynamic simulation

PSS™E has a completely revamped graphical user interface (GUI), one that's intuitive and compliant with the many other standard GUI applications. The new interface comprises all the functionality for steady state analysis, including load flow, fault analysis, optimal power flow, equivalencing, switching studies and open access. The dynamic simulation includes all the functionality for transient, dynamic and long term stability analysis. The time-tested and robust engine of PSS™E hasn't changed, we've just provided a powerful and efficient interface upon which to drive the engine.

In addition to steady-state and dynamic analysis, the PSS™E package also provides the user with a wide range of auxiliary programs for installation, data input, output, manipulation and preparation.

This manual comprehensively covers the operation and application of *only* the new PSS™E Interface. For comprehensive reference manuals, refer to the *PSS™E Program Operation Manual (POM)*, *Volumes I* and *II*.

Throughout the rest of this manual the user will become familiar with following:

- How to use the PSS™E interface
- How to introduce and manage PSS™E model data, and data files.
- How to perform basic power system planning and operating studies.

The PSS™E user does not need to be a Microsoft® Windows® Operating System expert, but a basic understanding of Windows and file management is essential. Knowledge in how to use a standard text editor and familiarity with word processing and spreadsheet type software will also prove beneficial, particularly when editing and managing data files and program output.

1.1.1 About the Users Manual and Other Manuals

This manual is structured to provide the user with the capability to:

- Understand and operate the PSS™E user interface (Chapter 2)
- Manage PSS™E model data and prepare data files (Chapter 3)
- Perform load flow studies (Chapter 4)
- Perform contingency analysis (Chapter 5)
- Perform transfer limit analysis (Chapter 6)
- Perform a fault analysis (Chapter 7)
- Perform balanced switching studies (Chapter 8)
- Equivalence and reduce networks (Chapter 9)
- Perform open access studies (Chapter 10)
- Perform PV/QV analysis (Chapter 11)
- Use program automation (Chapter 12)
- Export PSS™E results to a Microsoft Excel® spreadsheet (Chapter 13)
- Perform a dynamic simulation (Chapter 14)
- Create a PSS™E dynamic simulation user dll (Chapter 15)
- Plot dynamic simulation results (Chapter 16)
- Create dynamics and power flow event studies (Chapter 17)
- Create scenarios for a unique study (Chapter 18)

The manual also includes:

- A mapping of activity names to interface functions (Appendix A)
- Release compatibility issues (Appendix B)
- Start-up commands (Appendix C)
- Line mode differences (Appendix D)
- Sample data files (Appendix E)

Other manuals recommended for reading and reference include the *PSS™E Program Operation Manual (POM)* and *PSS™E Program Application Guide (PAG)* which discuss operational and engineering aspects of formulating problems for PSS™E and interpreting results.

To help in the transition from the older user interface to the new one, a map between the activity names and the corresponding menu items is provided in Appendix A, *Functional Summaries of PSS™E Activities.* Most of the traditional activity names are also included in the menu functions of the new interface.

1.1.2 Other Related Manuals

The *PSS™E Program Application Guide, Volume I and II,* discusses the engineering aspects of formulating problems for PSS™E and interpreting its results. The two part guide can be considered an engineering textbook specifically related to system modelling and techniques within PSS™E for engineers responsible for planning and operations studies.

The *PSS™E OPF Manual* comprehensively describes the operational and engineering aspects of formulating optimal power flow problems, solving them and interpreting the results. It pertains to the optional OPF module made available from a menu within PSS™E.

Computer platform specific user procedures, as well as PSS™E installation instructions and documentation on several PSS™E utility programs, are contained in a set of computer dependent installation manuals (i.e., *PSS™E for Windows*).

The *Guide to Printing and Plotting* manual describes the graphics and tabular output devices supported by the traditional PSS™E interface (i.e., PSS™E dynamics, PSSPLT, etc.). It includes both program user information as well as system-related instructions required by those responsible for PSS™E installation.

The *PSSPLT Program Manual* describes the use of the simulation channel output file processing program used for plotting dynamics study results.

The *IPLAN Program Manual* describes the Siemens PTI IPLAN programming language and use of the IPLAN compiler.

The *PSS™E WECC Data Conversion Manual* describes the auxiliary programs WECCLF, WECCDS, and RAWECC. These auxiliary programs convert data between the Western Electricity Coordinating Council (WECC) power flow and stability program data formats and PSS™E input data file formats.

The *Saved Case Data Extraction Subroutines* manual describes the programming interface functions whereby users may develop programs that access power flow data directly from PSS™E Saved Case Files.

The *PSAS User's Ready Reference* and *PSEB User's Ready Reference* describe the Command File structures that allow the PSS™E user to specify many routine power flow and dynamic simulation runs, respectively, in English sentence form. These command files are created by the user with a text editor before starting up PSS™E. The PSAS and PSEB commands are translated into a PSS™E Response File for immediate execution or for subsequent processing as a standard PSS™E Response File.

The *PSS™E Application Program Interface (API)* manual describes the Psspy Python procedures and PSS™E Batch Commands ("BAT_") used in the PSS™E automation facility.

The *Transmission Line Characteristics (TMLC) Program Manual* and the *PSS™E LineProp Manual* document the two auxiliary programs available to calculate line impedances from a transmission corridor definition.

1.1.3 Obsolete Manuals

The following manuals are obsolete and no longer available:

- The *PSS™E Grid Editor Users Guide* has been replaced by this *PSS™E Users Manual*.
- The *Programming Manual for Device Independent Plotting (INDEPLOT)* is obsolete.
- The *Graphic Report Generator GRPG User's Ready Reference* is obsolete.
- The *B-Matrix Program Manual* is obsolete.

What was titled *Guide to PSS™E Batch Commands* has been renamed the *PSS™E Application Program Interface (API) manual*.

1.1.4 Document Conventions

The following conventions are used throughout this manual:

Bold italic text denotes a menu option that the user must select, or a button the user must click. For example:

Choose ***File>Open*** from the main menu, or click the ***Open*** button on the File toolbar

Italic text is used to emphasize a word or phrase.

Indicates additional information of interest.

"Click" is a user instruction to click the *left* mouse button.

"Double-click" is a user instruction to click the *left* mouse button *twice*.

"Right-click" is a user instruction to click the *right* mouse button.

[Enter] is a user instruction to press the indicated keyboard key.

"n.a." is used as an abbreviation meaning "not applicable".

1.1.5 Accessing Documentation

All PSS™E manuals and reference guides (e.g., *PSS™E Program Operation Manual*, Vol. I and II, *PSS™E Program Application Guide*, Vol. I and II, etc.) are in PDF format and readily available and viewable with the Adobe Acrobat Reader (freely downloadable from the Adobe web site).

The PSS™E manuals and reference guides are located on the installation CD in the "DOCS" folder. If the option to install documentation with PSS™E is selected during the PSS™E installation, a shortcut to the PSS™E documentation will be placed on the PSS™E Start menu.

1.1.6 Contacting Siemens PTI for Support

If after consulting the documentation and online help you find that additional assistance with PSS™E is needed, you may contact Siemens PTI via any of the following methods (please send a thorough description of the problem or question, including files):

- Send an email to technical support at pti-psse-support.ptd@siemens.com.
- Send a fax to (518) 346-2777, attention PSS™E Support.
- Call the telephone support number between the hours of 8:00 a.m. and 5:00 p.m. Eastern Time, Monday through Friday. Dial (518) 395-5075 and select option "1" for PSS™E support.
- Visit the Siemens PTI Web Site at www.siemens.com/power-technologies and the PSS™E User Support Web Page.

Please note that access to the PSS™E User Support Web Page and to technical PSS™E support is only available to those users whose companies have purchased or renewed their PSS™E maintenance and support agreement for the current calendar year.

1.1.7 Submitting Bug Reports and Feature Requests

Bug reports and feature requests should be submitted directly to PSS™E support at pti-psse-support.ptd@siemens.com. Please provide as much detail as possible. If submitting a report for a potential bug please include the steps taken, along with pertinent data files and scripts so that we may accurately reproduce the problem. If an issue does turn out to be a program bug, one of the following priorities will be assigned to it:

- High priority is given to issues that cause the program to crash or produce incorrect results with no published work around.
- Medium priority is given to issues that cause incorrect functionality, however the problem can be remedied by a published work around.
- Low priority is given to those issues that do not fall into the above categories, or are purely cosmetic in nature.

Every effort is made to address high and medium issues in a PSS™E point release. Some low priority items may also be include in a point release although this cannot be guaranteed.

Feature requests are evaluated on the basis of whether it benefits a wide majority of PSS™E users. If it does, it will likely be considered for implementation in a point release or major release of PSS™E. If several users have the same feature request, the feature may sit higher in the queue than others for implementation in PSS™E.

1.2 Overview: PSS™E Functionality

PSS™E is not set up to solve *any* specific problem, rather, it is set of computational tools that are directed by the user in an interactive manner. By applying these tools in the appropriate sequence, the engineer can handle a wide range of investigations for the planning and operation of electric power systems. This manual is specifically structured to help the user become familiar with the available tools and the manner in which they can be used for such investigations, most specifically steady-state analysis.

Through the PSS™E interface the following functions and analyses are available:

- Power flow and related network functions
- Optimal power flow
- Open access
- Fault analysis
- Network equivalencing
- Dynamic simulation
- One-line diagrams
- Program automation

Additionally, one of the most basic premises of PSS™E is that the engineer can derive the greatest benefit from computational tools by retaining intimate control over their application. PSS™E users accustomed to such control by use of the IPLAN program language now have available the additional capability to run Python programs within PSS™E for batch control and automation of the simulation processes.

1.3 Overview: The PSS™E User Interface

The PSS™E interface supports a variety of interactive facilities including:

- Introduction, modification and deletion of network data using a spreadsheet.
- Creation of networks and one-line diagrams.
- Steady-state analyses (load flow, fault analysis, optimal power flow, etc.).
- Presentation of steady-state analysis results.
- Dynamic simulations (transient, dynamic and long term stability analysis).
- Presentation of Dynamic simulation results.

Initiation of the PSS™E application is covered in Section 1.6. Once opened, the key elements of the user interface are the Tree View, Spreadsheet View, Diagram View and the Output Bar, as pointed out in Figure 1-1.

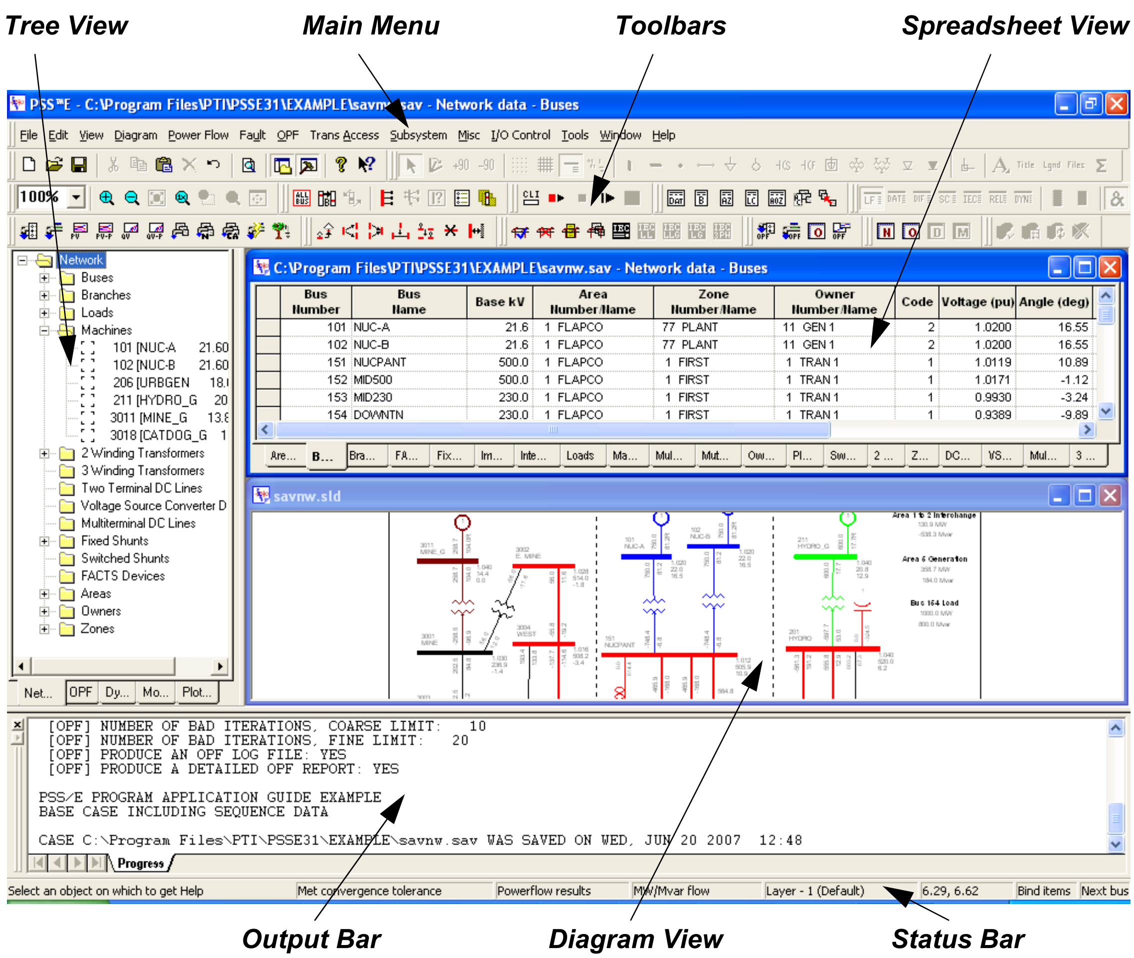


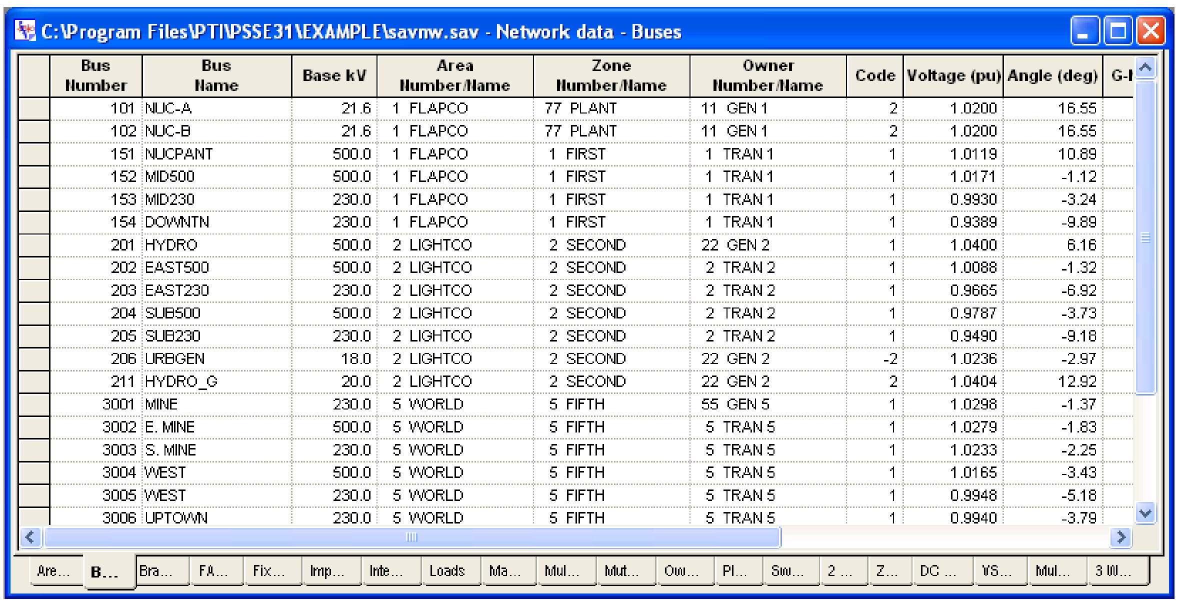
Figure 1-1. Key Elements of the Interface

1.3.1 Spreadsheet View

All network data components (e.g., buses, lines, loads) are represented within worksheet style tabs on the spreadsheet. The spreadsheet, or workbook, is synchronized with the bus subsystem selector so that only a subset of the data may be viewed at any time. New network elements may be entered or modified directly in the appropriate worksheet, or existing ones deleted. In the Spreadsheet View, standard Windows® commands such as copy and paste actions are supported. Sorting and filtering capabilities are provided to increase usability, especially with large systems.

At program startup the Spreadsheet View is not shown. It will appear when a raw data or saved case file is opened. The Spreadsheet View is the default view for the interface and remains open once it is populated. It can be minimized, but if closed will remove the current network from PSS™E.

In Figure 1-2, the ***Bus*** tab has been selected and the spreadsheet reflects the bus data records within the working case. Other data items may be viewed by clicking on the other tabs located at the bottom of the spreadsheet view.


C:\Program Files\PTI\PSSE31\EXAMPLE\savnw.sav - Network data - Buses

Bus Number	Bus Name	Base kV	Area Number/Name	Zone Number/Name	Owner Number/Name	Code	Voltage (pu)	Angle (deg)	G-I
101	NUC-A	21.6	1 FLAPCO	77 PLANT	11 GEN 1	2	1.0200	16.55	
102	NUC-B	21.6	1 FLAPCO	77 PLANT	11 GEN 1	2	1.0200	16.55	
151	NUCPANT	500.0	1 FLAPCO	1 FIRST	1 TRAN 1	1	1.0119	10.89	
152	MID500	500.0	1 FLAPCO	1 FIRST	1 TRAN 1	1	1.0171	-1.12	
153	MID230	230.0	1 FLAPCO	1 FIRST	1 TRAN 1	1	0.9930	-3.24	
154	DOWNTN	230.0	1 FLAPCO	1 FIRST	1 TRAN 1	1	0.9389	-9.89	
201	HYDRO	500.0	2 LIGHTCO	2 SECOND	22 GEN 2	1	1.0400	6.16	
202	EAST500	500.0	2 LIGHTCO	2 SECOND	2 TRAN 2	1	1.0088	-1.32	
203	EAST230	230.0	2 LIGHTCO	2 SECOND	2 TRAN 2	1	0.9665	-6.92	
204	SUB500	500.0	2 LIGHTCO	2 SECOND	2 TRAN 2	1	0.9787	-3.73	
205	SUB230	230.0	2 LIGHTCO	2 SECOND	2 TRAN 2	1	0.9490	-9.18	
206	URBGEN	18.0	2 LIGHTCO	2 SECOND	22 GEN 2	-2	1.0236	-2.97	
211	HYDRO_G	20.0	2 LIGHTCO	2 SECOND	22 GEN 2	2	1.0404	12.92	
3001	MINE	230.0	5 WORLD	5 FIFTH	55 GEN 5	1	1.0298	-1.37	
3002	E. MINE	500.0	5 WORLD	5 FIFTH	5 TRAN 5	1	1.0279	-1.83	
3003	S. MINE	230.0	5 WORLD	5 FIFTH	5 TRAN 5	1	1.0233	-2.25	
3004	WEST	500.0	5 WORLD	5 FIFTH	5 TRAN 5	1	1.0165	-3.43	
3005	WEST	230.0	5 WORLD	5 FIFTH	5 TRAN 5	1	0.9948	-5.18	
3006	UPTOWN	230.0	5 WORLD	5 FIFTH	5 TRAN 5	1	0.9940	-3.79	

Figure 1-2. Overview of the Spreadsheet View

1.3.2 Tree View

The Tree View provides a hierarchical, expandable and collapsible list view of the network, OPF, dynamics, model, and plot data in the system (see Figure 1-3). It is synchronized with the bus subsystem selector to enable the user to reduce the amount of data presented at any one time. The Tree View is also synchronized with the Spreadsheet and Diagram Views, reflecting their current content.

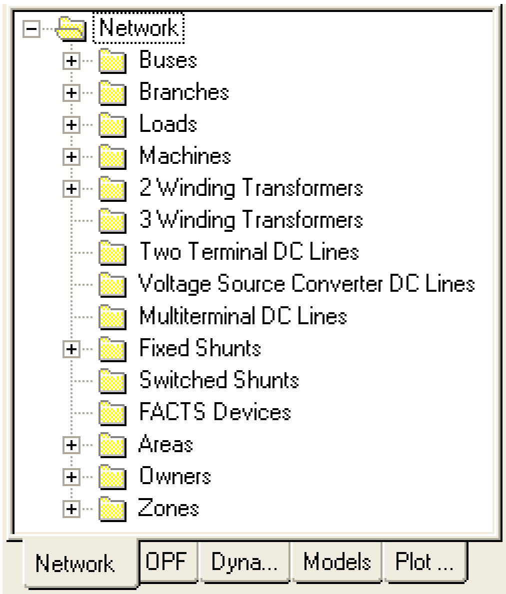


Figure 1-3. Tree View

1.3.3 Diagram View

The Diagram View is used to create, expand and display one-line diagrams of the electrical system (see Figure 1-4). As new elements are added to the diagram, the Spreadsheet and Tree Views are automatically updated to reflect the addition. Additional diagram capabilities include the ability to view power flow, short-circuit analysis, reliability and dynamic simulation results.

The Diagram View is not automatically opened. It is initiated by opening an existing one-line drawing file, or by starting a new diagram window.

The Diagram View can directly import old PSS™E DRAW files, which can then be saved to the new diagram Slider (SLD) format.

Note: One-line diagrams from the new interface are *not* backward compatible with the DRAW/DRED activities of previous versions of PSS™E.

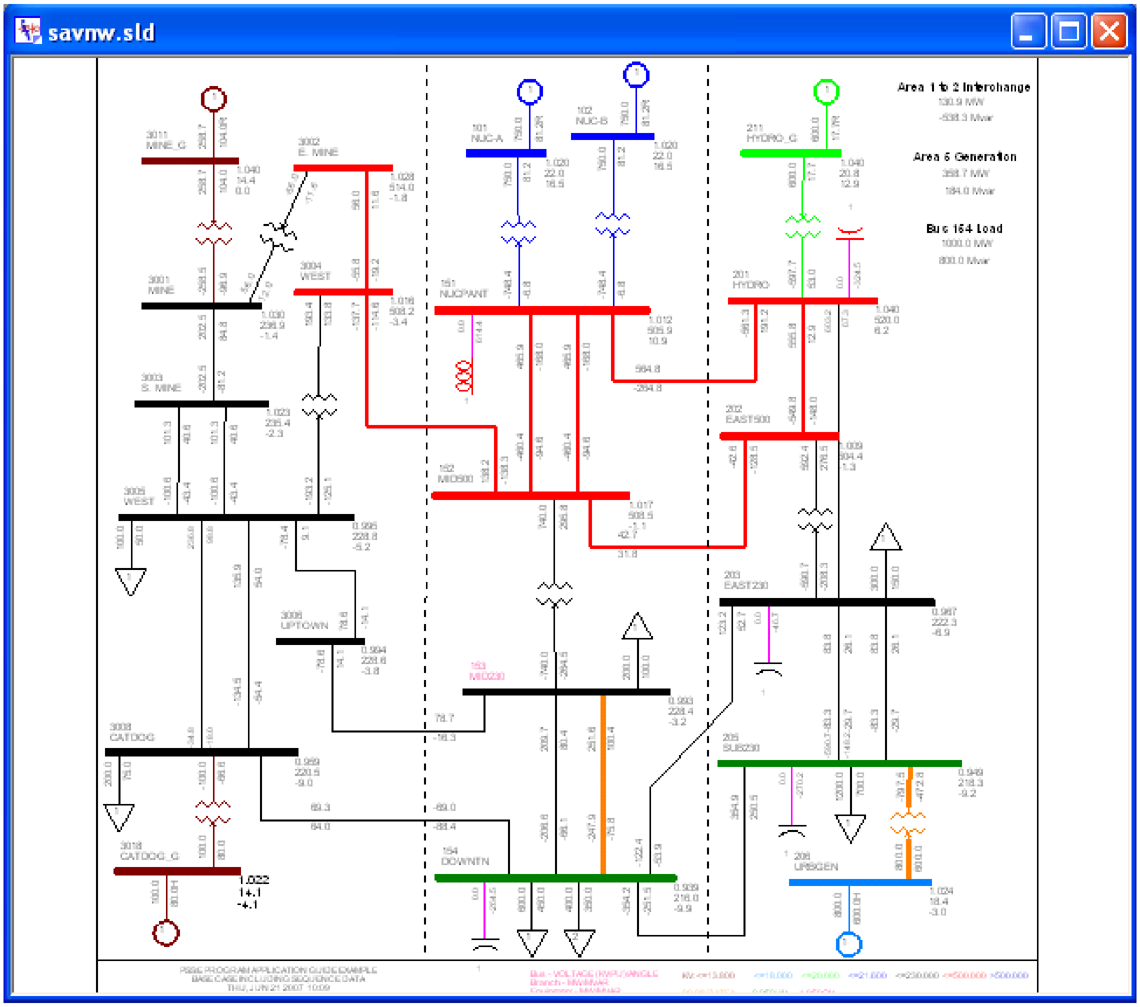


Figure 1-4. Overview of Diagram View

1.3.3.1 Automatically Building a New One-line Diagram

Given an existing PSS™E case, a one-line diagram may easily be built or expanded, bus by bus. This is accomplished by activating a Diagram View, right-clicking on an existing bus within the diagram or tree view, and selecting ***Grow***. All items connected to the selected bus are automatically drawn on the diagram. Simple mouse operations may then be used to rearrange elements on the diagram.

1.3.4 Output Bar

The Output Bar is used to display program information, dialog, errors, and warning messages (see Figure 1-5). It is activated by clicking on the Progress tab on the Output Bar.

The Output Bar is also used to display program output in the form of text reports. Reports can optionally be sent to a single report view or to individual reports, and are activated by clicking on the Report tab.

Standard Windows® capabilities for selecting and copying text to the clip board or saving it to an external file are supported in both views. This allows for easy transition between PSS™E and external applications such as Excel or Word.

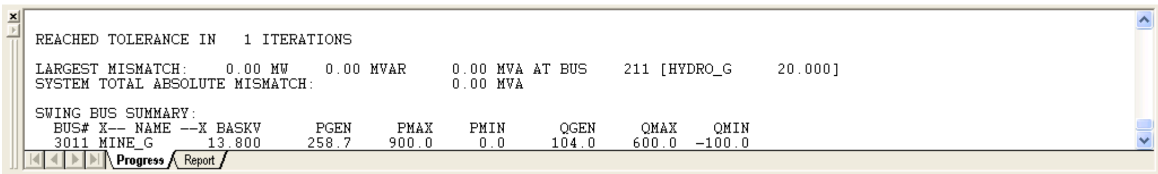


Figure 1-5. Output Bar

1.3.5 Status Bar

The Status Bar displays explanatory text while you are using PSS™E. For example, when moving the mouse arrow over a toolbar button the function of that button is displayed in the left portion of the Status Bar.

1.4 Using the PSS™E User Interface

Each analytical function of PSS™E is available directly from pull-down menus and user customizable toolbars. With very few exceptions, the functional activities of the old PSS™E interface all exist in the new PSS™E interface. For convenience, the traditional activity names are shown on many of the menu items, as illustrated in Figure 1-6.

For additional convenience, Appendix A of this manual provides a map from the old activity names to their new locations on the pull-down menus in the new user interface. The analytical functions are listed in accordance with their common applications in planning and operations studies.

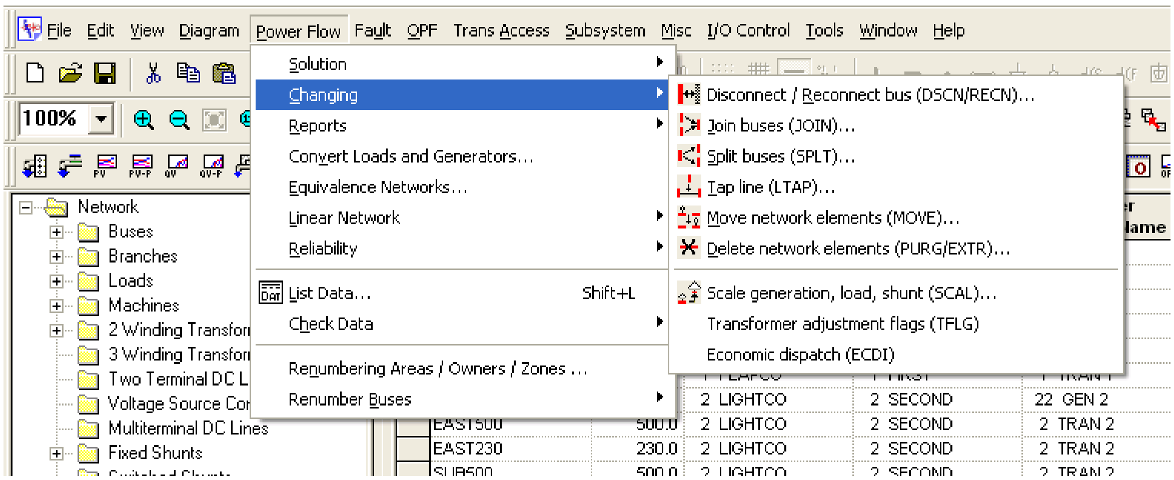


Figure 1-6. Typical Interface Menu Showing Historic Activity Names

1.4.1 Using the Command Line Input Processor

Many users remain faithful to the origins of PSS™E when the command line was used for all interactive dialogue with the program (line mode). Command line input continues to be available by selecting the ***I/O Control>Begin command line input session…*** menu option. The resulting command line input window supports the use of traditional activity names, batch (BAT_) commands and Python commands (see Figure 1-7). To enter batch commands or activity names, select the ***PSS™E Response*** Command language from the available list.

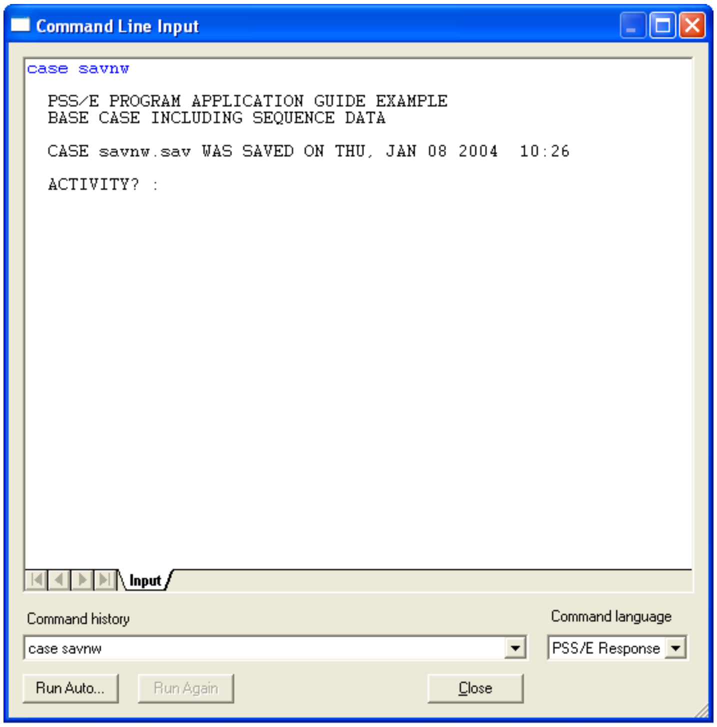


Figure 1-7. Command Line Input Session Window

1.4.2 Program Automation

A sequence of PSS™E actions may be recorded in a Python script or Response files (.IDV) by selecting ***I/O Control>Start recording…***. A file selector window is presented in which to specify the type of file to record and the file name. When done recording, select ***I/O Control>Stop recording*** to close the file.

Existing Python scripts (.py), Response files (.idv), IPLAN programs and PSAS/PSEB command files may be executed from within the user interface by selecting ***I/O Control>Run program Automation file***. PSS™E will open a file selector window and prompt for the appropriate filename to execute.

1.5 Co-existence of Multiple PSS™E Versions

PSS™E 31 can be installed and exist with previous versions of PSS™E on the same computer system. No special action is required by the user to do so. At PSS™E 30, the filenames for the application were modified so that other PSS™E versions could remain and function normally. For further information, please see the *PSS™E for Windows* installation guide.

1.6 Starting the PSS™E Application

PSS™E may be started through one of several methods:

- Select the ***PSS™E*** option from the Windows ***Start>Programs>PSSE 31*** menu.

  This is the default location as established during program installation. Other applications within the PSS™E suite of tools may also be initiated from this same PSS™E Start menu.

- Double-click on the psse31.exe file from within Windows Explorer.

  C:\Program Files\PTI\PSSE31\PSSBIN is the default directory location of psse31.exe. An alternate directory location may be specified during program installation.

- Invoke a PSS™E DOS prompt window by selecting ***Start>Programs>PSSE 31>PSSE-31 Command Prompt*** and enter "psse31.exe" (or simply "psse31") at the DOS prompt, followed by <Enter>.

- Double-click on a previously defined PSSE shortcut icon located on the desktop.

1.6.1 PSS™E Startup Command Options

Additional command options may be appended to the psse31.exe startup command to further direct and customize program execution. These optional arguments take the form of a keyword, sometimes followed by a value. All keywords begin with a hyphen (-).

The following command line options may be specified:

- -inifile *filename*

  Override the default "ini" file with the one specified by *filename*.

- -pyfile *filename*

  Begin the program by running the python program specified.

- -rspfile *filename*

  Begin the program by running the response file specified.

- -argstring *string*

  When -rspfile *filename* or -pyfile *filename* is also specified, use *string* as the argument for *filename*; otherwise the -argstring option is ignored.

- -buses *buses*

  Set the program bus size level. *Buses* will be rounded to the next multiple of 1000, up to a maximum of 150000. If zero is specified, the current default size level is used.

- -embed

  When -rspfile or -pyfile is also specified, do not display the user interface until that file has completed its execution; otherwise the -embed option is ignored.

The above keywords may be abbreviated to any unique string. The options may be specified in any order. If the same option is specified more than once, the last one specified is used. The -pyfile and -rspfile options are mutually exclusive; if both are used, the -rspfile option is ignored.

"*Filename*" is interpreted as a relative pathname, relative to the current working directory.

"*String*" and "*filename*" should be quoted if they contain embedded blanks - use the quote character ("). When the "string" value from -argstring is passed to the Python program or Response Rile, the surrounding quotes will be removed. Also any embedded pairs of quotes will be interpreted as a single quote character. For example, "abc""def" will appear to be the single 7-character string abc"def. When used with -rspfile, that resulting string will then be parsed according to the normal free-format parsing rules to assign the individual response file arguments. When used with -pyfile, that resulting string will be the value of sys.argv[1].

The above keywords may be appended to the PSS™E startup command by appending the argument to the psse31.exe path name specified in the Target field of the Properties window associated with the PSSE shortcut icon or **Start>Programs>PSSE 31>PSSE** menu item (see Figure 1-8).

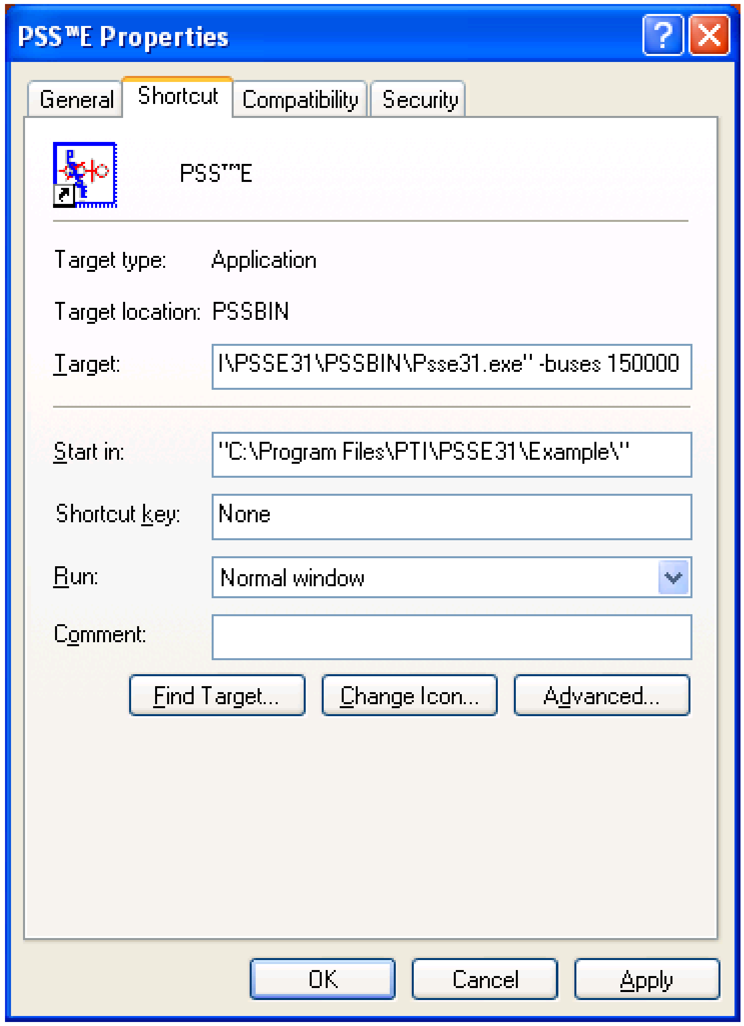


Figure 1-8. Specifying the -buses Command Line Option in the Properties Window

The keywords may also be appended to the psse command prompt by initiating the ***Start>Programs>PSSE 31>PSSE-31 Command Prompt*** window and appending the command keyword to the psse30.exe command (see Figure 1-9).

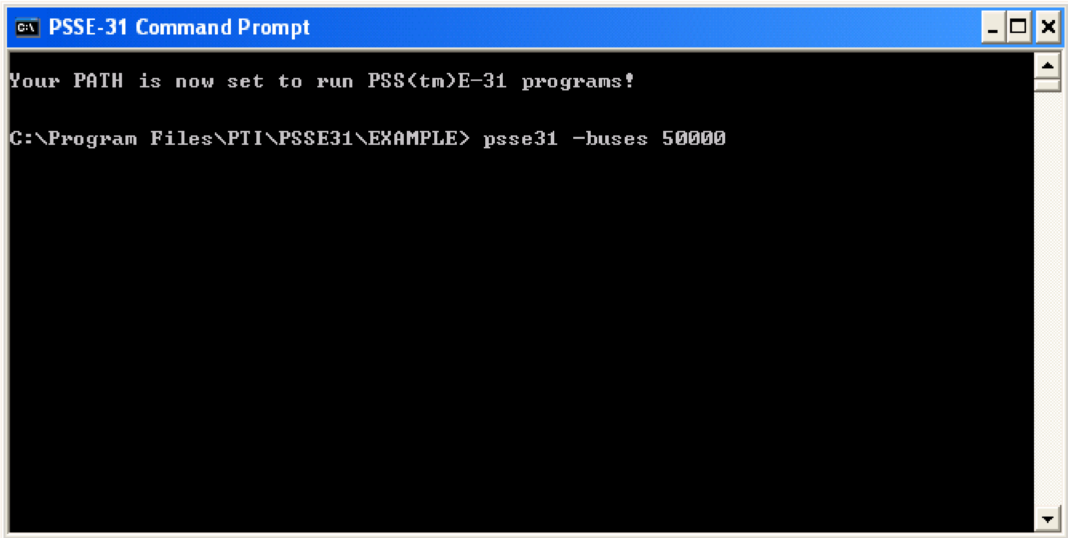


Figure 1-9. Specifying the "-buses" Option in the PSSE-31 Command Prompt Window

1.6.2 Defining the Program Size

Table 1-1 lists the dimensional capacities of the various PSS™E elements at the "standard" size levels of 1000, 4000, 12000 and 50000 buses, and at the largest size level of 150000 buses.

At PSS™E startup, the size assumed will be the default bus size level established during program installation. An alternate size level may be specified by either

- selecting ***Misc>Change program settings (OPTN)…*** from within PSS™E, and specifying the desired size level in the **Startup bus dimension** field. The new bus size level will take effect the next time PSS™E is started; or
- specifying the "-buses *buses*" command line option as described in Section 1.6.1.

If the specified bus size falls in between standard size levels, the dimensional capacities of some elements are interpolated between the two adjacent standard size dimensions and other elements take on the dimension of the nearest smaller standard size level. If the specified bus size level is greater than 50000 buses, the dimensional capacities of those elements not determined by extrapolation take on the dimensions of the 150000 bus size level. The "I/E or S" column of Table 1-1 contains "I/E" if interpolation or extrapolation is used or an "S" if the dimension of the nearest smaller standard size level is taken. For example, if PSS™E is started up at 10000 buses, the maximum number of loads, transformers, and switched shunts are determined by interpolating between the corresponding capacities at the 4000 and 12000 bus size levels, and the maximum number of areas, dc lines, and zero sequence mutuals are the same as at the 4000 bus size level.

Table 1-1. Standard Maximum Program Capacities for PSS™E

	I/E or S	1,000 Buses	4,000 Buses	12,000 Buses	50,000 Buses	150,000 Buses
TRANSMISSION NETWORK COMPONENTS						
Buses (including "star point" buses of three-winding transformers)	-	1,000	4,000	12,000	50,000	150,000
Loads	I/E	2,000	8,000	24,000	100,000	300,000
Plants	I/E	300	1,200	3,600	10,000	26,840
Machines	I/E	360	1,440	4,000	12,000	33,050
Switched shunts	I/E	126	500	1,500	4,000	10,580
Branches (including transformers and zero impedance lines)	I/E	2,500	10,000	24,000	100,000	300,000
Two-winding transformers (including three-winding transformer members)	I/E	400	1,600	4,800	20,000	60,000
Three-winding transformers	I/E	100	400	1,200	5,000	15,000
Transformer impedance correction tables	S	16	32	64	96	96
Zero impedance lines	I/E	50	200	500	2,000	5,950
Multisection line groupings	I/E	100	400	800	1,600	3,710
Multisection line sections	I/E	250	1,000	2,000	4,000	9,260
Two-terminal dc transmission lines	S	20	30	40	50	50
Voltage source converter (VSC) dc lines	S	10	20	30	40	40
Multiterminal dc lines	S	5	5	5	20	20
Converters per multiterminal dc line	S	12	12	12	12	12
Dc buses per multiterminal dc line	S	20	20	20	20	20
Dc circuits per multiterminal dc line	S	20	20	20	20	20
FACTS control devices	S	20	20	20	50	50
Interchange control areas	S	100	250	500	1,200	1,200
Inter-area transfers	S	300	500	1,000	2,000	2,000
Zones	S	999	999	999	2,000	2,000
Owners	S	999	999	999	1,200	1,200
Machine owner specifications	I/E	720	2,880	8,000	24,000	66,100
Branch owner specifications	I/E	5,000	20,000	48,000	200,000	600,000
Zero sequence mutual couplings	S	500	2,000	3,000	4,000	4,000

1.6.3 Establishing the Working Directory

PSS™E always operates out of a working directory. By default this is the "EXAMPLE" subdirectory under the main PSS™E directory.

It is perfectly reasonable to set up one directory for running the PSS™E programs (a working directory) and another for the storage of base case power flow and dynamics data files. Various other working directories may also be established in which to run PSS™E on a variety of different studies or investigations, each with its own set of data files.

A simple way of setting up PSS™E to run in a variety of working directories is to create a shortcut icon for each one and alter the Properties of the shortcut to indicate the directory in which the program is to start in. In Figure 1-10 the directory path specified in the **Start in:** field may be set to an alternate location.

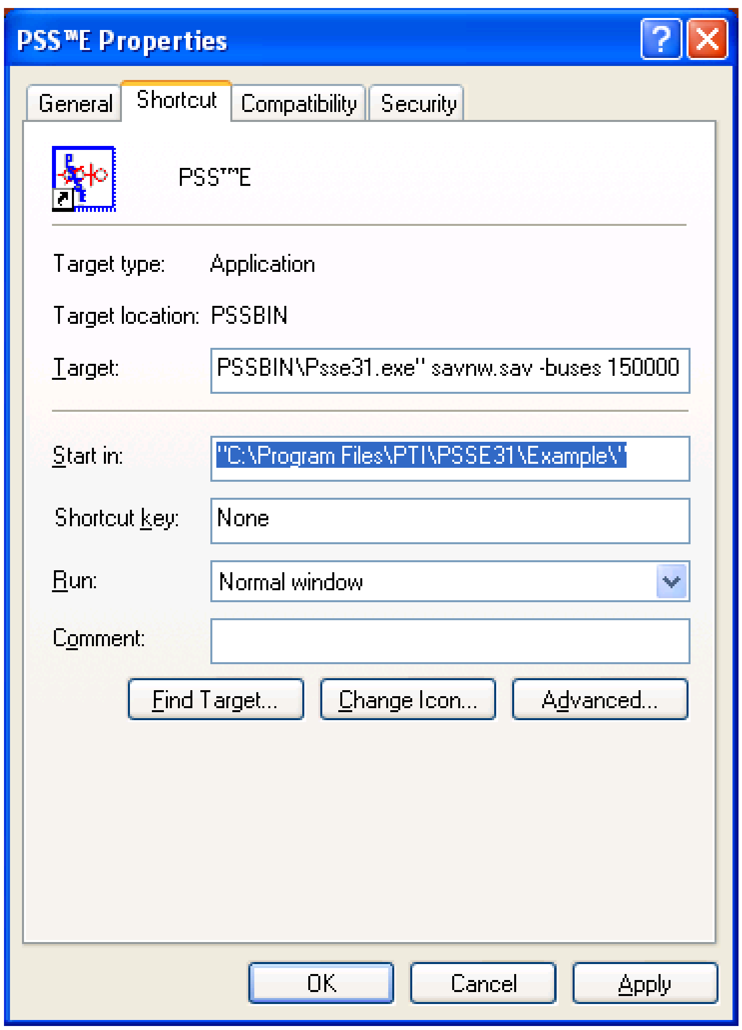


Figure 1-10. Identify the Working Directory

PSS™E requires that certain files reside in any working directory in which PSS™E is to be executed. Among these are the files on which PSS™E operates. Files containing input and output data for PSS™E, saved power flow binary files, and other files generated by PSS™E, may reside in the working directory or some other directory.

A set of arrays in PSS™E's address space contains a complete set of power flow data. The content of these arrays is referred to throughout this manual as the working case. The working case is modified by the load flow activities and is always a valid working case even though its voltages may not represent a solution of Kirchhoff's laws.

The working files are an integral part of the PSS™E package. The user never needs to reference these files by name but must be aware that processing may be performed on these files every time PSS™E is used. The names and general functions of the working files are:

FMWORK	Used by all activities involving the factorized system admittance matrix.
DSWORK	Used by dynamic simulation activities.
SCWORK	Used by power flow solution and unbalanced fault analysis activities.

On most systems, the working files have the extension *.BIN*.

The working files are used as scratch files by many PSS™E activities. Their contents are variable depending upon the recent sequencing and context of activity executions. The user of PSS™E does not need to be concerned with the specific contents of these files as long as the prerequisites listed for each activity are observed.

Before PSS™E can operate upon a power system model, the working files must be established in the user's directory. Upon initiation, PSS™E checks for the existence of the working files in the user's directory. If they are not present, PSS™E automatically creates them with a small amount of header information.

Once created, the user need not be concerned with the working files except to note that:

1. The working file filenames *FMWORK*, *SCWORK*, and *DSWORK* (with the appropriate host dependent suffix) must not be used for any other purpose.

2. The working files are accessed whenever PSS™E is executed.

3. Only one user may be executing PSS™E with a given set of working files at a time. Multiple simultaneous executions of PSS™E are permitted as long as each user utilizes a different set of working files.

1.6.4 Setting Program Options

Most PSS™E calculation and reporting functions recognize one or more program settings. When PSS™E is installed on the system, default PSS™E program settings are established. You may modify a given program setting during a PSS™E work session by selecting the ***Misc>Change program settings (OPTN)…*** option. The Program Settings dialog is displayed in Figure 1-11.

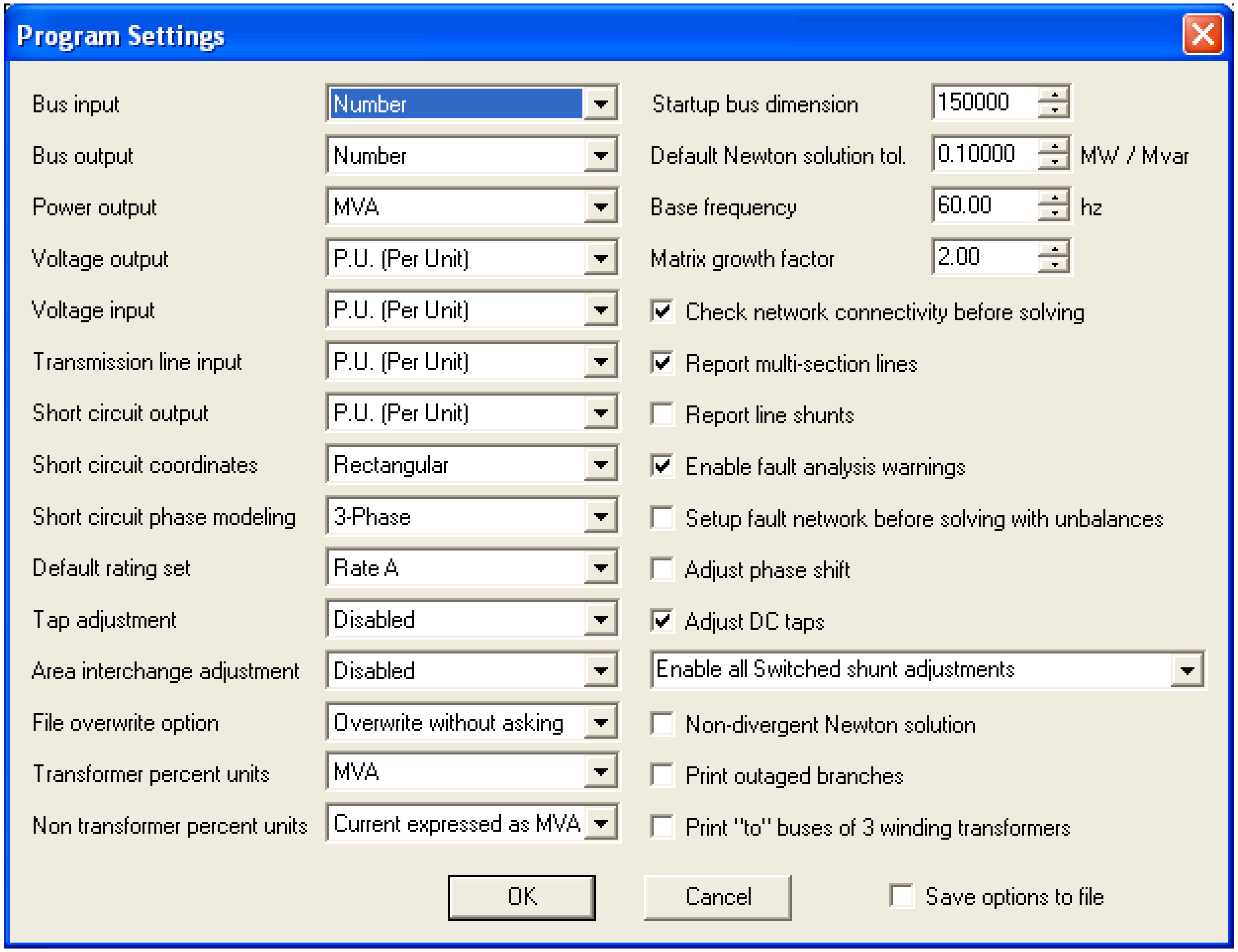


Figure 1-11. Program Settings Dialog

Bus Input: Buses are selected in the interactive dialog portions of PSS™E by either bus number ("Number" option) or extended bus name ("Extended Name" option). Extended bus names consist of the twelve-character alphanumeric name plus the bus base voltage.

Bus Output: Buses are ordered in PSS™E reports in either ascending bus number order ("Number" option) or alphabetical extended bus name order ("Extended Name" option).

Power Output: Power output may be output in units of either MVA or kVA.

Voltage Output: Voltages are tabulated in either per unit (pu) or kV.

Voltage Input: Voltages are reported and input in either per unit (pu) or kV.

Transmission Line Units: Transmission line (*not* transformer or generator) impedances input and/or output in either per unit (pu) or ohms; line capacitances are in either per unit or microfarads.

Short Circuit Units: Fault analysis results are tabulated in either physical units or per unit (pu).

Short Circuit Coordinates: Fault analysis results are tabulated in either rectangular (e.g., MW, Mvar) or polar coordinates (e.g., MVA, pf).

Short Circuit Phase Modelling: Fault analysis calculations handle either three-phase systems (3-Phase) modeled by their positive, negative, and zero sequence networks, or two-phase systems (2-Phase) used in some electric traction systems modeled by their positive and zero sequence networks.

Default Rating Set: Default branch rating used in power flow output and contingency analyses. Selections can be Rate A, Rate B, or Rate C.

Tap Adjustment: Sets the mode of tap adjustment in the solution process to be either Off, Step, or Direct.

- The **Off** mode suppresses transformer adjustments during the power flow solution.
- In the **Step** mode of tap adjustment each transformer is checked independently outside of the main power flow iteration. If the controlled voltage is outside of its specified band the tap ratio is moved at least one user-specified step.
- The **Direct** mode is a Newton-based method of tap adjustment. If any tap ratios need to be adjusted, a simultaneous adjustment is made of *all* voltage controlling transformers as well as all Mvar controlling transformers and all bus voltage magnitudes. Upon convergence of the main power flow iteration, tap ratios of controlling transformers are moved to their nearest step and the solution refined with tap ratios locked at those positions.

Area Interchange: Sets the mode of area interchange control.

- **Disabled** indicates to disable area interchange control.
- If **Tie lines only** is selected, an area's net interchange is defined as the sum of the flows on all of its tie lines; a tie line is a branch (ac line, dc line, or series FACTS device) connected to a bus residing in the area whose other end is connected to a bus that is not in the area. Tie flows are calculated at the metered end as power flowing out of the area.
- If **Tie lines and loads** is selected, a load whose area assignment differs from that of the bus to which it is connected is considered a tie branch for net interchange calculation purposes; that is, an area's net interchange includes tie line flows as

well as contributions from loads connected to area buses that are assigned to areas other than the bus' area, and from loads assigned to the area which are connected to buses assigned to other areas.

File Overwrite Option: If asked to save to a file that already exists, PSS™E may either automatically overwrite the file or ask the user before doing so.

Transformer percent units: Transformer percent loadings may be either percent MVA loadings or percent current loadings in the reports of a variety of output and analysis functions and the various AC contingency calculation reporting functions.

Non transformer percent units: Percent loadings on non-transformer branches may be either percent MVA loadings or percent current loadings in the reports of a variety of output and analysis functions and the various AC contingency calculation reporting functions.

Startup Bus Dimensions: Shows the current size level of PSS™E in terms of the maximum number of buses allowed. A new bus size level may be specified and will take effect when the program is restarted, assuming the **Save options to file** box is checked. This setting may be overridden by the user at the time PSS™E is initiated by specifying the "-buses" command line token followed by the desired bus dimension as described in Section 1.6.1.

Newton Solution Tolerance: The Newton Solution convergence tolerance (MW/Mvar) is set to this value when a Newton-Raphson solution is selected in PSS™E. This is the tolerance used to determine when the power flow has established convergence.

Base Frequency: The base or system frequency in Hertz (commonly 50 or 60 Hz).

Matrix Growth Factor: The matrix growth factor used in allocating working arrays by activities involving the ordering, factorization, or triangularization of network matrices. PSS™E updates this value as required, so that users do not normally need to be concerned with it.

Check Network Before Solving: The power flow solution activities may be instructed to perform a network connectivity check before beginning their voltage solution iterations. This ensures that all type one and two buses are connected back to a swing (type three) bus by in-service ac branches.

Report Multisection Lines: Multisection line groupings are either recognized or ignored in a variety of output and analysis functions, in the area interchange control option of the power flow solution activities and in the interchange subroutines accessible from IPLAN programs.

Report line shunts: Line shunt powers may optionally be reported in power flow output activities.

Enable fault analysis warnings: Certain warning messages can be either printed or suppressed in the fault analysis input and solution activities (i.e., missing generator data and sequence network isolated buses).

Setup fault network before solving with unbalances: Allows or suppresses automatic set-up of the factored matrix working file prior to running unbalanced fault analysis.

Adjust phase shift: Turns phase shift adjustment ON or OFF during the solution process.

Adjust DC taps: Locks or unlocks dc transformer taps during the solution process.

Switched shunt adjustments: Allows or suppresses the adjustment of switched shunts during the solution process.

Non-divergent Newton solution: Allows the voltage vector of diverging power flow iterations to be captured and the power flow solution to be terminated prior to blowing up when performing the fixed slope decoupled Newton-Raphson solution (FDNS), fully coupled Newton-Raphson solution (FNSL) or AC contingency analysis (see Section 4.3.9.6).

Print outaged branches: In the bus output blocks of output activities, out-of-service branches connected to the bus may optionally be listed.

Print "to" buses of 3 winding transformers: When reporting flows into three-winding transformer windings, the other two buses connected to the transformer may optionally be listed.

Save options to file: Checking this box saves the options settings to a binary file *psse.opt*. The file is saved in the current working directory, the location where the program was last invoked. This file must remain in the working directory, otherwise, the options will not be preserved. There is no default *psse.opt* file provided with the program installation. This file is created only when this option is checked.

If this option is not selected (checked), startup bus dimensions and other options will not be preserved.

1.7 Overview: Files Used by PSS™E

PSS™E takes full advantage of the file management capabilities of the host operating system. This allows PSS™E to be used at all times without the need to select file assignments before it is started up. As a result, the user has a great degree of flexibility in the use of files during a problem-solving session with PSS™E.

The user can instruct PSS™E to read from or write into virtually any existing file at any time and can have PSS™E create a new file at any time that it is needed. The prerequisite for full use of this capability is a sound understanding of the distinct classes of files used by PSS™E.

A file class is a distinction imposed by PSS™E, not by the computer’s file management system.

The two major types of files are:

1. Files created by the user – These are data files required for analysis, or batch and program control files used for directing the running of the program.

2. Files created by PSS™E – These are files generated when the user’s working case is saved, or output and results files are requested by the user.

Table 1-2 summarizes all classes of files used and created by the PSS™E Power Flow. With the exception of the Working Files and the PSS™E and OPF Options files, the user may assign any name to any file. The maximum filename or pathname length that PSS™E can handle is platform dependent, with the most restrictive platform able to handle 200-character filenames and pathnames. A file is always identified by this user-assigned name, both within the computer’s file management system and within PSS™E activities. The following subsections discuss these file classes in some detail.

Table 1-2. File Classes used in PSS™E (Power Flow)

File Class	Created By	Type	Accessible To
Input data files	User via text editor or auxiliary program	Source	PSS™E and user
Saved Case Files	PSS™E	Binary	PSS™E
Output listing files	PSS™E	Source	User
Response and Batch Process Command Files	User via text editor or PSS™E	Source	PSS™E and user
PSEB Command Files	User via text editor	Source	PSS™E and user
IPLAN Source Program Files	User via text editor	Source	IPLAN compiler and user
IPLAN Executable Program Files	IPLAN compiler	Binary	PSS™E
Python Program Files	User via text editor	Source	PSS™E and other Python supported applications (e.g., IDLE)
Options Files	PSS™E	Binary	PSS™E
Binary results files	PSS™E	Binary	PSS™E and other programs
Working files	PSS™E	Binary	PSS™E

1.7.1 Input Data Files

PSS™E must, from time to time, accept large volumes of data from external sources. Such large volumes of data could be typed directly into the PSS™E working case using the Spreadsheet View but this could be an onerous task. Voluminous data is best assembled in an input data file independent of PSS™E before PSS™E is started up. This file may then be used as the input source for PSS™E to feed the data through the appropriate input activity into the PSS™E working case.

Input data files may be obtained by reading from storage mediums (i.e. CD's) or e-mail attachments from external sources (other computer installations), or by the typing and file editing facilities of the host computer. In the case of power flow and dynamics data input, the input data files may often be created by reading and reformatting data obtained from other computer installations. While they are not a part of the PSS™E activity structure, reformatting programs are available for translating several widely used power flow and dynamics data formats into the PSS™E input format.

The principal PSS™E input data files are defined below. Their use in performing analysis is discussed in other chapters, as appropriate.

Power Flow Raw Data Files

These files contain power flow system specification data for the establishment of an initial working case. Several of these files may be read when a new power flow case is being built up from subsystem data being provided by several different power companies or organizations (see Section 3.2).

Machine Impedance Data Files

These files contain data describing the unit configurations at generator buses (plants) for input into the working case (see Section 3.3.5).

Dynamics Data Files

These files are used by the Dynamics simulation engine only. They contain data on synchronous machines and other system components as obtained from external data sources for input to the PSS™E dynamic simulation working memory (see the *PSS™E Program Operation Manual (POM) Vol I* and *II*).

Sequence Data Files

These files contain the negative and zero sequence data needed for unbalanced fault analysis (see Section 7.2).

Optimal Power Flow Raw Data Files

These files contain data on constraints and controls for defining and solving an optimal power flow problem (see the *PSS™E OPF Manual,* Chapter 4).

Economic Dispatch Data Files

These auxiliary data input files contain machine incremental heat rate data, fuel costs, and other data for performing its economic dispatch calculation. They are also used by the auxiliary program PLINC which plots incremental heat-rate curves (see Section 4.8.1).

Inertia and Governor Response Data Files

These auxiliary data input files contain machine inertia and governor response data for the generator redispatch used in the inertial and governor response power flow solution (see Section 5.6.1).

Linear Network Analysis Data Files

These auxiliary data input files define monitored elements, contingencies, and subsystems. They are used in linear network analysis applications such as transfer limit assessment (see Section 5.2.2).

Subsystem Participation Data Files

These auxiliary data input files define participation blocks for one or more of the subsystems defined in the Distribution Factor Data File used in interchange assessment (see Section 5.2.2.3).

Breaker Duty Data Files

These auxiliary data input files contain machine parameters used by the circuit breaker current interrupting duty analysis (see Section 7.9.2).

Fault Specification Data Files

These auxiliary data input files contain fault locations and fault duty times used by the circuit breaker current interrupting duty analysis (see Section 7.9.3).

ANSI Fault Specification Data Files

These auxiliary data input files contain fault locations, maximum operating voltages, and contact parting times used by the ANSI fault current calculation (see Section 7.10.1).

Fault Control Data Files

These auxiliary data input files contain various faulting and reporting options for use in fault calculations (see Section 7.8.3.1).

Machine Capability Curve Data Files

These auxiliary data input files contain machine capability curves for use by the reactive power limit checking and updating facility (see Section 4.4.5.3.1).

Load Throwover Data Files

These auxiliary data input files contain the bus load throwover data for use in contingency analysis (see Section 5.2.2).

Transactions Raw Data Files

These auxiliary data input files contain transaction event definitions that are used in Transmission Access studies (see Section 10.2).

Tripping Element Data Files

These auxiliary data input files contain tripping event specifications. They are required when multiple level contingency analysis is initiated with the selection of the Tripping simulation option (see Section 5.3.7).

Outage Statistics Data Files

These auxiliary data input files contain outage statistic data in the form of frequency and duration. They are required when performing probabilistic reliability studies (see Section 5.8.1.3).

Reading basic power flow data from input data files should be a relatively infrequent occurrence in PSS™E. Once an initial working case has been built up, the input data files should be set aside and all data changes and small additions should be made directly on the working case, specifically using the Spreadsheet View data editing capability. Attempts to keep a large input data file up to date with an ongoing power system study are usually both error prone and time consuming. PSS™E Saved Cases, as described in Section 1.7.2, are far more efficient vehicles for maintaining the power flow system database of a study. The PSS™E Power Flow has capabilities that allow power flow data, machine data, sequence data and optimal power flow data to be translated back into input data file form on those occasions when it is needed. These output processes are described in the appropriate sections.

1.7.2 Saved Case Files

The saved case file is a binary image of the load flow working case. To conserve disk space and minimize the time required for storage and retrieval, saved cases (*.sav*) are compressed in the sense that unoccupied parts of the data structure are not stored when the system model is smaller than the capacity limits of the program.

The user may create as many saved cases as desired. Each saved case is a complete power flow data set including analysis results that may be imported into PSS™E as a new base case at any time. Similarly, PSS™E Dynamics utilizes a binary snapshot file to store dynamics working memory (see the *PSS™E Program Operation Manual (POM) Vol I* and *II* for descriptions of dynamic activities and processes).

1.7.3 Output Listing Files

The majority of PSS™E report-generating functions may write their output to either the Report tab, a printer device or to a named file. When an output listing file is selected, the report is written into that file in exactly the same format as if it were being printed directly to a printing device.

Once written, the output listing file is available to all standard file manipulation functions; it may be printed, transferred to a backup medium, examined with a text editor, or simply discarded.

1.7.4 Response Files

These files allow the PSS™E user to automate the execution of a sequence of activities. A response file is an ordinary source file that is typed in by the user with a text editor *before* starting up PSS™E. The file would comprise a sequence of operations expressed as "BAT_" record(s) corresponding to activities and menu bar functions sequentially executed from the menu bar by the user.

Alternatively, the user can have the program record a sequence of operations or calculations which the user performs manually. That sequence of events is then stored in a file for subsequent use in automatically repeating the entire process. PSS™E can record the sequence of operations as "BAT_" commands. Activity names referenced in Response Files are currently supported, but only if they are entered through a text editor.

1.7.5 PSEB Command Files

These allow the PSS™E user to specify many routine power flow simulation runs in English sentence form. These files are ordinary source files that are typed in by the user with a text editor before starting up PSS™E. Each record is in the form of a command starting with a verb from a defined vocabulary. PSEB files may be executed from the PSS™E menu option ***IO Control>Run Program Automation File…***. See the *PSS™E Program Operation Manual (POM) Vol I* and the *PSEB User's Ready Reference* for information on the commands

1.7.6 PSAS Command Files

These allow the PSS™E user to specify many routine dynamic simulation runs in English sentence form. These files are ordinary source files that are typed in by the user with a text editor before starting up PSS™E. Each record is in the form of a command starting with a verb from a defined vocabulary. PSAS files may be executed from the PSS™E menu option ***IO Control>Run Program Automation File…***. See the *PSS™E Program Operation Manual (POM) Vol I* and the *PSAS User's Ready Reference* for information on the commands.

1.7.7 IPLAN Program Files

The user may define and implement processing and/or reporting functions in PSS™E via the IPLAN programming language. Programs written in this language are typed in by the user with a text editor and compiled with the IPLAN compiler program *before* starting up PSS™E. The resulting IPLAN Executable Program File may then be executed from the PSS™E menu option ***IO Control>Run program Automation file…***. For details on the IPLAN language, its hooks into the PSS™E working case, and the use of its compiler, refer to the *IPLAN Program Manual*.

1.7.8 Python Program Files

The user may define and implement processing and/or reporting functions in PSS™E via the Python programming language. Python scripts, or programs written in this language are generated by using a text editor or created by PSS™E's program automation capability. Python scripts may be executed from the PSS™E menu option ***IO Control>Run Program Automation File…***. Python commands may also be typed in directly through PSS™E's command line interface.

1.7.9 Binary Results Files

Several PSS™E functions output binary files intended to be used by other PSS™E functions. These can be read only by PSS™E. An example would be the distribution factor data file (.dfx) created for use in linear network analysis applications.

1.7.10 PSS™E Options File

When PSS™E is installed on the system, a set of default run-time options is established (see Section 1.6.4). Options settings may be modified and saved to the *PSSE.opt* file. Whenever PSS™E is subsequently started up, it first searches for this options file in the user's working directory. If the file does not exist in the working directory, the program will then search the user's home directory and subsequently the appropriate PSS™E master directory. If an options file is found, it is read in, and new default options settings are established. The PSSE.opt file is saved when PSS™E program settings are changed and the ***Save options to file*** option is checked.

1.7.11 Working Files

The working files are an integral part of the PSS™E package. The user never needs to reference these files by name but must be aware that processing may be performed on these files every time PSS™E is used (see Section 1.6.3).

1.8 Data In Non-PSS™E Formats

It is often desirable to be able to utilize data for a system model that might have been set up for a a program other than PSS™E. To that end, a group of auxiliary programs is supplied with PSS™E which, though not a part of the PSS™E activity structure, are valuable data preparation tools. They are listed below along with descriptions of other conversion programs used to convert PSS™E data files from and to earlier release data formats.

CMDYRE	From a PSS™E Dynamics Data File and a Machine Impedance Data File, builds a file containing card image records in the IEEE format for the exchange of stability data.
CNV27	From a Power Flow Raw Data File in the format required for PSS™E-24 through PSS™E-26, builds a Power Flow Raw Data File in the form required by PSS™E-27 or PSS™E-28, and then provides for the conversion to PSS™E-27 or later of any corresponding Sequence Data File which is in the form required for PSS™E-22 through PSS™E-26.
CNV29	From a Power Flow Raw Data File in the format required for PSS™E-27 or PSS™E-28, builds a Power Flow Raw Data File in the form required by PSS™E-29.
CNV30	From a Power Flow Raw Data File in the format required for PSS™E-29, builds a Power Flow Raw Data File in the form required by PSS™E-30.
CNVDRW	From a Drawing Coordinate Data File in the format required for PSS™E-15 through PSS™E-23, builds a Drawing Coordinate Data File in the form required by PSS™E-24 or later.
CNVRAW	From a Power Flow Raw Data File in the format required for PSS™E-15 through PSS™E-23, builds a Power Flow Raw Data File in the form required by PSS™E-24 through PSS™E-26.

CNVRSQ	From a Sequence Data File in the format required for PSS™E-21 or earlier, builds a Sequence Data File in the form required by PSS™E-22 through PSS™E-26.
COMDAT	From a file containing card image records in the IEEE format for the exchange of stability date, builds a PSS™E Dynamics Data File and a Machine Impedance Data File.
COMFOR	From a file containing load flow data records in IEEE Common Tape Format, builds a PSS™E-24 Power Flow Raw Data File.
ConvertRaw	Converts Power Flow Raw Data Files from PSS™E-15 format or later to any more recent Power Flow Raw Data File format, include PSS™E-31.
CreateRaw	Creates Power Flow Raw Data Files, back to PSS™E-15 format, given a PSS™E-31 Saved Case File.
PSAP4	From a file containing card image records in the PJM PSAP Version 4 or 5 power flow program data format, builds a PSS™E-23 Power Flow Raw Data File.
RAW23	From a PSS™E Saved Case File, builds a PSS™E-23 Power Flow Raw Data File.
RAW26	From a PSS™E Saved Case File, builds a PSS™E-26 Power Flow Raw Data File.
RAW28	From a PSS™E Saved Case File, builds a PSS™E-28 Power Flow Raw Data File.
RAW29	From a PSS™E Saved Case File, builds a PSS™E-29 Power Flow Raw Data File.
WECCLF	From a file containing records in the new Western Electricity Coordinating Council (WECC) power flow program data format, builds a PSS™E Power Flow Raw Data File.
RAWECC	From a PSS™E Saved Case File, builds a file containing records in the new WECC power flow program data format.
WECCDS	From a file containing records in the WECC stability program data format, builds a PSS™E Dynamics Data File, a Machine Impedance Data File, and a PSS™E Response File.

1.9 Using PSS™E Files

Before PSS™E can be started up, the user must organize and gather together any data and files needed for input. Files needed for PSS™E output and Saved Cases will be created by PSS™E as needed. The importance of planning and noting the contents of PSS™E-created files, as well as user input files, cannot be overemphasized. It is strongly recommended that, along with study notes, the engineer keeps a record identifying the names and contents of all significant files used in a particular study. A PSS™E File Planning Sheet of the form shown at the end of this chapter is suggested.

On completion of data collection, the user will have a completed file planning sheet giving the names of all files to be used in the initial phases of a study. The user will also have written out (in study notes, in spreadsheets, etc.) the input data that must be placed into the PSS™E input files.

The types of data files used by PSS™E, the activities that use them, and the default extensions or suffixes used when specifying filenames are summarized in Table 1-3. Except as described below, whenever a file type listed in the table is being specified to PSS™E, the extension designated in the table is automatically appended to the filename if the user specifies a filename without an extension. For file types not listed in Table 1-3 a platform dependent default extension is used.

PSS™E writes out various types of data in the form of input files for use by other PSS™E activities, and uses platform dependent default extensions. The data output processes which perform this function are listed in Table 1-4.

Input files need not be created if the activities that use them are not going to be executed.

1.10 Deleting PSS™E Files

The user may instruct PSS™E to create as many output listing files as are needed. It is good practice, however, to limit the number of such files since they can use a large amount of disk storage capacity. Soon after being created, output listing files should be processed (e.g., copied from disk to a backup medium for archival purposes) and then deleted from the disk.

If the user does not exercise discipline in this regard, confusion could result even if the user is careful in noting the significance of each file on a file planning sheet. Furthermore, disk space is unnecessarily wasted and, although disks have large capacities, they are finite.

Files that are not current, but need to be retained for documentation or archival purposes, should be kept on some off-line bulk storage medium.

The user is referred to the appropriate computer system documentation for details on the mechanics of archiving and deleting files.

1.11 Specifying PSS™E Filenames

In specifying filenames to PSS™E, entering a simple filename always results in PSS™E attempting to access the specified file in the user's current directory; specifying the complete pathname of a file allows the user access to other directories for which he has the appropriate privileges. In addition, PSS™E provides a shorthand method of designating the directory path component of a complete pathname (see Section 2.16.4). Then, anytime a simple filename is preceded by an ampersand ("&") when specified in PSS™E (e.g., &*case1* in the file input field), the ampersand is replaced by the specified directory path component and the resulting pathname is used as the filename.

PSS™E files over which the user has no naming control are generally accessed from the current directory or from some other system default directory (e.g., the "TEMP" directory on Windows® systems). This includes files such as the PSS™E working files, temporary files used during graphics-related activities, and so on. (PSS™E also looks to the user's "home" directory and to its own master directories for a PSS™E Options File, for output device parameter files, and for several other types of files if they are not found in the user's current directory; see Section 1.6.3).

1.12 Summary: PSS™E Files

The use of files by PSS™E gives the user great freedom in adapting handling of input, recording of cases, and output to suit the work as it progresses. As with all systems that give a user great flexibility and many options, PSS™E also gives the user the responsibility of managing available options and files in this case.

This mode of operation has been found in thousands of man-years of use of PSS™E and its predecessors to be the preferred way of handling files. It simply requires that the user keep effective records of the files that created. The best form of record is a concise written catalog to which the user can refer during use of PSS™E, together with a systematic way of assigning filenames. The catalog may take the form of the PSS™E File Planning Sheet shown at the end of this chapter.

PSS™E is able, at any time, to write over the contents of a file that had previously been created. PSS™E does not generally append to files; each time that a user specifies a file's name for saving and output processes, the writing commences at the *start* of that file, destroying the previous contents. The ***Misc>Change program settings (OPTN)…*** activity does offer a File overwrite option that can be set to either "Overwrite without asking" or "Ask first"; see Section 1.6.4.

Table 1-3. PSS™E Data File Summary

PSS™E Designation	Extension	File Type	Essential / Optional
Saved Case File	sav	Binary	One is essential. More are optional.
Snapshot File (Dynamics)	snp	Binary	One is essential. More are optional.
Source Form Snapshot File (Dynamics)	srs	Source	Optional
Channel Output File (Dynamics)	out	Binary	One is essential. More are optional.
Power Flow Raw Data File	raw	Source	Essential
Dynamics Data File (Dynamics)	dyr	Source	Optional
Machine Impedance Data File	rwm	Source	Optional
Sequence Data File	seq	Source	Optional
Optimal Power Flow Raw Data File	rop	Source	Optional
Economic Dispatch Data File	ecd	Source	Optional
Inertia and Governor Response Data File	inl	Source	Optional
Breaker Duty Data File	bkd	Source	Optional
Fault Specification Data File	bkf	Source	Optional
ANSI Fault Specification Data File	ans	Source	Optional
Fault Control Data File	fcd	Source	Optional
ASCC Relay Output File	rel	Source	Optional
Bus Subsystem Selection Data File	sbs	Source	Optional
Subsystem Description Data File	sub	Source	Optional
Monitored Element Data File	mon	Source	Optional
Contingency Description Data File	con	Source	Optional
Distribution Factor Data File	dfx	Binary	Optional
Load Throwover Data File	thr	Source	Optional
ACCC Solution Output File	acc	Binary	Optional
Subsystem Participation Data File	prt	Source	Optional
Machine Capability Curve File	gcp	Source	Optional
Transactions Raw Data File	mwm	Source	Optional
Bus Renumbering Translation File	trn	Source	Optional
Compiling Command File	*	Source	Optional
Relay Characteristic Data File (Dynamics)	rlc	Source	Optional

Table 1-3. PSS™E Data File Summary (Cont.)

PSS™E Designation	Extension	File Type	Essential / Optional
Response File	idv	Source	Optional
PSEB Command File	pse	Source	Optional
PSAS Command File (Dynamics)	psa	Source	Optional
IPLAN Executable Program File	irf	Binary	Optional
Conversion Program Log File	log	Source	Optional
IEEE Common Format Data File	*	Source	Optional
PSS™E Options File	OPT	Binary	Optional
Optimal Power Flow Options File	OPT	Binary	Optional
Working Files	*	Binary	Essential

Platform dependent.

Table 1-4. PSS™E Output Activities for Creating Data Files for Other PSS™E Applications

Menu Item	Function
File>Renumber buses in auxiliary files (RNFI)… (if Spreadsheet View is active) or ***File>Renumber buses in Diagram (RNFI)…*** (if Diagram View is active)	Uses file created by bus renumbering activity to change bus numbers in other auxiliary files.
File>Save or Show Select **Power Flow Raw Data** tab.	Creates a raw data file in PSS™E format.
File>Save or Show Select **Power Flow Raw Data, Previous Versions** tab	Creates a raw data file in previous PSS™E formats e.g. PSS™E-24
File>Save or Show Select **Sequence Data** tab.	Creates a file of sequence data from the working case for PSS™E fault analysis.
File>Save or Show Select **Optimal Power Flow Data** tab.	Creates an optimal powerflow data file in PSS™E OPF format.
File>Save or Show Select **Machine Impedance Data** tab.	Creates data file for use in augmenting powerflow with machine data.
File>Save or Show Select **Transaction Data** tab.	Creates report on transaction data for import to transmission access studies.
File>Save or Show Select **IEEE Format Power Flow Data** tab	Create a file of power flow data from the working case, in IEEE common format.
File>Save or Show Select **UCTE Data** tab	Create a file of power flow data from the working case, in UCTE-2 common format
Power Flow>Renumber Buses	Creates a file of original bus numbers to be changed, and the new bus numbers.

1.13 Other Auxiliary Programs

Section 1.8 lists several "data conversion" auxiliary programs which convert power system analysis data between PSS™E data formats and those of other programs. It also lists a set of programs that convert PSS™E data between the formats used in the current release of PSS™E and the corresponding formats used in earlier releases of the program.

The following auxiliary programs are also used outside of the main PSS™E program structure. This group includes programs to analyze and/or prepare data to be used as input to PSS™E, as well as programs to process files containing the results of certain PSS™E calculations.

ACCCBrwsGrid	This application, provided on the PC platform only, will post-process the AC Contingency Calculation's output file and provide spread sheet style reports of these results.
DBUILD	Incorporates information on user-written plant-related models into the data file used by the dynamics data modification utility.
IMD	Induction motor model data verification program.
IPLAN	Compiles programs written in the IPLAN programming language in preparation for their execution in PSS™E as an automation file.
LineProp	Transmission line constants calculation program, available on the PC platform only, with a modern user interface.
LSYSAN	Used to perform small disturbance dynamic analysis. This program is supplied to those whose lease includes the Linear Dynamic Analysis Program section.
PLINC	Plots incremental cost curve data as contained in an Economic Dispatch Data File.
PSSPLT	Processes PSS™E dynamic simulation Channel Output Files.
TMLC	Calculates the transmission line constant data required by many power system analysis programs including PSS™E. TMLC is supplied to only those users licensed for the Transmission Line Characteristics program section. Users on the PC are also supplied with the LineProp auxiliary program.
VCV	Plots generator "V-curves".

PSS™E File Planning Sheet

Name of Study:______________________________ Directory Name:____________________________

	Filename	Description
1.	Power Flow Raw Data Files (input data, source)	
a.	__________	__________
b.	__________	__________
2.	Diagram Data Files (input data, source and/or binary)	
a.	__________	__________
b.	__________	__________
3.	Dynamics Data Files (input data, source)	
a.	__________	__________
b.	__________	__________
4.	Load Flow Saved Case Files (saved case, binary)	
a.	__________	__________
b.	__________	__________
c.	__________	__________
d.	__________	__________
5.	Simulation Snapshot Files (snapshot, binary)	
a.	__________	__________
b.	__________	__________
6.	Sequence Data Files (input data, source)	
a.	__________	__________
b.	__________	__________
7.	Optimal Power Flow Data Files (input data, source))	
a.	__________	__________
b.	__________	__________
8.	Other Auxiliary Files (input data, source)	
a.	__________	__________
b.	__________	__________
c.	__________	__________
d.	__________	__________
9.	Linear Network Analysis Data Files (input data, source)	
a.	__________	__________
b.	__________	__________
c.	__________	__________
d.	__________	__________
10.	Channel Output Files (output, binary)	
a.	__________	__________
b.	__________	__________
11.	CONEC and CONET Subroutine Files (FORTRAN, source)	
a.	__________	__________
b.	__________	__________

Figure 1-12. PSS™E File Planning Sheet

Chapter 2

The User Interface

2.1 Components of the User Interface

The objective of this chapter is to describe the features and use of the PSS™E Interface.

The different components of the PSS™E Interface include the following:

- **Tree View:** All network items are represented as selectable elements in a hierarchical list. Items in the list are organized by data type and reside in expandable/collapsible folders.
- **Spreadsheet View:** All network data is presented in the Spreadsheet View. Tabs along the bottom of the Spreadsheet View allow selection and editing of the various data categories. The Spreadsheet View only appears when a case is opened.
- **Output Bar:** All progress and report output is directed toward this expandable window. Tabs along the bottom allow selection of reports and progress output.
- **Diagram View:** Facilitates the creation and display of one-line diagrams in the new Slider format. In addition to the display of power flow results, the **Diagram View** facilitates the building of new diagrams and networks bus by bus. Further, for existing power flow cases, this view enables the "growing" of one-line diagrams by automatically drawing selected buses and all their equipment and connected buses. The Diagram View appears only when a diagram is opened or created.
- **Toolbars:** Allows convenient selection of analytical tools, creation of one-line diagrams, generation of reports, selection of subsystems, and view management.
- **Main Menu:** Provides access to file handling, interface views, analytical functions, automation tools, I/O formatting, toolbar organization and online help.
- **Status Bar:** Provides information related to the diagram status and operating mode.

Figure 2-1 shows the main components of the interface. At startup only the **Output Bar** together with the Main Menu and toolbars will be shown. The populated Spreadsheet View will appear when a power flow case file or raw data file is imported.

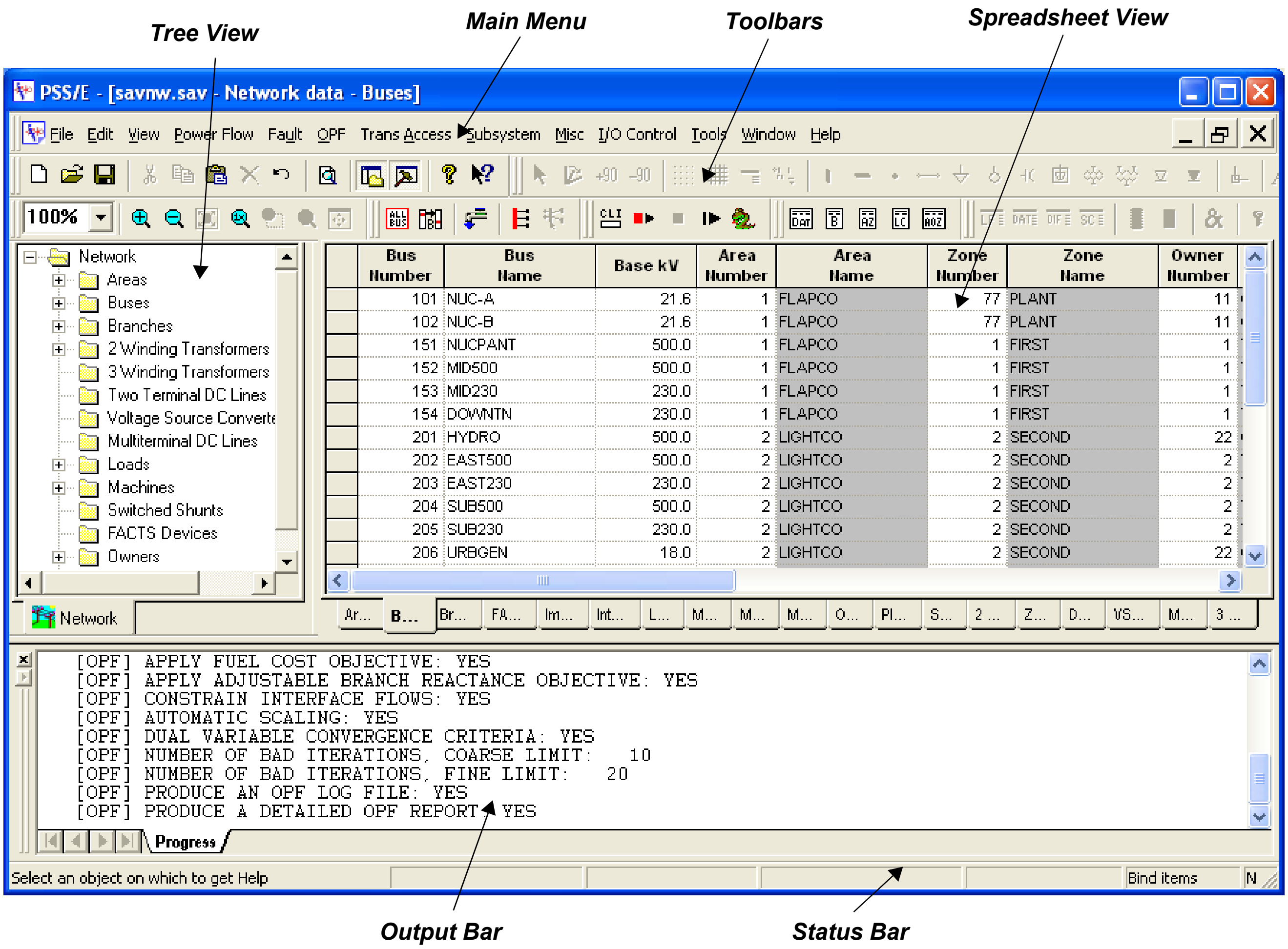


Figure 2-1. Overview of the PSS™E Interface

The Tree, Spreadsheet, Output and Diagram Views can be individually re-sized and located anywhere on the interface between the **Status Bar** and toolbars.

Although existing PSS™E DRAW files can be imported, diagrams can be saved only in the Slider format (.sld). The new diagrams are *not* backward compatible with the PSS™E DRAW/DRED activities used to display and edit one-line diagrams in earlier versions of PSS™E.

Figure 2-2 shows an example of a one-line diagram display of a power flow solution using the PSS™E Diagram View.

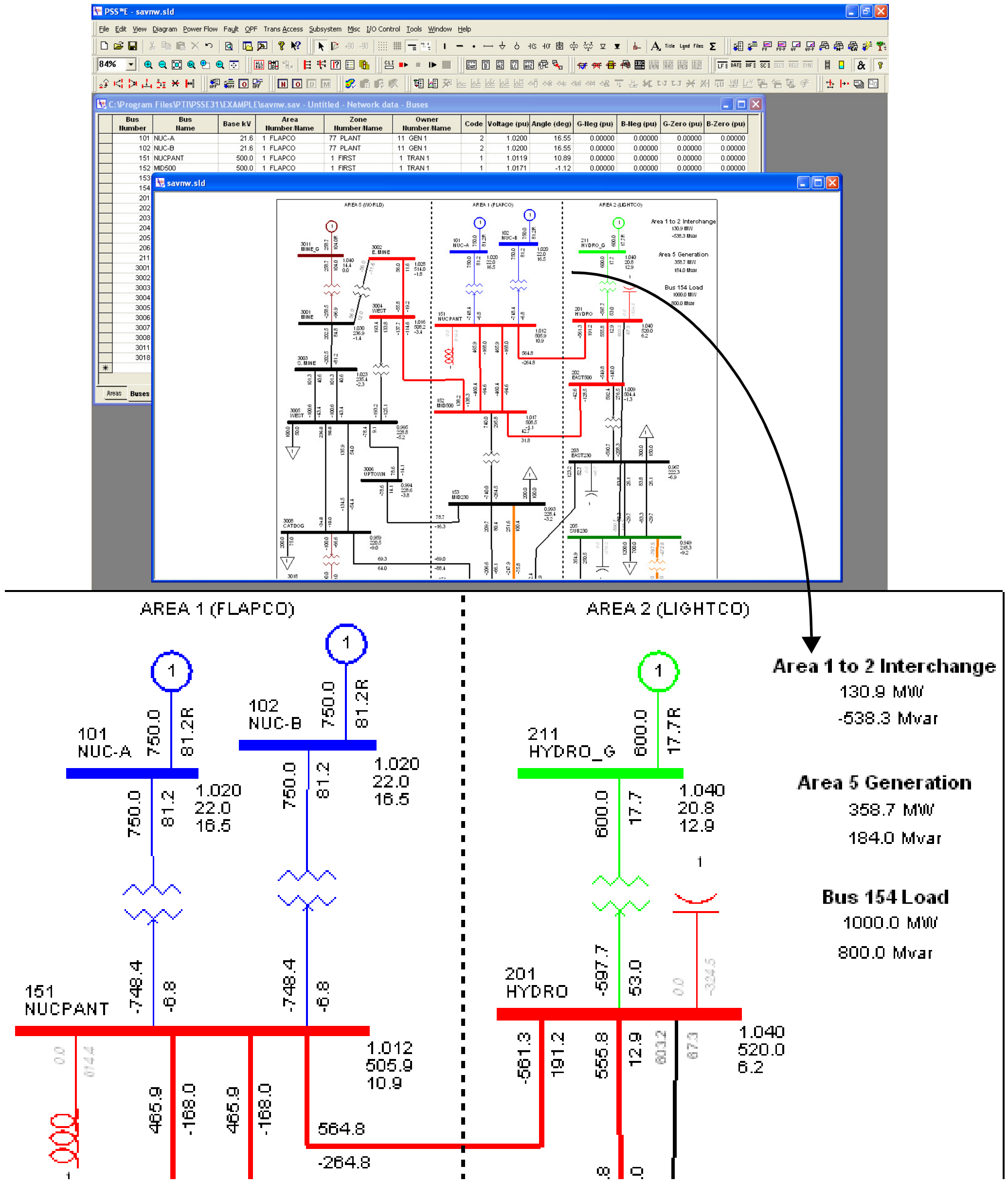


Figure 2-2. Diagram View Showing Power Flow Results

2.2 Managing Views

2.2.1 Views at Program Startup

As the program is launched, by default only the Main Menu and toolbars are displayed. The **Tree View, Output Bar** and the **Status Bar** will appear only if they were visible when the previous PSS™E session was closed. The **Spreadsheet View** will appear when a new case is opened or a PSS™E saved case or raw data file is opened.

The **Spreadsheet View** is the default view as cases are opened. It can be minimized and restored but will remain available until the user exits the program.

2.2.2 Opening and Hiding Views

The user can open and close (hide) the **Tree View**, **Output Bar** and the **Status Bar** by toggling the ***View*** menu items (see Figure 2-3).

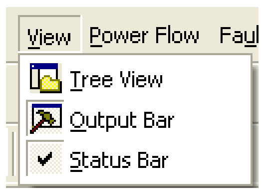
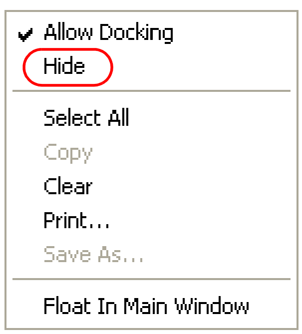
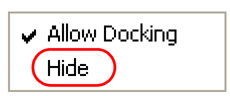


Figure 2-3. Open/Close View Menu

An alternative way to hide, or close, the Views is to right-click within the view and select the ***Hide*** option (see Figure 2-4). Use the ***View*** menu from the main menu to reopen them.



Output Bar Right-click Menu



Tree View Right-click Menu

Figure 2-4. Hiding the Output Bar and Tree View

2.2.3 Docking and Undocking Views

Right-clicking in the **Tree View** or **Output Bar** brings up a menu consisting of an **Allow Docking** option (see Figure 2-4). Toggling the ***Allow Docking*** ON and OFF allows the corresponding View to float as a window or be docked to the main PSS™E Window. When undocked, the two views can be moved at will and resized (see Figure 2-5).

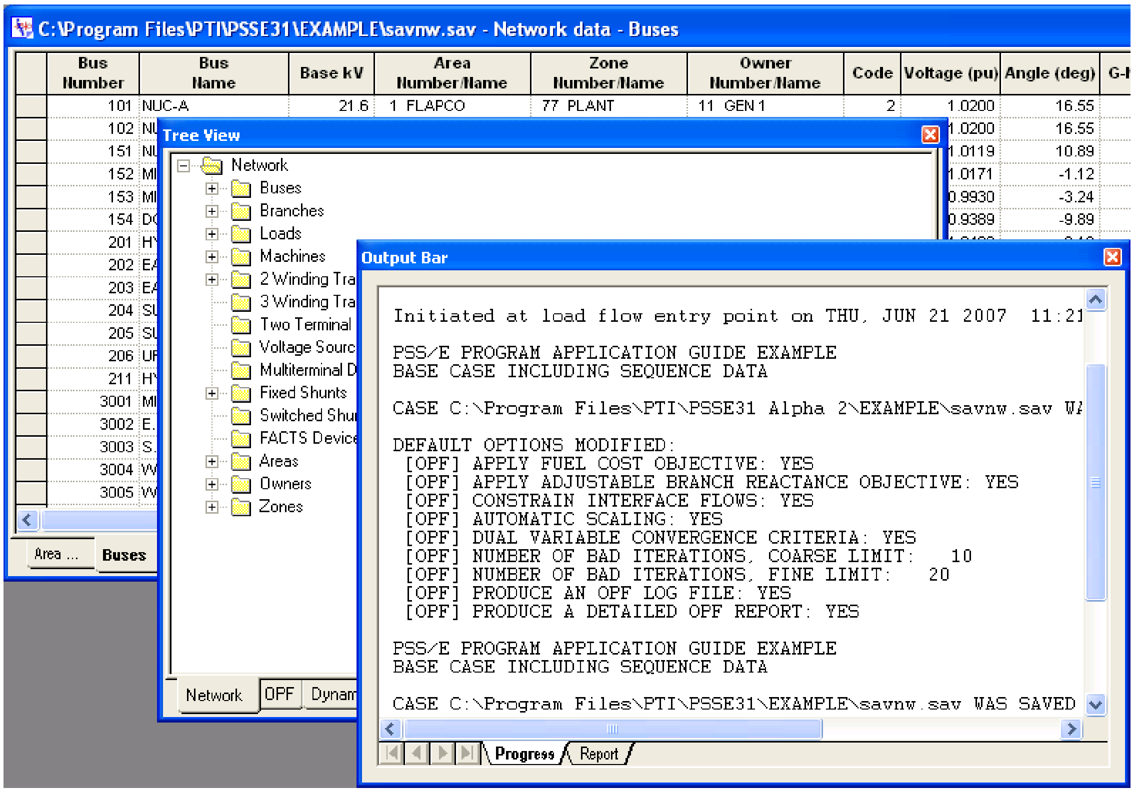


Figure 2-5. Undocking the Tree View and Output Bar

The **Diagram View** and Spreadsheet View can not be undocked but can be controlled using the standard Windows® controls found in the upper right corner of the window (i.e., Minimize, Maximize, Move, etc.). This allows the windows to be "layered" and relocated within the PSS™E main window.

2.3 Tree View

The **Tree View** (Figure 2-6) provides a quick glance at all network data in the system. The **Tree View** is synchronized with the bus subsystem selector to enable the user to reduce the amount of network data presented at any one time. Folders can be expanded or collapsed to control the amount of data visible. Only one folder may be expanded at a time. Expanding a folder while another is already expanded will cause the expanded folder to collapse and the new folder to be expanded.

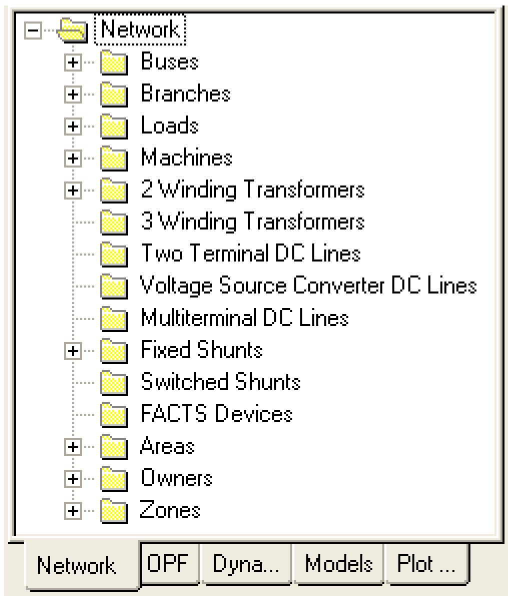
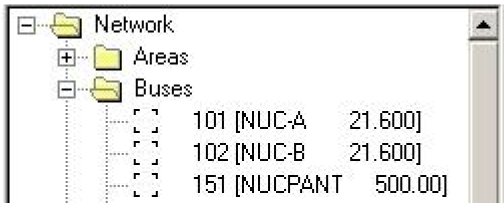


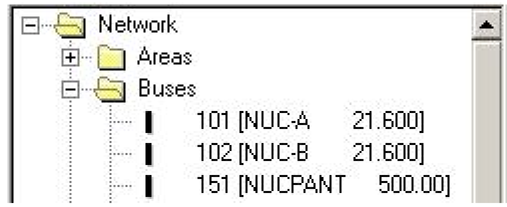
Figure 2-6. Tree View

When a **Diagram View** is active the data items in the **Tree View** are updated to reflect whether that particular item is drawn in the diagram or not. If the item is not drawn, then the symbol to the left of the item is blank. If the item is drawn, the symbol to the left of the item is filled with the symbol belonging to the data category (i.e., bus, branch, etc.). Refer to Figure 2-7b where a bus symbol is drawn.

The symbols in the **Tree View** are refreshed whenever a **Diagram View** is made active. A network item can be drawn in one **Diagram View** and not another, so the symbols found in the **Tree View** give a quick visual cue as to whether the network item is drawn in the active **Diagram View**. When the Spreadsheet **View** is active, all symbols are replaced with blanks.



(a) There is no active diagram with these buses drawn.



(b) These three buses are drawn in the active diagram where this symbol is used for buses.

Figure 2-7. Items Drawn in Active Diagram View indicated in the Tree View

2.3.1 Tree View Pop-Up Menus

A number of different pop-up menus are available by clicking the right mouse button (hereafter referred to as right-click) in and on items in the **Tree View**. The various pop-up menus are described below.

As was discussed in Section 2.2.2, a right-click in a blank area of the **Tree View** (without selecting a data category) will display the standard pop-up View Menu from which hiding/exposing and docking/undocking the view can be selected (see Figure 2-4).

Hide: Closes the view. The user must use the ***View*** men from the main menu to reopen them.

Allow Docking: Toggles whether the View is to be docked or a free-floating window.

2.3.1.1 Right-Click on a Tree View Data Category

Right-clicking on a specific **Tree View** data category (i.e., Branches) displays a pop-up menu (see Figure 2-8). In addition to the selections shown in Figure 2-4, the Sort option is added to the menu.

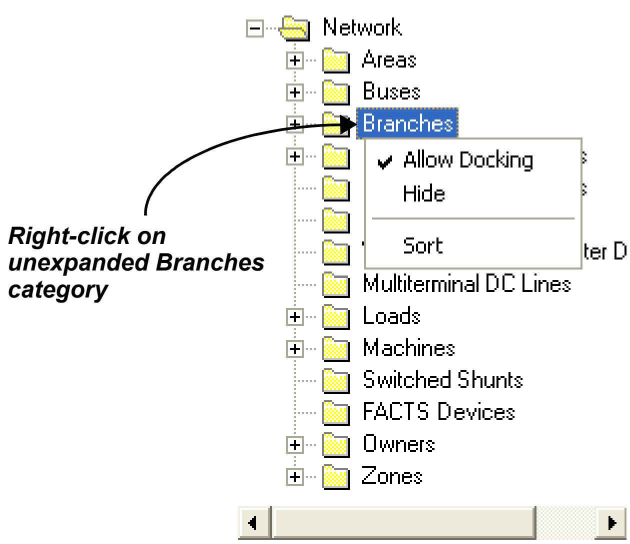


Figure 2-8. Accessing the Sort Option

The *Sort* option causes all items in the selected data category to be sorted in ascending alphanumeric order.

2.3.1.2 Right-Click on an Expanded Data Category Header

If the **Diagram View** is open and active (on top), then right-clicking on a **Tree View** data category that has an expanded list will display the pop-up menu shown in Figure 2-9. In addition to the selections shown in Figure 2-8, the ***Assign all items to Layer*** option is added to the menu.

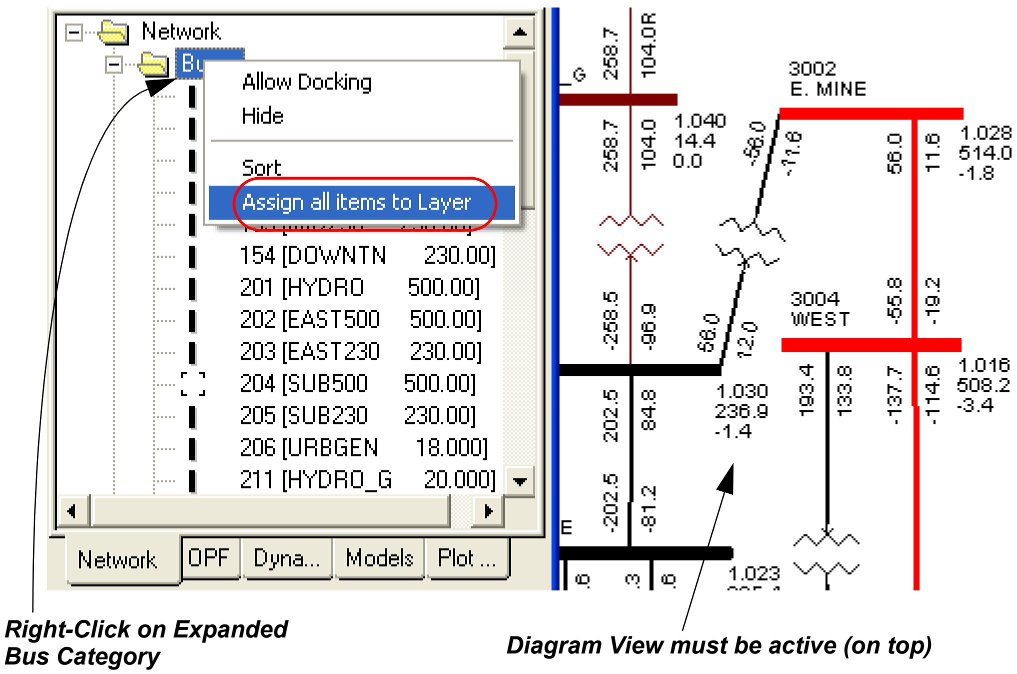


Figure 2-9. Assign Items to Layers from Right-Click Menu

The Assign all items to Layer option displays the **Select Layer** dialog. If a layer selection is made from this dialog, all drawn items in the expanded list will have their diagram layers re-assigned and the **Diagram View** will be refreshed. This tool can be useful for assigning network items to layers for existing or imported diagram views.

If elements are assigned to a layer that is not currently visible, assigning them to that layer will cause them to disappear from the display. Refer to Section 2.5.10 to see the discussion on managing layers in the **Diagram View**.

2.3.1.3 Right-Click on a Data Element within an Expanded Data Category

Right-clicking on a Tree View data item (i.e., a particular bus) in an expanded category list displays different menus depending upon the data element selected and whether the Diagram View is active or not.

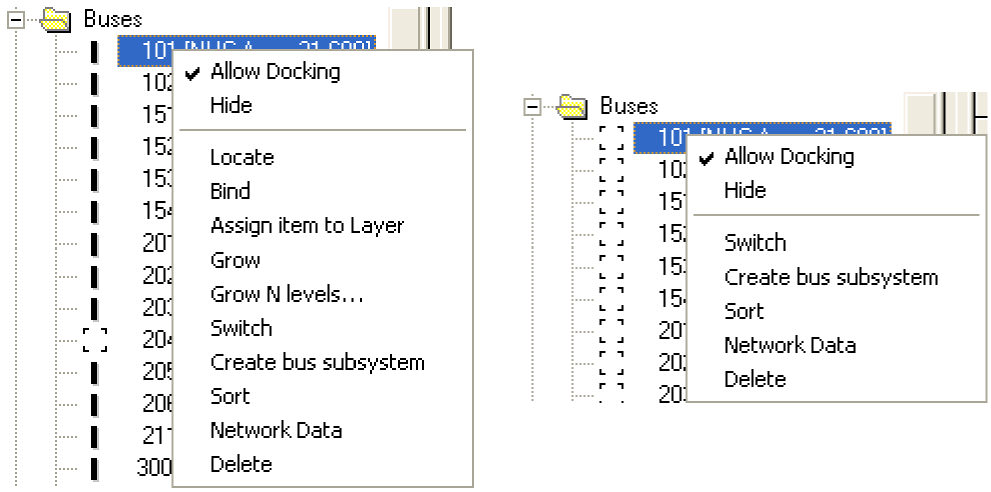


Diagram View Active ***Spreadsheet View Active***

Figure 2-10. Menu from Right-Clicking on Data Item in Expanded List

If the pop-up menu is launched with the Spreadsheet View active, the following menu options are available:

> **Switch:** Toggles the switch status of the selected network element (i.e., disconnects the device).
>
> **Network Data:** Points to the selected network element in the Spreadsheet View on the relevant data tab, and places the focus on the first spreadsheet cell of the selected item.
>
> **Delete:** Deletes the network element from the model.

If the selected element is a bus, area, zone or owner, the menu offers the user the ability to create a subsystem based on the selected element.

> **Create bus subsystem:** Create a bus-based subsystem. (i.e., filters the model by a set of selected buses).
>
> **Create area subsystem:** Create an area-based subsystem. (i.e., filters the model by a set of selected areas).
>
> **Create zone subsystem:** Create a zone-based subsystem. (i.e., filters the model by a set of selected zones).
>
> **Create owner subsystem:** Create an owner-based subsystem. (i.e., filters the model by a set of selected owners).

If the Diagram View is the active view, then the right-click menu for the selected element will offer some additional options:

Assign to Layer: Displays the **Select Layer** dialog. If a layer selection is made from this dialog, the network element can be assigned to a Diagram layer and the **Diagram View** is refreshed. This tool can be useful for assigning a network item to a layer for existing or imported diagram views.

Locate: The Locate menu option is available if the selected element is drawn in the diagram. It allows you to easily locate the element on the diagram.

Bind: Bind literally relates the model element to a graphical element on the diagram. Selecting an "unbound" element on the diagram, then selecting ***Bind*** from the right-click menu forces PSS™E to couple the two together. The Bind option is discussed in more detail in Section 2.9.8.

If the selected item is a bus and it is *not drawn* in the active Diagram View, then the Draw menu option become available:

Draw: Selecting ***Draw*** from the pop-up menu draws the bus and all its equipment in the active **Diagram View**.

If the selected item is a bus and is drawn in the active Diagram View, then only the Grow option is available.

Grow: Selecting ***Grow*** will draw the bus, all its equipment, all connected buses and their equipment, and all the lines and transformers between them. Grow differs from Draw in that Draw only draws the bus and it’s equipment.

Grow N Levels*...*: Selecting ***Grow N Levels...*** will draw the bus, all its equipment, all connected buses and their equipment, and all the lines and transformers between them. Then this will continue on to draw the next level of connected buses and their equipment until this procedure has been done *N* times. This will draw all buses, equipment, and all connections between buses that are *N* connections away from the original bus.

2.3.2 Double-Clicking

Double-clicking on a data element (i.e. particular bus) is equivalent to selecting the Network Data option from the right-click menu. Both actions activate the Spreadsheet View, change to the correct data tab, and place the focus on the first spreadsheet cell of the selected item (see Figure 2-11).

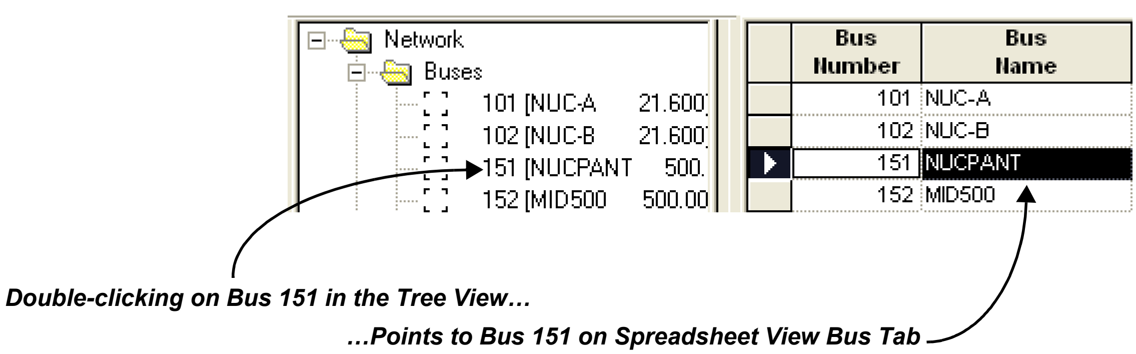
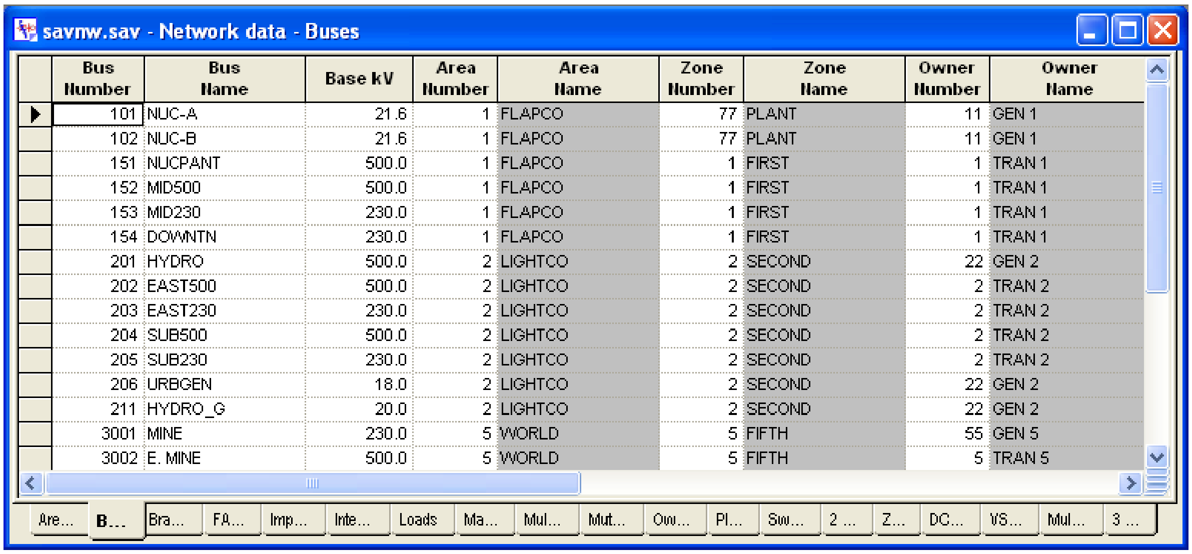


Figure 2-11. Double-Clicking on Tree View

2.4 Spreadsheet View

The **Spreadsheet View** (Figure 2-12) provides a means to view and edit all of the network data in the system. The subsystem selector may be used to reduce the amount of network data presented at any one time. Read only fields are colored light gray to distinguish them from editable fields.



Bus Number	Bus Name	Base kV	Area Number	Area Name	Zone Number	Zone Name	Owner Number	Owner Name
101	NUC-A	21.6	1	FLAPCO	77	PLANT	11	GEN 1
102	NUC-B	21.6	1	FLAPCO	77	PLANT	11	GEN 1
151	NUCPANT	500.0	1	FLAPCO	1	FIRST	1	TRAN 1
152	MID500	500.0	1	FLAPCO	1	FIRST	1	TRAN 1
153	MID230	230.0	1	FLAPCO	1	FIRST	1	TRAN 1
154	DOWNTN	230.0	1	FLAPCO	1	FIRST	1	TRAN 1
201	HYDRO	500.0	2	LIGHTCO	2	SECOND	22	GEN 2
202	EAST500	500.0	2	LIGHTCO	2	SECOND	2	TRAN 2
203	EAST230	230.0	2	LIGHTCO	2	SECOND	2	TRAN 2
204	SUB500	500.0	2	LIGHTCO	2	SECOND	2	TRAN 2
205	SUB230	230.0	2	LIGHTCO	2	SECOND	2	TRAN 2
206	URBGEN	18.0	2	LIGHTCO	2	SECOND	22	GEN 2
211	HYDRO_G	20.0	2	LIGHTCO	2	SECOND	22	GEN 2
3001	MINE	230.0	5	WORLD	5	FIFTH	55	GEN 5
3002	E. MINE	500.0	5	WORLD	5	FIFTH	5	TRAN 5

Figure 2-12. View of Spreadsheet Showing Read-Only Fields

2.4.1 Zoom Toolbar

The **Zoom Toolbar** (Figure 2-13) can be used to manipulate the **Spreadsheet View**.

The Zoom Extent, Zoom Window, Zoom Previous, and Pan buttons have no effect on the **Spreadsheet View** and are thus greyed out. They are designed to work with the **Diagram View only**.

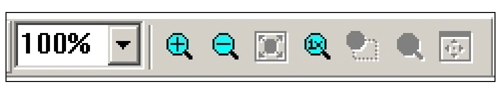
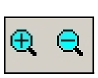


Figure 2-13. Zoom Toolbar in Spreadsheet View

The **Zoom Combo Box** is used to select a predefined zoom factor to apply to the **Spreadsheet View**. Click the arrow to the right of the combo box to drop down a list of predefined zoom factors from which to choose. A customized zoom factor may be entered directly in the field if the desired one is not found in the list. The **Zoom Combo Box** is also updated to display the current zoom factor which can be changed through the use of the other zoom tools.



The **Zoom In/Zoom Out** buttons are used to zoom the center of the **Spreadsheet View** in or out.

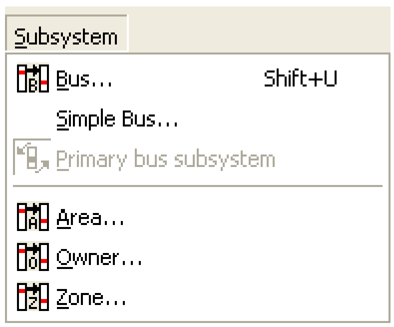
The **Zoom 100%** button is used to quickly return the **Spreadsheet View** to 100% zoom.

2.4.2 Reducing Data Volume in the Spreadsheet View

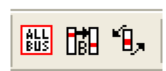
The amount of data displayed in the **Spreadsheet View** may be reduced by selecting a subsystem of the total network. Two methods for defining a subsystem are described below.

2.4.2.1 Defining a Subsystem through the Subsystem Menu

To activate the subsystem options, select ***Subsystem*** from the Main Menu and then choose the appropriate option (Figure 2-14a). The subsystem options can also be activated through the available toolbar buttons (Figure 2-14b). In this latter view, only the Select all buses and Create a bus subsystem buttons are shown.



(a) Subsystem Menu



(b) Toolbar Buttons

Figure 2-14. Subsystem Selection Tools

Selecting ***Area…, Owner…, or Zone…*** from the ***Subsystem*** menu opens a dialog window from which available areas, owners or zones can be selected. These tools can be used to select specific Areas, Owners, or Zones for reports that are specific to one of the three attributes.

Selecting ***Bus…*** from the ***Subsystem*** menu, or clicking on the ***Create a bus subsystem*** button displays the **Bus Subsystem Selector** dialog (Figure 2-15). The five tabs shown allow for a bus subsystem to be built using a combination of **Areas**, **Owners**, **Zones**, **Base kV**, or individual **Buses**.

Clicking on the ***All Buses*** button will remove the current subsystem so all buses can be seen in the tree and spreadsheet view.

Clicking the ***Toggle bus subsystems*** is used to toggle between two subsystems. Under normal operation, only one subsystem is created at a time. However, a second subsystem will be created when, in the diagram view, information is requested for an element that is not in the current subsystem. The creation of the second subsystem allows the first subsystem to be preserved.

When a selection has been made within any of the categories, an asterisk (*) appears on the tab.

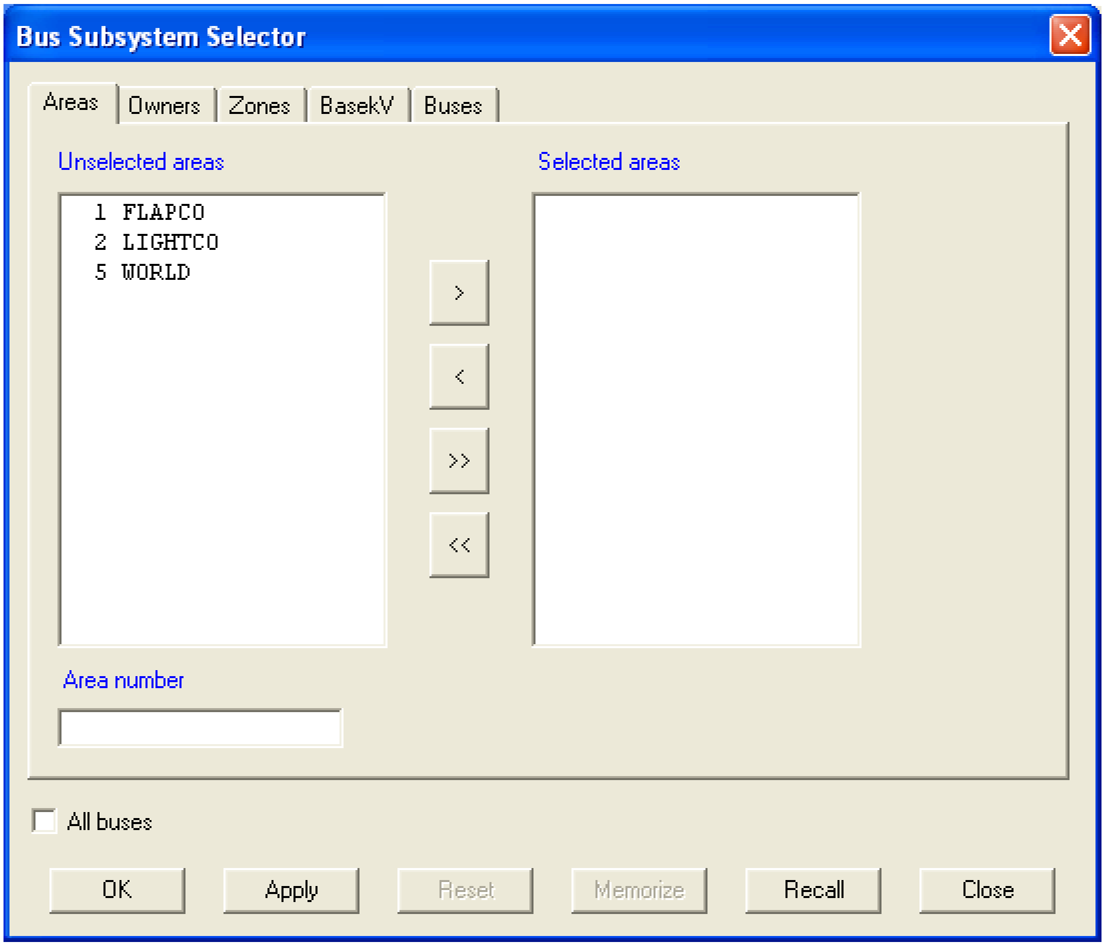


Figure 2-15. Bus Subsystem Selector Dialog

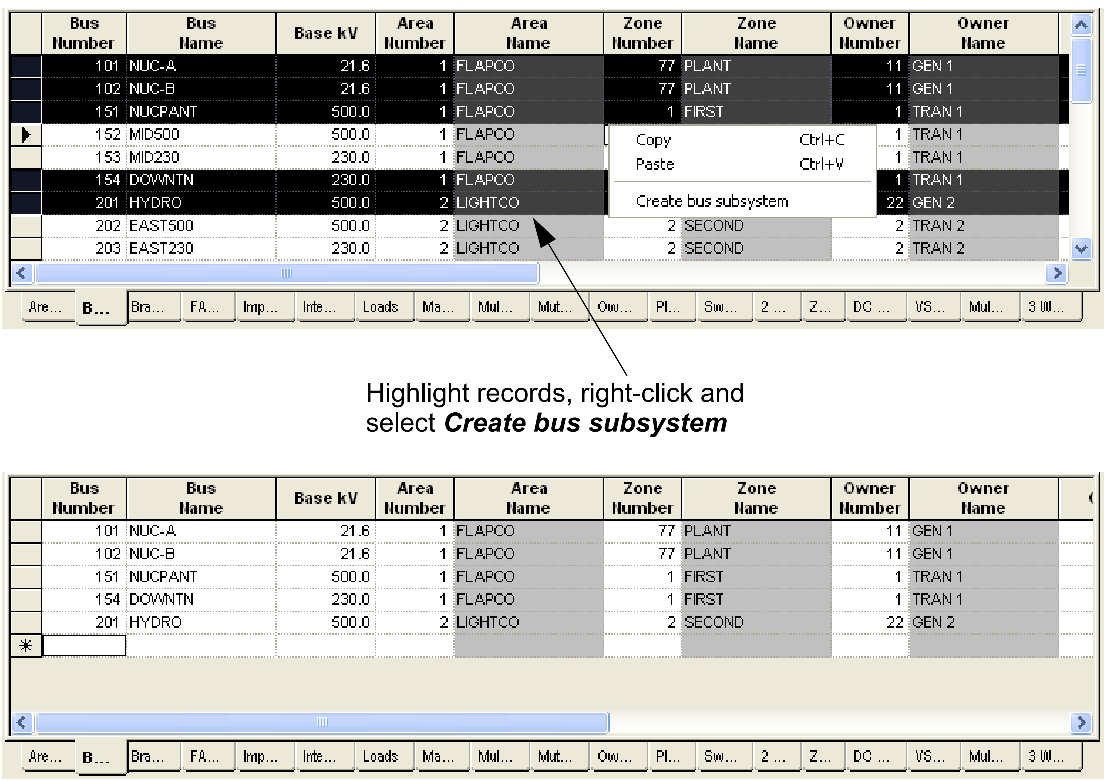
Once the subsystem selections have been made, click ***Apply*** to refresh the **Spreadsheet View**. Selecting the ***OK*** button closes the **Bus Subsystem Selector** dialog. The spreadsheet will now display data corresponding to only the subsystem selected until a new subsystem selection is made. To return to a complete **Spreadsheet View** select the ***All buses*** check box (see Figure 2-15).

To preserve a specific subsystem for later recollection select the ***Memorize*** button following use of the ***Apply*** button. The information will be stored in a specified file of type **.sbs*. The file can then be accessed later by selecting the ***Recall*** button. Selecting the ***Reset*** button will undo any changes made during the selection process.

2.4.2.2 Creating a Bus Subsystem from the Spreadsheet

A bus subsystem can be created directly from the bus data spreadsheet by selecting the buses to be included, bringing up the right-click menu and selecting the ***Create bus subsystem*** option (Figure 2-16a). Bus record selections can be made using standard Windows® selection techniques (holding the **[Shift]** key to include all rows between two selected rows and holding the **[Ctrl]** key to select individual rows.)

Once the buses have been selected and the ***Create bus subsystem*** option selected, the spreadsheet will show only those buses selected (Figure 2-16b).



Bus Number	Bus Name	Base kV	Area Number	Area Name	Zone Number	Zone Name	Owner Number	Owner Name
101	NUC-A	21.6	1	FLAPCO	77	PLANT	11	GEN 1
102	NUC-B	21.6	1	FLAPCO	77	PLANT	11	GEN 1
151	NUCPANT	500.0	1	FLAPCO	1	FIRST	1	TRAN 1
152	MID500	500.0	1	FLAPCO			1	TRAN 1
153	MID230	230.0	1	FLAPCO			1	TRAN 1
154	DOWNTN	230.0	1	FLAPCO			1	TRAN 1
201	HYDRO	500.0	2	LIGHTCO			22	GEN 2
202	EAST500	500.0	2	LIGHTCO	2	SECOND	2	TRAN 2
203	EAST230	230.0	2	LIGHTCO	2	SECOND	2	TRAN 2

Bus Number	Bus Name	Base kV	Area Number	Area Name	Zone Number	Zone Name	Owner Number	Owner Name
101	NUC-A	21.6	1	FLAPCO	77	PLANT	11	GEN 1
102	NUC-B	21.6	1	FLAPCO	77	PLANT	11	GEN 1
151	NUCPANT	500.0	1	FLAPCO	1	FIRST	1	TRAN 1
154	DOWNTN	230.0	1	FLAPCO	1	FIRST	1	TRAN 1
201	HYDRO	500.0	2	LIGHTCO	2	SECOND	22	GEN 2

Figure 2-16. Creating Bus Subsystem by Selecting Spreadsheet Rows

2.4.3 Spreadsheet View Right-click Menus

A number of different menus and dialogs are available by right-clicking on items in the **Spreadsheet View**. The various items are described below.

2.4.3.1 Right-clicking in a Column

Right-clicking on a column header in the **Spreadsheet View** opens a menu (see Figure 2-17). If right-clicking on an individual cell within a column, then the menu will only show the Copy and Paste options.

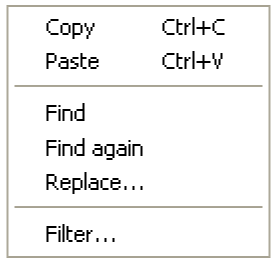
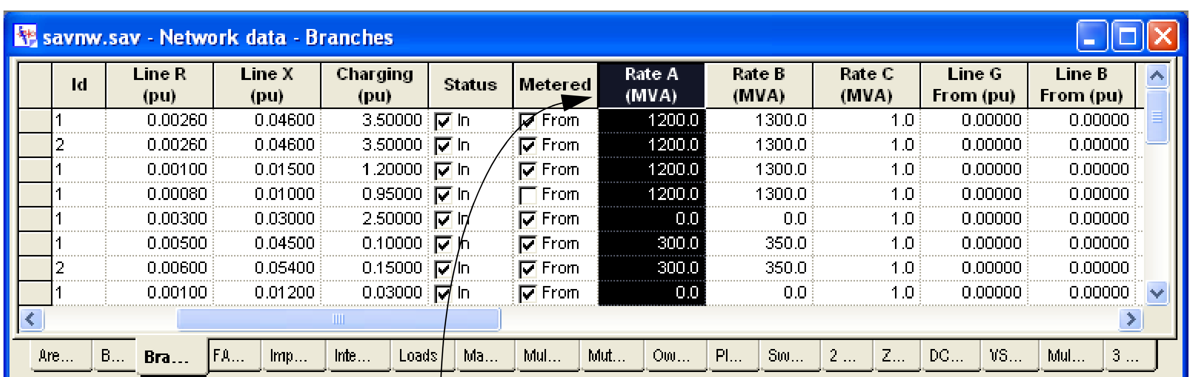


Figure 2-17. Right-Click Menu from a Column Header

Copy: Context sensitive, standard Windows® Copy. If the column header is selected, the entire column is copied to the Windows clipboard. If an individual element is selected, then only that element is copied in the clipboard.

Paste: Pastes the current contents of the clipboard. If the copied area exceeds the number of rows available, PSS™E will automatically create the extra network elements required (and generate appropriate bus numbers).



Id	Line R (pu)	Line X (pu)	Charging (pu)	Status	Metered	Rate A (MVA)	Rate B (MVA)	Rate C (MVA)	Line G From (pu)	Line B From (pu)
1	0.00260	0.04600	3.50000	In	From	1200.0	1300.0	1.0	0.00000	0.00000
2	0.00260	0.04600	3.50000	In	From	1200.0	1300.0	1.0	0.00000	0.00000
1	0.00100	0.01500	1.20000	In	From	1200.0	1300.0	1.0	0.00000	0.00000
1	0.00080	0.01000	0.95000	In	From	1200.0	1300.0	1.0	0.00000	0.00000
1	0.00300	0.03000	2.50000	In	From	0.0	0.0	1.0	0.00000	0.00000
1	0.00500	0.04500	0.10000	In	From	300.0	350.0	1.0	0.00000	0.00000
2	0.00600	0.05400	0.15000	In	From	300.0	350.0	1.0	0.00000	0.00000
1	0.00100	0.01200	0.03000	In	From	0.0	0.0	1.0	0.00000	0.00000

Click to Highlight Column

Figure 2-18. Preparing to Copy Data between Columns

Copy/Paste uses either the standard keystrokes (**[Ctrl]+C**, **[Ctrl]+V**) or the Main Menu (***Edit>Copy***, ***Edit>Paste***). The copied data can be pasted using either the standard keystrokes or the Main Menu.

Bus numbers and other identifiers are not copied as this would result in duplicate data items in the network. Instead, the next available unused identifier is placed in the field.

If a column or set of columns is selected, PSS™E offers the ***Find***, ***Find again*** and ***Replace*** options.

Find: Selecting the ***Find*** option displays the **Find** dialog window. A text string entered in the "Find what:" field can be searched for within the selected column. The Find window is the result of right-clicking on the Base kV column in the bus spreadsheet (see Figure 2-19).

The ***Find Next*** button may be used to continue searching up or down the column, based on the Direction toggle selection.

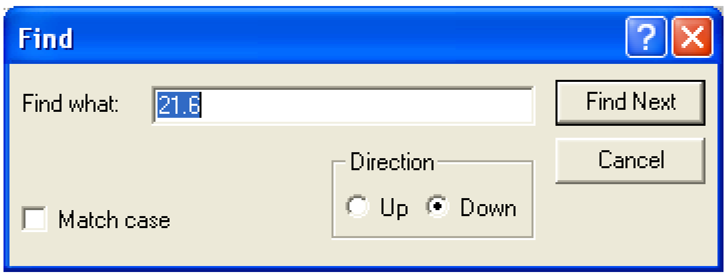


Figure 2-19. Using the Find Dialog

Find again: Use *Find again* to search within the selected column for the value entered during the previous **Find** operation. It will find only the first match and cannot be used to iterate through other matching items within the column. To iterate through matching items in the column, click ***Find Next*** in the **Find** dialog to find successive items.

Replace: The ***Replace*** option displays the **Replace** window from which a particular text string can be searched for and replaced by an alternate text string.

Filter: The ***Filter*** option displays the Filter Grid window (Figure 2-20) within which a subset of the spreadsheet data can be displayed based on a Boolean selection criteria applied to each individual cell in the column. The filtered spreadsheet will have the filtered columns appear with red headers. Any number of columns may be filtered in the spreadsheet to further reduce the amount of data. Selecting a previously filtered column will populate the **Filter Grid** dialog with the previous values used to filter the column. A range of values to filter a cell by may be selected by choosing either the ***AND*** or ***OR*** radio button. Doing so will enable the fields at the bottom of the dialog to allow the specification of the additional Boolean check.

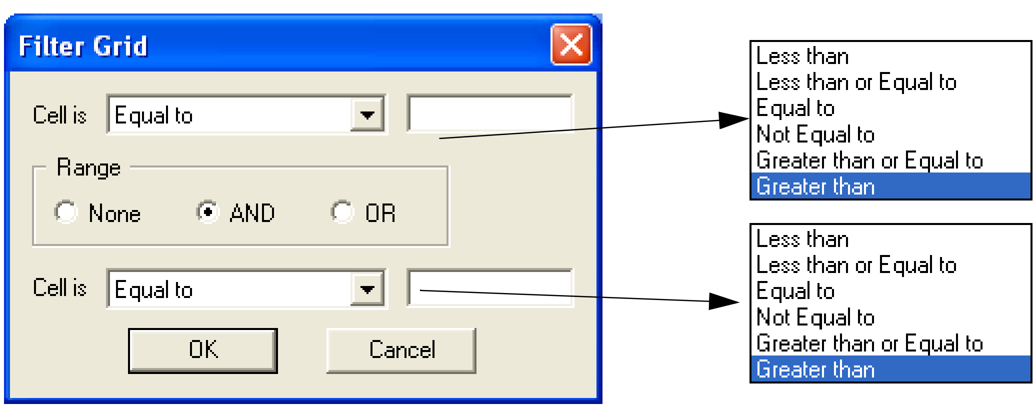


Figure 2-20. Using the Spreadsheet Filter

Any data edits performed within the filtered spreadsheet will automatically be reflected in the original unfiltered sheet. This allows the use of a reduced data set on which to perform edits.

Figure 2-21 shows the filter set up to reduce the records shown in the bus spreadsheet to only those records whose bus voltage levels fall below 500 kV and above 22 kV.

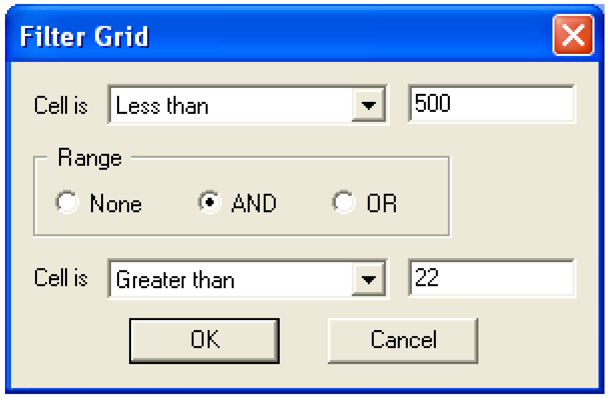


Figure 2-21. Filter on Base kV

2.4.3.2 Right-clicking in a Cell

Within a cell, a right-click brings up a menu from which either ***Copy*** or ***Paste*** may be selected to copy/paste the contents of the current cell to/from the clipboard or to/from another cell in the spreadsheet (see Figure 2-22).

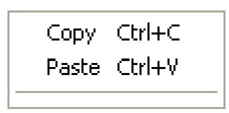


Figure 2-22. Right-Click on a Cell or Row

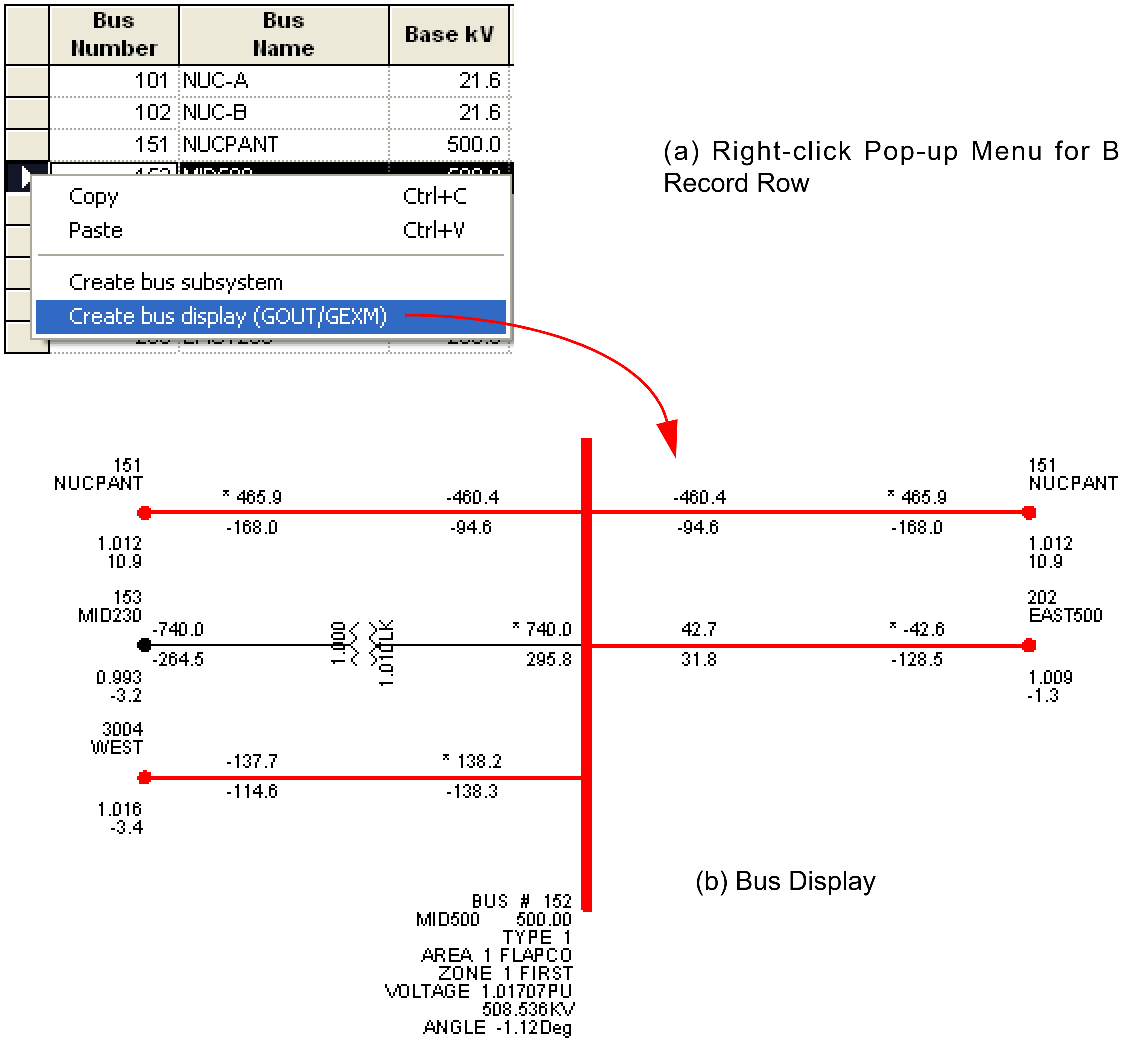
2.4.3.3 Right-clicking on a Row

Selecting and right-clicking on a row of a spreadsheet displays a menu for bus data (see Figure 2-23a).

Using the ***Copy*** and ***Paste*** options allow the entire row can be copied and pasted to another application or within the spreadsheet. This capability assists in adding equipment or lines to an existing case. The Copy and Paste options are available for all data category tabs.

The right-click menu for bus data records additionally contains ***Create bus subsystem*** and ***Create bus display (GOUT/GEXM)*** options. The Create bus subsystem is discussed in Section 2.4.2.2.

The ***Create bus display (GOUT/GEXM)*** option displays a pictorial view of the selected bus and all its associated data and equipment in a new Diagram View. The graphical bus display for bus 152 selected in Figure 2-23a is shown in Figure 2-23b.



(a) Right-click Pop-up Menu for Bus Record Row

(b) Bus Display

Figure 2-23. Right-clicking on a Spreadsheet Row

2.4.4 Sorting Columns

A double-click on a column header toggles the sorting of the column between ascending and descending order, either numerical or alphabetical.

2.4.5 Copying and Pasting between Applications

It is possible to copy and paste data from the spreadsheet into another application, such as Microsoft® Excel. Select the cells to copy, copy the data to the clipboard using **[Ctrl]+C** or ***Edit>Copy*** from the Main Menu, go to the application you wish to past the data into, and use the paste function of that application to copy the spreadsheet data from the clipboard into the application.

If copying data from another application, such as Microsoft® Excel, to the PSS™E spreadsheet, copy the data from the application to the clipboard, select the insertion point within the desired PSS™E spreadsheet and select ***Edit>Paste***.

2.4.6 Exporting Spreadsheet Data to a Text File

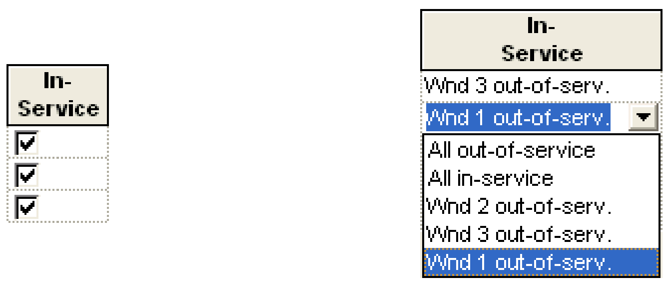
All data within a given data spreadsheet can be exported to a tab delimited file. To do this, select ***File>Export>Spreadsheet Tab to text file…*** from the Main Menu. Provide a filename and the exported tab delimited data file will then be created.

2.4.7 Editing Data in a Cell

The majority of data fields within the spreadsheet may be edited directly by clicking on the cell and typing in the desired value.

For data fields that must contain values from a predefined list of items, double-clicking within the white area of data field will bring up a window from which a list of valid entries may be chosen. This is predominately the case for fields requesting an area, owner, or zone number. The new data value is recorded in the PSS™E case when the cursor is moved to another row.

Data fields that contain check boxes (Figure 2-24a) may be toggled on or off by clicking on the box to display or remove a checkmark. Data fields that require a selection from a list of valid entries contain a pull-down menu. Clicking on the field produces an arrow in the right side of the field that, when clicked, displays a drop down list from which one value may be selected (Figure 2-24b).



(a) Check boxes

(b) Pull-down menu for three-winding transformers

Figure 2-24. Check Boxes and Pull-down Menus in the Spreadsheet

When one or more cells in a row have been modified, a pencil symbol is placed in column 1 of the row (Figure 2-25). The data changed is not recorded in the PSS™E case until the cursor is moved to another row. At that point, all data changes made to the row are recorded and the pencil symbol is removed.

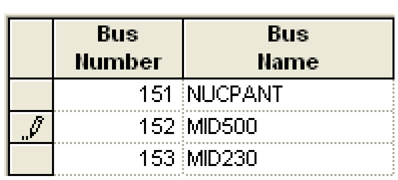


Figure 2-25. Pencil Indicator of Edited Data

2.4.8 Rearranging Columns

There are a number of ways to change the order of the columns in the spreadsheet view through the ***Edit*** menu. Some methods for changing column order are described below.

2.4.8.1 Freezing and Unfreezing Columns

For data spreadsheets that contain a large number of columns it may be desirable to hold the identification fields in place while scrolling to view the other columns. This can be achieved by clicking on the column headers and then selecting ***Edit>Freeze Columns.*** This will keep the selected columns static while scrolling right or left to view other columns. Select ***Edit>Unfreeze Columns*** to undo the action (see Figure 2-26).

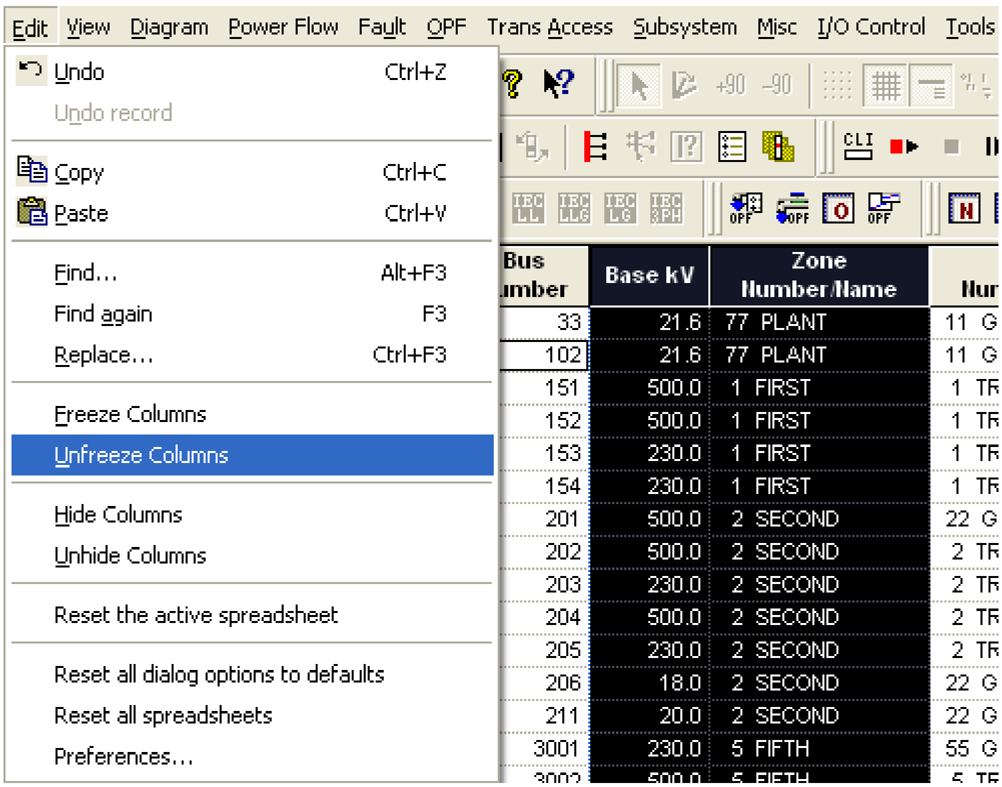


Figure 2-26. Freezing and Unfreezing Columns

2.4.8.2 Hiding and Unhiding Columns

Some data columns may hold data that is of little or no importance to the analysis the user is doing. In order to help the user organize the column so they can be viewed easily, columns can be hidden from view. After selecting the columns to hide, select ***Edit>Hide Columns***. In order to bring the columns back into view select ***Edit>Unhide Columns***. This will unhide all columns that were previously hidden. There is no way to unhide specific columns.

2.4.8.3 Clicking and Dragging a Column

When viewing the spreadsheet, it may be desirable to rearrange the order of the columns. This can be done by clicking and dragging the column header left and right. As the column is dragged, a red line will show which two columns the column being dragged will be put between.

2.4.8.4 Resetting the Spreadsheet

After freezing, hiding, and dragging columns to new places, it may be desirable to reset the spreadsheet back to the default layout. This can be done by selecting ***Edit>Reset Active Spreadsheet*** when the spreadsheet to be reset is the active view. It is also possible to reset all open spreadsheets at once. Selecting ***Edit>Reset All Spreadsheets*** will reset all open spreadsheets back to the default arrangement.

2.5 Diagram View

The **Diagram View** (Figure 2-27) is used to create and modify one-line diagrams and to display a variety of results such as:

- Power flow results.
- Short circuit three-phase and single-line-to-ground faults.
- Graphical differences between power flow cases.
- Network impedances.
- IECS fault calculations results.
- Probabilistic Reliability analysis results.
- Dynamics simulation results.

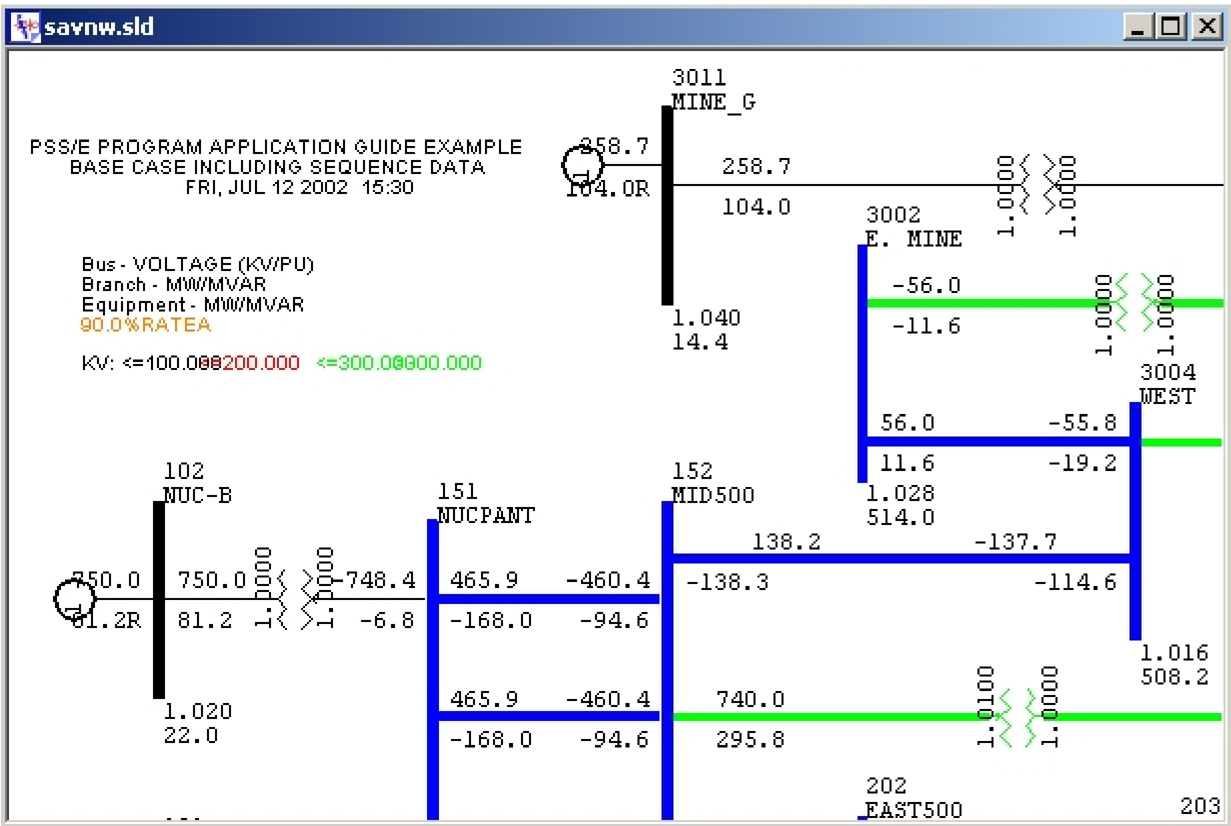


Figure 2-27. Diagram View

The **Diagram View** is also linked to the **Tree View** (Section 2.3) where right-click menus facilitate interaction with the Diagram View (Section 2.3.1.3), including:

- Locating buses
- Adding buses in automatic Draw and Grow
- Binding network items
- Assignment of network items to layers

It is also possible to link from the **Diagram View** directly to the **Spreadsheet View** where data handling options are available (Section 2.4).

Network components drawn in a **Diagram View** that *do not* correspond to existing items in the network will be displayed in an unbound item color. Network components drawn in a **Diagram View** that *do* correspond to existing items in the network will be displayed in bound item colors unless over-ridden by range checking coloration.

Both the bound and unbound colors can be set by the user in the **Diagram Properties** sheet discussed in Section 2.9.1.

Each type of result or information shown in the Diagram view has its own annotation options. The annotation options can be modified by choosing ***Diagram>Annotation*** from the Diagram Menu, (see Section 2.9). The title of this dialog and the annotation options will change to reflect the current results setting for the active **Diagram View**.

The diagram can be expanded, reduced and panned using the Zoom Toolbar buttons. Additionally the view can be panned horizontally and vertically using the mouse. These manipulations are discussed in Section 2.5.4.

2.5.1 Opening a New Diagram

A new one-line diagram may be created or existing diagram files may be opened within the Diagram View. To open a new diagram select ***File>New***, click on the ***Diagram*** option and click ***OK*** (see Figure 2-28). Alternatively the "new file" toolbar icon can be selected. In either case a new blank diagram will be displayed within which a small portion or an entire one-line network can be created. Multiple diagrams may be created for a network case and multiple views may be opened simultaneously.

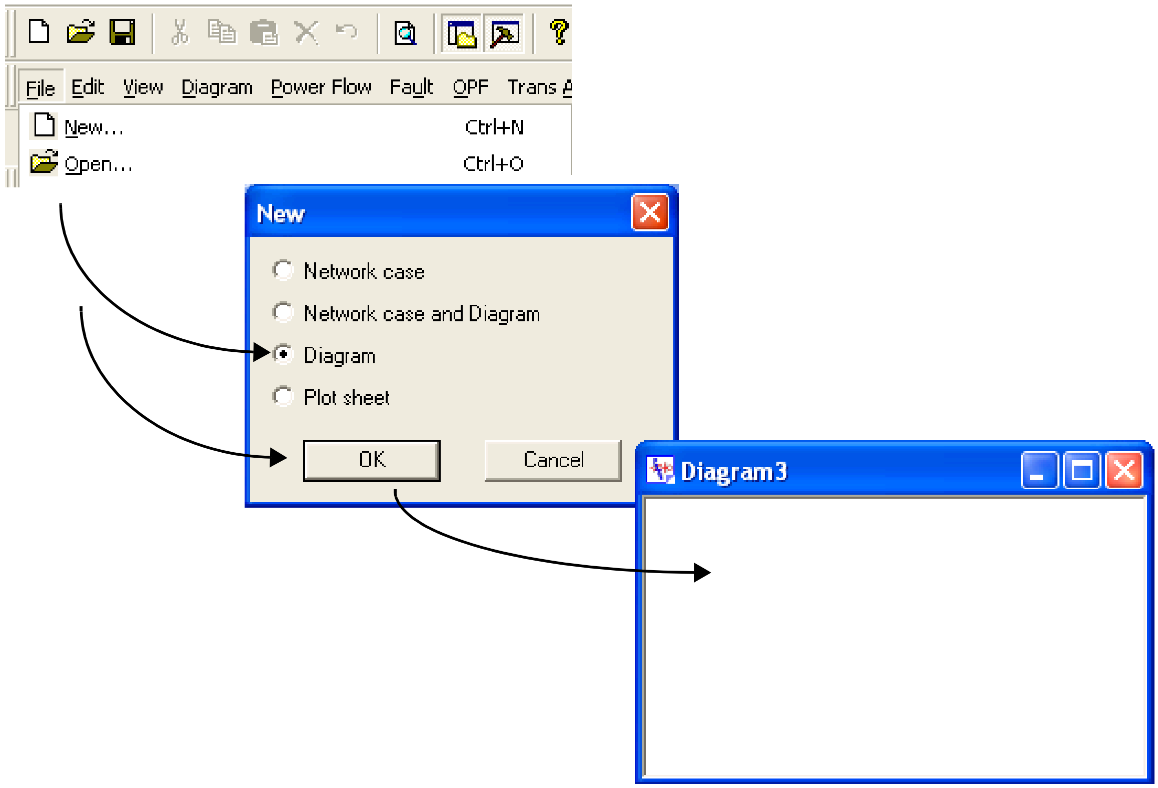


Figure 2-28. Opening a New Diagram View

2.5.2 Opening a Diagram File

Diagram data may be supplied in one of two formats: the old PSS™E DRAW format or the new Slider file format created by the current version of PSS™E and the file type that will be used for future versions. Once imported, a DRAW file can be saved as a Slider file.

2.5.2.1 Importing a DRAW File

In order to import a DRAW file, a Diagram View must already exist. This can be done by selecting the ***New Diagram*** button from the toolbar, or selecting ***File>New*** from the Main Menu, as described above.

With the new **Diagram View** open, select ***File>Import>DRAW file…*** from the Main Menu to import a DRAW file (Figure 2-29). A list of available **.drw* files will be provided from which to select. The diagram will appear in the previously opened **Diagram View**.

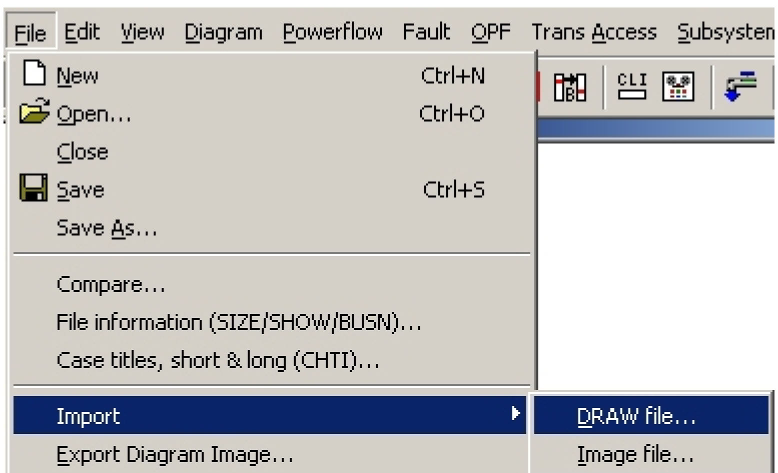


Figure 2-29. Importing a DRAW File

2.5.2.2 Opening a Slider Diagram File

To open an existing Slider Diagram file click either the ***Open*** button from the toolbar or ***File>Open*** from the Main Menu (see Figure 2-30). In the resulting file selector window, set the "File name" field to "Slider Binary File (*.sld)", navigate to the desired directory location and select from the list of available files. The resulting diagram will be displayed in a new diagram window.

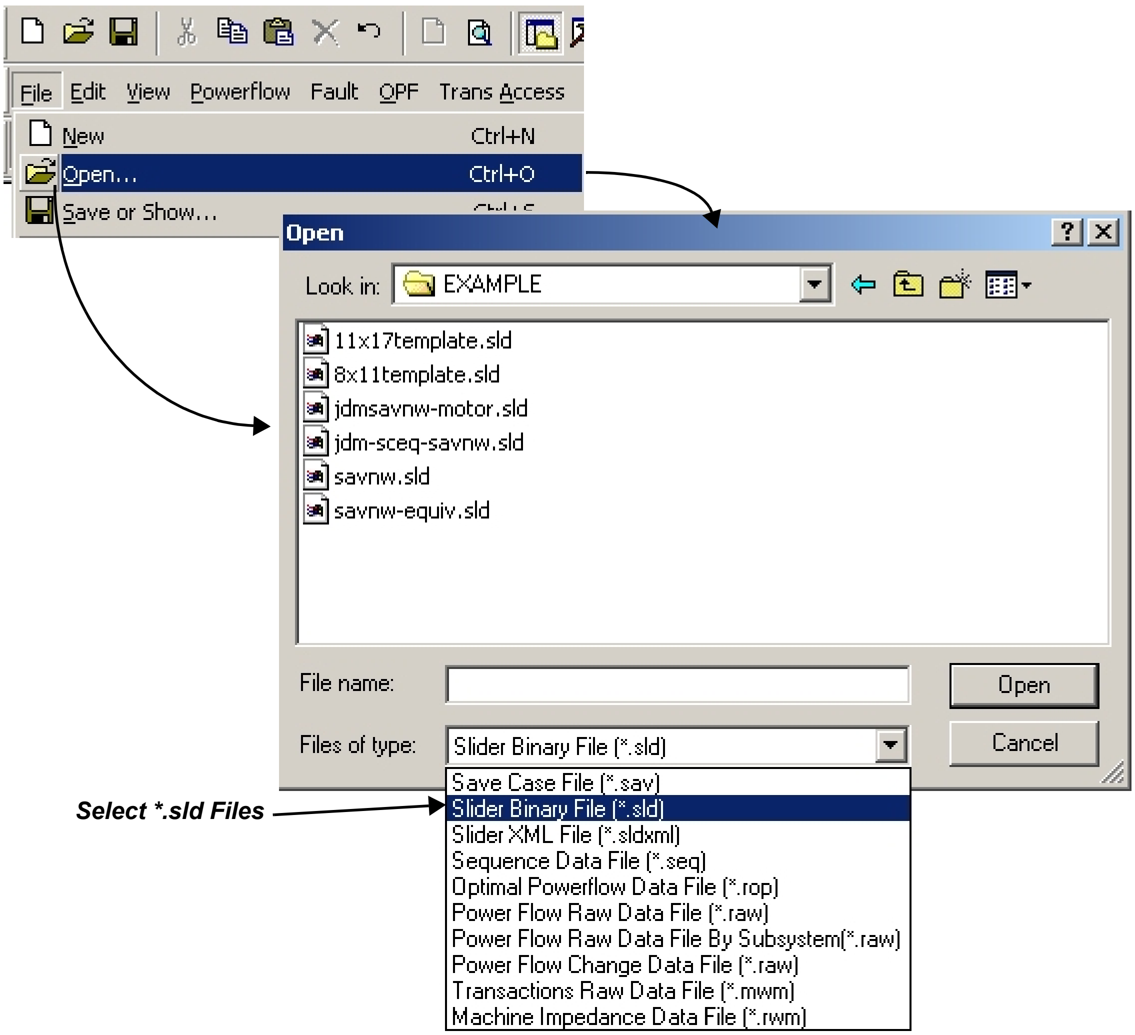


Figure 2-30. Opening an Existing SLIDER File

2.5.3 Specifying Bus Locations

The location of buses on a diagram can be specified through the use of a Bus Location file. This file can then be opened in PSS™E and used to position any buses drawn or "Grown" for which an entry exists in the file. The same file can also be used to reposition buses in an existing diagram. To open a Bus Location file for use in PSS™E, select ***File>Open*** and select "Bus Location Data File (*.loc)" from the "Files of type" selector. To enable Bus Location file positioning when drawing or "Growing" buses (as described in Section 2.5.5), select the ***Use Bus Location file to "Grow" items*** option on the Preferences dialog (Section 2.7.10). To reposition buses in a existing diagram, select the ***Diagram>Update bus locations*** menu option, as described in Section 2.9.13.

2.5.3.1 Bus Location Data File

Bus positions on a diagram may be specified in a Bus Location file that can be accessed whenever a bus is created. These positions can be specified as x/y coordinates or as GIS coordinates in an hour, minutes, seconds format. The format of the file is as follows:

CARTESIAN | GEOPHYSICAL

> The first record in the file describes the format of all bus position records. CARTESIAN specifies that bus positions are provided as x/y locations on the diagram. GEOPHYSICAL specifies that bus positions are provided in GIS form as two pairs of hour, minute, seconds inputs.

The next N lines specify the bus positions. The Bus Location file **does not** require an entry for every bus in the case. If a bus position record is not found in the file when positioning a bus on the diagram, default bus positioning is used.

The format of a CARTESIAN bus position record is as follows:

```
BusId, X location, Y location, Rotation, Length
```

where:

BusId	Either a bus number or a "quoted" extended bus name.
X location	The bus X location, in inches, on the diagram.
Y location	The bus Y location, in inches, on the diagram.
Rotation	The optional bus rotation, in degrees.
Length	The optional length of the busbar, in inches.

The format of a GEOPHYSICAL bus position record is as follows:

```
BusId, X location, Y location, Rotation, Length
```

where:

BusId	Either a bus number or a "quoted" extended bus name.
X location	The bus X location, in degrees latitude (see format, below).
Y location	The bus Y location, in degrees longitude (see format, below).
Rotation	The optional bus rotation, in degrees.
Length	The optional length of the busbar, in inches.

Degrees are specified as a set of 1 to 3 real numbers (degrees, minutes, seconds) followed by a direction (E, W, N, S) (the direction can be omitted if all three numbers are specified). Positive values are interpreted as E or N, negative values as W or S. The degree parts can be separated by spaces, commas, apostrophes, or by the specific unit markers for degree, minutes, or seconds (in which case they must be used in order). For example, the following all represent the same value:

> 79°30’36"W
>
> -79 -30 -36
>
> 79.51W
>
> -79.51,,,

The Bus Location file can also contain location entries for branches and two winding transformers found in the network.

Branch and two winding transformers records are indicated by the BRANCH record appearing in the file.

BRANCH

The format of a CARTESIAN branch position record is as follows:

FromBusId	Either a bus number or a "quoted" extended bus name of the "From" bus.
ToBusId	Either a bus number or a "quoted" extended bus name of the "To" bus.
CircuitId	Circuit Id of branch.
X From loc	The "From" bus X location, in inches, on the diagram.
Y From loc	The "From" bus Y location, in inches, on the diagram.
X KP1 loc	The first knee point X location, in inches, on the diagram.
Y KP1 loc	The first knee point Y location, in inches, on the diagram.
X KPn loc	The nth knee point X location, in inches, on the diagram.
Y KPn loc	The nth knee point Y location, in inches, on the diagram.
X To loc	The "To" bus X location, in inches, on the diagram.
Y To loc	The "To" bus Y location, in inches, on the diagram.

The format of a GEOPHYSICAL branch position record is as follows:

FromBusId	Either a bus number or a "quoted" extended bus name of the "From" bus.
ToBusId	Either a bus number or a "quoted" extended bus name of the "To" bus.
CircuitId	Circuit Id of branch.
X From loc	The "From" bus X location, in degrees latitude (see format, above).
Y From loc	The "From" bus Y location, in degrees latitude (see format, above).
X KP1 loc	The first knee point X location, in degrees latitude (see format, above).
Y KP1 loc	The first knee point Y location, in degrees latitude (see format, above).
X KPn loc	The nth knee point X location, in degrees latitude (see format, above).
Y KPn loc	The nth knee point Y location, in degrees latitude (see format, above).
X To loc	The "To" bus X location, in degrees latitude (see format, above).
Y To loc	The "To" bus Y location, in degrees latitude (see format, above).

If there are no kneepoints associated with the branch, there will be no X & Y KPn entries in the record.

The format of a CARTESIAN two winding transformer position record is as follows:

FromBusId	Either a bus number or a "quoted" extended bus name of the "From" bus.
ToBusId	Either a bus number or a "quoted" extended bus name of the "To" bus.

CircuitId	Circuit Id of two winding transformer.
X From loc	The "From" bus X location, in inches, on the diagram.
Y From loc	The "From" bus Y location, in inches, on the diagram.
X Sym loc	The two winding transformer symbol X location, in inches, on the diagram.
Y Sym loc	The two winding transformer symbol Y location, in inches, on the diagram.
X KP1 loc	The first knee point X location, in inches, on the diagram.
Y KP1 loc	The first knee point Y location, in inches, on the diagram.
X KPn loc	The nth knee point X location, in inches, on the diagram.
Y KPn loc	The nth knee point Y location, in inches, on the diagram.
X To loc	The "To" bus X location, in inches, on the diagram.
Y To loc	The "To" bus Y location, in inches, on the diagram.

The format of a GEOPHYSICAL two winding transformer position record is as follows:

FromBusId	Either a bus number or a "quoted" extended bus name of the "From" bus.
ToBusId	Either a bus number or a "quoted" extended bus name of the "To" bus.
CircuitId	Circuit Id of two winding transformer.
X From loc	The "From" bus X location, in degrees latitude (see format, above).
Y From loc	The "From" bus Y location, in degrees latitude (see format, above).
X Sym loc	The two winding transformer symbol X location, in degrees latitude (see format, above).
Y Sym loc	The two winding transformer symbol Y location, in degrees latitude (see format, above).
X KP1 loc	The first knee point X location, in degrees latitude (see format, above).
Y KP1 loc	The first knee point Y location, in degrees latitude (see format, above).
X KPn loc	The nth knee point X location, in degrees latitude (see format, above).
Y KPn loc	The nth knee point Y location, in degrees latitude (see format, above).
X To loc	The "To" bus X location, in degrees latitude (see format, above).
Y To loc	The "To" bus Y location, in degrees latitude (see format, above).

If there are no kneepoints associated with the two winding transformer, there will be no X & Y KPn entries in the record.

2.5.4 Zooming and Panning

The Zoom Toolbar may be used to manipulate the **Diagram View** (see Figure 2-31).

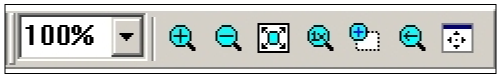
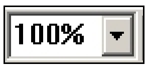
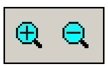


Figure 2-31. Zoom Toolbar

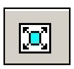


The **Zoom Combo Box** is used to select a pre-defined zoom factor to apply to the Diagram View. Click the arrow to the right of the combo box to drop down a list of pre-defined zoom factors from which to choose from.

A custom zoom factor can be entered directly in the box if the one desired is not found in the list. The value shown in the **Zoom Combo Box** always reflects the current zoom factor setting which may change through the use of the other zoom tools.

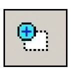


The **Zoom In/Zoom Out** buttons are used to zoom the center of the Diagram View in or out, typically by 10%.



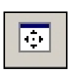
The **Zoom Extent** button is used to zoom the Diagram View out so as to encompass all the items within the borders.

The **Zoom 100%** button is used to quickly return the Diagram View zooming factor to 100%.



The **Zoom Window** button is used to zoom in on a selected portion of the Diagram View. Clicking on the button will cause a dashed square to appear along side the mouse pointer. Click the mouse on one corner of the portion of the diagram and, while holding the mouse button down, drag the mouse pointer out to create a box around the portion of the diagram to be zoomed into. The selected part of the Diagram View is then zoomed to fit in the extent of the Diagram View.

The **Zoom Previous** button is used to return the zooming factor of the Diagram View to its previous setting.



The **Pan** button is used to scroll around the Diagram View in any direction. Upon selecting this item, the cursor in the Diagram View changes to a hand. The Diagram View is then panned by holding down the left mouse button and dragging the hand around the window.

For users who have computers equipped with a mouse-wheel, the **Diagram View** may also be manipulated with the mouse wheel. Moving the mouse-wheel with the **Diagram View** active will pan the **Diagram View** vertically. Holding down the **[Shift]** key while moving the mouse-wheel will pan the **Diagram View** horizontally. Holding down the **[Ctrl]** key while moving the mouse-wheel will zoom the **Diagram View**.

The keyboard cursor keys may also be used to pan the image.

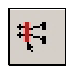
2.5.5 Creating a Diagram for an Existing Power Flow Case

One of the features of the **Diagram View** is the ability to automatically create one-line diagrams of PSS™E power flow cases bus by bus or by groups of buses. This facilitates the rapid population of a blank **Diagram View** with a one-line diagram of the open power flow case. To begin the process of creating a one-line diagram, a **Diagram View** must be active.

Using the Auto Draw function will place a selected bus on the diagram graphically, and automatically draw adjacent equipment, including adjacent buses. The Auto Draw feature also allows the specification of the number of bus levels to extend out of the first bus. Auto Draw will draw and connect these buses and neighboring facilities of all of these buses.

The initiation of the creation of a one-line diagram is done using the ***Auto Draw*** button found in the Diagram Toolbar.

The user has two options to quickly draw a diagram. The first approach involves the following steps:

1. Open a Diagram View.
2. Select the ***Auto Draw*** button  and click on the **Diagram View** to set the bus position.
3. A **Bus Selector** window will appear in which to select or specify the bus to grow and the number of levels to grow out from this bus. For example, using the *savnw.sav* power flow case, bus 101 has been selected and "grown" two levels (see Figure 2-32).

The bus, all it’s equipment, all lines, transformers, and attached buses are then laid out in the **Diagram View**. Figure 2-32 shows the result of selecting to grow bus 101. The bus along and its one neighboring bus is drawn, along with their attached equipment and connecting transformer branch.

If a Bus Location file has been opened (see Section 2.5.3), and the ***Use Bus Location file to "Grow" items*** option is enabled on the diagram Preferences dialog (see Section 2.7.6), then the buses will be placed at the locations specified in the Bus Location file. If the bus location data for the bus does not exist or the option is disabled, then the bus will be placed at the default location.

The process could be continued by selecting locations on the diagram and bus numbers from the **Select Bus** dialog. If, in this example, bus 152 were the next one selected and one level was grown out of this bus, the diagram would grow to include the other attached buses to bus 152, which are buses 153, 202, and 3004, their connected equipment, and the branches from these buses back to bus 152.

You can experiment with this method using the *savnw.sav* power flow case.

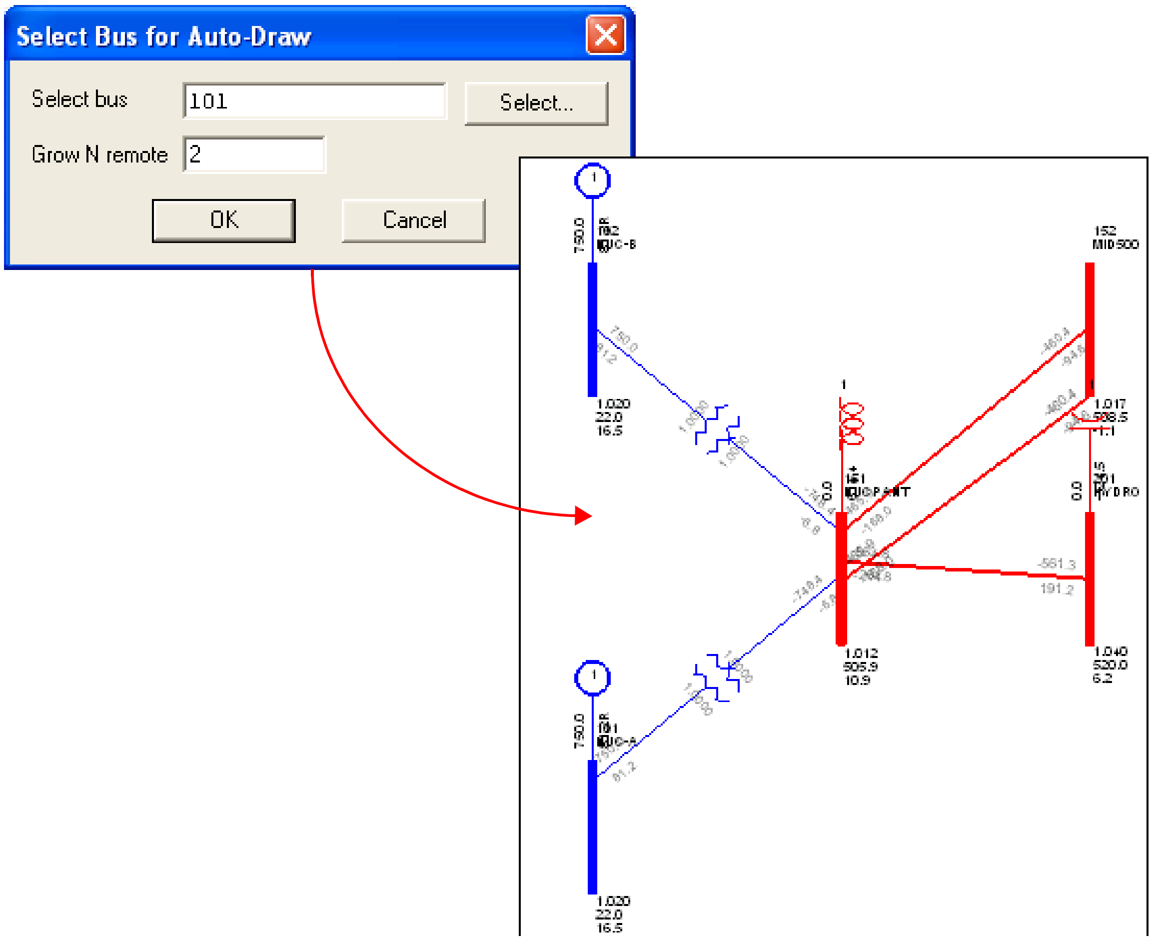


Figure 2-32. Drawing Bus 101 and Buses Two Levels Out, using the Auto Draw Toolbar Button

The second approach to start drawing a diagram is to reverse the order of selections, namely:

1. Select (highlight) the desired starting bus in the Tree View.
2. Click on the ***Auto Draw*** button from the Diagram Toolbar and click on the **Diagram View** to place the bus.

If the first bus selected in the Tree View were bus 101, the result would be bus 101 and 151 plus all equipment attached to either bus. The process could be continued by selecting other buses from the Tree View.

If there is a bus or buses already drawn on the one-line diagram it is possible to use the Grow option from the Tree View (Section 2.3.1.3) to add more one more level of buses. Also, the ***Grow N Levels…*** option can be used to add multiple levels of buses to the diagram. The ***Grow N Levels…*** option is accessed by right-clicking on a bus in the expanded bus list in the **Tree View** *or* right-clicking on a bus in the **Diagram View** (see Figure 2-33).

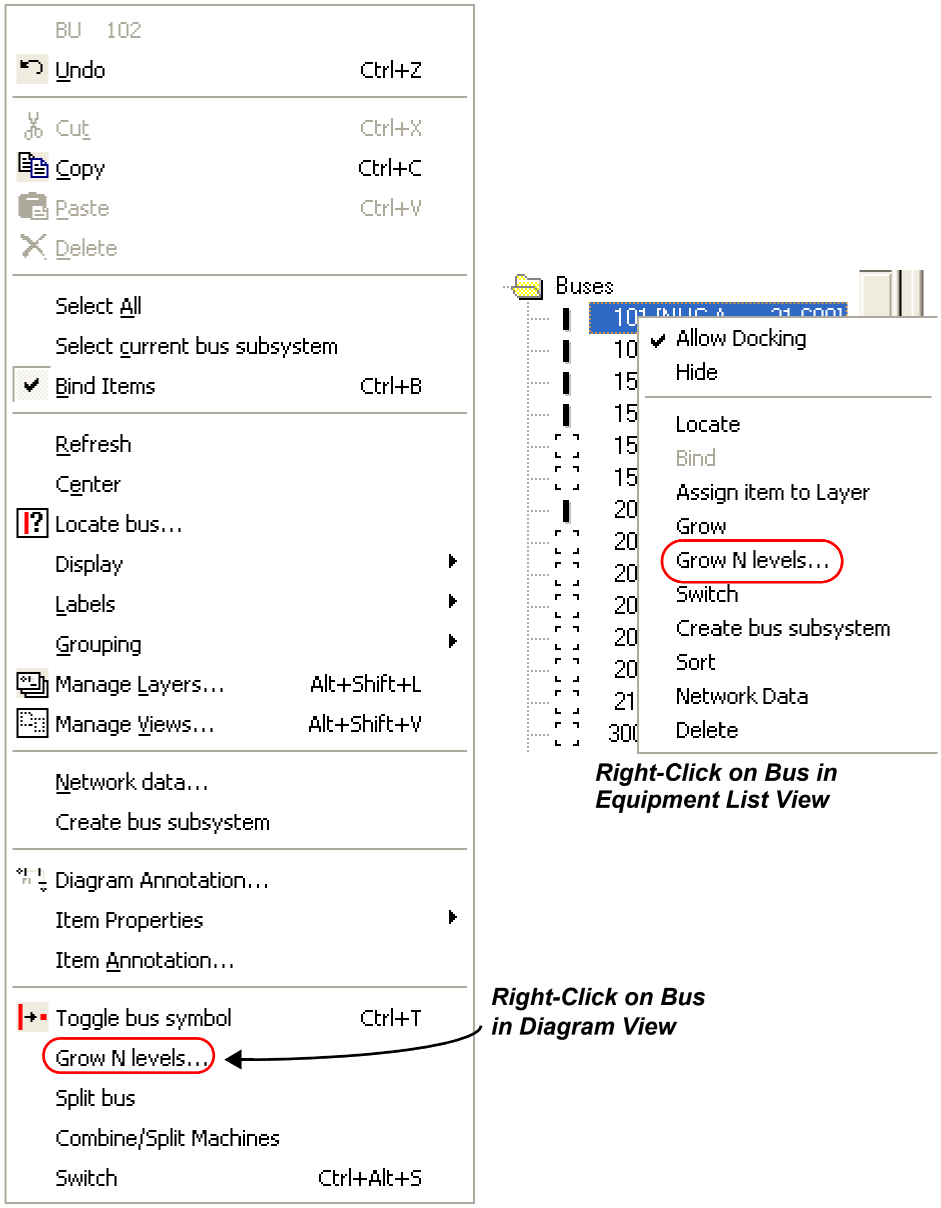


Figure 2-33. Accessing the Grow N Levels... Option

Selecting ***Grow N Levels...*** on either of these menus will initiate the drawing of all buses attached to the bus selected, along with the connected equipment and the branches back to the selected bus *N* levels out from the bus. This method assists in rapidly creating a one-line diagram of the open power flow case.

If a connecting bus or branch already exists on the diagram when a Grow is performed, any new connections will be made to the existing equipment.

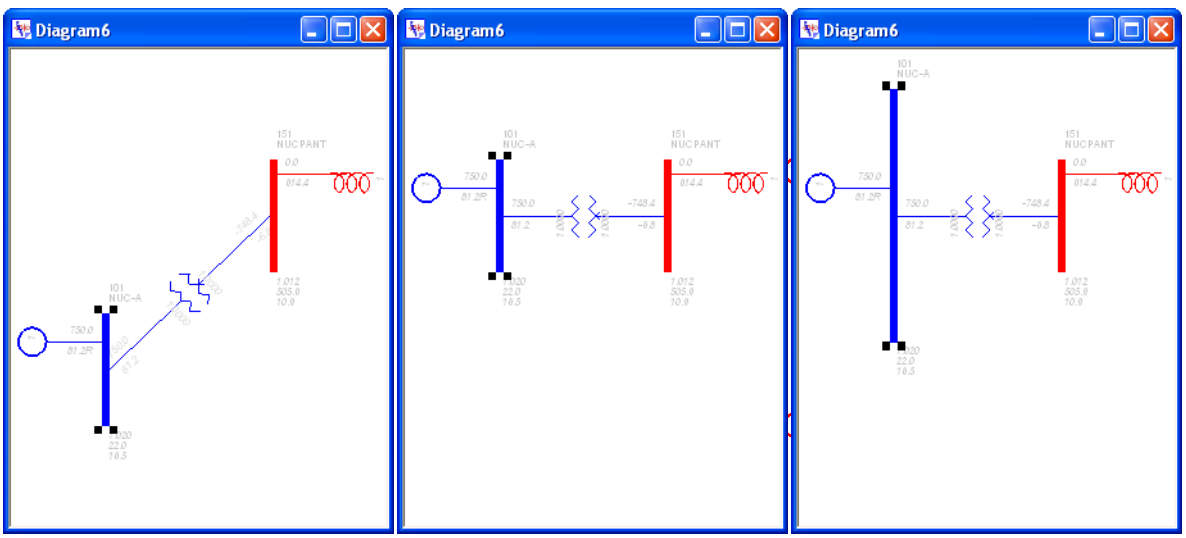
2.5.6 Moving Diagram Elements

Existing diagram items can easily be manipulated within the **Diagram View**. Buses can be moved and their length changed. Equipment and lines can be repositioned on a bus as well as be moved to another bus. If the ***Bind Items*** option is selected, then moving equipment and lines to another bus in the **Diagram View** will also move the equipment and lines within the network data.

To move or resize a bus first to select the bus in the diagram with a mouse click, (see Figure 2-34a).

To move the bus to a different location, select the desired bus and position the mouse over the center of the bus. The mouse pointer will change to a four arrow cursor. Click on the bus and, while holding the mouse button down drag (move) the bus to the new position (Figure 2-34b).

To make the bus longer or shorter, select the desired bus and position the mouse over one end of the bus. The pointer will change to a double sided arrow. Click on the bus end handle and move it in desired direction (Figure 2-34c).



(a) Select Bus to Move **(b) New Position** **(c) Grab Bus End to Re-size**

Figure 2-34. Moving and Resizing Buses

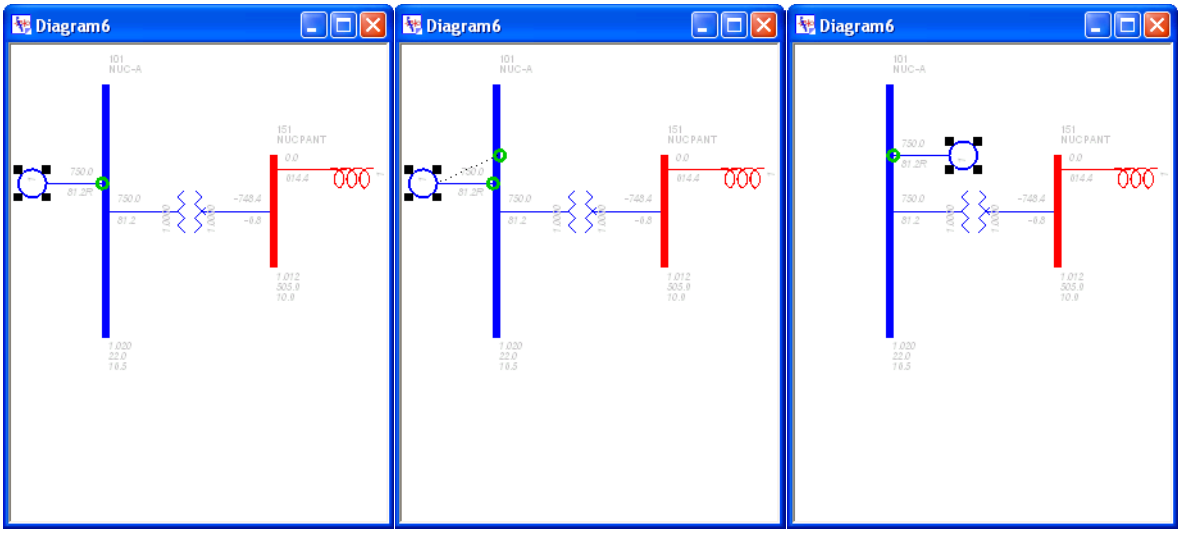
To move existing equipment and lines:

1. Click on the end of the diagram item you wish to move. The diagram item will be selected and the bus end(s) connection illuminated with gray or green circles (Figure 2-35a).

2. Move the desired end by selecting and dragging the end to the new attachment point. Valid attachment points will be illuminated with gray circles as the mouse passes over them (Figure 2-35b).

3. When the end illuminates the desired attachment point, release the mouse to attach the diagram item to the selected attachment point, (Figure 2-35c).

The direction in which the capacitor symbol points away from the bus is decided by the edge on which the grey circle is located. Either the left or right edge of the bus diagram element can be selected.



(a) Selecting **(b) Dragging to New Position** **(c) New position**

Figure 2-35. Moving Equipment

Not only can equipment and lines can be moved to another location on their bus but they can also can be moved to another bus, using the same technique. If ***Bind Items*** is selected, (see Section 2.5.8) moving equipment and lines to another bus in the **Diagram View** will also move the equipment and lines in the **Tree View**. The change will also be reflected in the **Spreadsheet View**. Consequently, this is another form of modifying not only the power flow topology but also the location of equipment.

2.5.7 Copying and Pasting Diagram Elements

All cutting, copying and pasting of diagram items in a **Diagram View** is done from the application diagram clipboard. Diagram items placed on the application diagram clipboard may only be used in other diagram views within the same instance of PSS™E.

To copy diagrams between applications, such as copying a diagram from PSS™E to Microsoft® Word, the system clipboard is utilized. A **Diagram View** can be copied to the system clipboard by selecting ***Edit>Copy to clipboard*** from the Main Menu. This action copies everything visible in the Diagram View to the clipboard; the user is not required to select any elements before initiating this type of Copy.

Another way to use a **Diagram View** in other applications is to export the **Diagram View** into either a JPEG (**.jpg*) or Bitmap (**.bmp*) image file. To export a **Diagram View** into an image file, select ***File>Export Diagram Image…*** from the Main Menu. A File dialog will appear prompting for a name to save the image file under. Select the image file format, either JPEG or Bitmap, by using the ***Save as type:*** drop-down box at the bottom of the dialog. Click Save to export the visible area of the Diagram View to the specified file.

When saving as a JPEG file, a JPEG Quality dialog will appear where the user can control the quality level of the saved file (see Figure 2-36).

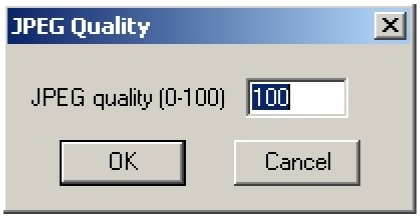


Figure 2-36. JPEG Quality Dialog for Diagram Export to JPEG File

The behavior of **Cut/Copy/Paste** in the **Diagram View** is dependent on the setting of the Bind Items option (Figure 2-37) when the diagram items are cut, copied or pasted. When ***Bind Items*** is selected, changes to diagram items are synchronized with the associated network items. Cutting items from the **Diagram View** in this mode will delete the items from the network as well as the diagram. Pasting items into the **Diagram View** will add the items to the network as well as the diagram.

When ***Bind Items*** is not selected, changes to the diagram items are not synchronized with the network. Cutting and pasting in the **Diagram View** will have no effect on the underlying network. Consequently there will be no apparent data changes in the Spreadsheet View.

Cutting diagram items from the **Diagram View** places a copy of the diagram items and associated network items in the PSS™E diagram clipboard and deletes the diagram items from the **Diagram View**. Network items are also deleted if the ***Bind Items*** is active.

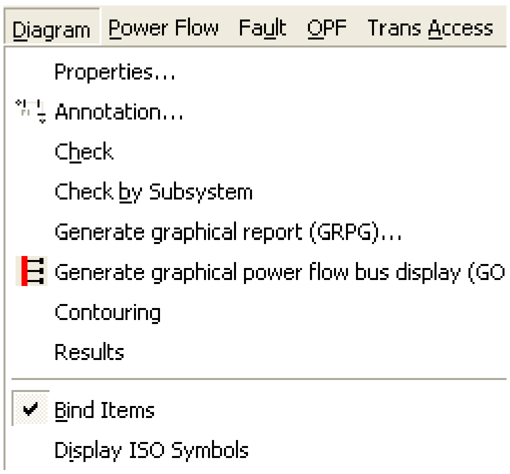


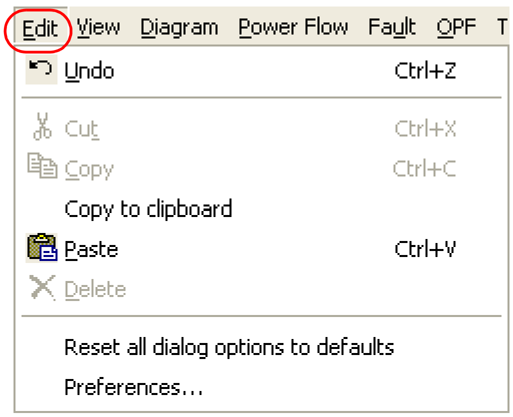
Figure 2-37. Bind Items in the Diagram Menu

Copying diagram items from the **Diagram View** places a copy of the diagram items and associated network items in the PSS™E diagram clipboard.

Pasting diagram items from the PSS™E diagram clipboard places copies of the diagram items in the **Diagram View**. New network items are created in the network if ***Bind Items*** is selected.

Currently, the **Diagram View** provides undo support for the last 30 actions in the **Diagram View**. The ***Edit>Undo*** option provides support for undoing both **Diagram View** and network changes. If a bus is deleted from the **Diagram View** with ***Bind Items*** enabled, both the diagram item and the associated network bus is deleted. The ***Undo*** option will restore both the diagram item and the network bus.

To Cut or Copy from the **Diagram View**, first select the items to be cut or copied and then click the ***Edit menu to select Cut or Copy***. The ***Undo*** and ***Paste*** options are also on the same menu. Right-clicking on the **Diagram View** displays a menu containing the same items (see Figure 2-38).



Edit Menu

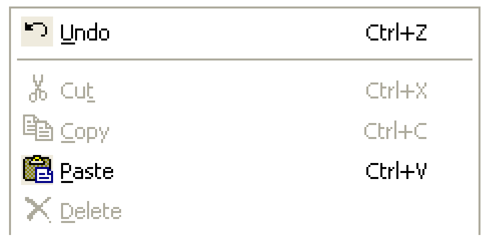


Diagram View Right-click Menu

Figure 2-38. Diagram View Edit Menus

2.5.8 Diagram View Right-click Menus

Various menus are available by right-clicking in the **Diagram View**; with or without a diagram item selected, or by right-clicking directly on a diagram element.

Right-clicking in a **Diagram View** without a diagram item selected brings up the following menu (see Figure 2-39.)

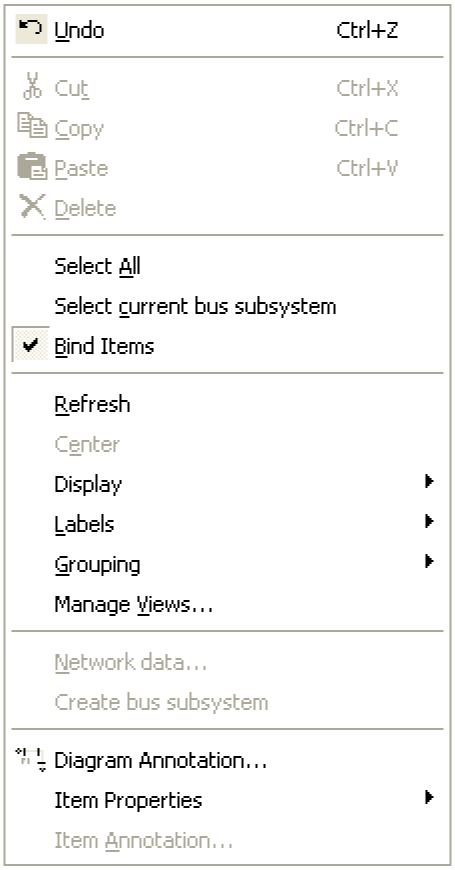


Figure 2-39. Diagram View Right-click Menu

Selecting a network item in the **Diagram View** and then right-clicking in the view, or right-clicking directly on the network item brings up a menu for that item. The bottom part of the menu displays menu items specific to the type of network element selected:

Cut: Context sensitive, standard Windows® Cut menu option. In the case of a selected diagram element, the system will either cut the graphic representation or cut the representation and the corresponding model information into the System Clipboard, depending on whether the Bind option is set or not.

Copy: Context sensitive, standard Windows Copy menu option. In the case of a selected diagram element, the system will either take a copy of the graphic representation or a copy of the representation and the corresponding model information into the System Clipboard, depending on whether the Bind option is set or not.

Paste: Pastes the current contents of the clipboard. If the Bind option is on, and the copied area exceeds the number of existing elements, PSS™E will automatically create the extra network elements required (and generate appropriate bus numbers).

The Copy/Paste functions relate to the type of window involved. Specifically, when you copy or cut from the Diagram View, you can only paste back into the Diagram View. When working from the Spreadsheet View, when you copy a cell or group of cells, you can paste the results into the Spreadsheet view or an outside application like Microsoft® Excel. Further, you can copy a piece of your network from a diagram into PSS™E's clipboard, you are allowed to copy a collection of cells from a Spreadsheet view into PSS™E clipboard at the same time; PSS™E will keep track of both copies. After, when you paste back onto the spreadsheet or an external application like Notepad, the software will know to paste the copied data from the spreadsheet. If you paste on the diagram, the software will paste the copied data from the diagram.

The Undo/Cut/Copy/Paste options are discussed in some detail in Section 2.5.7. Some of this menu's other options are active only when a diagram item has been selected. The items active in this menu are discussed below.

Select All: Selects all items in the diagram.

Select current bus subsystem: Selects all items on the diagram that are in the current bus subsystem (***Subsystem>Bus…***). If no bus subsystem is defined, all diagram items are selected.

Bind Items: Selecting Bind Items toggles the binding mode. When ***Bind Items*** is selected (as indicated by the presence of a checkmark), all selected diagram items are synchronized with their associated network items. In this mode, if a network item is deleted in the diagram, it will be deleted from the power flow case. Consequently, there will be no data shown in either the Tree View or Spreadsheet View and the item symbol will disappear from the diagram. Similarly if network items are pasted into the **Diagram View** with the ***Bind Items*** selected, then a corresponding network item will be added to the power flow case and will appear in both the Tree View and the Spreadsheet View.

Finally, if a network item is selected in the Tree View with a right-click, the resulting menu will include the Delete option. With the ***Bind Items*** selected, the delete action will remove the selected network item from the power flow case. Consequently, it will not be shown in the **Spreadsheet View**. In the **Diagram View** the symbol representing the network item will remain in view but will change to the user's selected unbound color, indicating that the item is no longer part of the power flow case. Conversely, if the Bind Items option is not selected when a diagram item is deleted, it is deleted only from the diagram but remains part of the power flow case. It will thus still be available in both the Tree View and **Diagram View**.

The following set of menu options directly affect the display of selected elements.

Refresh: Refreshes (redraws) all items in the diagram.

Center: Selecting ***Center*** places the selected item in the center of the Diagram View window.

Locate bus…: This option can be used to locate a specific bus on the diagram. When this is selected a Select Bus box comes up, which takes the bus number of the bus to be found in the diagram. If the bus exists in the diagram the diagram will highlight the bus and center the view over the bus.

Diagram displays may be comprised of multiple layers where each layer has an associated display list, i.e., a list of graphical objects. When a layer is drawn in the **Diagram View**, the individual diagram items are drawn in the order they appear in the display list. In some cases, it might be desirable to have a particular item drawn after or before another. This would be the case where two diagram items occupy the same general area in the **Diagram View** and one needs to be drawn over the other.

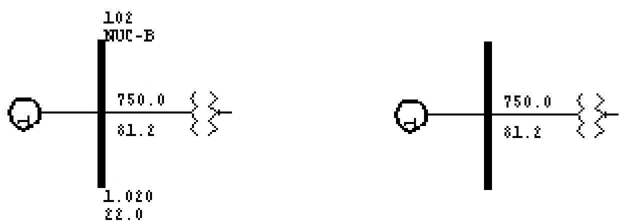
Display>Bring to Front: Selecting ***Display*>*Bring to Front*** moves the selected item to the end of the display list. This indicates to the application that the selected object should be drawn last, on top of the other graphical objects in the same layer.

Display>Send To Back: Selecting ***Display*>*Send to Back*** moves the selected item to the beginning of the display list. This indicate to the application that the selected item should be drawn first and the other items in the same layer should be drawn after (on top of) this item.

Display>Assign To Layer: Selecting ***Display*>*Assign to Layer*** sets the selected item to a predefined layer. Layers and layer management are discussed in Section 2.5.10.

Labels>Hide: Selecting ***Labels*>*Hide*** hides the labels associated with the selected item. This serves to reduce clutter in the **Diagram View**.

Labels>Show: Selecting ***Labels*>*Show*** displays the labels for the selected item. Figure 2-40 shows the difference.



Bus Labels Shown

Bus Labels Hidden

Figure 2-40. Showing and Hiding Labels

Diagram items may be "grouped" together to form logical units. These units can then be modified as a single entity. Diagram items can belong to only one group at a time. If a diagram item already belongs to group and is added to a new group, it is removed from the existing group before being added to the new group. Grouping items together is particularly helpful when wanting to move a collection of diagram elements as a group.

Grouping>Group: Before selecting the Group option first define a group by either holding down and dragging the left mouse button on a portion of the diagram to block select the items to be grouped, or use **[Ctrl]**+ left-mouse-click to selectively add items to the group. After doing so select ***Grouping>Group*** to build a group out of all the selected diagram items. Figure 2-41shows a group of items selected for grouping. Selecting only one item and clicking ***Group*** has no effect.

Grouping>Ungroup: To ungroup a previously grouped set of items, select the group in the diagram and select ***Grouping>Ungroup*** to explode the group back into individual items. Ungrouping a selected item which is not part of a group has no effect on the selected item.

To include any item in the group, it must be totally selected. The figure shows the selection of buses 3001 and 3002 and the branch between them. Once the items are grouped, the particular group can be selected by clicking on any one of its elements.

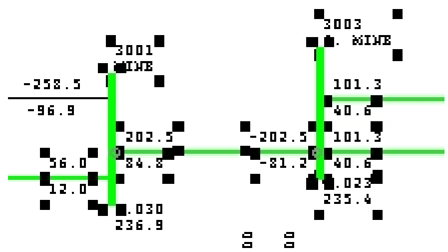


Figure 2-41. Selecting Diagram Items for Grouping

The system manages annotations (labels) associated with a given device as if it were "grouped" with the device. If the device is deleted, the related annotation is also deleted. If the selected device is moved, the related annotation is also moved. Therefore, adding a device to a larger group, in effect, adds all the related annotation to the larger group as well. This grouping behavior automatically moves annotations when the device is moved (called autopositioning), but can be disabled by selecting ***Properties>Auto Position***. When autopositioning is disabled, the annotation must be explicitly selected to be added to the group during the grouping operation.

Manage Layers: This tool provides a way to easily hide and show different groups of diagram items. Multiple diagram items can be assigned to a layer. Each layer has its own visibility options, as well as an option to turn selectability on and off.

Manage Views: This option provides a way to store and retrieve a variety of one-line diagram presentations at different zoom levels and with data presentations. At times this may be desirable for establishing unique views of the data in different one-line diagrams such as for displaying different results or other information and zooming or panning to different levels to examine different parts of the network. If these specific views are needed on a regular basis, then those views can be stored for rapid retrieval. Selecting the ***Manage Views*** option opens the **Saved Views** dialog (see Figure 2-42).

- To save the current view, click on the **New (insert)** icon, type in a name for the view and click ***Save***. With several views saved, the desired view can be selected from the available list.
- To restore a view, select the view from the list and click ***Restore***. The image will be repositioned and zoomed to the settings specified for the view.
- To delete a view, select the view to delete from the list and click the ***Delete*** icon.
- To reposition a view within the list, use the **Move Up** and **Move Down** arrow buttons.

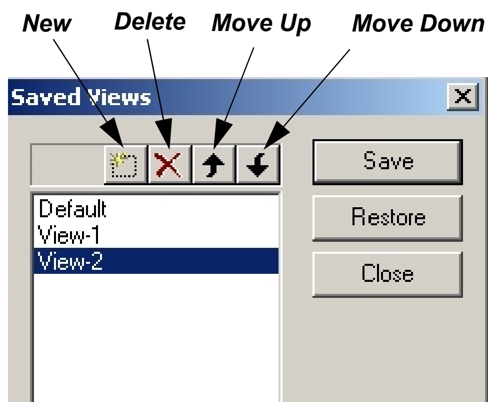


Figure 2-42. Saved Views Dialog

Network Data: With a diagram element selected, selecting the ***Network Data*** option activates the spreadsheet, changes to the correct data tab, and places the focus on the first spreadsheet cell of the selected data item. The data can then be examined and manipulated as desired. If more then one diagram item is selected or no items are selected, then the ***Network Data*** option is disabled.

Create bus subsystem: Defines a bus subsystem consisting of all elements selected on the diagram. Both the Spreadsheet View and the Tree View will be updated to reflect the new subsystem selection.

Diagram Annotation: Opens the Powerflow Data Annotation window. From here diagram annotations (i.e. Branch, bus, equipment annotation and diagram title) and diagram range checking options can be set. These are described in Section 2.9.2.

Item Properties>Auto Position: Without a network item selected in the diagram, the ***Auto Position*** option setting will indicate the auto-positioning setting for the entire diagram.

If an equipment item or annotation is selected (i.e. machine, load, capacitor), then the ***Auto Position*** option can be toggled ON or OFF for only the selected element. With auto-positioning enabled, the selected equipment or annotation connected to a bus will orient itself perpendicular to the bus. Toggling this property OFF allows the diagram item to be positioned in any orientation (see Figure 2-44).

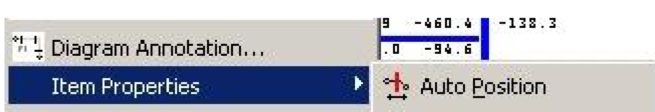


Figure 2-43. Toggling Auto Positioning

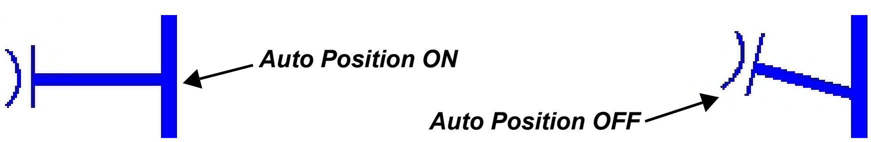


Figure 2-44. Impact of Auto-Positioning

Item Properties>Auto Relink: Without a bus selected in the diagram, the ***Auto Relink*** option setting will indicate the auto-relinking setting for all buses in the diagram.

If a busbar/bus node is selected, then the ***Auto Relink*** option can be toggled ON or OFF for only the selected busbar/bus node. With auto-relinking enabled, moving or re-sizing a busbar causes the attached branches and transformers to re-attach themselves for a perceived optimal representation. Toggling this property OFF allows the busbar to be moved or re-sized without affecting the attachment of branches and transformers.

Item Properties>Auto Rotate: Indicates whether equipment connected to a bus should rotate when the bus is rotated. Toggling this property off (no checkmark) retains the position of the equipment when the bus is rotated. **This menu option is only available when a non-bus item is selected.**

Item Properties>Font: Displays the **Font Selection** dialog from which a new text font, style, and point size for the selected item and its result labels can be applied. **This item is only available when a label (annotation) is selected.**

Item Properties>Line Style / Color: Displays the Line Style dialog for changing the color and style of lines, annotation or primitive shapes. Primitive shapes include straight lines, arcs, circles, polygons, etc that may be placed in any location on the **Diagram View**. The button icons for accessing them are located on the Diagram Toolbar along with the other network diagram elements.

Item Properties>Visible: Toggles whether the selected item is to be made visible or invisible on the diagram. When the ***Visible*** option is toggled off the item is still selectable, as denoted by the selection handles that appear when the location of the item is clicked on, however it is not visible. This option is only available when an item, or items, are selected (whether visible or invisible!).

Item Properties>Unbind: Selecting the ***Unbind*** option overrides the binding of the selected diagram item from the associated network model. Unbinding an item causes the diagram element to be disassociated with the network item. The network model item in the Tree View and the diagram element must be reselected and the Bind option from the Tree View right-click menu must be invoked to bind the items again. **This item is only available when a network item (or items) on the diagram is selected.**

Item Annotation: Launches an Item-specific Annotation Properties dialog box that provides control over the annotation displayed with the selected item. For example, when the selected item is a bus, selecting ***Item Annotation*** brings up the **Bus Annotation Properties** sheet for the bus shown in Figure 2-45.

The Item Annotation Properties dialog will depend on what diagram item was previously selected. **The *Item Annotation* option is only available when a network element is selected.**

A variety of options for selecting and positioning the annotation are available. The standard positions for bus information, which include numbers, names and voltages are to have name and/or number at the top right of vertical buses and the voltage at bottom right.

For horizontal buses, the positions are top left for names and numbers and bottom right for voltages. In addition, the annotation changes can be applied to all diagram items of the selected type, in this case buses, by checking the ***Apply the selected option to all buses*** checkbox at the bottom of the properties sheet. Similar selection boxes appear on other equipment annotation properties windows.

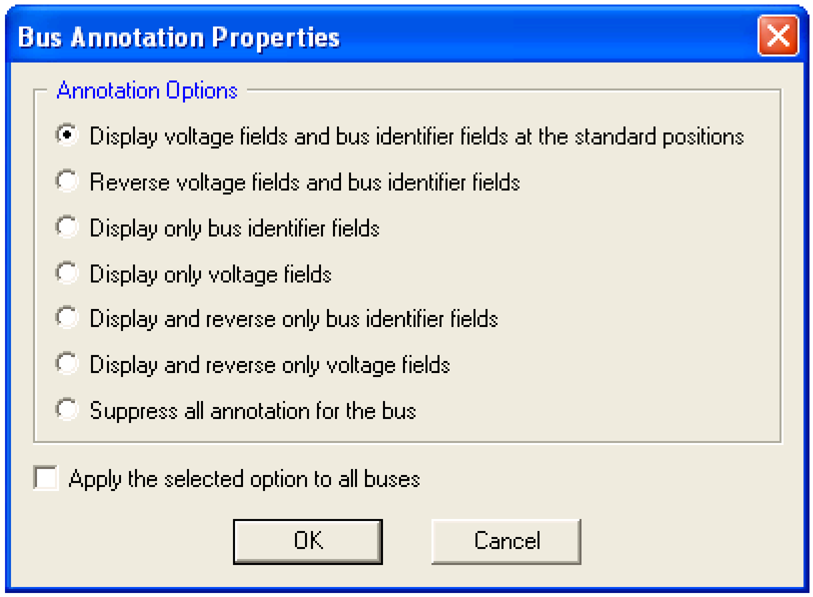
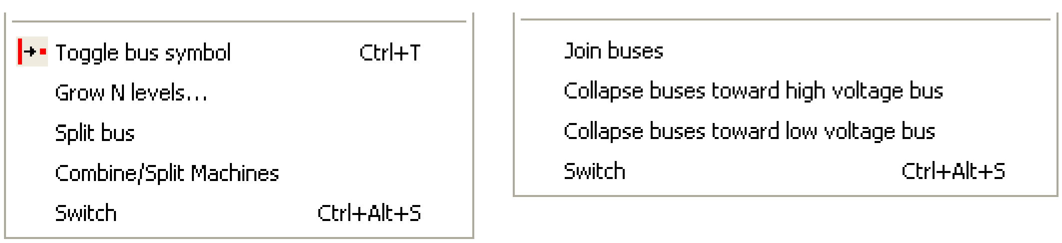


Figure 2-45. Bus Annotation Properties Options

As mentioned at the start of this section, the items shown at the bottom of the right-click Diagram View menu are customized to the element(s) selected on the diagram. Figure 2-46 shows the lower portion of the right-click menu when a bus is selected. There may be other options when another type of equipment is selected on the diagram (i.e., load, machine, etc). Below are inclusive descriptions of all possible options that may appear.



One Bus Selected ***Two Buses Selected***

Figure 2-46. Bottom Part of Pop-up Menu for Selected Bus

Toggle bus symbol: If a bus was the selected item, the Toggle bus symbol option appears on the menu. Selecting ***Toggle bus symbol*** toggles the selected bus between the busbar and busnode representations (see Figure 2-47).

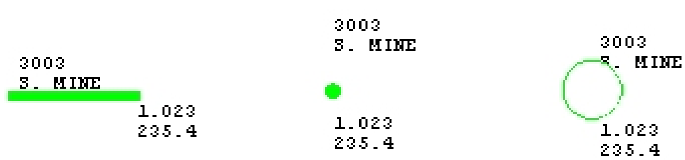


Figure 2-47. Alternative Bus Symbols

Grow N Levels...: Selecting ***Grow N Levels...*** draws any undrawn elements connected to the bus using the method described in Section 2.5.5.

Split bus: If a single bus is selected on the diagram, then the ***Split bus*** option appears on the menu. Selecting ***Split bus*** displays a dialog prompting for a new bus number, name and base kV. Pressing ***OK*** will split the bus into two bus, preserving the existing one and adding a new one. Equipment and lines can then be moved between the buses by holding the **[Ctrl]** key and clicking on the end of the equipment/line and dragging to the new bus. See Section 4.6.5 for a detailed description.

Join buses: If two buses are selected on the diagram, then the ***Join buses*** option appears on the menu. Selecting ***Join buses*** displays a dialog prompting how to handle line shunts of deleted in-service branches. Pressing ***OK*** will join the two buses into a single retained bus. See Section 4.6.4 for a detailed description.

Switch: Selecting ***Switch*** toggles the status of the selected item(s) to either in-service or out-of-service. The graphical representation of the diagram item is changed accordingly.

Combine/Split Machines: If a single bus with at least one connected machine diagram item is selected, then the ***Combine/Split Machines*** option appears on the menu. Selecting ***Combine/Split Machines*** combines multiple machine diagram items at the bus into a single summing machine symbol, where results are summed for total generation at the bus. A summing machine symbol has no machine ID in the center of the symbol whereas a machine diagram item representing a single machine has a machine ID in the center of the symbol.

If only a summing machine symbol exists on the bus, selecting the bus and then the ***Combine/Split Machines*** option will remove the summing machine symbol and replace it with one or more machine diagram items representing the individual machines at the bus.

Combine/Split Loads: This operation does the same operation as ***Combine/Split Machines*** but for Loads.

Combine/Split Fixed Shunts: This operation does the same operation as ***Combine/Split Machines*** but for Fixed Shunts.

Collapse buses towards high voltage bus: When two buses are selected and the ***Collapse buses towards high voltage bus*** is used, all elements on the lower voltage bus will now appear to be connected to the high voltage bus, and the lower voltage bus will be removed, as well as any elements that were connecting the two buses. These elements will be removed from the diagram, but they will not been removed from the actual network. When any analysis is done, these elements are still included in the calculations. This function is used to visually change the layout in the diagram view, and has no effect on the actual network.

Collapse buses towards low voltage bus: When two buses are selected and the ***Collapse buses towards low voltage bus*** is used, all elements on the higher voltage bus will now appear to be connected to the low voltage bus, and the higher voltage bus will be removed, as well as any elements that were connecting the two buses. These elements will be removed from the diagram, but they will not been removed from the actual network. When any analysis is done, these elements are still included in the calculations. This function is used to visually change the layout in the diagram view, and has no effect on the actual network.

The right-click menu obtained from selecting a line element is similar to that for a bus selection but the bus related options will not exist. The bottom portion of the menu list may now include the Switch and Tap line option (see Figure 2-48).

The ***Switch*** option toggles the status of the equipment to either in-service or out-of-service and changes the visual properties of the line.

The ***Tap Line*** option allows for the introduction of a new bus into the working file at a designated location along a selected AC branch. Any nontransformer branch may be tapped. The Tap Line option is discussed in detail in Section 4.6.6.

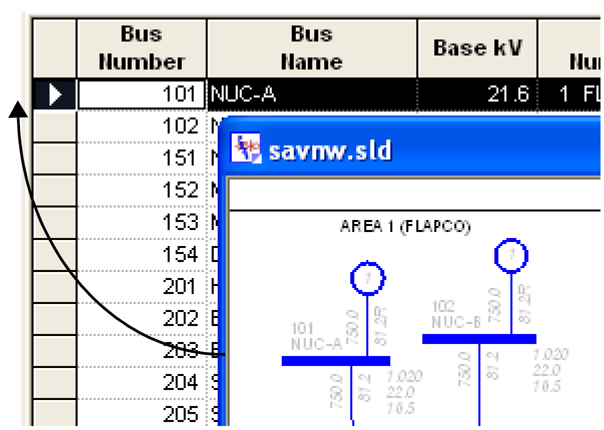
Figure 2-48. Right-Click Menu Items for Lines

If the selection is a transformer, the ***Tap line*** option will be absent but the ***Switch*** option will remain.

For bus connected capacitors and reactors the ***Switch*** option **will not** be available. To switch the status of capacitors and reactors, double-click on the network item (or right-click and select ***Network data…***) to edit the status field of the corresponding data record in the Spreadsheet View.

2.5.9 Double-Clicking in the Diagram View

Double-clicking on a diagram item activates the spreadsheet, changes to the correct data tab, and places the focus on the first spreadsheet cell of the selected item (see Figure 2-49).



Double-click on bus 101 diagram item to move directly to that bus in the spreadsheet.

Figure 2-49. Moving from the Diagram to the Spreadsheet

2.5.10 Managing Diagram Layers

A simple way to visualize layers is to imagine the Diagram View as an infinite number of sheets of clear mylar, stacked on top of another. Diagram items are drawn on a single sheet of mylar, that is, they belong to a particular layer. When all sheets are laid down, the Diagram View is seen in its entirety. The capability exists to view only selected layers at a time. For example, layers could be defined for base voltages of 110 kV, 200 kV, and 300 kV. The diagram items that correspond to these base voltages could then be created on the appropriate layer. To view the entire network, all layers would be made visible. To view only the 200 kV elements, the 100 kV and 300 kV layers would be made invisible, leaving only the 200 kV layer visible. The use of layers is controlled through the Layers dialog which is opened by selecting ***Diagram>Manage Layers...*** from the Main Menu (Figure 2-50).

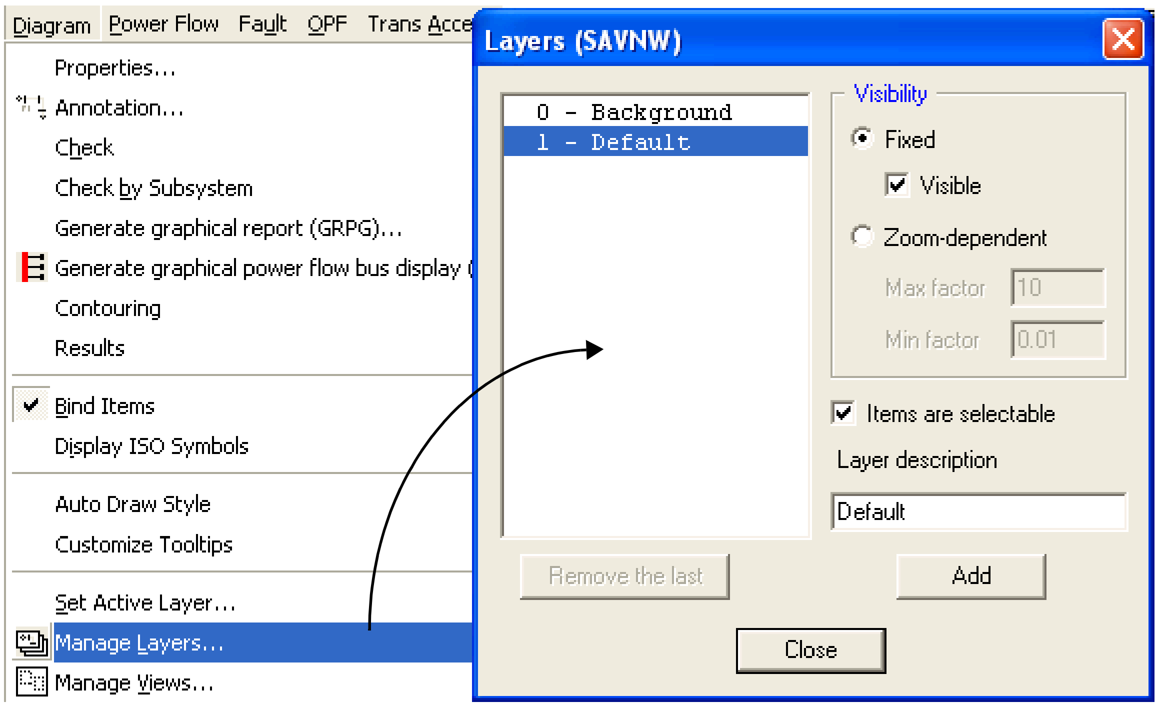


Figure 2-50. Opening the Layers Dialog

At a minimum, all diagram views contains two layers:

- **Layer 0:** The background layer and contains imported images.
- **Layer 1:** The default layer.

These layers can have their attributes changed but cannot be removed from the **Diagram View**. The single layer selected by the user is the active layer. All new diagram items added to the **Diagram View** are created on the active layer.

Even if all layers are visible, only one is considered the "active" layer. The active layer and its name is always displayed in the **Status Bar** at the bottom of the **Spreadsheet View**. The active layer is the layer selected when the **Layers** dialog is closed.

The Visibility of the layers may be made either **Fixed** or **Zoom-dependent**, depending on the option selected. If a layer is **Fixed**, it is in the Diagram View but can additionally be made either visible or invisible by checking or unchecking the ***Visible*** checkbox. If a layer is **Zoom-dependent**, its visibility in the Diagram View is determined by the current zooming factor. If the current zooming factor is within the minimum and maximum zooming factors specified, then the layer is visible. If the zooming factor is outside of the range, then the layer is invisible.

It is not necessary to close the dialog to save the changes to a layer. Changes are saved whenever a different layer is selected from the list. All items on a selected layer may be made unselectable by unchecking the ***Items are selectable*** checkbox. This can be handy if you want to avoid the inadvertent selection or manipulation of certain diagram items. Simply place those items of concern on a layer that it made unselectable.

The layer's description may be changed by selecting the layer from the list and entering a new description in the Layer description field.

Layers are added by clicking the ***Add*** button. The attributes of this new layer may then be modified as described above. Layers are removed by selecting the layer from the list and clicking the ***Remove the last*** button.

The ***Diagram>Set Active Layer*** option from the Main Menu, as shown in Figure 2-50, invokes a Select Layer dialog for assigning selected items to a specific layer (see Figure 2-51).

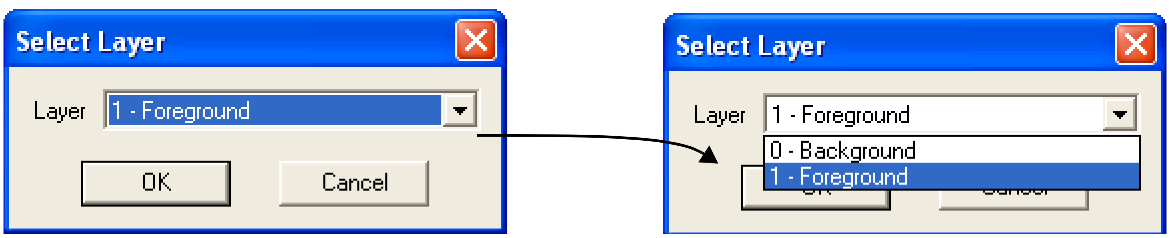


Figure 2-51. Setting the Active Layer

Diagram items may be assigned to a given layer by selecting ***Display>Assign to Layer… on the right-click menu.*** The desired layer for the selected item is specified via the **Select Layer** dialog (see Figure 2-51).

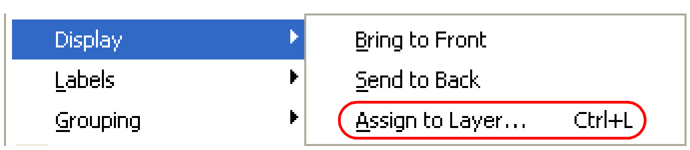


Figure 2-52. Assigning Diagram Items to a Layer

This method can be used to assign diagram items to a layer one at a time, or a group of items can be selected and all be assigned to a layer. As an example, all diagram items from Area 1 of the *savnw.sav* power flow case can be selected and assigned to a layer with the name Area 1. To add the new layer, open the open the **Layers** dialog, as shown in Figure 2-50, click ***Add***, and enter the desired information. After adding the additional layer, the **Layers** dialog will appear (see Figure 2-53).

To see the entire one-line diagram, select all layers to be "visible" (see Figure 2-54). If the Area 1 layer is selected to be *not* visible, the one-line diagram will show only the diagram items belonging to Default (see Figure 2-55).

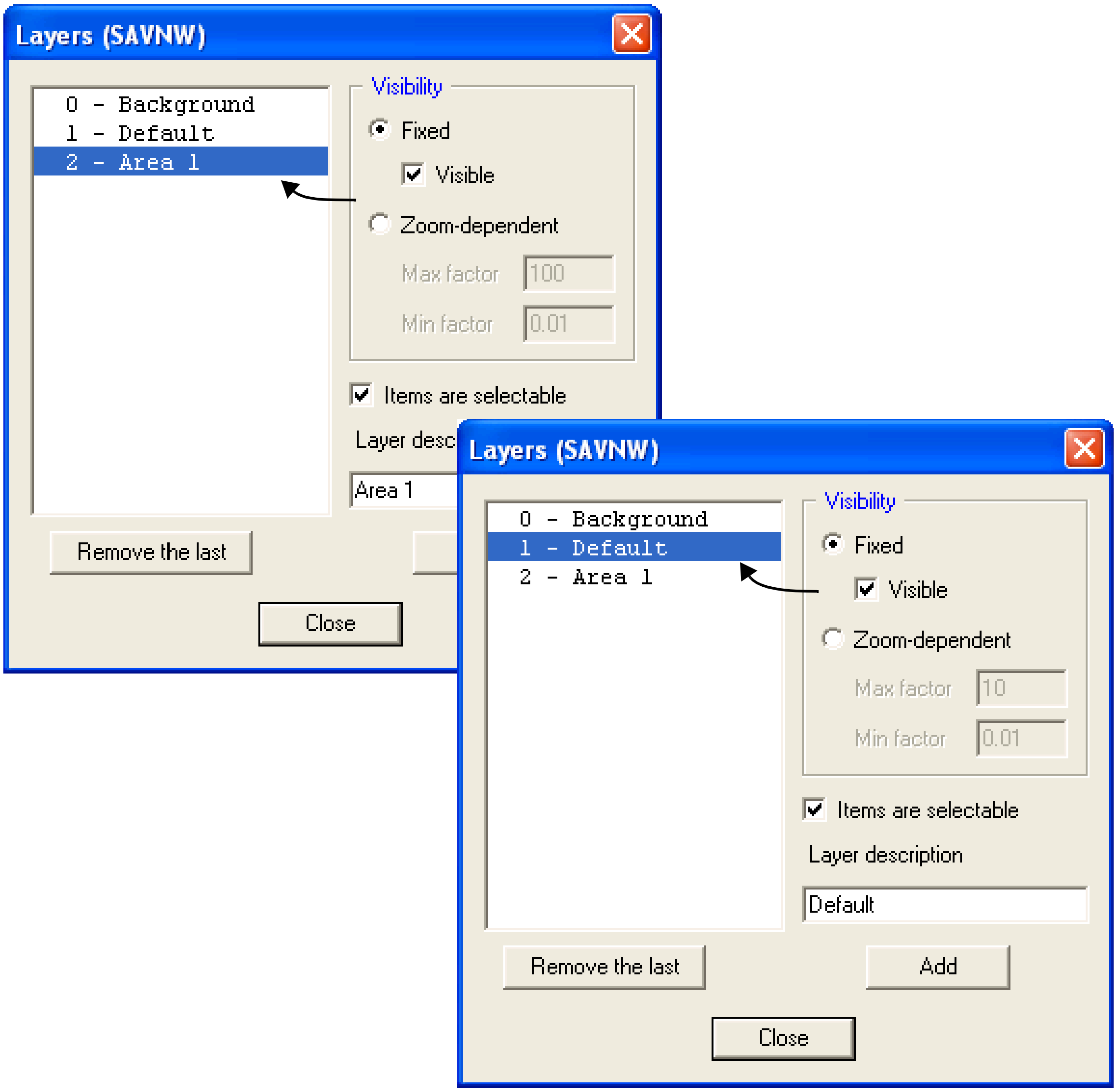


Figure 2-53. Both Default and Area 1 Layers Visible

In this case the background layer has no content.

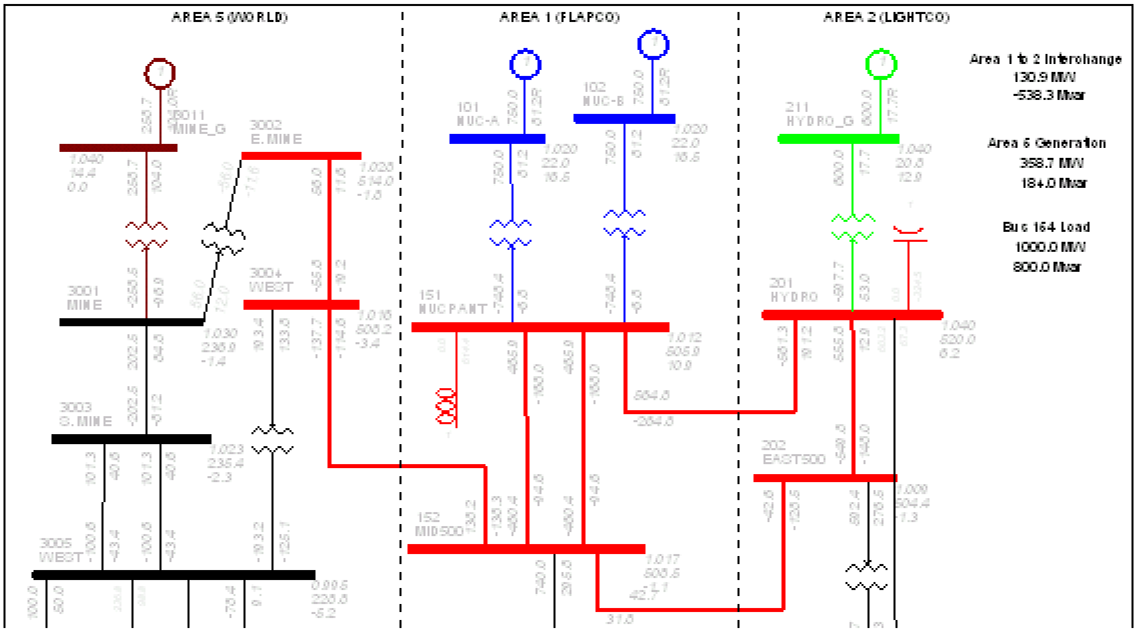


Figure 2-54. All Layers Visible from Layers Dialog

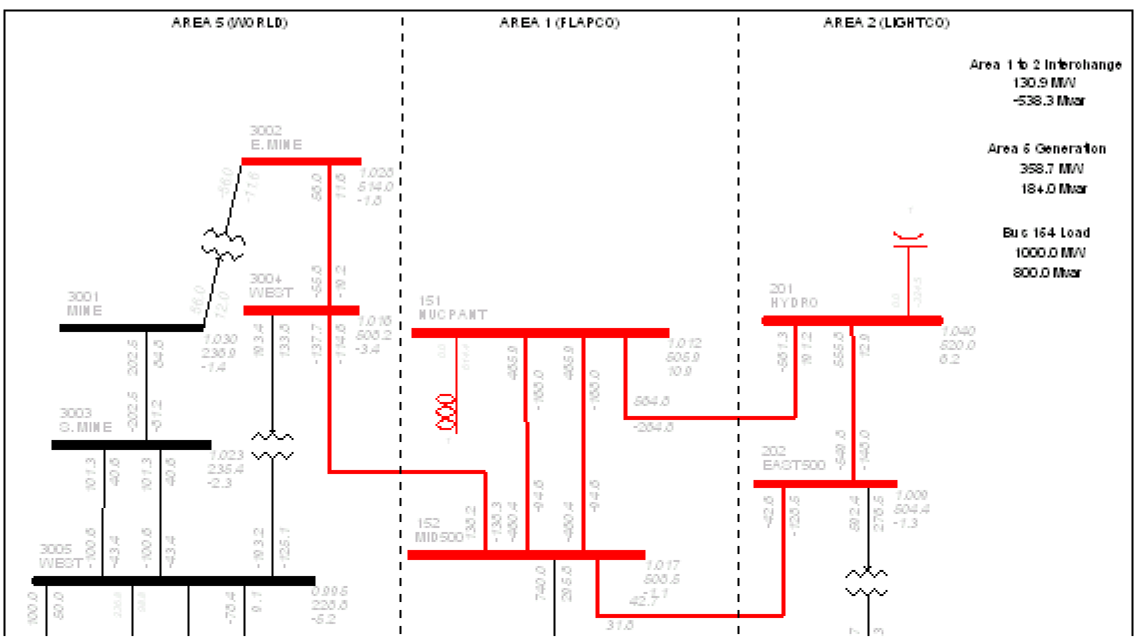


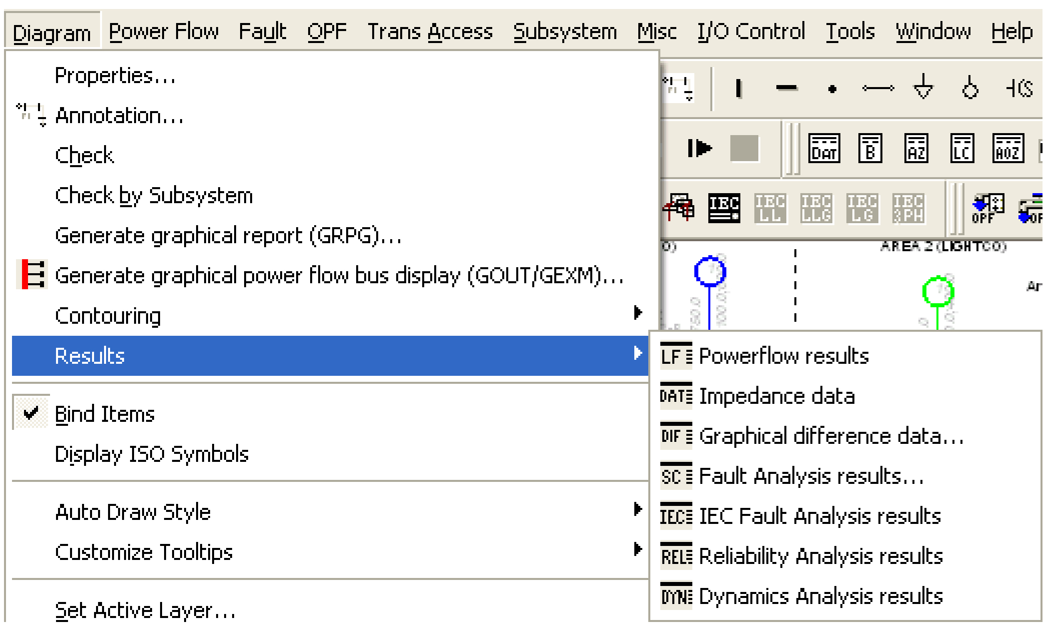
Figure 2-55. Only Default Visible

2.5.11 Viewing Results on the Diagram

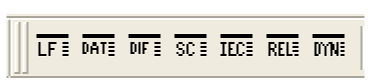
With the **Diagram View** active, seven types of information or results may be displayed on the diagram. These include:

- The power flow solution results
- impedance data
- Difference between the current power flow case and another saved case
- Short-circuit levels for both three-phase and single-line-to-ground faults
- IEC Fault analysis
- Reliability results
- Dynamics results

To select the results type displayed in the active **Diagram View**, select one of the options shown on the ***Diagram>Results menu*** or alternatively, choose from one of the toolbar buttons in the **Results Toolbar** (Figure 2-56b).



(a) Results Menu Options



(b) Results Toolbar Buttons

Figure 2-56. Accessing Alternative Results Presentations

2.5.11.1 Power Flow Results

If Powerflow results is selected the diagram will be annotated with the power flow results (see Figure 2-57).

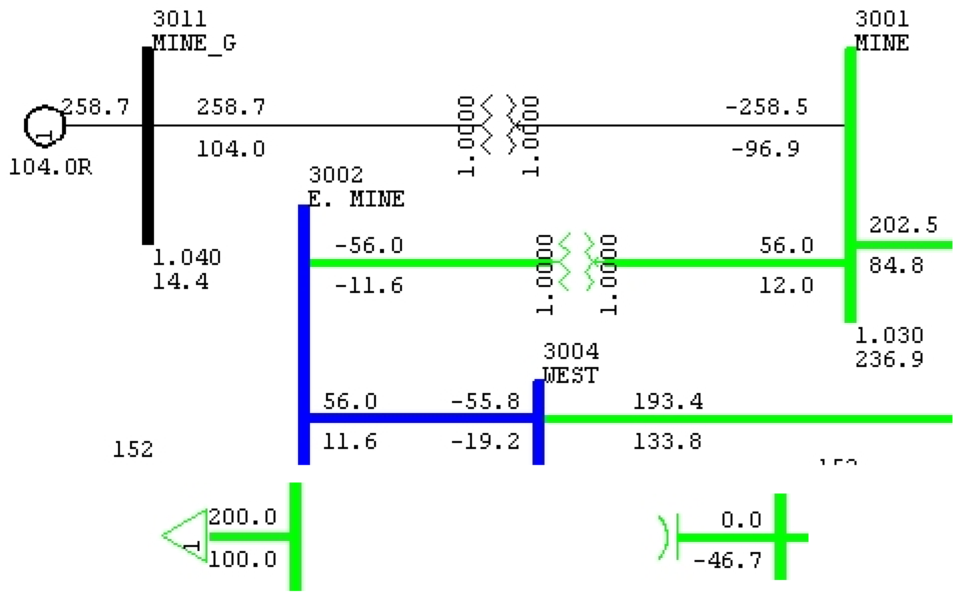


Figure 2-57. Typical Power Flow Results

The default information shown for buses includes the number, name and the voltage expressed as magnitude (pu) and angle. Flows are shown at both ends of each branch in MW and Mvar units. A positive number indicates the flow is away from the bus, (56 MW is flowing from bus 3002 towards bus 3004).

Generator information includes power in MW and reactive power in Mvar. On bus 3011 the "R" indicates that the machine is within its reactive limits.

Separately shown are a Load of 200 MW + j100 Mvar and a shunt capacitor providing 46.7 Mvar.

The results presentation shown may be modified globally for the diagram by selecting ***Diagram>Annotation***. The details of this option is described in Section 2.9. Using the right-click menu applied to a specific diagram item opens an annotation dialog for that specific network item.

Bus Annotation

Right-clicking on a bus in the Diagram View opens the Bus Annotation Properties sheet (see Figure 2-58). The information displayed, as well as its positioning, can be selected. Further, you can select to suppress all annotation at the selected bus or choose to apply the annotation properties selected to all buses by checkmarking the **Apply the selection option to all buses** box.

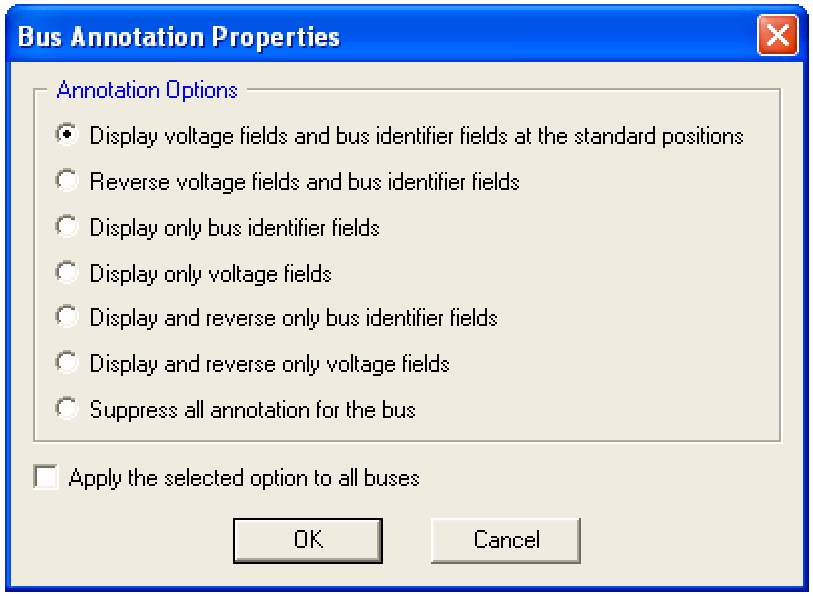


Figure 2-58. Bus Annotation Properties Options

Equipment Annotation

Right-clicking on a load or a shunt capacitor/reactor opens the appropriate annotation properties dialog (see Figure 2-59). You can choose the type of display, whether to suppress the display, and optionally whether to apply the properties to all shunt or load items.

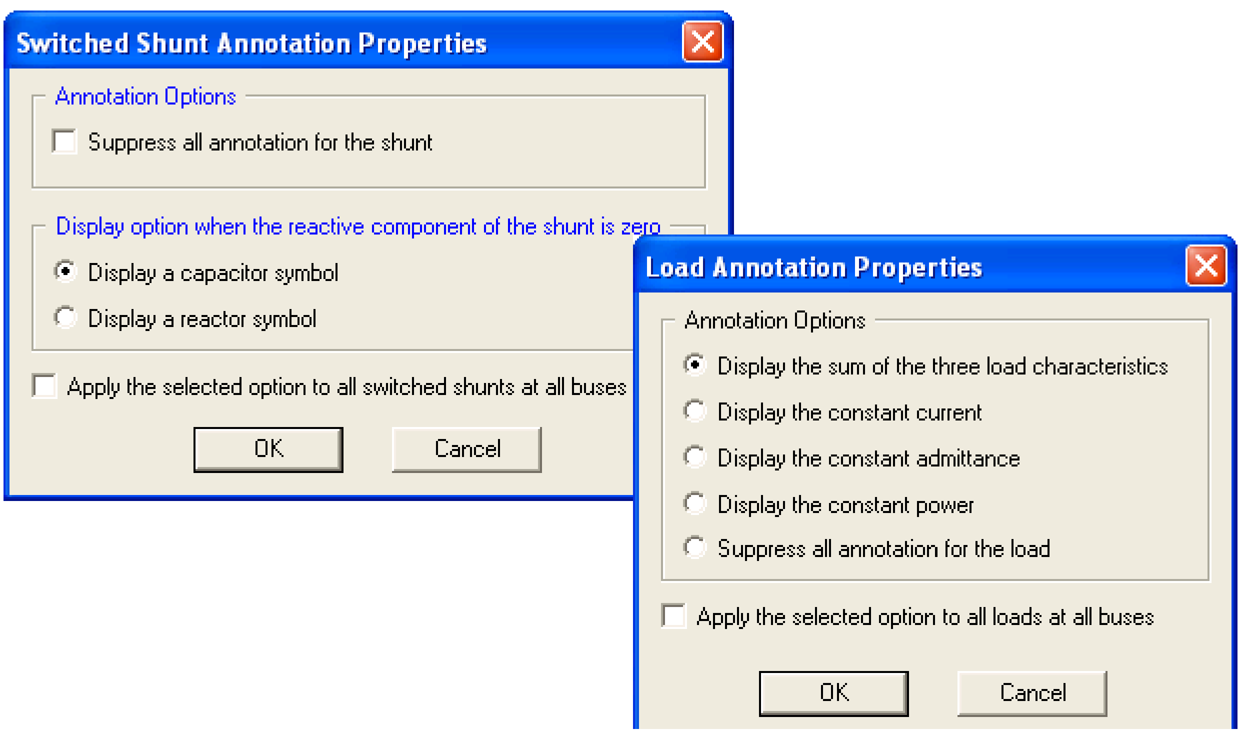


Figure 2-59. Annotation Properties Options for Shunts and Loads

Transformer and Non-Transformer Branch Annotations

Right-clicking on a branch or transformer (the transformer symbol itself, not the transformer line!) in the Diagram View and selecting the ***Item Annotation…*** menu option opens the Branch Annotation Properties sheet or Two Winding Transformer Annotation Properties window respectively. The latter is shown in Figure 2-60. If the menu is opened by right-clicking on a nontransformer branch, then only the top two Flow Annotation Options are activated, along with the option to draw a series capacitor symbol.

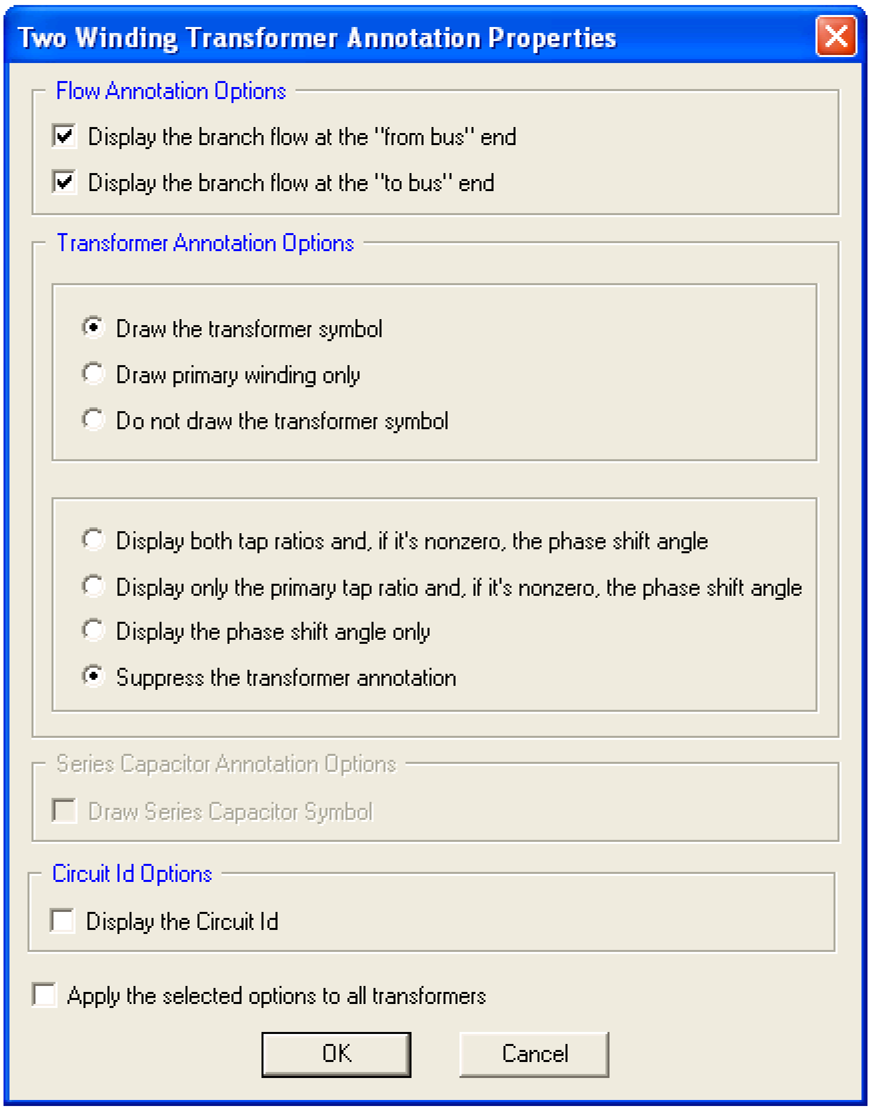


Figure 2-60. Two-winding Transformer Annotation Properties Options

2.5.11.2 Showing Impedance Data on the Diagram

In Figure 2-57 the power flow results are shown for the *savnw.sav* power flow case. Selecting the ***Diagram>Results>Impedance data*** option from the Main Menu or the ***Impedance data*** toolbar button shown in Figure 2-56, displays network data shown in the one-line diagram in Figure 2-61.

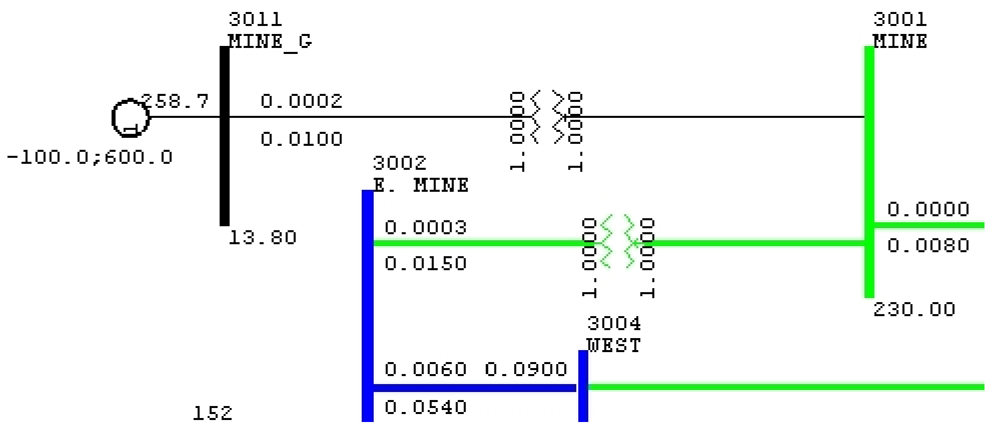


Figure 2-61. Presenting Network Data in the One-Line Diagram

By default the diagram displays the generator scheduled power and the reactive power limits. Bus information includes the bus number, name and base kV. Line and transformer information shows the R, X and B values, as appropriate and the transformer tap information is included. The presentation can be modified using the annotation properties tools discussed in the previous section for the power flow results.

2.5.11.3 Displaying Power Flow Solution Differences on the Diagram

Selecting the Diagram>Results>GDIF data option from the Main Menu or the ***GDIF data*** toolbar button opens the Graphical case comparison activity GDIF dialog (see Figure 2-62). The function performs a graphical case comparison by calculating the differences in power flow solution results and certain power flow boundary condition data contained in the open power flow case with those of a designated saved case and displays them in the **Diagram View**.

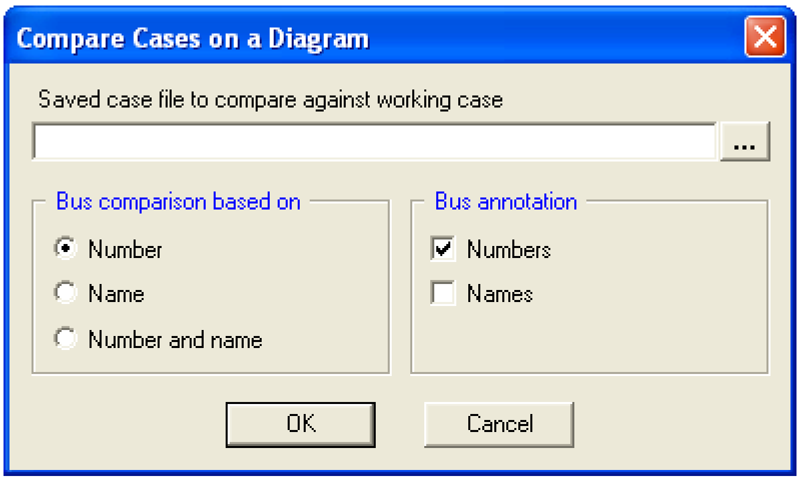


Figure 2-62. Initiating the Graphical Case Comparison

Within the Graphical case comparison window enter or select the saved case file to be compared against the currently open power flow case.

In the **Bus comparison based on** section select the identification method to be used for comparing the buses within the two sets of cases. This selection establishes how buses in each case are determined to be the "same" bus. Choices include comparison by bus number, bus name or both. If buses in the two cases are matched using only their extended bus names, then the extended bus names of the bus in each case must match and no other bus in either case can have the same extended bus name. Alarms are printed in the Output View or the selected reporting device if any problems occur.

The **Bus annotation** option allows for either bus names, bus numbers or both to be displayed on the diagram.

The results in the one-line diagram show the differences in solution results and bus boundary conditions between the current power flow case and the selected saved case. Differences are always calculated as comparison case values minus power flow case values. At each bus in the bus comparison list, voltage differences in per unit and phase angle differences in degrees are shown. All other difference values are shown in MW and Mvar. An example diagram is shown in Figure 2-63.

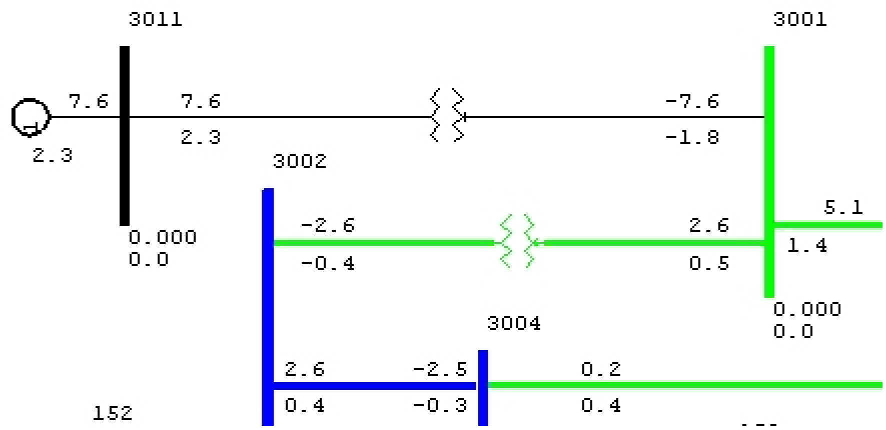


Figure 2-63. Graphical Difference Output

The difference fields are left blank for equipment items present in the power flow case, but not in the comparison case. Those items present in the comparison case that are not included in the power flow case are omitted from the diagram.

Load and shunt differences include voltage sensitivity effects.

Differences in flow into a converter bus of DC line "n" are shown if all of the following conditions apply:

- DC line "n" is present in both cases.
- The converter bus is in the bus compare list.
- The same converter bus is specified in both cases.

Two-terminal dc lines are annotated according to the annotation properties currently set in the diagram.

Differences in the sending end bus' shunt element of FACTS device "n" are shown if all of the following conditions apply:

- FACTS device "n" is present in both cases.
- The sending end bus is in the bus compare list.
- The same sending end bus is specified in both cases.

If the above conditions are satisfied and FACTS device "n" has a series element in the power flow case, differences in series flow at the sending end bus are also shown.

Differences in series flow at the terminal end bus are shown if all of the following conditions apply:

- FACTS device "n" is present and has a series element in both cases.
- The terminal end bus is in the bus compare list.
- The same terminal end bus is specified in both cases.

2.5.11.4 Reporting Unbalance Fault Conditions on the Diagram

With the Diagram View open, it is possible to perform an unbalanced fault calculation on the basis of a three-phase or single-line-to-ground bus fault at a single bus or at a selection of buses. The faults are calculated simultaneously but are not applied simultaneously.

To initiate the calculation process select the ***Diagram>Results>Short circuit data*** option from the Main Menu or the associated toolbar button. The resulting dialogue and fault calculation procedure is covered in detail in Chapter 7 and more specifically Section 7.6.3.2.

2.5.11.5 Reporting IEC Results on the Diagram

With the Diagram View open, it is possible to display the IEC Results if the calculations have been run. This calculation procedure is covered in detail in Section 4.132 of the *Program Operation Manual, Volume I*.

2.5.11.6 Reporting Reliability Results on the Diagram

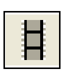
With the Diagram View open, it is possible to display the Reliability Results if the calculations have been made previously. The procedure for the calculations is covered in more depth in Section 5.8.

2.5.11.7 Reporting Dynamics Results on the Diagram

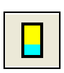
If the Dynamics data has been opened it is possible to display the Dynamics Results on the Diagram View. More detail about the Dynamics Results can be found in more depth in Section 5.8.4.

2.5.11.8 Additional Diagram Display Capabilities

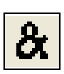
In addition to the toolbar buttons shown on the Results Toolbar (see Figure 2-56b), there are three other useful toolbar buttons:



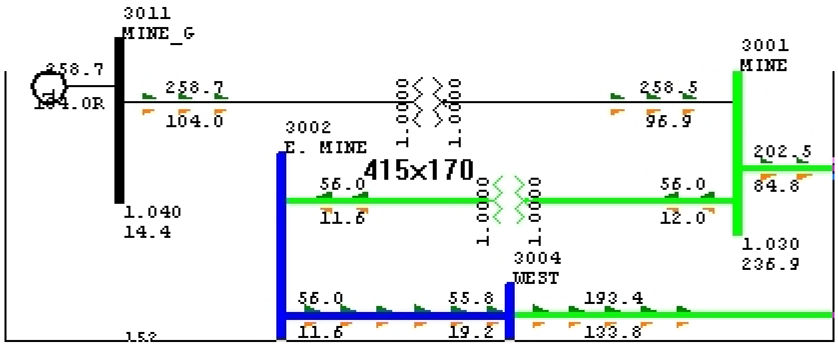
The **Animate flows** button is used to animate branch flows on the active Diagram View. The branch flows are animated using the flows from the last load flow solution (see Figure 2-64a).



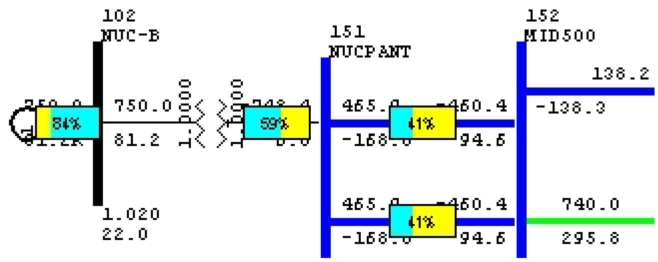
The **Current loadings** button is used to display line loading graphs. The graph values are set using values from the last load flow solution. See Figure 2-64b



The **Multisection line reporting** button is used to expose or hide the dummy buses that constitute the terminals of multiple sections that make up a single line between buses (see Figure 2-65).



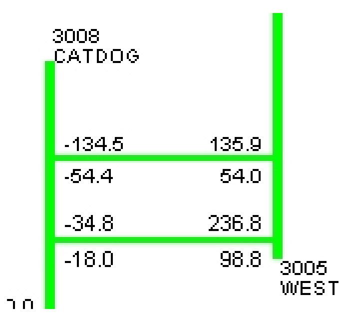
(a) Animate Flows



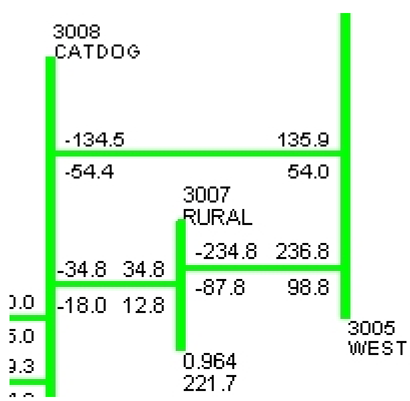
(b) Current Loading

Figure 2-64. Animating Flows and Showing Current Loading Graphs

The partial one-line diagrams in Figure 2-65 show the presentation with and without multisection line reporting. There is a multisection (2 section) line between bus 3008 and bus 3005 which is shown as a single section with the reporting OFF. With reporting ON the "dummy" bus (bus 3007) is shown. The diagram automatically draws the two line sections and the dummy bus when the multisection line reporting is ON although the diagram might need to be adjusted.



(a) Reporting OFF



(b) Reporting On

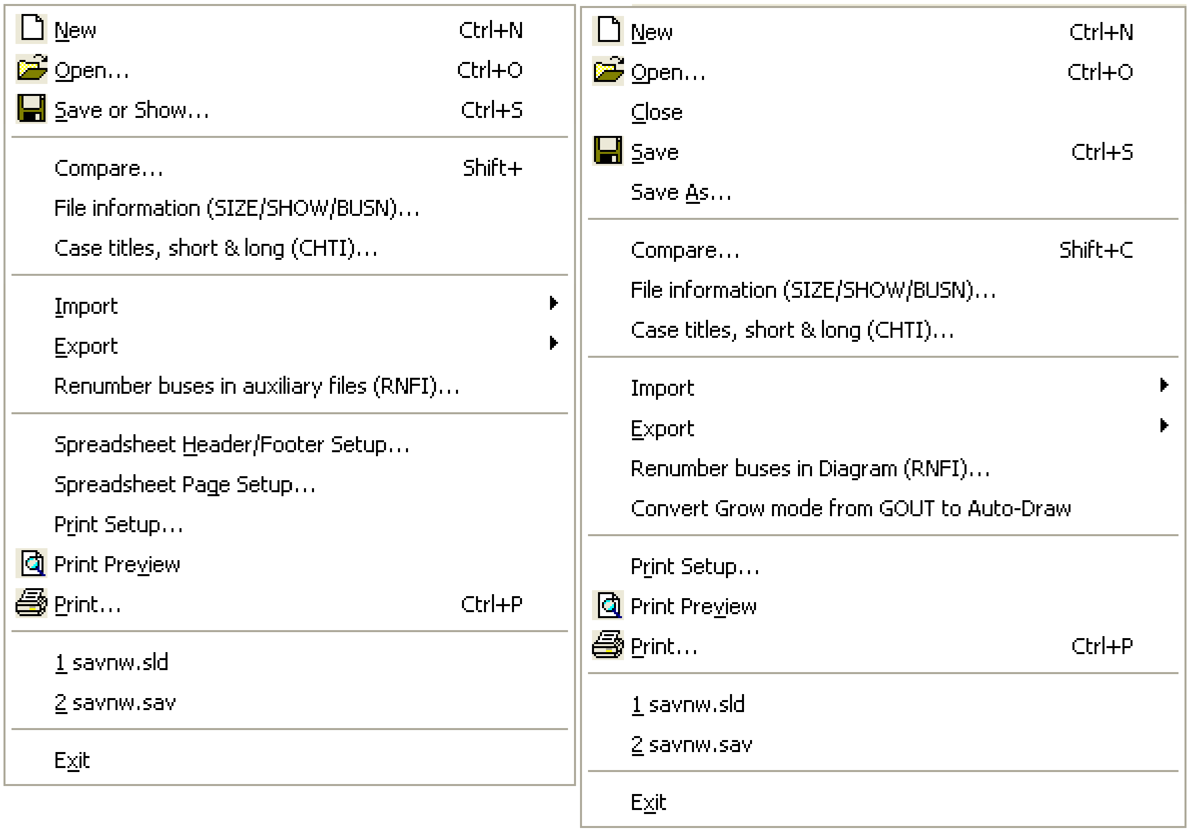
Figure 2-65. Multi-Line Section Reporting ON and OFF

2.5.11.9 Contouring

Contours can be drawn on the Diagram View.

2.6 File Menu

Two File Menus are shown in Figure 2-66: one available when the Spreadsheet View is active and the other when the Diagram View is active.



(a) Spreadsheet Active **(b) Diagram Active**

Figure 2-66. Alternative File Menus for Active Spreadsheet and Diagram Views

Within the Main Menu the Diagram Menu appears only when the Diagram View is active. Additionally, there are two other Menus on the Main Menu that change depending on whether the Diagram View or the Spreadsheet View is open.

2.6.1 Creating a New File or Diagram

Selecting ***File>New*** facilitates the creation of a new diagram, a new power flow case, a new diagram and power flow case, or a plot sheet. Figure 2-67a shows the **New** dialog. If the ***Diagram*** option is selected, a blank diagram will open in the **Diagram View**. If the ***Plot Sheet*** is selected, a blank plot sheet will open up. If a new ***Case*** option is selected, then the **Build New Case** dialog opens for initiation of data input (Figure 2-67b). Once the system ***Base MVA*** has been selected and the two header lines are optionally input, a blank spreadsheet is produced in the Spreadsheet View. The new case can be built entirely in the **Spreadsheet View** or jointly with the **Diagram View**.

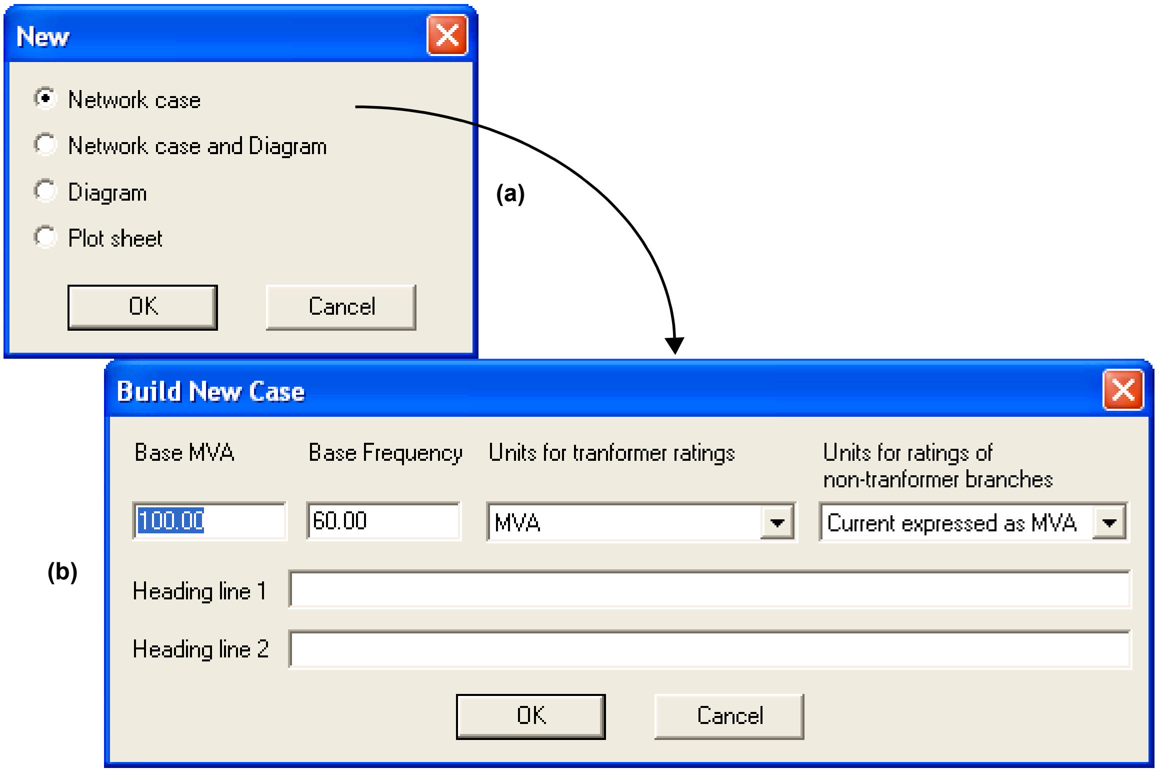


Figure 2-67. Opening the New and Build New Case Dialogs

The system stores the Heading lines as comments within the exported case. They are used to document the case.

2.6.2 Opening a File

Selecting ***File>Open*** or the ***Open*** toolbar button, with either the Spreadsheet or the Diagram View active, opens the dialog shown in Figure 2-68. From this window a variety of file types are accessible and may be opened.

The DRAW coordinate data files cannot be opened in this menu. Refer to Section 2.5.2.1 for importing a DRAW file.

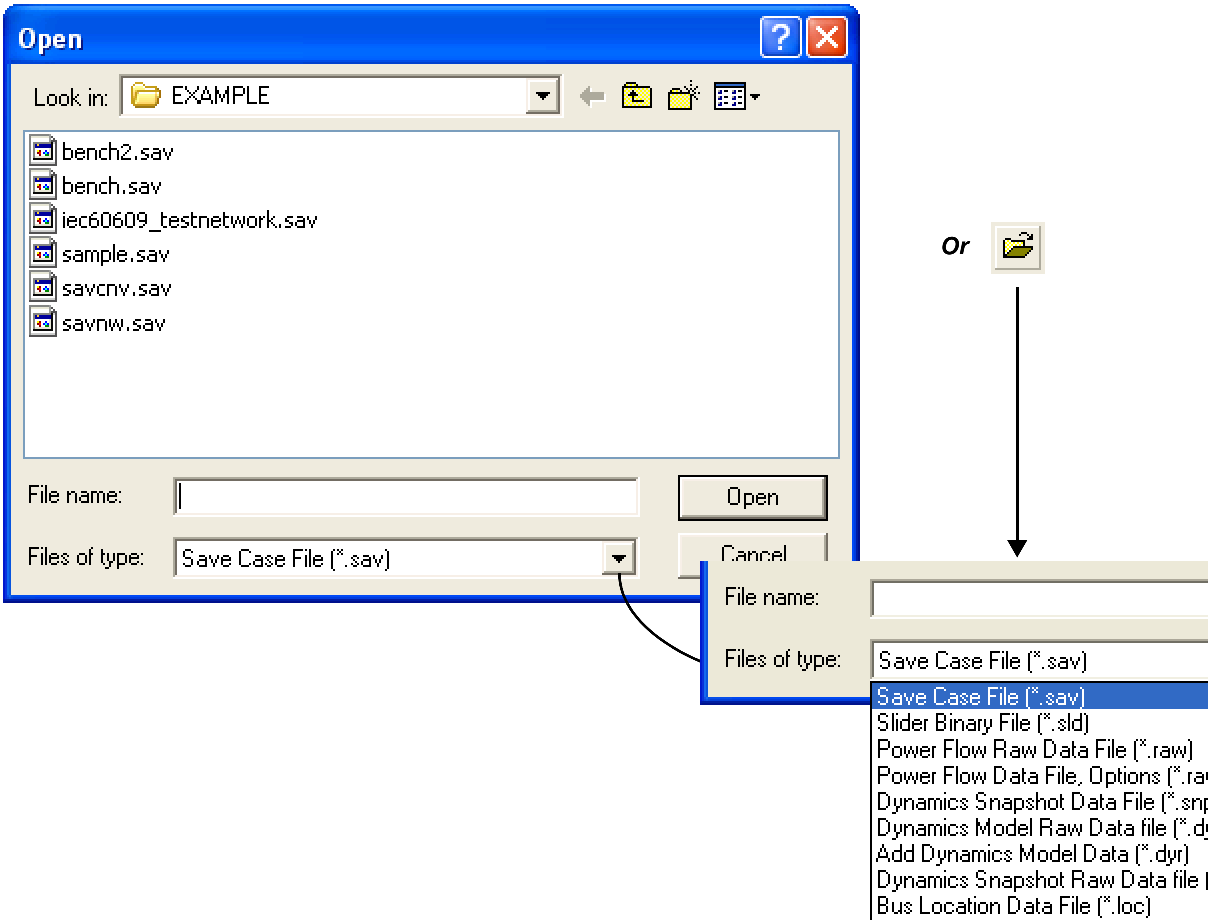


Figure 2-68. Selecting *File>Open* or the Open Toolbar Button

2.6.3 Saving or Showing a File *(Spreadsheet View Only)*

Selecting ***File>Save or Show*** facilitates the writing of a variety of data types to a file of the user's choice or listing (showing) the data in the **Output Bar**. If the case data is being saved to a binary **.sav* file, the option to list data in the **Output Bar** is not available.

When ***Save or Show*** option is selected, the **Save/Show Network Data** dialog will open (see Figure 2-69). Data that can be saved includes:

- Case Data
- Power Flow Raw Data
- Optimal Power Flow Data
- Machine Impedance Data
- Sequence Data
- Transaction Data
- Power flow data in IEEE format
- UCTE Data

Each data type has its own tab. When a tab is selected options on how to handle the data and a subsystem selector option is available. The choice of a destination; either a file or Output Bar (for raw data files), is available.

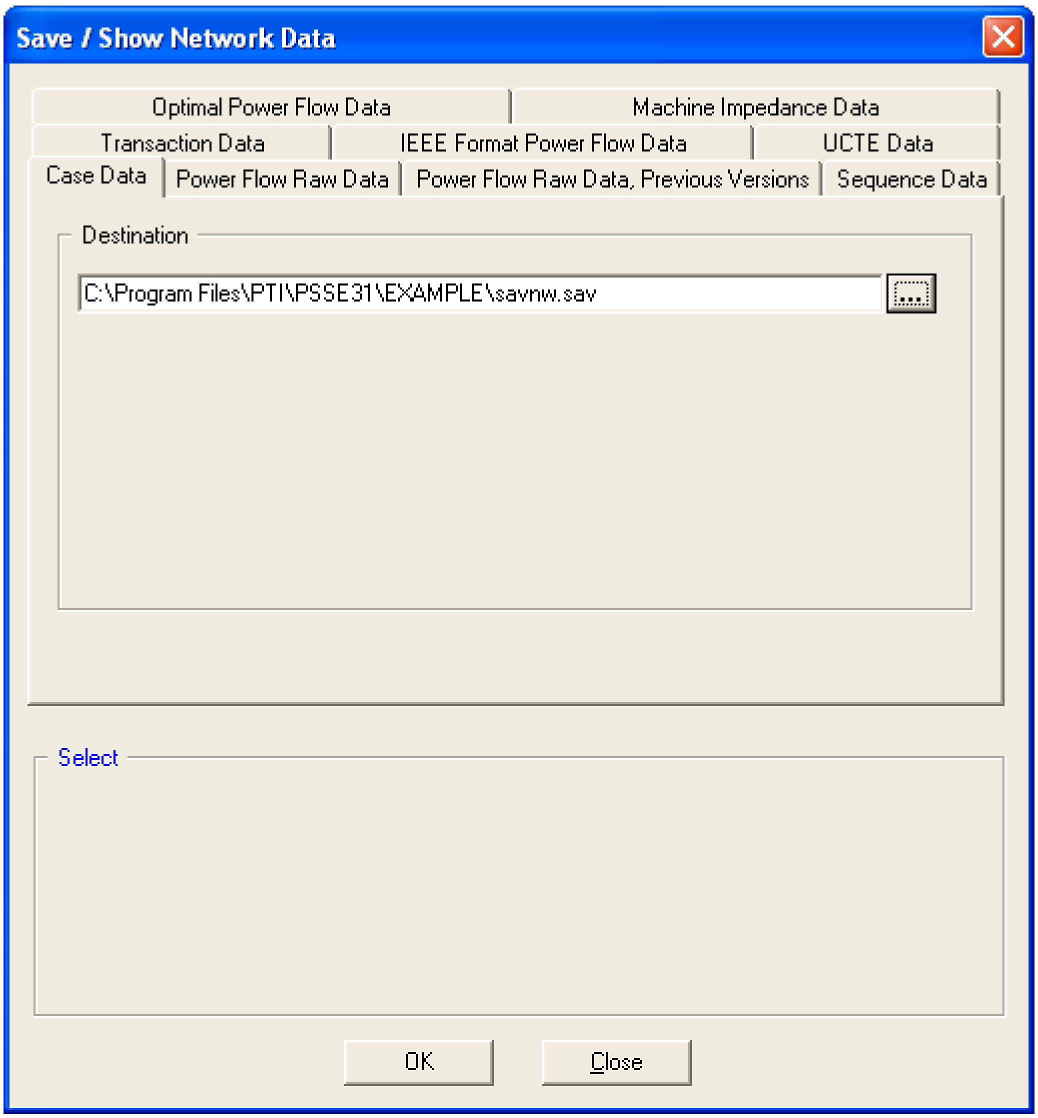


Figure 2-69. Save/Show Network Data Dialog

2.6.4 Closing a Diagram File

Selecting ***File>Close***, with a **Diagram View** open, will prompt the closure of the diagram and will present the option to save any changes made to the diagram since it was last opened (see Figure 2-70).

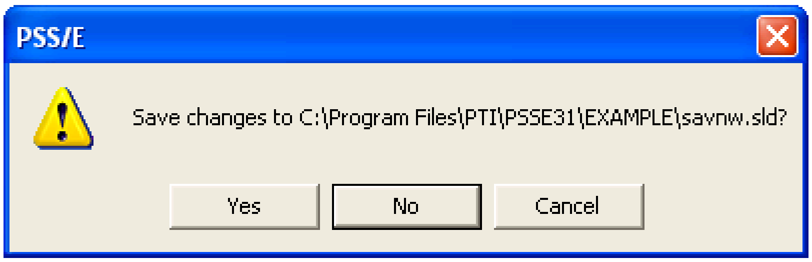


Figure 2-70. Closing a Diagram View

2.6.5 Saving a Diagram File

Selecting ***File>Save*** from the Main Menu or clicking on the ***Save*** toolbar button saves the current diagram. If the diagram has been previously saved to a file, the Save option will simply save the current diagram to the same file, with no additional dialog. If the diagram is newly created or the ***File>Save As…*** option is selected, then the Save As or Show dialog is displayed and the diagram can be save under a new name (see Figure 2-71).

Two file type options are available for saving the file to. The Slider Binary File (*.sld) is the standard Slider format in which to save diagrams. An alternative Slider XML File (*.sldxml) selection will save the diagram to an XML text file.

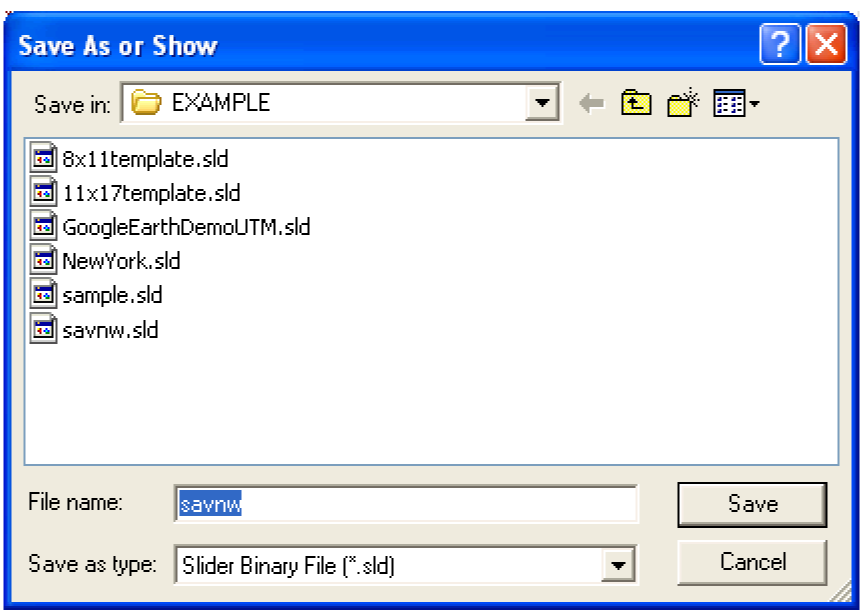


Figure 2-71. Save As or Show Dialog

2.6.6 Comparing Files

Selecting ***File>Compare, with either the Spreadsheet or Diagram view active, displays the Compare dialog window*** (see Figure 2-72). Within this dialog a variety of information between the current power Flow case and another saved case can be compared.

There are three options for making the comparisons:

- Case Totals
- Power Flow Cases
- Tie Lines

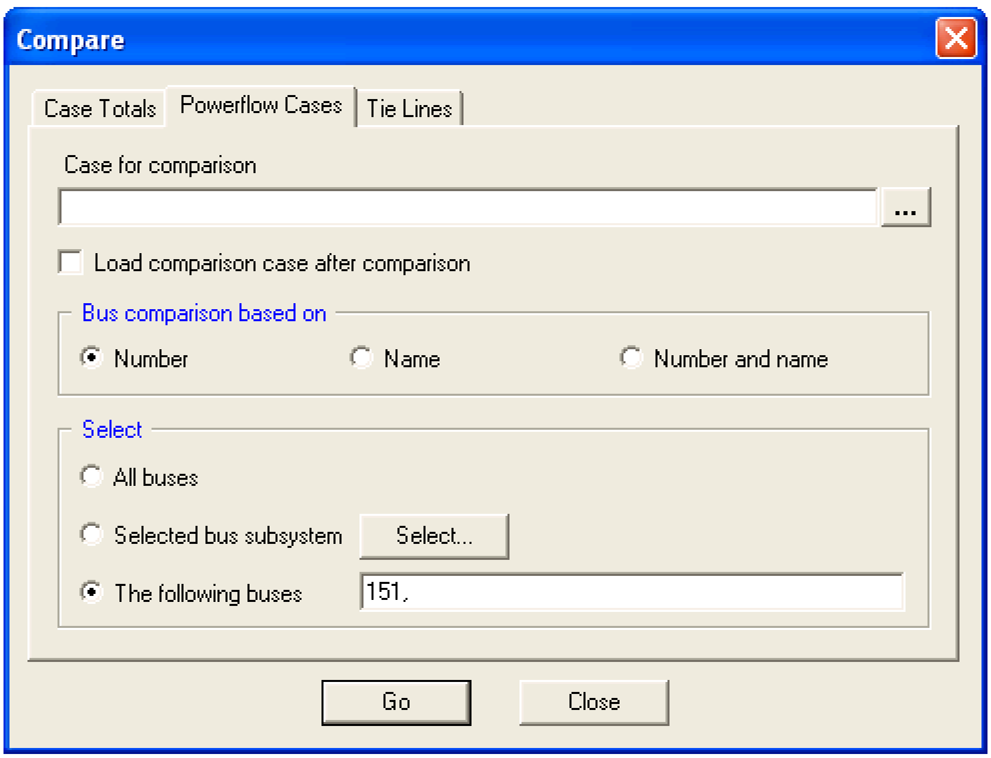


Figure 2-72. Compare Dialog

2.6.6.1 Comparing Case Totals

Selecting the Case Totals tab compares the "total" system values between two power flow cases based on either the entire cases or by selected area, owner or zone subsystems (see Figure 2-72). The two power flow cases used in the comparison comprise the currently open case and the case specified in the **Case for comparison** field. If the **Substitute working case after comparison** option is checkmarked, then the currently open case will be replaced by the comparison case once the comparison has been completed.

A typical report produced by the comparison is shown in Figure 2-73. The report compares the total generation, load, losses and solution mismatches. Differences in the totals for each case as also presented (under the DELTA columns).

```
            IN WORKING CASE    IN C:\Program Files\PTI\PSSE30\EXAMPLE\jdmsavnw.sav
               MW       MVAR       MW       MVAR   DELTA MW     %   DELTA MVAR    %
GENERATION  3258.7      964.2    3266.3     972.6       7.6    0.2         8.4   0.9
LOAD        3200.0     1950.0    3207.5    1953.9       7.5    0.2         3.9   0.2
LOSS          58.7     1115.7      58.8    1118.0       0.1    0.2         2.3   0.2
MISMATCH          0.018 MVA          0.010 MVA                        -0.008 MVA  43.6
```

Figure 2-73. Result of the Compare Case Totals

2.6.6.2 Comparing Power Flow Cases

Selecting the ***Powerflow Cases*** tab opens the dialog window shown in Figure 2-74a. Enter the case in which to compare against in the **Case for comparison** field. Checkmarking the **Substitute working case after comparison** checkbox replaces the current working case with the comparison case after the case comparison is completed. As with the Case Totals comparison, the criteria for exactly matched buses between the two cases may be based on bus number, name or both. The comparison may be made to the entire case or to a subset of the case by selecting one of the options within the **Select** field. Once the selection has been made, click the ***Go*** button. This action opens the Select Power Flow Comparison Options dialog (see Figure 2-74b).

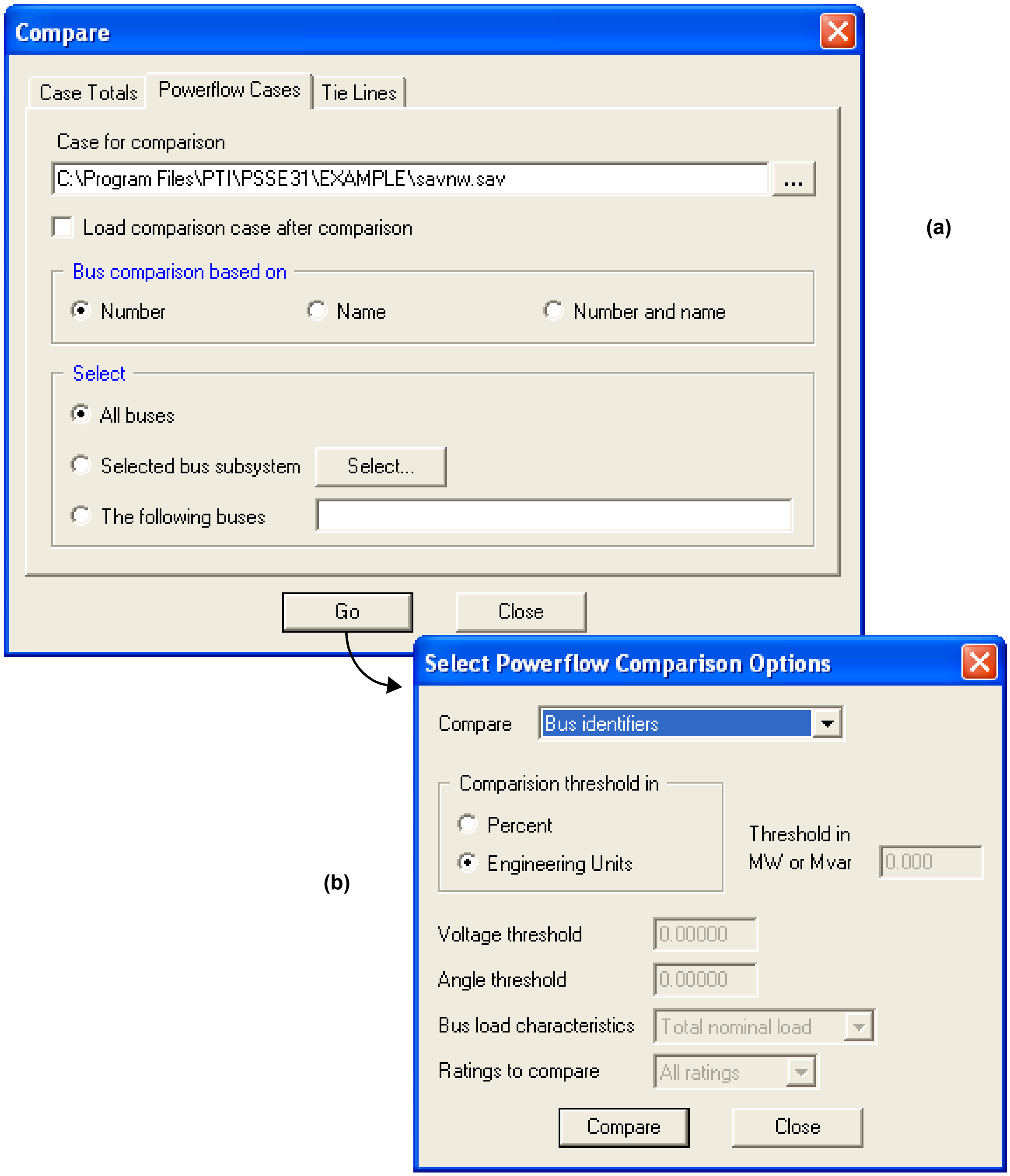


Figure 2-74. Accessing the Select Power Flow Comparison Options Dialog

Clicking on the ***Compare*** field produces the drop-down list for all the data and results categories available for comparison (see Figure 2-75).

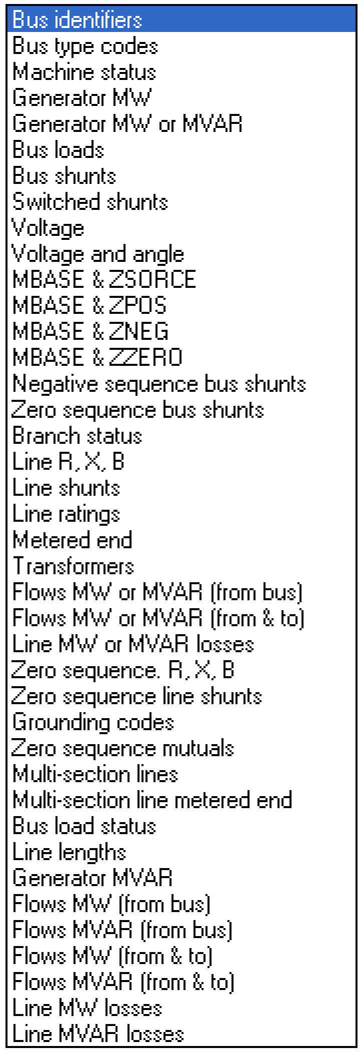


Figure 2-75. Compare Categories

When a category is selected, the options shown in Figure 2-74b will change to those appropriate to the category.

The **Comparison threshold** type may be set to either percent or engineering units whenever appropriate.

The comparison results are output to a Report tab in the **Output Bar** or to a report file designated by the user through ***I/O Control>Direct Report output (OPEN)…***.

The results displayed show all differences between the case that are greater than the defined threshold values.

2.6.6.3 Comparing Tie Lines

Selecting the ***Tie Lines*** tab produces dialog similar to the other tabs on the Compare dialog. A comparison case is entered in the Case for comparison field, the toggle for whether to replace the current case with the comparison case upon completion may be selected, and the bus matching criteria between the two cases may be set to either bus number, name or both. Additionally, one or more buses or a subsystem must be specified for which the tie line data or results are to be compared.

When selections are complete, clicking ***Go*** opens the **Select Tie Line Comparison Options** dialog (see Figure 2-76a). Clicking on the Compare field produces the drop-down list shown in Figure 2-76b from which a comparison value may be selected. Units for the comparison threshold, the level of threshold, and, where applicable, the ratings to be compared are also specified. Clicking the ***Compare*** button performs the comparison and outputs the results to either a Report tab in the **Output Bar** or to a file designated by the user.

The results displayed will show all differences which are greater than the selected thresholds.

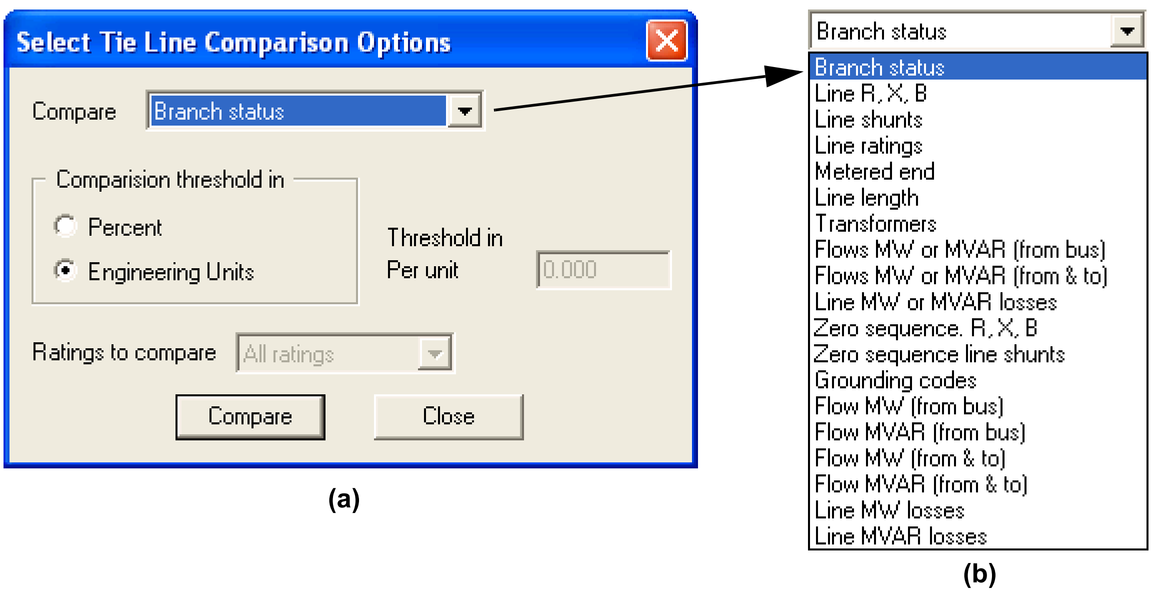


Figure 2-76. Accessing the Compare Tie Line Quantities

2.6.7 Displaying File Information

Selecting ***File>File information (SIZE/SHOW/BUSN)…***, with either the Spreadsheet or Diagram View active, brings up the **File Information** dialog (see Figure 2-77). From here both general and specific information on the working case as well as a listing of other binary files such as **.sav* (load-flow) and **.snp* (dynamic) files may be obtained.

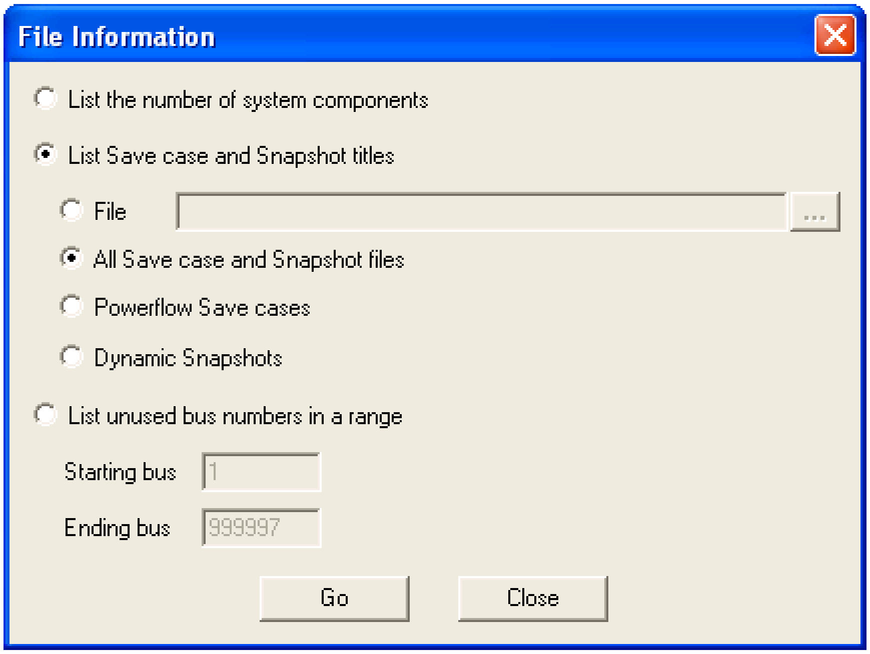


Figure 2-77. File Information Dialog

The information requested may be written to a Report tab in the **Output Bar** or to a file designated by the user through the ***I/O Control*** Menu. Below is a description of each available option on the File Information dialog.

2.6.7.1 Listing System Components

The **List the number of system components** option produce a report of the number of components in the power flow case, along with the maximum number of allowable components for the bus size level being used. A sample output is shown in Figure 2-78.

```
              BUSES          PLANTS        MACHINES   MACHINE OWNERS
TOTAL            23               6               6               14
MAXIMUM       50000           10000           12000            24000

  SWITCHED SHUNTS             LOADS       TRANSFERS          MUTUALS   FACTS DEVICES
TOTAL             0               8               4                6               0
MAXIMUM        4000          100000            2000             4000              50

                      T R A N S F O R M E R S
           BRANCHES     TWO-WINDING   THREE-WINDING  ZERO IMPEDANCE   BRANCH OWNERS
TOTAL            34              11               0               0              35
MAXIMUM      100000           20000            5000            2000          200000

             MULTI-SECTION LINE
          GROUPINGS        SECTIONS      2-TERM. DC      N-TERM. DC          VSC DC
TOTAL             2               4               0               0               0
MAXIMUM        1600            4000              50              20              40
```

Figure 2-78. Output Listing Showing the Number of System Components

2.6.7.2 Listing Saved Case and Snapshot Files

Selecting the **List Save case and Snapshot titles** option produces a listing of the names of saved case and/or snapshot files residing in the current working directory. An additional specification can indicate whether only a particular file be listed, only Powerflow Save cases, only Dynamics Snapshot files, or all Save cases and Snapshot files.

2.6.7.3 Listing Unused Bus Numbers

Selecting the **List unused bus numbers in a range** option displays all the bus numbers between the specified Starting bus number and Ending bus number that are not being used by the currently open power flow case. A sample report is shown in Figure 2-79.

```
                   UNUSED BUS NUMBERS BETWEEN      1 AND 999997
     1  THROUGH    100
   103  THROUGH    150
   155  THROUGH    200
   207  THROUGH    210
   212  THROUGH   3000
  3009  THROUGH   3010
  3012  THROUGH   3017
  3019  THROUGH 999997

 23 NUMBERS USED AND 999974 NUMBERS AVAILABLE BETWEEN 1 AND 999997
```

Figure 2-79. List of Unused Bus Numbers

2.6.8 Displaying Case Titles, Short and Long

Selecting ***File>Case titles, short & long (CHTI)…*** displays a Case Titles dialog (see Figure 2-80). Here the two line short title may be changed, and the long title, with up to 16 lines and 72 characters per line, may be edited or created. The short title is imported with the network data as part of the raw data file.

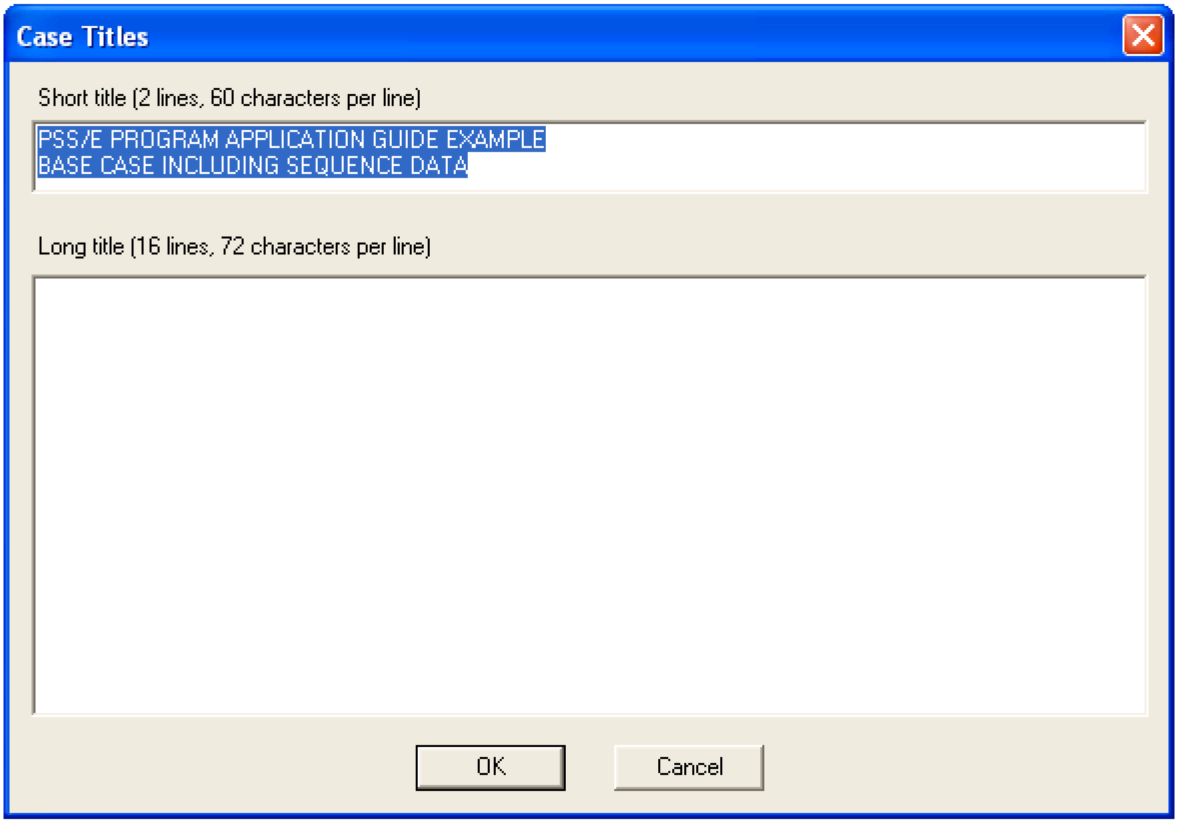


Figure 2-80. Case Titles Dialog

2.6.9 Importing Files into the *Spreadsheet View*

Selecting ***File>Import*** with the Spreadsheet View active presents three import options. The first is to import a long title. The second is to import an economic dispatch data file. The third is to import a UCTE file.

Selecting the ***Import long title (RETI)*** option opens a file selector dialog from which an existing text file containing the long title text may be imported.

Selecting the ***Import ECDI File*** option opens a file selector dialog from which an existing ASCII file containing economic dispatch data may be read in. The data populates the Optimal Power Flow (OPF) generator cost curve data records for use in the OPF solution.

2.6.10 Importing Files into the *Diagram View*

Selecting ***File>Import*** with the Diagram View active presents the option to either import a PSS™E DRAW file… (*.drw*) or an Image file… into a diagram within the Diagram View. If there is no active **Diagram View**, open one using ***File>New*** or the ***New*** toolbar button.

Selecting ***File>Import>DRAW file…*** displays the file selector dialog from which a DRAW file may be selected for import into the one-line diagram. The DRAW file is the coordinate data file constructed and used in previous versions of PSS™E.

Once imported the diagram can be saved (using ***Save*** or ***Save As…***) in the new Slider format file (*.sld). When the diagram is imported, all diagram items are placed on one layer. The user is then free to move diagram items to other layers.

Selecting ***File>Import>Image file…*** displays the **Import Image File** dialog (see Figure 2-81). From here a variety of image file types may be imported including bitmaps (*.bmp), JPEG files (*.jpg), GIF files (*.gif) and PNG files (*.png). The image is imported into the active **Diagram View** and is placed in the background layer. From there it can be move if required.

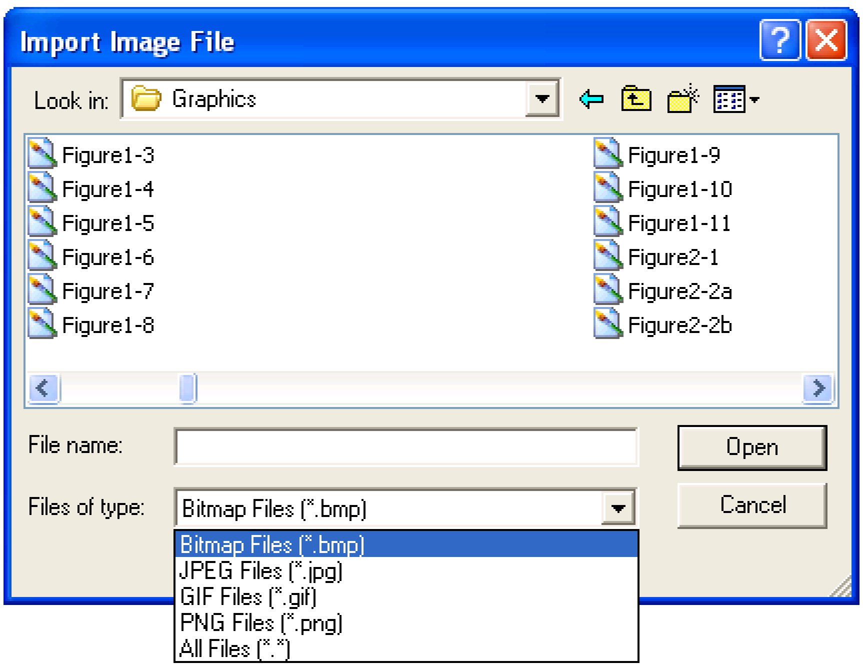


Figure 2-81. Importing an Image File

2.6.11 Exporting a Diagram Image (*Diagram View Only*)

Selecting ***File>Export>Diagram Image…*** facilitates the exporting of the entire active **diagram** to either a Bitmap or a JPEG file. An Export Image As dialog is displayed, where the name of the file in which to save the image is specified (see Figure 2-81).

When a JPEG file type is selected, the export process facilitates the selection of the JPEG quality level on a scale of 1 to 100 (see Figure 2-36). Some experimentation may be necessary to find the desired level of quality.

2.6.12 Exporting a Bus Location file *(Diagram View Only)*

Selecting ***File>Export>Bus Locations…*** facilitates exporting the x/y coordinates from all buses, branches and two winding transformers in the active diagram to a text file. Bus, branch and two winding transformer locations are output as Cartesian coordinates.

2.6.13 Exporting Google Earth Locations file *(Diagram View Only)*

Selecting ***File>Export>Google Earth Locations…*** allows users to export slider diagrams to KML (Keyhole Markup Language) format. Geographic Coordinate information in the WGS-84 (World Geodetic System) is required for graphical elements that will be exported. The KML file can then be opened and manipulated in Google Earth. This feature allows a power network to be viewed against the backdrop of location specific, geographic data.

2.6.14 Exporting a Spreadsheet Tab (*Spreadsheet View Only*)

Selecting ***File>Export>Spreadsheet Tab to text file…*** exports the currently visible data of the selected tab of the spreadsheet to a text file. A Save As dialog, similar to that shown Figure 2-71, will be opened but with only *.txt* type files facilitated.

2.6.15 Exporting the Network Admittance Matrix

Selecting ***File>Export>Network admittance matrix…*** exports the network admittance matrix to the report window, or a data file. This is the matrix used for the powerflow calculations. This matrix can be used for external calculations such as flow loss. When this matrix is generated by PSS™E, buses connected together by zero impedance are combined together in the matrix. Therefore, the matrix may not have separate rows and columns for each bus. Instead one bus ID will represent the combine buses.

2.6.16 Renumbering Buses in Auxiliary Files

PSS™E employs a variety of data files associated with the power flow network and analysis. If buses in the power flow data file are to be renumbered, it will be necessary to perform the same renumbering on the associated auxiliary data files in order for them to remain consistent. The ***File>Renumber buses in auxiliary file (RNFI)…*** option, available when the Spreadsheet view active, facilitates the conversion of auxiliary files from using one set of bus numbers to another. The process of renumbering is covered in Section 4.7 and the ***Renumber buses in auxiliary file*** option is discussed in detail in Section 4.7.4.

2.6.17 Renumbering Buses in the Diagram

The need to renumber buses can apply equally to a Slider file. With the Diagram view active, Selecting ***File>Renumber Buses in Diagram (RNFI)...***, opens the **Bus number translation file** dialog (see Figure 2-82). Specify a previously created **Bus Number Translation File** (**.trn*) for the conversion. The creation of this file is described in Section 4.7. The file contains records of old bus numbers and the corresponding new numbers.

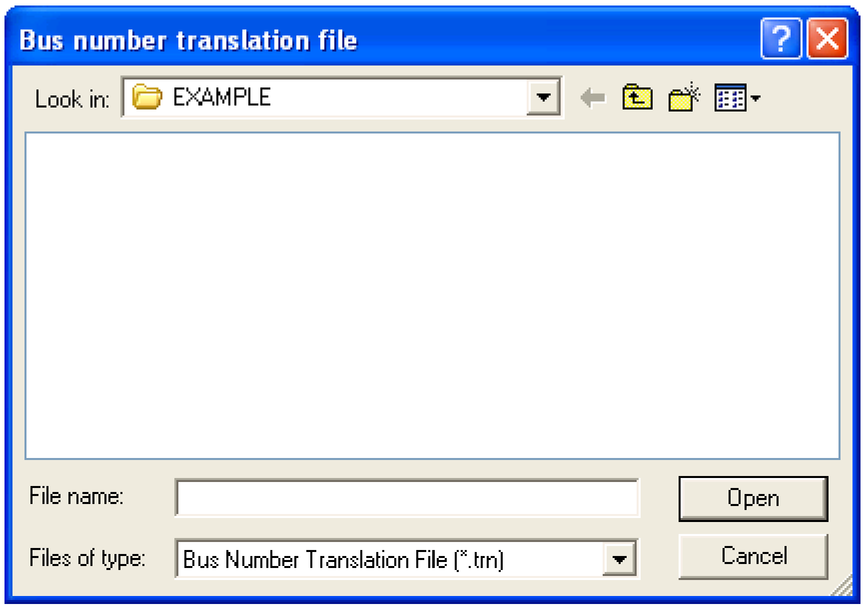


Figure 2-82. Bus Number Translation File Dialog

2.6.18 Converting Grow Mode

A diagram originally created with GOUT/GEXM will respond to "growing" elements differently than a diagram created using Auto-Draw or Grow. GOUT/GEM based diagrams are used for quickly traversing the network. During a Grow operation they simply display everything connected to the bus. The Grow operations pays no attention to whether the element already exists on the Diagram or not, the item is simply created again to lend clarity to the layout. The **Convert Grow mode from GOUT to Auto-Draw** command can be used to convert the "grow" behavior of a diagram from GOUT/GEXM to an Auto-Draw style "grow" where each specific element only is created once.

2.6.19 Setting Up the Spreadsheet Header/Footer

Any spreadsheet can be printed or exported to a file. Selecting ***File>Spreadsheet Header/Footer Setup…*** provides the ability to define a header and footer for the printed spreadsheet (see Figure 2-83).

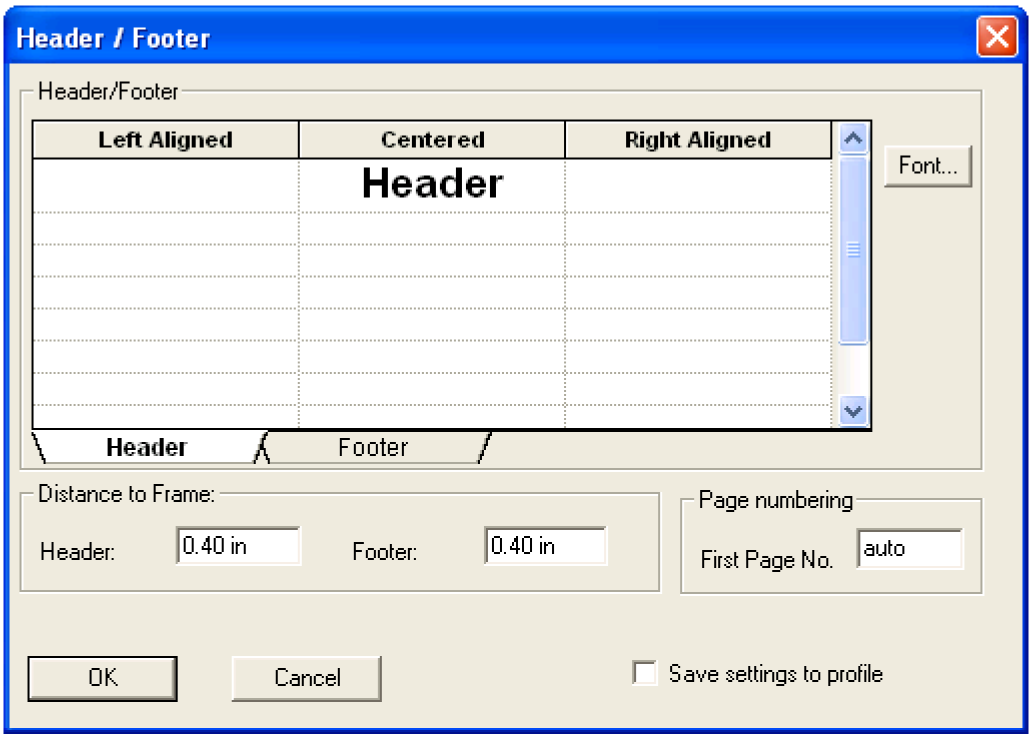


Figure 2-83. Setting Up Header and Footer for Printed Spreadsheet Tab

The Header/Footer dialog presents a full facility for setting the header and footer spacing, the alignment, page numbering and the style, size and other font characteristics. If the **Save settings to profile** option is checkmarked, then the next time PSS™E is used, the saved profile will be assumed and activated.

2.6.20 Setting Up the Spreadsheet Page

The ***File>Spreadsheet Page Setup…*** option provides a way to specify the presentation of the spreadsheet when printed. A variety of parameters, including margins and grid lines, may be adjusted in the Page Setup dialog (see Figure 2-84). By checkmarking the **Save settings to profile**, the settings will be preserved for future uses.

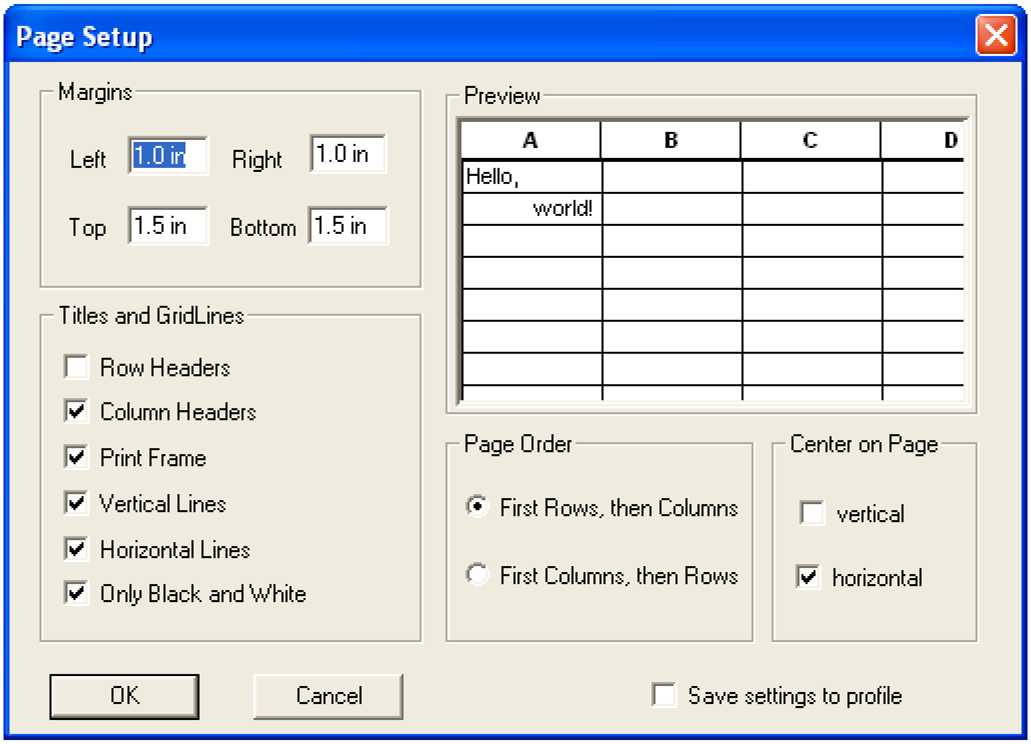


Figure 2-84. Setting Up the Spreadsheet Page

2.6.21 Setting Print Options

Selecting ***File>Print Setup…*** opens the **Print Setup** dialog (see Figure 2-85a). The common printer setup facilities are available, including selection of the printer or a network, the printer properties, the paper size, source and orientation.

Selecting ***File>Print…*** opens the **Print** dialog (see Figure 2-85b). The common print setup facilities are available including the printer or network selection, the printer properties, the page range and number of copies.

The print activity can also be used to save to a file designated by the user.

The ***File>Print Preview*** option show a facsimile of the page as it will be printed.

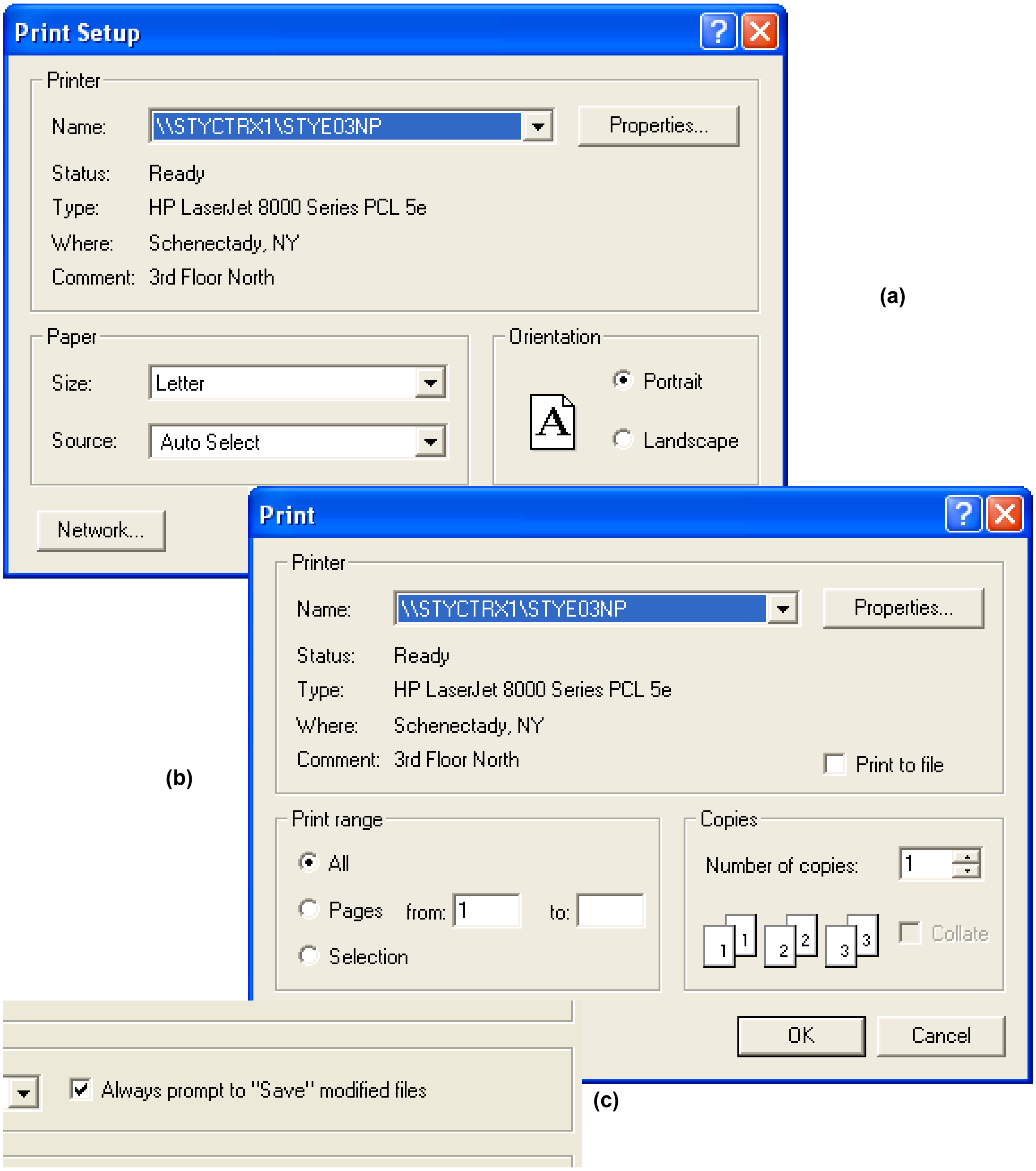


Figure 2-85. Print Setup and Print Dialogs

2.6.22 Exiting PSS™E

Selecting ***File>Exit*** closes down the PSS™E application. A prompt to save any previously unsaved network or diagram data to a file will be presented unless the check box shown in Figure 2-85c is unchecked. If the check box is unchecked, all files will be closed without saving regardless of their status, e.g., modified or un-modified. By default, the "Always prompt to 'Save' modified files" check box is checked. The setting of this check box is preserved between runs of the application.

2.7 Edit Menu

The Edit Menu is customized to either the active Spreadsheet View or Diagram View (see Figure 2-86). When the **Spreadsheet View** is active, the **Diagram View** menu is *not* available.

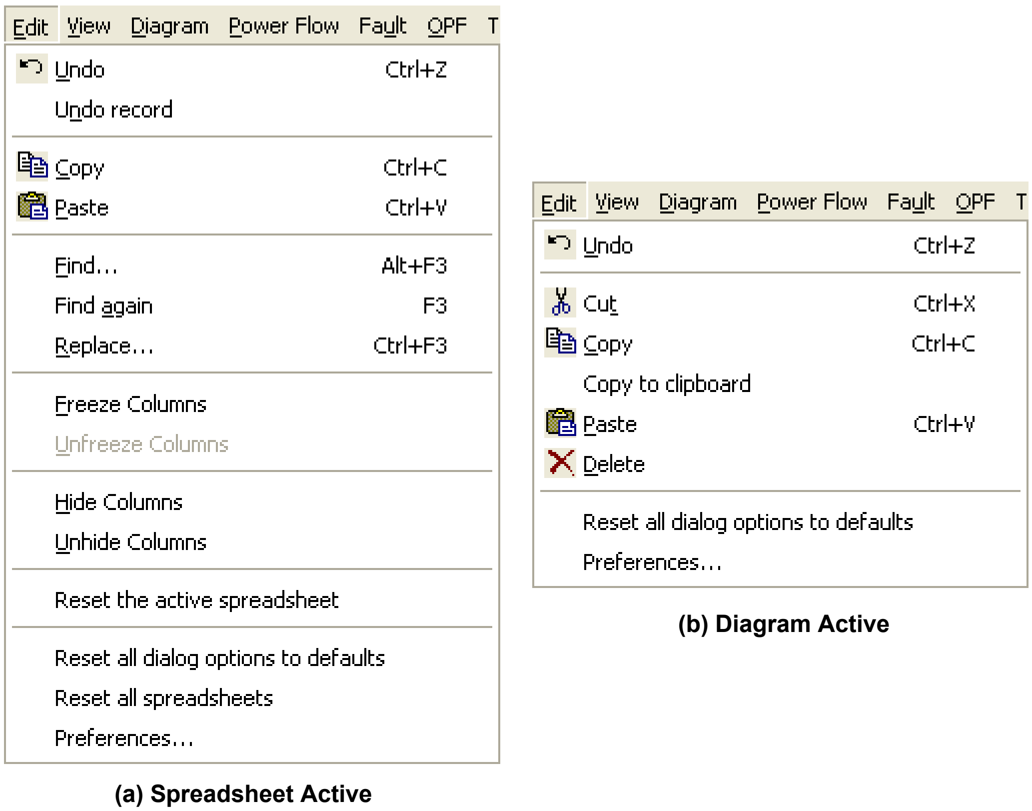


Figure 2-86. Alternative Edit Menus for Active Spreadsheet and Diagram Views

2.7.1 Undoing an Edit Action

The ***Edit>Undo*** option will undo up to the last 30 actions in either the **Spreadsheet View** or Diagram View. If the status of a network item is changed in the spreadsheet (i.e., a branch taken out of service), the change is reflected in the **Diagram View** if that specific element is drawn. When ***Edit>Undo*** is selected in the **Spreadsheet View**, the change is automatically reflected in the **Diagram View** as well.

If a bus is deleted from the **Diagram View** with ***Bind Items*** selected, both the diagram item and the underlying network bus is deleted. If ***Edit>Undo*** is then executed, both the diagram item and the network bus are restored.

2.7.2 Undoing a Record Edit Action

The ***Edit>Undo Record*** option will undo a current record edit. This is used when adding a new record to any of the spreadsheets and the application generates an error message about missing information. At certain points, this can lead to application lockup. The Add operation cannot continue until the missing data is provided and the missing data cannot be provided because the application keeps notify the user of the problem. At this point, ***Edit>Undo Record*** operation will reset the application back to the state before the Add operation was begun. The missing data can then be added in other spreadsheets and the item added again. Once the data has been entered, however, the ***Undo Record*** operation will not do anything.

2.7.3 Copying and Pasting in the Spreadsheet View

Data can be copied and pasted from cell to cell, column to column and row to row in the **Spreadsheet View**. Data may also be copied and pasted to other applications.

Between Cells

Data can be copied and pasted between cells using the standard **[Ctrl]+*C***, **[Ctrl]+*V*** keystrokes, or by selecting ***Edit>Copy*** and ***Edit>Paste*** from the Main Menu.

Between Rows

All or some of the cells in a row can be copied to another row on the same spreadsheet tab. To do this, select the row(s) to copy by clicking in the row header column(s). The **[Shift]**+left-mouse-click and **[Ctrl]**+left-mouse-click can be used to select multiple rows. Once the row(s) are highlighted copy the data using either the standard keystrokes **[Ctrl]+C** or the ***Edit>Copy*** function. Click on the row(s) where the data is to be placed and use either the standard **[Ctrl]+V** keystroke or the ***Edit>Paste function***.

Bus numbers and other identifiers are not copied as this would result in duplicate data items in the network. These identifiers will automatically adjust to the next available value when pasted.

Copy/Paste Spreadsheet Data to Another Application

It is possible to copy and paste data from the spreadsheet into another application, such as Microsoft® Excel. Simply select the cells to be copied, copy the data to the clipboard using **[Ctrl]+C** or by selecting ***Edit>Copy*** from the Main Menu. Activate the application to which the data will be pasted and use the paste function in that application to paste the spreadsheet data contained in the clipboard.

Copy/Paste of Diagram Items

All cutting, copying and pasting of diagram items in a **Diagram View** is done from the application diagram clipboard. Diagram items placed on the application diagram clipboard may only be used in other **Diagram Views** within the same invocation of PSS™E. To copy diagrams between applications, such as copying a diagram from PSS™E to Microsoft® Word, the system clipboard needs to be used. A **Diagram View** can be copied to the system clipboard by selecting ***Edit>Copy to clipboard***.

Select the diagram items to be copied before selecting ***Edit>Copy to clipboard***. To paste the clipboard contents to another application, use the paste function in that application. To paste the clipboard contents to a **Diagram View**, select ***Edit>Paste*** or right-click on the Diagram View and select ***Paste***.

2.7.4 Finding Items in the Spreadsheet

Select ***Edit>Find…*** to display the Find dialog used to find a particular value in a selected column.

Select ***Edit>Find Again*** to search a selected column for the value entered during the last Find operation. It will only find the first match. It cannot be used to iterate through matching items in the column. To iterate through matching items in the column, click the ***Find Next*** button in the Find dialog to find successive items.

The Find and Find Again dialogs can also be opened by selecting a column and right-clicking on the column header. See Section 2.4.3.1 and Figure 2-19.

2.7.5 Replacing Items in the Spreadsheet

Select ***Edit>Replace…*** to display the Replace dialog used to replace a particular matching item, or replace all matching items.

2.7.6 Freezing and Unfreezing Columns

Some data categories have a considerable number of columns. In order to easily facilitate examination and editing of data in the right-most columns of the spreadsheets, you can freeze selected columns. After selecting the columns to freeze or unfreeze, select ***Edit>Freeze Columns*** or ***Edit>Unfreeze Columns*** (see Figure 2-26).

2.7.7 Hiding and Unhiding Columns

Some data columns may hold data that is of little or no importance to the analysis the user is doing. In order to help the user organize the column so they can be viewed easily, columns can be hidden from view. After selecting the columns to hide, select ***Edit>Hide Columns***. In order to bring the columns back into view select ***Edit>Unhide Columns***. This will unhide all columns that were previously hidden. There is no way to unhide specific columns.

2.7.8 Resetting Spreadsheets

Since it is possible to reorganize the spreadsheet layout, freezing, moving and hiding columns, it is also possible to make arrange a spreadsheet into a un-recognizable state. If a spreadsheet becomes too disorganized or confusing, selecting ***Edit>Reset the active spreadsheet*** will reset all columns back to the default layout. If it is necessary to reset all open spreadsheets, then selecting ***Edit>Reset all spreadsheets*** will set the layout of all open spreadsheets to the default layout.

2.7.9 Resetting Dialog Options

As the user uses PSS™E, PSS™E will remember the last used options in each dialog box. However, the user may want to go back to the default dialog options, but does not remember what they are. Using ***Edit>Reset all dialog options to defaults*** will reset the dialog boxes so that all options selected in the dialog boxes when they are first opened are the original defaults, and not what the user last selected.

2.7.10 Setting Program Preferences

The Preferences option allows for the selection of output and auto-save options with either the Spreadsheet or the Diagram View active. Selecting ***Edit>Preferences*** opens the Program Preferences dialog (see Figure 2-87).

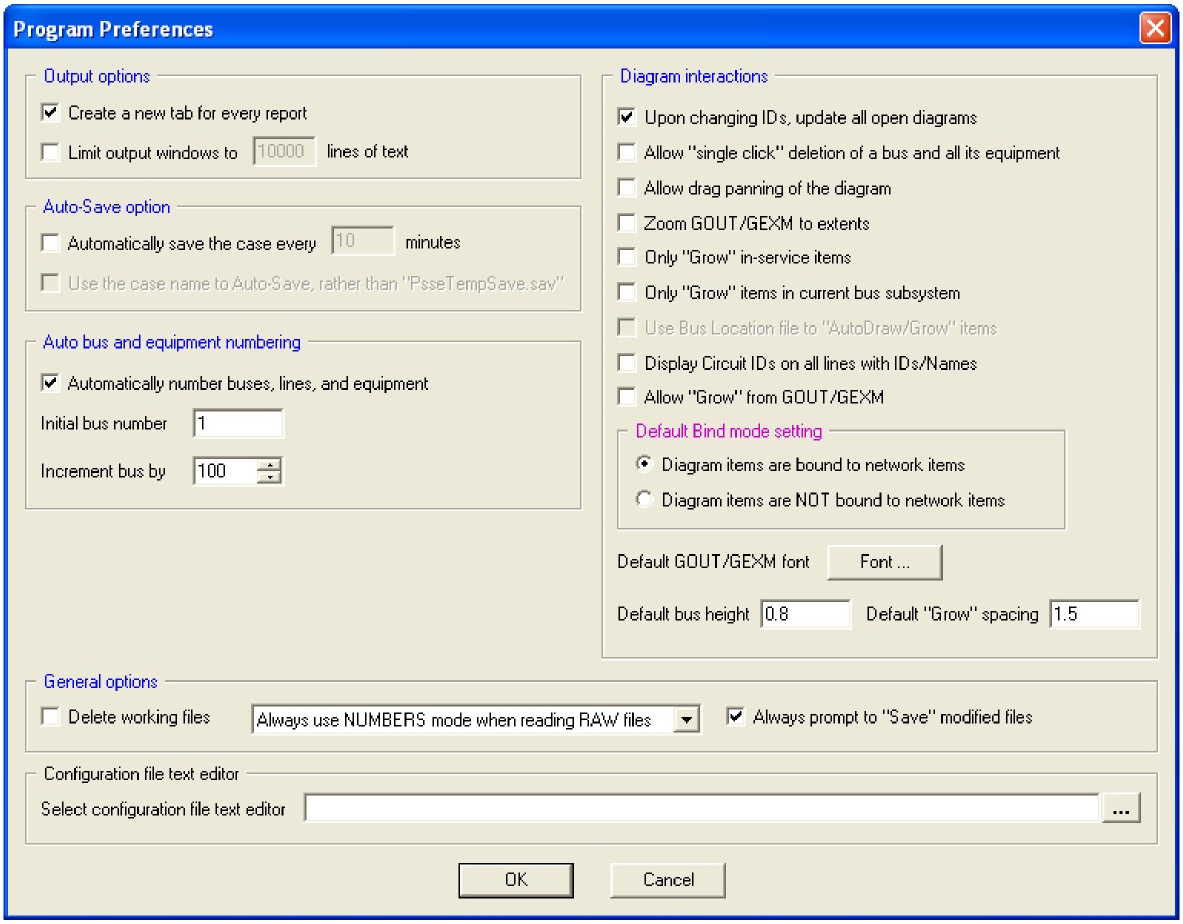


Figure 2-87. Program Preferences Dialog

The dialog window contains several groups of options:

Output options: Allows you to choose whether to create a new tab for each output report, and to specify the maximum number of lines to display.

Auto-Save option: Allows for the automatic saving of the currently open power flow case and how often the case is to be saved. The option to save the case under its current name or to save it to a temporary file named *PsseTempSave.sav is also provided*.

Auto bus and equipment numbering: When creating a one-line diagram from scratch, with the Bind option on (see Section 2.9.8), the addition of network items into the **Diagram View** will populate the **Spreadsheet View** with data as you build a new network (see Section 3.7). Without the Bind option selected, the network items added will belong to only the **Diagram View**. In either case, if the option to ***Automatically number buses, lines, and equipment*** is enabled, the program will automatically number the buses as they are added. The initial bus number and the increments by which subsequent buses are numbered may be specified in the fields provided.

Diagram interactions:

If the ***Upon changing IDs, update all open diagrams*** option is enabled, then when IDs in the spreadsheet are changed, the IDs in the **Diagram View** will automatically be updated.

If the ***Allow "single click" deletion of a bus and all its equipment*** option is enabled, then a selected bus on the diagram may be deleted, along with all its equipment, by either using the **[Delete]** key or selecting Delete from the right-click menu. Otherwise these options are not available.

If the ***Allow drag panning of the diagram*** option is enabled, then the "select" mouse pointer will turn to Pan mode when the left-mouse-button is clicked on the diagram, held down and dragged. Otherwise, the default behavior of holding down and dragging the "select" pointer is to form a selection box around a portion of the diagram.

If the ***Zoom GOUT/GEXM to extents*** option is enabled, then a bus is displayed in the diagram via the GOUT/GEXM command will fill the entire diagram viewing area.

If the ***Only "Grow" in-service items*** option is enabled, then only those items currently in-service will be drawn during a Grow operation.

If the ***Only "Grow" items in current bus subsystem*** option is enabled, then only those items in the current bus subsystem will be drawn during a Grow operation.

If the ***Use Bus Location file to "Grow" items*** option is enabled and a Bus Location file has been opened, then any Grow or Auto-Draw operations will use the Bus Location file when placing buses on the diagram.

If the ***Display Circuit ID's on all lines with ID's/Names*** option is enabled, then circuit ID's will be displayed for every line that is drawn that is bound to line in the network.

If the ***Allow "Grow" from GOUT/GEXM*** option is enabled, then the user will be able to grow a diagram generated from GOUT/GEXM. This grow method does not work the same as the grow method for auto draw. When an element is told to grow it will draw all lines connected to it along with all buses connected to those lines regardless of whether or not the bus is already drawn. In other words, grow in GOUT does not avoid redrawing the same bus.

The **Default Bind mode setting** indicates the default setting for whether diagram items are to be bound to network items or not bound.

The **Default GOUT/GEXM font** is used to select a font for the labels created when using GOUT/GEXM diagrams.

The **Default Bus Height** is the default length of the bus, in inches, that is drawn when either Auto-Draw or Grow operations take place in a one-line Diagram.

The **Default "Grow" Spacing** is the default distance between buses, in inches, when either Auto-Draw or Grow operations take place in a one-line Diagram.

General Options:

If the ***Delete working files*** option is enabled, then the working files are deleted when the program is closed.

The mode selection box is used to select a mode used to read in raw files.

If the ***Always prompt to "Save" modified files*** is enabled then the user will be prompted to save any modified files when attempting to close the file or the program.

Configuration file text editor: This field is used to select a text editor that can be launched wherever an input configuration text file is specified. The file selector can be used to browse for a *.exe file that is capable of editing a text file.

2.8 View Menu

Selection or deselection of the Tree View, Output Bar and Status Bar options on the View Menu indicates whether to expose or hid the **Tree View**, Output Bar or **Status Bar** (see Figure 2-3). See Section 2.2.2 for more detail.

2.9 Diagram Menu

When the Diagram View is active, the Diagram Menu is made available on the Main Menu. Figure 2-88 shows the active menu options available.

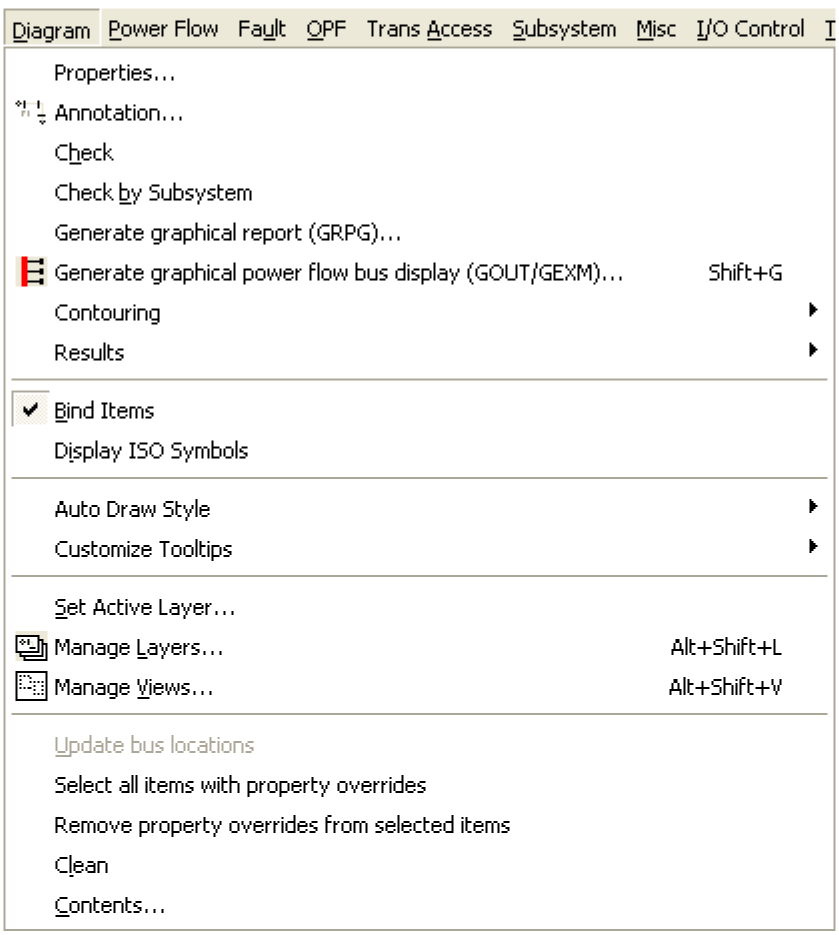


Figure 2-88. Diagram Menu

2.9.1 Configuring Diagram View Properties

The **Diagram View** has user-configurable settings, such as units, background colors, grid spacing, zoom, and pan thresholds. When a **Diagram View** is active, selecting the ***Diagram>Properties…*** option displays the **Diagram Properties** sheet (see Figure 2-89).

This comprehensive group of selections includes options for managing:

- Labels
- Grid
- Printing
- Colors
- Zoom and Pan
- Display

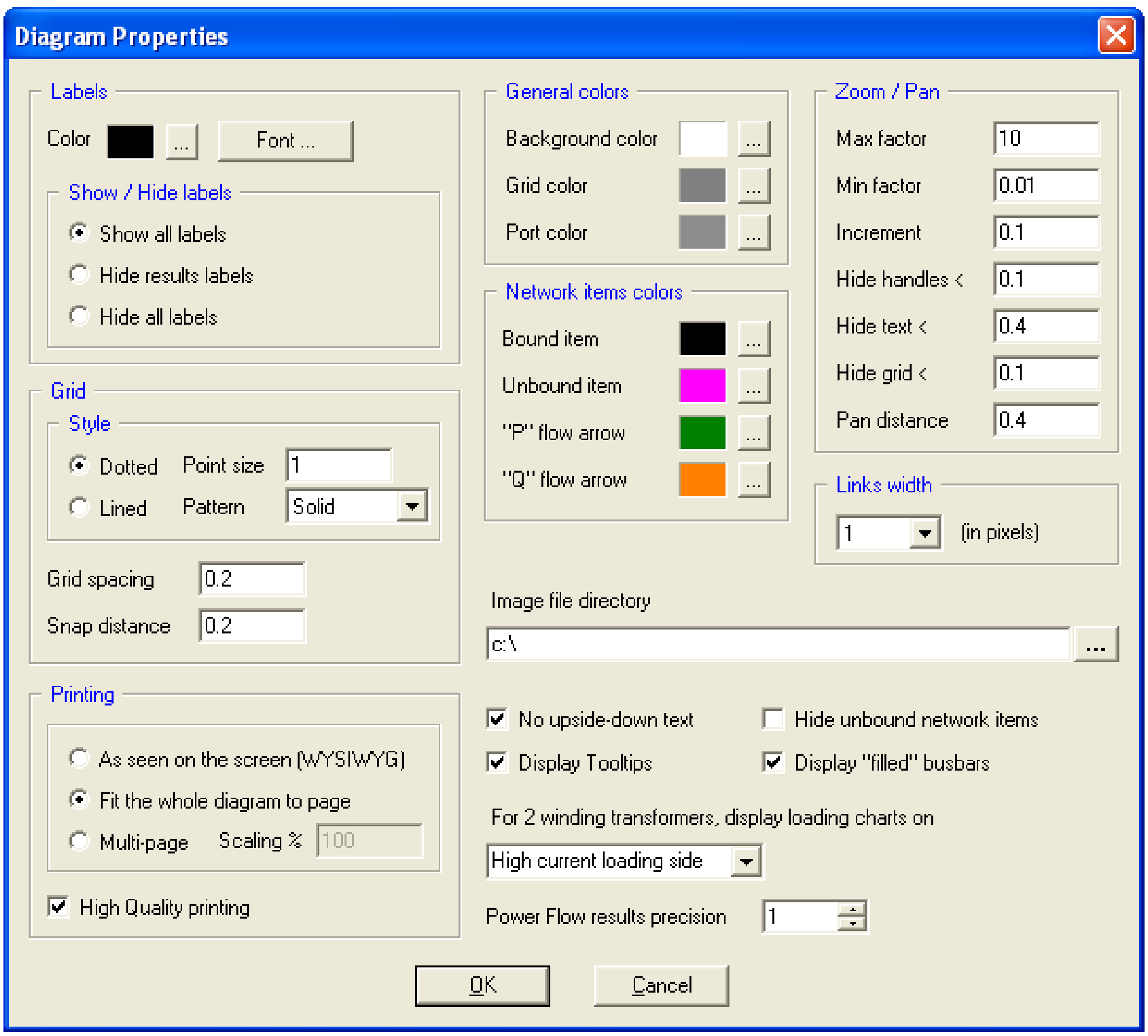


Figure 2-89. Diagram Properties Options

Labels: Select from a variety of font styles, sizes and colors to apply to the labels on the diagram. Options for hiding or showing all labels and hiding results labels are also available.

Grid: The **Diagram View** contains an underlying grid pattern that may or not be visible. The line style and width, as well as the spacing and snap distance, of the grid may be specified. For very dense diagrams the snap distance must be sufficiently small to better ensure that items snap to the desired grid point instead of one further away.

Printing: Three options are available for printing a diagram:

- **As seen on the screen (WYSIWYG):** "What you see is what you get" (WYSIWYG). Prints only that part of the one-line diagram which can be seen in the Diagram View. This might be only part of the diagram if you have zoomed in to see more detail. This can be checked by selecting ***File>Print Preview***.
- **Fit the whole diagram to page:** The entire one-line diagram is printed on one page independent of whether or not the entire diagram is shown in the Diagram View.
- **Multi-page:** Allows the user to print the entire diagram over multiple pages, independent of whether or not the entire diagram is visible in the Diagram View. This is useful when the one-line diagram is large.

High Quality printing: If the diagram is zoomed out, labels and text can appear blurry when printed. Enabling ***High Quality printing*** will smooth out all text and labels. The use of this option will result in larger print files and longer print times. Some experimentation may be necessary to determine the effectiveness of this option.

General Colors: Defines the colors for the **Background**, **Grid** and **Port**. The ports are symbolized by small circles that appear at the locations where lines and equipment connect to buses. Ports appear when lines and equipment are selected and along the bus as connection points when a network item is moved to a new bus location.

Network Item Colors: Defines the colors for bound and unbound diagram items. All network items in the **Diagram View** that represent actual data in the network are drawn in the bound color, unless over-ridden by range checking coloration. All network items in the **Diagram View** that do not represent data in the network are drawn in the unbound color. The range checking colorations are discussed in Section 2.9.2.

The power flow results can be animated to show flow directions for real and reactive power (see Figure 2-90). The "P" flow arrow and the "Q" flow arrow palettes allow for selection of a color for these arrows.

Zoom/Pan: Values for the maximum and minimum zoom multipliers, and value in which to increment/decrement the zoom factor by each time the diagram is zoomed in or out, may be entered directly in the fields provided. In addition, it is possible to hide some diagram items when the zoom factor is small and the diagram becomes more crowded. These include such things as the "handles" which appear at each end of a bus when it is selected.

Image File Directory: Images may be imported to the background layer of the **Diagram View**. Specifying an Image file directory identifies the default path for commonly used images.

Display Options: Located in the lower right hand corner of the **Diagram Properties** sheet, are several self-evident display options. If the ***Display Tooltips*** option is checkmarked, then when the mouse cursor is held over a diagram item such as a bus, a pop-up note will be displayed that gives basic information about the bus such as number, name and base kV.

Power Flow results precision: Defines the number of decimal places used in representing Power Flow results.

2.9.2 Annotating the Diagram

2.9.2.1 Powerflow Annotation

When the powerflow results are being shown on the diagram, the ***Diagram>Annotation…*** option brings up the Powerflow Data Annotation dialog from which different diagram annotation and range checking options can be selected and specified (see Figure 2-90).

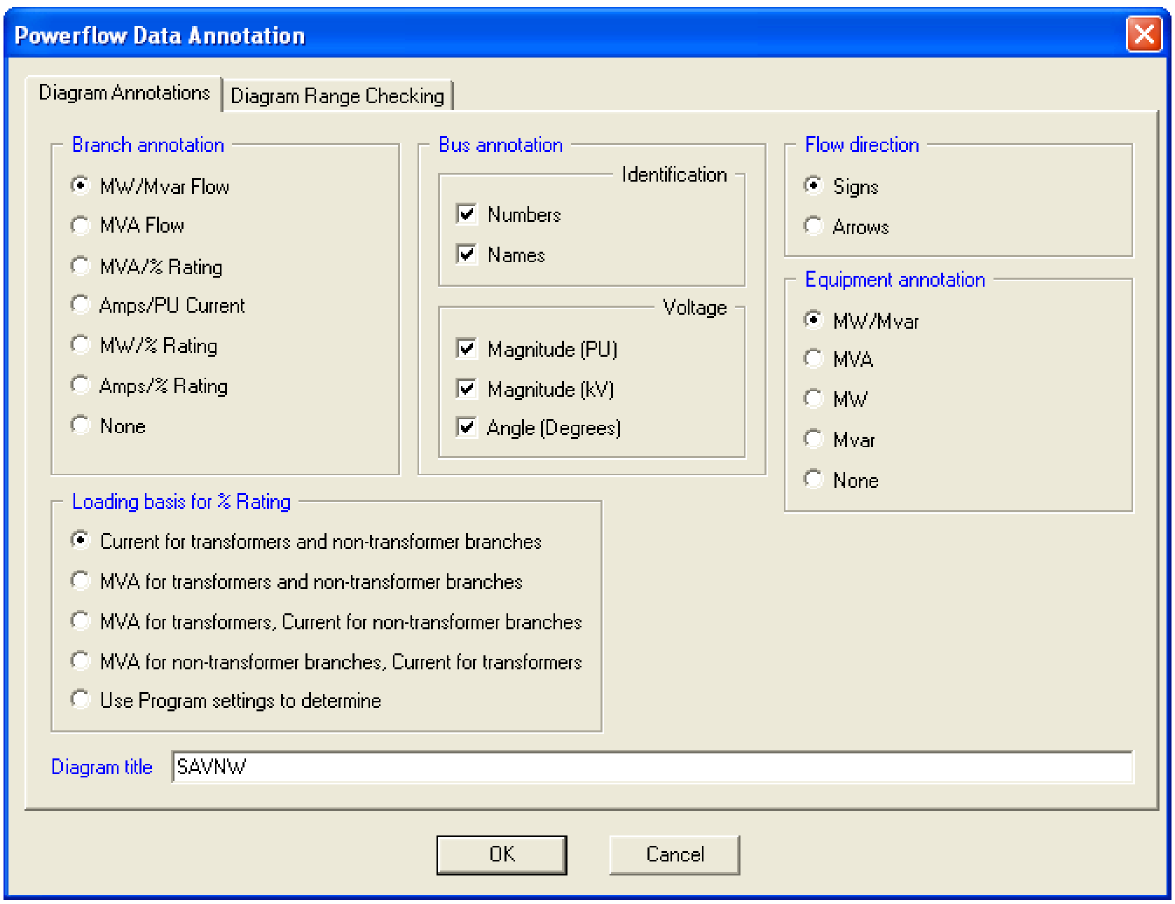


Figure 2-90. Power Flow Data Annotation Dialog

Diagram annotations can easily be adjusted by changing options in the Diagram Annotation tab. Choices include the type of results annotation information to be displayed for **Branches**, **Buses** and Equipment. Additionally, the user can elect to represent flows on the branches with either signs or arrows (see Figure 2-91). The real power, in each case is shown above the branch.

(a) Signs (b) Arrows

Figure 2-91. Signs and Arrows to Display Flow

The Diagram Range Checking tab is a very useful tool for the user (see Figure 2-92). Not only can the **Diagram View** show numerical results for bus voltage, line flow and equipment loading, but color coding can be set up to provide rapid identification of problems. In addition, the user can choose to over-ride the color selected for bound items and select colors for each voltage level in the network. This makes it easy to identify networks at different voltage levels.

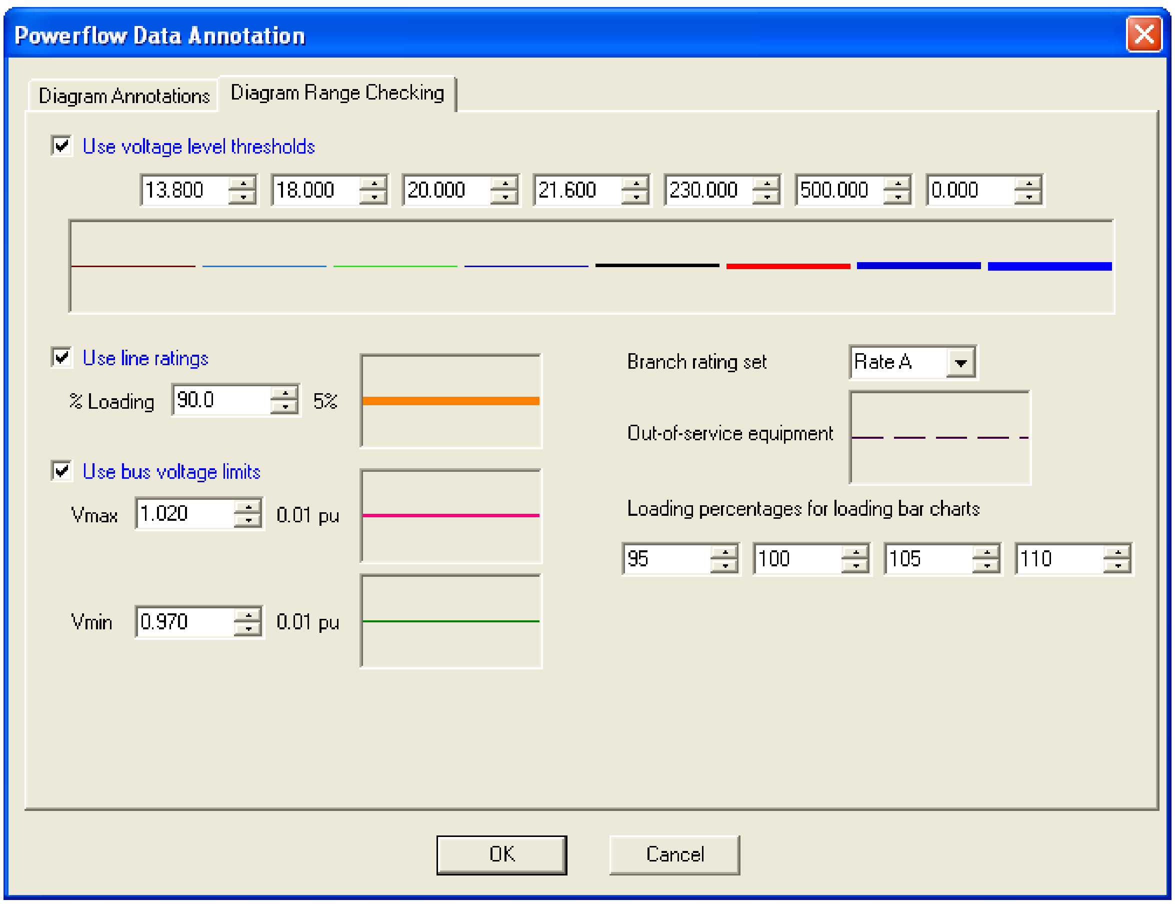


Figure 2-92. Diagram Range Checking Tab

The **Use voltage level thresholds** option, when checkmarked, visually identifies equipment and lines based on their voltage level. Voltage levels may be specified by entering a value directly in the input field or using the scroll buttons. Color and style specification may be modified by clicking on the sample image shown under the corresponding voltage value.

The **Use line ratings** option, when checkmarked, visually identifies lines that are loaded above the specified percent loading value. The color and style of the line may be modified by clicking on the sample image to the right of the % loading field. To identify the branch rating to which the % loading value is to be applied, click on the ***Branch Rating Set*** drop-down menu and select from one of the options. Rate A is typically used for normal power flow conditions while Rate B or C would be used to examine contingency conditions where loadings are often allowed to be higher.

The **Use bus voltage limits** option, when checkmarked, visually identifies buses with voltages above or below specific levels. The maximum and minimum voltage levels may be set by entering values directly in the fields or using the scroll buttons. The color and style of buses that go above the maximum voltage setting or below the minimum setting may be modified by clicking on the sample image to the right of the corresponding voltage value.

The **Out-of-service equipment** setting identifies how equipment whose status has been switched to out-of-service should be visually represented on the diagram. To specify the appearance of out-of-service equipment, such as a branch or bus, click on the sample image.

The **Loading percentages for loading bar charts** input fields are used to control the percentage at which overload colors are applied to the loading bar charts. Overload colors progress from purple to red to deeper shades of red.

2.9.2.2 Impedance Annotation

When the impedance results are being shown on the diagram, the ***Diagram>Annotation…*** option brings up the Impedance Data Annotation dialog.

Only the bus, branch, and equipment annotations, as well as voltage level thresholds are available in the impedance data annotation.

2.9.2.3 Comparison Annotation

When the case comparison data is being shown on the diagram, the ***Diagram>Annotation…*** option brings up the Graphical Case Comparison Data Annotation dialog.

Only the bus annotation, and voltage thresholds are available in the case comparison annotation.

2.9.2.4 Fault Analysis Data Annotation

When the fault analysis data is being shown on the diagram, the ***Diagram>Annotation…*** option brings up the Graphical Fault Analysis Data Annotation dialog.

Only the voltage thresholds are available in the fault analysis annotation.

2.9.2.5 IEC Fault Analysis Annotation

When the IEC fault analysis data is being shown on the diagram, the ***Diagram>Annotation…*** option brings up the IEC Fault Analysis Annotation dialog.

2.9.2.6 Reliability Annotation

When the reliability data is being shown on the diagram, the ***Diagram>Annotation…*** option brings up the Reliability Annotation dialog.

2.9.2.7 Dynamics Annotation

When the dynamics data is being shown on the diagram, the ***Diagram>Annotation…*** option brings up the Dynamics Annotation dialog.

2.9.3 Checking the Diagram for Errors/Missing Items

2.9.3.1 Check All Elements

Selecting ***Diagram>Check*** immediately performs an examination of the entire network and diagram for apparent errors and missing items. Figure 2-93 shows an example of the output generated in the Output Bar by selecting this option.

```
           Missing Network Items

           ---------- None ----------

           Missing Diagram Items

Bus #      152 [MID500      500.00]
    Branch 152 3004 1  not found in current diagram

Bus #      204 [SUB500      500.00]
    Bus 204 not found in current diagram
```

Figure 2-93. Results Generated by the Check Menu Option

2.9.3.2 Check by Subsystem

Selecting ***Diagram>Check by Subsystem*** immediately performs an examination of the network and diagram for apparent errors and missing items. Only items in the current bus subsystem are checked.

2.9.4 Generate A Graphical Report

Diagram>Generate a graphical report (GRPG)... will generate the old GRPG style report. Selecting ***Diagram>Generate a graphical report (GRPG)...*** will prompt for the graphic report file, *.grp. Once a file has been selected, a prompt for the output device appears. The most common response is 26, directing the output to the screen. Future releases will provide support for GPRG style reporting directly from Diagram View.

.

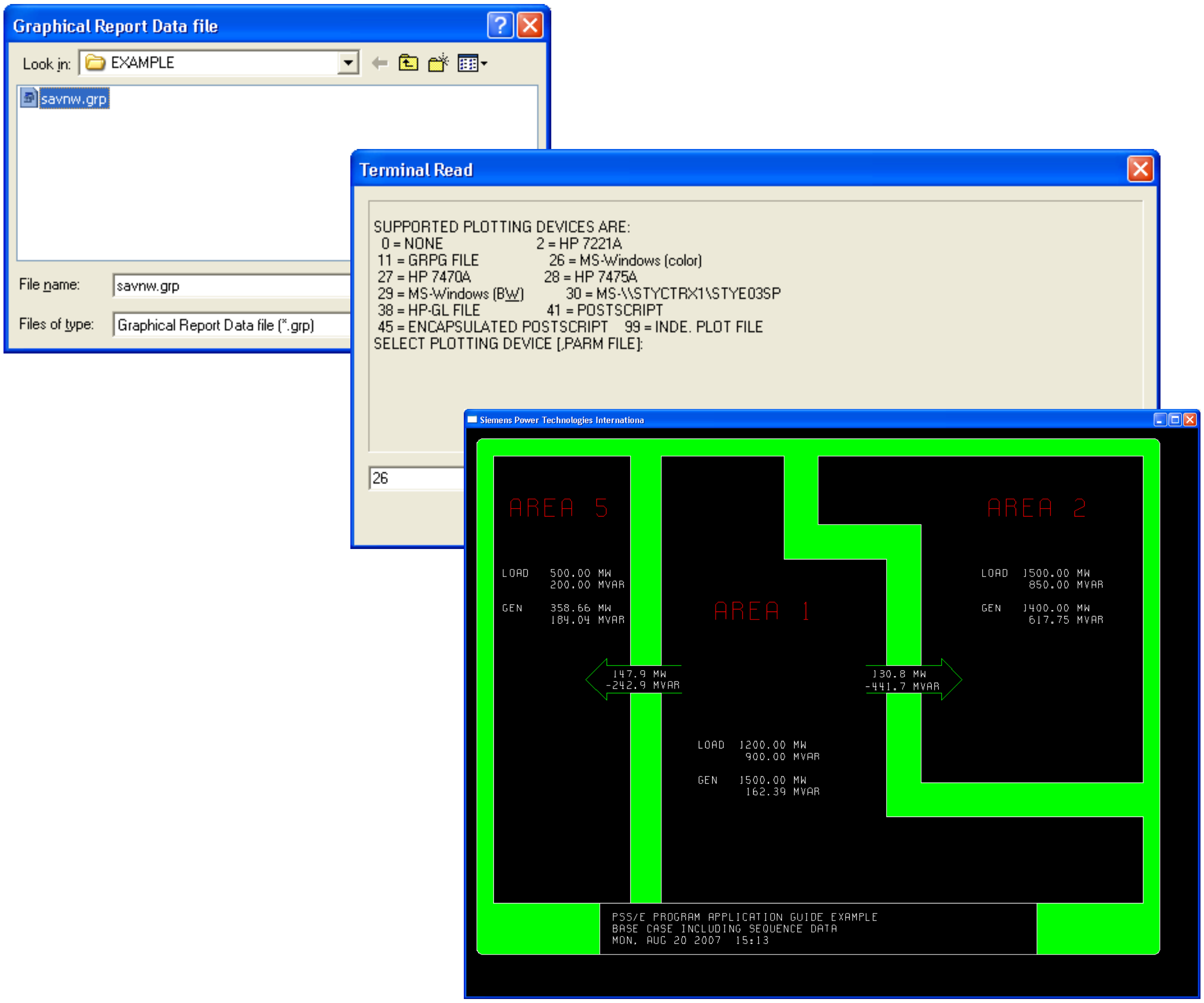


Figure 2-94. Generating a Graphical Report

2.9.5 Generate A Graphical Power Flow Bus Display

Selecting ***Diagram>Generate a graphical power flow bus display*** brings up a bus selection box. After a bus is selected a Diagram View will be generated for the selected bus showing associated lines and equipment and distant "to buses". All distant buses will be represented as nodes. The Graphical Power Flow Bus Display is discussed in more detail in Section 4.6.6

2.9.6 Contouring

2.9.7 Viewing Results on the Diagram

The ***Diagram>Results*** menu is discussed in detail in Section 2.5.11. Figure 2-56 shows the menu displaying the different choices for the type of results to be presented.

2.9.8 Binding Items in the Diagram

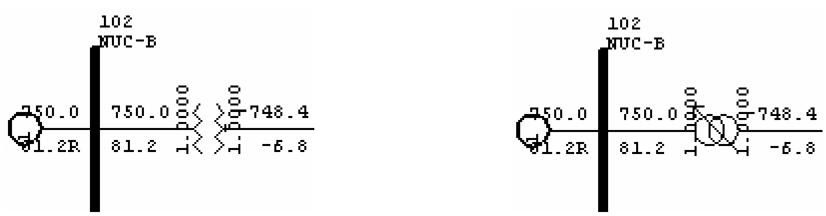
Adding items to a **Diagram View** can have two different effects:

- Every item added to a **Diagram View** will create a corresponding piece of data in the power flow case (e.g., adding a bus to the **Diagram View** will automatically add a new bus to the power flow case); or
- Items that are added in the **Diagram View** are not added to the power flow case. These items exist in the **Diagram View** only as annotation and do not represent real data in the network.

If the ***Diagram>Bind Items*** option is checkmarked (see Figure 2-88) then an element in the power flow case will be created for every element added to the **Diagram View**. If no checkmark appears next to the Bind Items option, then the elements created in the **Diagram View** will **not** be added to the power flow case.

2.9.9 Displaying ISO Symbols

Selecting the ***Diagram>Display ISO Symbols*** option will result in the display of network items using standard ISO symbols. Figure 2-95 shows the standard PSS™E transformer symbol as compared to the ISO symbol that is displayed when the Display ISO Symbols option is selected.



PSS™E Symbols **ISO Symbols**

Figure 2-95. PSS™E and ISO Transformer Symbols

2.9.10 Using the Auto Draw Style Option

When buses are added to the **Diagram View** by clicking the ***Auto Draw*** button on the General Toolbar (see Section 2.19.3) or selecting the ***Grow*** option described in Section 2.5.5, the buses will be drawn either horizontally or vertically. By selecting the ***Diagram>Auto Draw Style*** menu, you can move between Vertical or Horizontal buses as the one-line diagram is being developed (see Figure 2-96).

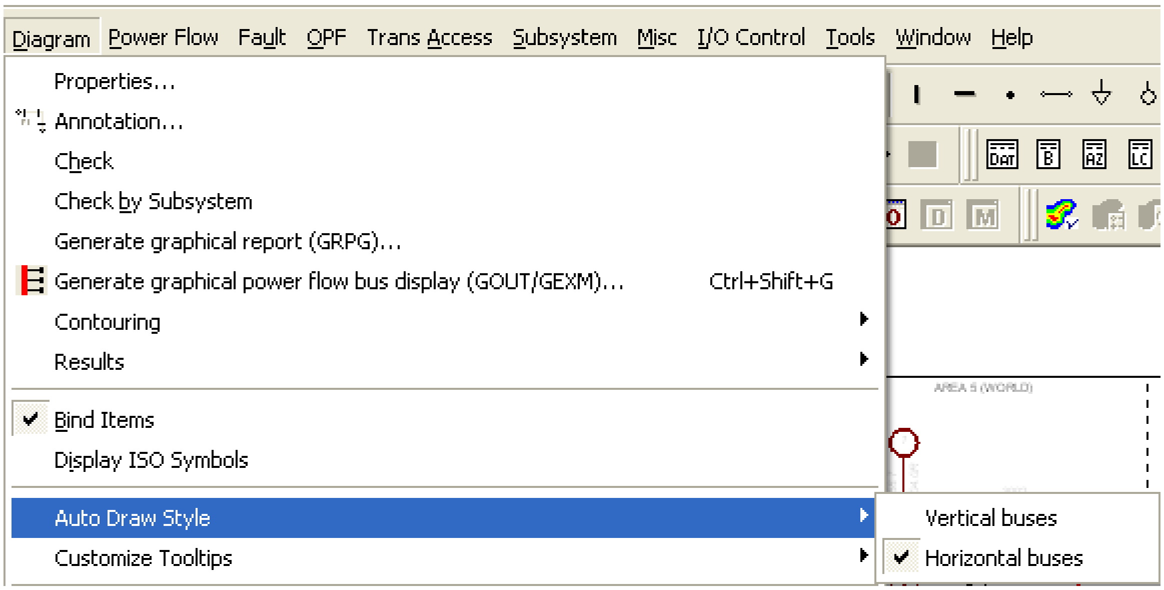


Figure 2-96. Auto Draw Style Options

2.9.11 Customizing Tooltips

Tooltips are the pop-up informational boxes that appear when the mouse cursor is held over a component in the diagram. The Display Tooltips option (***Diagram>Properties…***) must be enabled for tooltips to function. If the option to display tooltips is enabled, the ***Diagram>Customize Tooltips*** menu allows for up to three types of information to be displayed in the tooltip (see Figure 2-97).

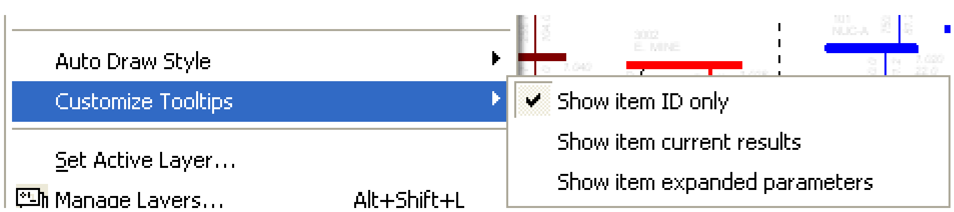
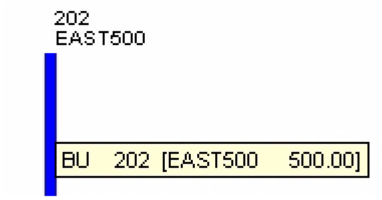
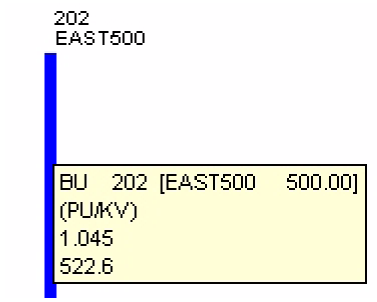


Figure 2-97. Customize Tooltips Options

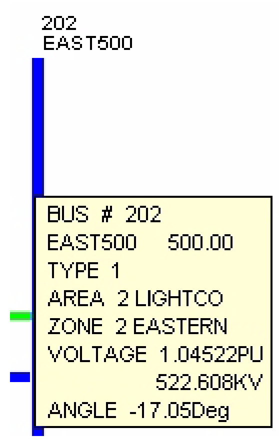
An example of each option, as it would appear for a bus, is shown in Figure 2-98.



(a) ID Only



(b) Current Results



(c) Expanded Parameters

Figure 2-98. Alternative Tooltip Presentations for a Bus

2.9.12 Set Active Layer and Manage Layers Diagram Menu Option

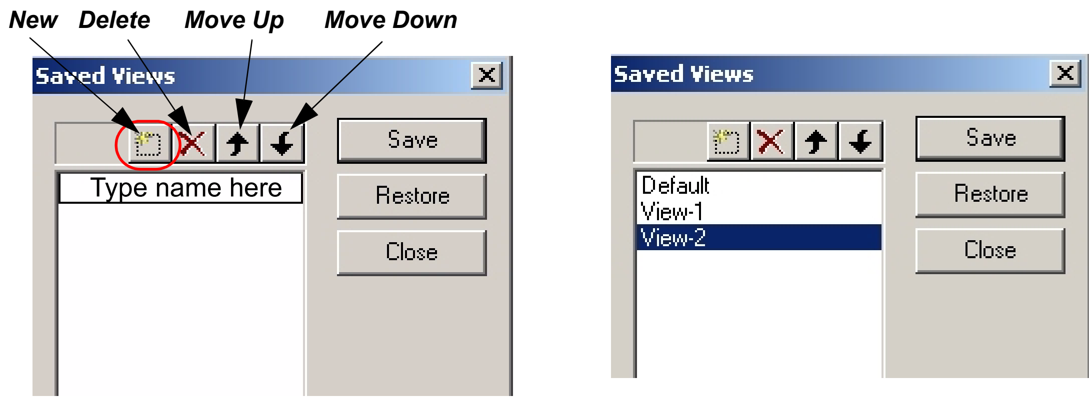
The ***Diagram>Set Active Layer*** and ***Diagram>Manage Layers…*** options handle the managing and setting of active layers. These options are covered in Section 2.5.10.

2.9.13 Manage Views Diagram Menu Option

Oftentimes, an alternate diagram view is desired in order to display results or other information, or it may be necessary to zoom to different levels and examine different parts of the network. If there are specific views that you need to examine or print on a regular basis, those views can be stored for rapid retrieval.

Selecting ***Diagram>Manage Views…*** opens the Saved Views dialog from which new views can be added or a specific view can be selected for presentation (see Figure 2-99).

To preserve the current diagram view for later retrieval, click on the ***New*** icon, type in a name for the view and click ***Save*** (Figure 2-99a). With several views saved, you can retrieve the desired view by selecting it from the Saved Views list and clicking ***Restore*** (Figure 2-99b).



(a) Add New View

(b) Select from View List

Figure 2-99. Saving and Retrieving Diagram Views

2.9.14 Viewing the Contents of the Diagram

Selecting ***Diagram>Contents…*** presents an itemized list of the number of components in the entire diagram, including diagram items, annotations, images, and text annotations added by the user (Figure 2-100).

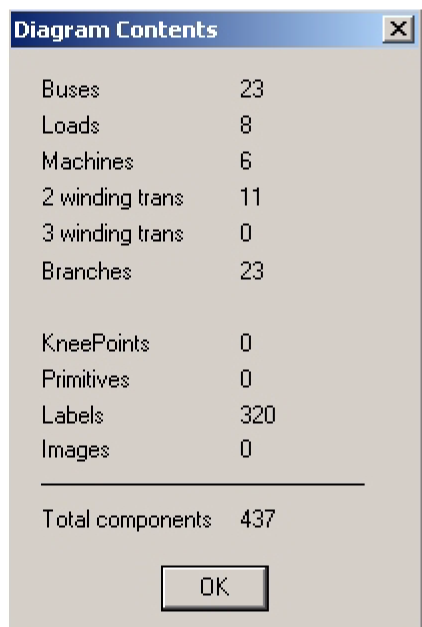


Figure 2-100. Contents of Diagram View

2.9.15 Updating Bus Locations

Selecting ***Diagram>Update bus locations*** will update the bus location for all buses for which a bus position record exists in the current Bus Location file. If no Bus Location file has been loaded, this selection will be disabled. If no buses are selected, all buses in the diagram will be evaluated for update. If buses are selected in the diagram, only those buses selected will be evaluated for update.

2.9.16 Select All Items with Property Overrides

Selecting ***Diagram>Select all items with property overrides*** will select all items in the diagram that have had either their color, line style or line width overridden through the use of the ***Item Properties>Line Style / Color*** dialog.

2.9.17 Removing Property Overrides

Selecting ***Diagram>Remove property overrides from selected items*** will remove property overrides from all selected items in the diagram that have had either their color, line style or line width overridden through the use of the ***Item Properties>Line Style / Color*** dialog. The line style, width and color will return to those specified by the ***Diagram>Properties*** and ***Diagram>Annotation*** dialogs.

2.9.18 Cleaning the Diagram

Selecting ***Diagram>Clean*** will perform a general diagram cleanup. As bugs are discovered in existing diagrams, new "cleaning" modes will be added to this function and released in program patches so that users will be able to repair their diagrams. Repeatedly executing this activity will have no effect on a diagram, it's use is to address specific diagram issues. The current issues addressed are:

1. Makes sure any name extension is separated by a ' ' from the end of the internally generated name.
2. Removes any unattached Branch or Radial symbols.
3. Checks for Summations that have lost their Identity strings.
4. Fixes any bad annotation tags found on branches and two winding transformers.

2.10 Power Flow Menu

The Power Flow Menu gives access to the majority of the PSS™E steady-state analyses (see Figure 2-101). Included are the power flow solutions for both ac and dc network analysis, data access and listing, network, dispatch, load and topology manipulations as well as checking network conditions and exporting results.

The analyses methods not contained in the Power Flow Menu are short-circuit analysis (Section 2.11), the Optimal Power Flow (Section 2.12), Transmission Access analysis (Section 2.13) and Dynamics and Disturbances (Chapter 16). These solution methods are available on their own menus.

The functionality of the applications available from the Power Flow Menu are discussed extensively in other chapters. The Power Flow Menu is described below in this subsection.

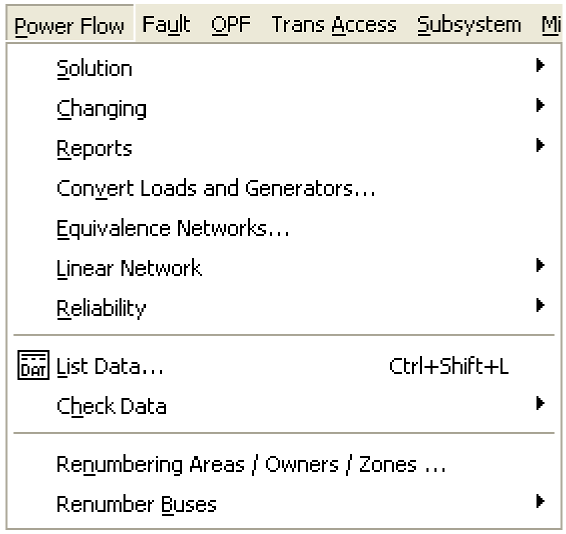


Figure 2-101. Power Flow Menu

References for the Power Flow Menu options are shown in Table 2-1 below.

Table 2-1. Chapter References for Power Flow Menu Options

Power Flow Menu Options	Reference
Solution	Sections 4.1, 4.3, 4.4, and 4.8
Changing	Section 4.6
Reports	Section 4.4
Convert Loads and Generators	Section 4.5.2
Equivalence Networks…	Chapter 9
Linear Network	Chapter 5
Reliability	
List Data…	Section 3.4
Check Data	Section 3.5
Renumbering Areas/Owners/Zones…	Section 4.7
Renumbering Buses	Section 4.7

2.11 Fault Menu

The Fault Menu options are shown in Figure 2-102. These options initiate calculation procedures for fault analysis as described in Chapter 7.

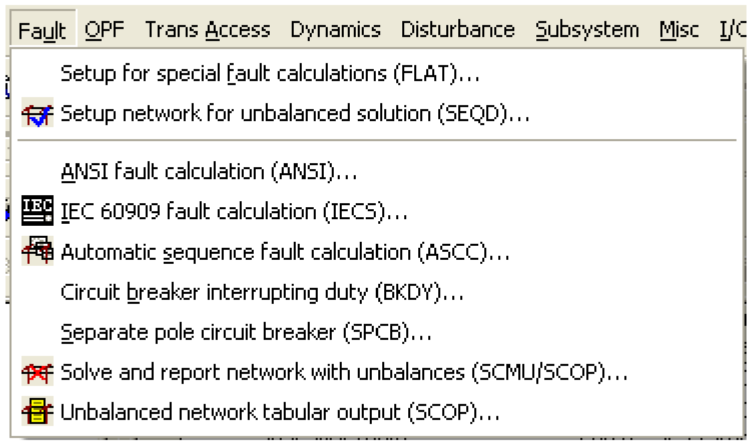


Figure 2-102. Fault Menu

References for the Fault Menu options are shown in Table 2-2 below.

Table 2-2. Chapter References for Fault Menu Options

Fault Menu Options	Reference
Setup for special fault calculations (FLAT)…	Section 7.4.2
Setup network for unbalanced solution (SEQD)…	
ANSI fault calculations (ANSI)…	Section 7.10
IEC 60909 fault calculation (IECS)…	
Automatic sequence fault calculation (ASCC)…	Section 7.8
Circuit breaker interrupting duty (BKDY)…	Section 7.9
Separate pole circuit breaker (SPCB)…	Section 7.11
Solve and report network with unbalances (SCMU/SCOP)…	Section 7.6
Unbalanced network tabular output (SCOP)…	

2.12 OPF Menu

The OPF Menu provides access to the data input and solution functions of the optimal power flow (see Figure 2-103). ***OPF>Solve…*** initiates the optimal power flow solution, the ***Data…*** and ***Data tables…*** options are for entering and editing OPF data, and the ***Parameters…*** option is for setting OPF solution options and tolerances. Refer to the *PSS™E OPF Manual* for detailed information.

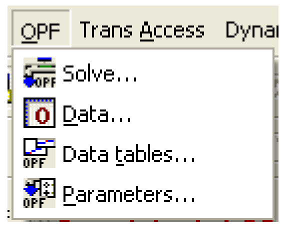


Figure 2-103. OPF Menu

2.13 Transmission Access (Trans Access) Menu

The Trans Access Menu, when selected, initiates the program applications related to transmission access studies. The options are shown in Figure 2-104 and referenced in Table 2-3 below.

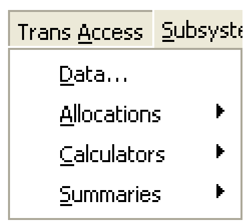


Figure 2-104. Transmission Access Menu

Table 2-3. Chapter References for Open Access Menu Items

Trans Access Menu Options	Reference
Data	Section 10.2
Allocations	Section 10.3
Calculators	Section 10.4
Summaries	Section 10.5

2.14 Subsystem Menu

The elements of the Subsystem Menu options are the toolbar buttons shown in Figure 2-105. For a detailed description of the toolbar buttons and the manner in which subsystems are established, refer to Section 2.4.2 and Figure 2-14.

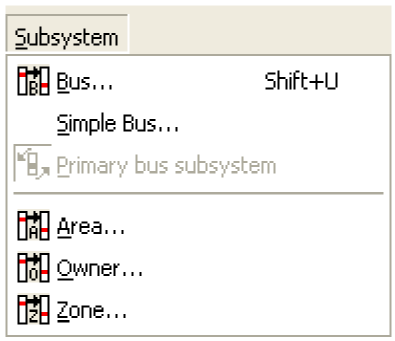


Figure 2-105. Subsystem Menu

2.15 Miscellaneous (Misc) Menu

The Misc Menu presents a variety of menu options aptly referred to as miscellaneous (see Figure 2-106).

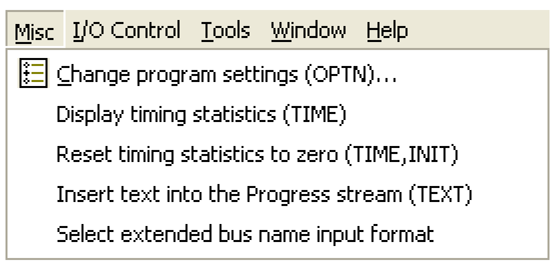


Figure 2-106. Miscellaneous Menu Options

2.15.1 Display and Resetting Timing Statistics

The Display timing statistics option obtains and displays execution time statistics during a PSS™E work session. Selecting ***Misc>Display timing statistics (TIME)*** initializes a timer and outputs a message to the selected output device. For example:

```
FRI, MAY 21 2004 08:36 - TIMER INITIALIZED
```

On subsequent selections of this option, a summary of elapsed time, in seconds, since the previous selection and cumulative times from the point at which the timers were last initialized are printed. In addition, two additional system statistics are printed, one of which indicates CPU utilization. The output is displayed in the following format:

```
FRI, MAY 21 2004  15:21   ELAPSE    USER      KERNEL
  SINCE LAST "TIME"       XX.XXX    XX.XXX    XX.XXX
  CUMULATIVE              XX.XXX    XX.XXX    XX.XXX
```

The timing process is not sensitive to any interrupt control code options.

At any time during a work session in PSS™E, if the ***Misc>Reset timing statistics to zero (TIME,INIT)*** is selected, the timers are initialized and the same initialization message is printed to the progress output device.

2.15.2 Inserting Text into the Progress Output

During the operation of PSS™E, a variety of information is sent to the **Output Bar**. Selecting the ***Misc>Insert text into the Progress stream (TEXT)*** option provides a mechanism for inserting descriptive comments. Comments can be directed to the **Output Bar** and into any other output device that may have been selected for recording the PSS™E work session (see Section 2.16). Upon selecting ***Insert text into the Progress stream (TEXT)*** option, an Insert Text into the Progress Stream dialog is displayed (see Figure 2-107). A comment or message may be entered directly into the input field provided.

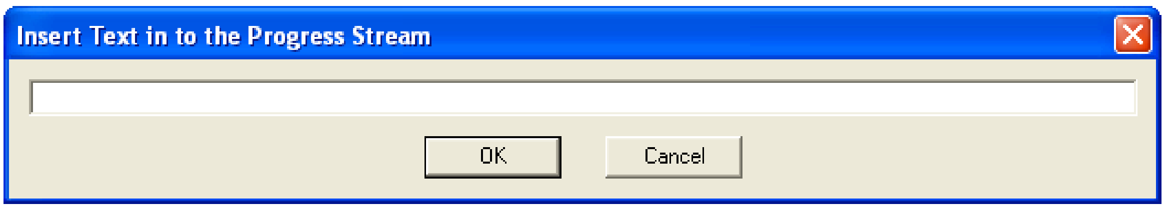


Figure 2-107. Insert Text into the Progress Stream Dialog

2.15.3 Selecting Extended Bus Name Input Format

The extended bus name format was changed at PSS™E Version 30 to accommodate longer bus names. The ***Misc>Select extended bus name input format*** option allows you to select the desired input format. When this option is selected, the dialog shown in Figure 2-108 is displayed, and the desired toggle button may be selected. All application functions that process buses based on the extended bus name will use the selected format for processing. This setting is not preserved between runs of the application.

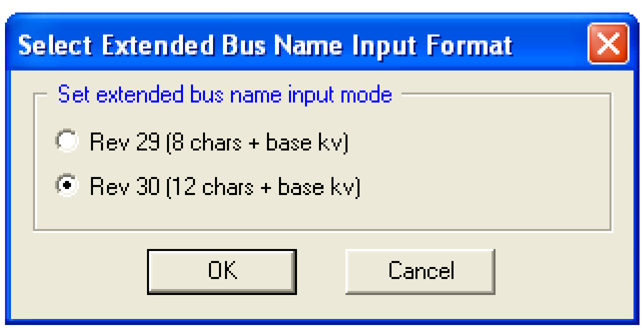


Figure 2-108. Select Extended Bus Name Input Format Dialog

2.16 I/O Control Menu

Output from an interactive session in PSS™E is typically directed to the Output Bar. I/O control options allow output to be diverted to other reporting devices. In addition, PSS™E can also facilitate the recording of program actions as the user selects data manipulation and analytical procedures. Those recorded procedures can be used as part of an automation process or running in batch mode.

The I/O Control Menu options are shown in Figure 2-109. The first four items involve directing output to a device of the users' choice. The next item deals with providing a short cut path to the users's files.

The bottom items in the menu are related to recording and re-playing control commands issued by the user during interactive sessions with the program running under control of automation files and initializing command line interface sessions.

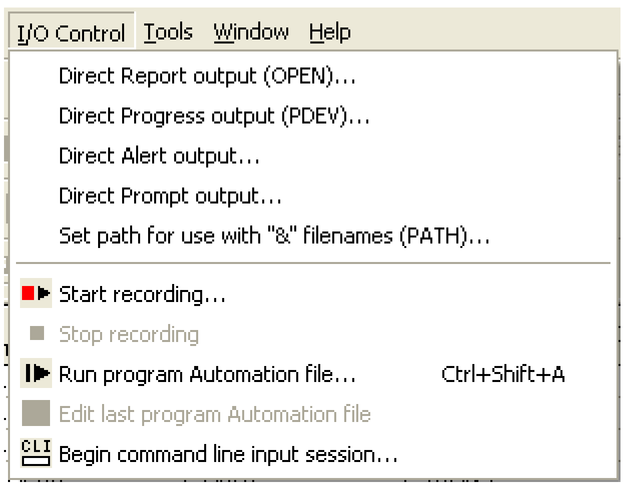


Figure 2-109. I/O Control Menu

2.16.1 Selecting Direct Report Output (OPEN)

Selecting ***Direct Report output (OPEN)…*** opens the Report Output Destination Selector dialog displayed in Figure 2-110. By default, reports are sent to the **Output Bar**. Options are available for redirecting reports to a file, printer or to the current progress device. The option also exists for suppressing all reporting output.

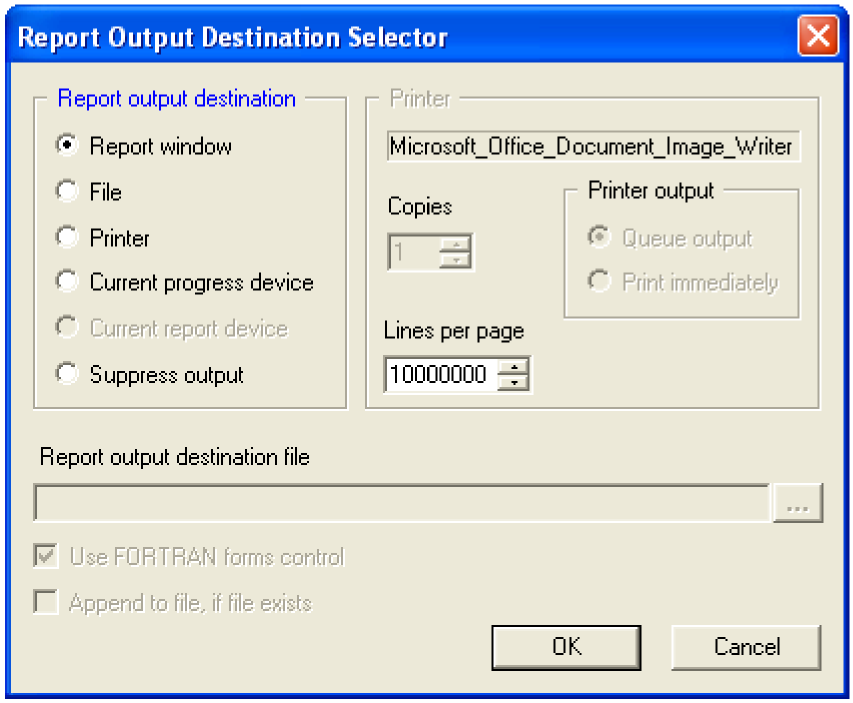


Figure 2-110. Report Output Destination Selector Dialog

Both the Report and Progress destinations could be the same.

If the Printer option is selected, the **Printer** group of the dialog is enabled for selection of the printer and printing options.

The **Report output destination file** field is for specifying a filename if file output is selected.

Fortran forms control can be enabled if either file or printer output is specified.

The **Append to file, if file exists** option may be selected if file output is selected. If enabled, then any new report output will be appended to the specified file instead of overwriting it.

2.16.2 Selecting Direct Progress Output (PDEV)

This ***I/O Control>Direct Progress output (PDEV)…*** option can be used to direct Progress output to an alternative device. The dialog and operation of the resulting Progress Output Destination Selector window is essentially the same as that described for directing Report output inSection 2.16.1. The only difference is that the default output destination is the Progress Device instead of the Report Device (see Figure 2-111).

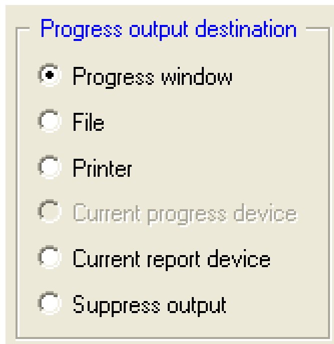


Figure 2-111. Options for Directing Progress Dialog

2.16.3 Selecting Direct Alert and Prompt Output

PSS™E generated "Alerts" and "Prompts" are sent to Alert and Prompt boxes, respectively. Alerts are error and/or warning messages generated by the program. Prompts are generated by the program during interactive command line interface sessions (Section 2.22). The ***I/O Control>Direct Alert output…*** and ***I/O Control>Direct Progress output…*** options direct alerts and/or prompts to an alternate destination, or suppress the writing of output. The dialogs are similar to that used for redirecting progress and report output (see Figure 2-112).

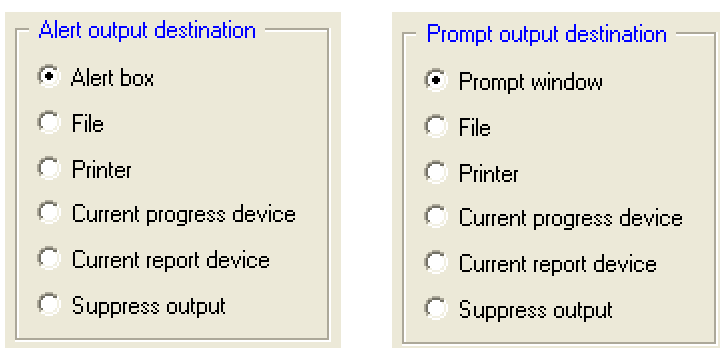


Figure 2-112. Redirecting the Alerts and Prompts Destination

2.16.4 Setting the Path for Use with "&" Filenames (PATH)

The ***I/O Control>Set path for use with "&" filenames (PATH)...*** option allows you to specify a directory path name that can later be represented by an ampersand (e.g., &myfile). This short hand method for specifying a path name can be used by PSS™E file accessing activities. A filename prefixed by this ampersand will be obtained from the directory specified in the path setting.

When invoking this option, a dialog box is opened in which the directory path to be accessed by the & short-hand method is selected by clicking on any file in the desired directory (see Figure 2-113).

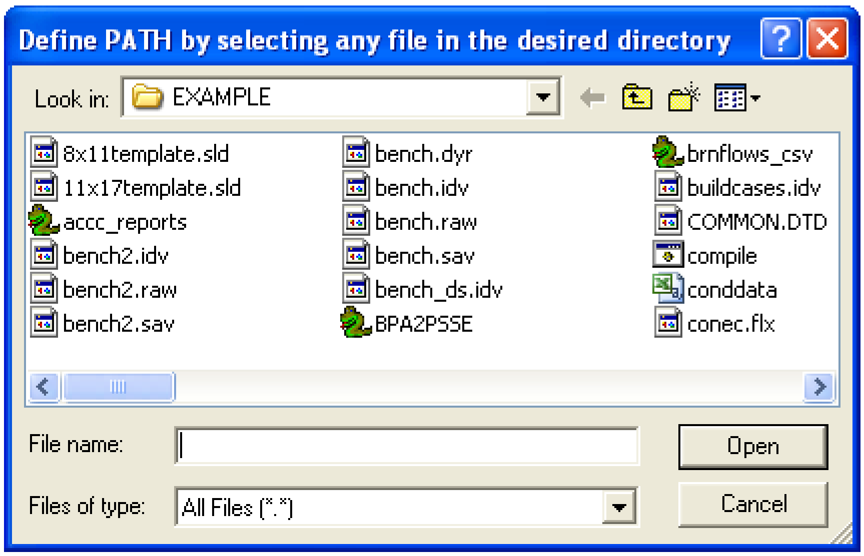


Figure 2-113. Selecting PATH Name

2.16.5 Using Command Line and Program Automation Options

The remaining options in the I/O window refer to automation processes (Section 2.21) and the command line interface operation (Section 2.22) and are covered in detail in the sections indicated (see Figure 2-114).

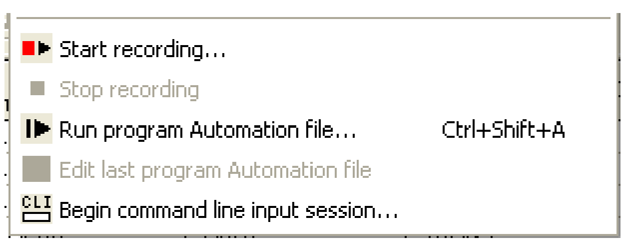


Figure 2-114. Automation and Command Line Input Options

2.17 Tools Menu

The Tools Menu, as seen in Figure 2-115, allows for selection of the active toolbars, the icons (commands) that are to be shown on each toolbar, the definition of the Custom Toolbar buttons, the definition of model search paths and the creation of the User Dynamics DLL. Descriptions of each toolbar icon are itemized in Section 2.19.

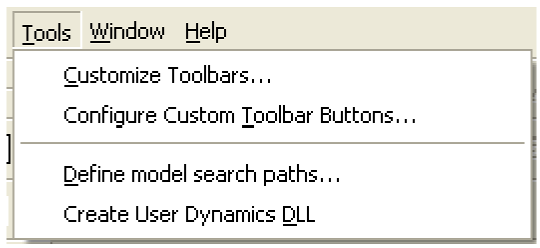


Figure 2-115. Tools Menu

2.17.1 Customizing Toolbars

The ***Tools>Customize Toolbars...*** option provides access to customizing the toolbar displays. Toolbars can be turned on/off and individually customized by adding and removing any number of buttons to them. Custom toolbars can also be created rather than editing existing configurations.

When selecting the ***Tools>Customize...*** option, the **Customize** dialog is displayed. This gives access to both a Toolbars tab and a Commands tab (see Figure 2-116).

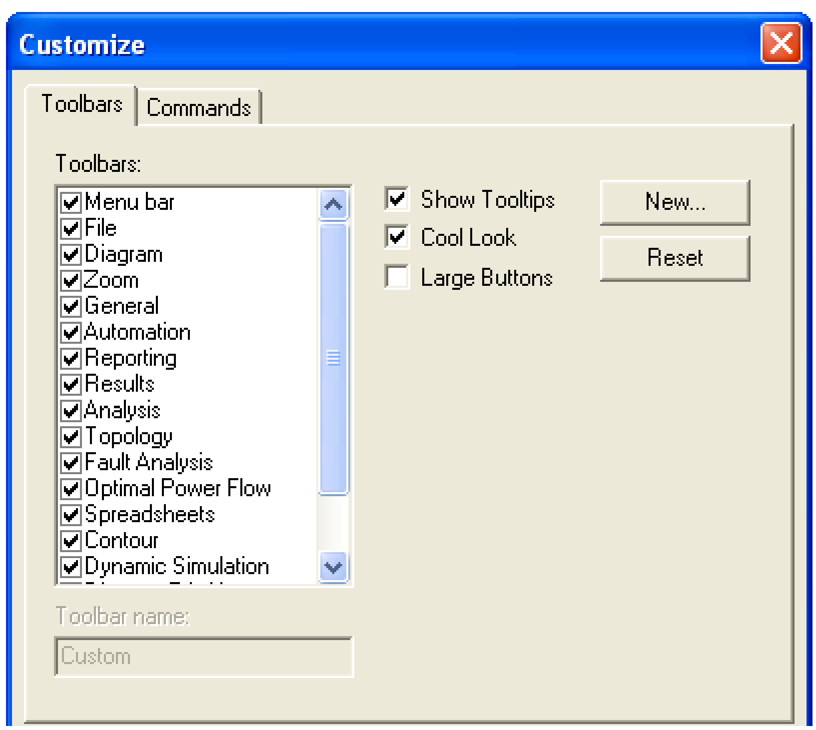


Figure 2-116. Customize Dialog: Toolbars Tab

The Toolbars tab facilitates the selection of those toolbars that are to be active and displayed on the interface. It also allows you to choose whether to show tooltip messages when the mouse pointer is held over the toolbar button. The tooltips identify the function of each toolbar button.

In the above figure all toolbars are selected to be visible on the interface except for the Custom Toolbar. The Custom Toolbar can be made active by checkmarking the Custom option. The resulting toolbar contains all the user definable buttons. Customization of these buttons is covered below (Section 2.17.2).

Toolbars can be rearranged in any position on the interface. They can also be dragged off the toolbar location and converted into floating windows.

The Commands tab displays the individual toolbar categories and shows the buttons currently assigned to each bar. An example showing the File Toolbar and its associated buttons is shown in Figure 2-117. Clicking on one of the toolbar buttons will provide a description of its command function. In this case it is the "Show or hide the output bar". A button can be removed from an active toolbar by clicking and dragging it from the toolbar to the Buttons area of the toolbar on the Commands tab. Likewise, a button in a particular toolbar category may be added to an active toolbar by dragging the icon of the button from the Commands tab to the desired location on the toolbar.

Many of the toolbar buttons (or toolbar commands) are duplicates of menu options and will open the same dialog.

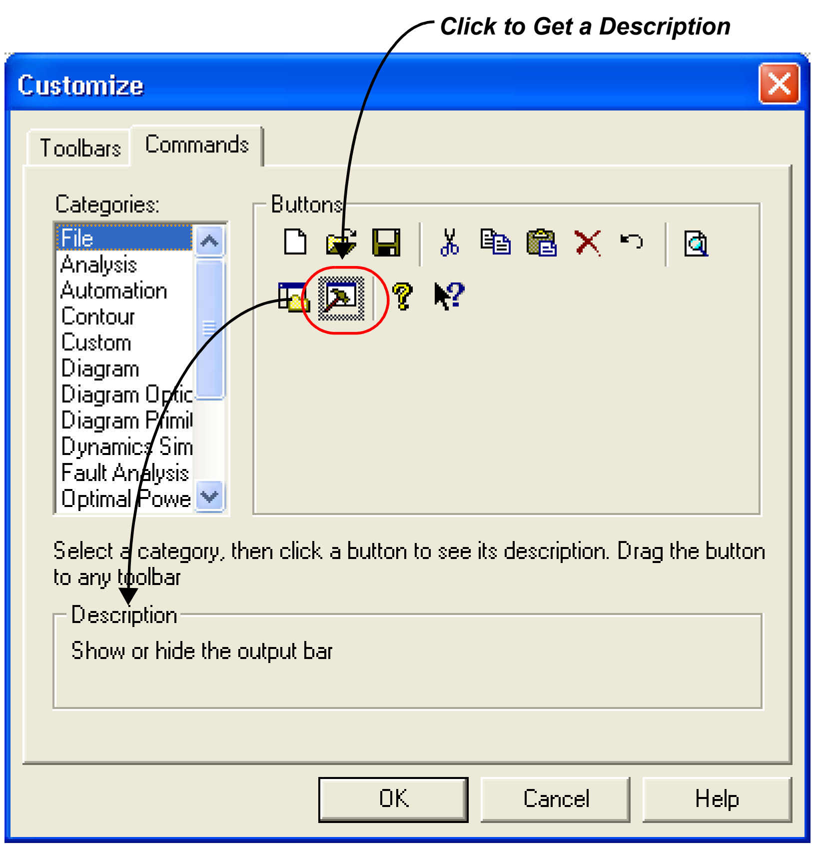


Figure 2-117. Customize Dialog: Commands Tab

2.17.2 Configure Custom Toolbar Buttons

When selecting the ***Tools>Configure Custom Toolbar Buttons…*** option, the Customize Toolbar Buttons dialog is displayed. This dialog displays and gives the user access to a list of the available custom toolbar buttons and a list of active toolbar buttons (see Figure 2-118).

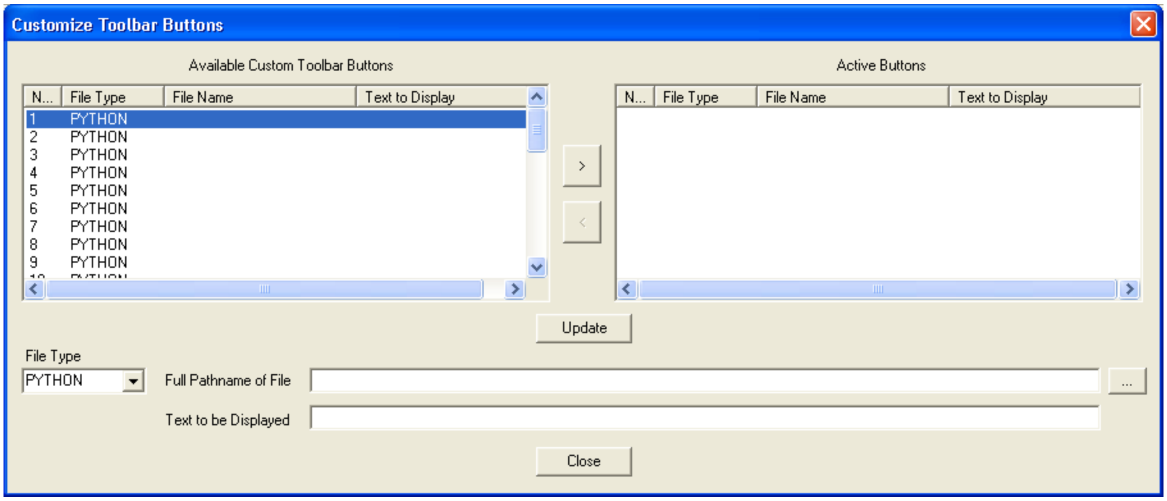


Figure 2-118. Customize Toolbar Buttons

There are 30 buttons which may be defined to invoke a user specified command. Each button requires a file type, a file name. An optional tooltip to display can also be provided.

File Type - specifies the type of Automation file to be run when the button is clicked. Options include:

- PYTHON - A Python script file (*.py) (default)
- RESPONSE - A Response file (*.idv)
- IPLAN - An IPLAN program (*.irf)

File Name - the name of the Automation file to be executed when clicking the corresponding custom toolbar button. The filename will contain the full pathname of the file.

Text To Display - an *optional* description (tooltip) of the operation to be performed when the corresponding custom toolbar button is clicked. If specified, the description will popup when the mouse cursor is held over the custom toolbar button. If it is not specified, the name of the file, as specified by filename, will be displayed as the tooltip.

To define a toolbar button, select one of the buttons from either the available or active button list. Initially, all buttons will appear in the available button list with a default file type of **PYTHON**. You can change the File Type by selecting from the dropdown list of types. Select the pathname of the file (file must exist), and then type in the tooltip text that you wish to have displayed. Click on the Update button to apply the changes that you've made.

The arrows in the center of the dialog move buttons from being available to being active. Figure Figure 2-119 shows the results of several buttons having been defined and two being moved to the active list.

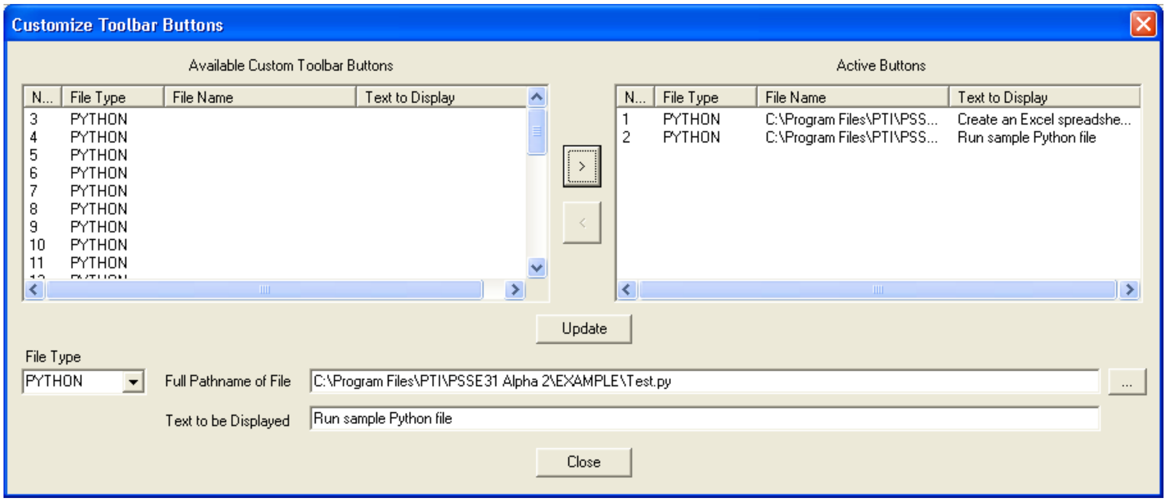


Figure 2-119. Defined Toolbar Buttons

Only those buttons which are in the “Active Button” list will be highlighted when the custom toolbar is displayed. The others will be grayed out (see Figure 2-119).

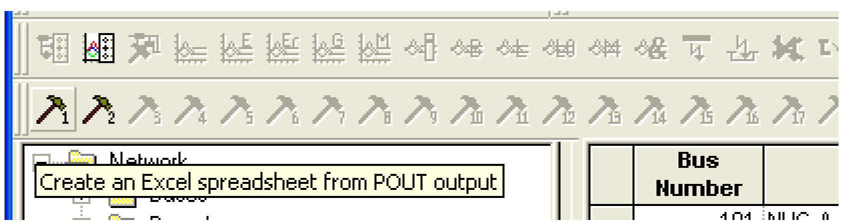


Figure 2-120. Custom Toolbar Showing Defined Buttons

Only those buttons which are in the “Active Button” list will be highlighted when the custom toolbar is displayed. The others will be grayed out (see Figure 2-120).

When the application exits, these custom toolbar button definitions will be preserved in a file named “Toolbar.prm” found in the "Document and Settings" directory for the active user.

2.17.3 Creating Custom Toolbars

A custom designed toolbar can be created by selecting the ***New…*** button in the Toolbars tab of the Customize dialog (see Figure 2-116). A new New Toolbar dialog window will be displayed into which a name for the new toolbar may be entered. When ***OK*** is clicked the new toolbar will appear within the list of toolbars and a small, free-floating toolbar window will appear on the PSS™E interface.

To add command buttons to the new toolbar, click on the Commands tab and drag the desired toolbar buttons to the new toolbar window. The new toolbar window can be docked to the toolbar area by dragging the window to the desired location on the toolbar and releasing the mouse.

To remove a user defined toolbar from the list of toolbars on the Toolbars tab, highlight the desired toolbar to be deleted and click ***Delete***. The standard toolbars can only be reset to their default settings.

2.17.4 Define Model Search Paths

The use of external formats to support Dynamics models was first made available in Version 30.3 with the Graphical Model Builder (GMB). The GMB uses a Visio-based interface to graphically create Dynamics equipment models. These GMB models can then be attached to network equipment in the same manner as PSS™ E standard models and user written and compiled models. Since the GMB models are defined in external files, the application must be made aware of the location of these files. When ***Tools>Define model search paths…*** is selected, the dialog seen in Figure 2-121 will be displayed. which allows the user to define specific directories in which the program can search to find required data-driven files.

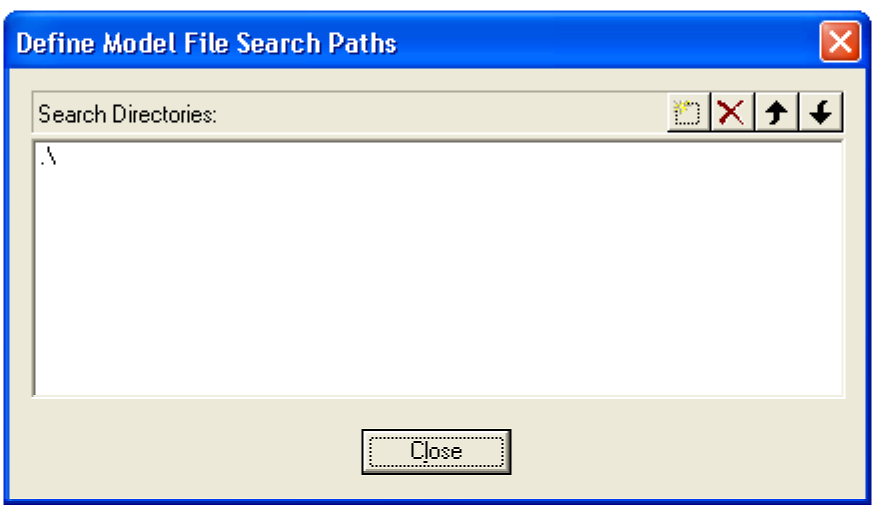


Figure 2-121. Define Model Search Paths

The initial default directory is the current directory (.\). Click on the New (Insert) button to add a new directory to the search list. A blank line will be displayed (see Figure 2-122).

.

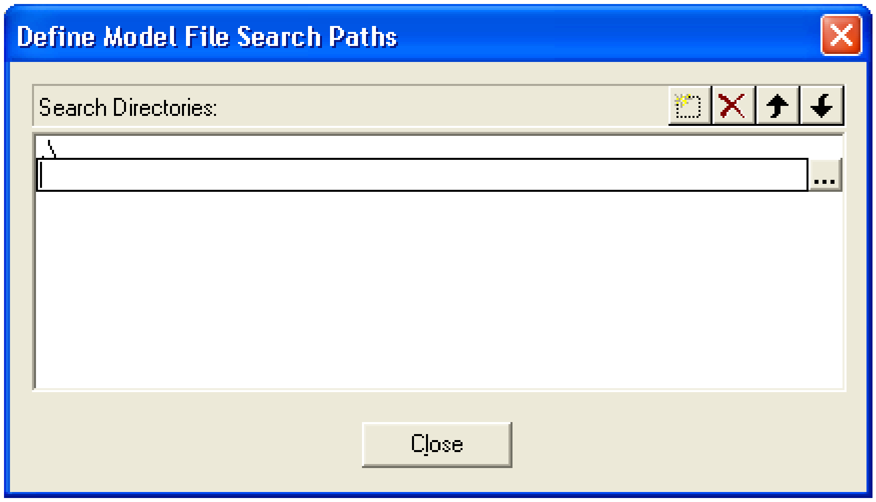


Figure 2-122. Add a New Directory to the Search List

Click the button at the end of the blank line to bring up the File Directory dialog (see Figure 2-123).

.

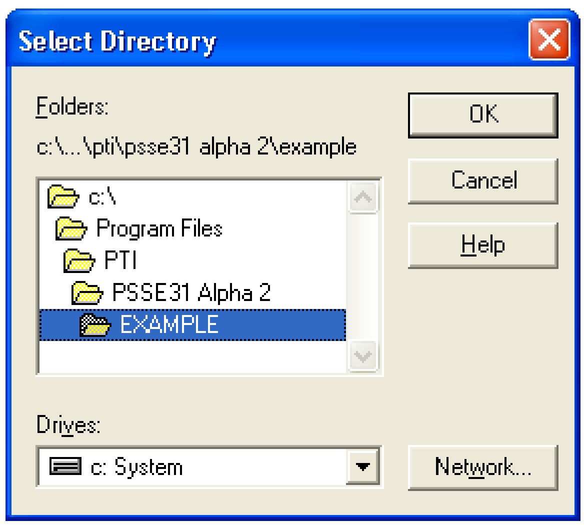


Figure 2-123. Select File Directory

Select a file directory to be searched and press OK. The new filepath will be added to the search list, as seen in Figure 2-124.

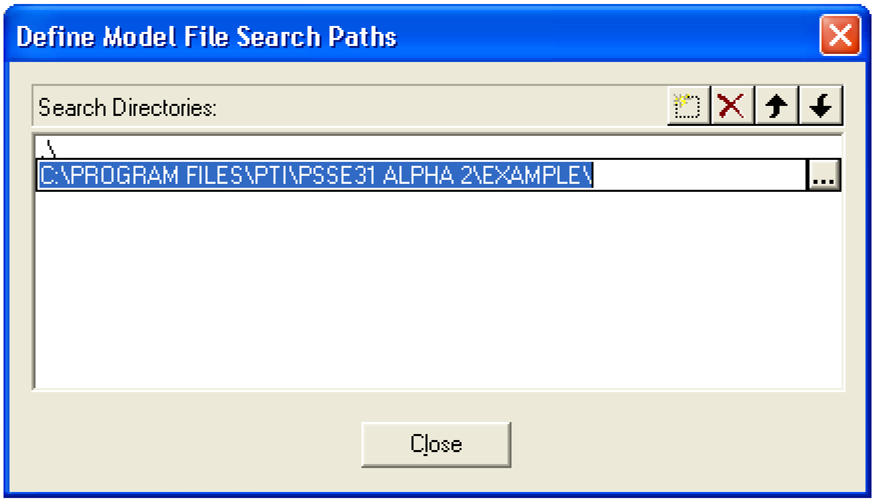


Figure 2-124. New Search Item

Additional directories may be added, deleted or moved up and down in the search list by using the buttons at the top of the dialog.When the application exits, the defined paths will be saved in a file named “DynModelPaths.prm” found in the "Document and Settings" directory for the active user.

Directories are searched for GMB models in the order in which they appear in the dialog shown in Figure 2-124. To change the search order, select an item file item in the dialog and move it up or down in the search order by use of the "arrow" icons found on the dialog.

A total of five model search paths may be defined at any given time.

2.18 Window Menu

The Window Menu provides the means for controlling the window displays (see Figure 2-125). With the spreadsheet and multiple diagram views open, this menu can be useful in arranging window placement.

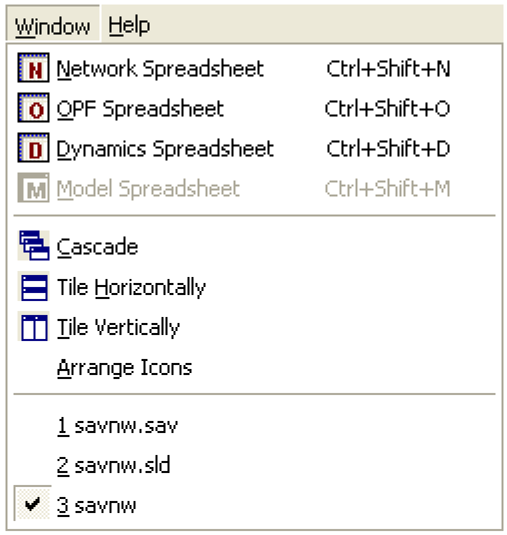
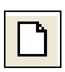


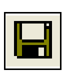
Figure 2-125. Window Menu

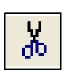
2.19 Toolbars

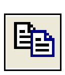
2.19.1 File Toolbar


Create a new case or diagram.

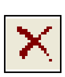

Open an existing file.

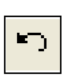

Save the active documents.

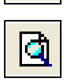

Cut the selection and put it on the clipboard.

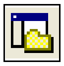

Copy the selection and put it on the clipboard.

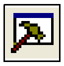

Insert clipboard contents.


Delete selected items.


Undo the previous action.


Print preview.

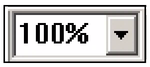

Show or hide the network tree.


Show or hide the output bar.

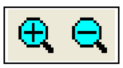

Display program information, version number and copyright.

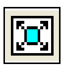

Display help for clicked on buttons, menus and windows.

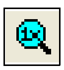
2.19.2 Zoom Toolbar

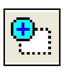


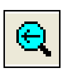
The **Zoom Combo Box** is used to select a predefined zoom factor to apply to the Diagram View. Click the arrow to the right of the combo box for a drop down a list of predefined zoom factors from which to choose from. You can also type in a desired zoom factor if it is not found in the list. The **Zoom Combo Box** is automatically reflects the current zoom factor, which can be changed through the use of the other zoom tools.

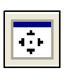

The **Zoom in/Zoom out** buttons are used to zoom the center of the diagram in or out.


The **Zoom Extent** button is used to zoom the diagram out to encompass all items drawn.


The **Zoom 100%** button is used to quickly return the Diagram View zooming factor to 100%.

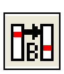

The **Zoom Window** button is used to zoom in on a selected portion of the Diagram View. The user selects this item and then drags a rectangle over the Diagram View to encompass the part of the Diagram View they want zoomed. The selected part of the Diagram View is then zoomed to fit in the extent of the Diagram View window.


The **Zoom Previous** button is used to return the zooming factor of the Diagram View to its previous setting.

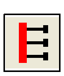

The **Pan** button is used to scroll around the Diagram View. Upon selecting this item, the cursor in the Diagram View changes to a hand. The Diagram View is then panned by holding down the left mouse button and dragging the hand around the window.

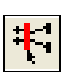
2.19.3 General Toolbar

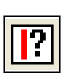
Select all buses.


Create a bus subsystem.

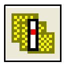

Toggle between the primary bus subsystem and an alternate.


Create a graphical power flow bus display (GOUT/GEXM).


Set interaction mode to automatically draw parts of the network.

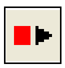

Locate and center the selected bus on the Diagram.

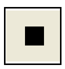
 Change general program settings.

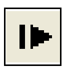
 Create or modify SUB, MON, and CON configuration files.

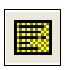
2.19.4 Automation Toolbar

Start the command line interface.

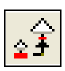
 Start recording automation file.

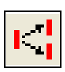
 Stop recording automation file.

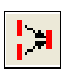
 Select and run a program automation file.

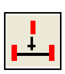
 Edit the current or last accessed automation file.

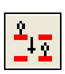
2.19.5 Topology Toolbar

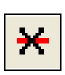
 Scale load, generation, and shunts.

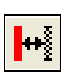
 Split a bus into two buses.

 Join two buses into one.

 Insert another bus into a line.

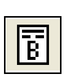
 Move equipment /lines between buses.

 Delete buses/equipment/lines.

 Disconnect/Reconnect bus to network.

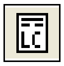
2.19.6 Reporting Toolbar

List Powerflow, sequence and OPF data.

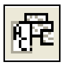


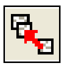
Generate Bus based reports.

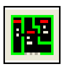
Generate Area/Zone based reports.

 Generate limit checking reports.

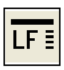
 Generate Area/Owner/Zone total reports.

 Generate AC solution output reports.

 Append to existing AC solution output file.

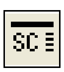
 Create a graphical report.

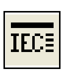
2.19.7 Results Toolbar

 Display power flow results.

 Display power flow impedance data.

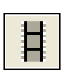
 Run graphical case comparison.

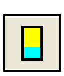
 Run graphical fault analysis.

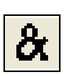
 Display IEC results.

 Display reliability results.

 Display dynamics results.

 Animate Flows.

 Display current loading bar charts.

 Multisection Line reporting.

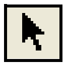
 Lock the diagram.

2.19.8 Diagram Toolbar

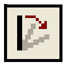
The Diagram Toolbar contains the toolbar buttons for creating and manipulating diagram items. The "manipulation" term implies that an existing **Diagram View** can be modified subsequent to its construction or during its development.

The "creation" term implies that diagram items, network items or simple annotation items, are selected from the Diagram Toolbar for construction of a new network diagram. This can imply the construction of a new power flow case if the diagram items are "bound" to network items. The creation of a power flow case using the **Diagram View** and Diagram Toolbar is discussed in Section 3.8.

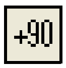
2.19.8.1 Diagram Manipulation Toolbar Buttons



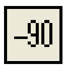
The **Select** button is used to select diagram items in a **Diagram View**. Items can be selected using common selection techniques (e.g., dragging a rectangle around several objects, clicking on an item and then holding down the **[Ctrl]** key to add more selections to the selection list). The selected items can then be manipulated in many ways.



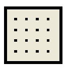
The **Rotation** button is used to rotate diagram items. If the rotation item is selected, and then a diagram item is selected, the cursor changes to a circular arrow. Holding down the left mouse button while dragging the cursor will rotate the selected item around its center.



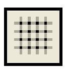
The **+90** button is used to rotate a selected item positive 90 degrees.



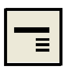
The **–90** button is used to rotate a selected item negative 90 degrees.



The **Show Grid** button is used to toggle on or off the display of a grid in the **Diagram View**.

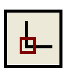


The **Grid Snap** button is used to toggle on or off the feature that causes the location of any newly created diagram item to snap to the nearest grid point in the **Diagram View**.



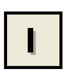
The **Toggle Labels** button is used to toggle on or off the display of labels in the Diagram.

The **Diagram Annotation** button is used to edit the diagram annotation.

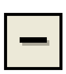


The **Kneepoint** button is used to put bends, or kneepoints, in a link that connects two diagram items. Links are used to represent lines, the connections between two- and three-winding transformer symbols and buses, and the connections between equipment and buses. When the kneepoint item is selected the cursor changes to a crosshair. Clicking on a link will place a red square on the link. This red square can later be dragged with the select item to achieve the desired shape. Kneepoints can be deleted by selecting the kneepoint and pressing the **[Delete]** key.

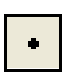
2.19.8.2 Diagram Toolbar Buttons for Network Creation



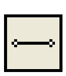
The **Bus** button is the basic building block of a PSS™E case and a Diagram View. Buses need to exist in a Diagram View before any lines or equipment can be drawn. Buses have a number of discrete "ports" arranged along both sides of the busbar. When connecting lines and equipment to a bus, the connection point will snap to the nearest port.



The **Horizontal Bus** is the same as a regular bus, except that when drawn on the Diagram View it is placed horizontally across the screen instead of vertically placed.

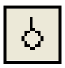


The **Bus Node** button is used when busbar representation of the bus is not desired. The bus node has a number of "ports" "stacked" in the center of the node. When connecting lines or equipment to a bus node, the connection point will snap to the center.

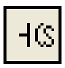


The **Branch** button is used to create a line between two buses. When the branch item is selected, the cursor changes to a crosshair. The branch is started by placing the cross-hair on the FROM bus and clicking. Any number of intermediate kneepoints may then be created by clicking on the way to the TO bus. Clicking on the TO bus will complete the creation of the branch. At any point during the creation of the branch, the branch may be canceled and removed by pressing the **[Esc]** key. The attachment point of a branch on a bus may be changed by **[Ctrl]** clicking on the attachment point of the link and then moving it to another port on the bus.

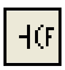
The **Load** button is used to create a load on a bus. When the load item is selected, the cursor changes to a crosshair. The load is started by placing the crosshair on the bus and pressing the left mouse button. The mouse is then dragged to where the load symbol is to appear and released.



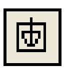
The **Generator** button is used to create a generator on a bus. When the generator item is selected, the cursor changes to a crosshair. The generator is started by placing the crosshair on the bus and pressing the left mouse button. The mouse is then dragged to where the generator symbol is to appear and released.



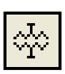
The **Switched Shunt** button is used to create a switched shunt on a bus. When the switched shunt item is selected, the cursor changes to a crosshair. The switched shunt is started by placing the crosshair on the bus and pressing the left mouse button. The mouse is then dragged to where the switched shunt symbol is to appear and released.



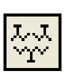
The **Fixed Shunt** button is used to create a fixed shunt on a bus. When the fixed shunt item is selected, the cursor changes to a crosshair. The fixed shunt is started by placing the crosshair on the bus and pressing the left mouse button. The mouse is then dragged to where the fixed shunt symbol is to appear and released.



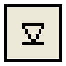
The **FACTS Device** button is used to create a FACTS device between two buses. The FACTS device is started by selecting one or two buses. One bus is selected to create a shunt element FACTS device. Two buses are selected to create a series element FACTS device. When the FACTS device item is selected, the cursor changes to a crosshair. If a single bus was selected, the FACTS device is started by placing the crosshair on the selected bus and pressing the left mouse button. The mouse is then dragged to where the FACTS device is to appear and released. If two buses were selected, the FACTS device is started by placing the crosshair on the *"sending bus"* and clicking. Any number of intermediate kneepoints may then be created by clicking on the way to the *"terminal bus"*. Clicking on the *"terminal bus"* will complete the creation of the FACTS device. At any point during the creation of the FACTS device, the FACTS device may be canceled and removed by pressing the **[Esc]** key.



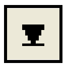
The **Two-winding Transformer** button is used to create a two-winding transformer between two buses. The two-winding transformer is started by placing the crosshair on the FROM bus and clicking. Any number of intermediate kneepoints may then be created by clicking on the way to the TO bus. Clicking on the TO bus will complete the creation of the two-winding transformer. At any point during the creation of the two-winding transformer, the two-winding transformer may be canceled and removed by pressing the **[Esc]** key. The attachment point of a two-winding transformer on a bus may be changed by **[Ctrl]** clicking on the attachment point of the two-winding transformer and then moving it to another port on the bus.



The **Three-winding Transformer** button is used to create a three-winding transformer between three buses. The three-winding transformer is created by first selecting three buses. The three buses will be regarded as the FROM, TO, and last bus in the order they were initially selected. The three-winding transformer item is then selected, the cursor placed in the Diagram View at the desired location for the symbol to be placed, and the left mouse button clicked. Any number of intermediate kneepoints may be added to the links between the symbol and the three buses, or the attachment points modified in the manner described above.



The **Two-terminal dc Line** button is used to create a two-terminal dc line between two buses. When the dc line item is selected, the cursor changes to a crosshair. The dc line is started by placing the crosshair on the FROM bus and clicking. Any number of intermediate kneepoints may then be created by clicking on the way to the TO bus. Clicking on the TO bus will complete creation of the dc line. At any point during the creation of the dc line, the dc line may be canceled and removed by pressing the **[Esc]** key. The attachment point of a link on a bus may be changed by **[Ctrl]** clicking on the attachment point of the link and then moving it to another port on the bus.



The **VSC dc Line** button is used to create a VSC dc line between two buses. When the VSC dc line item is selected, the cursor changes to a crosshair. The VSC dc line is started by placing the crosshair on the FROM bus and clicking. Any number of intermediate kneepoints may then be created by clicking on the way to the TO bus. Clicking on the TO bus will complete creation of the VSC dc line. At any point during the creation of the VSC dc line, the VSC dc line may be canceled and removed by pressing the **[Esc]** key. The attachment point of a link on a bus may be changed by **[Ctrl]** clicking on the attachment point of the link and then moving it to another port on the bus.

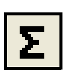
2.19.8.3 Diagram Toolbar Buttons for Adding Annotation to the Diagram View

The **Annotation Text** button is used to place annotation text anywhere on the Diagram View. The annotation text item is selected and text can then be placed anywhere in the Diagram View by clicking at the location to display the text annotation.

The **Title** button is used to place a title on the Diagram View. The title item displays the two-line diagram title as well as the time and date of the last diagram update on the third line. The time and date is updated on the title item whenever a solution is run and the diagram is open in the application. The title item is selected and titles can then be placed anywhere in the Diagram View by clicking on the location where the title is to be placed.

The **Legend** button is used to place a legend on the Diagram View. The legend item displays the two-line diagram legend. The legend item is selected and legends can then be placed anywhere in the Diagram View by clicking at the location where the legend is to be displayed.

The **Files** button is used to place a Diagram File Block on the Diagram View. The Diagram File Block contains the current case filename and the current Diagram filename. The files item is selected and file blocks can then be placed anywhere in the Diagram View by clicking the location where the file block is to be displayed.



The **Summation** button is used to place a summation record on the Diagram View. The summation item is selected and summations can then be placed anywhere in the Diagram View by clicking. As each summation is placed, the Edit Summation dialog is displayed that allows the setting of the summation records (see Section 2.19.8.4).

2.19.8.4 Adding a Summation Record to the Diagram View

The user can augment the power flow results shown in the Diagram View by providing summations of flow information which could be useful for reporting current results for help when testing a variety of network conditions for documentation.

The Summation button shown above in Section 2.19.8.3 is used to open the dialog shown in Figure 2-126. The user can supply a title line for the summation, as shown, and then select a variety of system results to sum. These can be generator output and line flows for example. The example show in Figure 2-126 sums the difference between generator output at bus 101 and the flow on circuit 1 of the line from bus 151 to 201.

The "Title" and the value of the summation will be placed in the Diagram View at the point selected by the user. Subsequently, it can be edited and/or moved to a different location.

2.19.8.4.1 Summation Block Structure

The summation block structure provides for:

- Initializing a summing variable; usually, the initial value of the summing variable is zero, but a nonzero value may be specified.
- Specifying individual ac branches, generator buses, and/or load buses whose active power components of line flow, generation, and load, respectively, are added to or subtracted from the summing variable.
- Specifying a character string to be printed in front of the calculated value of the summing variable anywhere on the one-line diagram.

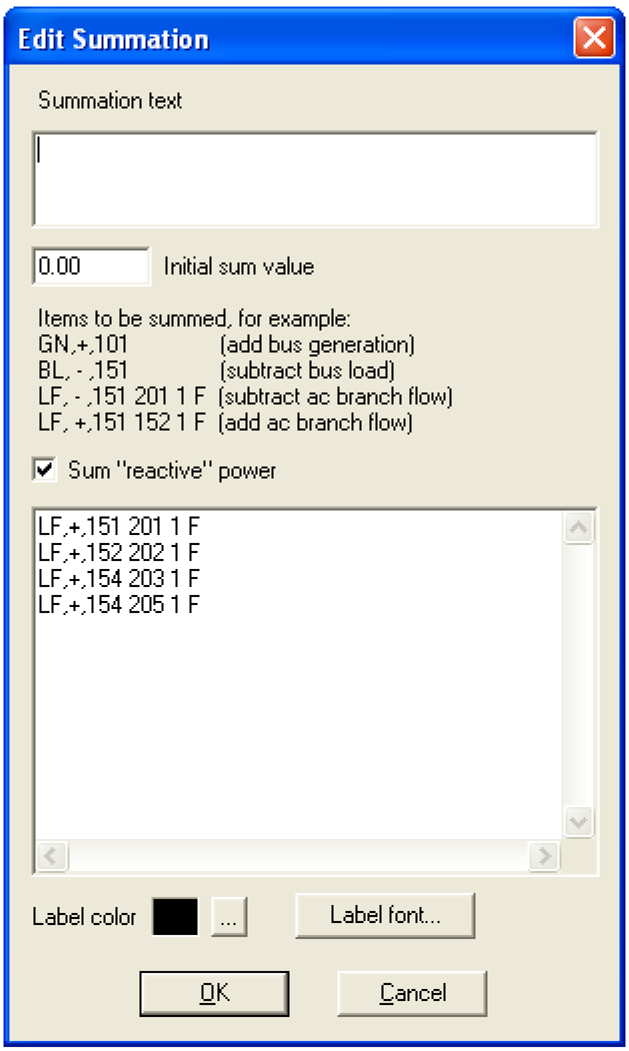


Figure 2-126. Edit Summation Dialog

Each summation block structure consists of:

- One summation record, "SUM" or "SU" (see below).
- Optionally followed by one or more summation participation records "GN", "BL", and "LF" (see below).
- Followed by one terminator record, "EN".

Summation records are of the form:

```
SU, O, '...text...', X, Y, TSIZ, TANG, CNST
```

where:

O	Is a valid option (blank, or "1" through "8"; blank and "1" are equivalent); see below.
text	Is the character string to be displayed in front of the summing variable's value. It must be enclosed in single quotes and is limited to 40 characters.
X,Y	Is the (x,y) coordinate of the first character of the text string, specified in inches.
TSIZ	Is the character height specified in inches. TSIZ must be between 0.05 and 1.5 in.
TANG	Is the angle of rotation of the character string, specified in degrees between 0 and 360; 0 degrees is the angle at which the title lines are written on the diagram.
CNST	Is the initial value to be assigned to the summing variable. The default value is zero.

The option field is used to designate a line width, pen number, or color for the drawing of the text. It is the user's responsibility to ensure that the designated number is appropriate for the graphics output device being used (e.g., "6" would be invalid for a pen plotter with only four pens). If the numeric option is invalid, a device dependent default is used.

The summation record in the summation block structure may be followed by summation participation records. These define the generator buses, load buses, and ac branches whose active power components are to be included in the summation. The summation participation records may be entered in any order and are of the following forms:

```
GN, O, IB                   (for bus generation)
BL, O, IB                   (for bus load)
LF, O, IFR, ITO, ID, DIR    (for ac branch flow)
```

where:

O	Is a valid option (blank, "+" or "-"). Blank or "+" indicates that the active power of the corresponding network element is to be added to the summing variable; "-" indicates that it is to be subtracted from the summing variable.
IB	Is a bus identifier.
IFR	Is the "*from bus*" identifier.
ITO	Is the "*to bus*" identifier.
ICKT	Is the circuit or multisection line grouping identifier; default value is '1'.

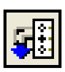
DIR Is either ’F’ or ’T’ and indicates flow direction. Line flow is always calculated at the bus IFR end of the line; if DIR is ’F’, flow is in the bus IFR "*to bus*" ITO direction, and if it is ’T’, flow is in the bus ITO "*to bus*" IFR direction. DIR is ’F’ by default.

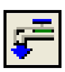
If an element specified on a summation participation record is out-of-service, it does not contribute to the summation.

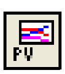
The following records illustrate an example of the summation block structure:

```
SUM, ,'AREA 1 = ', 4.8  2.4  0.12  45. 0.
 GN,+,101
 GN,+,102
 LF,-,151 201 1 F
 LF,-,152 202 1 F
 BL,-,151
 EN
```

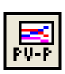
2.19.9 Analysis Toolbar


Change network solution settings.

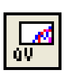

Solve.



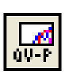
Perform a PV analysis.



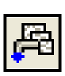
Perform a PV analysis using previous results.

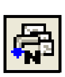


Perform a QV analysis.

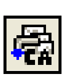


Perform a QV analysis using previous results.


Perform AC contingency calculation.

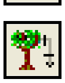


Perform multi-level AC contingency calculation.

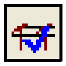


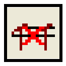
Perform AC corrective actions.

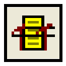

Perform Reliability assessment.


Perform network connectivity check (TREE).

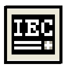
2.19.10 Fault Analysis Toolbar


Setup network for unbalanced solution.

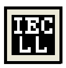

Solve and report network with unbalances.


Unbalanced network report.

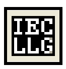

Automatic sequence fault calculation.



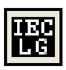
IEC 60909 fault calculation.



Perform an IEC LL fault calculation.



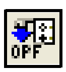
Perform an IEC LLG fault calculation.



Perform an IEC LG fault calculation.

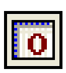
Perform an IEC LLLG fault calculation.

2.19.11 Optimal Power Flow Toolbar

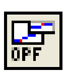


Change OPF solution settings.

Solve OPF.

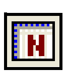


Make the OPF spreadsheet active.

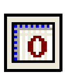


Create/modify OPF data tables.

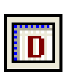
2.19.12 Spreadsheets Toolbar



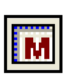
Make the Network spreadsheet active.



Make the OPF spreadsheet active.



Make the Dynamics spreadsheet active.

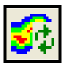


Make the Model spreadsheet active.

2.19.13 Contour Toolbar

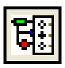
 Enable color contouring.

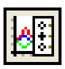
 Edit contour settings.

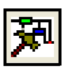
 Refresh contours.

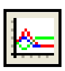
 Remove contours.

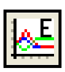
2.19.14 Dynamic Simulation Toolbar

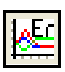
 Change Dynamic simulation options.

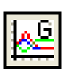
 Change Dynamics solution parameters.

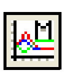
 Perform network model maintenance functions.

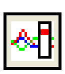
 Initialize and perform a Dynamic simulation.

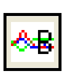
 Initialize and perform an Exciter simulation.

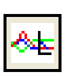
 Initialize and perform an Exciter response ratio simulation.

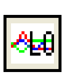
 Initialize and perform a Governor Response simulation.

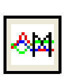
 Initialize and perform an Extended Term simulation.

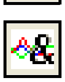
 Select channels by subsystem.

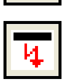
 Select bus channels.

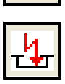
 Select branch and 3 winding transformer channels.

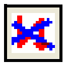
 Select load channels.

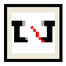
 Select machine channels.

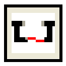
 Select VAR/STATE channels.

 Apply a bus fault.

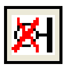
 Apply a line fault.

 Clear a fault.

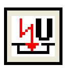
 Trip a line.

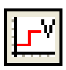
 Close a line.

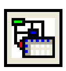
 Disconnect a bus.

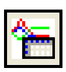
 Disconnect a machine.

 Calculate and apply an unbalanced bus fault.

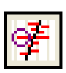
 Calculate and apply a branch unbalance.

 Change or increment Vref.

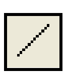
 List model and data by model type.

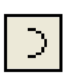
 List Dynamics variables in network.

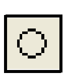
 List model storage locations by type and subsystem.

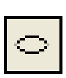
 Launch NEVA Eigenvalue analysis module.

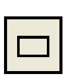
2.19.15 Diagram Primitives Toolbar

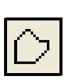
 The **line primitive** button is used to place annotation lines anywhere on the Diagram View. The line primitive item is selected and lines can then be placed anywhere in the Diagram View by clicking. Be aware, they are not branches!

 The **arc primitive** button is used to place annotation arcs anywhere on the Diagram View. The arc primitive item is selected and arcs can then be placed anywhere in the Diagram View by clicking.

 The **circle primitive** button is used to place annotation circles anywhere on the Diagram View. The circle primitive item is selected and circles can then be placed anywhere in the Diagram View by clicking.

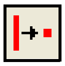
 The **ellipse primitive** item is used to place annotation ellipses anywhere on the Diagram View. The ellipse primitive item is selected and ellipses can then be placed anywhere in the Diagram View by clicking.

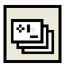
 The **rectangle primitive** button is used to place annotation rectangles anywhere on the Diagram View. The rectangle primitive item is selected and rectangles can then be placed anywhere in the Diagram View by clicking.

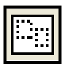
 The **region primitive** button is used to place annotation regions anywhere on the Diagram View. The region primitive item is selected and multi-segment polygon regions can then be placed anywhere in the Diagram View by clicking the end point for each edge of the polygon. The region is complete when the last point clicked is on the first point.

2.19.16 Diagram Options Toolbar


Toggle auto-position for selected elements.


Toggle bus symbol.

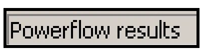

Manage diagram layers.


Manage diagram views.

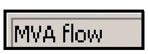
2.20 Status Bar

The Status Bar fields, when in view, indicate various conditions for the user's reference. Interactions with the Diagram View cause updates to items in the fields. The fields are listed below.

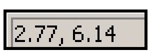
Pops-up tooltip or item under cursor.



Indicates the type of results currently shown in the Diagram View. These include, power flow, impedances, case differences and short circuit results.



Indicates units currently in use for the indicated type of results.



The current cursor location in the Diagram View is constantly updated in the Status Bar. The X and Y location of the cursor are displayed in the units specified for the Diagram View in the Diagram Settings dialog described above.

The current binding mode for new items created in the Diagram View is displayed in the Status Bar. The idea of the binding mode is introduced in Section 2.5.7. The field displays either ***Bind items***, indicating that new network items added to the Diagram View will create new data in the PSS™E case, or ***No binding***, indicating that no data is added to the PSS™E case. Items added when this field displays ***No binding*** will be displayed in the color red, indicating no corresponding PSS™E case data exists.

The next bus number for new buses created in the Diagram View is also displayed in the Status Bar. Autonumbering is handled with the Power Flow Options menu; see Section 2.7.10. If autonumbering is on, this field displays the number of the next bus created. If autonumbering is off, this field displays ***Autonumber disabled***.

2.21 Program Automation

It is frequently necessary, once a study has progressed through the initial investigative phase, to produce large numbers of runs of substantially repetitive format. In making such runs, the user can be relieved from the need to manually operate the program through the interface menus and tool-buttons by prepackaging operations and inputs to dialog windows in a source file; referred to as a "Response" file. Such files have the "*idv*" extension. PSS™E may then be instructed to operate in the standard way, but to accept inputs that would normally come from manual interaction with the interface from a variety of files instead.

More sophisticated control is available through operation of programs created with the IPLAN or Python programming language. Such programs control operation of PSS™E in a manner which enables not only basic program operations but also examination of data and results which can lead to subsequent operation of PSS™E based on looping through repetitive processes or boolean/logical decisions. Custom made reporting formats can be established. An IPLAN file has the extension "*irf*". A Python file has the extension "*py*".

For details on the IPLAN programming language, the IPLAN language interface to the PSS™E working case and dynamics data, and the IPLAN compiler, refer to the *IPLAN Program Manual*.

For details on the Python programming language, refer to one of the widely available resource books or on the web at http://www.python.org.

2.21.1 Running a Program Automation File

To run an automation file, the user should employ the ***I/O Control>Run program Automation file…*** option or the ***Run Automation File*** toolbar button (see Figure 2-127).

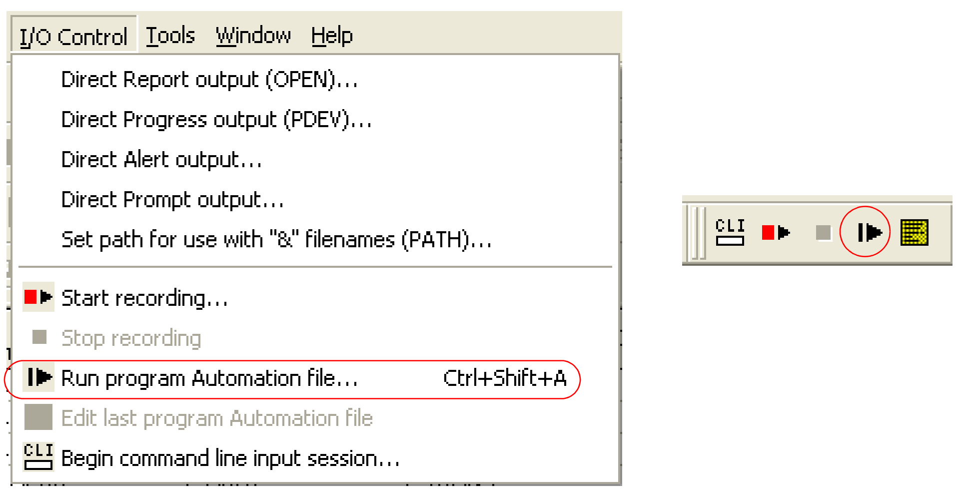


Figure 2-127. Menu and Toolbar Button for Running Automation Files

Selecting from the ***I/O Control>Run program Automation file…*** option or the ***Run Automation File*** toolbar button will open the Select Program Automation File dialog (see Figure 2-128). The drop-down menu provides access to a Response file, an IPLAN or a Python file. When the selected file is opened, the processes packaged in the Response file or programmed into the IPLAN or Python file will be initiated.

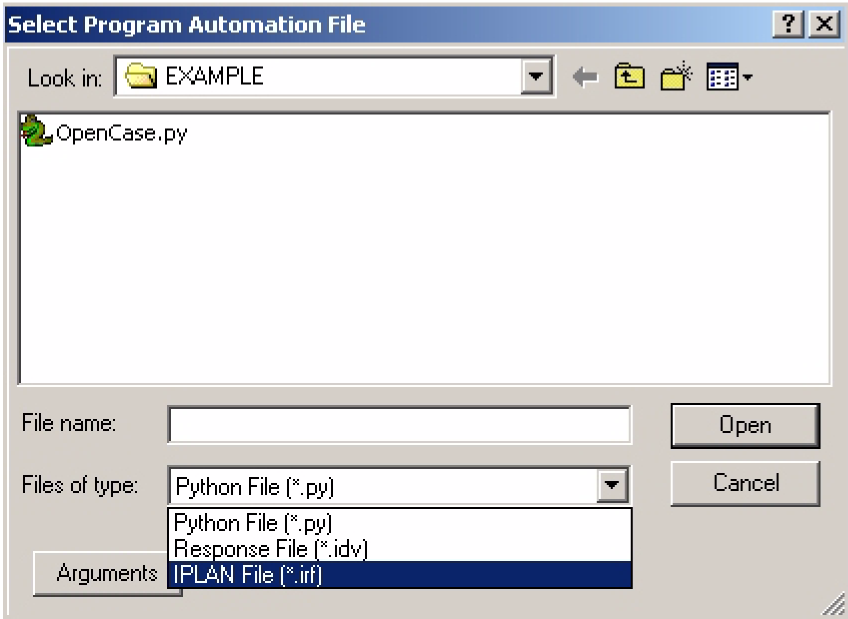


Figure 2-128. Selecting an Automation File

2.21.2 Constructing a Response File

An experienced user can created a response file using a text editor. The simplest and most robust way, however, is to select the ***I/O Control>Start recording*** option (see Figure 2-129). Note that this equivalent to executing the activity ECHO in previous versions of PSS™E.

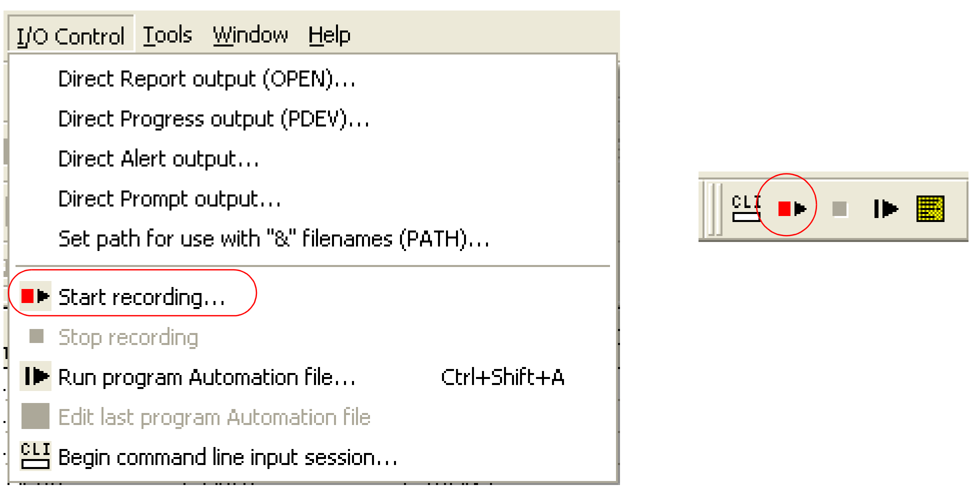


Figure 2-129. Constructing a Response File

Selecting the ***Start recording…*** option displays the Select Program Automation File dialog where the user selects a file in which the response file elements will be recorded (see Figure 2-130).

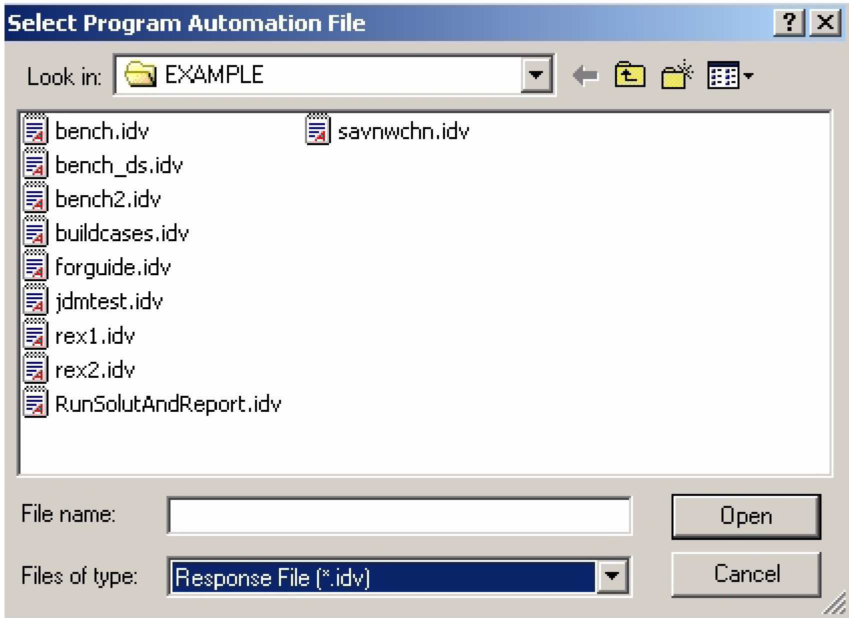


Figure 2-130. Selecting a Program Automation File for Recording

Having selected the file, the user now executes the required sequence of activities or operations using the menu and toolbar facilities in the interface. The resulting response file will contain, in Response File form, a series of commands reflecting the user's sequence of activities. This file can be opened when using the ***Run program Automation file…*** option described in Section 2.21.1. The user can to tailor this basic Response File for subsequent runs by editing the created response file by changing some of the filenames and bus numbers specifying faulted nodes, switched branches, and so on.

As an example it can be assumed that, using the *savnw.sav* power flow case, the user wishes to open one circuit between buses 151 and 152, solve the case and then output the power flow results for bus 151.

Using the interface:

- Right-click on the branch in the Diagram View and select ***Switch*** from the pop-up menu.
- Employ the ***Power Flow>Solution>Solve*** option or the ***Solve*** toolbar button.
- Select the ***Bus Based Output*** toolbar button and, subsequently, bus number 151.

If this series of operations were recorded, a response file would be constructed (see Figure 2-131).

```
@! File:"C:\Program Files\PTI\PSSE30\EXAMPLE\forguide.idv"
BAT_OPENDIAGFILE,'C:\Program Files\PTI\PSSE30\EXAMPLE\savnw.sld'
BAT_SETDIAGRESTYPEPFLOW,;
BAT_BRANCH_DATA,151,152,'1',0,,,,,,,,,,,,,,,,,,,,,,;
BAT_MSLV,0,0,0,1,1,0
BAT_BSYS,1,0,0.0,0.0,0,1,151,0,0
BAT_POUT,1,0
```

Figure 2-131. Created Response File

It can be seen that the Response file contains PSS™E batch (BAT_) commands. Consequently, the manual creation of a Response File, which could be done with the text editor, requires an intimate familiarity with the PSS™E batch commands. These commands are covered in the *PSS™E API Manual*.

2.21.3 Constructing Python and IPLAN Files

The process described in the previous section for creating a Response file can also be used to create a Python file (**.py*) by selecting this file type instead of the Response file type (**.idv*). The file type is selected (see Figure 2-130). The program records the sequence of events selected by the user in the same manner.

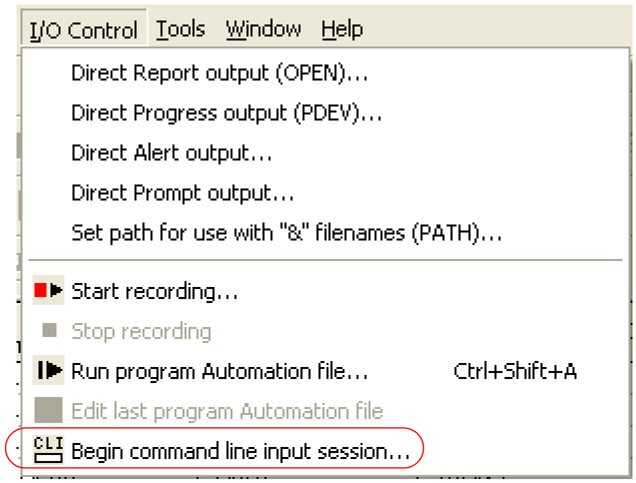
Alternatively the user can create a Python file using the Python programming language. This will facilitate a more sophisticated control of PSS™E by enabling looping and decision making based on results of analyses. Standard concepts such as looping and subroutine calling are available. For details on the Python programming language refer to a Python reference book or http://www.python.org.

It is not possible to construct an IPLAN file using the PSS™E recording facility. The file must be created manually and compiled. It is very beneficial to be familiar with at least one programming language and the standard programming concepts such as assignment statements, looping and subroutine calls.

For details on the IPLAN programming language, the IPLAN language interface to the PSS™E working case and dynamics data, and the IPLAN compiler, refer to the *IPLAN Program Manual*.

2.22 Running Command Line Interactive Sessions

Access to the Command line for interactive sessions is initiated using the ***I/O Control>Begin command line input session…*** option or the ***Command Line Input*** toolbar button (Figure 2-132).



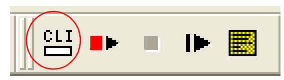


Figure 2-132. Initiating the Command Line Processor

Selection of the command line processor will open the Command Line Input dialog (see Figure 2-133). The user input can be either by use of conventional activity names or by Python language commands. Set the Command language drop-down menu in the upper right corner of the dialog to the desired entry method.

An interactive session can be run by typing in activity names and responding to program responses in the traditional manner. The user input must be in the Enter commands field. The program responses will be seen in the Progress View area of the Command Line Input dialog.

The example shows that the commands are recorded and accessible in the Previous commands drop-down menu. Selection of a previous command will result in its execution.

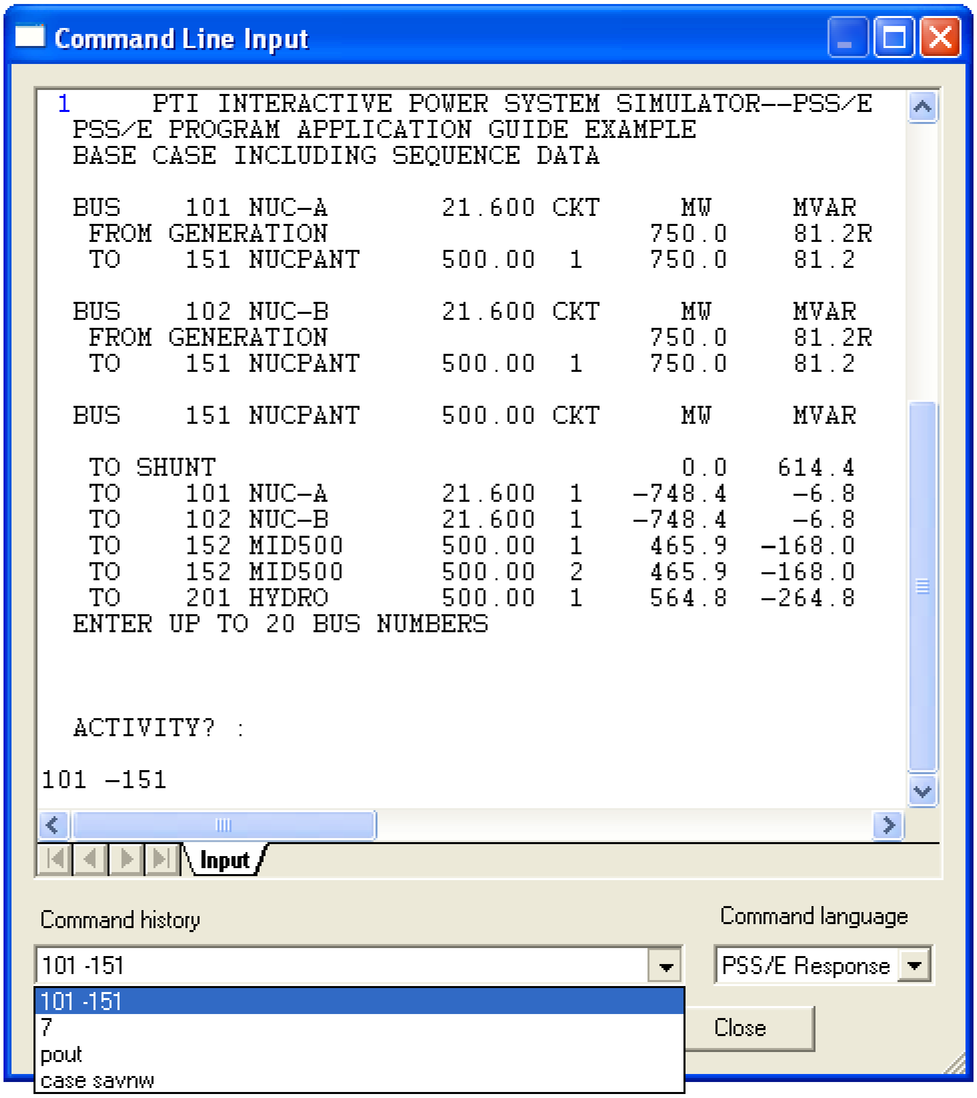


Figure 2-133. Command Line Input Dialog

Closing this dialog will take the user back to the newly reactivated menus and toolbars.

Chapter 3

Managing Power Flow Data

3.1 Overview: Managing Power Flow Data

This chapter describes the data requirements for establishing a power flow data set suitable for use in steady-state analyses. The application of this data for planning and operations studies is treated in detail in Chapters 4 through 10.

In addition to the basic data set describing the network elements, PSS™E requires other data and control element files for specific applications. Those files and their data requirements will be described in the subsections of Chapters 4 through 10, where they are appropriate.

Objectives of this chapter are to describe several aspects of data preparation, including:

- Specific network data required and their format for importation into PSS™E.
- Methods of importing data.
- Means by which data can be listed and examined.
- Methods to check data for errors and conflicts.
- Data editing.
- Data exportation.
- Building a network using the Diagram View.
- Building a network using the Spreadsheet View.

The user should be aware that not all the data described in this chapter are needed for all applications and that some data can be defaulted. The following subsection will indicate which data fall into those categories.

3.2 Power Flow Data Categories

Representation of power networks in PSS™E comprises 16 data categories of network and equipment elements, each of which requires a particular type of data. The data categories and the order in which they are input are shown in Figure 3-1.

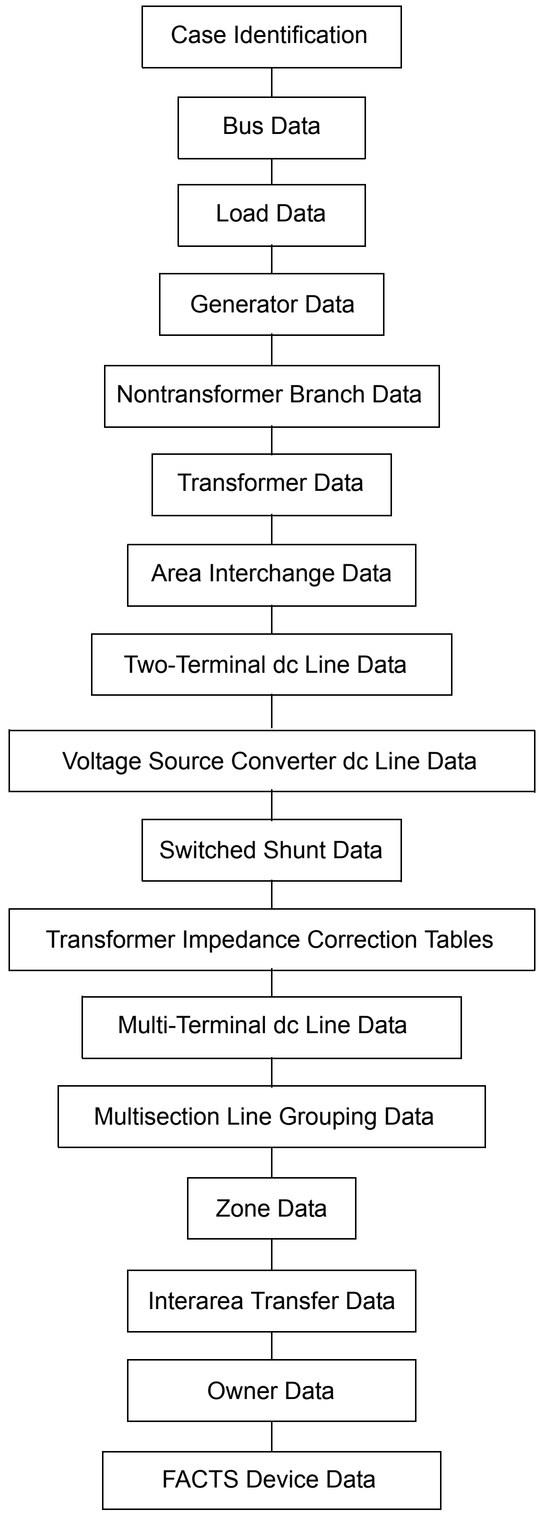


Figure 3-1. Power Flow Data Categories

The bulk power flow data input facility, ***File>Open…*** (Section 2.6.2) imports hand-typed power flow source data from a correctly formatted Power Flow Raw Data File (*.raw*) and enters it into the load flow working case, rearranging it from its original format into a computationally oriented data structure in the process.

All data is read in "free format" with data items separated by a comma or one or more blanks. Tabbed delimited data items are not recommended. The ***File>Open…*** command may also import binary saved case files (*.sav) containing power flow data as well as solution values and related options (see Section 1.7.2).

The following sections identify the power flow data categories in the order of presentation expected in the Power Flow Raw Data File.

3.2.1 Case Identification Data

Case identification data consists of three data records.

The first record contains two items of data as follows:

```
IC, SBASE
```

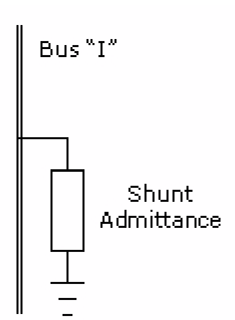
where:

IC	Change code: 0 - base case (i.e., clear the working case before adding data to it) 1 - add data to the working case IC = 0 by default.
SBASE	System base MVA. SBASE = 100.0 by default.

The next two records each contain a line of heading to be associated with the case. Each line may contain up to 60 characters.

3.2.2 Bus Data

Each network bus to be represented in PSS™E is introduced through a bus data record. Each bus data record includes not only data for the basic bus properties but also includes information on an optionally connected shunt admittance to ground. That admittance can represent a shunt capacitor or a shunt reactor (both with or without a real component) or a shunt resistor. It *must not* represent line connected admittance, loads, line charging or transformer magnetizing impedance, all of which are entered in other data categories.



Bus data has the following format:

```
I, 'NAME', BASKV, IDE, GL, BL, AREA, ZONE, VM, VA, OWNER
```

where:

I	Bus number (1 to 999997).
NAME	Alphanumeric identifier assigned to bus "I". The name may be up to twelve characters and *must* be enclosed in single quotes. NAME may contain any combination of blanks, uppercase letters, numbers and special characters, but the first character *must not* be a minus sign. NAME is twelve blanks by default.
BASKV	Bus base voltage; entered in kV. BASKV = 0.0 by default.
IDE	Bus type code: 1 - load bus or other bus without any generator boundary condition. 2 - generator or plant bus either regulating voltage or with a fixed reactive power (Mvar). A generator that reaches its reactive power limit will no longer control voltage but rather hold reactive power at its limit. 3 - swing bus or slack bus. It has no power or reactive limits and regulates voltage at a fixed reference angle. 4 - disconnected or isolated bus. IDE = 1 by default.
GL	Active component of shunt admittance to ground; entered in MW at one per unit voltage. GL should not include any resistive admittance load, which is entered as part of load data. GL = 0.0 by default.
BL	Reactive component of shunt admittance to ground; entered in Mvar at one per unit voltage. BL should not include any reactive impedance load, which is entered as part of load data; line charging and line connected shunts, which are entered as part of non-transformer branch data; or transformer magnetizing admittance, which is entered as part of transformer data. BL is positive for a capacitor, and negative for a reactor or an inductive load. BL = 0.0 by default.
AREA	Area number. (1 through the maximum number of areas at the current size level; see Table 1-1). AREA = 1 by default.
ZONE	Zone number (1 through the maximum number of zones at the current size level; see Table 1-1). ZONE = 1 by default.
VM	Bus voltage magnitude; entered in pu. VM = 1.0 by default.
VA	Bus voltage phase angle; entered in degrees. VA = 0.0 by default.
OWNER	Owner number (1 through the maximum number of owners at the current size level; see Table 1-1). OWNER = 1 by default.

VM and VA could be set to values obtained from a previously solved case if they were available. Normally, however, they can be set to default value.

When entering bus data in the Power Flow Raw Data File, bus data input is terminated with a record specifying a bus number of zero.

3.2.2.1 Extended Bus Names

When bus data records are input, each bus is identified by either its number or its name. The name comprises a twelve character alphanumeric in single quotes.

When the "Extended Name" bus input option is enabled in the ***Misc>Change Program Settings (OPTN)…*** dialog, data fields designating buses on load, generator, branch, transformer, area, two-terminal dc line, VSC dc line, switched shunt, multi-terminal dc line, multisection line, and FACTS device data records may be specified as either extended bus names enclosed in single quotes or as bus numbers.

As for data output, reports developed by PSS™E functions can be ordered in ascending bus number or by the buses extended bus name, in alphabetical order. The setting of bus output to either bus number or extended name is made using the ***Misc>Change Program Settings (OPTN)…*** option (see Section 1.6.4).

The requirements to specify an extended bus name are:

1. It must be enclosed in single quotes.
2. The twelve-character bus name, including any trailing blanks, must be the first twelve characters.
3. The bus base voltage in kV must immediately follow the bus name. Up to six characters may be used.
4. For those data fields whose sign is used to indicate a modeling attribute, a minus sign may be specified between the leading single quote and the first character of the twelve-character bus name.

Thus, valid forms of an extended bus name include '*aaaaaaaaaaaavvvvvv*' and '*aaaaaaaaaaaavvv*'. For those data fields cited in (4) above, '-*aaaaaaaaaaaavvvvvv*' and '-*aaaaaaaaaaaavvv*' are also valid forms of extended bus names.

As an example, consider a 345 kV bus with the name FRONT-STREET. Its extended bus name would be:

```
'FRONT-STREET   345'
```

3.2.2.2 Using Defaults to Minimize Bus Data

Because there are default values for some of these data, you can include only the specific information you need. For example, if bus # 99 is a 345 kV, Type 1 bus without a shunt admittance, which lies in Zone #3, the data line within the Power Flow Raw Data File could be:

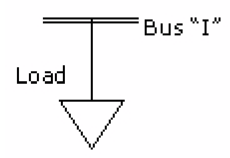
```
99,,345, 1,,,,3
```

If, in addition, you name the bus ERIE BLVD and it has a 200 Mvar shunt reactor, the minimum data line would be:

```
99, 'ERIE BLVD', 345,1,,- 200,,3
```

3.2.3 Load Data

Each network bus at which a load is to be represented must be specified in at least one load data record. If multiple loads are to be represented at a bus, they must be individually identified in a load data record for the bus with a different load identifier. Each load at a bus can be a mixture of loads with different characteristics, (see Section 4.5).



Each load data record has the following format:

```
I, ID, STATUS, AREA, ZONE, PL, QL, IP, IQ, YP, YQ, OWNER
```

where:

I	Bus number, or extended bus name enclosed in single quotes (see Section 3.2.2.1).
ID	One- or two-character uppercase non blank alphanumeric load identifier used to distinguish among multiple loads at bus "I". It is recommended that, at buses for which a single load is present, the load be designated as having the load identifier '1'. ID = '1' by default.
STATUS	Initial load status of one for in-service and zero for out-of-service. STATUS = 1 by default.
AREA	Area to which the load is assigned (1 through the maximum number of areas at the current size level, see Table 1-1). By default, AREA is the area to which bus "I" is assigned (see Section 3.2.2).
ZONE	Zone to which the load is assigned (1 through the maximum number of zones at the current size level, see Table 1-1). By default, ZONE is the zone to which bus "I" is assigned (see Section 3.2.2).
PL	Active power component of constant MVA load; entered in MW. PL = 0.0 by default.
QL	Reactive power component of constant MVA load; entered in Mvar. QL = 0.0 by default.
IP	Active power component of constant current load; entered in MW at one per unit voltage. IP = 0.0 by default.
IQ	Reactive power component of constant current load; entered in Mvar at one per unit voltage. IQ = 0.0 by default.
YP	Active power component of constant admittance load; entered in MW at one per unit voltage. YP = 0.0 by default.
YQ	Reactive power component of constant admittance load; entered in Mvar at one per unit voltage. YQ is a negative quantity for an inductive load and positive for a capacitive load. YQ = 0.0 by default.

OWNER	Owner to which the load is assigned (1 through the maximum number of owners at the current size level, see Table 1-1). By default, OWNER is the owner to which bus "I" is assigned (see Section 3.2.2).

As for buses, it is possible to enter only the data items which apply to the analyses to be undertaken. An example entry in the Power Flow Raw Data File for a constant MVA load of 100 MW and 50 Mvar, at bus 123, with no assigned area, zone or owner, would be:

```
123, '1',,,,100,50
```

Within the Raw Data File, load data input is terminated by a record specifying a bus number of zero.

3.2.3.1 Load Characteristics

The constant power characteristic holds the load power constant as long as the bus voltage exceeds a value specified by the solution parameter PQBRAK. The constant power characteristic assumes an elliptical current-voltage characteristic of the corresponding load current for voltages below this threshold. Figure 3-2 depicts this characteristic for PQBRAK values of 0.6, 0.7, and 0.8 pu. The user may modify the value of PQBRAK by selecting ***Power Flow>Solution>Parameters…*** and modifying the ***Constant power characteristic threshold (PQBRAK)*** located on the General tab.

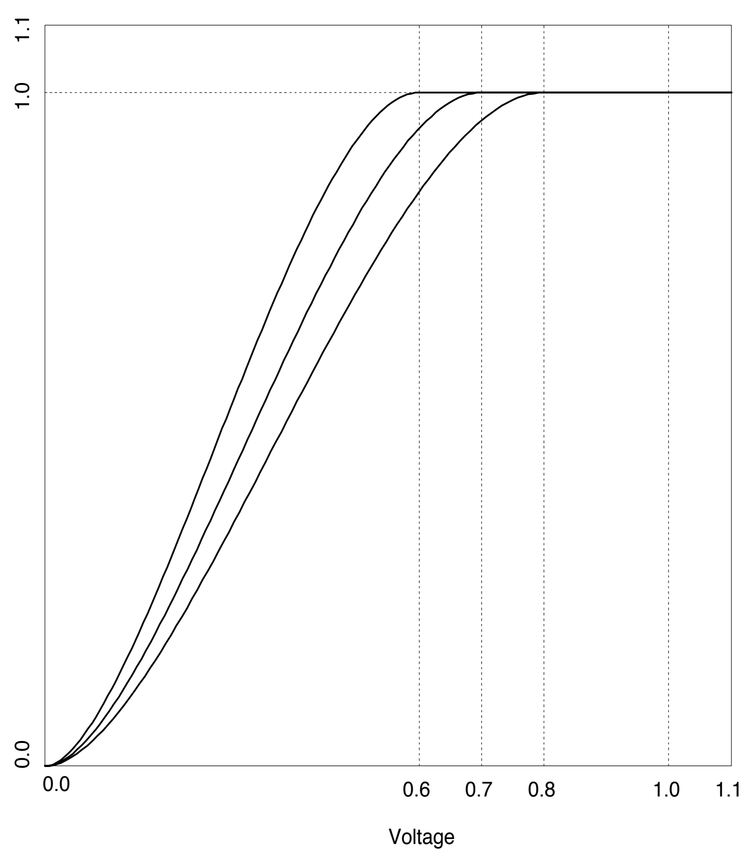


Figure 3-2. Constant Power Load Characteristic

The constant current characteristic holds the load current constant as long as the bus voltage exceeds 0.5 pu, and assumes an elliptical current-voltage characteristic as shown in Figure 3-3 for voltages below 0.5 pu.

Further details on load characteristic and modeling requirements are given in Section 4.5.

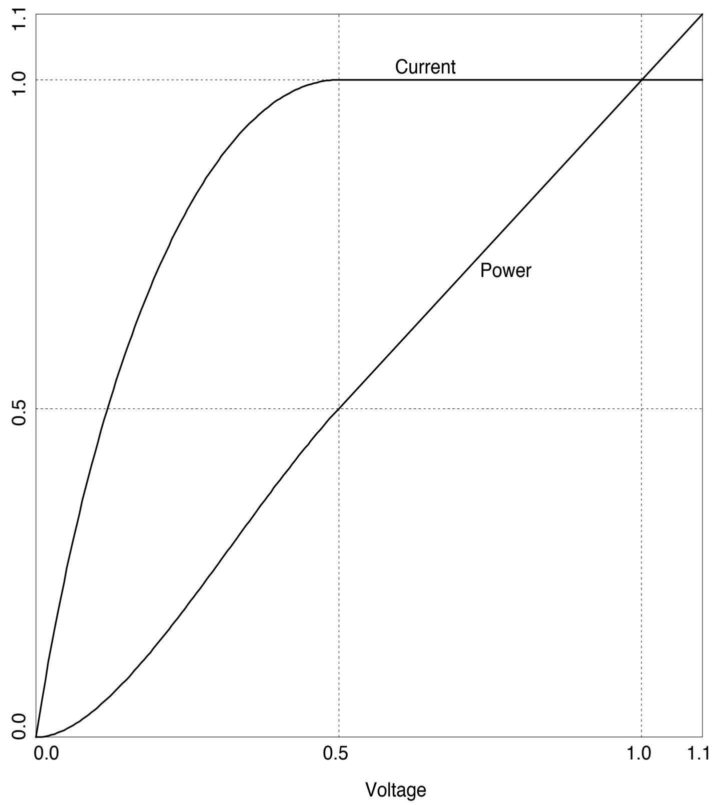
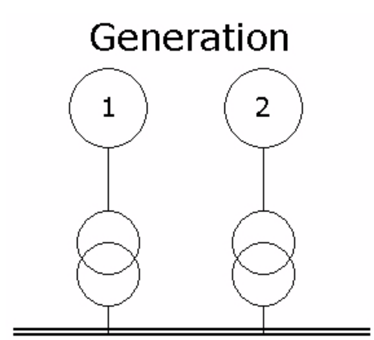


Figure 3-3. Constant Current Load Characteristic

3.2.4 Generator Data

Each network bus to be represented as a generator or plant bus in PSS™E must be specified in a generator data record.

In particular, each bus specified in the bus data input with a type code of two (2) or three (3) *must* have a generator data record entered for it.



Each generator has a single line data record with the following format:

```
I, ID, PG, QG, QT, QB, VS, IREG, MBASE, ZR, ZX, RT, XT, GTAP, STAT,
RMPCT, PT, PB, O1, F1, ....O4, F4
```

where:

I	Bus number, or extended bus name enclosed in single quotes (see Section 3.2.2.1).
ID	One- or two-character uppercase non blank alphanumeric machine identifier used to distinguish among multiple machines at bus "I". It is recommended that, at buses for which a single machine is present, the machine be designated as having the machine identifier ’1’. ID = ’1’ by default.
PG	Generator active power output; entered in MW. PG = 0.0 by default.
QG	Generator reactive power output; entered in Mvar. QG needs to be entered only if the case, as read in, is to be treated as a solved case. QG = 0.0 by default.
QT	Maximum generator reactive power output; entered in Mvar. For fixed output generators (i.e., nonregulating), QT must be equal to the fixed Mvar output. QT = 9999.0 by default.
QB	Minimum generator reactive power output; entered in Mvar. For fixed output generators, QB must be equal to the fixed Mvar output. QB = -9999.0 by default.
VS	Regulated voltage setpoint; entered in pu. VS = 1.0 by default.
IREG	Bus number, or extended bus name enclosed in single quotes (see Section 3.2.2.1), of a remote type 1 or 2 bus whose voltage is to be regulated by this plant to the value specified by VS. If bus IREG is other than a type 1 or 2 bus, bus "I" regulates its own voltage to the value specified by VS. IREG is entered as zero if the plant is to regulate its own voltage and *must* be zero for a type three (swing) bus. IREG = 0 by default.
MBASE	Total MVA base of the units represented by this machine; entered in MVA. This quantity is not needed in normal power flow and equivalent construction work, but is required for switching studies, fault analysis, and dynamic simulation. MBASE = system base MVA by default.
ZR,ZX	Complex machine impedance, ZSORCE; entered in pu on MBASE base. This data is not needed in normal power flow and equivalent construction work, but is required for switching studies, fault analysis, and dynamic simulation. For dynamic simulation, this impedance must be set equal to the unsaturated subtransient impedance for those generators to be modeled by subtransient level machine models, and to unsaturated transient impedance for those to be modeled by classical or transient level models. For short-circuit studies, the saturated subtransient or transient impedance should be used. ZR = 0.0 and ZX = 1.0 by default.
RT,XT	Step-up transformer impedance, XTRAN; entered in pu on MBASE base. XTRAN should be entered as zero if the step-up transformer is explicitly modeled as a network branch and bus "I" is the terminal bus. RT+jXT = 0.0 by default.
GTAP	Step-up transformer off-nominal turns ratio; entered in pu. GTAP is used only if XTRAN is nonzero. GTAP = 1.0 by default.
STAT	Initial machine status of one for in-service and zero for out-of-service; STAT = 1 by default.

RMPCT	Percent of the total Mvar required to hold the voltage at the bus controlled by this bus "I" that are to be contributed by the generation at bus "I"; RMPCT must be positive. RMPCT is needed if IREG specifies a valid remote bus and there is more than one local or remote voltage controlling device (plant, switched shunt, FACTS device shunt element, or VSC dc line converter) controlling the voltage at bus IREG to a setpoint. RMPCT is needed also if bus "I" itself is being controlled locally or remotely by one or more other setpoint mode voltage controlling devices. RMPCT = 100.0 by default.
PT	Maximum generator active power output; entered in MW. PT = 9999.0 by default.
PB	Minimum generator active power output; entered in MW. PB = -9999.0 by default.
Oi	Owner number; (1 through the maximum number of owners at the current size level: see Table 1-1). Each machine may have up to four owners. By default, O1 is the owner to which bus "I" is assigned and O2, O3, and O4 are zero.
Fi	Fraction of total ownership assigned to owner Oi; each Fi must be positive. The Fi values are normalized such that they sum to 1.0 before they are placed in the working case. By default, each Fi is 1.0.

In specifying reactive power limits for voltage controlling plants (i.e., those with unequal reactive power limits), the use of very narrow var limit bands is discouraged. The Newton-Raphson solutions require that the difference between the controlling equipment's high and low reactive power limits be greater than 0.002 pu for all setpoint mode voltage controlling equipment (0.2 Mvar on a 100 MVA system base). It is recommended that voltage controlling plants have Mvar ranges substantially wider than this minimum permissible range.

3.2.4.1 Modeling of Generator Step-Up Transformers (GSU)

Before setting-up the generator data, it is important to understand the two methods by which a generator and its associated GSU are represented.

The Implicit Method

- The transformer data forms part of the generator data list
- The transformer is not represented as a transformer branch

Figure 3-4 shows that Bus K is the Type 2 bus. This is the bus at which the generator will regulate/control voltage unless the user specified otherwise.

As with other data sets, some of the generator data have default values and, further, it is not necessary to specify all the data for basic power flow studies.

If an implicit transformer model is used, the minimum data set needed is:

```
I, ’ID’, PG, QG, QT, QB, VS,,,,,RT, XT, GTAP
```

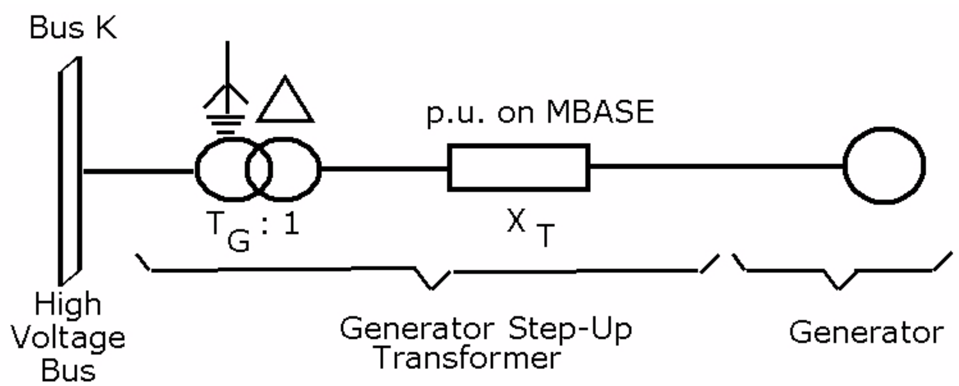


Figure 3-4. Implicit GSU Configuration – Specified as Part of the Generator

The Explicit Method

In this method, the Transformer data does not appear in the generator data. It is entered separately (see Section 3.2.6) in a transformer branch data list.

In Figure 3-5, there is an additional bus to represent the generator terminal. This is the Type 2 bus where the generator will regulate/control voltage unless the user specifies otherwise.

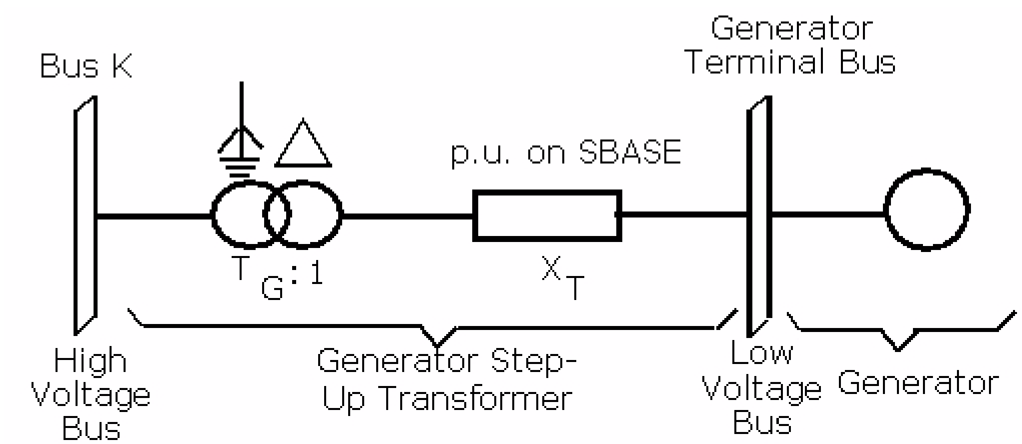


Figure 3-5. Explicit GSU Configuration – Specified Separately from the Generator

Multiple Generators

If a generating plant has several units, they can be represented separately even if they are connected to the same Type 2 bus.

Figure 3-6 shows three Type 2 buses, each having two connected units. For generators 1 through 4, the GSU is explicitly represented while for generators 5 and 6 the GSU is implicitly represented.

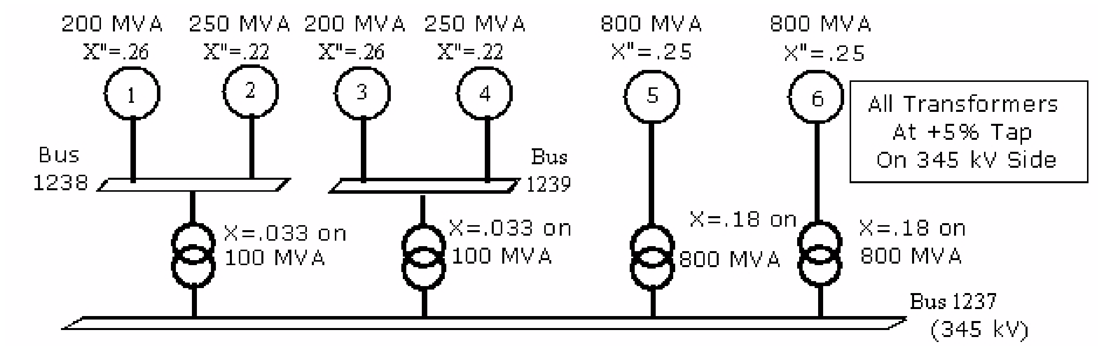


Figure 3-6. Multiple Generators at a Single Plant

To clarify the data requirements, Figure 3-7 shows a properly formatted listing for the generators in Figure 3-6.

The separate transformer branches from Buses 1238 and 1239 to Bus 1237 are not included in this generator list.

Generator Data Records:

```
1238  1  200  , ,  120  0  1.03  0  200  0  .26  0  0    1.     1   50  200   60
1238  2  250  , ,  150  0  1.03  0  250  0  .22  0  0    1.     1   50  250   75
1239  3  200  , ,  120  0  1.03  0  200  0  .26  0  0    1.     0   50  200   60
1239  4  250  , ,  150  0  1.03  0  250  0  .22  0  0    1.     0   50  250   75
1237  5  750  , ,  500  0  1.06  0  800  0  .25  0  .18  1.05   1   50  760  240
1237  6  750  , ,  500  0  1.06  0  800  0  .25  0  .18  1.05   1   50  760  240

I     ID  PG  QG   QT  QB  VS  IREG MBASE ZR,ZX  RT,XT  GTAP STAT RMPCT PT  PB
           (not specified)
```

Figure 3-7. Data Set for the Multiple Generators in Figure 3-6

Generator data input from a Power Flow Raw Data File is terminated with a record specifying a bus number of zero.

3.2.5 Nontransformer Branch Data

In PSS™E, the basic transmission line model is an Equivalent Pi connected between network buses. Figure 3-8 shows the required parameter data where the equivalent Pi comprises:

- (R + jX) series impedance
- Two admittance branches + $jB_{ch}/2$, representing the line's capacitive admittance

Data for shunt equipment units, such as reactors, which are connected to and switched with the line, are entered in the same data record. The figure shows these shunts represented as (G + jB).

To represent shunts connected to buses, that shunt data should be entered in the bus data record.

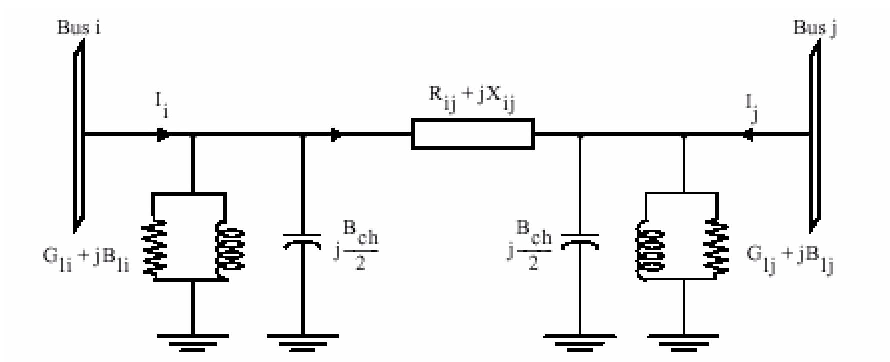


Figure 3-8. Transmission Line Equivalent Pi Model

Each nontransformer branch data record has the following format:

```
I,J,CKT,R,X,B,RATEA,RATEB,RATEC,GI,BI,GJ,BJ,ST,LEN,O1,F1,...,O4,F4
```

where:

I	Branch "*from bus*" number, or extended bus name enclosed in single quotes (see Section 3.2.2.1).
J	Branch "*to bus*" number, or extended bus name enclosed in single quotes (see Section 3.2.2.1). "J" is entered as a negative number, or with a minus sign before the first character of the extended bus name, to designate it as the metered end; otherwise, bus "I" is assumed to be the metered end.
CKT	One- or two-character uppercase nonblank alphanumeric branch circuit identifier; the first character of CKT *must not* be an ampersand "&" (see Section 3.4.4.12 for a discussion on use of the ampersand in designation of multisection transmission lines). It is recommended that single circuit branches be designated as having the circuit identifier '1'. CKT = '1' by default.
R	Branch resistance; entered in pu. A value of R must be entered for each branch.
X	Branch reactance; entered in pu. A nonzero value of X must be entered for each branch. See Section 3.2.5.1 for a discussion of the treatment of branches as zero impedance lines.
B	Total branch charging susceptance; entered in pu. B = 0.0 by default.

RATEA	First loading rating; entered in MVA. If RATEA is set to 0.0, the default value, this branch will not be included in any examination of circuit loading (see Section 4.4.5.1.1).
RATEB	Second loading rating; entered in MVA. RATEB = 0.0 by default.
RATEC	Third loading rating; entered in MVA. RATEC = 0.0 by default.

Ratings are entered as:

$$MVA_{rated} = SQRT(3) \times E_{base} \times I_{rated} \times 10^{-6}$$

where:

E_{base}	is the base line-to-line voltage in volts of the buses to which the terminal of the branch is connected
I_{rated}	is the branch rated phase current in amperes.

GI,BI	Complex admittance of the line shunt at the bus "I" end of the branch; entered in pu. BI is negative for a line connected reactor and positive for line connected capacitor. GI + jBI = 0.0 by default.
GJ,BJ	Complex admittance of the line shunt at the bus "J" end of the branch; entered in pu. BJ is negative for a line connected reactor nd positive for line connected capacitor. GJ + jBJ = 0.0 by default.
ST	Initial branch status where 1 designates in-service and 0 designates out-of-service. ST = 1 by default.
LEN	Line length; entered in user-selected units. LEN = 0.0 by default.
Oi	Owner number; (1 through the maximum number of owners at the current size level: see Table 1-1). Each branch may have up to four owners. By default, O1 is the owner to which bus "I" is assigned and O2, O3, and O4 are zero.
Fi	Fraction of total ownership assigned to owner Oi; each Fi must be positive. The Fi values are normalized such that they sum to 1.0 before they are placed in the working case. By default, each Fi is 1.0.

When specifying a nontransformer branch between buses "I" and "J" with circuit identifier CKT, if a two-winding transformer between buses "I" and "J" with a circuit identifier of CKT is already present in the working case, it is *replaced* (i.e., the transformer is deleted from the working case and the newly specified branch is then added to the working case).

Branches to be modeled as transformers are not specified in this data category; rather, they are specified in the transformer data category described in the following Section 3.2.6.

Nontransformer branch data input to the Power Flow Raw Data File is terminated with a record specifying a "*from bus*" number of zero.

3.2.5.1 Zero Impedance Lines

PSS™E provides for the treatment of bus ties, jumpers, and other low impedance branches as zero impedance lines. For a branch to be treated as a zero impedance line, it must have the following characteristics:

- Its resistance must be zero.
- Its magnitude of reactance must be less than or equal to the zero impedance line threshold tolerance, THRSHZ.
- It must not be a transformer.

There are points to be noted, and restrictions to be observed, in using zero impedance lines as discussed below.

During network solutions, buses connected by such lines are treated as the same bus, thus having identical bus voltages. At the completion of each solution, the loadings on zero impedance lines are determined.

When obtaining power flow solutions, zero impedance line flows, as calculated at the end of the solution, are preserved with the power flow case and are available to the power flow solution procedures. Similarly, in unbalanced fault calculations, the positive, negative, and zero sequence branch currents on zero impedance lines are determined and preserved, and are subsequently available to be reported. In other applications such automatic contingency analysis, short-circuit scanning and in linearized network analyses, zero impedance line results are calculated and reported as needed.

The zero impedance line threshold tolerance, THRSHZ, may be changed by launching the Solution Parameters dialog (see Figure 4-22) from the ***Power Flow>Solution>Parameters*** option under the General tab. Setting THRSHZ to zero disables zero impedance line modeling, and all branches are represented with their specified impedances.

A zero impedance line may not have a transformer in parallel with it. Although not required, it is recommended that **no** other in-service lines exist in parallel with a zero impedance line.

A zero impedance line may have nonzero values of line charging and/or line connected shunts. This allows, for example, a low impedance cable to be modeled as a zero impedance line.

While more than two buses may be connected together by zero impedance lines, buses may not be connected in a loop arrangement by zero impedance lines. For example, connecting bus 1 to bus 2 and bus 2 to bus 3 by zero impedance lines is allowed; adding a third zero impedance line connecting buses 1 and 3 would form a zero impedance line connected loop and is not allowed.

It is important to note that buses connected together by zero impedance lines are treated as a single bus by the power flow solution activities. Hence, equipment controlling the voltages of multiple buses within a zero impedance connected group of buses must have coordinated voltage schedules.

With large databases it is important to have the ability to easily identify which bus voltages are being regulated and which equipment is controlling the regulation. This helps to avoid situations in which there are potential regulation conflicts. Clicking the ***Regulated buses*** tab in the ***Power Flow>Reports>Limit checking reports…*** dialog, will facilitate generation of a report that tabulates those buses whose voltages are controlled by generation, switched shunts, voltage controlling transformers, FACTS devices, and/or VSC dc line converters.

Similarly, if multiple voltage controlling devices are present within a group of buses connected together by zero impedance lines, the power flow solution activities handle the boundary condition as if they are all connected to the same bus.

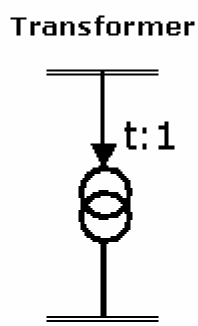
In the fault analysis activities, a branch treated as a zero impedance line in the positive sequence is treated in the same manner in the zero sequence, regardless of its zero sequence branch impedance. Zero sequence mutual couplings involving a zero impedance line are ignored in the fault analysis solution activities.

3.2.6 Transformer Data

Each ac transformer to be represented in PSS™E is introduced through transformer data record blocks that specify all the data required to model transformers in power flow calculations, with one exception.

That exception is a set of ancillary data, comprising transformer impedance correction tables, which define the manner in which transformer impedance changes as off-nominal turns ratio or phase shift angle is adjusted. Those data records are described in Section 3.2.12.

Both two-winding and three-winding transformers are specified in transformer data record blocks. Two-winding transformers require a block of four data records. Three-winding transformers require five data records.



The data records for the two-winding transformer are common to the three-winding transformer. Figure 3-9 shows the transformer winding configurations.

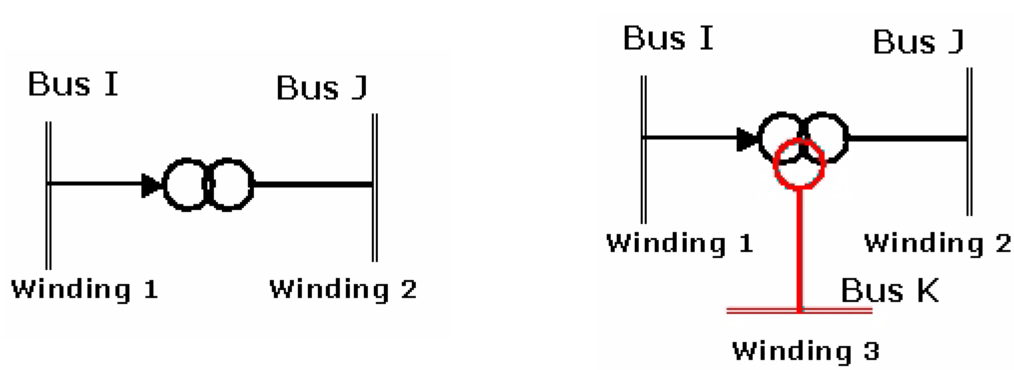


Figure 3-9. Two and Three-winding Transformer Configurations Related to Data Records

The five record transformer data block for three-winding transformers has the following format:

```
I,J,K,CKT,CW,CZ,CM,MAG1,MAG2,NMETR,'NAME',STAT,O1,F1,...,O4,F4
R1-2,X1-2,SBASE1-2,R2-3,X2-3,SBASE2-3,R3-1,X3-1,SBASE3-1,VMSTAR,ANSTAR
WINDV1,NOMV1,ANG1,RATA1,RATB1,RATC1,COD1,CONT1,RMA1,RMI1,VMA1,VMI1,NTP1,TAB1,CR1,CX1
WINDV2,NOMV2,ANG2,RATA2,RATB2,RATC2,COD2,CONT2,RMA2,RMI2,VMA2,VMI2,NTP2,TAB2,CR2,CX2
WINDV3,NOMV3,ANG3,RATA3,RATB3,RATC3,COD3,CONT3,RMA3,RMI3,VMA3,VMI3,NTP3,TAB3,CR3,CX3
```

The four-record transformer data block for two-winding transformers is a subset of the data required for three-winding transformers and has the following format:

```
I,J,K,CKT,CW,CZ,CM,MAG1,MAG2,NMETR,'NAME',STAT,O1,F1,...,O4,F4
R1-2,X1-2,SBASE1-2
WINDV1,NOMV1,ANG1,RATA1,RATB1,RATC1,COD1,CONT1,RMA1,RMI1,VMA1,VMI1,NTP1,TAB1,CR1,CX1
WINDV2,NOMV2
```

The three-winding transformer model in PSS™E is in fact a grouping of three two-winding transformers models where each of these two-winding transformers models one of the windings. While most of the three-winding transformer data is stored in the two-winding transformer data arrays, it is accessible for reporting and modification only as three-winding transformer data.

Record 1

```
I,J,K,CKT,CW,CZ,CM,MAG1,MAG2,NMETR,'NAME',STAT,O1,F1,...,O4,F4
```

I	The bus number, or extended bus name enclosed in single quotes, of the bus to which the first winding is connected. The transformer's magnetizing admittance is modeled on winding one. The first winding is the only winding of a two-winding transformer whose tap ratio or phase shift angle may be adjusted by the power flow solution activities; any winding(s) of a three-winding transformer may be adjusted. No default is allowed.
J	The bus number, or extended bus name enclosed in single quotes, of the bus to which the second winding is connected. No default is allowed for "J".
K	The bus number, or extended bus name enclosed in single quotes, of the bus to which the third winding is connected. Zero is used to indicate that no third winding is present (i.e., that a two-winding rather than a three-winding transformer is being specified). This winding may have a fixed, off-nominal tap ratio assigned to it. K = 0 by default.
CKT	One- or two-character uppercase nonblank alphanumeric transformer circuit identifier; the first character of CKT *must not* be an ampersand ("&") (see Section 3.4.4.12). CKT = '1' by default.
CW	The winding data I/O code which defines the units in which the turns ratios WINDV1, WINDV2 and WINDV3 are specified (the units of RMAi and RMIi are also governed by CW when |CODi| is 1 or 2): 1 for off-nominal turns ratio in pu of winding bus base voltage; 2 for winding voltage in kV; 3 for off-nominal turns ratio in pu of nominal winding voltage, NOMV1, NOMV2 and NOMV3. CW = 1 by default.

CZ	The impedance data I/O code that defines the units in which the winding impedances R1-2, X1-2, R2-3, X2-3, R3-1 and X3-1 are specified: 1 for resistance and reactance in pu on system base quantities; 2 for resistance and reactance in pu on a specified base MVA and winding bus base voltage; 3 for transformer three phase load loss in watts and impedance magnitude in pu on a specified base MVA and winding bus base voltage. CZ = 1 by default.
CM	The magnetizing admittance I/O code that defines the units in which MAG1 and MAG2 are specified: 1 for complex admittance in pu on system base quantities; 2 for three phase no-load loss in watts and exciting current in pu on winding one to two base MVA and nominal voltage. CM = 1 by default.
MAG1, MAG2	The magnetizing conductance and susceptance, respectively, in pu on system base quantities when CM is 1; MAG1 is the three phase no-load loss in watts and MAG2 is the exciting current in pu on winding one to two base MVA (SBASE1-2) and nominal voltage (NOMV1) when CM is 2. MAG1 = 0.0 and MAG2 = 0.0 by default.
NMETR	The nonmetered end code of either 1 (for the winding one bus) or 2 (for the winding two bus). In addition, for a three-winding transformer, 3 (for the winding three bus) is a valid specification of NMETR. NMETR = 2 by default.
NAME	An alphanumeric identifier assigned to the transformer. The name may be up to twelve characters and must be enclosed in single quotes. NAME may contain any combination of blanks, uppercase letters, numbers and special characters. NAME is twelve blanks by default.
STAT	The initial transformer status, where 1 designates in-service and 0 designates out-of-service. In addition, for a three-winding transformer, 2 designates that only winding two is out-of-service, 3 indicates that only winding three is out-of-service, and 4 indicates that only winding one is out-of-service, with the remaining windings in-service. STAT = 1 by default.
Oi	An owner number; (1 through the maximum number of owners at the current size level: see Table 1-1). Each transformer may have up to four owners. By default, O1 is the owner to which bus "I" is assigned and O2, O3, and O4 are zero.
Fi	The fraction of total ownership assigned to owner Oi; each Fi must be positive. The Fi values are normalized such that they sum to 1.0 before they are placed in the working case. By default, each Fi is 1.0.

Record 2

The first three data items described on the second record are used for both two- and three-winding transformers; the remaining data items are used *only* for three-winding transformers:

```
R1-2,X1-2,SBASE1-2,R2-3,X2-3,SBASE2-3,R3-1,X3-1,SBASE3-1,VMSTAR,
ANSTAR
```

R1-2, X1-2	The measured impedance of the transformer between the buses to which its first and second windings are connected. When CZ is 1, they are the resistance and reactance, respectively, in pu on system base MVA and winding voltage base; when CZ is 2, they are the resistance and reactance, respectively, in pu on winding one to two base MVA (SBASE1-2) and winding voltage base; when CZ is 3, R1-2 is the three phase load loss in watts, and X1-2 is the impedance magnitude in pu on winding one to two base MVA (SBASE1-2) and winding voltage base. R1-2 = 0.0 by default, but no default is allowed for X1-2.
SBASE1-2	The winding one to two base MVA of the transformer. SBASE1-2 = SBASE (the system base MVA) by default.
R2-3, X2-3	The measured impedance of a three-winding transformer between the buses to which its second and third windings are connected; ignored for a two-winding transformer. When CZ is 1, they are the resistance and reactance, respectively, in pu on system base MVA and winding voltage base; when CZ is 2, they are the resistance and reactance, respectively, in pu on winding two to three base MVA (SBASE2-3) and winding voltage base; when CZ is 3, R2-3 is the three phase load loss in watts, and X2-3 is the impedance magnitude in pu on winding two to three base MVA (SBASE2-3) and winding voltage base. R2-3 = 0.0 by default, but no default is allowed for X2-3.
SBASE2-3	The winding two to three base MVA of a three-winding transformer; ignored for a two-winding transformer. SBASE2-3 = SBASE (the system base MVA) by default.
R3-1, X3-1	The measured impedance of a three-winding transformer between the buses to which its third and first windings are connected; ignored for a two-winding transformer. When CZ is 1, they are the resistance and reactance, respectively, in pu on system base MVA and winding voltage base; when CZ is 2, they are the resistance and reactance, respectively, in pu on winding three to one base MVA (SBASE3-1) and winding voltage base; when CZ is 3, R3-1 is the three phase load loss in watts, and X3-1 is the impedance magnitude in pu on winding three to one base MVA (SBASE3-1) and winding voltage base. R3-1 = 0.0 by default, but no default is allowed for X3-1.
SBASE3-1	The winding three to one base MVA of a three-winding transformer; ignored for a two-winding transformer. SBASE3-1 = SBASE (the system base MVA) by default.
VMSTAR	The voltage magnitude at the hidden star point bus; entered in pu. VMSTAR = 1.0 by default.
ANSTAR	The bus voltage phase angle at the hidden star point bus; entered in degrees. ANSTAR = 0.0 by default.

Record 3

All data items on the third record are processed for both two- and three-winding transformers.

```
WINDV1,NOMV1,ANG1,RATA1,RATB1,RATC1,COD1,CONT1,RMA1,RMI1,VMA1,
VMI1,NTP1,TAB1,CR1,CX1
```

WINDV1	The winding one off-nominal turns ratio in pu of winding one bus base voltage when CW is 1; WINDV1 = 1.0 by default. WINDV1 is the actual winding one voltage in kV when CW is 2; WINDV1 is equal to the base voltage of bus "I" by default. WINDV is the winding one off-nominal turns ratio in pu of nominal winding one voltage, NOMV1 when CW is 3; WINDV1 = 1.0 by default.
NOMV1	The nominal (rated) winding one voltage in kV, or zero to indicate that nominal winding one voltage is to be taken as the base voltage of bus "I". NOMV1 is used in converting magnetizing data between per unit admittance values and physical units when CM is 2. NOMV1 is used in converting tap ratio data between values in per unit of nominal winding one voltage and values in per unit of winding one bus base voltage when CW is 3. NOMV1 = 0.0 by default.
ANG1	The winding one phase shift angle in degrees. ANG1 is positive when winding two leads the winding one side (for a two-winding transformer), or when the "T" (or star) point bus leads the winding one side (for a three-winding transformer). ANG1 must be greater than -180.0 and less than or equal to +180.0. ANG1 = 0.0 by default.
RATA1,	The first winding's three ratings entered in MVA (*not* current expressed in MVA).
RATB1, RATC1	RATA1 = 0.0, RATB1 = 0.0 and RATC1 = 0.0 (bypass flow limit check for this transformer winding) by default.
COD1	The transformer control mode for automatic adjustments of the winding one tap or phase shift angle during power flow solutions: 0 for no control (fixed tap and phase shift); ±1 for voltage control; ±2 for reactive power flow control; ±3 for active power flow control; ±4 for control of a dc line quantity (±4 is valid only for two-winding transformers). If the control mode is entered as a positive number, automatic adjustment of this transformer winding is enabled when the corresponding adjustment is activated during power flow solutions; a negative control mode suppresses the automatic adjustment of this transformer winding. COD1 = 0 by default.
CONT1	The bus number, or extended bus name enclosed in single quotes, of the bus whose voltage is to be controlled by the transformer turns ratio adjustment option of the power flow solution activities when COD1 is 1. CONT1 should be nonzero only for voltage controlling transformer windings. CONT1 may specify a bus other than "I", "J", or "K"; in this case, the sign of CONT1 defines the location of the controlled bus relative to the transformer winding. If CONT1 is entered as a positive number, or a quoted extended bus name, the ratio is adjusted as if bus CONT1 is on the winding two or winding three side of the transformer; if CONT1 is entered as a negative number, or a quoted extended bus name with a minus sign preceding the first character, the ratio is adjusted as if bus |CONT1| is on the winding one side of the transformer. CONT1 = 0 by default.

RMA1, RMI1 — The upper and lower limits, respectively, of either:

- Off-nominal turns ratio in pu of winding one bus base voltage when |COD1| is 1 or 2 and CW is 1; RMA1 = 1.1 and RMI1 = 0.9 by default.
- Actual winding one voltage in kV when |COD1| is 1 or 2 and CW is 2. No default is allowed.
- Off-nominal turns ratio in pu of nominal winding one voltage (NOMV1) when |COD1| is 1 or 2 and CW is 3; RMA1 = 1.1 and RMI1 = 0.9 by default.
- Phase shift angle in degrees when |COD1| is 3. No default is allowed.
- Not used when |COD1| is 0 or 4; RMA1 = 1.1 and RMI1 = 0.9 by default.

VMA1, VMI1 — The upper and lower limits, respectively, of either:

- Voltage at the controlled bus (bus |CONT1|) in pu when |COD1| is 1. VMA1 = 1.1 and VMI1 = 0.9 by default.
- Reactive power flow into the transformer at the winding one bus end in Mvar when |COD1| is 2. No default is allowed.
- Active power flow into the transformer at the winding one bus end in MW when |COD1| is 3. No default is allowed.
- Not used when |COD1| is 0 or 4; VMA1 = 1.1 and VMI1 = 0.9 by default.

NTP1 — The number of tap positions available; used when COD1 is 1 or 2. NTP1 must be between 2 and 9999. NTP1 = 33 by default.

TAB1 — The number of a transformer impedance correction table if this transformer winding's impedance is to be a function of either off-nominal turns ratio or phase shift angle (see Section 3.4.4.7), or 0 if no transformer impedance correction is to be applied to this transformer winding. TAB1 = 0 by default.

CR1, CX1 — The load drop compensation impedance for voltage controlling transformers entered in pu on system base quantities; used when COD1 is 1.
CR1 + j CX1 = 0.0 by default.

Record 4

The first two data items on the fourth record are read for both two- and three-winding transformers; the remaining data items are used *only* for three-winding transformers.

```
WINDV2,NOMV2,ANG2,RATA2,RATB2,RATC2,COD2,CONT2,RMA2,RMI2,VMA2,
VMI2,NTP2,TAB2,CR2,CX2
```

WINDV2 — The winding two off-nominal turns ratio in pu of winding two bus base voltage when CW is 1; WINDV2 = 1.0 by default. WINDV2 is the actual winding two voltage in kV when CW is 2; WINDV2 is equal to the base voltage of bus "J" by default. WINDV2 is the winding two off-nominal turns ratio in pu of nominal winding two voltage, NOMV2 when CW is 3; WINDV2 = 1.0 by default.

NOMV2 — The nominal (rated) winding two voltage in kV, or zero to indicate that nominal winding two voltage is to be taken as the base voltage of bus "J". NOMV2 is used in converting tap ratio data between values in per unit of nominal winding two voltage and values in per unit of winding two bus base voltage when CW is 3. NOMV2 = 0.0 by default.

ANG2	The winding two phase shift angle in degrees; ignored for a two-winding transformer. ANG2 is positive when the "T" (or star) point bus leads the winding two side. ANG2 must be greater than -180.0 and less than or equal to +180.0. ANG2 = 0.0 by default.
RATA2, RATB2, RATC2	The second winding's three ratings entered in MVA (*not* current expressed in MVA); ignored for a two-winding transformer. RATA2 = 0.0, RATB2 = 0.0 and RATC2 = 0.0 (bypass flow limit check for this transformer winding) by default.
COD2	The transformer control mode for automatic adjustments of the winding two tap or phase shift angle during power flow solutions: 0 for no control (fixed tap and phase shift); ±1 for voltage control; ±2 for reactive power flow control; ±3 for active power flow control. If the control mode is entered as a positive number, automatic adjustment of this transformer winding is enabled when the corresponding adjustment is activated during power flow solutions; a negative control mode suppresses the automatic adjustment of this transformer winding. COD2 = 0 by default.
CONT2	The bus number, or extended bus name enclosed in single quotes, of the bus whose voltage is to be controlled by the transformer turns ratio adjustment option of the power flow solution activities when COD2 is 1. CONT2 should be nonzero only for voltage controlling transformer windings. CONT2 may specify a bus other than "I", "J", or "K"; in this case, the sign of CONT2 defines the location of the controlled bus relative to the transformer winding. If CONT2 is entered as a positive number, or a quoted extended bus name, the ratio is adjusted as if bus CONT2 is on the winding one or winding three side of the transformer; if CONT2 is entered as a negative number, or a quoted extended bus name with a minus sign preceding the first character, the ratio is adjusted as if bus |CONT2| is on the winding two side of the transformer. CONT2 = 0 by default.
RMA2, RMI2	The upper and lower limits, respectively, of either: • Off-nominal turns ratio in pu of winding two bus base voltage when |COD2| is 1 or 2 and CW is 1; RMA2 = 1.1 and RMI2 = 0.9 by default. • Actual winding two voltage in kV when |COD2| is 1 or 2 and CW is 2. No default is allowed. • Off-nominal turns ratio in pu of nominal winding two voltage (NOMV2) when |COD2| is 1 or 2 and CW is 3; RMA2 = 1.1 and RMI2 = 0.9 by default. • Phase shift angle in degrees when |COD2| is 3. No default is allowed. • Not used when |COD2| is 0; RMA2 = 1.1 and RMI2 = 0.9 by default.
VMA2, VMI2	The upper and lower limits, respectively, of either: • Voltage at the controlled bus (bus |CONT2|) in pu when |COD2| is 1. VMA2 = 1.1 and VMI2 = 0.9 by default. • Reactive power flow into the transformer at the winding two bus end in Mvar when |COD2| is 2. No default is allowed. • Active power flow into the transformer at the winding two bus end in MW when |COD2| is 3. No default is allowed. • Not used when |COD2| is 0; VMA2 = 1.1 and VMI2 = 0.9 by default.
NTP2	The number of tap positions available; used when COD2 is 1 or 2. NTP2 must be between 2 and 9999. NTP2 = 33 by default.

TAB2	The number of a transformer impedance correction table if this transformer winding's impedance is to be a function of either off-nominal turns ratio or phase shift angle (see Section 3.4.4.7), or 0 if no transformer impedance correction is to be applied to this transformer winding. TAB2 = 0 by default.
CR2, CX2	The load drop compensation impedance for voltage controlling transformers entered in pu on system base quantities; used when COD2 is 1. CR2 + j CX2 = 0.0 by default.

Record 5

The fifth data record is specified only for three-winding transformers.

```
WINDV3,NOMV3,ANG3,RATA3,RATB3,RATC3,COD3,CONT3,RMA3,RMI3,VMA3,
VMI3,NTP3,TAB3,CR3,CX3
```

WINDV3	The winding three off-nominal turns ratio in pu of winding three bus base voltage when CW is 1; WINDV3 = 1.0 by default. WINDV3 is the actual winding three voltage in kV when CW is 2; WINDV3 is equal to the base voltage of bus K by default.
NOMV3	The nominal (rated) winding three voltage in kV, or zero to indicate that nominal winding three voltage is to be taken as the base voltage of bus K. NOMV3 is used in converting tap ratio data between values in per unit of nominal winding three voltage and values in per unit of winding three bus base voltage when CW is 3. NOMV3 = 0.0 by default.
ANG3	The winding three phase shift angle in degrees. ANG3 is positive when the "T" (or star) point bus leads the winding three side. ANG3 must be greater than -180.0 and less than or equal to +180.0. ANG3 = 0.0 by default.
RATA3, RATB3, RATC3	The third winding's three ratings entered in MVA (*not* current expressed in MVA). RATA3 = 0.0, RATB3 = 0.0 and RATC3 = 0.0 (bypass flow limit check for this transformer winding) by default.
COD3	The transformer control mode for automatic adjustments of the winding three tap or phase shift angle during power flow solutions: 0 for no control (fixed tap and phase shift); ±1 for voltage control; ±2 for reactive power flow control; ±3 for active power flow control. If the control mode is entered as a positive number, automatic adjustment of this transformer winding is enabled when the corresponding adjustment is activated during power flow solutions; a negative control mode suppresses the automatic adjustment of this transformer winding. COD3 = 0 by default.
CONT3	The bus number, or extended bus name enclosed in single quotes, of the bus whose voltage is to be controlled by the transformer turns ratio adjustment option of the power flow solution activities when COD3 is 1. CONT3 should be nonzero only for voltage controlling transformer windings. CONT3 may specify a bus other than "I", "J", or "K"; in this case, the sign of CONT3 defines the location of the controlled bus relative to the transformer winding. If CONT3 is entered as a positive number, or a quoted extended bus name, the ratio is adjusted as if bus CONT3 is on the winding one or winding two side of the transformer; if CONT3 is entered as a negative number, or a quoted extended bus name with a minus sign preceding the first character, the ratio is adjusted as if bus |CONT3| is on the winding three side of the transformer. CONT3 = 0 by default.

RMA3, RMI3 — The upper and lower limits, respectively, of either:

- Off-nominal turns ratio in pu of winding three bus base voltage when |COD3| is 1 or 2 and CW is 1; RMA3 = 1.1 and RMI3 = 0.9 by default.
- Actual winding three voltage in kV when |COD3| is 1 or 2 and CW is 2. No default is allowed.
- Off-nominal turns ratio in pu of nominal winding three voltage (NOMV3) when |COD3| is 1 or 2 and CW is 3; RMA3 = 1.1 and RMI3 = 0.9 by default.
- Phase shift angle in degrees when |COD3| is 3. No default is allowed.
- Not used when |COD3| is 0; RMA3 = 1.1 and RMI3 = 0.9 by default.

VMA3, VMI3 — The upper and lower limits, respectively, of either:

- Voltage at the controlled bus (bus |CONT3|) in pu when |COD3| is 1. VMA3 = 1.1 and VMI3 = 0.9 by default.
- Reactive power flow into the transformer at the winding three bus end in Mvar when |COD3| is 2. No default is allowed.
- Active power flow into the transformer at the winding three bus end in MW when |COD3| is 3. No default is allowed.
- Not used when |COD3| is 0; VMA3 = 1.1 and VMI3 = 0.9 by default.

NTP3 — The number of tap positions available; used when COD3 is 1 or 2. NTP3 must be between 2 and 9999. NTP3 = 33 by default.

TAB3 — The number of a transformer impedance correction table if this transformer winding's impedance is to be a function of either off-nominal turns ratio or phase shift angle (see Section 3.4.4.7), or 0 if no transformer impedance correction is to be applied to this transformer winding. TAB3 = 0 by default.

CR3, CX3 — The load drop compensation impedance for voltage controlling transformers entered in pu on system base quantities; used when COD3 is 1. CR3 + j CX3 = 0.0 by default.

Transformer input in Raw Data File format is terminated with a record specifying a winding one bus number of zero.

Notes

- When specifying a two-winding transformer between buses I and J with circuit identifier CKT, if a nontransformer branch between buses I and J with a circuit identifier of CKT is already present in the working case, it is *replaced* (i.e., the nontransformer branch is deleted from the working case and the newly specified two-winding transformer is then added to the working case).
- In deriving winding impedances, for three-winding transformers, from the measured impedance data input values, one winding with a small or negative impedance may result. It is possible to specify a set of measured impedances which themselves do not individually appear to challenge the precision limits of typical power system calculations, but which result in one winding impedance of nearly (or identically) 0.0. Such data could result in precision difficulties, and hence inaccurate results, when processing the system matrices in power flow and short circuit calculations.
- Whenever a set of measured impedance results in a winding reactance which is identically 0.0, a warning message is printed by the three-winding transformer data input or data changing function, and the winding's reactance is set to the zero impedance line

threshold tolerance (or to 0.0001 pu if the zero impedance line threshold tolerance itself is 0.0). Whenever a set of measured impedances results in a winding impedance whose magnitude is less than 0.00001 pu, a warning message is printed. As with all warning and error messages produced during data input and data modification phases of PSS™E, the user should resolve the cause of the message (e.g., was correct input data specified?) and use engineering judgement to resolve modeling issues (e.g., is this the best way to model this transformer or would some other modeling be more appropriate?).

3.2.6.1 Example Transformer Data Records

Figure 3-10 shows the data records for a 50 MVA, 138/34.5 kV two-winding transformer connected to system buses with nominal voltages of 134 kV and 34.5 kV, and sample data on 100 MVA system base and winding voltage bases of 134 kV and 34.5 kV.

Example of 2-Winding Transformer:

Data Formats

```
I, J, K, CKT, CW, CZ, CM, MAG1, MAG2, NMETR, 'NAME', STAT, O1, F1, ..., O4, F4

R1-2, X1-2, SBASE1

WINDV1,NOMV1,ANG1,RATA1,RATB1,RATC1,COD,CONT,RMA,RMI,VMA,VMI,NTP,
TAB,CR,CX

WINDV2, NOMV2
```

Data

```
6150, 6151, 0, '1 ', 1, 1, 1, 0.0, 0.0, 2, 'TWO-WINDINGS', 1, 5, 1.0
0.0, 0.30, 100.0
1.01, 0.0, 0.0, 50.0, 60.0, 75.0, 1, 6151, 1.1, 0.9, 1.025, 1.0, 33, 0, 0.0, 0.0
1.0, 0.0
```

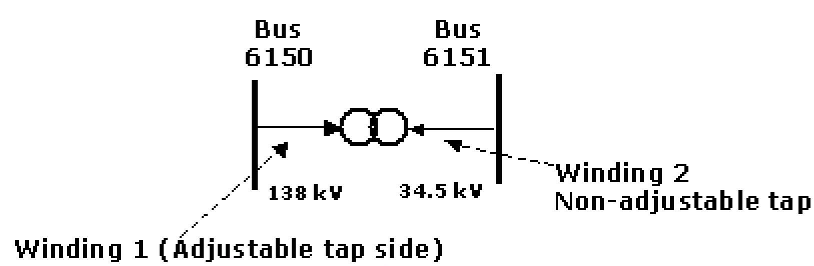


Figure 3-10. Sample Data for Two-Winding Transformer

Figure 3-11 shows the data records for a 300 MVA, 345/138/13.8 kV three-winding transformer connected to system buses with nominal voltages of 345 kV, 138 kV and 13.8 kV, respectively, and sample data on 100 MVA system base and winding base voltages of 345 kV, 138 kV and 13.8 kV.

Example of 3-Winding Transformer:

Data Formats

I, J, K, CKT, CW, CZ, CM, MAG1, MAG2, NMETR, 'NAME', STAT, O1, F1, ..., O4, F4

R1-2, X1-2, SBASE1, R2-3, X2-3, SBASE2, R3-1, X3-1, SBASE3, VMSTAR, ANSTAR

WINDV1,NOMV1,ANG1,RATA1,RATB1,RATC1,COD,CONT,RMA,RMI,VMA,VMI,NTP,TAB,CR,CX

WINDV2, NOMV2, ANG2, RATA2,RATB2,RATC2

WINDV3, NOMV3, ANG3, RATA3,RATB3,RATC3

Data

```
3001, 3002, 3000, '1', 1, 1, 1, 0.0, 0.0, 2, 'THREEWINDING', 1, 5, 1.0
0.003, 0.03, 100.0, 0.001, 0.03, 100.0, 0.001, 0.035, 100.0, 1.025, 0.0
1.00, 0.0, 0.0,300, 400, 600, 0, 3001, 1.1, 0.9, 1.04, 1.0 , 33, 0, 0.0, 0.0
1.02, 0.0, 0.0,300, 400, 600
1.00, 0.0, 0.0, 50, 60, 75
```

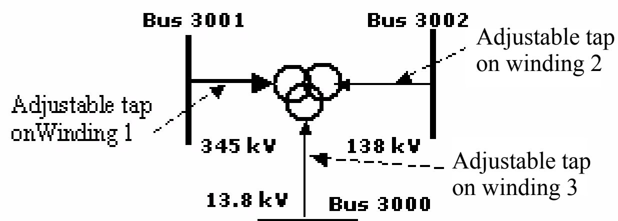


Figure 3-11. Sample Data for Three-Winding Transformer

3.2.7 Areas and Zones

Areas are commonly used to designate sections of the network which represent control areas between which there are scheduled flows. PSS™E facilitates the identification of both areas and schedules. Alternatively, the network can be subdivided between utility companies or other subdivisions useful for specific analyses.

Designating buses to specific zones allows additional subdivision of the network to facilitate analyses and documentation but PSS™E provides no analytical facility to schedule interchange between zones.

Although areas cannot overlap other areas and zones cannot overlap other zones, areas and zones can overlap each other.

Figure 3-12 shows a system subdivided into three areas and three zones, each with a unique name. Notice the following:

- An area does not have to be contiguous. Area #1 covers two separate parts of the network.
- Zone #1 lies entirely in Area #1.
- Zone #2 lies partly in Area #1 and partly in Area #4.
- Zone #3 lies partly in Area 4 and Area 2.

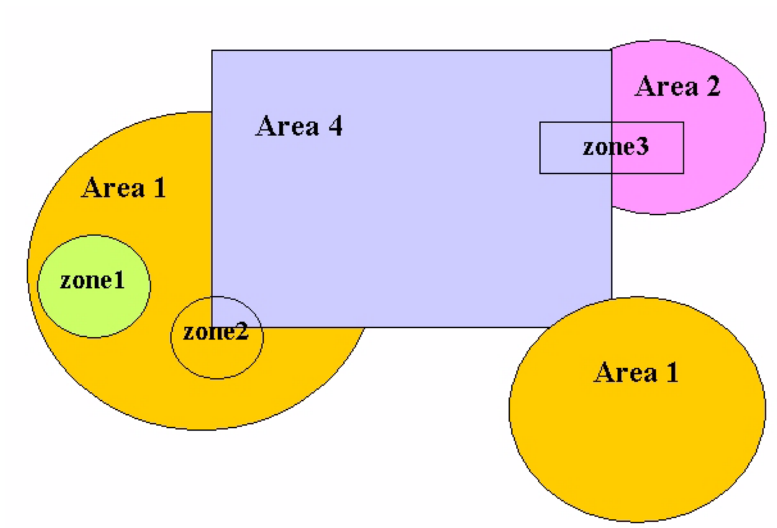
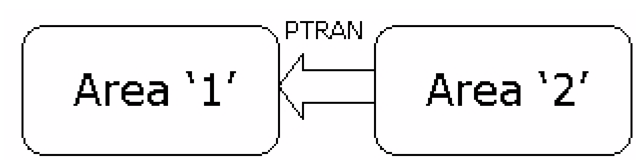


Figure 3-12. Overlapping Areas and Zones

3.2.8 Area Interchange Data

Area interchange is a required net export of power from, or net import of power to, a specific area. This does not imply that the power is destined to be transferred to or from any other specific area. To specify transfers between specific pairs of areas see Section 3.2.16.



Each bus in the PSS™E working case may be designated as residing in an interchange area, for purposes of both interchange control and selective output and other processing. When the interchange control option is enabled during a power flow solution, each interchange area for which an area slack bus is specified has the active power output of its area slack bus modified such that the desired net interchange for the area falls within a desired band.

Area identifiers and interchange control parameters are specified in area interchange data records which have the following format:

```
I, ISW, PDES, PTOL, 'ARNAME'
```

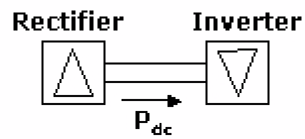
where:

I	Area number, (1 through the maximum number of areas at the current size level: see Table 1-1).
ISW	Bus number, or extended bus name enclosed in single quotes, of the area slack bus for area interchange control. The bus *must* be a generator (type two) bus in the specified area. Any area containing a system swing bus (type three) *must have* either that swing bus or a bus number of zero specified for its area slack bus number. Any area with an area slack bus number of zero is considered a "floating area" by the area interchange control option of the power flow solution activities. ISW = 0 by default.
PDES	Desired net interchange leaving the area (export); entered in MW. In the power flow solution process there are two options for handling the interchange. One assumes that the interchange is exported only on tie lines out of the area. The other assumes that the interchange is a combination of flow on the tie lines plus any loads whose area assignment is different from the bus to which it is connected. Thus the PDES must be specified such that is consistent with these two options either of which will be selected at initiation of the power flow solution. PDES = 0.0 by default.
PTOL	Interchange tolerance bandwidth; entered in MW. PTOL = 10.0 by default.
ARNAME	Alphanumeric identifier assigned to area I. The name may contain up to twelve characters and **must** be enclosed in single quotes. ARNAME may be any combination of blanks, uppercase letters, numbers, and special characters. ARNAME is set to twelve blanks by default.

Area interchange data input from the Power Flow Raw Data File is terminated with a record specifying an area number of zero.

3.2.9 Two-terminal dc Line Data

The two-terminal dc transmission line model is used to simulate either a point-to-point system with rectifier and inverter separated by a bipolar or mono-polar transmission system or a Back-to-Back system where the rectifier and inverter are physically located at the same site and separated only by a short bus-bar.



The data requirements fall into three groups:

- Control parameters and set-points
- Converter transformers
- The dc line characteristics

The steady-state model comprising this data enables not only power flow analysis but also establishes the initial steady-state for dynamic analysis.

Data for each two-terminal dc transmission line are specified on three consecutive data records. The three data records have the following formats.

Record 1

The first of the three dc line data records defines the following line quantities and control parameters:

```
I,MDC,RDC,SETVL,VSCHD,VCMOD,RCOMP,DELTI,METER,DCVMIN,CCCITMX,
CCCACC
```

I	The dc line number.
MDC	Control mode: 0 for blocked, 1 for power, 2 for current. MDC = 0 by default.
RDC	The dc line resistance; entered in ohms. No default allowed.
SETVL	Current (amps) or power (MW) demand. When MDC is one, a positive value of SETVL specifies desired power at the rectifier and a negative value specifies desired inverter power. No default allowed.
VSCHD	Scheduled compounded dc voltage; entered in kV. No default allowed.
VCMOD	Mode switch dc voltage; entered in kV. When the inverter dc voltage falls below this value and the line is in power control mode (i.e., MDC = 1), the line switches to current control mode with a desired current corresponding to the desired power at scheduled dc voltage. VCMOD = 0.0 by default.
RCOMP	Compounding resistance; entered in ohms. Gamma and/or TAPI is used to attempt to hold the compounded voltage (VDCI + DCCUR∗RCOMP) at VSCHD. To control the inverter end dc voltage VDCI, set RCOMP to zero; to control the rectifier end dc voltage VDCR, set RCOMP to the dc line resistance, RDC; otherwise, set RCOMP to the appropriate fraction of RDC. RCOMP = 0.0 by default.

DELTI	Margin entered in per unit of desired dc power or current. This is the fraction by which the order is reduced when ALPHA is at its minimum and the inverter is controlling the line current. DELTI = 0.0 by default.
METER	Metered end code of either 'R' (for rectifier) or 'I' (for inverter). METER = 'I' by default.
DCVMIN	Minimum compounded dc voltage; entered in kV. Only used in constant gamma operation (i.e., when GAMMX = GAMMN) when TAPI is held constant and an ac transformer tap is adjusted to control dc voltage (i.e., when IFI, ITI, and IDI specify a two-winding transformer). DCVMIN = 0.0 by default.
CCCITMX	Iteration limit for capacitor commutated two-terminal dc line Newton solution procedure. CCCITMX = 20 by default.
CCCACC	Acceleration factor for capacitor commutated two-terminal dc line Newton solution procedure. CCCACC = 1.0 by default.

Record 2

The second of the three dc line data records defines rectifier end data quantities and control parameters:

```
IPR,NBR,ALFMX,ALFMN,RCR,XCR,EBASR,TRR,TAPR,TMXR,TMNR,STPR,ICR,IFR,
ITR,IDR,XCAPR
```

IPR	Rectifier converter bus number, or extended bus name enclosed in single quotes. No default allowed.
NBR	Number of bridges in series (rectifier). No default allowed.
ALFMX	Nominal maximum rectifier firing angle; entered in degrees. No default allowed.
ALFMN	Minimum steady-state rectifier firing angle; entered in degrees. No default allowed.
RCR	Rectifier commutating transformer resistance per bridge; entered in ohms. No default allowed.
XCR	Rectifier commutating transformer reactance per bridge; entered in ohms. No default allowed.
EBASR	Rectifier primary base ac voltage; entered in kV. No default allowed.
TRR	Rectifier transformer ratio. TRR = 1.0 by default.
TAPR	Rectifier tap setting. TAPR = 1.0 by default.
TMXR	Maximum rectifier tap setting. TMXR = 1.5 by default.
TMNR	Minimum rectifier tap setting. TMNR = 0.51 by default.
STPR	Rectifier tap step; must be positive. STPR = 0.00625 by default.
ICR	Rectifier firing angle measuring bus number, or extended bus name enclosed in single quotes. The firing angle and angle limits used inside the dc model are adjusted by the difference between the phase angles at this bus and the ac/dc interface (i.e., the converter bus, IPR). ICR = 0 by default.
IFR	Winding one side "*from bus*" number, or extended bus name enclosed in single quotes, of a two-winding transformer. IFR = 0 by default.
ITR	Winding two side "*to bus*" number, or extended bus name enclosed in single quotes, of a two-winding transformer. ITR = 0 by default.

IDR	Circuit identifier; the branch described by IFR, ITR, and IDR *must* have been entered as a two-winding transformer; an ac transformer may control at most only one dc converter. IDR = '1' by default.

If no branch is specified, TAPR is adjusted to keep alpha within limits; otherwise, TAPR is held fixed and this transformer's tap ratio is adjusted. The adjustment logic assumes that the rectifier converter bus is on the winding two side of the transformer. The limits TMXR and TMNR specified here are used; except for the transformer control mode flag (COD of Section 3.2.6), the ac tap adjustment data is ignored.

XCAPR	Commutating capacitor reactance magnitude per bridge; entered in ohms. XCAPR = 0.0 by default.

Record 3

Data on the third of the three dc line data records contains the inverter quantities corresponding to the rectifier quantities specified on the second record described above.

The significant difference is that the control angle ALFA for the rectifier is replaced by the control angle GAMMA for the inverter.

```
IPI,NBI,GAMMX,GAMMN,RCI,XCI,EBASI,TRI,TAPI,TMXI,TMNI,STPI,ICI,IFI,
ITI,IDI,XCAPI
```

Dc line converter buses, IPR and IPI, may be type one, two, or three buses. Generators, loads, fixed and switched shunt elements, other dc line converters, and FACTS device sending ends are permitted at converter buses.

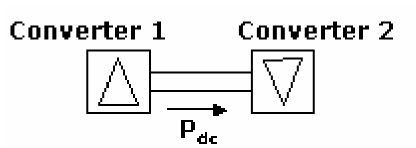
When either XCAPR > 0.0 or XCAPI > 0.0, the two-terminal dc line is treated as capacitor commutated. Capacitor commutated two-terminal dc lines preclude the use of a remote ac transformer as commutation transformer tap and remote commutation angle buses at either converter. Any data provided in these fields are ignored for capacitor commutated two-terminal dc lines.

Further details on dc line modeling in power flow solutions are given in Section 4.3.5.

The dc line data input from a Power Flow Raw Data File is terminated with a record specifying a dc line number of zero.

3.2.10 Voltage Source Converter dc Line Data

Each voltage source converter (VSC) dc line to be represented in PSS™E is introduced by a set of three consecutive data records.



The first of the three VSC dc line data records defines line quantities and control parameters.

Record 1

```
'NAME', MDC, RDC, O1, F1, ... O4, F4
```

NAME	The non-blank alphanumeric identifier assigned to this VSC dc line. Each VSC dc line *must* have a unique NAME. The name may be up to twelve characters and *must* be enclosed in single quotes. NAME may contain any combination of blanks, uppercase letters, numbers and special characters. No default allowed.
MDC	Control mode: 0 for out-of-service, 1 for in-service. MDC = 1 by default.
RDC	The dc line resistance entered in ohms. RDC must be positive. No default allowed.
Oi	An owner number; (1 through the maximum number of owners at the current size level: see Table 1-1). Each VSC dc line may have up to four owners. By default, O1 is 1, and O2, O3 and O4 are zero.
Fi	The fraction of total ownership assigned to owner Oi; each Fi must be positive. The Fi values are normalized such that they sum to 1.0 before they are placed in the working case. By default, each Fi is 1.0.

Records 2 and 3

The remaining two data records define the converter buses (converter 1 and converter 2), along with their data quantities and control parameters.

```
IBUS,TYPE,MODE,DOCET,ACSET,ALOSS,BLOSS,MINOSS,SMAX,IMAX,PWF,MAXQ,
MINQ,

REMOT,RMPCT
```

IBUS	Converter bus number, or extended bus name enclosed in single quotes. No default allowed.
TYPE	Code for the type of converter dc control: 0 for converter out-of-service, 1 for dc voltage control, or 2 for MW control. When both converters are in-service, exactly one converter of each VSC dc line must be TYPE 1. No default allowed.
MODE	Converter ac control mode: 1 for ac voltage control or 2 for fixed ac power factor. MODE = 1 by default.
DCSET	Converter dc setpoint. For TYPE = 1, DCSET is the scheduled dc voltage on the dc side of the converter bus; entered in kV. For TYPE = 2, DCSET is the power demand, where a positive value specifies that the converter is feeding active power into the ac network at bus IBUS, and a negative value specifies that the converter is withdrawing active power from the ac network at bus IBUS; entered in MW. No default allowed.
ACSET	Converter ac setpoint. For MODE = 1, ACSET is the regulated ac voltage set-point; entered in pu. For MODE = 2, ACSET is the power factor setpoint. ACSET = 1.0 by default.
A_{loss}, B_{loss}	Coefficients of the linear equation used to calculate converter losses: $$KW_{conv\ loss} = A_{loss} + I_{dc}*B_{loss}$$ A_{loss} is entered in kW. B_{loss} is entered in kW/amp. A_{loss} = B_{loss} = 0.0 by default.
MIN_{loss}	Minimum converter losses; entered in kW. MIN_{loss} = 0.0 by default.
SMAX	Converter MVA rating; entered in MVA. SMAX = 0.0 to allow unlimited converter MVA loading. SMAX = 0.0 by default.

IMAX	Converter ac current rating; entered in amps. IMAX = 0.0 to allow unlimited converter current loading. If a positive IMAX is specified, the base voltage assigned to bus IBUS must be positive. IMAX = 0.0 by default.
PWF	Power weighting factor fraction ($0.0 \le PWF \le 1.0$) used in reducing the active power order and either the reactive power order (when MODE is 2) or the reactive power limits (when MODE is 1) when the converter MVA or current rating is violated. When PWF is 0.0, only the active power is reduced; when PWF is 1.0, only the reactive power is reduced; otherwise, a weighted reduction of both active and reactive power is applied. PWF = 1.0 by default.
MAXQ	Reactive power upper limit; entered in Mvar. A positive value of reactive power indicates reactive power flowing into the ac network from the converter; a negative value of reactive power indicates reactive power withdrawn from the ac network. Not used if MODE = 2. MAXQ = 9999.0 by default.
MINQ	Reactive power lower limit; entered in Mvar. A positive value of reactive power indicates reactive power flowing into the ac network from the converter; a negative value of reactive power indicates reactive power withdrawn from the ac network. Not used if MODE = 2. MINQ = -9999.0 by default.
REMOT	Bus number, or extended bus name enclosed in single quotes, of a remote type 1 or 2 bus whose voltage is to be regulated by this converter to the value specified by ACSET. If bus REMOT is other than a type 1 or 2 bus, bus IBUS regulates its own voltage to the value specified by ACSET. REMOT is entered as zero if the converter is to regulate its own voltage. Not used if MODE = 2. REMOT = 0 by default.
RMPCT	Percent of the total Mvar required to hold the voltage at the bus controlled by bus IBUS that are to be contributed by this VSC; RMPCT must be positive. RMPCT is needed only if REMOT specifies a valid remote bus and there is more than one local or remote voltage controlling device (plant, switched shunt, FACTS device shunt element, or VSC dc line converter) controlling the voltage at bus REMOT to a setpoint, or REMOT is zero but bus IBUS is the controlled bus, local or remote, of one or more other setpoint mode voltage controlling devices. Not used if MODE = 2. RMPCT = 100.0 by default.

VSC dc line data input within a Power Flow Raw Data File is terminated with a record specifying a blank dc line name (’ ’) or a dc line name of ’0’ or zero.

Each VSC dc line converter bus:

- must be a type one or two bus. Generators, loads, fixed and switched shunt elements, other dc line converters, and FACTS device sending ends are permitted at converter buses.
- must not have the terminal end of a FACTS device connected to the same bus.
- must not be connected by a zero impedance line to another bus which violates any of the above restrictions.

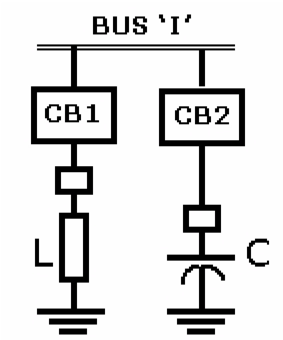
In specifying reactive power limits for converters which control ac voltage (i.e., those with unequal reactive power limits whose MODE is 1), the use of very narrow var limit bands is discouraged. The Newton-Raphson based power flow solutions require that the difference between the controlling equipment's high and low reactive power limits be greater than 0.002 pu for all setpoint mode voltage controlling equipment (0.2 Mvar on a 100 MVA system base). It is recommended that voltage controlling VSC converters have Mvar ranges substantially wider than this minimum permissible range.

For interchange and loss assignment purposes, the dc voltage controlling converter is assumed to be the non-metered end of each VSC dc line. As with other network branches, losses are assigned to the subsystem of the non-metered end, and flows at the metered ends are used in interchange calculations.

Further details on dc line modeling in power flow solutions are given in Section 4.3.5.

3.2.11 Switched Shunt Data

It is possible to represent switched shunt devices, in the form of capacitors and/or reactors on a network bus.



The switched shunt elements at a bus may consist entirely of blocks of shunt reactors (each B_i is a negative quantity) or entirely of blocks of capacitor banks (each B_i is a positive quantity). Any bus can have both switched capacitors and reactors.

Each network bus to be represented in PSS™E with switched shunt admittance devices must have a switched shunt data record specified for it. The switched shunts are represented with up to eight blocks of admittance, each one of which consists of up to nine steps of the specified block admittance.

Each switched shunt data record has the following format:

```
I, MODSW, VSWHI, VSWLO, SWREM, RMPCT, 'RMIDNT', BINIT, N1, B1, N2,
B2, ... N8, B8
```

where:

I	Bus number, or extended bus name enclosed in single quotes.
MODSW	Control mode:
	0 - fixed
	1 - discrete adjustment, controlling voltage locally or at bus SWREM
	2 - continuous adjustment, controlling voltage locally or at bus SWREM
	3 - discrete adjustment, controlling reactive power output of the plant at bus SWREM

4 - discrete adjustment, controlling reactive power output of the VSC dc line converter at bus SWREM of the VSC dc line whose name is specified as RMIDNT

5 - discrete adjustment, controlling admittance setting of the switched shunt at bus SWREM

MODSW = 1 by default.

VSWHI — When MODSW is 1 or 2, the controlled voltage upper limit; entered in pu.

When MODSW is 3, 4 or 5, the controlled reactive power range upper limit; entered in pu of the total reactive power range of the controlled voltage controlling device.

VSWHI is not used when MODSW is 0. VSWHI = 1.0 by default.

VSWLO — When MODSW is 1 or 2, the controlled voltage lower limit; entered in pu.

When MODSW is 3, 4 or 5, the controlled reactive power range lower limit; entered in pu of the total reactive power range of the controlled voltage controlling device.

VSWLO is not used when MODSW is 0. VSWLO = 1.0 by default.

SWREM — Bus number, or extended bus name enclosed in single quotes (see Section 3.2.2.1), of the bus whose voltage or connected equipment reactive power output is controlled by this switched shunt.

When MODSW is 1 or 2, SWREM is entered as 0 if the switched shunt is to regulate its own voltage; otherwise, SWREM specifies the remote type one or two bus whose voltage is to be regulated by this switched shunt.

When MODSW is 3, SWREM specifies the type two or three bus whose plant reactive power output is to be regulated by this switched shunt. Set SWREM to "I" if the switched shunt and the plant which it controls are connected to the same bus.

When MODSW is 4, SWREM specifies the converter bus of a VSC dc line whose converter reactive power output is to be regulated by this switched shunt. Set SWREM to "I" if the switched shunt and the VSC dc line converter which it controls are connected to the same bus.

When MODSW is 5, SWREM specifies the remote bus to which the switched shunt whose admittance setting is to be regulated by this switched shunt is connected.

SWREM is not used when MODSW is 0. SWREM = 0 by default.

RMPCT — Percent of the total Mvar required to hold the voltage at the bus controlled by bus I that are to be contributed by this switched shunt; RMPCT must be positive. RMPCT is needed only if SWREM specifies a valid remote bus and there is more than one local or remote voltage controlling device (plant, switched shunt, FACTS device shunt element, or VSC dc line converter) controlling the voltage at bus SWREM to a setpoint, or SWREM is zero but bus I is the controlled bus, local or remote, of one or more other setpoint mode voltage controlling devices. Only used if MODSW = 1 or 2. RMPCT = 100.0 by default.

RMIDNT — When MODSW is 4, the name of the VSC dc line whose converter bus is specified in SWREM. RMIDNT is not used for other values of MODSW. RMIDNT is a blank name by default.

BINIT	Initial switched shunt admittance; entered in Mvar at unity voltage. BINIT = 0.0 by default.
N_i	Number of steps for block i. The first zero value of N_i or B_i is interpreted as the end of the switched shunt blocks for bus I. N_i = 0 by default.
B_i	Admittance increment for each of N_i steps in block i; entered in Mvar at unity voltage. B_i = 0.0 by default.

Switched shunt data input from a Power Flow Raw Data File is terminated with a record specifying a bus number of zero.

The following notes apply to switched shunts:

- BINIT needs to be set to its actual solved case value only when the network, as entered into the working case, is to be considered solved as read in, or when the device is to be treated as fixed (i.e., MODSW is set to zero or switched shunts are to be locked during power flow solutions).
- The switched shunt elements at a bus may consist entirely of reactors (each B_i is a negative quantity) or entirely of capacitor banks (each B_i is a positive quantity). In these cases, the shunt blocks are specified in the order in which they are switched on the bus.
- If the switched shunt devices at a bus are a mixture of reactors and capacitors, the reactor blocks are specified first in the order in which they are switched on, followed by the capacitor blocks in the order in which they are switched on.
- In specifying reactive power limits for setpoint mode voltage controlling switched shunts (i.e., those with MODSW of 1 or 2), the use of a very narrow admittance range is discouraged. The Newton-Raphson based power flow solutions require that the difference between the controlling equipment's high and low reactive power limits be greater than 0.002 pu for all setpoint mode voltage controlling equipment (0.2 Mvar on a 100 MVA system base). It is recommended that voltage controlling switched shunts have admittance ranges substantially wider than this minimum permissible range.
- When MODSW is 3, 4 or 5, VSWLO and VSWHI define a restricted band of the controlled device’s reactive power range. They are specified in pu of the total reactive power range of the controlled device (i.e., the plant QMAX - QMIN when MODSW is 3, MAXQ - MINQ of a VSC dc line converter when MODSW is 4, and $\Sigma N_i B_i - \Sigma N_j B_j$ when MODSW is 5, where "i" are those switched shunt blocks for which B_i is positive and "j" are those for which B_i is negative). VSWLO must be greater than 0.0 and less than VSWHI, and VSWHI must be less than 1.0. That is, the following relationship must be honored:

  0.0 < VSWLO < VSWHI < 1.0
- The reactive power band for switched shunt control is calculated by applying VSWLO and VSWHI to the reactive power band extremes of the controlled plant or VSC converter. For example, with MINQ of -50.0 and MAXQ of +50.0, if VSWLO is 0.2 and VSWHI is 0.75, then the reactive power band defined by VSWLO and VSWHI is:

  -50.0 + 0.2*(50.0 - (-50.0)) = -50.0 + 0.2*100.0 = -50.0 + 20.0 = -30.0 MVAr

  through:

  -50.0 + 0.75*(50.0 - (-50.0)) = -50.0 + 0.75*100.0 = -50.0 + 75.0 = +25.0 MVAr

- The switched shunt admittance is kept in the working case and reported in output tabulations separately from the fixed bus shunts, which are input on the bus data record (see Section 3.2.2).
- Details on the handling of switched shunts during power flow solutions are discussed in Section 4.3.3.
- It is recommended that data records for switched shunts whose control mode is 5 (i.e., they control the setting of other switched shunts) be grouped together following all other switched shunt data records. This practice will eliminate any warnings of no switched shunt at the specified remote bus simply because the remote bus' switched shunt record has not as yet been read.

3.2.11.1 Example Combination Switched Shunts

To assist in clarifying the data record, Figure 3-13 shows the data record set up to match the shown combination of switched elements on Bus 791.

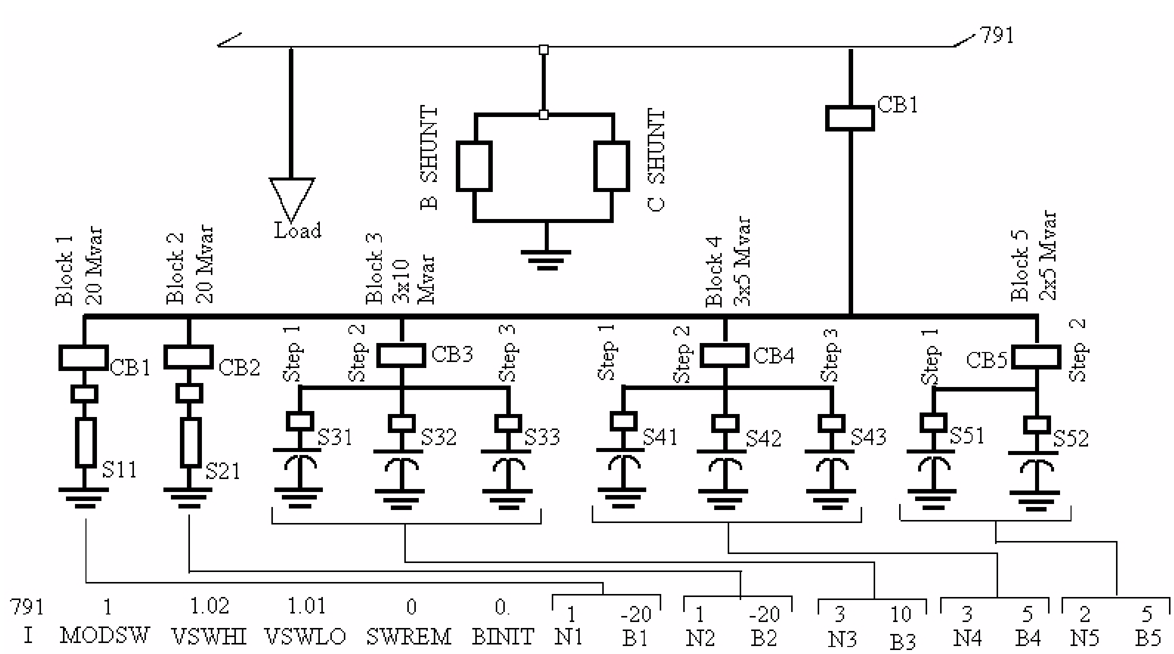


Figure 3-13. Example Data Record for Combination of Switched Shunts

3.2.12 Transformer Impedance Correction Tables

Transformer impedance correction tables are used to model a change of transformer impedance as off-nominal turns ratio or phase shift angle is adjusted. Each transformer impedance correction data record has the following format:

```
I, T1, F1, T2, F2, T3, F3, ... T11, F11
```

where:

I	Impedance correction table number.
T_i	Either off-nominal turns ratio in pu or phase shift angle in degrees. T_i = 0.0 by default.
F_i	Scaling factor by which transformer nominal impedance is to be multiplied to obtain the actual transformer impedance for the corresponding T_i. F_i = 0.0 by default.

The T_i values on a transformer impedance correction table record must all be either tap ratios or phase shift angles. They must be entered in strictly ascending order; i.e., for each "i", T_{i+1}>T_i. Each F_i entered must be greater than zero. On each record, at least 2 pairs of values must be specified and up to 11 may be entered. For a graphical view of a correction table, see Figure 3-14.

The T_i values for tables that are a function of tap ratio (rather than phase shift angle) are in units of the controlling winding's off-nominal turns ratio in pu of the controlling winding's bus base voltage.

Although a transformer winding is assigned to an impedance correction table, each table may be shared among many transformer windings. If the first "T" in a table is less than 0.5 or the last "T" entered is greater than 1.5, "T" is assumed to be the phase shift angle and the impedance of each transformer winding assigned to the table is treated as a function of phase shift angle. Otherwise, the impedances of the transformer windings assigned to the table are made sensitive to off-nominal turns ratio.

The power flow case stores both a nominal and actual impedance for each transformer winding impedance. The value of transformer impedance entered by the user is taken as the nominal value of impedance. Each time the complex tap ratio of a transformer is changed, either automatically by the power flow solution activities or manually by the user, and the transformer winding has been assigned to an impedance correction table, actual transformer winding impedance is redetermined if appropriate. First, the scaling factor is established from the appropriate table by linear interpolation; then nominal impedance is multiplied by the scaling factor to determine actual impedance. An appropriate message is printed any time the actual impedance is modified.

Transformer impedance correction data input from a Power Flow Raw Data File is terminated with a record specifying a table number of zero.

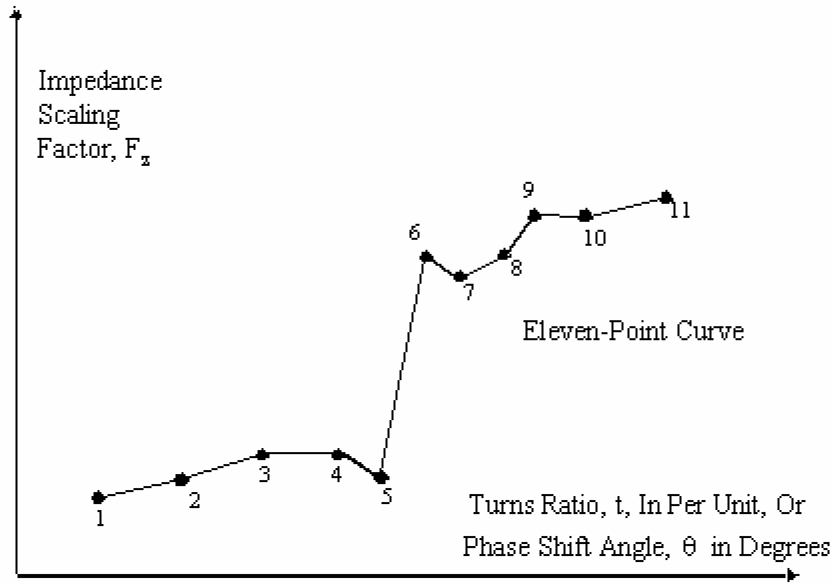
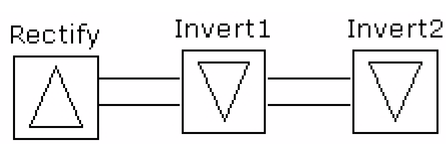


Figure 3-14. Typical Impedance Correction Factor Curve

3.2.13 Multi-Terminal dc Line Data

PSS™E allows the representation of up to 12 converter stations on one multi-terminal dc line. Further, the program allows the modelling of multi-terminal networks of up to 20 buses including the ac convertor buses and the dc network buses.



Each multi-terminal dc transmission line to be represented in PSS™E is introduced through a series of data records. Each set of multi-terminal dc line data records begins with a record which defines the number of converters, number of dc buses and dumber of dc links as well as related bus numbers and control mode.

Following this first record there are subsequent records for:

- each converter
- each dc bus
- each dc link

Data Record 1

```
I, NCONV, NDCBS, NDCLN, MDC, VCONV, VCMOD, VCONVN
```

where:

I	Multi-terminal dc line number.
NCONV	Number of ac converter station buses in multi-terminal dc line "I". No default allowed.
NDCBS	Number of dc buses in multi-terminal dc line "I" (NCONV $\leq$ NDCBS). No default allowed.
NDCLN	Number of dc links in multi-terminal dc line "I". No default allowed.
MDC	Control mode 0 - blocked 1 - power 2 - current MDC = 0 by default.
VCONV	Bus number, or extended bus name enclosed in single quotes, of the ac converter station bus that controls dc voltage on the positive pole of multi-terminal dc line "I". Bus VCONV *must* be a positive pole inverter. No default allowed.
VCMOD	Mode switch dc voltage; entered in kV. When any inverter dc voltage magnitude falls below this value and the line is in power control mode (i.e., MDC = 1), the line switches to current control mode with converter current setpoints corresponding to their desired powers at scheduled dc voltage. VCMOD = 0.0 by default.
VCONVN	Bus number, or extended bus name enclosed in single quotes, of the ac converter station bus that controls dc voltage on the negative pole of multi-terminal dc line "I". If any negative pole converters are specified (see below), bus VCONVN *must* be a negative pole inverter. If the negative pole is not being modeled, VCONVN must be specified as zero. VCONVN = 0 by default.

Data Record 2

Data record 1 is followed by NCONV converter records of the following format:

```
IB,N,ANGMX,ANGMN,RC,XC,EBAS,TR,TAP,TPMX,TPMN,TSTP,SETVL,DCPF,MARG,
CNVCOD
```

where:

IB	Ac converter bus number, or extended bus name enclosed in single quotes. No default allowed.
N	Number of bridges in series. No default allowed.
ANGMX	Nominal maximum ALPHA or GAMMA angle; entered in degrees. No default allowed.
ANGMN	Minimum steady-state ALPHA or GAMMA angle; entered in degrees. No default allowed.
RC	Commutating resistance per bridge; entered in ohms. No default allowed.
XC	Commutating reactance per bridge; entered in ohms. No default allowed.

EBAS	Primary base ac voltage; entered in kV. No default allowed.
TR	Actual transformer ratio. TR = 1.0 by default.
TAP	Tap setting. TAP = 1.0 by default.
TPMX	Maximum tap setting. TPMX = 1.5 by default.
TPMN	Minimum tap setting. TPMN = 0.51 by default.
TSTP	Tap step; must be a positive number. TSTP = 0.00625 by default.
SETVL	Converter setpoint. When IB is equal to VCONV or VCONVN, SETVL specifies the scheduled dc voltage magnitude, entered in kV, across the converter. For other converter buses, SETVL contains the converter current (amps) or power (MW) demand; a positive value of SETVL indicates that bus IB is a rectifier, and a negative value indicates an inverter. No default allowed.
DCPF	Converter participation factor. When the order at any rectifier in the multi-terminal dc line is reduced, either to maximum current or margin, the orders at the remaining converters on the same pole are modified according to their DCPFs to: `SETVL + (DCPF/SUM)*R` where SUM is the sum of the DCPFs at the unconstrained converters on the same pole as the constrained rectifier, and R is the order reduction at the constrained rectifier. DCPF = 1. by default.
MARG	Rectifier margin entered in per unit of desired dc power or current. The converter order reduced by this fraction, (1.-MARG)∗SETVL, defines the minimum order for this rectifier. MARG is used only at rectifiers. MARG = 0.0 by default.
CNVCOD	Converter code. A positive value or zero must be entered if the converter is on the positive pole of multi-terminal dc line "I". A negative value must be entered for negative pole converters. CNVCOD = 1 by default.

Data Record 3

Following are NDCBS records, one for each dc bus, with the following format:

```
IDC, IB, IA, ZONE, 'NAME', IDC2, RGRND, OWNER
```

where:

IDC	Dc bus number (1 to NDCBS). The dc buses are used internally within each multi-terminal dc line and *must* be numbered 1 through NDCBS. No default allowed.
IB	Ac converter bus number, or extended bus name enclosed in single quotes, or zero. Each converter station bus specified in a converter record must be specified as IB in exactly one dc bus record. Dc buses that are connected only to other dc buses by dc links and not to any ac converter buses must have a zero specified for IB. A dc bus specified as IDC2 on one or more other dc bus records must have a zero specified for IB on its own dc bus record. IB = 0 by default.
IA	Area number, (1 through the maximum number of areas at the current size level: see Table 1-1). IA = 1 by default.
ZONE	Zone number, (1 through the maximum number of zones at the current size level: see Table 1-1). ZONE = 1 by default.

NAME	Alphanumeric identifier assigned to dc bus IDC. The name may be up to twelve characters and *must* be enclosed in single quotes. NAME may contain any combination of blanks, uppercase letters, numbers, and special characters. NAME is twelve blanks by default.
IDC2	Second dc bus to which converter IB is connected, or zero if the converter is connected directly to ground. For voltage controlling converters, this is the dc bus with the lower dc voltage magnitude and SETVL specifies the voltage difference between buses IDC and IDC2. For rectifiers, dc buses should be specified such that power flows from bus IDC2 to bus IDC. For inverters, dc buses should be specified such that power flows from bus IDC to bus IDC2. IDC2 is ignored on those dc bus records that have IB specified as zero. IDC2 = 0 by default.
RGRND	Resistance to ground at dc bus "IDC"; entered in ohms. During solutions RGRND is used only for those dc buses specified as IDC2 on other dc bus records. RGRND = 0.0 by default.
OWNER	Owner number, (1 through the maximum number of owners at the current size level: see Table 1-1). OWNER = 1 by default.

Data Record 4

Following the above records are NDCLN records, one for each dc link, with the following format:

```
IDC, JDC, DCCKT, RDC, LDC
```

where:

IDC	Branch "*from bus*" dc bus number.
JDC	Branch "*to bus*" dc bus number. JDC is entered as a negative number to designate it as the metered end for area and zone interchange calculations. Otherwise, bus "IDC" is assumed to be the metered end.
DCCKT	One-character uppercase alphanumeric branch circuit identifier. It is recommended that single circuit branches be designated as having the circuit identifier ’1’. DCCKT = ’1’ by default.
RDC	Dc link resistance, entered in ohms. No default allowed.
LDC	Dc link inductance, entered in mH. LDC is not used by the power flow solution activities but is available to multi-terminal dc line dynamics models. LDC = 0.0 by default.

Multi-terminal dc line data input from a Power Flow Raw Data File is terminated with a record specifying a dc line number of zero.

A multi-terminal layout is shown in Figure 3-15. There are 4 convertors, 5 dc buses and 4 dc links.

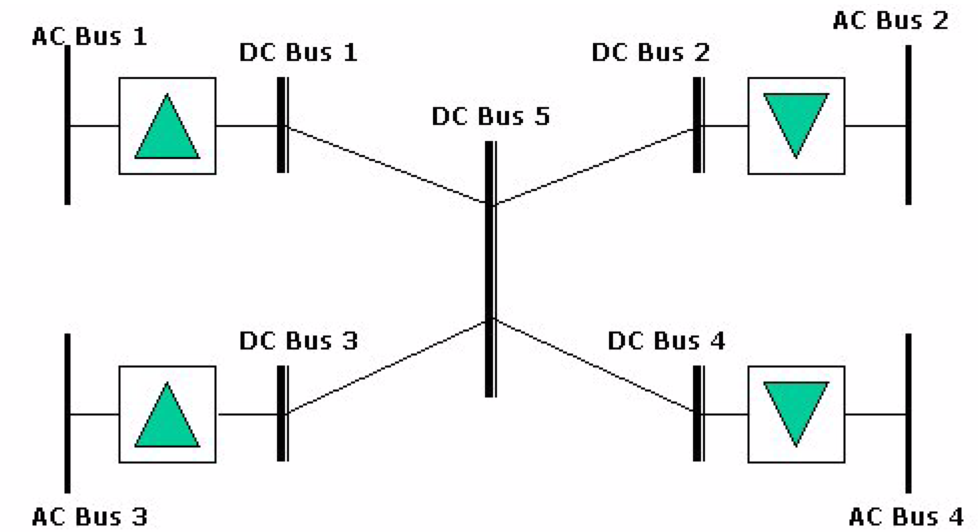


Figure 3-15. Multi-Terminal DC Network

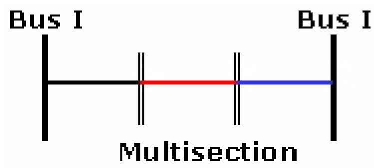
The following are notes on multi-terminal links:

- Conventional two-terminal and multi-terminal dc lines are stored separately in PSS™E working memory. Therefore, there may simultaneously exist, for example, a two-terminal dc line identified as dc line number 1 along with a multi-terminal line numbered 1.
- Multi-terminal lines should have at least three converter terminals; conventional dc lines consisting of two terminals should be modeled as two-terminal lines (see Section 3.2.9).
- Ac converter buses may be type one, two, or three buses. Generators, loads, fixed and switched shunt elements, other dc line converters, and FACTS device sending ends are permitted at converter buses.
- Each multi-terminal dc line is treated as a subnetwork of dc buses and dc links connecting its ac converter buses. For each multi-terminal dc line, the dc buses must be numbered 1 through NDCBS.
- Each ac converter bus must be specified as IB on exactly one dc bus record; there may be dc buses connected only to other dc buses by dc links but not to any ac converter bus.
- Ac converter bus "IB" may be connected to a dc bus "IDC", which is connected directly to ground. "IB" is specified on the dc bus record for dc bus "IDC"; the IDC2 field is specified as zero.
- Alternatively, ac converter bus "IB" may be connected to two dc buses "IDC" and "IDC2", the second of which is connected to ground through a specified resistance. "IB" and "IDC2" are specified on the dc bus record for dc bus "IDC"; on the dc bus record for bus "IDC2", the ac converter bus and second dc bus fields (IB and IDC2, respectively) must be specified as zero and the grounding resistance is specified as RGRND.
- The same dc bus may be specified as the second dc bus for more than one ac converter bus.

- All dc buses within a multi-terminal dc line must be reachable from any other point within the subnetwork.
- The area number assigned to dc buses and the metered end designation of dc links are used in calculating area interchange and assigning losses as well as in the interchange control option of the power flow solution activities. Similarly, the zone assignment and metered end specification are used in Zonal reporting activities.
- Further details on dc line modeling in power flow solutions are given in Section 4.3.5.

3.2.14 Multisection Line Grouping

Transmission lines commonly have a series of sections with varying physical structures. The section might have different tower configurations, conductor types and bundles or various combinations of these. The physical differences can result in the sections having different resistance, reactance and charging.



A transmission line with several distinct sections can be represented as one multisection line group.

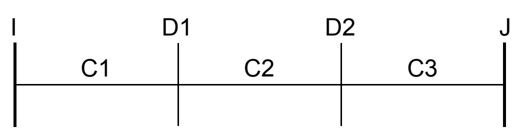
Each multisection line grouping to be represented in PSS™E is introduced by reading a multisection line grouping data record. Each multisection line grouping data record has the following format:

```
I, J, ID, DUM1, DUM2, ... DUM9
```

where:

I	"*From bus*" number, or extended bus name enclosed in single quotes.
J	"*To bus*" number, or extended bus name enclosed in single quotes. J is entered as a negative number or with a minus sign before the first character of the extended bus name to designate it as the metered end; otherwise, bus I is assumed to be the metered end.
ID	Two-character upper case alphanumeric multisection line grouping identifier. The first character *must* be an ampersand ("&"). ID = ’&1’ by default.
DUM_i	Bus numbers, or extended bus names enclosed in single quotes (see Section 3.2.2.1), of the dummy buses connected by the branches that comprise this multisection line grouping. No defaults allowed.

The DUM_i values on each record define the branches connecting bus "I" to bus "J", and are entered so as to trace the path from bus "I" to bus "J". Specifically, for a multisection line grouping consisting of three line sections (and hence two dummy buses):



The path from "I" to "J" is defined by the following branches:

From	To	Circuit
I	D1	C1
D1	D2	C2
D2	J	C3

If this multisection line grouping is to be assigned the line identifier "&1", the corresponding multisection line grouping data record is given by:

```
I    J    &1    D1    D2
```

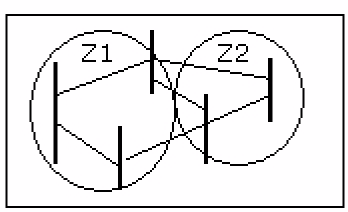
Multisection line grouping data input from a Power Flow Raw Data File is terminated with a record specifying a "*from bus*" number of zero.

The following notes apply to multisection line groups:

- Up to 10 line sections (and hence 9 dummy buses) may be defined in each multisection line grouping. A branch may be a line section of at most one multisection line grouping.
- Each dummy bus must have exactly two branches connected to it, both of which must be members of the same multisection line grouping. A multisection line dummy bus may not be a converter bus of a dc transmission line. A FACTS control device may not be connected to a multisection line dummy bus.
- The status of line sections and type codes of dummy buses are set such that the multisection line is treated as a single entity with regards to its service status.
- When the multisection line reporting option is enabled, several power flow reporting activities, specifically bus related reports, do not tabulate conditions at multisection line dummy buses. Accordingly, care must be taken in interpreting power flow output reports when dummy buses are other than passive nodes (e.g., if load or generation is present at a dummy bus).

3.2.15 Zone Data

All buses (ac and dc) and loads can be assigned to reside in a zone of the network. To enable this facility, each zone should be assigned a name and number. Specifically, the zone number is entered as part of the data records for the buses and loads. The use of zones enables the user to develop reports and to check results on the basis of zones and, consequently be highly specific when reporting and interpreting analytical results.



Zone identifiers are specified in zone data records with the following format:

```
I, 'ZONAME'
```

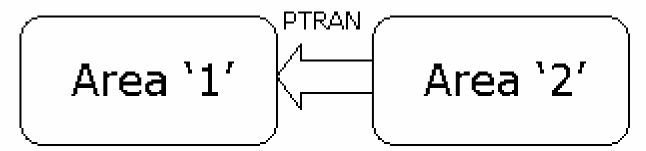
where:

I	Zone number, (1 through the maximum number of zones at the current size level: see Table 1-1).
ZONAME	Alphanumeric identifier assigned to zone I. The name may contain up to twelve characters and *must* be enclosed in single quotes. ZONAME may be any combination of blanks, uppercase letters, numbers, and special characters. ZONAME is set to twelve blanks by default.

Zone data input from a Power Flow Raw Data File is terminated with a record specifying a zone number of zero.

3.2.16 Interarea Transfer Data

Using PSS™E, the user has the capability to identify in which area each bus or load resides (see Sections 3.2.2 and 3.2.3). Further, the user can schedule active power transfers between pairs of areas.



Scheduled active power transfers between pairs of areas are specified in interarea transfer data records each of which has the following format:

```
ARFROM, ARTO, TRID, PTRAN
```

where:

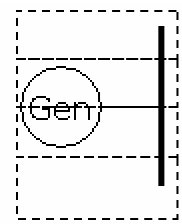
ARFROM	"*From area*" number (1 through the maximum number of areas at the current size level: see Table 1-1).
ARTO	"*To area*" number (1 through the maximum number of areas at the current size level: see Table 1-1).
TRID	Single-character (0 through 9 or A through Z) upper case interarea transfer identifier used to distinguish among multiple transfers between areas ARFROM and ARTO. TRID = '1' by default.
PTRAN	MW comprising this transfer. A positive PTRAN indicates that area ARFROM is selling to area ARTO. PTRAN = 0.0 by default.

Following the completion of interarea transfer data input, PSS™E alarms any area for which at least one interarea transfer is present and whose sum of transfers differs from its desired net interchange, PDES (see Section 3.2.8 for the definition of PDES).

Interarea transfer data input from a Power Flow Raw Data File is terminated with a record specifying a *"from area"* number of zero.

3.2.17 Owner Data

PSS™E allows the user to identify which organization or utility actually owns a facility, a piece of equipment or a load. Major network elements can have up to four different owners. This facilitates interpretation of results and reporting of results on the basis of ownership.



Owner identifiers are specified in owner data records with the following format:

```
I, 'OWNAME'
```

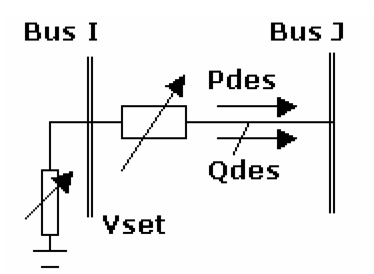
where:

I	Owner number, (1 through the maximum number of owners at the current size level: see Table 1-1).
OWNAME	Alphanumeric identifier assigned to owner I. The name may contain up to twelve characters and must be enclosed in single quotes. OWNAME may be any combination of blanks, uppercase letters, numbers, and special characters. OWNAME is set to twelve blanks by default.

Owner data input from a Power Flow Raw Data File is terminated with a record specifying an owner number of zero.

3.2.18 FACTS Device Data

There is a multiplicity of Flexible AC Transmission System devices currently available comprising shunt devices, such as the Static Compensator (STATCOM), series devices such as the Static Synchronous Series Compensator (SSSC), combined devices such as the Unified Power Flow Controller (UPFC) and the Interline Power Flow Controllers (IPFC), of which the latter are parallel series devices.



PSS™E facilitates these devices with one generic set of data records.

Each FACTS device data record has the following format:

```
N,I,J,MODE,PDES,QDES,VSET,SHMX,TRMX,VTMN,VTMX,VSMX,IMX,LINX,RMPCT,
OWNER,SET1,SET2,VSREF
```

where:

N	FACTS device number.
I	Sending end bus number, or extended bus name enclosed in single quotes. No default allowed.
J	Terminal end bus number, or extended bus name enclosed in single quotes; 0 for a STATCON. J = 0 by default.
MODE	Control mode:
	0 - out-of-service (i.e., series and shunt links open).
	1 - series and shunt links operating.
	2 - series link bypassed (i.e., like a zero impedance line) and shunt link operating as a STATCON.
	3 - series and shunt links operating with series link at constant series impedance.
	4 - series and shunt links operating with series link at constant series voltage.
	5 - master device of an IPFC with P and Q setpoints specified; FACTS device N+1 must be the slave device (i.e., its MODE is 6 or 8) of this IPFC.
	6 - slave device of an IPFC with P and Q setpoints specified; FACTS device N-1 must be the master device (i.e., its MODE is 5 or 7) of this IPFC. The Q setpoint is ignored as the master device dictates the active power exchanged between the two devices.
	7 - master device of an IPFC with constant series voltage setpoints specified; FACTS device N+1 must be the slave device (i.e., its MODE is 6 or 8) of this IPFC.
	8 - slave device of an IPFC with constant series voltage setpoints specified; FACTS device N-1 must be the master device (i.e., its MODE is 5 or 7) of this IPFC. The complex $V_d + jV_q$ setpoint is modified during power flow solutions to reflect the active power exchange determined by the master device.
	If J is specified as 0, MODE must be either 0 or 1. MODE = 1 by default.
PDES	Desired active power flow arriving at the terminal end bus; entered in MW. PDES = 0.0 by default.
QDES	Desired reactive power flow arriving at the terminal end bus; entered in MVAR. QDES = 0.0 by default.
VSET	Voltage setpoint at the sending end bus; entered in pu. VSET = 1.0 by default.
SHMX	Maximum shunt current at the sending end bus; entered in MVA at unity voltage. SHMX = 9999.0 by default.
TRMX	Maximum bridge active power transfer; entered in MW. TRMX = 9999.0 by default.
VTMN	Minimum voltage at the terminal end bus; entered in pu. VTMN = 0.9 by default.
VTMX	Maximum voltage at the terminal end bus; entered in pu. VTMX = 1.1 by default.
VSMX	Maximum series voltage; entered in pu. VSMX = 1.0 by default.

IMX	Maximum series current, or zero for no series current limit; entered in MVA at unity voltage. IMX = 0.0 by default.
LINX	Reactance of the dummy series element used during model solution; entered in pu. LINX = 0.05 by default.
RMPCT	Percent of the total Mvar required to hold the voltage at bus I that are to be contributed by the shunt element of this FACTS device; RMPCT must be positive. RMPCT is needed only if there is more than one local or remote voltage controlling device (plant, switched shunt, FACTS device shunt element, or VSC dc line converter) controlling the voltage at bus I to a setpoint. RMPCT = 100.0 by default.
OWNER	Owner number, (1 through the maximum number of owners at the current size level: see Table 1-1). OWNER = 1 by default.
SET1,SET2	If MODE is 3, resistance and reactance respectively of the constant impedance, entered in pu; if MODE is 4, the magnitude (in pu) and angle (in degrees) of the constant series voltage with respect to the quantity indicated by VSREF; if MODE is 7 or 8, the real (V_d) and imaginary (V_q) components (in pu) of the constant series voltage with respect to the quantity indicated by VSREF; for other values of MODE, SET1 and SET2 are read, but not saved or used during power flow solutions. SET1 = 0.0 and SET2 = 0.0 by default.
VSREF	Series voltage reference code to indicate the series voltage reference of SET1 and SET2 when MODE is 4, 7 or 8: 0 for sending end voltage, 1 for series current. VSREF = 0 by default.

FACTS device data input from a Power Flow Raw Data File is terminated with a record specifying a FACTS device number of zero.

PSS™E's FACTS device model contains a shunt element that is connected between the sending end bus and ground, and a series element connected between the sending and terminal end buses.

A unified power flow controller (UPFC) has both the series and shunt elements active, and allows for the exchange of active power between the two elements (i.e., TRMX is positive). A static synchronous series compensator (SSSC) is modeled by setting both the maximum shunt current limit (SHMX) and the maximum bridge active power transfer limit (TRMX) to zero (i.e., the shunt element is disabled).

A static synchronous condenser (STATCON) or static compensator (STATCOM) is modeled by a FACTS device for which the terminal end bus is specified as zero (i.e., the series element is disabled).

An Interline Power Flow Controller (IPFC) is modeled by using two consecutively numbered series FACTS devices. The first of this pair must be assigned as the IPFC master device by setting its control mode to 5 or 7, and the second must be assigned as its companion IPFC slave device by setting its control mode to 6 or 8. In an IPFC, both devices have a series element but no shunt element. Therefore, both devices typically have SHMX set to zero, and VSET of both devices is ignored. Conditions at the master device define the active power exchange between the two devices.

Figure 3-16 shows the PSS™E FACTS control device model with its various setpoints and limits.

Each FACTS sending end bus must be a type 1 or 2 bus, and each terminal end bus must be a type 1 bus. Refer to Section 4.3.4 for other topological restrictions and for details on the handling of FACTS devices during the power flow solution activities.

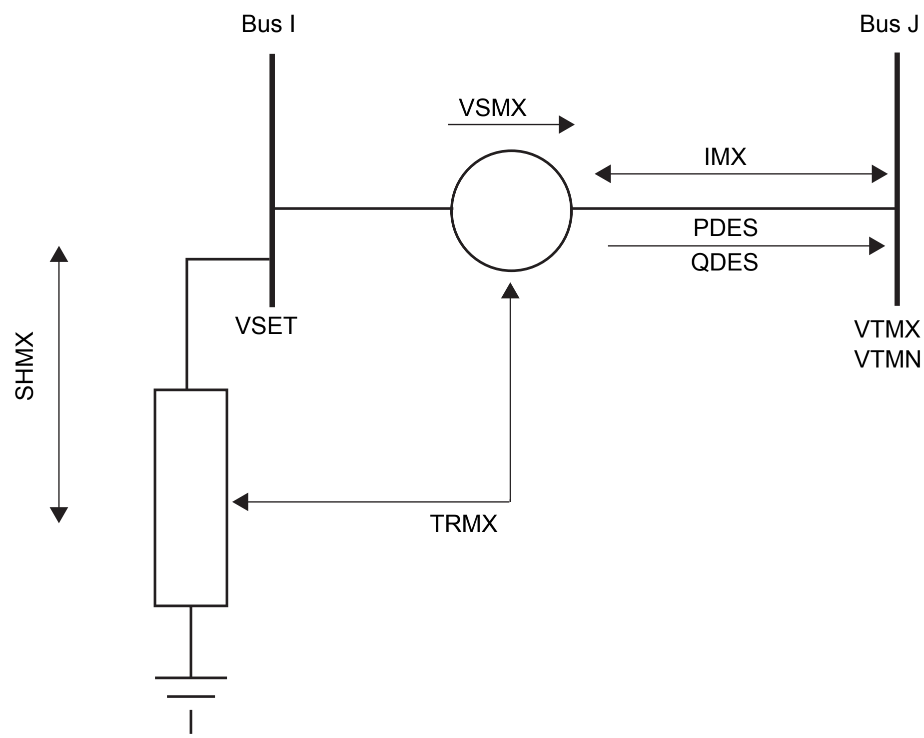


Figure 3-16. Basic FACTS Control Device Model

3.3 Importing Power Flow Data

Importing the Power Flow Raw Data File is facilitated by the ***File>Open*** option, or more directly by clicking the ***Open*** toolbar button on the File toolbar.

This option will give access to the Open dialog where the available *.raw* files will be listed in the user's directory (see Figure 3-17). Clicking the ***Open*** button will initiate data import once the required file has been selected. Prior to data import, the user will be given the option of using the NAMES or NUMBERS option for importing data records. This selection will override the selection made (see Section 1.7.10).

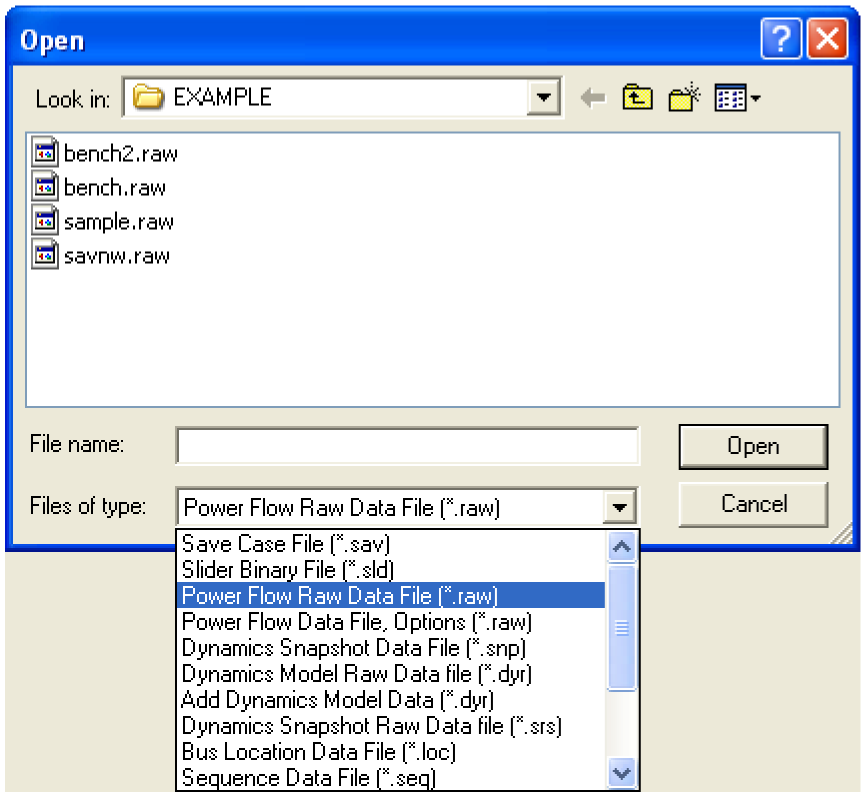


Figure 3-17. Open Dialog Showing Available Raw Data Files for Selection

During the processing of data records, the Output Bar will show a message each time a category of data is imported. Additionally, the view of the populated spreadsheet will open to show the data in the working case.

Generally, specifying a data record within the Power Flow Raw Data File with a 'Q' in column one is used to indicate that the end of all data records in the raw data file. This end of data input indicator:

1. Is not permitted during the input of the case identification data records.

2. Is allowed when the first record of the four or five record block for a two- or three-winding transformer are being processed but not on the subsequent records of such a block.

3. Is allowed when the first record of the three record block for a two-terminal dc transmission line is being processed but not on the second or third records of such a block.

4. Is allowed when the first record of the three record block for a VSC dc transmission line is being processed but not on the second or third records of such a block.

5. Is permitted when the first of the series of data records defining a multi-terminal dc transmission line is being processed but not on the remaining records of such a block.

The data processing may be terminated by entering the AB interrupt control code.

3.3.1 How PSS™E Manages Sequence Numbers

Specific Network element data imported into a working file in PSS™E are stored in data arrays. The following subsections briefly describe the assignments for each data category.

As each bus data record is read (i.e., a bus not previously read), it is assigned to a bus sequence number which defines the location of data for the bus in the various bus data arrays. Bus sequence numbers are assigned sequentially starting with 1 in the order in which bus data records are read.

Each bus for which a generator data record is read is assigned a plant sequence number, which defines the location of its plant-related generator data in the plant data arrays. Within each plant's data, for each machine for which a generator data record is read, a machine sequence number is assigned defining the location of its machine-specific data in the machine data arrays. Plant and machine sequence numbers are assigned sequentially starting with 1 in the order in which generator data records are read. It is permissible to enter a generator data record for a bus that was assigned a type code of 1 or 4 during bus data input.

Each load introduced into PSS™E is assigned a load sequence number, which defines the location of its data in the load data arrays. Load sequence numbers are assigned sequentially starting with 1 in the order in which load data records are read.

Each ac branch introduced into PSS™E is assigned a branch sequence number, which defines the location of its data in the branch data arrays. Branch sequence numbers are assigned sequentially starting with 1 in the order in which branch data and transformer data records are read.

Each two-winding transformer is assigned a two-winding transformer sequence number, which defines the location of its data in the two-winding transformer data arrays; it is also assigned a branch sequence number. Similarly, each three-winding transformer is assigned a three-winding transformer sequence number, as well as three two-winding transformer sequence numbers and three branch sequence numbers. Transformer sequence numbers are assigned sequentially starting with 1 in the order in which transformer data record blocks are read.

3.3.2 Adding Data to an Existing Case

When the user wishes to add data from a Power Flow Raw Data file to the network contained in the working case, the IC data item on the first input record must be set to 1 (see Section 3.2.1).

New buses, loads, generators, branches, and transformers are treated in the same manner as in base case data input. Bus sequence numbers, machine sequence numbers, and so on are assigned starting with the next available location in the respective data arrays.

When entering data for an existing piece of equipment, complete data records must be entered. If not, omitted data items will take on their default values rather than retaining their previous values.

3.3.3 Adding a Subsystem to an Existing Case

PSS™E facilitates the capability to add to the working case a subsystem of the network whose complete representation is contained in a Power Flow Raw Data By Subsystem file (with the *.raw* file extension). When using this mode of data entry, the following functions may be performed:

1. All buses and their connected equipment within a specified subsystem contained in the Power Flow Raw Data File may be appended to the working case.

2. All branches in the Power Flow Raw Data File for which both buses are in the working case and only one bus is within a specified subsystem (ties) may be appended to the working case.

3. Any bus that is within a specified subsystem and connected to a bus that is not in the working case may be identified as a boundary bus; the type code of each boundary bus is changed to 5, 6, or 7 as appropriate. For more information see Chapter 9, where the process of making network equivalents, along with the topic of boundary, buses is discussed.

The process of adding complete subsystems to an existing working case is facilitated with the ***File>Open*** menu when selecting the Power Flow Raw Data File, Options file type is selected (see Figure 3-18).

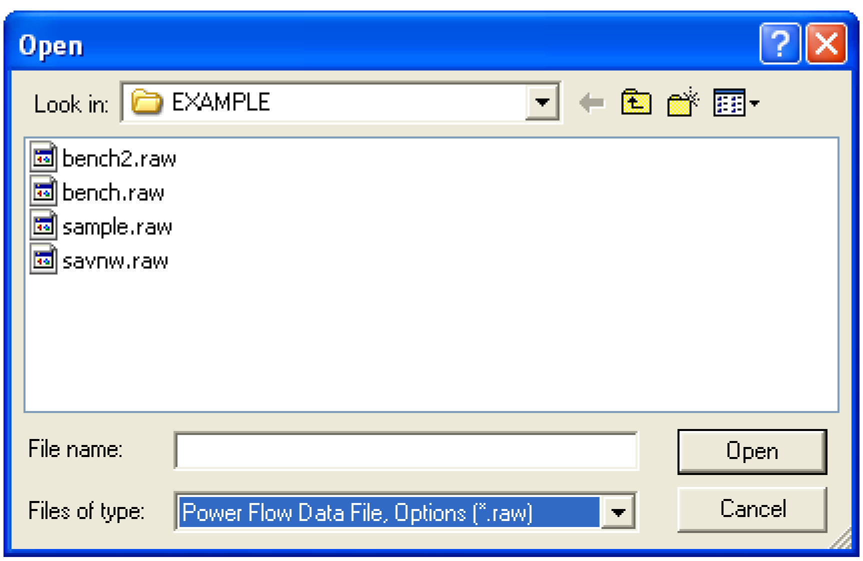


Figure 3-18. Available Raw Data Files with Options

When the file is opened another dialog will pop up with several options for reading the raw power flow data (see Figure 3-19). Selecting the Subsystem option will read in the raw data as a complete subsystem to the working case.

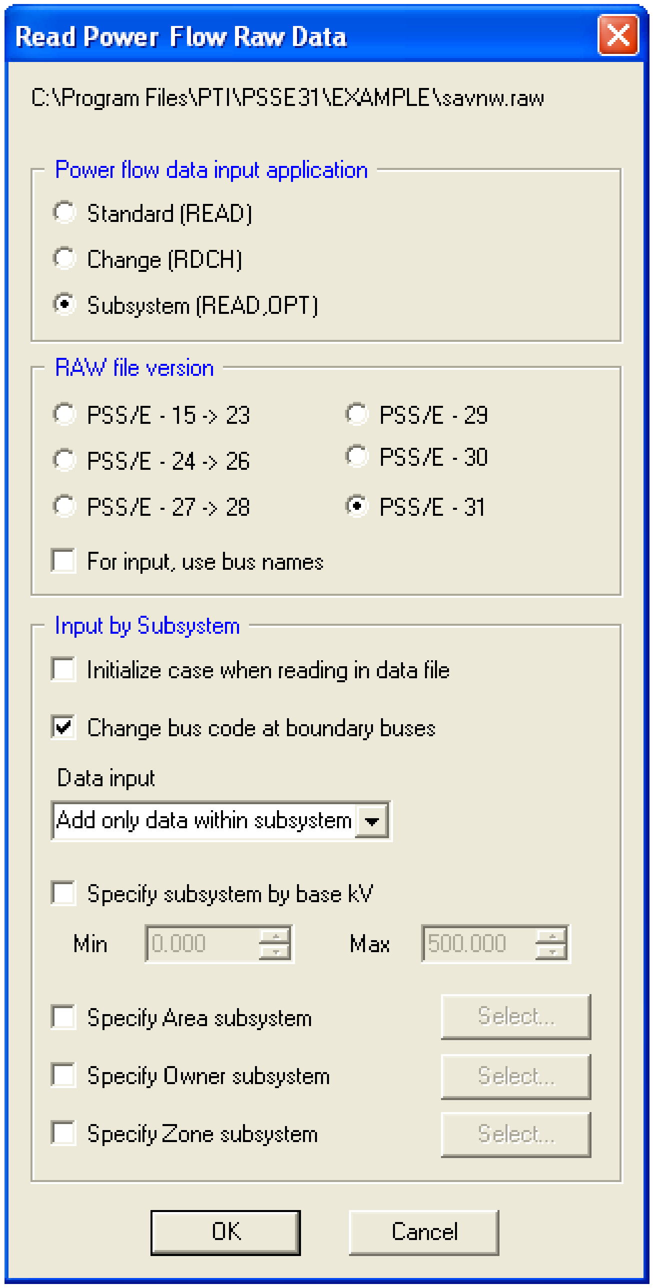


Figure 3-19. Add Subsystem File Type in the Read Power Flow Raw Data Dialog

3.3.4 Changing Data in an Existing Case

Existing data in a working file can be changed in bulk by reading from a Power Flow Change Data file (with the *.raw* file extension). That file will have the same format used for bulk data entry as described in Section 3.2 with the exception that the case identification data records are omitted (i.e., the first data record is expected to be a bus data record).

For all record types, except the multisection line grouping data, when reading a data record corresponding to an existing component, data items that are specified replace those contained in the working case while data items omitted on the data record have their values unchanged in the working case.

Data entry is performed as for a new case using the ***File>Open***. The objective of changing data rather than reading in new data, is signaled by selection of a Power Flow Data File, Options in the ***Open*** dialog, followed by selecting the Change option in the Read Power Flow Raw Data dialog, (see Figure 3-20).

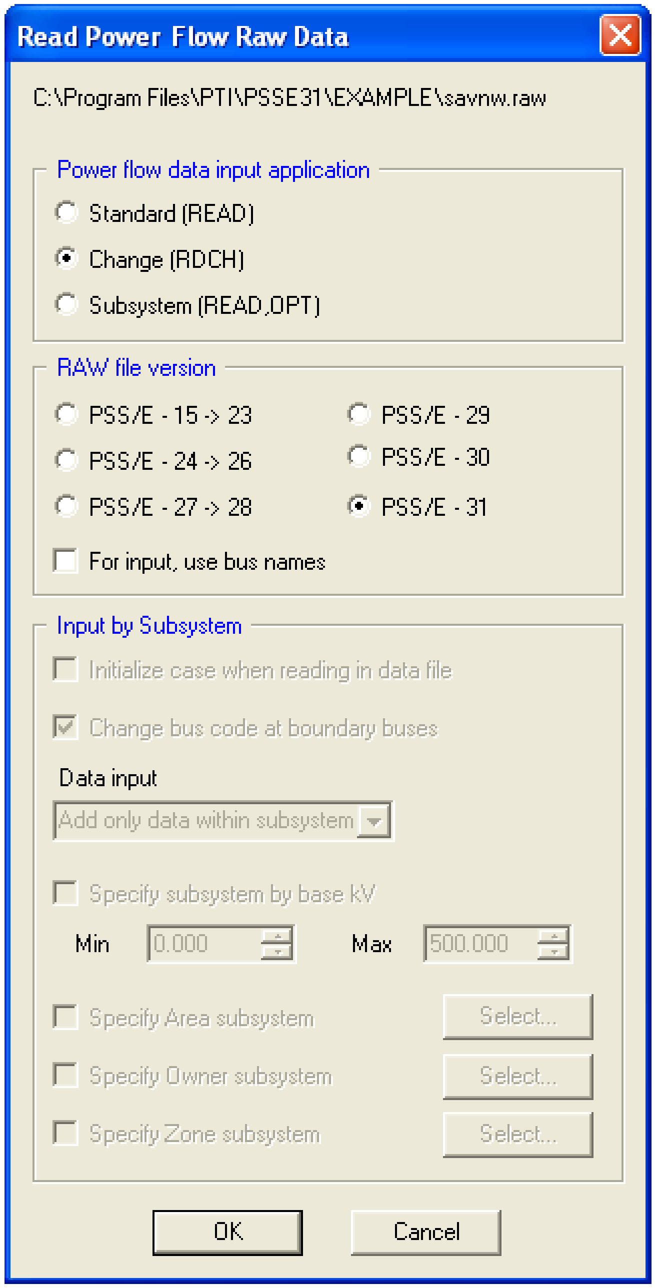


Figure 3-20. Selecting the Power Flow Change Data File

3.3.5 Adding Machine Impedance Data

When establishing an initial working case in PSS™E for basic power flow studies it is not necessary to make a complete data record in the Generator data category. Some analytical activities however, including fault analysis and balanced switching, require more detailed information on generating plants. That data can be entered from a Machine Impedance Data File (with the *.rwm* extension).

Using this data file it is possible to:

1. Add machines at an existing generator bus (i.e., at a plant).
2. Enter the machine quantities MBASE, ZSORCE, XTRAN, and GENTAP into the working case.
3. Apportion the total plant output and power limits, as contained in the working case, among the machines at the plant.

The Machine Impedance Data File will comprise a series of records in the following format:

```
I, ID, FP, FQ, MBASE, ZR, ZX, RT, XT, GENTAP, STAT
```

where:

I	Bus number. Bus I must reside in the working case with a generator table entry assigned to it. No default is allowed.
ID	One- or two-character machine identifier used to distinguish among multiple machines at a plant (i.e., at a generator bus). ID = '1' by default.
FP,FQ	Fractions of total plant active and reactive power output, respectively, to be assigned to this machine. FP and FQ are 1.0 by default.
MBASE	Total MVA base of the units represented by this machine; entered in MVA. This quantity is not needed in normal power flow and equivalent construction work, but is required for switching studies, fault analysis, and dynamic simulation. MBASE = system base MVA by default.
ZR,ZX	Complex machine impedance, ZSORCE; entered in pu on MBASE base. This data is not needed in normal power flow and equivalent construction work, but is required for switching studies, fault analysis, and dynamic simulation. For dynamic simulation, this impedance must be set equal to the unsaturated subtransient impedance for those generators to be modeled by subtransient level machine models, and to unsaturated transient impedance for those to be modeled by classical or transient level models. ZR = 0.0 and ZX = 1.0 by default.
RT,XT	Step-up transformer impedance, XTRAN; entered in pu on MBASE base. XTRAN should be entered as zero if the step-up transformer is explicitly modeled as a network branch and bus I is the terminal bus. RT+jXT = 0.0 by default.
GENTAP	Step-up transformer off-nominal turns ratio; entered in pu. GENTAP is used only if XTRAN is nonzero. GENTAP = 1.0 by default.
STAT	Machine status; 1 for in-service and zero for out-of-service. STAT = 1 by default.

Data records may be input in any order. Input is terminated with a record specifying an "I" value of zero.

Data entry uses the ***File>Open*** option. In the Open dialog, a Machine Impedance Data File will be selected, (see Figure 3-21).

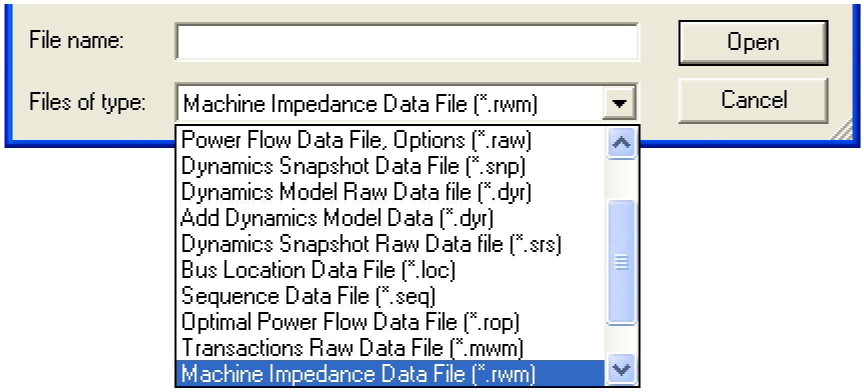


Figure 3-21. Selecting the Machine Impedance Data File

The following are notes on adding machine data:

- If, on any input record, bus I is not in the working case, if it does not have a generator (i.e., plant) slot assigned to it, or if an invalid machine identifier is specified, an appropriate message is printed, the record is ignored, and processing continues.
- If, in attempting to add a machine to the machine data arrays, the maximum number of machines or machine ownership specifications for which PSS™E is dimensioned is exceeded, an error message is printed and the record is ignored.
- When entering data records for machines already contained in the working case, complete data records must be entered. Omitted data items take on their default values rather than retaining their previous values.
- If sequence data is contained in the working case, for all machines being added to the working case their three sequence machine impedances used in the fault analysis activities are set to the impedance ZSORCE specified on the data input record.
- PSS™E cycles through all plants for which at least one machine data record had been successfully read from the Machine Impedance Data File. The sums of the active and reactive power split fractions of all the plant's machines for which a data record was read with a status flag of one are calculated. Then the plant totals of machine powers and power limits for those machines with a status flag of one which were initially in the case are calculated. (If any of the above sums are zero, the corresponding quantities of the out-of-service machines are used.) Finally, the machine power outputs and limits of all machines at the bus for which a data record was read are set to the product of the corresponding plant quantity and the ratio of the machine fraction to the plant's sum of machine fractions. Plant totals are then updated as the sum of the corresponding machine quantities
- In processing each plant, if any machine is encountered that existed at the plant prior to reading the Machine Impedance Data File, and for which no data was read, such machine is alarmed and either placed out-of-service with its data items in the working case unchanged or deleted from the working case, as appropriate. Further, any machine whose status flag is changed is tabulated. In either of these cases, the plant totals could be changed and the plant configuration should be examined to verify that it is as intended.
- This data input activity is not sensitive to any interrupt control code options.

3.3.6 Importing a Saved Case

Bulk power flow data can be imported from a previously saved binary case file (Saved Case File with extension *.sav*).

PSS™E is able to access Saved Case Files written on other computer platforms. Refer to the host-specific PSS™E usage manual for further information on reading foreign files.

If the file to be used is not in a Saved Case File format recognized by this release of PSS™E, the following error message is generated and the importing process is terminated:

```
FILE filename NOT IN SAVED CASE FORMAT
```

If the Saved Case exceeds the current capacity limits of PSS™E, an appropriate error message is printed along with the case title and dimensional information.

Generally, saved Case Files created by the current and previous releases of PSS™E can be accessed. However, a Saved Case File written by the current version of PSS™E is normally not able to be read by earlier releases of the program.

PSS™E can access only Saved Case Files written by PSS™E. It cannot read files written by any other programs.

To import a Saved Case file, the ***File>Open*** option is used. In the Open dialog, selection is made from the Save Case File (**.sav*) file list (see Figure 3-22).

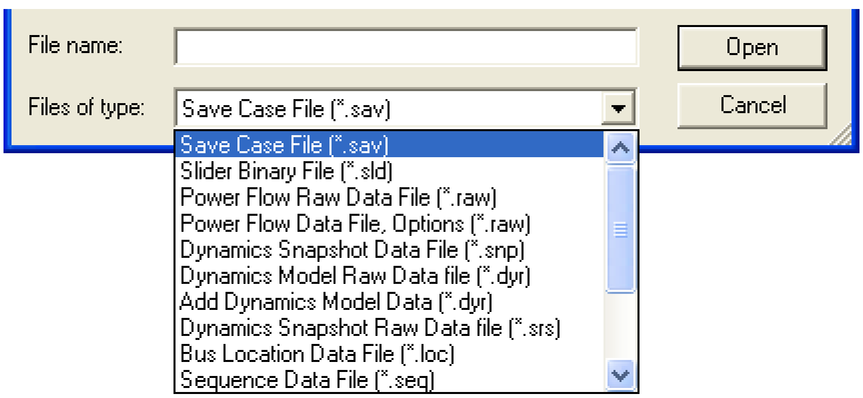


Figure 3-22. Selecting Saved Case File List

When picking up Saved Case Files created prior to PSS™E-27, transformers with nonzero values of charging and winding 2 side (previously referred to as untapped side) line shunt in the positive sequence are logged in the Output Bar (see Section 1.3.4); charging is set to zero, and the winding 2 side line shunt is added to the winding 1 side line shunt and then the winding 2 side line shunt set to zero. In the zero sequence, nonzero transformer charging and line shunts are alarmed and set to zero. Nonzero values of line length for transformers are set to zero but are not logged.

When picking up Saved Case Files created prior to PSS™E-20, zone assignments are checked and any bus assigned to zone zero is reassigned to the zone with the largest permissible zone number. The number of buses whose zone assignments are so changed is tabulated at the progress output device.

When picking up Saved Case Files created prior to PSS™E-18, branch circuit identifiers are examined to check that none contain an ampersand ("&") as their first character. If any such branches are detected, they are tabulated and the user is asked to designate a character to which these ampersands are to be changed. A check is made to ensure that this substitution does not result in two or more branches with the same circuit identifiers connecting a pair of buses; if it does the user is asked to specify another character to be used.

Very old Saved Case Files created prior to PSS™E-7 cannot be opened directly. Such files must be converted to PSS™E-7 Saved Case File format by the auxiliary program CASCNV, which was supplied with PSS™E-7 through PSS™E-10.

Following the successful restoration of the Saved Case into the working case, the two-line case title is printed, in the Output Bar, followed by the time and date at which the case was last saved. In addition, whenever any of the PSS™E run-time option settings as contained in the Saved Case File differ from those set in PSS™E's working memory, the settings from the Saved Case are established and an appropriate message is printed.

This import activity is not sensitive to any interrupt control code options.

3.3.7 Adding a Long Title to the Existing Case

In the Case Identification data, which is the initial information in a Power Flow Raw Data file, a two line header is included. Those two lines of data are limited to 60 characters (see Section 3.2.1).

PSS™E allows the use of a long title containing up to 16 lines of alphanumeric data, each of which may contain up to 72 characters. This data is placed into an array that is carried along with the case as it is saved and retrieved. The user may utilize the long title to enter more detailed case descriptive information than the two 60-character title lines, which are printed by each output reporting activity, can accommodate.

Long title records are placed into the long title arrays in the exact format in which they are entered. If any input record contains more than 72 characters, those beyond column 72 are ignored. If a record contains fewer than 72 characters, the corresponding title line is blank filled.

The long title can be entered manually or read from a file. If input is taken from a data file and it contains more than 16 lines, only the first 16 are recognized. If the data file contains fewer than 16 lines, the following message is printed, those title lines for which no data was read are blank filled, and the input activity is terminated.:

```
OUT OF FILE DATA--SWITCH TO TERMINAL INPUT MODE
```

At this point the user can continue to add to the long title or initiate other PSS™E functions.

Import of a long title is not sensitive to any interrupt control code options.

To import data comprising the long title, the ***File>Import>Import long title (RETI)…*** option is used (see Figure 3-23).

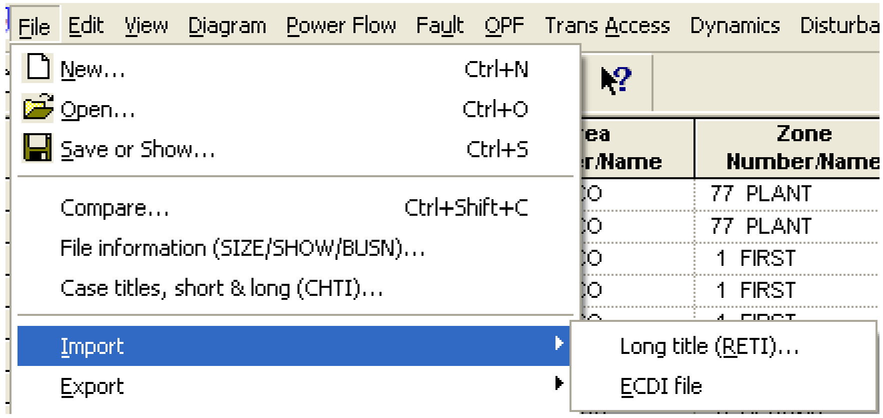


Figure 3-23. Initializing Import of Long Title Data

Subsequent to selecting the ***Import long title (RETI)*** option, a **Select file containing long case title** dialog will be opened where the appropriate file can be selected and the ***Open*** button clicked to initiate the import of the long title data, (see Figure 3-24).

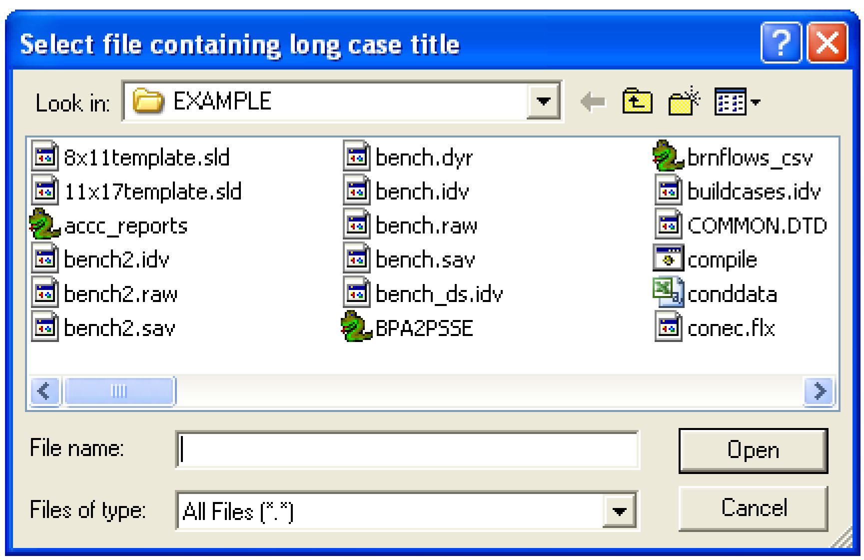


Figure 3-24. Selecting Long Title File

Once entered it is possible to edit the long title as well as:

- Enter the entire long title manually without prior preparation of a Long Title File.
- Continue adding long title lines if there were less than 16 lines of data in the Long Title File selected by the ***File>Import*** option.
- Enter and/or edit the short two-line title lines.

To initiate editing or addition of short and long title line data, use the ***File>Case titles, short & long (CHTI)...*** option (see Figure 3-25).

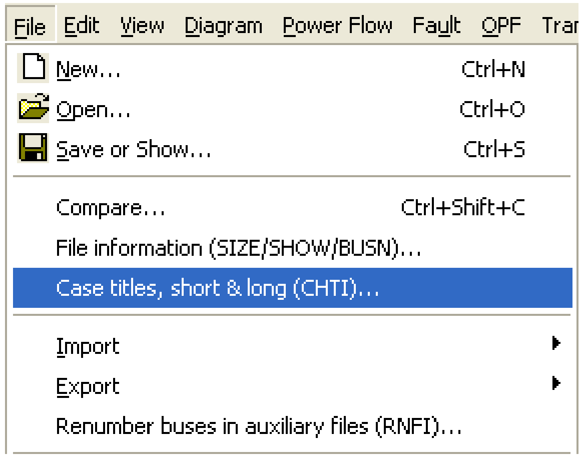


Figure 3-25. Initializing the Long Title Editing Facility

Selecting this option will open the Case Titles dialog where both long and short titles can be edited or appended (see Figure 3-26).

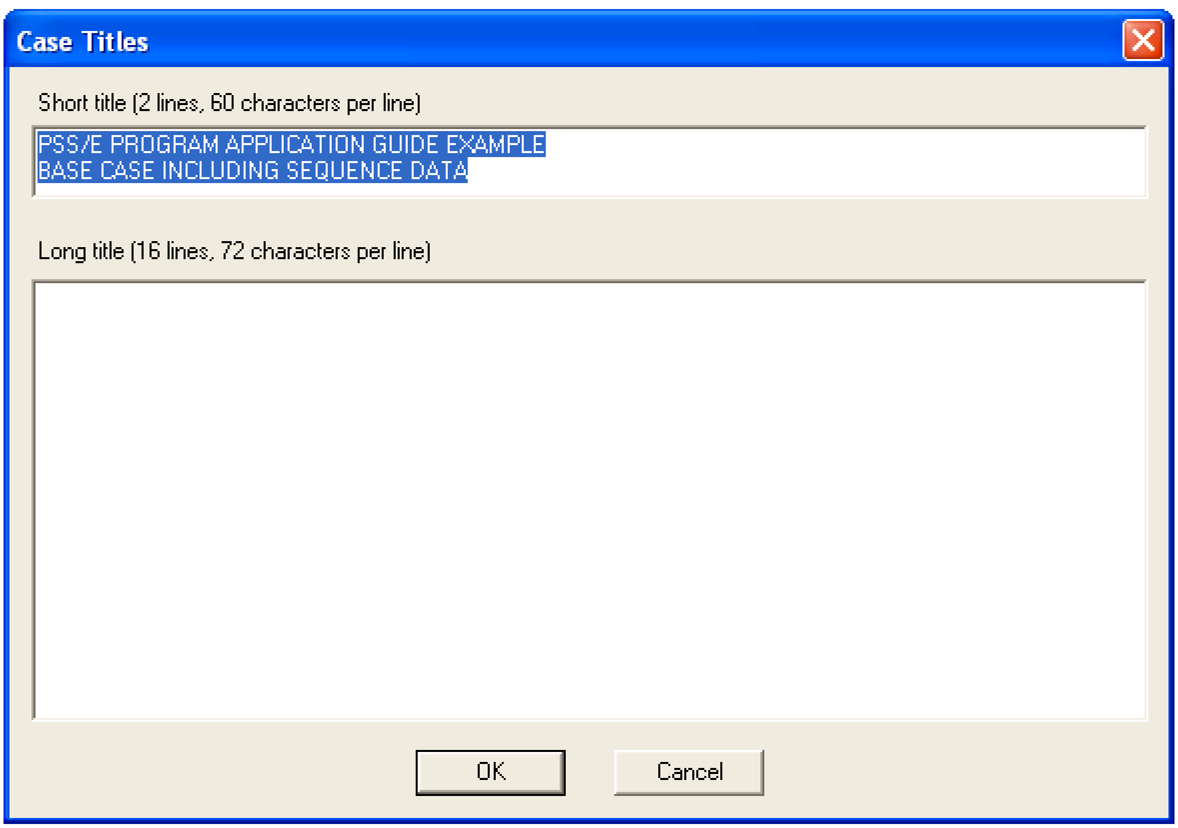


Figure 3-26. Case Titles Dialog for Title Editing

3.4 Viewing Power Flow Data

PSS™E facilitates the listing of all data in the working case for viewing, problem checking or for documentation. Data can be listed in their entirety or by category. Further it is possible to filter the amount of data to be listed based on areas, owners, zones, base kV, buses or any combination thereof.

The data listing is initiated from the ***Power Flow>List Data…*** option, the selection of which will open the List Data dialog (see Figure 3-27). Alternatively, the user can use the ***List Data*** toolbar button which appears on the Reporting toolbar.

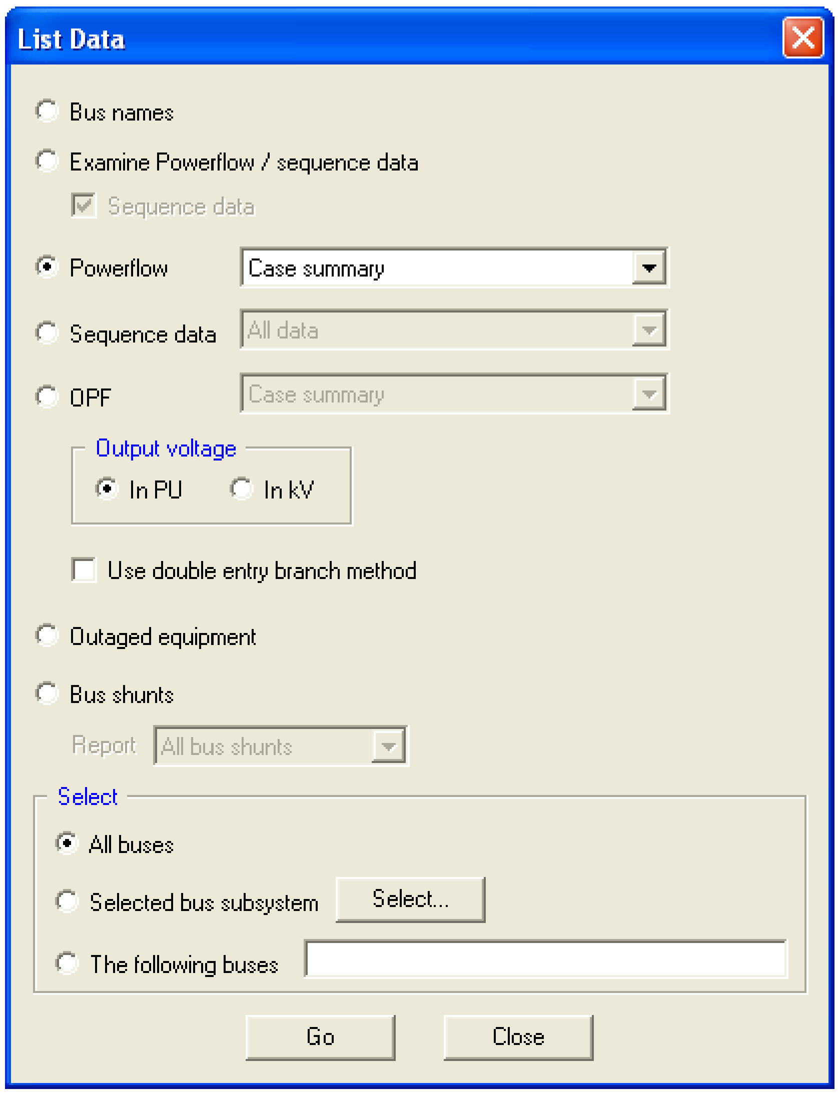


Figure 3-27. List Data Dialog

3.4.1 Selecting an Output Device

By default the listing described above will appear in the Report tab of the Output Bar. From here it may be copied and pasted to the user's word processor of choice, saved to a file or printed.

Since the lists can be lengthy, the user has the option to direct the lists to alternative devices using the ***I/O Control*** option (see Figure 3-28). The figure is an abbreviated view of the complete set of I/O functions but shows the menu items relevant here for directing Report and Progress output.

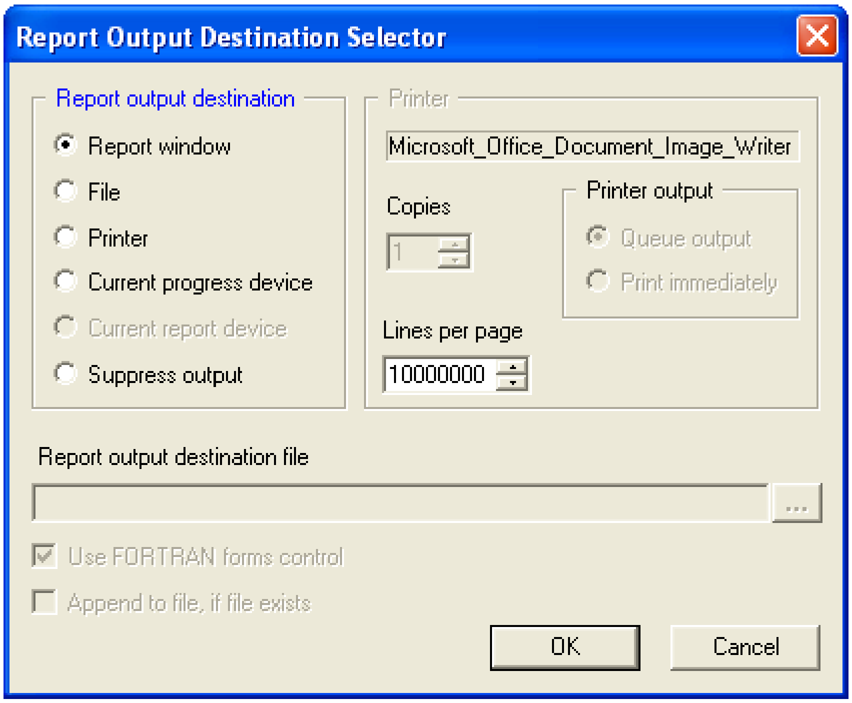


Figure 3-28. Input/Output Control Options

To re-direct a list it is necessary to select the ***Direct Report output (OPEN)…*** option at which point the Report Output Destination Selector dialog is open (see Figure 3-29).

```
ALPHABETIC BUS LIST:

X-- NAME --X BASKV    BUS#  X-- NAME --X BASKV    BUS#  X-- NAME --X BASKV    BUS#
CATDOG       230.00   3008  CATDOG_G     13.800   3018  DOWNTN       230.00    154
E. MINE      500.00   3002  EAST230      230.00    203  EAST500      500.00    202
HYDRO        500.00    201  HYDRO_G      20.000    211  MID230       230.00    153
MID500       500.00    152  MINE         230.00   3001  MINE_G       13.800   3011
NUC-A        21.600    101  NUC-B        21.600    102  NUCPANT      500.00    151
RURAL        230.00   3007  S. MINE      230.00   3003  SUB230       230.00    205
SUB500       500.00    204  UPTOWN       230.00   3006  URBGEN       18.000    206
WEST         230.00   3005  WEST         500.00   3004
```

Figure 3-29. Report Output Destination Selector Dialog

There are a variety of options in the window.

Reports can be directed to:

- A file, for which is specified in the Report output destination file input field.
- A printer, for which the available printers will be made available with options on output, copies and lines per page plus it is possible to print immediately or queue the output.
- Current progress device.
- Current report device.

In addition:

- Output can be suppressed.
- Fortran forms control can be used.
- The report being generated can be appended to an existing file or the file overwritten.

3.4.2 Listing Bus Names

The first item in the List Data dialog is Bus names. This selection will result in a listing of all buses in the working case in alphabetical order showing the extended bus name and bus number. A listing for the example case *savnw.sav* (see Figure 3-30).

```
ALPHABETIC BUS LIST:

X-- NAME --X BASKV   BUS# X-- NAME --X BASKV   BUS# X-- NAME --X BASKV   BUS#
CATDOG       230.00  3008 CATDOG_G     13.800  3018 DOWNTN       230.00   154
E. MINE      500.00  3002 EAST230      230.00   203 EAST500      500.00   202
HYDRO        500.00   201 HYDRO_G      20.000   211 MID230       230.00   153
MID500       500.00   152 MINE         230.00  3001 MINE_G       13.800  3011
NUC-A        21.600   101 NUC-B        21.600   102 NUCPANT      500.00   151
RURAL        230.00  3007 S. MINE      230.00  3003 SUB230       230.00   205
SUB500       500.00   204 UPTOWN       230.00  3006 URBGEN       18.000   206
WEST         230.00  3005 WEST         500.00  3004
```

Figure 3-30. Bus Alphabetical Listing

3.4.3 Listing Power Flow/Sequence Data

The second item in the List Data dialog is Power Flow/Sequence Data. This will result in an examination of all network elements in the selected subsystem on a bus by bus basis. That information includes the bus and bus shunt data as well as all elements connected to the bus.

If the Sequence data option is checked, only the sequence data is listed on the same basis.

3.4.4 Power Flow Details

There are three menu items which facilitate the listing of data by application. They are:

- Power flow data discussed in Section 3.2.
- Sequence data, to be discussed in Chapter 7.
- OPF data, to be discussed in the *PSS™E OPF Manual*.

In Figure 3-27, two options are available when listing by category:

- **Output voltage:** The user can select to output voltage information by kV or by pu.
- **Use double entry branch method:** This allows selection of nontransformer branch listing in either single or double entry format. In single entry format, each nontransformer ac series branch appears once in the listing: with the lower ordered bus (number or name) listed as the *"from bus"*. In double entry format, each branch is listed in both directions.

The drop-down list for the Power flow data is shown in Figure 3-31 where, in addition to having all the power flow data categories available for listing, there is the option to see a case summary.

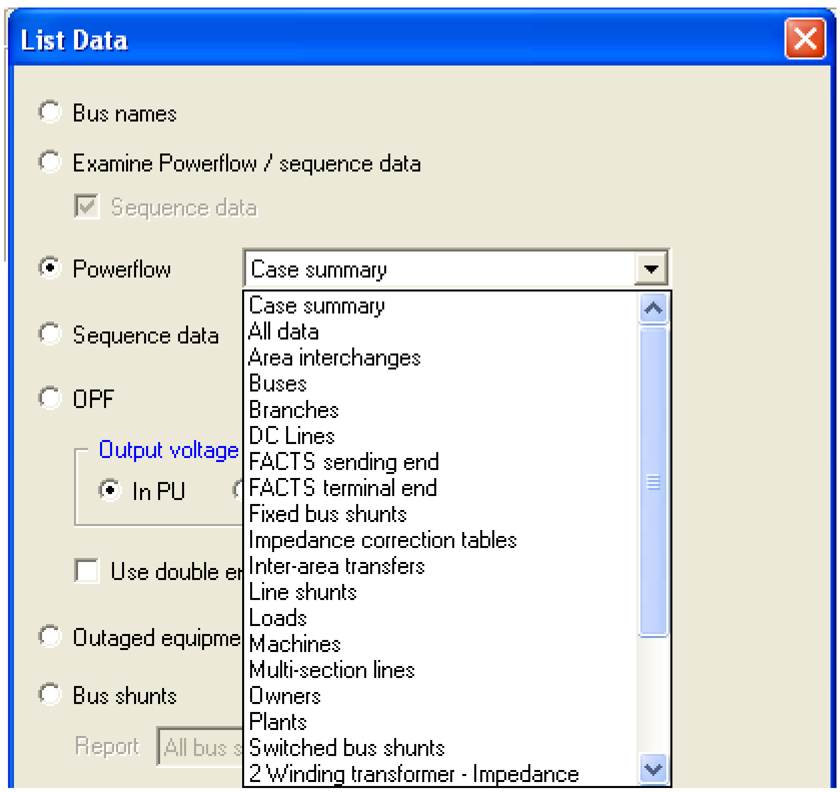


Figure 3-31. Power Flow Drop-down List by Category

3.4.4.1 Case Summary

Figure 3-32 shows the case summary for the *savnw.sav* working file.

The first case summary page tabulates various system totals and solution parameters. The BUSES summary items are interpreted as follows:

TOTAL	Total number of buses in the case, including star point buses of three-winding transformers.
PQ<>0.	Total number of type one buses with nonzero load.

PQ=0.	Total number of type one buses with no load, including star point buses of in-service three-winding transformers.
PE/E	Total number of type two buses that are regulating voltage (i.e., not at a var limit).
PE/Q	Total number of type two buses that are at a reactive power limit (these buses have their type code set to -2 by the power flow solution activities).
SWING	Total number of type three buses.
OTHER	Total number of buses having other type codes, including star point buses of out-of-service three-winding transformers (these are usually type four (i.e., disconnected) buses and/or those buses identified as boundary buses).

```
     PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E      WED, APR 07 2004  20:13
PSS/E PROGRAM APPLICATION GUIDE EXAMPLE                          SYSTEM SUMMARY
BASE CASE INCLUDING SEQUENCE DATA

------------------BUSES------------------        GENERATION AREAS ZONES OWNERS AREA
TOTAL PQ<>0. PQ=0. PE/E  PE/Q SWING OTHER  LOADS PLANTS MACHS USED  USED  USED TRANS
  23     7    10     3     2     1     0      8     6     6     3     4     7     4
------------------AC BRANCHES------------------- 3WND MULTI-SECTION X---DC LINES--X FACTS
 TOTAL    RXB     RX    RXT   RX=0.    IN    OUT XFRM  LINES SECTNS 2-TRM N-TRM VSC  DEVS
    34     22      1     11      0     34      0    0      2      4     0     0   0     0

TOTAL GENERATION PQLOAD   I LOAD   Y LOAD   SHUNTS  CHARGING  LOSSES    SWING
MW      3258.7   3200.0      0.0      0.0      0.0       0.0    58.7    258.7
MVAR     964.2   1950.0      0.0      0.0   -291.5    1810.1  1115.7    104.0

TOTAL MISMATCH =    0.02 MVA X------- AT BUS --------X    SYSTEM   X-------- SWING --------X
 MAX. MISMATCH =    0.01 MVA    211 HYDRO_G     20.000      BASE     3011 MINE_G      13.800
  HIGH VOLTAGE = 1.04043 PU     211 HYDRO_G     20.000     100.0
  LOW  VOLTAGE = 0.93892 PU     154 DOWNTN     230.00   ADJTHR ACCTAP TAPLIM  THRSHZ  PQBRAK
                                                        0.0050 1.0000 0.0500 0.000100  0.700
X------ SOLV AND MSLV ------X  X--------- NEWTON ---------X  X----- TYSL -----X
 ACCP  ACCQ  ACCM   TOL  ITER  ACCN  TOL ITER  DVLIM NDVFCT  ACCTY   TOL  ITER BLOWUP
1.600 1.600 1.000 0.00010 100  1.00 0.100  20 0.9900 0.9900  1.000 0.000010  20  5.00

-------------------------------------------------------------------------------

     PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E      WED, APR 07 2004  20:13
PSS/E PROGRAM APPLICATION GUIDE EXAMPLE                                 WORST
BASE CASE INCLUDING SEQUENCE DATA                                   MISMATCHES
  BUS# X-- NAME --X BASKV      MW       MVAR       MVA
   211 HYDRO_G      20.000    -0.01      0.00      0.01
   201 HYDRO        500.00     0.01      0.00      0.01
```

Figure 3-32. Case Summary for the savnw.sav Working File

The BRANCHES summary tabulates ac branches. Its data items are interpreted as follows:

TOTAL	Total number of ac branches in the case; includes two-winding transformers (both those which were specified as two-winding transformers and those which are members of three-winding transformer models), branches treated as zero impedance lines, and branches that are members of multisection line groupings.
RXB	Total number of nontransformer branches with charging (i.e., transmission lines); excludes zero impedance lines.
RX	Total number of nontransformer branches with no charging (e.g., series capacitors, equivalent branches); excludes zero impedance lines.
RXT	Total number of two-winding transformer branches; includes those at nominal ratio and those which are members of three-winding transformers.

RX=0.	Total number of branches treated as zero impedance lines.
IN	Total number of in-service branches.
OUT	Total number of out-of-service branches.

The number of multisection line groupings and the number of ac branches that are members of multisection line groupings are tabulated separately. The total numbers of three-winding transformers, dc transmission lines, and FACTS devices are tabulated separately. The service status of three-winding transformers, multisection line groupings, dc lines, and FACTS devices is not tabulated.

System totals of generation, load, and so on are tabulated. The quantity shown as SHUNTS is the sum of bus shunts, switched shunts, line connected shunts, magnetizing admittance of transformers, and the shunt elements of FACTS devices. Losses are the sum of I^2R and I^2X losses for in-service lines plus dc line and FACTS device losses, and do not include charging and line shunt contributions. The loss and swing bus power totals are meaningful only if the working case represents a solved system condition. The highest and lowest pu bus voltages are listed along with the largest individual bus and total system mismatch. Up to two swing buses are identified and if more than two type three buses exist in the case, only two of these are listed.

The second page of the case summary tabulates those buses in the working case with the largest mismatches. Up to 25 buses are listed, but not more than the number that can fit on one page.

3.4.4.2 Area Interchange Data

Any area containing one or more equipment items is listed in the area interchange data listing. The tabulation is in ascending area number order. If the output listing is by area subsystem, the area listing is restricted to those areas specified.

If an area has an area slack bus designated for it, its number, name, base voltage, and active power output are tabulated in the listing. This is followed by the plant active power limits, which are taken as the sums of these limits for the in-service machines at the plant. If the total power output is outside of these limits, an asterisk ("*") is printed following the generator power. The number of buses, loads, and dc buses residing in each area is also tabulated.

The final line tabulates the summation of the listed desired interchanges.

3.4.4.3 Bus Data

A bus type code of -2 indicates a type two bus whose generation is at a reactive power limit. This is set by the various power flow solution activities.

The number of loads independently modeled at the bus is tabulated in the column labeled LOADS. Shunt data tabulated are at nominal values (i.e., at 1.0 pu voltage), and do not include any constant admittance load modeled at the bus.

3.4.4.4 Branch Data

The branch data listing may be in either single or double entry format. In single entry format, each nontransformer ac series branch appears once in the listing: with the lower ordered bus (number or name) listed as the "*from bus*". In double entry format, each branch is listed in both directions.

Branches are ordered in ascending numerical or alphabetical order by "*from bus*", and, for each "*from bus*", in ascending order by "*to bus*". Parallel circuits between any pair of buses are tabulated in ascending circuit identifier order. An asterisk ("*") follows the number, name and base voltage of the bus designated as the metered end.

The column labeled "ZI" contains a "Z" if the branch is treated as a zero impedance line; for other branches, the "ZI" column is blank. The column labeled "ST" is the status flag of the branch, with 0 indicating out-of-service, and 1 indicating in-service. The remaining data items in this report category correspond to data items specified in branch data input records.

3.4.4.5 Dc Line Data

Each dc line contained in the working case is tabulated in the dc line listing. The dc line listing has two-terminal lines in ascending dc line number order listed first, followed by multi-terminal lines in ascending dc line number order, followed by VSC dc lines in VSC dc line name alphabetical order. In addition to the dc line input data, solution results are listed. For each converter of a two-terminal or multi-terminal line, the alpha or gamma angle is printed along with the apparent ac system complex load and the tap setting.

For each two-terminal line, the dc line current (DCAMPS) and the compounded dc line voltage (VCOMP) are printed on the first line of the output block, and the dc voltage at each end of the line is printed with the converter data. The winding one tap ratio (RATIO) of an ac transformer that is controlling a dc line quantity is shown following the ac transformer identifiers in the output block of the appropriate dc line.

For each multi-terminal line, the voltage at each dc bus and the current on the dc side of each converter transformer is printed. For each dc link in the line, the metered end dc bus is listed in the column labeled MET.

For each VSC dc line, the dc line current (DCAMPS) is printed. For each converter, the apparent ac system complex generation, the ac current in amps (ACAMPS), and the voltage on the dc side of the converter are listed.

3.4.4.6 FACTS Device Data

Each FACTS device contained in the working case is tabulated in the FACTS device sending end data listing and in the FACTS device terminal end data listing. FACTS devices are ordered in ascending FACTS device number order.

3.4.4.7 Transformer Impedance Correction Tables

Each transformer impedance correction table in the working case is tabulated in ascending table number order. Each table is followed by a listing of those transformers assigned to the table, their winding one off-nominal turns ratio or phase shift angle as appropriate, and their actual and nominal impedances. When the output reporting is restricted to a selected subsystem of the working case, only those transformers with at least one of its buses in the specified subsystem are tabulated. Transformers are listed in single entry format except when double entry format is specifically selected.

3.4.4.8 Interarea Transfer Data

Transfers between pairs of areas are listed in the interarea transfer data listing. Interarea transfers are ordered in ascending order by "*from area*" number, and, for each "*from area*", in ascending order by "*to area*" number. Multiple transfers between any pair of areas are tabulated in ascending interarea transfer identifier order. Interarea transfers are listed in double entry format, with each interarea transfer listed in both directions.

The line reporting the last transfer for each "*from area*" includes the algebraic sum of all transfers involving the "*from area*", as well as the area's desired net interchange.

3.4.4.9 Line Connected Shunt Data

Any nontransformer branch with a nonzero line connected shunt entry at either end is listed in the line shunt data category. Branches are tabulated in single entry format as under the branch data category except when the double entry option is selected. Branch status is tabulated in the column labeled "ST".

3.4.4.10 Load Data

Data for each load in the working case is tabulated in the load data category. Loads are listed in ascending bus order (numeric or alphabetic), and loads at each bus are in ascending load identifier order.

Loads tabulated are at nominal values (i.e., at 1.0 pu voltage). The nominal constant MVA load component may be adjusted by a load multiplier associated with an Optimal Power Flow adjustable bus load table; the load multiplier is tabulated in the column labeled "PSI". Constant admittance loads do not include any shunt elements modeled at the bus.

3.4.4.11 Generator Unit Data

Data for each machine in the working case is tabulated in the generator unit data category. Machines are listed in ascending bus order (numeric or alphabetic) and machines within each plant are in ascending machine identifier order.

For each machine, the bus type code, machine identifier and machine status flag are listed in the columns labelled CD, ID, and ST, respectively. Recall that the actual status of a machine is determined *both* by its status flag *and* the bus type code.

3.4.4.12 Multisection Line Groupings

Each multisection line grouping, along with the ac branches that are its members, is listed in the multisection line grouping data. The multisection line groupings are tabulated in single entry format as under the branch data category except when double entry option is selected. An asterisk ("*") follows the identifiers of the bus designated as the metered end.

The branches comprising each grouping are listed in series order starting at the bus listed as the "*from bus*".

3.4.4.13 Owner Data

Any owner assigned one or more equipment items is listed in the owner data listing. The tabulation is in ascending owner number order, and includes the owner name and number of buses, loads, machines, branches, dc buses, FACTS devices, and VSC dc lines assigned to each owner. If the output listing is by owner, the owner listing is restricted to those owners specified.

3.4.4.14 Plant Data

Any bus that has a generator slot assigned to it is included in the plant data listing. Note that this includes plants that are out-of-service (i.e., with a type code of one or four). The number of machines independently modeled at the plant is tabulated in the column labeled MCNS.

Any plant that regulates the voltage at a remote bus has the remote bus listed at the right-hand side of the report. Any plant regulating its own terminal voltage has no entry in this field.

3.4.4.15 Switched Shunt Data

Any bus that has a switched shunt slot assigned to it is included in the switched shunt data listing. The value listed as SHUNT is the admittance presently switched on at the bus.

Any switched shunt that regulates the voltage at a remote bus or the reactive power output of a voltage controlling device at a remote bus has the remote bus listed at the right-hand side of the report; those regulating their own terminal voltage have no entry in this field.

3.4.4.16 Two-Winding Transformer Data

Any transformer which was specified as a two-winding transformer is tabulated in the two-winding transformer impedance data listing, in the two-winding transformer winding data listing, and in the two-winding transformer control data listing. The two-winding transformer tabulations are ordered in the same manner as the branch data portion of the report; single entry format is used. The majority of data items in these report categories correspond to data items specified in the two-winding transformer data input block.

In the transformer impedance and control data listings, the column labeled "W1" contains an "F" if the bus listed as the "*from bus*" is the bus to which the transformer’s first winding is connected, or a "T" if the "*to bus*" is the bus to which the first winding is connected.

In the transformer impedance data listing, the column labeled "ST" is the status flag of the transformer, with 0 indicating out-of-service, and 1 indicating in-service. The column labeled "MT" contains an "F" if the bus listed as the "*from bus*" is the metered end, or a "T" if the "*to bus*" is the metered end.

In the transformer control data listing, the controlled bus number is preceded by a minus sign if it is on the winding one side of the transformer.

3.4.4.17 Three-Winding Transformer Data

Any transformer which was specified as a three-winding transformer is tabulated in the three-winding transformer general data listing, in the three-winding transformer impedance data listing, in the three-winding transformer winding data listing, and in the three-winding transformer tap and control data listing. The three-winding transformer tabulations are ordered in ascending numerical or alphabetical order by winding one bus, and, for each winding one bus, in ascending order by winding two bus, and for each winding one-winding two bus combination, in ascending order by winding three bus. Transformers connecting the same three buses are tabulated in ascending circuit identifier order. Single entry format is always used. The majority of data items in these report categories correspond to data items specified in the three-winding transformer data input block.

In the general and impedance data listings, the column labeled "ST" is the status flag of the three-winding transformer.

The winding data and the tap and control data listings are comprised of three lines of data for each three-winding transformer: one for each of the two-winding transformers in the star model used to model a three-winding transformer.

In the winding data listing, the winding bus identifiers of the two metered windings are followed by an asterisk ("*"). The column labeled "ST" is the status flag of the two-winding transformer, as derived from the status flag of the three-winding transformer, with 0 indicating out-of-service, and 1 indicating in-service. The winding impedances are derived from the values entered as measured impedances, and are listed in the units indicated by CZ; the measured impedances are listed in the three-winding transformer impedance data listing.

In the control data listing, the controlled bus number is preceded by a minus sign if it is on the same side of the transformer as the bus connected to the controlling winding.

3.4.4.18 Zone Data

Any zone containing one or more equipment items is listed in the zone data listing. The tabulation is in ascending zone number order, and includes the zone name and number of buses, loads, and dc buses residing in each zone. If the output listing is by zone, the zone listing is restricted to those zones specified.

3.4.5 Outaged Equipment

This selection will list equipment which is out-of-service or not functioning. They are:

- Out-of-service Branches
- Isolated Buses
- Out-of-service Plants
- Out-of-service Machines at In-service Plants
- Out-of-service Loads at In-service Buses
- Blocked two-terminal dc Lines
- Blocked Multi-terminal dc Lines
- Blocked VSC dc Lines
- Out-of-service Converters at In-service VSC dc Lines
- Blocked FACTS Control Devices.

3.4.6 Listing Bus Shunts

This selection will list shunts including Fixed bus shunts as well as Switched bus shunts. The List Data dialog provides options for selection of either type of shunt or both (see Figure 3-33).

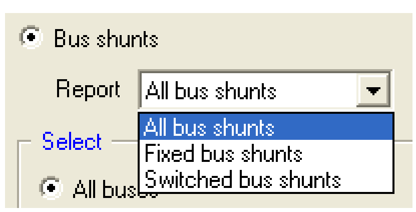


Figure 3-33. List Shunts Drop-down Menu

The information provided shows the nominal shunt ratings (i.e., at nominal voltage) as well as the actual voltage at the bus. See Figure 3-34 for a listing from the *savnw.sav* power flow case.

```
                                       N O M I N A L
BUS# X-- NAME --X BASKV                 MW       MVAR   VOLTAGE
 151 NUCPANT      500.00               0.0     -600.0    1.0119   FIXED
 154 DOWNTN       230.00               0.0      300.0    0.9389   FIXED
 201 HYDRO        500.00               0.0      300.0    1.0400   FIXED
 203 EAST230      230.00               0.0       50.0    0.9665   FIXED
 205 SUB230       230.00               0.0      300.0    0.9490   FIXED
```

Figure 3-34. Shunt Data Listing from the savnw.sav Working File

3.5 Validating Power Flow Data

PSS™E provides a variety of means by which data can be checked in order to identify such things as suspect parameters, conflicting voltage controls, unacceptable tap controls and isolated buses or inadvertent islands. The data checking is accompanied by generation of reports which can be merely examined or directed to documentation devices.

These are not checks on the state of the power flow solution for which PSS™E provides other reporting capabilities (see Section 4.1.4).

The data checking option is launched from the ***Power Flow>Check Data*** menu option which makes available four data checking activities (see Figure 3-35).

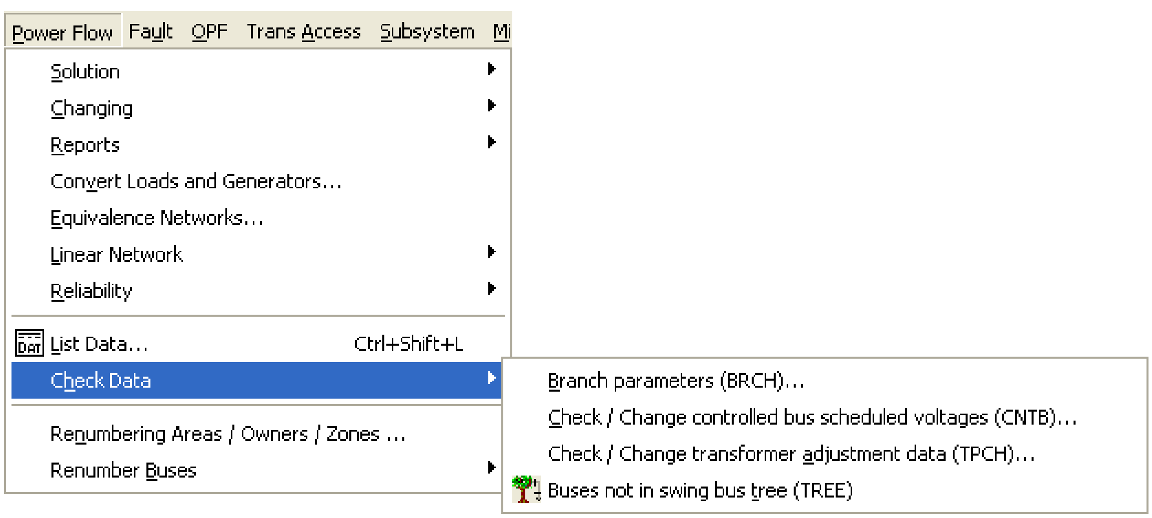


Figure 3-35. Available Data Checking Activities

3.5.1 Checking Branch Parameters

Branch parameter checking tabulates those branches whose impedances or other characteristics are such that they may be detrimental to the rate of convergence of one or more of the power flow solution activities. This does not imply that the data is not correct but rather indicates potential problems in obtaining a converged solution.

When the ***Power Flow>Check Data>Branch parameters (BRCH)…*** option is selected, the Check Branch Parameters dialog is opened (see Figure 3-36). There are seven threshold values for checking branch parameters.

In performing the checks, the user is free to change the threshold values to values which might be more appropriate for the working case under examination.

The Select facility is available to limit the output based on area, zone, owner, voltage, bus or any combination of these.

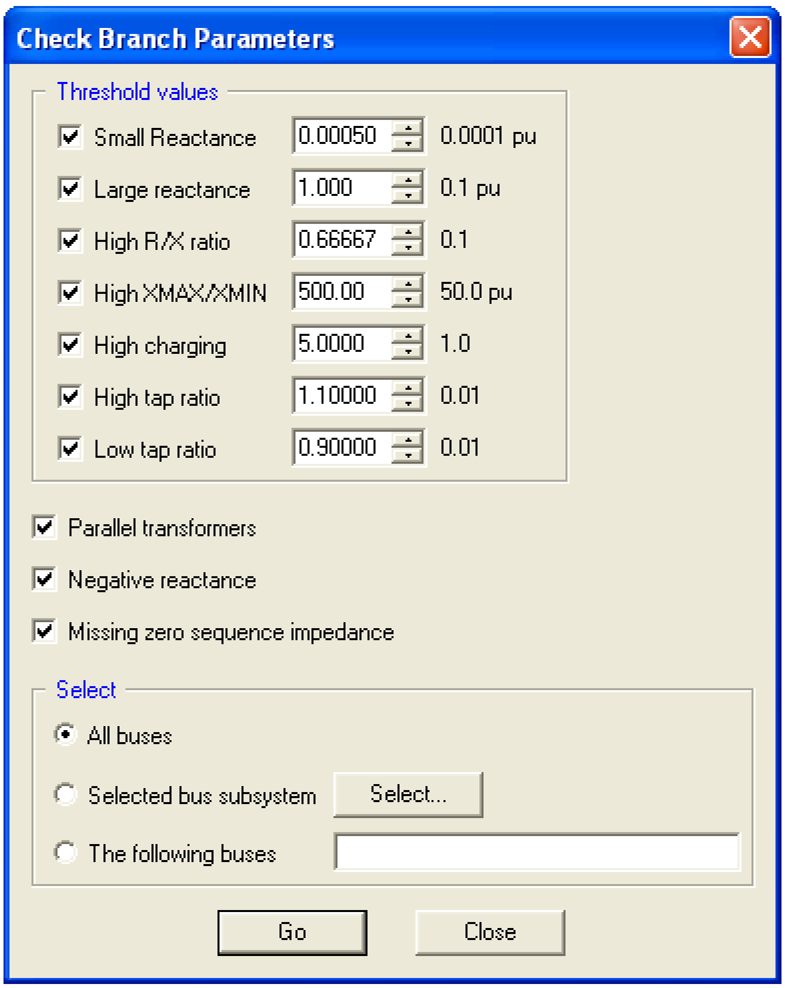


Figure 3-36. Check Branch Parameters Dialog

The figure shows the default threshold levels against which checks are made for parameters which could be considered suspect. At the right of the threshold level selectors are shown the incremental steps by which changes in the threshold values can be changed.

The following are notes on the branch check:

- Very small impedance branches not being treated as zero impedance lines may result in a slowing of the rate of convergence of the power flow solution activities, and their inability to reach the default convergence tolerances.
- Large impedance branches in themselves do not cause problems with the power flow solution methods. However, when relatively small impedance branches are also connected to these buses, convergence may be slowed and the solution activities may not be able to reach the default convergence tolerances. In addition, *very* large impedances are often present in inefficient network equivalents with some buses having an unusually large number of branches connected to them. This will generally result in the loss of the beneficial sparsity characteristics present with real system when the system matrices are processed, with a corresponding increase in solution times.
- High R/X Ratio. The Newton-Raphson decoupled solution, NSOL, will diverge if there are any branches whose resistance is greater than reactance. The other solution methods are not particularly sensitive to this ratio.
- High Xmax/Xmin ratio. In determining the largest and smallest connected reactance; zero impedances are neglected in determining the smallest reactance. The presence of a bus with a wide range of reactances connected to it may slow the rate of convergence of the power flow solution activities and result in failure to reach the default convergence tolerances.
- High values of line charging do not necessarily cause problems with the power flow solution methods except in cases of data entry errors (for example, all charging values entered in Mvar rather than per unit resulting in abnormally high voltages). Negative values of line charging are data errors.
- High and Low transformer tap ratios for which the default thresholds are 1.1 and 0.9, respectively. Any transformer branch for which either the winding one tap ratio or winding two tap ratio is beyond the specified limit is tabulated.
- The parallel transformer check scans parallel branches between pairs of buses and alarms:
  - Nontransformer and transformer branches in parallel.
  - Parallel two-winding transformers with different first winding complex tap ratios.
  - Parallel two-winding transformers with different second winding tap ratios.
  - Parallel two-winding transformers with their winding one/winding two side relationship reversed.
- The negative reactance check tabulates all negative reactance branches. If either of the buses for such a branch is a generator bus (i.e., type two or three), an asterisk ("*") is printed before the branch circuit identifier. The Gauss-Seidel solution method usually diverges if the working case contains any in-service negative reactance branches. The Modified Gauss-Seidel method, however, is able to handle negative reactance branches between type one buses, but negative reactances connected to type two or three buses usually result in divergence.
- For the missing zero sequence data check, the branch check procedure alarms any branch with a zero sequence impedance of zero. This test is bypassed if sequence data is not contained in the working case.

3.5.2 Checking Controlled Bus Scheduled Voltage Checks

The check controlled bus scheduled voltage function tabulates the voltage setpoints or desired voltage bands of voltage controlling equipment in the working case, and, optionally, allows the user to specify new scheduled voltages. It also performs certain checks on voltage controlling buses which are not themselves voltage controlled buses. It is possible to process all such buses, or only those with suspect or conflicting voltage schedules or other errors.

When the ***Power Flow>Check Data>Check/Change controlled bus scheduled voltages (CNTB)...*** dialog is opened, three basic options are available (see Figure 3-37).

- List controlled buses with conflicts
- Allow voltage schedule changes
- Process only active elements

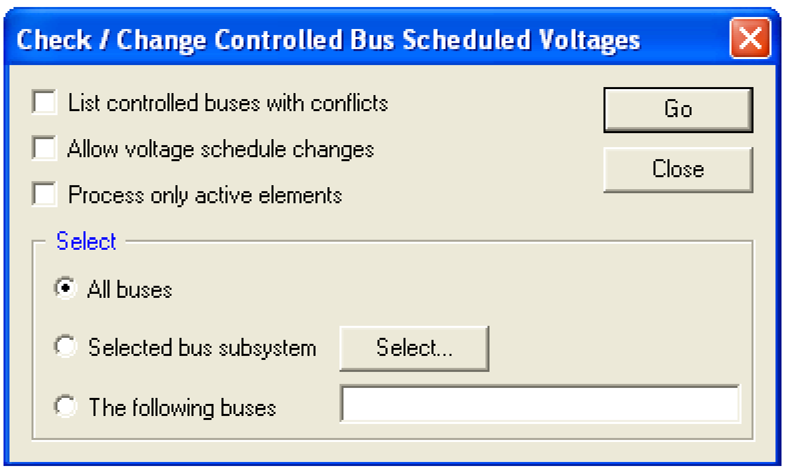


Figure 3-37. Check/Change Controlled Bus Scheduled Voltages Dialog

If only in-service elements are to be processed, any bus which is designated as the controlled bus of some voltage controlling equipment item but whose type code is greater than three is not considered a voltage controlled bus. In addition, the following voltage controlling equipment is ignored.

- Generation at a bus whose type code is not two or three.
- A switched shunt at a bus whose type code is greater than three or whose switched shunt control mode is not 1 (discrete voltage control) or 2 (continuous voltage control).
- A voltage controlling transformer which is out-of-service or whose adjustment control mode is –1 (i.e., control is disabled).
- The shunt element of a FACTS device whose control mode is zero.
- The series element of a FACTS device whose control mode is zero.
- A converter of a VSC dc line whose VSC dc line control mode (MDC) is zero or whose converter dc control code (TYPE) is zero.

For each bus tabulated, if it has a generator, switched shunt, or VSC dc line converter (again, either all or only in-service and enabled devices) that is controlling the voltage at some other bus or the reactive power output of a remote device, an appropriate message is printed. Then a list is created of equipment whose control parameter data is such that it is controlling the voltage at the bus being processed. Such equipment includes:

- Generation at the bus itself, if it is not remotely controlling the voltage at some other bus. The type code of the generator bus is printed in the STATUS column.
- Generation at a remote bus, which is controlling the voltage at this bus. The type code of the remote generator bus is printed in the STATUS column.
- A switched shunt at the bus itself, if it is not remotely controlling the voltage at some other bus or the reactive power output of some other voltage controlling device. The control mode of the switched shunt is printed in the STATUS column.
- A switched shunt at a remote bus, which is controlling the voltage at this bus. The type code of the bus to which the switched shunt is connected and the control mode of the switched shunt are printed in the STATUS column.
- A FACTS device connected to the bus. The device's control mode is printed in the STATUS column.
- A converter of a VSC dc line connected to the bus itself, if the converter is in ac voltage control mode and is not remotely controlling the voltage at some other bus. The VSC dc line's control mode (MDC) and the converter's dc control code (TYPE) are printed in the STATUS column.
- A converter of a VSC dc line connected to a remote bus, if the converter is in ac voltage control mode and is remotely controlling the voltage at this bus. The VSC dc line's control mode (MDC) and the converter's dc control code (TYPE) are printed in the STATUS column.
- A voltage controlling transformer without load drop compensation. For two-winding transformers, transformer status is printed; for three-winding transformers, winding status is printed in the STATUS column.

For each such equipment, the desired voltage setpoint or voltage band, as appropriate, is tabulated. A list is then generated of any suspect voltage control specifications. If the ***Allow voltage schedule changes*** option was selected, the user has the option of specifying a new scheduled voltage.

If a new value is entered, the control parameters are modified accordingly. For those devices controlling to a voltage band, the band retains its previous voltage spread with the designated voltage as the midpoint.

Each voltage controlling transformer with load drop compensation, whose controlled bus is being processed is then listed, along with the compensated voltage it would sense and its voltage limits. If the ***Allow voltage schedule changes*** option was selected, the user then has the option of specifying a new voltage band:

Buses connected together by zero impedance lines are treated as the same bus. Controlling equipment, along with any error and warning messages, apply to the combined bus. In the interactive mode, each group of buses connected together by zero impedance lines, which has at least one of the buses in the specified subsystem, is tabulated once, even if more than one of its buses is in the specified subsystem. In the reporting mode, each such bus is reported in its usual position in the bus collating sequence.

The process of voltage schedule processing may be terminated by entering the AB interrupt control code.

3.5.3 Checking/Changing Transformer Adjustment Data

The controlling transformer parameter checking procedure performs several checks on the adjustment data associated with voltage or power flow controlling transformers. Transformers which control dc line quantities are bypassed during the procedure.

When the ***Power Flow>Check Data>Check/Change transformer adjustment data (TPCH)...*** dialog is opened, eight control checks are available (see Figure 3-38).

- One absolute value of Tap Step.
- Two Tap Step levels compared to a threshold level.
- One absolute value of Voltage Band.
- Two Voltage Band levels compared to a threshold.
- Two Flow Band levels compared to a threshold.

The threshold levels can be defaulted or selected by the user.

```
PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E      MON, DEC 01 2003  13:59
PSS/E PROGRAM APPLICATION GUIDE EXAMPLE                            TRANSFORMER
BASE CASE INCLUDING SEQUENCE DATA                                    SUMMARY

                    ** TRANSFORMERS CONTROLLING VOLTAGE **

X--- ADJUSTABLE SIDE ---X X--------- TO ----------X                               X--- CONTROLLED BUS ----X
  BUS# X-- NAME --X BASKV    BUS# X-- NAME --X BASKV CKT     VOLT     MAX V   MIN V   BUS# X-- NAME --X BASKV  RATIO     MAX RAT MIN RAT NTAPOS
   152 MID500       500.00    153 MID230       230.00  1   0.93892LO 1.00000 0.98000   154 DOWNTN       230.00 1.01000   1.05000 0.95000     33
   204 SUB500       500.00    205 SUB230       230.00  1   0.94902LO 1.00000 0.98000   205 SUB230       230.00 1.00000   1.05000 0.95000     33

                   ** PHASE SHIFTERS CONTROLLING MW FLOW **

X--- ADJUSTABLE SIDE ---X X--------- TO ----------X
  BUS# X-- NAME --X BASKV    BUS# X-- NAME --X BASKV CKT     MW     MAX MW   MIN MW   ANGLE    MAX AN  MIN AN
   202 EAST500      500.00    203 EAST230      230.00  1    592.4HI  555.0    545.0    0.00    30.00  -30.00
```

Figure 3-38. Check/Change Transformer Adjustment Data Dialog

If any transformers fail the check, the user has the option of modifying the data of all transformers tabulated. The user may then designate the next check to be performed. Prior to performing the check, the user can select transformers to be checked on the basis of areas, zone, owners, voltage, buses or any combination.

As an example use of this function, assume we need to check the controlling Flow band for all MW controlling transformers in the *savnw.sav* working file. Use a threshold Flow band of 5.0 MW. Figure 3-39 shows the Check/Change Transformer Adjustment Data dialog for this check.

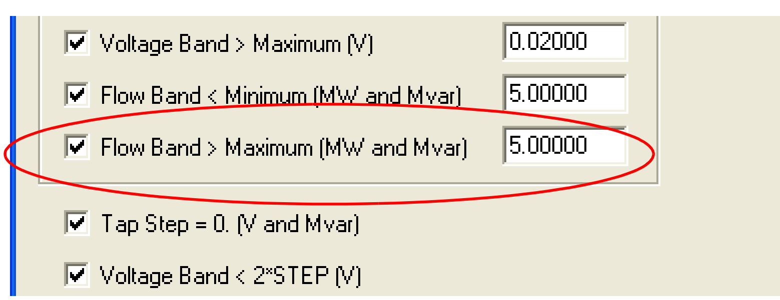


Figure 3-39. Example Check on Transformer MW Flow Band in savnw.sav Case

The result of this example check shows one power controlling transformer with a Flow band of 10 MW compared to the threshold check of 5.0 MW (see Figure 3-40).

```
MW OR MVAR CONTROLLING TRANSFORMERS WITH FLOW BAND >   5.00
X--- ADJUSTABLE SIDE ---X  X--------- TO ----------X
  BUS# X-- NAME --X BASKV     BUS# X-- NAME --X BASKV CKT  FLOMAX  FLOMIN    BAND  CONTROLLING
   202 EAST500      500.00     203 EAST230      230.00  1   555.00  545.00   10.00  MW

    1 TRANSFORMERS FOUND
```

Figure 3-40. Results of Example Transformer Flow Band Check

The failure to pass the test prompts an option to change the transformer Flow band to the threshold level or to any other required level as necessary (see Figure 3-41).

Failing this test does not imply incorrect data.

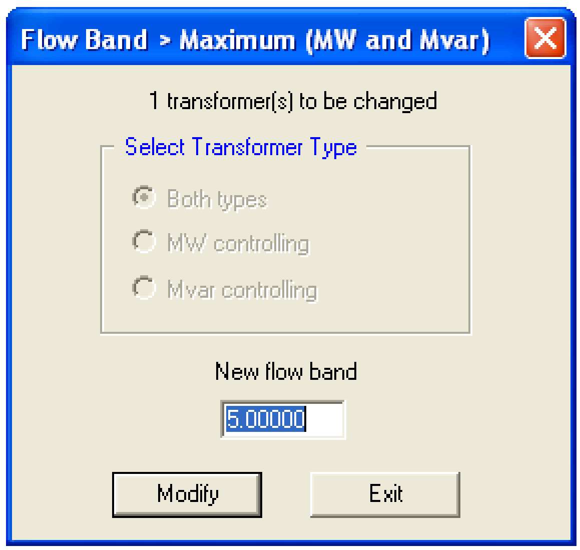


Figure 3-41. Dialog Showing Option to Change Transformer Control

3.5.4 Checking Bus Not in Swing Bus Tree

This network continuity checking activity enables the user to identify buses not connected back to a swing bus (i.e., a type three bus) via in-service ac branches. The result of the check tabulates both isolated buses and islands not containing a swing bus. It also provides a tabulation of in-service branches connected to type four (isolated) buses.

The Report produced first lists any type four bus with one or more in-service branches connected to it. Such error conditions usually result from manually isolating a bus by changing its bus type code and the branch status flags to the appropriate values but overlooking one or more branches.

The Report then tabulates all type three buses in the working case, followed by a listing of buses that do not have a type code of four and are not looped back to a swing bus. These buses are grouped by island, and, within each island, in ascending bus number (under the numbers output option) or alphabetical (under the names output option) order. The tabulation of each island is followed by a summary of the number of buses and plants in the island along with total island load, shunt, generation, and var limits.

The Report will appear in the Progress or Report tab of the Output Bar or at the report output device selected by the user. Following the tabulation of each island, the user is given the option of disconnecting it or continuing the check, see Figure 3-42.

Figure 3-42. Option to Disconnect Islands

If the user elects to disconnect the island, PSS™E performs the required bus type code and branch status flag changes to disconnect *all* buses that were listed as not tied back to a swing bus. Any in-service dc lines connected to such buses are blocked. Any in-service series FACTS devices connected to such buses are placed out-of-service. This process is repeated for each island.

This checking activity does not allow subsystem selection. It always scans the entire working case.

The island output listing may be terminated by entering the AB interrupt control code.

3.6 Editing Data

Sections 3.3 through 3.5 discussed the importation, adding and changing of data by reading from a raw data file. The following sections discuss the means by which data items can be edited manually through the graphical user interface.

Data changes are made in the Spreadsheet View which can be accessed merely by bringing the view to the top (over any diagram views which might be open). With the spreadsheet active, the user can select the data category tab of interest and scroll to the particular cell of interest. From here data can be modified or deleted using the usual spreadsheet editing techniques.

3.6.1 Moving Data Between the Diagram and Spreadsheet Views

With the Tree View or Diagram View active, the user can move directly to the data item in the spreadsheet by double-clicking the item in the Tree View or on the diagram. Figure 3-43 shows that the data line for bus 101, on the Spreadsheet Bus tab, can be selected by clicking on ***bus 101*** in the diagram or by double-clicking on ***bus 101*** in the expanded bus data category in the Tree View.

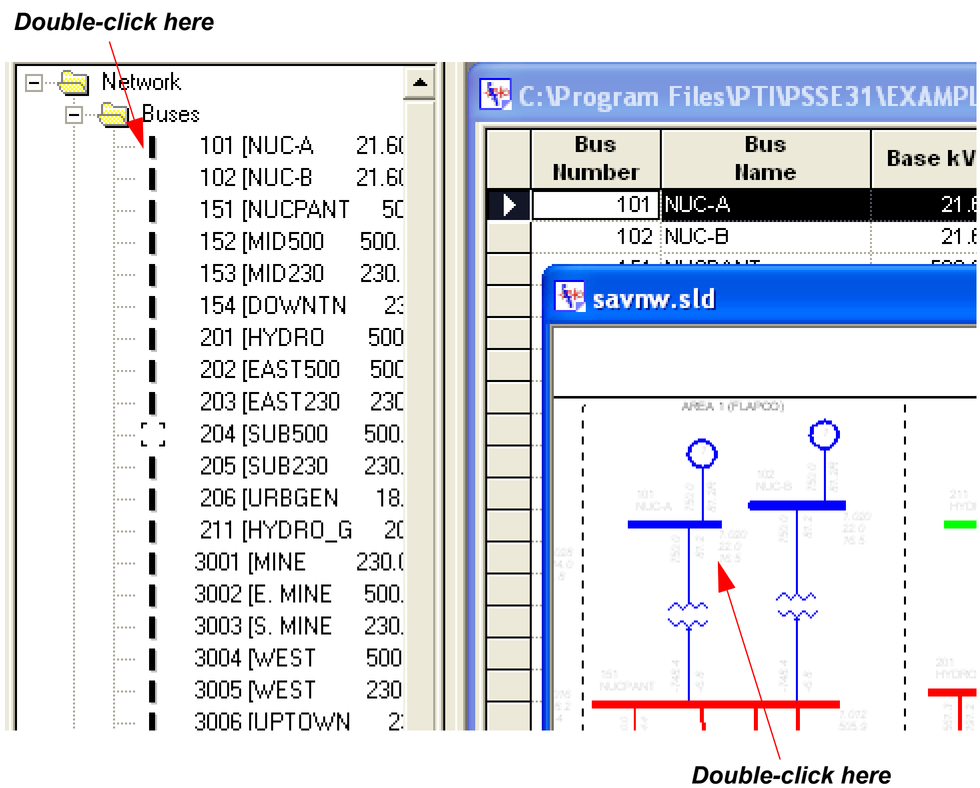
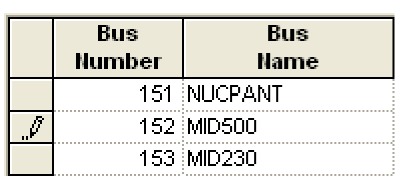


Figure 3-43. Moving to a Spreadsheet Item from the Tree or Diagram View

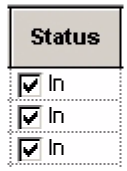
Data in a cell is edited using standard techniques. When one or more cells in a row have been modified, a pencil symbol is placed in column 1 of the row (Figure 3-44). The data changed is not recorded in the PSS™E working case until the cursor is moved to another row. At that point, all data changes made to the row are recorded and the pencil symbol is removed.



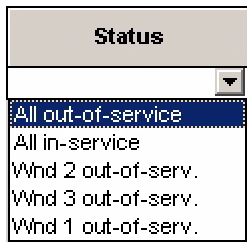
	Bus Number	Bus Name
	151	NUCPANT
✎	152	MID500
	153	MID230

Figure 3-44. Pencil Icon Indicating Changed Data in the Row

Some cells of a record contain check boxes (Figure 3-45a) for the user to select an option. Other cells contain combo boxes (Figure 3-45b) in which a user can choose a value from a drop-down list.



(a) Check box within a cell for branch status.



(b) Combo box within a cell for three-winding transformers.

Figure 3-45. Check and Combo Boxes in the Spreadsheet

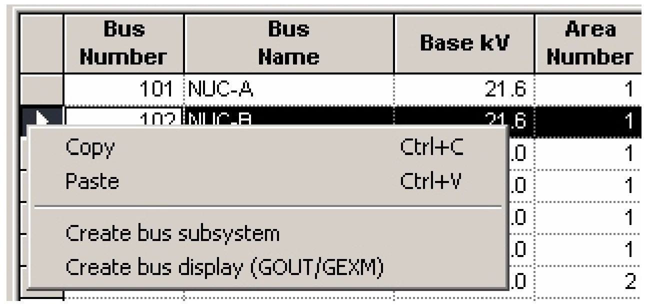
3.6.2 Copying Data

An entire row of data or rows of data can be copied and pasted in the spreadsheet. The Copy and Paste option are made available by right-clicking in the left-most column (Figure 3-46). The user should select a row or rows prior to right-clicking on the selection.

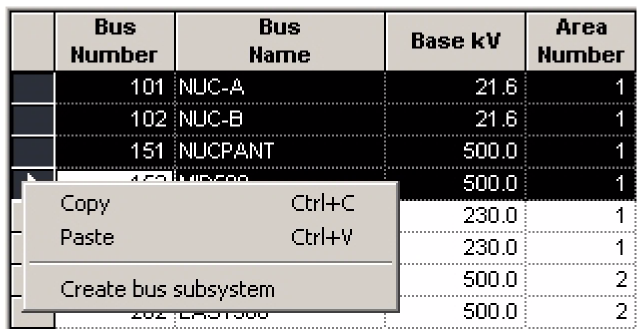
If a single row is selected, the options shown in Figure 3-46a are available. If multiple rows are selected, the options shown in Figure 3-46b are available.

Use of the Create a bus subsystem option is discussed in Section 2.4.2.2. This is available when either a single row or multiple rows are selected.

Use of the Create bus display (GOUT/GEXM) option is discussed in Section 2.4.3.3. This is only available when a single row is selected.



(a) Right-clicking on Single Row Selection



(b) Right-clicking on Multiple Row Selection

Figure 3-46. Selecting Rows for Copy and Paste Operations in the Spreadsheet

3.6.3 Importing Changes Via a File

The data copied using the method described in the previous section can be pasted to the same spreadsheet in order to duplicate data items.

New or additional data can be introduced by pasting data copied from an external application (for example Excel). This facility accommodates the addition or editing of data on a specific data category tab. This is the reverse of the ***File>Export*** option (Section 2.4.6) used for copying a data tab in PSS™E for exporting to another application.

3.6.4 Deleting Data

As previously mentioned in this subsection, data can be deleted directly in the spreadsheet. Selecting a row will facilitate its deletion using the **[Delete]** key.

When working in the Diagram View, right-clicking an element will open the pop-up menu that includes the ***Delete*** option. Deleting the item in the diagram will delete that item data from the spreadsheet; meaning that the element is deleted from the data base. See Section 2.9.8 for more details on this operation and the Bind Items requirement for deleting via the Diagram View.

3.7 Creating a New Power Flow Case

A new data base can be created merely by typing data elements directly into a blank spreadsheet. This method would typically be limited to only small cases or to establish a small data base into which significantly more data could be pasted into or imported.

To initiate creation of the new data base the user should use the ***File>New*** option. The New dialog will give the option of creating a new case, a new case and new diagram, a new diagram or a new plot sheet. (Figure 3-47).

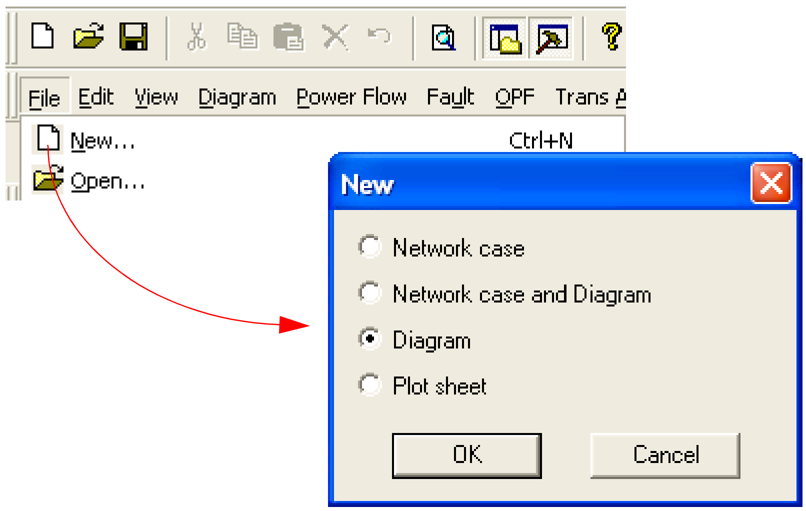


Figure 3-47. Initiating Creation of a New Database

Having selected the **Network *case*** option, the user will be presented with the Build New Case dialog where the Base MVA and a two line title can be supplied (Figure 3-48).

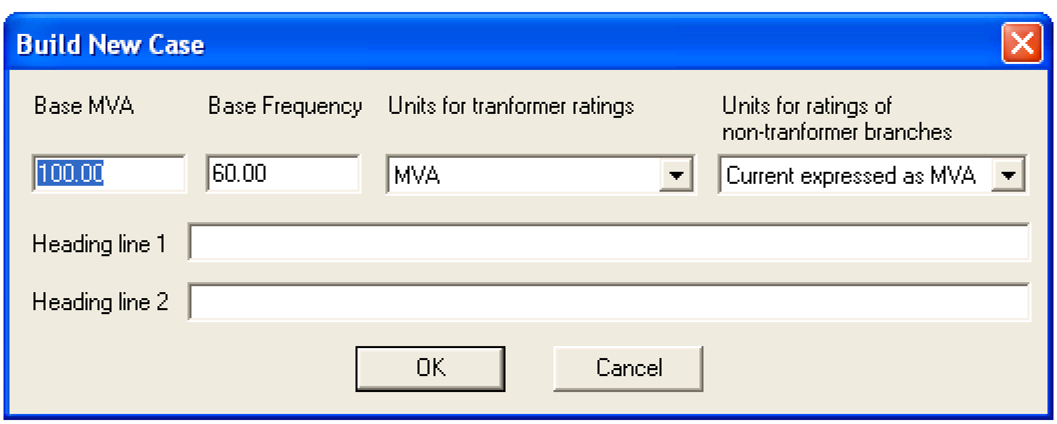


Figure 3-48. Initial Data Requirement for Creation of a New Data Base

Once this information is provided, a blank Spreadsheet View will be made available. The user can now type in data elements or paste information copied from another application on to each tab.

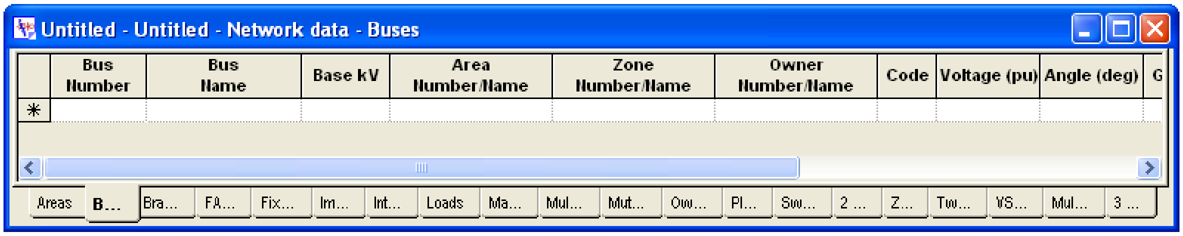


Figure 3-49. Blank Spreadsheet Ready for Introduction of New Data

3.8 Creating a Power Flow Case using the Diagram View

Section 3.7 discussed the means by which the user can created a new data base by initiating a new case and adding data directly into the newly created blank Spreadsheet View.

An alternative is to open a blank Diagram View after initiating the new case and creating the blank Spreadsheet View. Then network elements can be added graphically, in the newly opened Diagram View instead of typing data into the spreadsheet.

The new Diagram View is opened as using the ***File>New*** option but this time selecting ***Diagram*** instead of ***Network case*** (see Figure 3-47).

First, however, the user should choose to number the buses automatically or not. Selecting ***Edit>Preferences*** will display the Program Preferences dialog partially shown in Figure 3-50. For the purposes of this example, the buses will be numbered starting from 1 at increments of 100.

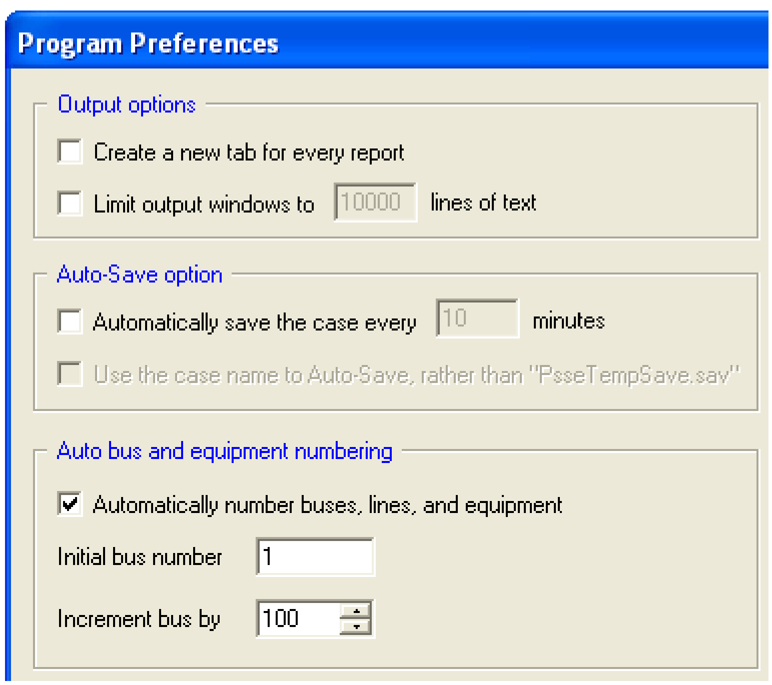


Figure 3-50. Program Preferences Dialog for Automatic Bus Numbering

The new data base will have:

- A generator at bus 1 and bus 201.
- A non transformer branch between bus 1 and 101.
- A non transformer branch between bus 101 and 102.
- A load at bus 101.

To add buses to the diagram, and consequently the data base.

1. Select the ***Bus*** toolbar button in the Diagram toolbar.
2. Click on the Diagram View in those locations where the buses are to be placed (remember, they can be moved and otherwise adjusted later).

If three buses are added, they will be numbered, 1, 101 and 201. As they are added to the diagram, they will also be added to the spreadsheet with default values. Default values can be modified subsequently by editing in the Spreadsheet View (Figure 3-51).

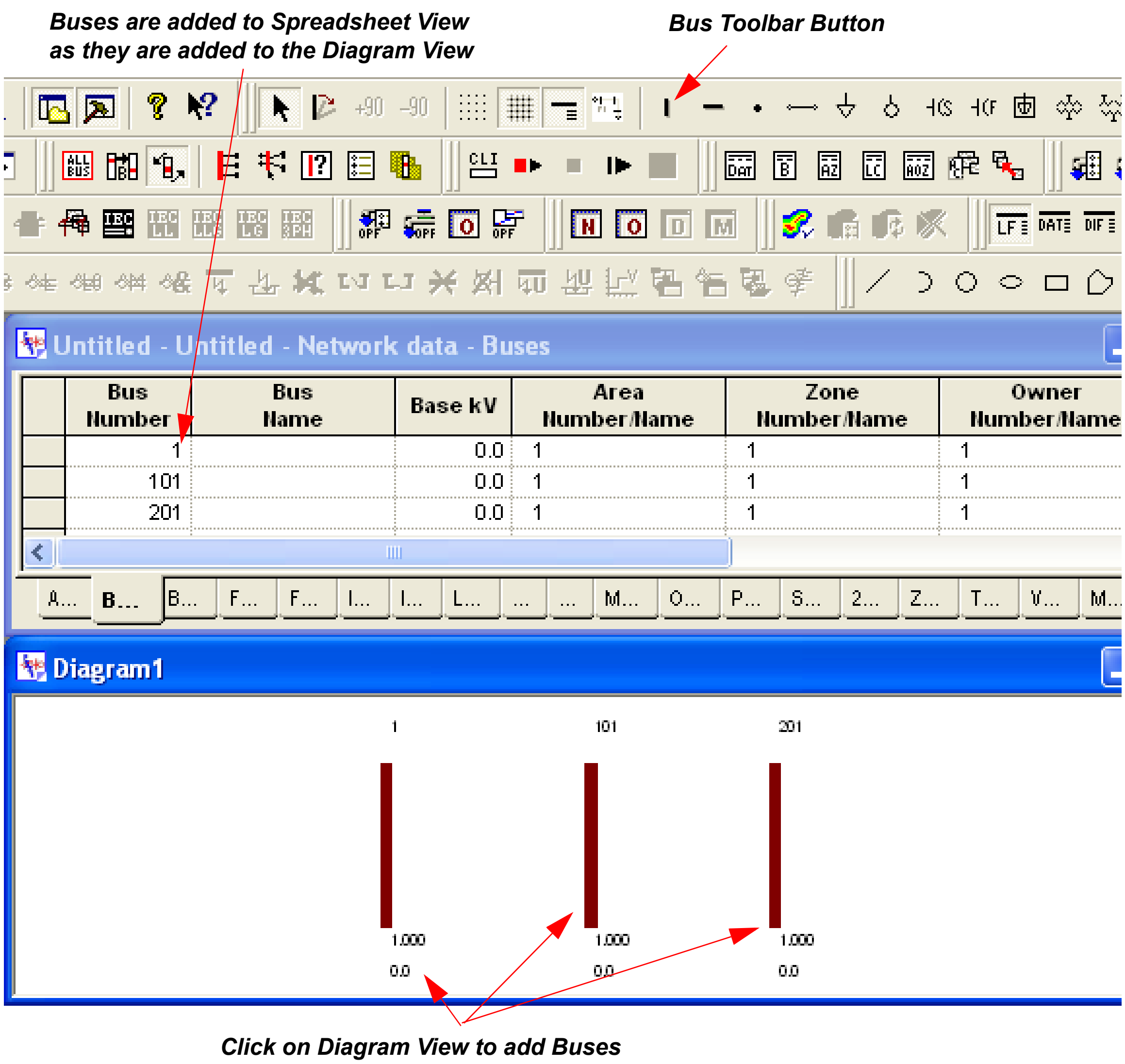


Figure 3-51. Adding Buses to the Data Base via the Diagram View

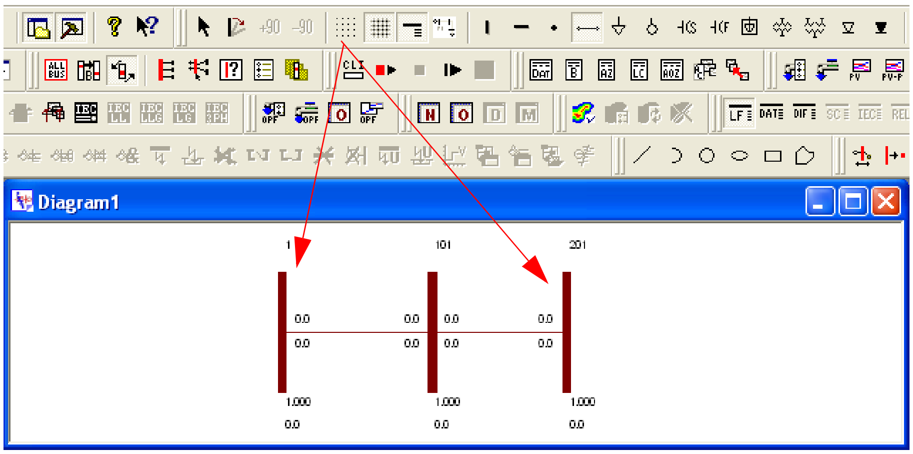
With the buses positioned, the following steps are required to add the equipment:

1. Select the ***Branch*** toolbar button and drag branches with the mouse between buses 1 and 101 and between buses 101 and 102.

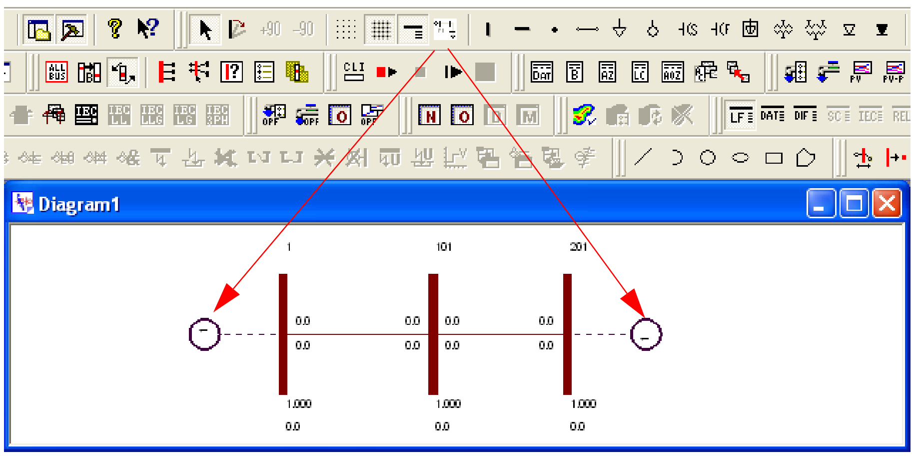
- Select the ***Generator*** toolbar button and draw the symbol by dragging the mouse from bus 1 and bus 201.
- Select the ***Load*** toolbar button and draw the symbol by dragging the mouse from bus 101.
- Because default values will be assumed for each data type, now edit the data in the spreadsheet.

The result are displayed in Figure 3-52.

Adding a Branch



Adding a Generator



Adding a Load

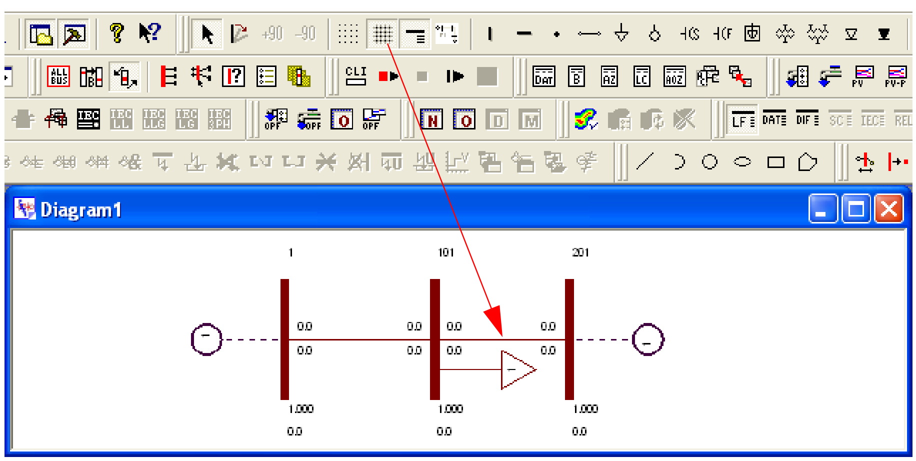


Figure 3-52. Adding Network Elements to the Diagram View

3.9 Exporting and Merging Power Flow Data

Power flow data can be output to a data file in raw data format to facilitate the merging of the data with another power flow case. Similarly, raw data can be imported to an existing case to either add to or modify the data in that existing case.

This section describes specifically how raw data can be exported for later use in establishing a new power flow case or modifying an existing case.

3.9.1 Exporting Power Flow Data

To initiate raw data export select the ***File>Save or Show…*** option. This will display the Save/Show Network Data dialog (see Figure 3-53).

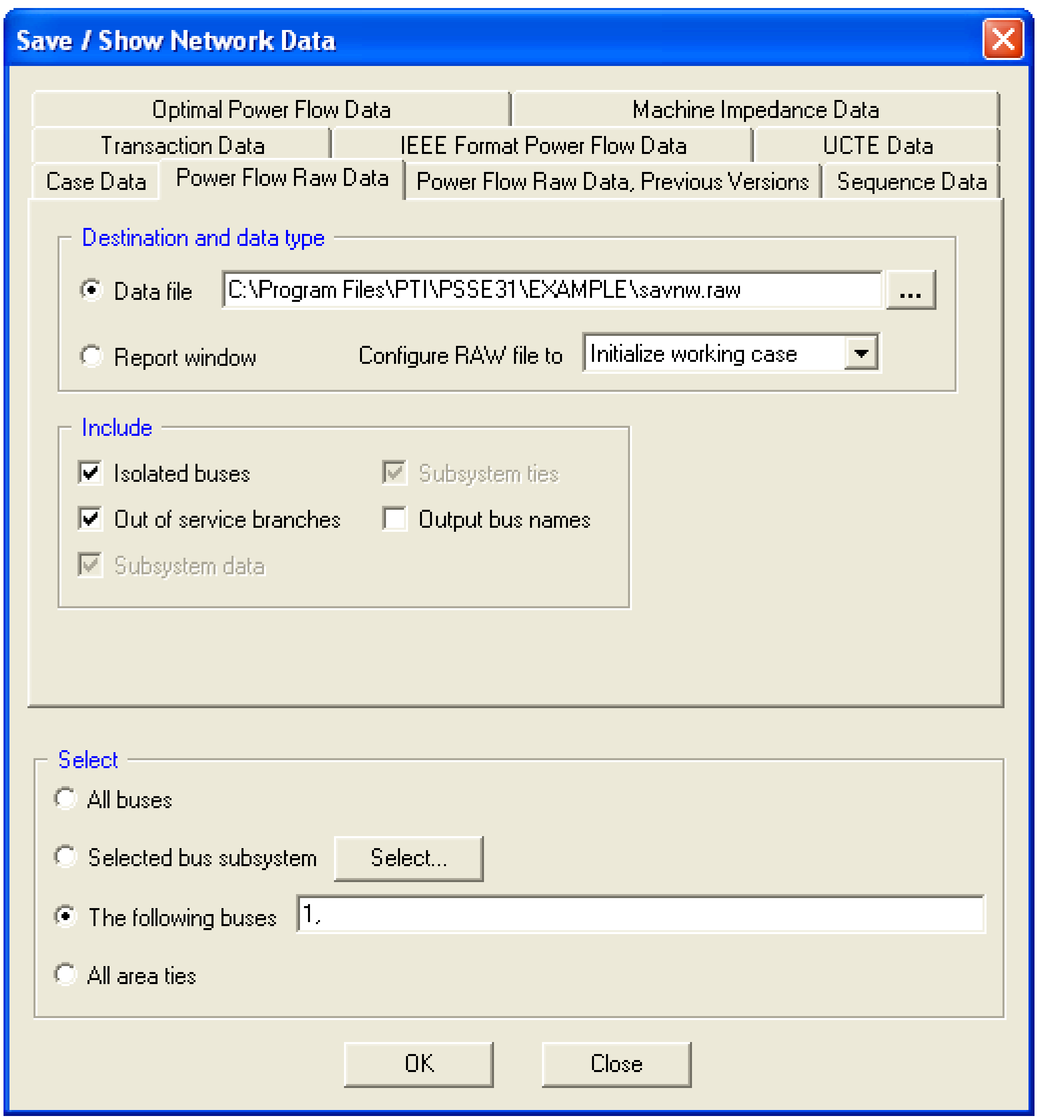


Figure 3-53. Save/Show Network Data Dialog – Power Flow Raw Data

The Exporting facility allows data to be exported by:

- A selected subsystem (Area, Owner, Zone, Base kV, Buses)
- All buses or selected buses.
- Only area ties.

Additionally the user can elect to include isolated buses and out of service branches as well as to export data in name order. If data is selected by subsystem there are the additional options to included subsystem data and subsystem ties (see Figure 3-54).

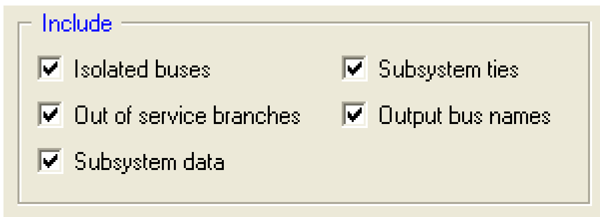


Figure 3-54. Options for Data Export when Selecting by Subsystem

When exporting raw data there are three alternative methods. In Figure 3-55, the data file can be formatted to:

- Initialize a working case (the IC code in the file will be zero; see Section 3.2.1).
- Add data to a working case (the IC code in the file will be 1; see Section 3.2.1).
- Provide change data ("use with RDCH" option) (no case identification information; see Section 3.3.4).

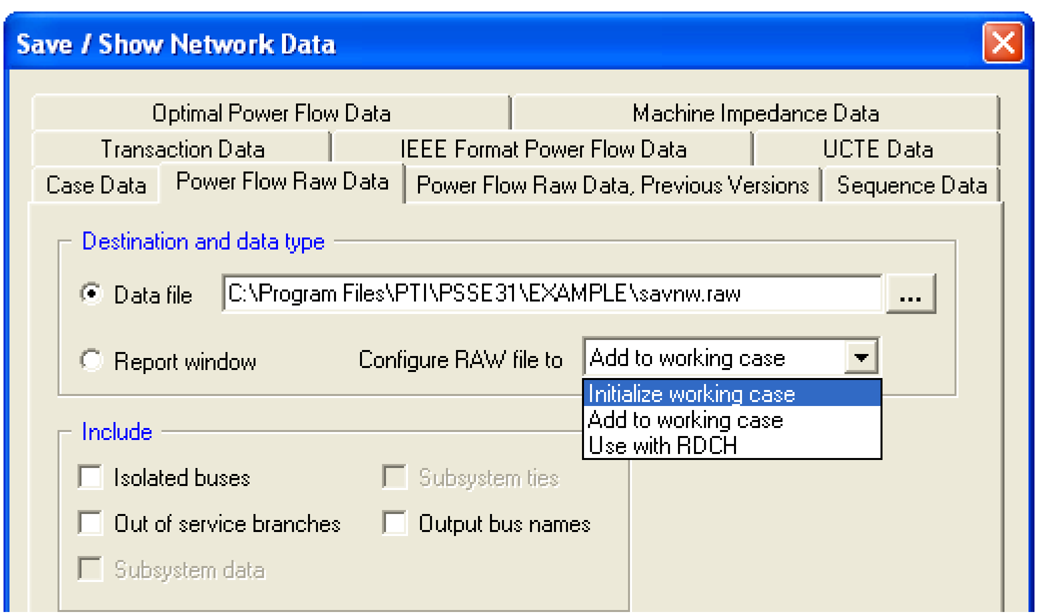


Figure 3-55. Formatting the Exported Raw Data File

3.9.2 Merging Power Flow Data

Merging a raw data file with an existing one requires the avoidance of overlapping bus, area, zone and owner numbers. When two power utility organizations, or any owner of power flow information, wishes to create a jointly representative power flow case it is likely that they are using the same numbers in their independent files to represent buses, areas, zones and owners unique to each case. A pre-requisite, therefore is to ensure that the two files to be merged are examined to verify the absence of such overlaps. If overlaps exist then it will be necessary to perform a renumbering operation in at least one of the two cases to be merged. Reference should be made to Section 4.7 on the methods to perform the renumbering process. The same will be required for auxiliary files dependent on bus numbering.

To merge two power flow cases, designated Case A and Case B, first open Case A and then input the raw data for Case B. The raw data file must be formatted to add data rather than initialize the case; independent of its origins, and must be free of bus and other numbering problems. The import can be initialized by opening the raw data file for Case B by using the ***File>Open*** and selecting the *.raw type file category (see Figure 3-56).

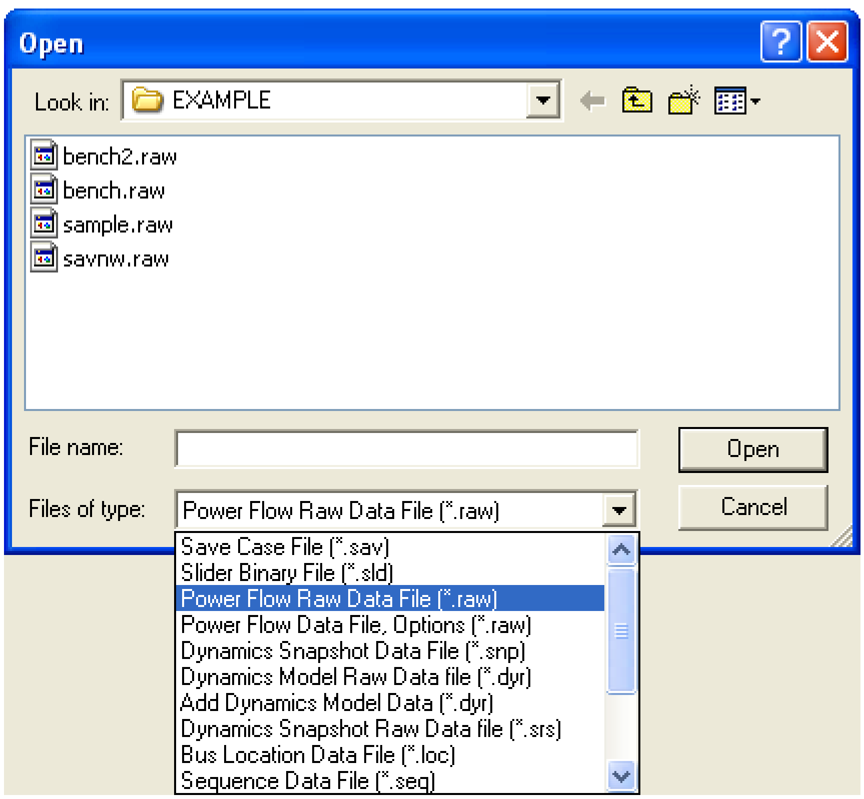


Figure 3-56. Importing Raw Data

When the file is opened as shown in the figure, the user will be given the option to save or not the file which is currently open before the raw data is added. The new data, from Case B will appear in the spreadsheet together with the existing data of Case A.

As described in Section 3.3.3, it is possible to add data by subsystem. Figure 3-56 shows that option in the file type list as Power Flow Data File, Option(*.raw). After initiating the action to append the raw data, by clicking the ***Open*** button, and having elected to Save or not the current case, the Read Power Flow Raw Data dialog appears (see Figure 3-57).

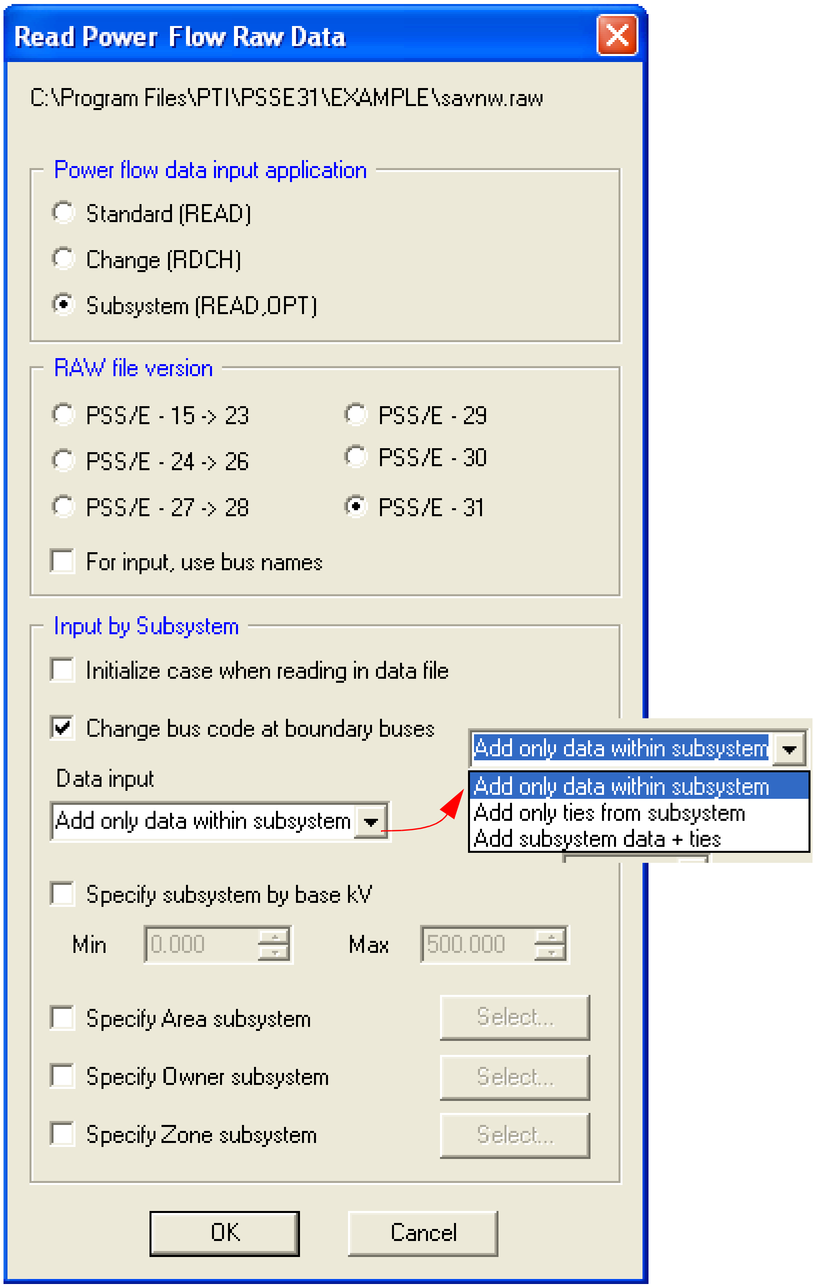


Figure 3-57. Importing Raw Data by Subsystem

When appending data by subsystem, the user can elect to use the name option for input and to initialize the case. Further, the user can change the "boundary buses". Any bus that is within a specified subsystem and connected to a bus that is not in the working case may be identified as a "boundary bus"; the type code of each boundary bus is changed to 5, 6, or 7 as appropriate. For more information see Chapter 9, where the process of making network equivalents along with the topic of "boundary buses", is discussed.

Additional flexibility is available for data input. It can be seen that data can be appended not only by selected subsystems but also limited to either data within a subsystem or only ties from the subsystem.

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Chapter 4

Power Flow

4.1 Overview: Power Flow

This chapter contains a considerable amount of information on the power flow solutions and parameters, load models, network modification, and data output and modification. This section provides the user with a brief but useful introduction to performing power flows with PSS™E and examining the results. Reference can be made to Chapter 2 where the interface menus and toolbuttons are described and to the subsequent sections in this chapter for detailed discussions of the various aspects of working with the power flow.

4.1.1 Importing the Power Flow Case

The bases for network data are the raw data files (**.raw*), which are ASCII text files, and the Save Case files (**.sav*), which are binary files containing not only the network element data but also other information such as run-time options. Other data files having specific applications are used by PSS™E and described in the appropriate sections of this guide. For now the raw data and saved case files are of interest.

Having started the PSS™E application the user will see a blank page with only the menu and toolbars visible. If, however, the Tree View, Output Bar or Status Bar were open when the program was previously closed, these will be open.

To import data, use the ***File>Open*** option or the ***Open*** toolbar button as shown in Figure 4-1 and select either a Save Case file or a Raw Data file. Selecting either type will provide a list of available files from which to select.

PSS™E uses a wide variety of files including three type of raw data files. The file of interest, at this time, is the basic Power Flow Raw Data file, as indicated, or the Save Case file.

In the PSS™E EXAMPLE directory there are many files for the user's use. To perform some basic tests, as described here, select either the *savnw.sav* or *savnw.raw* files. Selection of either will open a populated Spreadsheet View containing the savnw power flow base case; a partial view is shown in Figure 4-2.

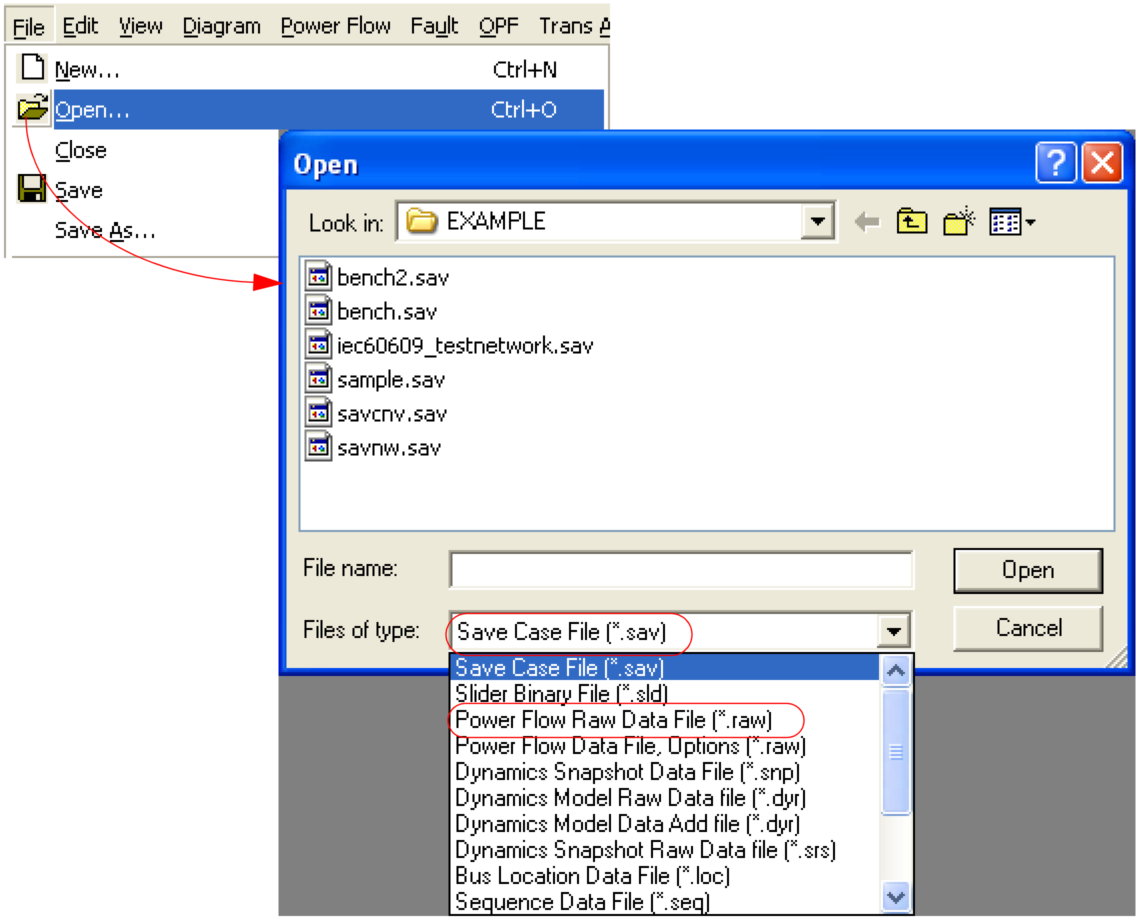


Figure 4-1. Opening a Data File

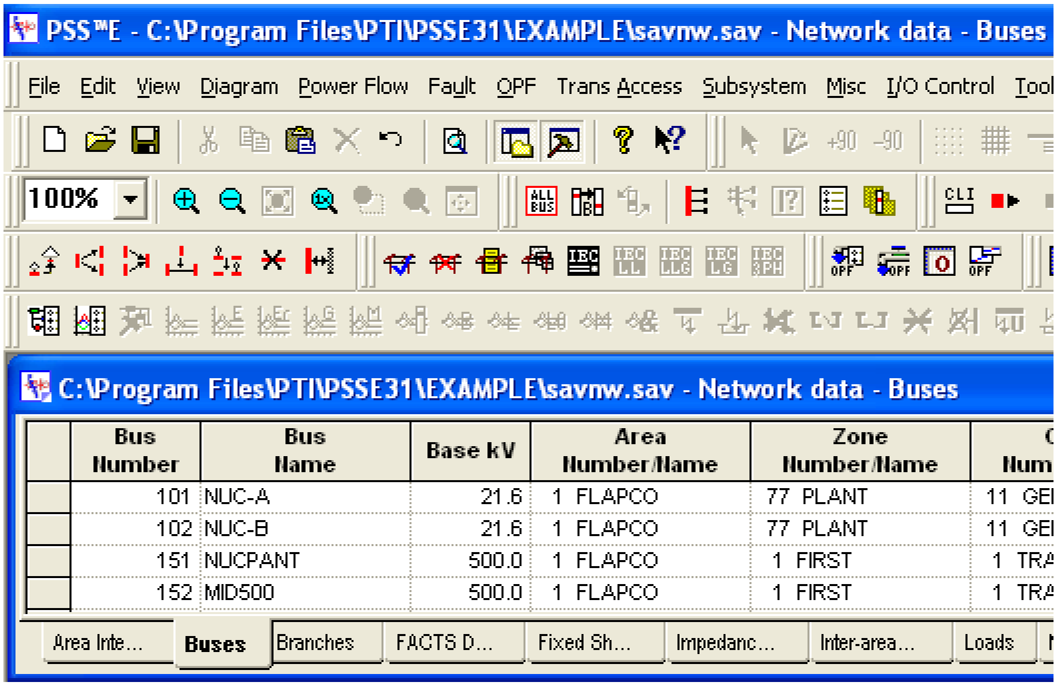
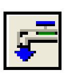


Figure 4-2. Newly Populated Spreadsheet

4.1.2 Obtaining a Power Flow Solution

If the imported data were from a Power Flow Raw Data File, it will be necessary to obtain a power flow solution. If the data were in the form of a Saved Case, it is probably already solved. In either case, for the purpose of this exercise, a power flow solution can be run.



To run a power flow case, use the ***Power Flow>Solution>Solve...*** option (see Figure 4-3) or the ***Solve*** button.

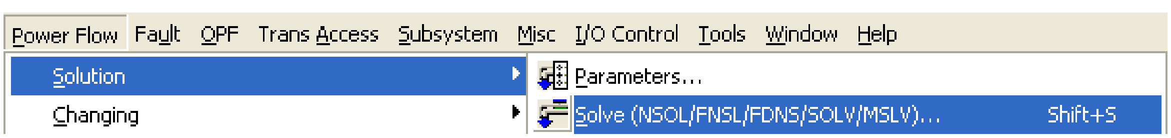


Figure 4-3. Initiating a Power Flow Solution

The initiation of the power flow solution will open the Loadflow solutions dialog (Figure 4-4) where the user can select the type of power flow solution to use and the control parameters. If this is not the first power flow solution used in the work session, then clicking the Powerflow toolbar button will not open the dialog but will assume the previous power flow solution and control selection.

As shown in Figure 4-4 there are two tabs in the dialog; one for Newton solutions and one for Gauss-Seidel solutions.

There are three Newton solutions and two Gauss solutions. The user should select the appropriate solution as a function of the network conditions and solution starting point (Section 4.3).

Other controls are available for use during the iteration process. These include, depending on the type of solution selected:

- Area interchange control (both Newton and Gauss).
- Control of Transformer taps (both Newton and Gauss.)
- A variety of other solution options (vary by type of solution).
- Control of Var limits (only Newton).

These options and controls are discussed in more detail in the subsequent sections of this chapter.

A quick note of value is that the Gauss-Seidel solution cannot handle negative series reactances (series capacitors) but the Newton and Modified Gauss-Seidel can.

When the solution type and control options have been selected, the user needs to click the ***Solve*** button. The solution will proceed and a printout of the convergence monitor and power flow conditions will appear in the Output Bar. It will be clear whether of not the solution has converged and what the mismatch conditions are (Section 4.3.9.4).

If the case has not converged, the user can modify the solution parameters (Sections 4.3.7.1 and 4.3.9.2) and solution type, if warranted, and re-run the solution. If the solution had diverged (blown up), the ***Flat start*** control option should be used to establish a feasible starting point for the next solution.

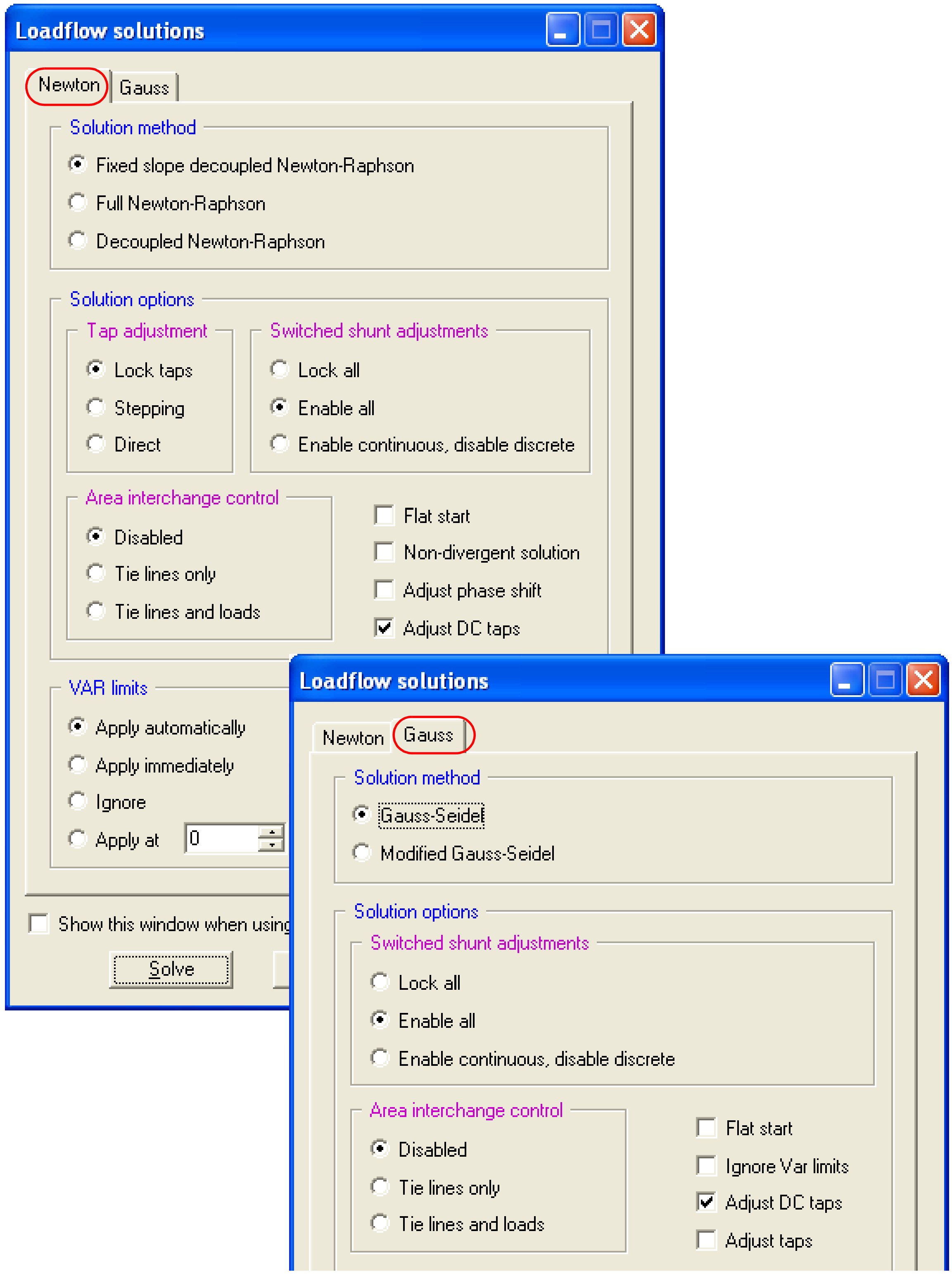


Figure 4-4. Selecting Solution Type and Controls

4.1.3 Examining Tabular Power Flow Results

To examine the power flow results in tabular format the user can generate a variety of reports. Access to the reports is facilitated by the ***Power Flow>Reports*** menu or the toolbar buttons (see Figure 4-5). These reports are discussed in more detail in Section 4.4.1. In Figure 4-5, the **Bus based reports…** option is highlighted.

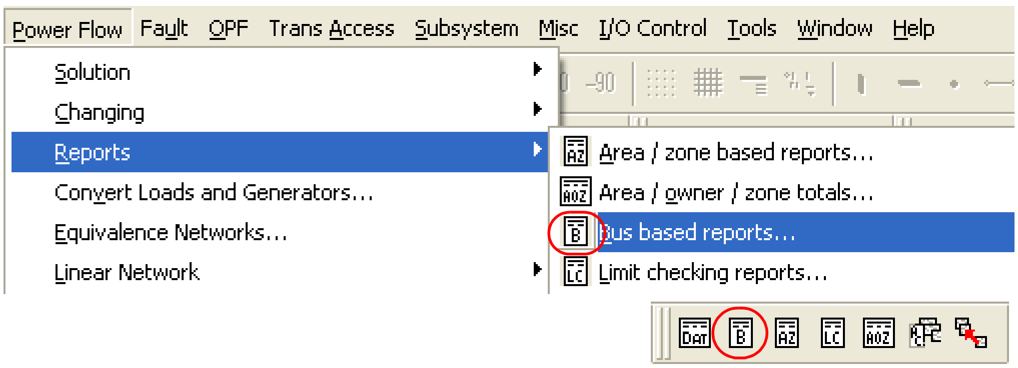


Figure 4-5. Accessing Reports on Power Flow Conditions

To examine only the power flow results, the bus based report is most appropriate. This will list the flow and bus conditions in tabular format (as did the activity POUT available in previous versions of PSS™E). Selecting the ***Bus based report…*** option will open the Bus Based Reports dialog where buses or subsystems of buses can be selected for output; see Figure 4-6 where bus 152 has been selected.

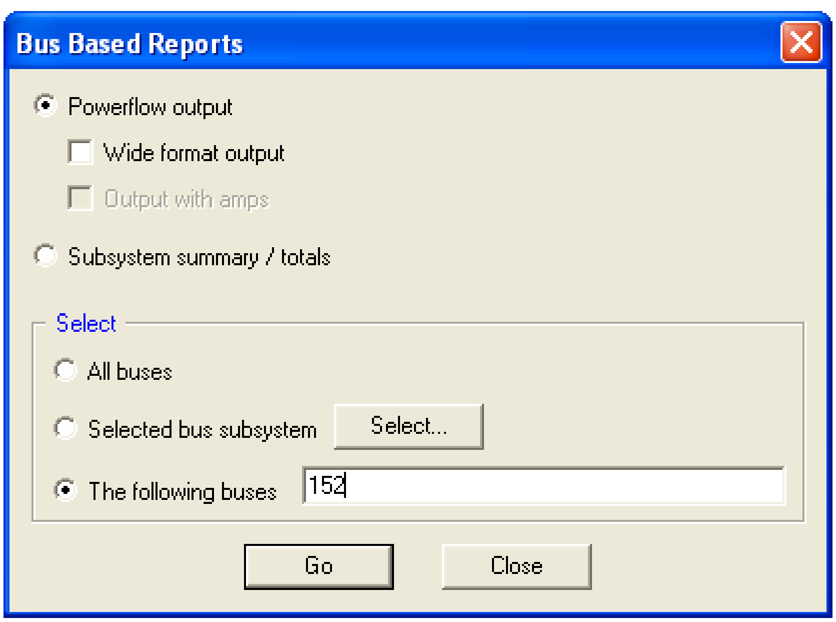


Figure 4-6. Bus Based Report Dialog

A partial view of the bus based report for bus #152 is shown in Figure 4-7. The report will be printed on a Report tab or to an alternative location (file, printer) of the user's choice, (see Section 2.16). Reference should be made to Section 4.4 for a more detailed discussion of the output reports.

```
     PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E      THU, JUL 22 2004  14:25
PSS/E PROGRAM APPLICATION GUIDE EXAMPLE                                  RATING
BASE CASE INCLUDING SEQUENCE DATA                                         SET A

BUS     152 MID500       500.00 CKT     MW     MVAR     MVA  %I 1.0171PU   -1.12
                                                              508.54KV
 TO     151 NUCPANT      500.00  1  -460.4   -94.6   470.1  39
 TO     151 NUCPANT      500.00  2  -460.4   -94.6   470.1  39
 TO     153 MID230       230.00  1   740.0   295.7   796.9  31 1.0100RG
 TO     202 EAST500      500.00  1    42.6    31.7    53.2   4
 TO    3004 WEST         500.00  1   138.2  -138.3   195.5
```

Figure 4-7. Partial Bus Based Report for Bus #152 in the savnw.sav Power Flow Case

4.1.4 Examining Power Flow Results Graphically

In order to examine the results graphically, the user must open a diagram file appropriate to the power flow case. For the purposes of this exercise, the *savnw.sld* slider file (available in the PSS™E EXAMPLE directory) can be opened using the ***File>Open*** option and selecting files of type (**.sld*) (see Figure 4-1). The Slider file will populate the Diagram View (see Figure 4-8). The view has been expanded to show details on bus 152 to compare with the tabular output. Details on the manipulation of the view are discussed in Section 2.5.

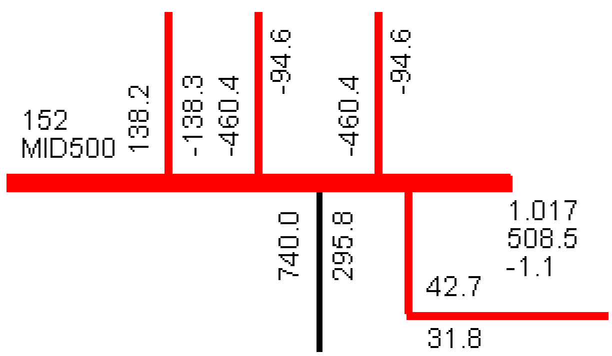


Figure 4-8. Graphical Output for Power Flow savnw.sav - Bus 152

4.1.5 Running a Contingency Case

Most work done with a power flow data base is investigative and linked to system performance under contingency conditions, usually N-1 (loss of any one element).

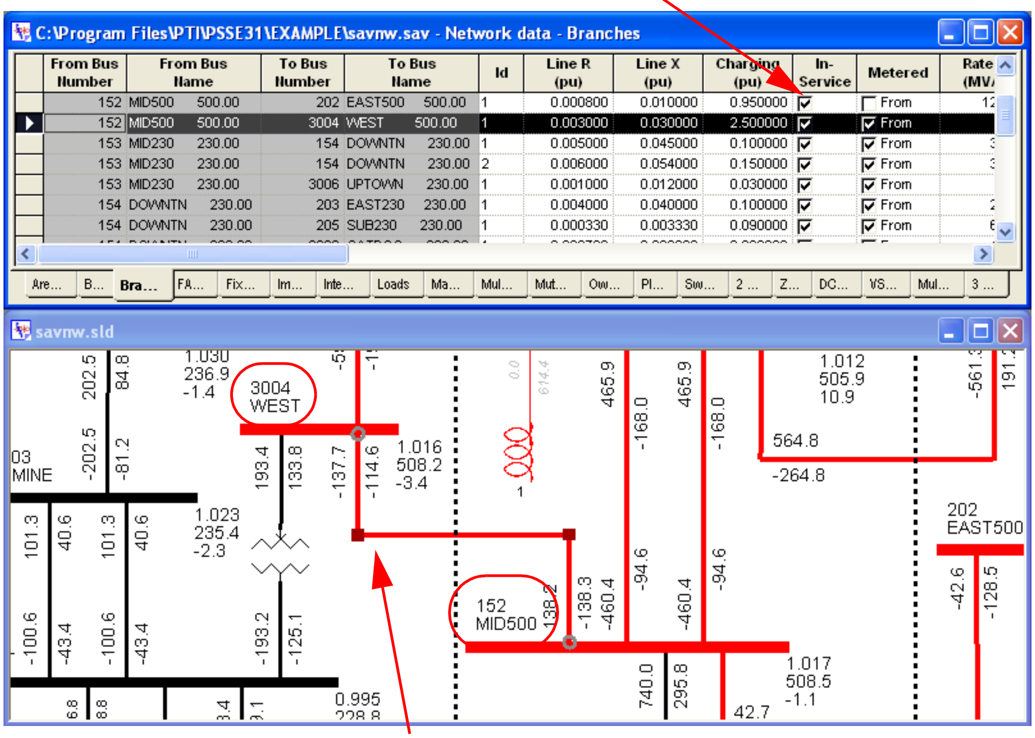
The user can switch a network element out of service or modify element ratings (loads, shunts, element ratings, element impedances etc) by editing data cells in the spreadsheet. Specifically, to take an element out of service, its status will be changed from "1" to "0" (see Figure 4-9).

When operating in the Diagram View, the user should merely double-click on the element to be taken out of service or have its data modified. The program will switch the view to the spreadsheet directly to the data tab and appropriate row for the data item to be changed.

If data is changed in the spreadsheet by editing a specific cell, the user must point to a different row before the data change is recorded by the program.

Once the data change is made (status or value), the user can click on the ***Solve*** button to obtain a revised power flow.

Second, change line status in spreadsheet.



First, double-click on line 152 - 3004 to highlight the line's data row on the Branch tab in the spreadsheet.

Figure 4-9. Changing Line Status from Diagram View

This section is only an introduction to running power flow cases. The following sections and chapters provide a significant amount of detail on using PSS™E as the simulator for sophisticated and complex power system analyses.

4.2 About Power Flow Calculations

The most common power system network simulation is the power flow calculation, described in the following question:

> "Given the load power consumption at all buses of the electric power system and the generator power production at each power plant, what is the power flow in each line and transformer of the interconnecting network?"

Calculated answers to this question are the basic means by which the power system is engineered to serve its load. The power system must operate without overloading transmission lines or transformers, stay within acceptable voltage limits at all buses, and maintain generator reactive power outputs between acceptable limits.

The power flow problem pertains to balanced steady-state operation of the power system. Because it considers balanced operation in which all negative- and zero-sequence voltages are zero, the power flow calculation deals with the *positive-sequence* model of all system components.

The following are the basic known input data for power flow calculations:

- Transmission line impedances and charging admittances.
- Transformer impedances and tap ratios.
- Admittances of shunt-connected devices such as static capacitors and reactors.
- Load-power consumption at each bus of the system.
- Real-power output of each generator or generating plant.
- Either voltage magnitude at each generator bus or reactive power output of each generating plant.
- Maximum and minimum reactive power output capability of each generating plant.

The quantities to be determined are

- The magnitude of the voltage at every bus where this is not specified in the input data.
- The phase of the voltage at every bus, except swing buses.
- The reactive power output of each plant for which it is not specified.
- The real power, reactive power, and current flow in each transmission line and transformer.

The power flow calculation is a network solution problem. The network of transmission lines and transformers is described by the linear algebraic equation:

$$I_n = Y_{nn}V_n \tag{4.1}$$

where:

I_n	=	Vector of positive-sequence currents flowing into the network at its nodes (buses).
V_n	=	Vector of positive-sequence voltages at the network nodes (buses).
Y_{nn}	=	Network admittance matrix.

If either I_n or V_n is known, the power flow calculation is straightforward. In practice, neither I_n nor V_n is known and the task of the power flow program is to devise successive trials of both I_n and V_n such that they satisfy both (4.1) and all the load and generation conditions specified in the problem data. Once V_n has been determined, all individual transmission line and transformer flows can be obtained directly from their individual component equations.

4.2.1 About the Power Flow Network Admittance Matrix

Consider a bus, i, of a power network which connects two transmission lines, two transformers, and a shunt element (see Figure 4-10).

Bus i is connected only to buses j, k, m, and n. Also note the designation of the tap-changing side of each transformer.

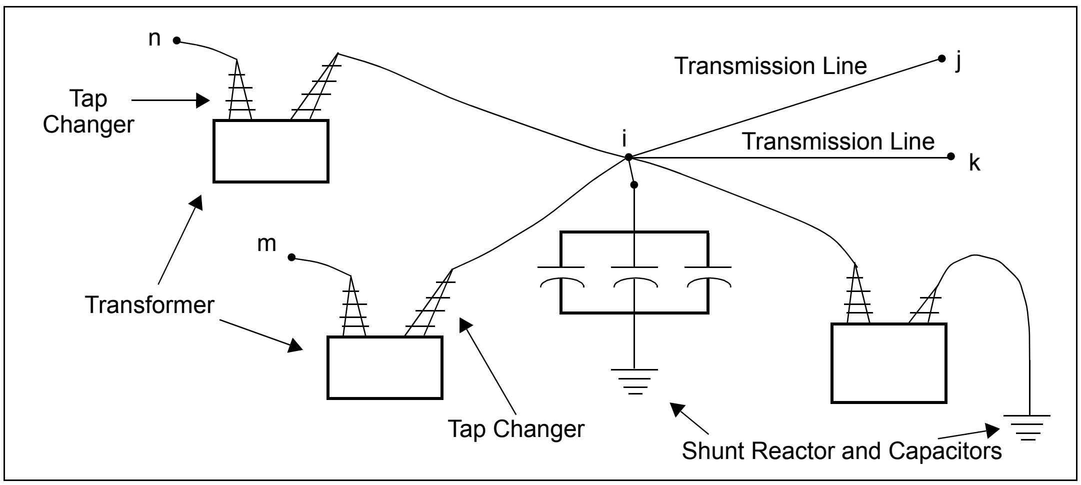


Figure 4-10. Equipment Connected at Bus, i

Each line and transformer may be represented by a per-unit equivalent circuit, with per-unit parameters being calculated from spacing, length, and nameplate data with respect to a common system MVA base. The resulting equivalent circuit surrounding network node, i, which represents bus i in the equivalent circuit of the whole system, is shown in Figure 4-11.

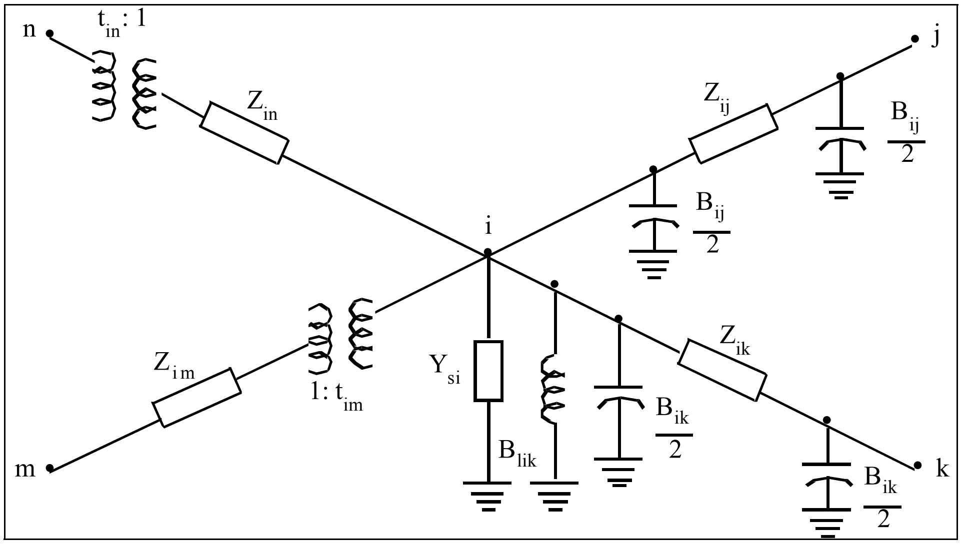


Figure 4-11. Equivalent Circuit for Node i of Transmission Network Model

The total current, i_i, flowing into node i when voltages, v_i, v_j, v_k, v_m, and v_n are applied to the network are determined by adding up the flow into each leg of Figure 4-11 at its connection to node i. In the case shown above, the total current, i_i, is zero since there is no source or load connected there. Hence:

$$\begin{aligned} i_i = {} & v_i Y_{si} \\ & + (v_i - v_j)/z_{ij} + \frac{v_i B_{ij}}{2} \\ & + (v_i - v_k)/z_{ik} + \frac{v_i B_{ik}}{2} + v_i B_{lik} \\ & + \left(\frac{v_i}{t_{im}} - v_m\right)/(z_{im} t_{im}) \\ & + \left(v_i - \frac{v_n}{t_{in}}\right)/z_{in} \end{aligned} \tag{4.2}$$

Expansion of (4.2) for the i-th element of I_n, which is i_i, gives:

$$i_i = \sum_{n=1}^{n} y_{ih} v_h \tag{4.3}$$

where

y_{ih} are the elements of Y_{nn}

and

v_h are the elements of the node voltage vector, V_n

The expressions for the elements, y_{ih}, in terms of transmission line and transformer parameters can be found by collecting terms in (4.2) and comparing the result with (4.3). The construction of the individual elements, y_{ii}, of the network admittance matrix from the line and transformer data is a key section of all power flow solution procedures of PSS™E.

Examination of (4.2) shows that only the diagonal element, y_{ii}, and four off-diagonal elements, y_{ih}, of the i-th row of the admittance matrix are nonzero. That is, a line or transformer from bus i to bus j contributes nonzero elements only to the i-th and j-th rows of Y_{nn}. Realistic power systems have between 1.5 and 2 transmission lines or transformers for each node. A transmission network of 2000 buses might, therefore, be expected to have approximately 4000 branches and, correspondingly, 8000 nonzero off-diagonal elements in its admittance matrix. This typical bus-to-branch ratio results in very sparse admittance matrices. In the above example only 8000 out of (2000) (2000-1), or 0.2% of the off-diagonal elements of Y_{nn} are nonzero.

The great majority of modern power flow calculation programs, including those of PSS™E, take advantage of this sparsity in their management of computer storage. They also take advantage of procedures that allow the admittance matrix to be manipulated into triangular factor and partial inverse forms which have similar sparsity properties, but whose number of nonzero off-diagonal elements is typically two to three times the number of such elements in the original Y_{nn} matrix.

Presenting a power flow program with a power system network model, whose original Y_{nn} matrix (or derivatives therefrom), has a number of nonzero elements that exceed the program’s allocated capacity, results in an error condition that prevents the use of some, but not all, of the available power flow iteration algorithms.

4.2.2 Exporting the Power Flow Network Admittance Matrix

All or part of the network admittance ("Y") matrix, as used in the PSS™E power flow solutions, may be exported in the form of a source file. To initiate the output Y matrix function, select the ***File>Export>Network admittance matrix…*** menu entry. This results in the display of the Output the Network Admittance Matrix dialog (see Figure 4-12).

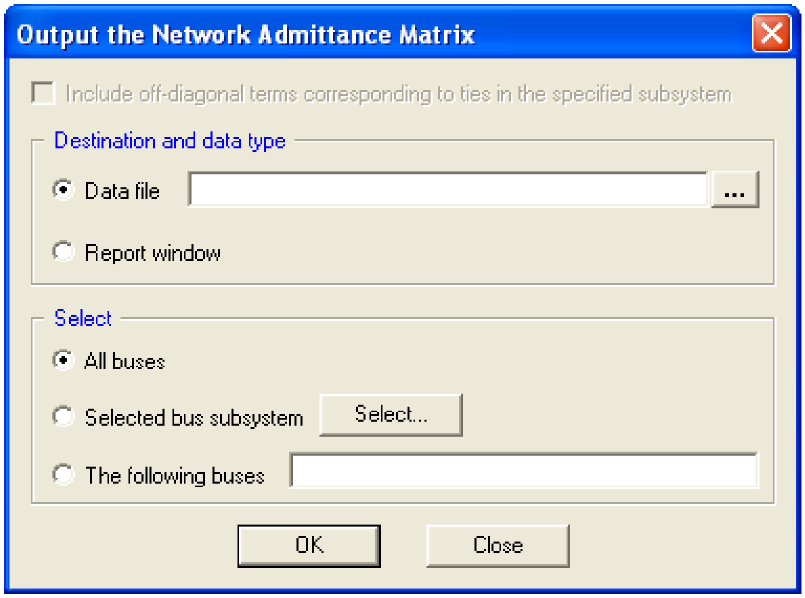


Figure 4-12. Output the Network Admittance Matrix Dialog

The **Select** area allows the user to select the portion of the admittance matrix to be output. The following selections are available:

- The entire admittance matrix.
- Admittance matrix rows corresponding to buses in the current bus subsystem, either as it is now defined, or as redefined following the "pressing" of the **Select…** button.
- The set of buses specified in **The following buses** field.

Unless the **All buses** toggle button is selected, the **Include off-diagonal terms corresponding to ties in the specified subsystem** check box is enabled. If this check box option is selected, all non-zero off-diagonal terms in the rows being processed are output. If this check box option is not selected, only off-diagonal terms corresponding to other rows being processed are output.

In the **Destination and data type** area, the user elects to direct the output to either a named file or to the Output Bar of the PSS™E window.

The admittance matrix terms produced are extracted from the admittance constructed by, and used during, the PSS™E power flow solution functions. As such, they include constant admittance loads, off-nominal tap ratios, and phase shifts, but exclude constant MVA load, constant current load, generator, switched shunt, dc line, and FACTS device contributions. Further, the admittance matrix used during the power flow solutions excludes rows and columns for swing (i.e., type 3) buses; this function also *excludes* terms from these rows and columns *unless* generators are "converted" (i.e., activity CONG is executed) prior to initiating this function.

Since the admittance matrix is extremely sparse, its terms are output as a set of matrix terms, using external bus numbers, as in the following example:

```
154,   154,  41.9126    , -404.786
154,  3008, -5.49574    ,  44.7801
154,   153, -4.47154    ,  40.2439
154,   205, -29.4701    ,  297.380
154,   203, -2.47525    ,  24.7525
```

The output of the output Y matrix function may be terminated with the AB interrupt control code.

4.2.3 About Power Flow Iterative Solution Algorithms

The power flow problem is nonlinear and requires an iterative trial and error process for its solution. One simple but effective iterative scheme follows:

1. Make an initial estimate of the voltage at each bus.
2. Build up an estimated current inflow vector, I_n, at each bus from a boundary condition such as:

$$P_k + jQ_k = v_k i_k^* \tag{4.4}$$

where:

3. $P_k + jQ_k$= Net load and generation demand at bus k.

   v_k = Present estimate of voltage at bus k.
4. Use (4.1) to obtain a new estimate of the bus voltage vector, v_n.
5. Return to Step 2 and repeat the cycle until it converges on an unchanging estimate of v_n.

While this scheme is useful in some specific situations (to be discussed later), it does not work well for the general power flow calculation where the terminal voltage magnitude, rather than reactive power output, is specified for many generators.

4.2.4 About Power Flow Boundary Conditions

Steps 2 and 3 of the iterative scheme in Section 4.2.3 refer to two aspects of the power flow solution calculation. The solution of the power flow problem is a set of bus (or node) voltages that simultaneously satisfy the network condition, $I_n = Y_{nn}v_n$, derived from Kirchhoff's laws, and the boundary conditions derived from load and generator characteristics, such as $P_k + jQ_k = v_k i_k^*$.

The network condition (4.1) is linear and can be solved without iteration if either the voltage vector, v_n, or the current vector, I_n, is specified. The solution is a direct calculation if v_n is specified, and requires a standard computer procedure for solving linear simultaneous equations if I_n is given.

The boundary conditions may be specified quite arbitrarily, depending upon the loads that electricity users choose to connect to the network, and are usually nonlinear. It is the nonlinearity of the boundary conditions that forces the use of an iterative procedure for power flow solution. It must be noted though, that while the network condition *can* be handled in a non iterative, closed-form manner, it is often advantageous to use an iterative method to solve both the network condition and the boundary conditions.

In the commonly used power flow iteration procedures:

- Gauss-Seidel methods solve both network and boundary conditions by iteration.
- Newton-Raphson methods solve the network condition by closed-form calculation, while using iteration to solve the boundary conditions.

4.2.4.1 Boundary Conditions of Constant MVA Loads

The most common load boundary condition is a specification of load real and/or reactive power consumption

$$\text{Real}\ (v_k i_k^*) = -P_k \tag{4.5}$$

$$\text{Imag}\ (v_k i_k^*) = -Q_k \tag{4.6}$$

This characteristic is not realistic for voltages below approximately 0.8 per unit. All PSS™E power flow voltage solutions, in both power flow and dynamic simulation, therefore, modify (4.5) and (4.6) to make P_k and Q_k functions of the magnitude of the bus voltage as shown in Figure 4-13.

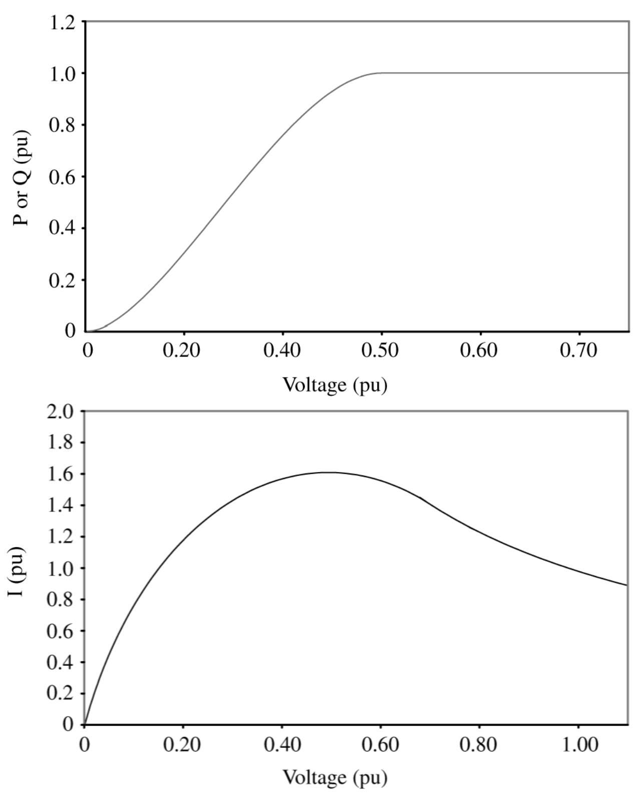


Figure 4-13. Constant MVA Load Characteristic (Top) and Resultant Form of Current/Voltage Curve (Bottom)

The constant power characteristic holds the load power constant as long as the bus voltage exceeds the value specified by the solution parameter PQBRAK, and assumes an elliptical current-voltage characteristic of the corresponding load current for voltages below this threshold.

Figure 4-15 depicts this characteristic for PQBRAK values of 0.6, 0.7, and 0.8 pu. The user may modify the value of PQBRAK via the ***Power Flow>Solution>Parameters…*** option. This will open the Solution Parameters dialog where the value of PBRAK can be edited (see Figure 4-14).

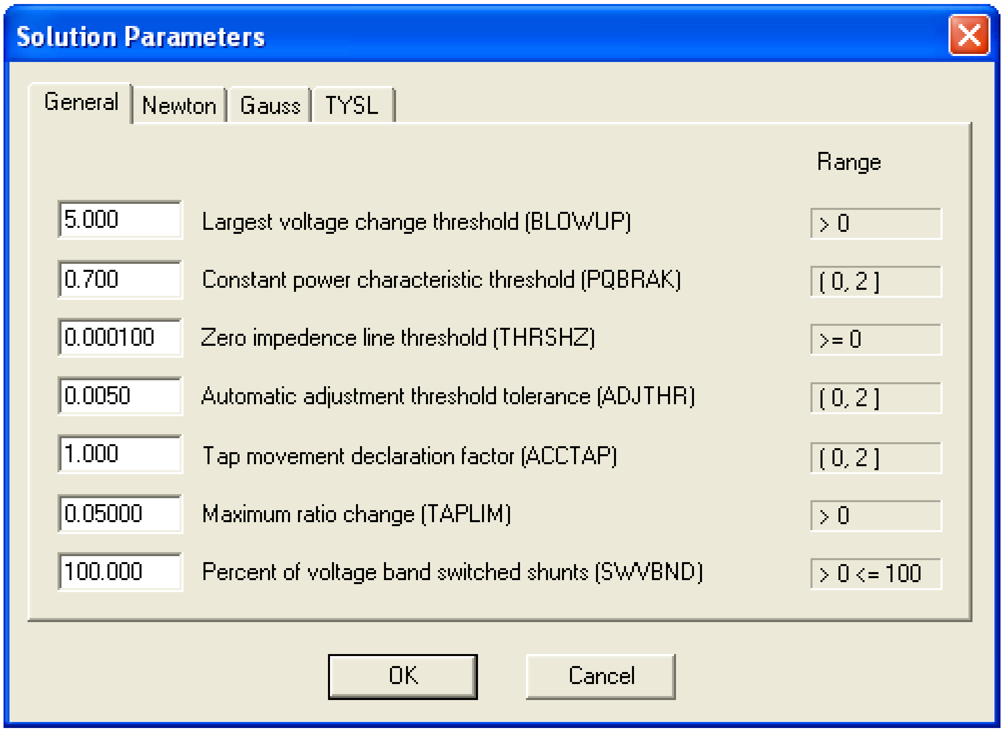


Figure 4-14. Changing the Constant Power Threshold PQBRAK

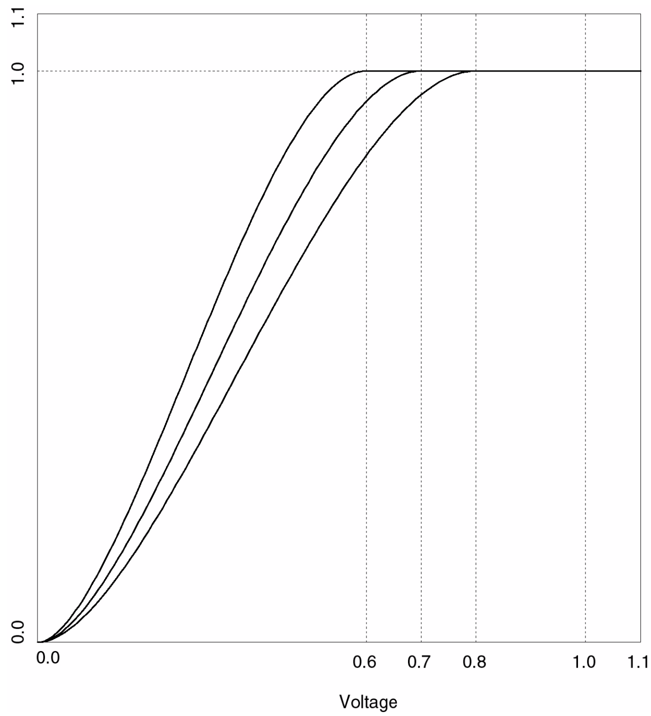


Figure 4-15. Constant Power Load Characteristic

4.2.4.2 Boundary Conditions of Constant Current Loads

Load may be specified as a given active or reactive component of current such that:

$$\frac{\text{Real }(v_k i_k^*)}{|v_k|} = -I_{pk} \tag{4.7}$$

$$\frac{\text{Imag }(v_k i_k^*)}{|v_k|} = -I_{qk} \tag{4.8}$$

Again, because this characteristic is unrealistic for voltages below about 0.5 per unit, all PSS™E power flow solutions modify (4.7) and (4.8) to make I_{pk} and I_{qk} functions of the magnitude of v_k, as shown in Figure 4-16.

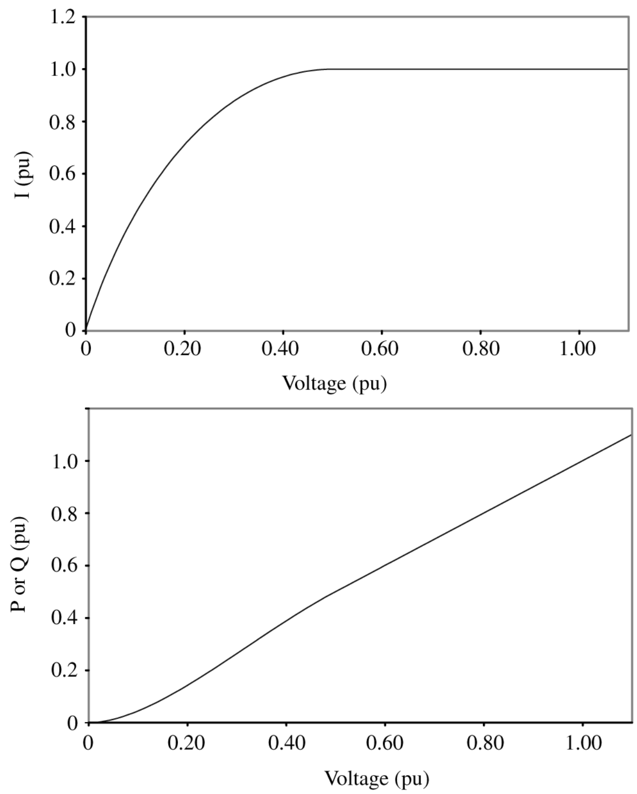


Figure 4-16. Constant Current Load Characteristic (Top) and Resultant Form of Load MVA/Voltage Curve (Bottom)

4.2.4.3 Boundary Conditions of Constant Impedance Loads

Finally, load may be specified by given real and reactive parts of shunt admittance such that

$$\frac{i_k}{v_k} = G_k + jB_k = \frac{P_k - jQ_k}{v_k v_k^*} = \frac{P_k - jQ_k}{|v_k|^2} = \frac{P_k}{|v_k|^2} - j\frac{Q_k}{|v_k|^2} \tag{4.9}$$

Note that (4.9) is not treated as a boundary condition in the solution process; it can be more convenient to incorporate this type of load as a bus shunt branch unless there is a need, at some time, to convert this load to another type.

4.2.4.4 Boundary Conditions of Composite Loads

All PSS™E network solutions allow the load at each bus to be a composite of arbitrary amounts of load with each of the characteristics described in the previous subsections. The composite characteristic becomes the boundary condition used in iterative power flow solutions.

The normal practice is to specify the load at each bus initially as a compendium of constant MVA and constant admittance loads. Subsequently the data can be adjusted to comprise the required amounts of each characteristic. This course gives compatibility with external power flow data formats such as the IEEE Common Format.

Conversion and construction of load data is facilitated by the ***Power Flow>Convert Loads and Generators…*** which launches the Convert/Reconstruct Loads and Generators dialog (see Figure 4-17). The operation is described in detail in Section 4.5.2.

4.2.4.5 Boundary Conditions of the Swing Bus

Every power flow simulation case must have at least one bus designated as a *swing bus*. The corresponding boundary condition is

$$v_{k\,(\text{complex})} = \text{constant} \tag{4.10}$$

The net real and reactive power inflow to a swing bus are free variables and follow from the power flow solution, rather than being boundary conditions imposed upon it.

Power flow solution cases must have at least one swing bus in every separate section (island) of the network. An AC island is defined as the set of all in-service buses such that each bus in the island may be reached from every other bus in the island through the in-service AC network. If a working case contains more than one island, any island is either electrically disjoint from all other islands, or connected to one or more other islands by one or more asynchronous ties (e.g., DC lines).

To be a valid power flow case, each AC island in the working case must contain at least one type 3 (swing) bus. Further, the buses connected by each in-service branch must be in-service (i.e., none of them may be type 4 buses). No swing bus is needed in fault analysis, switching, and dynamic simulation calculations, although swing buses may be used in these simulations.

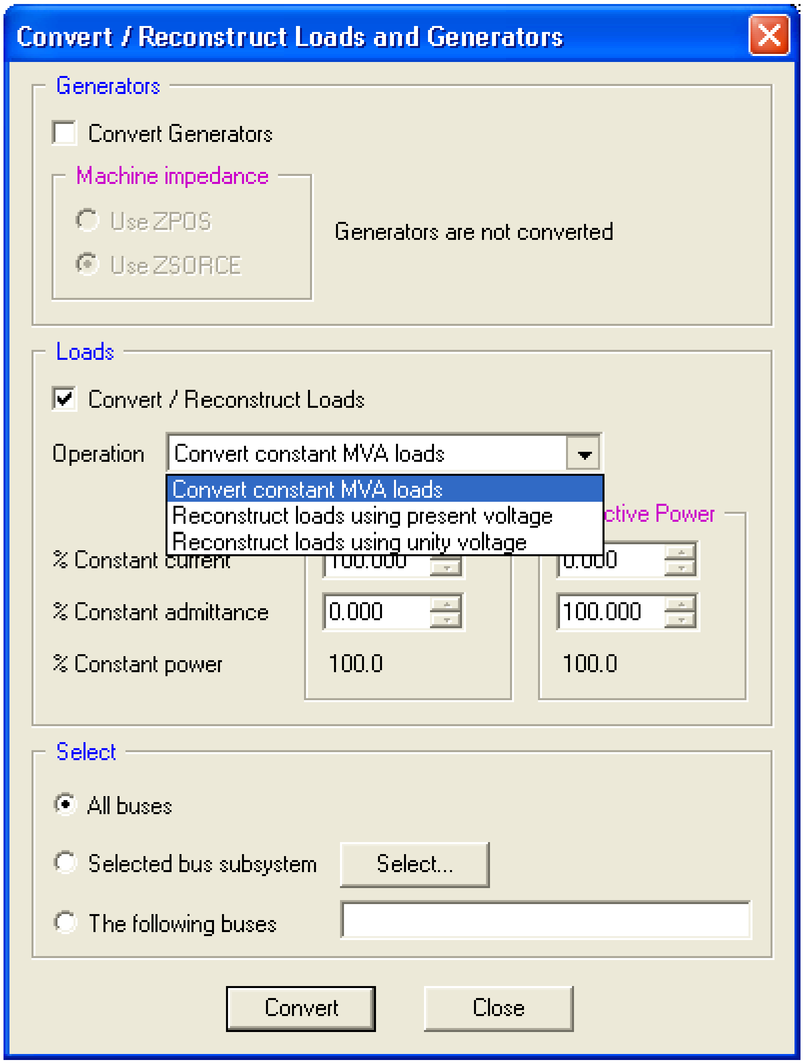


Figure 4-17. Convert/Reconstruct Load and Generators Dialog

When enabled, the solution connectivity checking option checks for the presence of swingless islands at the start of each power flow solution (see Section 1.6.4).

The user can check that every subsystem of a power system power flow case includes a swing bus via the ***Power Flow>Check Data>Buses not in swing bus tree (TREE)*** option (see Figure 4-18).

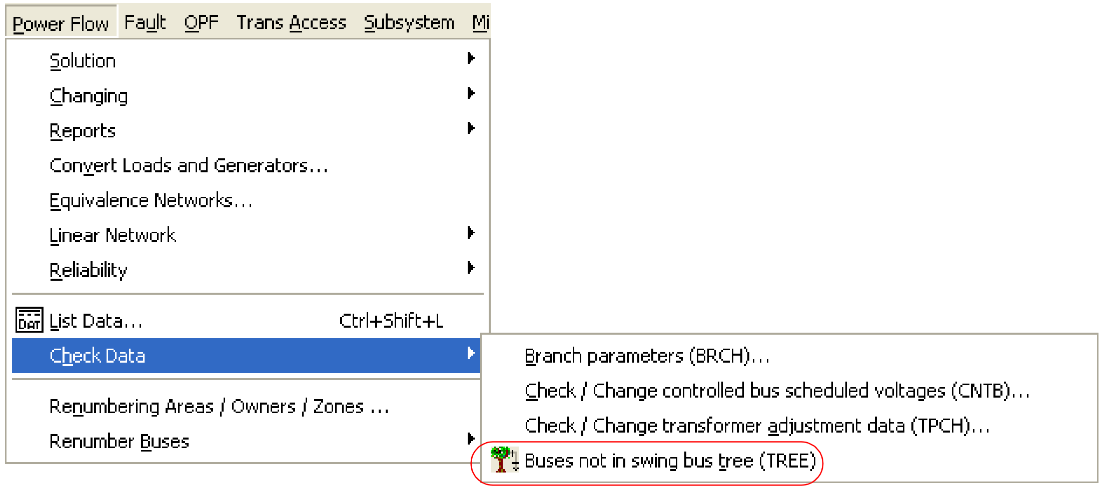


Figure 4-18. Checking for Buses not Connected to a Swing Bus

4.2.4.6 Boundary Conditions of Standard Generators

The standard generator arrangement used throughout PSS™E is shown in Figure 4-19. The generator is assumed to be connected to bus k by a step-up transformer whose per unit impedance is Z_t, (R_t + TX_t), on generator MVA_{base}. The transformer impedance may be set to zero to model a generator connected directly to the bus such that bus k is the generator terminal bus.

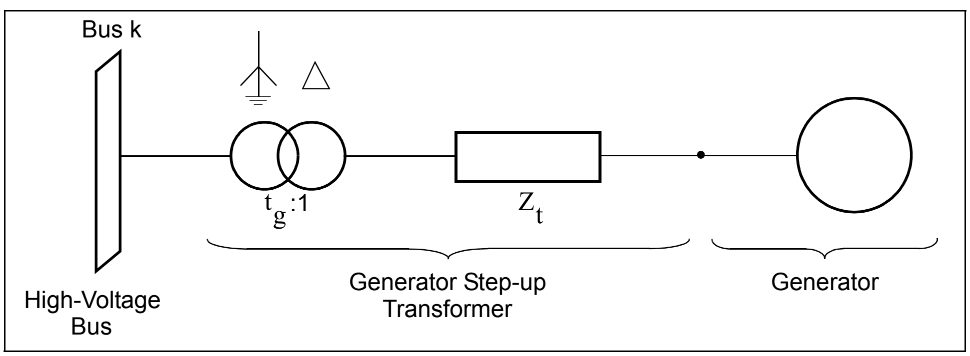


Figure 4-19. Standard PSS™E Generator Configuration

The standard generator boundary condition is a specification of real power output at the high voltage bus, bus k, and of voltage magnitude at some designated bus, not necessarily bus k.

$$\text{Real }(v_k i_k^*) = P_k \tag{4.11}$$

$$|V_1| = V_{\text{sched}} \tag{4.12}$$

This characteristic is subject to the following reactive power output limitations:

$$Q_{mn\ k} \le \mathrm{Imag}(v_k i_k^*) \le Q_{mx\ k} \tag{4.13}$$

which overrides the voltage schedule condition (4.12).

It is important to recognize that the maximum and minimum reactive power limits assigned to bus k apply to generator reactive power output measured at the high-voltage bus and not at the generator terminals. Determination of $Q_{min\ k}$ and $Q_{max\ k}$ must, therefore, recognize the reactive power loss in the step-up transformer reactance. A reasonable assumption for assigning reactive power limits to bus k, in this situation, is to subtract a reactive loss corresponding to full load current (1.0 pu) from the generator terminal reactive power limits.

Since Z_t has a per-unit value with respect to generator MVA base and $Q_{min\ k}$, $Q_{max\ k}$ are in megavars,

$$Q_{limit\ k} = Q_{limit\ g} - X_t \times MBASE \tag{4.14}$$

for lagging generator terminal power factor, and

$$Q_{limit\ k} = Q_{limit\ g} + X_t \times MBASE \tag{4.15}$$

for leading generator terminal power factor, where

X_t	=	Step-up transformer reactance in per unit on generator base.
$Q_{limit\ g}$	=	Limiting reactive power in Mvar at generator terminals.
$Q_{limit\ k}$	=	$Q_{min\ k}$ or $Q_{max\ k}$.

4.2.4.7 Boundary Conditions of Multiple Identical Generators

Multiple, *identical* generators and generator step-up transformer units may be represented by the standard model, as shown in Figure 4-19, by specifying the generator MVA base to be the total MVA rating of all connected generators and specifying Z_t as the impedance of a single step-up transformer on its own single generator rating. This representation is illustrated in Figure 4-20.

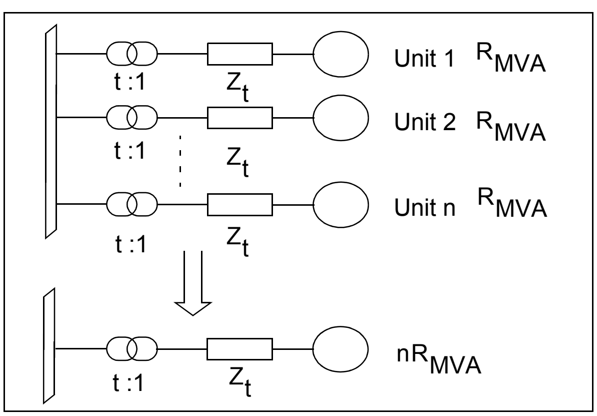


Figure 4-20. Identical Generators at Bus

Lumping several identical generators may, for example, be used where startup and shutdown of individual units within a plant are scheduled to meet increasing and decreasing plant loading. This is achieved by adjusting P_{gen}, $Q_{max\ k}$, $Q_{min\ k}$, and $MBASE_k$. No adjustment of Z_t or of the network branch data is necessary.

Use of this lump approach to handle multiple units implies that real and reactive power output are distributed uniformly between them. If loadings of multiple units are not identical, they must be treated as different generators even though their impedances and other characteristics are identical. This offers the advantage of having to change only unit status flags to account for a change in the number of operating units at the plant.

4.2.4.8 Boundary Conditions of Multiple Non-Identical Generators

A plant having several different generators connected to its high voltage bus cannot be represented by a single generator model. Correct representation of such plants requires the use of multiple, individual generator models at the plant bus.

4.3 About Power Flow Solution Methods

PSS™E includes five power flow solution activities, each of which operates on the bus voltage estimates in the working file to attempt to bring them to a solution of Kirchhoff's laws. Each activity makes successive adjustments to the bus voltages in accordance with a different iterative scheme. The iterative schemes are listed in Table 4-1 along with the "activity" names familiar to users of previous versions of PSS™E. Access to power flow solutions is from the ***Power Flow>Solutions>Solve*** option.

Table 4-1. Available Iteration Schemes in PSS™E

Iterative Scheme	Activity Name
Gauss-Seidel	SOLV
Modified Gauss-Seidel handles series capacitors	MSLV
Full Newton-Raphson	FNSL
Decoupled Newton-Raphson	NSOL
Fixed-Slope Decoupled Newton-Raphson	FDNS

Because their convergence properties are dependent upon network and load attributes, each of the five power flow iteration methods of PSS™E has its own strengths and weaknesses. The most significant strengths and weaknesses are summarized in Table 4-2.

Any of these five methods can fail to converge on the solution of some problems. It is rare, however, to find a problem whose correct voltage solution vector cannot be found by the application of one or more of the five methods. There are many problems that are difficult or impossible to solve with a single iterative method but which can be solved readily by the successive application of more than one method.

A general guide to the selection of an iterative method follows:

- The Gauss-Seidel methods are generally tolerant of power system operating conditions involving poor voltage distributions and difficulties with generator reactive power allocation, but do not converge well in situations where real power transfers are close to the limits of the system.
- The Newton-Raphson methods are generally tolerant of power system situations in which there are difficulties in transferring real power, but are prone to failure if there are difficulties in the allocation of generator reactive power output or if the solution has a particularly bad voltage magnitude profile.
- The Gauss-Seidel methods are quite tolerant of poor starting voltage estimates, but converge slowly as the voltage estimate gets close to the true solution.
- The Newton-Raphson methods are prone to failure if given a poor starting voltage estimate, but are usually superior to the Gauss-Seidel methods once the voltage solution has been brought close to the true solution.

Experimentation is needed to determine the optimum combination of iterative methods for each particular power system model.

Experience suggests the following as the most advantageous approach to new power flow cases whose specific characteristics have yet to be learned:

- Initialize all voltages to either unity amplitude, or to scheduled amplitude if given, and initialize all phase angles to zero. (This step is referred to as a *flat start.)*
- Execute Gauss-Seidel iterations until the adjustments to the voltage estimates decrease to, say, 0.01 or 0.005 per unit in both real and imaginary parts.
- Switch to Newton-Raphson iterations until either the problem is converged, or the reactive power output estimates for generators show signs of failure to converge.
- Switch back to Gauss-Seidel iterations if the Newton-Raphson method does not settle down to a smooth convergence within 8 to 10 iterations.

Experience with each specific problem will suggest modifications to this procedure. In particular, the initial Gauss-Seidel iterations and flat-start steps will be bypassed when the result of a previous solution is known to be a close estimate of the expected new solution.

Table 4-2. Power Flow Solution Activities—Selection Guide

Iteration Method/ Old Activity name	Advantages	Disadvantages	Use When	Do Not Use When	Convergence Monitor	Interrupt Options
Gauss-Seidel Iteration (SOLV)	Tolerant of data errors, insoluble conditions in local areas of network. Fails gently, indicates areas of network causing problem.	Cannot handle negative series reactances. Acceleration factor must be tuned to match system for optimum performance. Number of iterations increases as system size increases.	Initial voltage estimates are poor. Network has reactive power problem. NSOL or FNSL has failed to converge. Data is suspect.	Network has series capacitors or very low impedance branches.	Prints bus number of bus having largest ΔV each iteration together with /ΔV/ and rectangular components of ΔV. /ΔV/ is printed as multiple of solution tolerance.	AB to stop iterating and return directly to activity selector. NC to suppress convergence monitor listing. DC to print DC line operating parameters at each iteration. NM to suppress adjustment monitors.
Modified Gauss-Seidel Iteration (MSLV)	Has most advantages of Gauss-Seidel and is able to handle series capacitors between Type 1 buses.	Convergence is very sensitive to tuning of acceleration factor, ACCM. Slight deviation of ACCM from optimum. Value gives poor convergence.	As for Gauss-Seidel.	Network has very low impedance branches, series compensation exceeding about 80%, or series capacitors connected directly to generator buses.	As for Gauss-Seidel.	As for Gauss-Seidel.

Table 4-2. Power Flow Solution Activities—Selection Guide (Cont.)

Iteration Method/ Old Activity name	Advantages	Disadvantages	Use When	Do Not Use When	Convergence Monitor	Interrupt Options
Full Newton-Raphson Iteration(FNSL)	Rapid convergence on well-conditioned cases. Small bus mismatches can be achieved.	Intolerant of data errors. Cannot start from poor voltage estimates. No indication of cause of problem when failing to converge. Can give problems converging cases where reactive power limits are restrictive.	Network is conventional and well-behaved. Network contains series capacitors or other negative series reactance branches.	Overloading has produced reactive power problems.	Prints largest mismatch (real and reactive) and voltage changes (magnitude and angle) for each iteration. Identifies the bus numbers where these maxima occur.	As for Gauss-Seidel.
Newton-Raphson method with real and reactive power equations decoupled (NSOL)	Rapid convergence on well-conditioned cases. Small bus mismatches can be achieved.	Intolerant of data errors. Cannot start from poor voltage estimates. Cannot handle network with low X/R ratio branches (e.g., equivalents). No indication of cause of problem when failing to converge. Can give problems converging cases where reactive power limits are restrictive.	Poor voltage estimate and network contains negative reactive branch.	Network contains branches with low X/R ratios. Overloading has produced reactive power problems.	As for Full Newton-Raphson.	As for Gauss-Seidel.
Newton-Raphson method with real and reactive power equations decoupled using a fixed Jacobian matrix (FDNS)	Rapid convergence on well-conditioned cases. Small bus mismatches can be achieved.	As mismatches are reduced, rate of improvement may be allowed. Intolerant of data errors. No indication of cause of problem when failing to converge. Can give problems converging cases where reactive power limits are restrictive.		Overloading has produced reactive power problems.	As for Full Newton-Raphson.	As for Gauss-Seidel.

4.3.1 Defining Power Flow Solution Interrupt Control Codes

In general the solution methods all respond to the following interrupt control codes. Where specific solutions respond to additional codes they will be identified in the appropriate sections.

AB — Abandon solution activity following completion of the next iteration.

NC — Suppress the convergence monitor.

NM — Suppress any automatic adjustment monitors.

DC — Tabulate the conditions for each in-service DC line after each iteration. The data printed for each noncapacitor commutative two-terminal DC line includes the DC line number followed by two lines including the following quantities:

```
IPR IPI ALPHA GAMMA VDCR VDCI TAPR TAPI DCCUR
          PACR   QACR   PACI   QACI
```

The information printed for each capacitor commutated two-terminal DC line includes the DC line number, followed by an iteration report of the Newton solution performed for one or more operating modes, followed by:

```
ALPHA_R MU_R VDC_R(kV) TAP_R PAC_R QAC_R DC_CURRENT
GAMA_I  MU_I VDC_I(kV) TAP_I PAC_I QAC_I ALPHA_I
```

For multi-terminal lines, the DC line number is followed by conditions at each converter bus:

```
bus #  ANGLE  TAP  VDC  DCCUR  PAC  QAC
```

For VSC DC lines with both converters in-service, the DC line name is followed by line and converter bus conditions as follows:

- DC voltages at the power and voltage controlling converters and DC current
- if a limit violation is relieved at this iteration, the converter bus at which it occurs, the present AC injections at that bus, and the reduced values are tabulated, followed by the new DC voltages and the DC current
- DC power, converter losses, and AC power at the power controlling converter
- DC line losses
- DC power, converter losses, and AC power at the voltage controlling converter

For VSC DC lines with only one converter in-service, the DC line name is followed by the DC power, converter losses, and AC power at the in-service converter.

FD — Tabulate the conditions for each in-service FACTS device after each iteration. The data printed for each FACTS device includes conditions at the sending end and terminal end buses, series voltage and current in polar coordinates, series voltage with respect to both series current and sending end voltage in rectangular coordinates, and an indication of those quantities currently at a limit.

4.3.2 Power Flow Handling of Generation Equipment

During the solution, generator buses are treated as follows:

1. Those generators that regulate their own voltage hold their scheduled voltage as long as their reactive power limits are not violated.
2. Those generators that regulate the voltage of a remote type 1 or 2 bus have their own voltage adjusted as required to hold the desired voltage at the remote bus as long as their reactive power limits are not violated.
3. Those generators that are swing buses (i.e., with a type code of three) are held at constant voltage and phase angle. Their active and reactive power outputs are set as required prior to leaving the solution process. For such buses with both generators and synchronous condensers, only the generators share the swing bus' active power output.
4. At the end of the solution process, generator plant reactive powers (and active powers for type three buses) are apportioned among the machines at the plant; var values are split so as to achieve identical power factor at all machines in a plant, except that machine reactive power limits are honored.

4.3.3 Power Flow Handling of Switched Shunt Devices

Buses for which switched shunt data has been specified are handled according to the following rules:

1. Automatically switched shunts are permitted only at type 1 and 2 buses. At type 3 (swing) buses, switched shunts are treated as fixed at the value initially specified as BINIT or as subsequently modified by editing the working case.
2. For those switched shunts designated as fixed (i.e., MODSW = 0 or the bus is a type 3 bus), the specified admittance is held constant during the solution.
3. Those switched shunts controlling local or remote bus voltage to a voltage setpoint (i.e., VSWHI = VSWLO) are handled as follows:
   a. Those switched shunts designated as continuous (i.e., MODSW = 2) hold their scheduled voltage as long as the admittance limits are not violated. The high admittance limit is the admittance when all reactor blocks are switched off and all capacitor blocks are switched on; the low limit represents all reactor blocks switched on and all capacitor blocks are switched off. (Note that for reactors, B_L<0 0 and for shunt capacitors, BC>0).
   b. Switched shunt devices designated as operating in discrete mode (i.e., MODSW = 1) are initially treated as the continuously operating devices described above. When the network solution convergence tolerance is reached, the discretely operating shunts are set to the nearest discrete step. The network solution iteration then continues with the switched shunts held constant.
4. Switched shunts controlling local or remote bus voltage to a voltage band (i.e., VSWHI > VSWLO) *must* be designated as operating in discrete mode. Such devices are moved in single steps between network solution iterations.

5. Continuous mode control to a voltage band is not allowed. Such devices are alarmed and treated as controlling to a voltage setpoint (taken as the midpoint of the specified voltage band) in continuous mode as described in (3a) above.

6. Those switched shunts controlling other voltage controlling devices check the reactive power output of the controlled device against the more restrictive limits described in Section 3.2.11 which describes the data records and control modes for switched shunt devices. If the reactive power is outside of those limits, one step of switched shunt admittance is switched on or off so as to bring the reactive output of the controlled device toward the nearest of the more restrictive limits. In the example in Section 3.2.11, if the output of the controlled voltage controlling device exceeds 25 Mvar, the reactive output of the switched shunt will be increased: if the switched shunt has inductors switched on, one step of inductors will be switched off; otherwise one step of capacitors will be switched on.

An adjustment monitor is printed at the progress output device any time a step wise adjustment as in (4) and (6) above, or the setting to the nearest discrete step as in (3b) above, occurs.

When an iterative solution process is initiated on a system which has previously been solved, the presence of discretely operating switched shunts as described in (3b) above may result in more than one network solution iteration being required. Although the network should have been in balance, significant voltage changes may initially be imposed as these devices are (temporarily) switched to the continuous mode. This may be overcome by locking the switched shunts at their present settings (see Section 4.3.12).

4.3.4 Power Flow Handling of FACTS Devices

For an in-service FACTS device to be modeled during power flow solutions, it must satisfy the following conditions:

1. The sending end bus must be either a type 1 or type 2 bus.

2. The sending end bus must not be connected by a zero impedance line to type 3 bus.

3. If it is specified, the terminal end bus must be a type one bus with exactly one in-service AC branch connected to it; this branch must not be a zero impedance line and it must not be in parallel with the FACTS device.

4. If it is specified, the terminal end bus must not have a switched shunt connected to it.

5. If it is specified, the terminal end bus must not be a converter bus of a DC line.

6. A bus which is specified as the terminal end bus of an in-service FACTS device may have no other in-service FACTS device connected to it. However, multiple FACTS device sending ends on the same bus are permitted.

7. A bus which is specified as the terminal end bus of an in-service FACTS device may not have its voltage controlled by any remote generating plant, switched shunt, or VSC DC line converter.

The FACTS device model is called at the start of each iteration to set the boundary conditions to be imposed upon the AC network at the sending and terminal end buses during that iteration.

The shunt element at the sending end bus is used to hold the sending end bus voltage magnitude to VSET subject to the sending end shunt current limit SHMX. This is handled in power flow solutions in a manner similar to that of locally controlling synchronous condensers and continuous switched shunts. In terms of the boundary conditions they impose at the buses to which they are connected, these three devices differ only in their representation of limits: synchronous condensers have Mvar limits; switched shunts have admittance limits; and the shunt elements of FACTS devices have current limits. Current in the shunt-connected bridge is determined by both the shunt Mvar output and the amount of active power transferred between the shunt and the series elements. If the current limit is violated, sending end voltage control is abandoned and the magnitude of the shunt Mvar output is reduced.

The series element may be set to operate in one of eight modes as described in the following sections.

4.3.4.1 Normal Mode

The normal operating mode of the series element is enabled by setting the control mode of the FACTS device to 1, (see Section 3.2.18 for control codes). In unconstrained operation, the series element is used to maintain the desired active (PDES) and reactive (QDES) power flow between the sending and receiving end buses. If the series current limit (IMX) is violated, the magnitude of the desired reactive power flow is reduced; if reducing the desired reactive power flow to zero still results in a series current limit violation, the magnitude of the desired active power flow is reduced as required. With desired power setpoints established (either as specified or as reduced due to a series current limit violation), the bus boundary conditions, which are to be presented to the power flow solution, are determined.

Limits on three quantities may prohibit the series element from maintaining power flow at the established active and/or reactive power setpoints: the series voltage magnitude (maximum of VSMX); the receiving end bus voltage magnitude (maximum of VTMX and minimum of VTMN); and the magnitude of the active power transfer between the shunt and series-connected bridges (maximum of TRMX). These limits result in seven possible states of the model:

1. Series voltage, receiving bus voltage, and bridge active power transfer are all treated as dependent variables. Active and reactive power flows meet their established setpoints.

2. Series voltage is held at VSMX; terminal bus voltage and bridge active power transfer are both dependent variables. If possible, active power flow is maintained at its established setpoint and reactive power flow control is abandoned; otherwise, active power flow control is abandoned and the model attempts to hold reactive power flow at its established setpoint.

3. Terminal bus voltage magnitude is held at either VTMX or VTMN; series voltage and bridge active power transfer are both dependent variables. Reactive power flow control is abandoned and active power flow is maintained at its established setpoint.

4. Bridge active power transfer is held at either TRMX or -TRMX; series voltage and receiving bus voltage are both dependent variables. Reactive power flow control is abandoned and active power flow is maintained at its established setpoint.

5. Series voltage is held at VSMX and receiving bus voltage magnitude is held at either VTMX or VTMN; bridge active power transfer is a dependent variable. Both active and reactive power flow control are abandoned.

6. Series voltage is held at VSMX and bridge active power transfer is held at either TRMX or -TRMX; receiving bus voltage is a dependent variable. Both active and reactive power flow control are abandoned.

7. Terminal bus voltage magnitude is held at either VTMX or VTMN and bridge active power transfer is held at either TRMX or -TRMX; series voltage is a dependent variable. Both active and reactive power flow control are abandoned.

Generally, the model remains in its current state until network convergence is achieved. Then model quantities are checked to determine if a change in model state is required (i.e., if a limited quantity can be made a dependent variable, or if a dependent variable violates its limit). If a change of model state is applied, the power flow solution continues until convergence is again achieved, and then the model is again tested for a change of state.

The PSS™E FACTS model will not attempt to solve for the state in which all three of the above quantities are simultaneously held at a limit. Such a state defines an over constrained problem. In such a system condition, the FACTS model will usually cycle among model states (5) through (7) above. Observing the FACTS device conditions monitor via the FD interrupt control code (see Section 4.3.1) reveals such a situation. It is the user’s responsibility to decide which of the three limits is to be relaxed, and then make the appropriate data change.

4.3.4.2 Bypassed Mode

The bypassed operating mode of the series element is enabled by setting the control mode of the FACTS device to 2 (see Section 3.2.18 for control codes). In this mode, the series element is solved to a series voltage magnitude of zero. No limits are enforced other than SHMX, the maximum shunt current at the sending end bus. The solution is identical to that which would be obtained by replacing the series element with a zero impedance line.

4.3.4.3 Constant Series Impedance Mode

The constant series impedance operating mode of the series element is enabled by setting the control mode of the FACTS device to 3 (see Section 3.2.18 for control codes). In this mode, the series element is modeled with a fixed series impedance specified on system base. No limits are enforced other than SHMX, the maximum shunt current at the sending end bus.

4.3.4.4 Constant Series Voltage Mode

The constant series voltage operating mode of the series element is enabled by setting the control mode of the FACTS device to 4 (see Section 3.2.18 for control codes). In this mode, the series element is solved to a specified complex series voltage expressed relative to the value indicated by VSREF (i.e., relative to either sending end voltage or series current). No limits are enforced other than SHMX, the maximum shunt current at the sending end bus.

4.3.4.5 IPFC Master and Slave Modes

An IPFC (Interline Power Flow Controller) may be modeled using two consecutively numbered FACTS devices. The first of this pair must be assigned as the IPFC "master" device by setting its FACTS device control mode (see Section 3.2.18 for control codes) to 5 or 7, and the second must be assigned as the IPFC "slave" device by setting its control mode to 6 or 8.

In the IPFC model, both devices have a series element but no shunt element. The "master" device is solved in the same manner as a series device in normal mode when the control mode is 5 or in constant series voltage mode when the control mode is 7, except that the active power transfer is exchanged with the series element of the "slave" device. The "slave" device is always solved with its bridge active power transfer fixed as dictated by the "master" device; that is, when its control mode is 6, it is always in one of solution states 4, 6, or 7. When its control mode is 8, the specified value of series voltage is modified to reflect the active power exchange dictated by the "master".

In control mode 8 when VSREF is 1 (i.e., desired series voltage is specified relative to series current), the specified V_d is replaced with that calculated from the active power exchange determined by the "master" and the series current of the "slave". In control mode 8 when VSREF is 0 (i.e., desired series voltage is specified relative to sending end bus voltage), the specified V_d and V_q are first transformed to the series current axis, and the resulting V_d is then replaced with that calculated from the active power exchange determined by the "master" and the series current of the "slave".

Therefore, both devices typically have SHMX set to zero, and VSET of both devices is ignored. TRMX of the "master" device is the maximum active power exchange between the two devices, and TRMX of the "slave" device is set to zero. QDES of the "slave" device is ignored.

4.3.4.6 All Modes

It is possible for the power flow iteration to continue even though its voltage change or mismatch tolerance has been achieved. This can occur in several model states described above when the limited quantity is "too far away from" the limit being held.

The solution of the series FACTS device in all of the above model states except the constant series impedance mode includes the temporary insertion into the network of AC series and shunt elements and a corresponding Norton current injection at the sending and receiving end buses of the FACTS device. This technique can improve the convergence properties of the power flow solution. The insertion of these dummy elements is handled automatically by the FACTS model using the reactance specified as LINX. If the convergence monitor indicates an under accelerated convergence, increasing LINX (which decreases its effect) may be helpful. When the shunt element is at a current limit, and therefore the sending end voltage magnitude is changing from one iteration to the next, slow network convergence may be observed with several of the model states described above. Manually adjusting LINX can improve the convergence characteristics.

4.3.5 Power Flow Handling of DC Lines

The two-terminal DC line, multi-terminal DC line, and voltage source converter (VSC) DC line models are called at the start of each iteration to set the active and reactive powers flowing from the AC network into the DC line at each converter bus during that iteration. If a DC line is blocked by its model, an appropriate message is printed at the progress output device. DC line conditions may be monitored via the DC interrupt control code (see Section 4.3.1).

4.3.5.1 Capacitor Commutated DC Lines

At each power flow solution iteration, capacitor commutated two-terminal DC lines require an iterative Newton solution to compute the active and reactive power boundary conditions. If this Newton solution fails to converge, an appropriate message is printed at the progress output device.

4.3.5.2 VSC DC Lines

Whenever converter limits are checked by the VSC DC line model, the following procedure is used:

1. Convert the current limit IMAX to MVA using the present AC voltage and the base voltage of the converter bus. If IMAX is positive, but the base voltage at the converter bus is zero, unlimited current loading is permitted.

2. Use IMAX converted to MVA or SMAX, whichever is smaller, as the converter limit.

3. If in power factor mode, limits are checked during each power flow iteration as follows:
   a. Get the Mvar corresponding to the desired MW.
   b. If |P + jQ| exceeds the limit from 2, reduce the magnitude of P and/or Q using PWF.
4. If in AC voltage control mode, limits are checked whenever convergence of the power flow iteration is achieved as follows:
   a. Get the Mvar from the last iteration.
   b. If |P + jQ| exceeds the limit from 2, reduce the magnitude of P and/or the appropriate Q limit using PWF.
   c. If, on any iteration during which limits are checked, both converters are controlling voltage *and* both are loaded beyond a limit, only the converter with the larger overload has its loading reduced so that it is at its limit.
   d. Whenever a limit violation is detected and relieved are described above, the convergence flag is reset and the power flow solution continues.
5. Whenever a converter has its active power order reduced due to a limit violation, the active power order at the other converter is reduced accordingly.

Power orders and/or reactive power limits are reduced such that the following two equations are simultaneously satisfied:

$$(P_i + \Delta P)^2 + (Q_i + \Delta Q)^2 = SMAX^2$$

$$\frac{\Delta P}{\Delta Q} = \frac{P_i}{Q_i} \times \frac{(1.0 - PWF)}{PWF}$$

Thus, if PWF is 0.0, only active power is reduced; if PWF is 1.0, only reactive power is reduced; otherwise, the above equations are applied.

One of two solution strategies is used for solving the conditions at a VSC DC line at each iteration. The following approach is used when the following three conditions are satisfied: both converters are in AC voltage control mode; limits are being checked on this iteration; and both converters are overloaded.

1. At the converter whose amount of overload is greater, relieve the overload as described above.
2. Solve for the DC current using the specified DC voltage at the voltage controlling converter, the active power order and the converter loss coefficients at the converter whose overloading was relieved, and the DC line resistance.
3. Calculate the active power order at the other converter.

In all other situations, the following solution approach is used:

1. At the power controlling converter, check limits as described above.
2. Solve for the DC current using the specified DC voltage at the voltage controlling converter, the active power order and the converter loss coefficients at the power controlling converter, and the DC line resistance.

3. Calculate the active power order at the voltage controlling converter.

4. Check limits at the voltage controlling converter as described above.

5. If a limit is violated at the voltage controlling converter, calculate a new power order for the power controlling converter and repeat steps 1 and 2.

When an iterative solution process is invoked on a system which had previously been solved by one of the PSS™E network solution methods, the presence of VSC converters which control AC voltage and which are at an MVA or current limit usually results in more than one network solution iteration being required. Although the network should have been in balance, significant voltage changes may initially be imposed as these devices are solved with limits ignored until convergence is achieved.

4.3.6 AC Voltage Control

The power flow model may include several types of AC voltage controlling equipment. Each such device may be considered as belonging to one of the following categories:

1. Swing bus.

2. Setpoint mode voltage control device.

3. Band mode voltage control device.

The following paragraphs discuss each of these types of AC voltage control.

4.3.6.1 Swing Buses

During power flow solutions, the voltage magnitude *and phase angle* at each type 3 bus are held constant. The voltage magnitude is held to the value specified by VS in the type 3 bus' generator data (see Section 3.2.4), and the phase angle is held to the value specified by VA in the type 3 bus' bus data (see Section 3.2.2) or to zero degrees if a "flat start" is selected. At the completion of each power flow solution, the active and reactive power generation at each type 3 bus are set such that the mismatch at the bus is zero. Each type 3 bus *must* have at least one in-service machine connected to it.

While more than one type 3 bus may be present in an island, this is generally not recommended. It is the user's responsibility to coordinate their phase angle settings when multiple swing buses are present in an island. Further, care must be taken in the use of the "flat start" option of the power flow solution activities, which always sets the phase angles of all buses, including type 3 buses, to zero degrees.

4.3.6.2 Setpoint Voltage Control

Those devices that provide for voltage control to a setpoint have their reactive power output or consumption set during each power flow iteration such that the voltage magnitude at the controlled bus is held at its scheduled value as long as the device's reactive power limits are not violated. Most devices provide for either local bus voltage control or voltage control of a remote type 1 or 2 bus; the shunt element of FACTS devices may not control voltage at a remote bus.

The following setpoint mode voltage controlling devices may be modeled in PSS™E:

- An in-service generating plant at a type 2 bus may control either local bus voltage or the voltage at a remote bus.

- A switched shunt for which MODSW is 1 or 2 at a type 1 or 2 bus may control either local bus voltage or the voltage at a remote bus to a voltage setpoint. Such switched shunts for which MODSW = 1 (i.e., discrete control) are initially treated as continuous, then moved to the nearest step and locked.
- A voltage controlling converter of a VSC DC line at a type 1 or 2 bus may control either local bus voltage or the voltage at a remote bus. To be a voltage controlling converter, the VSC DC line must be in-service (MDC = 1), the converter must be in-service (TYPE = 1 or 2), and the AC control mode must be set for voltage control (MODE = 1).
- The shunt element at the sending end of an in-service FACTS device at a type 1 or 2 bus may control local bus voltage.

When multiple voltage controlling devices control the same bus voltage, the reactive power requirements are shared among the controlling devices in proportion to their RMPCTs, subject to each device's reactive power, current or admittance limits, as appropriate. The Mvar output of each device controlling the voltage at bus "I" is set to the product of the total Mvar required at all devices controlling the voltage at bus "I" times a fraction; the numerator of this fraction is RMPCT of the device and the denominator is the sum of the RMPCTs of all the devices controlling the voltage at bus "I". It is the responsibility of the user to ensure that voltage control specifications for all the setpoint mode devices controlling the same bus voltage are identical, and that the RMPCT values are such that the desired reactive power sharing is obtained.

When multiple setpoint mode voltage controlling devices are present at a bus, they should normally all be specified with the same voltage control objective. Similarly, when multiple setpoint mode voltage controlling devices are present among a group of buses connected together by zero impedance lines, the same voltage control objective should be specified for all of them. (Recall that buses connected together by zero impedance lines are treated as the same bus during power flow solutions; see Section 3.2.5.1)

When one or more devices are controlling the voltage at a remote bus, any setpoint mode voltage controlling devices at the controlled bus should be specified so as to control local bus voltage.

Other than generation at the bus itself, setpoint mode voltage controlling devices at type 3 buses and at buses connected to type 3 buses through zero impedance lines may not be used for voltage control purposes. Such devices are handled as follows by the power flow solution activities:

- A zero impedance line connected generating plant is held at its present active and reactive power output.
- A local or zero impedance line connected switched shunt controlling to a voltage setpoint is locked at its present admittance.
- A local or zero impedance line connected VSC DC line is blocked.
- A local or zero impedance line connected FACTS device is blocked.

Section 4.4.5.6 describes how to check for suspect or erroneous voltage control specifications.

4.3.6.3 Band Mode Voltage Control

Those devices which control voltage at a bus or the reactive power output of another voltage controlling device are termed band mode voltage controlling devices. Their settings are adjusted between (rather than during) power flow iterations.

The following band mode voltage controlling devices may be modeled in PSS™E:

- A switched shunt for which MODSW is 1 at a type 1 or 2 bus may control either local bus voltage or the voltage at a remote bus to a voltage band.
- A switched shunt for which MODSW is 3 at a type 1 or 2 bus may control the reactive power output of a generating plant to fall within a reduced reactive power limit band.
- A switched shunt for which MODSW is 4 at a type 1 or 2 bus may control the reactive power output of a voltage controlling VSC DC line converter to fall within a reduced reactive power limit band.
- A switched shunt for which MODSW is 5 at a type 1 or 2 bus may control the admittance setting of a remote switched shunt to fall within a reduced reactive admittance limit band.
- A transformer may have its winding one turns ratio adjusted to hold the voltage at a designated bus within a specified band.
- The terminal end of an in-service FACTS device at a type 1 or 2 bus may deviate from its desired power setpoints to keep the voltage at the terminal end bus within a specified band.

4.3.7 Gauss-Seidel Power Flow Iteration Methods

The Gauss-Seidel iterative algorithms solve for the bus voltages needed to satisfy the bus boundary conditions contained in the working case. The solutions are launched from the ***Power Flow>Solution>Solve*** option which in turn opens the Loadflow solutions dialog (see Figure 4-21). Both the Gauss-Seidel and Modified Gauss-Seidel solutions are available for selection on the Gauss tab.

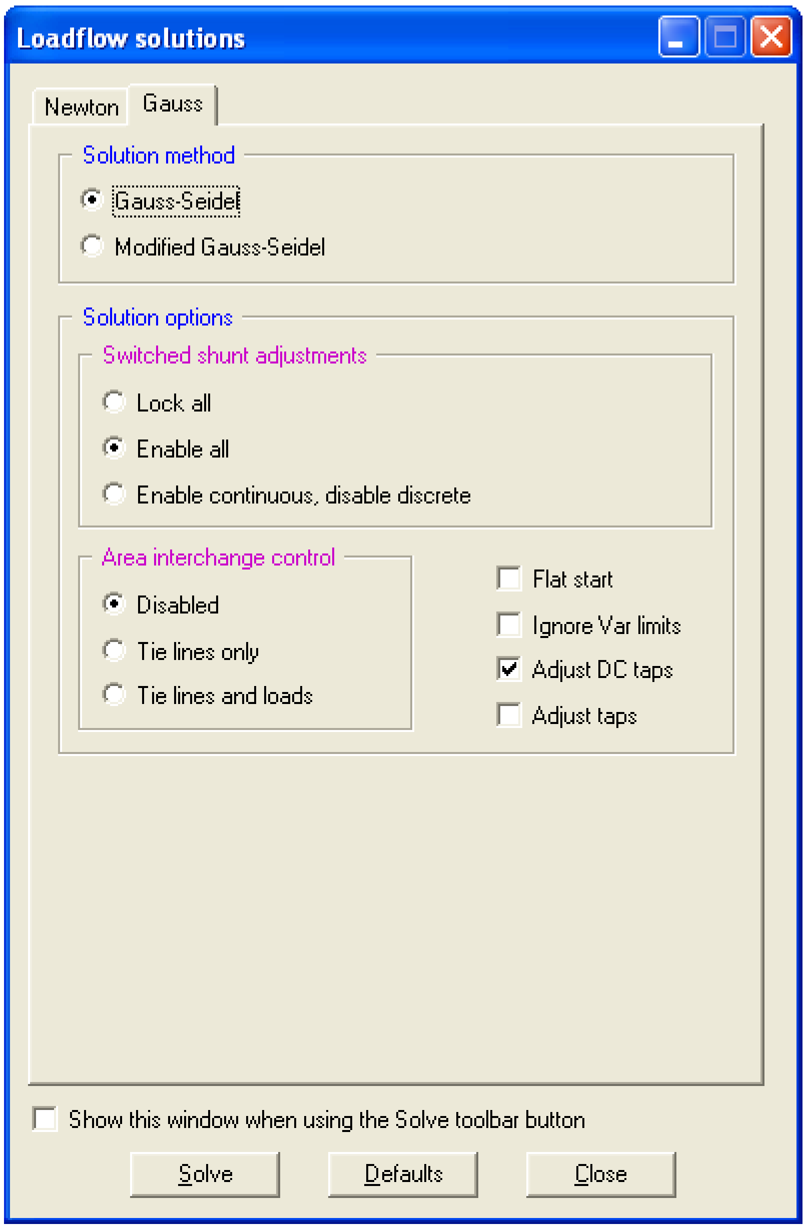
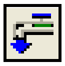


Figure 4-21. Loadflow Solutions Dialog



Alternatively, the solution can be launched using the ***Solve*** button. This will open the same dialog shown in Figure 4-21, or will automatically invoke the previously used solution method without offering the selection dialog.

Following selection of any or all Solution Options and/or Area Interchange Control options (see Section 4.3.12), the solution is initiated by clicking the ***Solve*** button in the dialog.

If the load flow solution network connectivity checking option is enabled (see Section 1.6.4), a check is made to confirm that each non type four bus is connected back to a type three (swing) bus through the in-service AC network. If any violations are detected, an appropriate message is printed and the solution is terminated.

At the completion of each iteration, a convergence monitor is shown in the Output Bar. The monitor tabulates:

1. The iteration number.
2. The largest voltage magnitude change as a multiple of the convergence tolerance.
3. The number, name and base voltage of the bus experiencing the largest voltage change; alternatively, if the bus is the star point bus of a three-winding transformer, the transformer name followed by "`* BUS`" is printed.
4. The real part of the largest voltage change.
5. The imaginary part of the largest voltage change.

At completion of the solution or exhaustion of the allowable number of iterations, the largest bus mismatch is tabulated, along with the system total MVA mismatch and a summary of swing (type three) bus power outputs. An asterisk ("`*`") following a machine's active or reactive power output in the swing bus summary indicates that the power output is beyond its limits.

4.3.7.1 Gauss-Seidel Controls

The Gauss-Seidel and the Modified Gauss-Seidel have much of their operation and characteristics in common. This section will summarize the aspects of the Gauss-Seidel method. Section 4.3.8.2 will discuss the differences found with the Modified method.

The Gauss-Seidel solution method has five available solution control parameters:

- ACCP - Acceleration factor for the real part of the voltage adjustment.
- ACCQ - Acceleration factor for the imaginary part of the voltage adjustment.
- TOL - Convergence tolerance in pu.
- ITMX - Default limit on number of iterations. (= 100)
- BLOWUP - Largest voltage change threshold.

Both acceleration factors have default values of 1.6, but ACCP need not be equal to ACCQ. The guide to the tuning of the acceleration factors should be:

- If the voltage change on successive iterations is oscillating in magnitude and/or sign, decrease acceleration.
- If the voltage change on successive iterations is decreasing smoothly, convergence *may* be improved by increasing acceleration.

The acceleration factors should never be set greater than two, and the optimum seldom exceeds about 1.8. Although the acceleration must be tuned to the system for optimum performance, deviations from the optimum values do not have a dramatic effect on the number of iterations required.

At the completion of each iteration, the largest voltage change is checked against the "blowup" tolerance, BLOWUP, which has a default value of 5.0 pu. If the largest change exceeds this tolerance, an appropriate message is printed and the solution is terminated.

The voltage convergence tolerance default is 0.0001 pu. This tolerance applies to the largest voltage change each iteration, and convergence is assumed when the magnitude of the largest bus voltage change is less than this tolerance. Reducing the tolerance as low as 0.00001 pu is permissible to achieve reduced node mismatches, but such a small tolerance is not recommended since the convergence of the Gauss-Seidel method becomes very slow as the voltage changes fall below about 0.0001 pu.

The user may modify any of these solution parameters by launching the Solution Parameters dialog (see Figure 4-22) from the ***Power Flow>Solution>Parameters...*** option. On the Gauss tab, changes can be made to the acceleration factors, ACCP/ACCQ, and the TOL and ITMX parameters. The BLOWUP parameter is available on the General tab (see Figure 4-22).

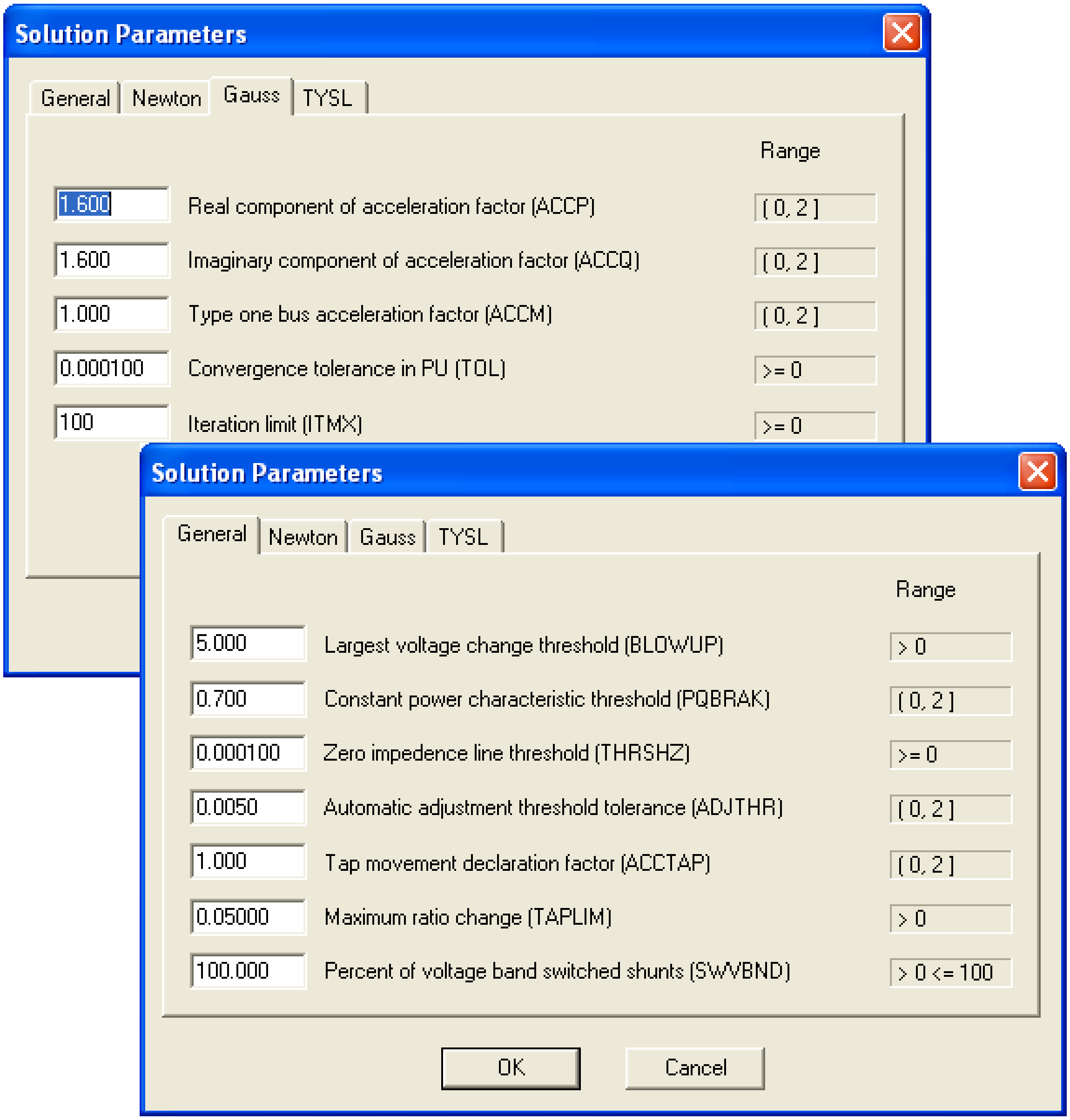


Figure 4-22. Solution Parameters Available for the Gauss Solution

The acceleration factor ACCM is used only for the Modified Gauss-Seidel method.

The General solution parameters are independent of the type of iterative solution. In addition to the BLOWUP parameter, previously described, they are:

- **PQBRAK –** This is the voltage level below which the load characteristic will change from constant MVA to an elliptical current-voltage characteristic. (see Section 4.2.4.1).
- **THRSHZ –** This is the threshold reactance for branches below which they will be treated as zero impedance lines. (see Section 3.2.5.1)

- **ADJTHR** – When tap adjustment is enabled for the Gauss-Seidel and the Full Newton-Raphson solutions, those transformers controlling voltage are checked for adjustment whenever the largest voltage magnitude change in per unit on the previous iteration is less than the automatic adjustment threshold tolerance, ADJTHR. When using the decoupled and fixed slope decoupled Newton-Raphson solutions, this adjustment check occurs following any "P-angle half iteration" in which the largest voltage phase angle change in radians is less than ADJTHR.
- **ACCTAP** – This is a tap movement deceleration factor. The voltage error, for a voltage controlling transformer is multiplied by ACCTAP. If ACCTAP is set less than its default value of 1.0, the apparent voltage error is reduced and the number of tap changes occurring during the iterative process is reduced.
- **TAPLIM** – The solution parameter TAPLIM, which has a default value of 0.05, defines the maximum ratio change that may be applied to a transformer during any adjustment calculation. If the tap STEP of a transformer exceeds TAPLIM and the controlled voltage is outside of its voltage band, the ratio is changed by one tap STEP.

Reducing ACCTAP and/or TAPLIM below their default values may be beneficial on systems with a high concentration of Load Tap Changers or whose voltage profile is extremely sensitive to tap settings.

4.3.7.2 Gauss-Seidel Rules and Convergence Characteristics

The following rules and convergence characteristics apply to the Gauss-Seidel solution method:

1. The presence of negative reactance branches in a network usually causes divergence of the solution.
2. The presence of very low impedance branches (e.g., jumpers with an impedance of j0.0001 pu) which are not being treated as zero impedance lines often results in slow convergence as the voltage adjustments get small, and in mismatches at the buses involved.
3. The number of iterations required to reach the convergence tolerance increases as the system size increases.
4. Can be used if the initial voltage estimate is poor.
5. Is tolerant of reactive power problems.
6. Is tolerant of data errors and insoluble conditions in local areas of the network. It is generally well converged everywhere except in the problem areas.
7. When it diverges, it usually fails gently.

4.3.8 Modified Gauss-Seidel Power Flow Solution Methods

4.3.8.1 Modified Gauss-Seidel Solution Controls

The Modified solution handles the network connectivity checking option, inter-area controls, solution controls, the "blowup" check, and interrupt control codes in the same way as the Gauss-Seidel method. The solution convergence monitor, largest mismatch tabulation, and swing bus summary are identical.

4.3.8.2 Difference Between Gauss-Seidel and Modified Gauss-Seidel

Unlike the Gauss-Seidel solution method, the Modified Gauss-Seidel iterative algorithm employs a secondary adjustment based on each primary voltage change to enable negative reactance branches to be represented between type one buses. Specifically, the Modified method applies the standard Gauss-Seidel voltage adjustment formula at type two buses and a modified formula at type one buses. This allows it to handle series capacitors connecting type one buses but it usually cannot handle negative reactance branches connected to type two or three buses.

Although the Modified method uses the same acceleration factors, ACCP and ACCQ, at type two buses as does the standard Gauss method, at type one buses, it uses a separate acceleration factor, ACCM, which has a default value of unity. The principles for setting ACCM are the same as outlined in Section 4.3.7.1 for setting ACCP and ACCQ. The convergence of activity MSLV is, however, very much more sensitive to the value of ACCM than the standard Gauss solution is to the values of ACCP and ACCQ. Changing ACCP and ACCQ by 0.05 has very little effect on the convergence of either Gauss-Seidel solution but the same change in ACCM may cause a major change in the convergence properties of the Modified solution. Typical values for ACCM range from about 1.2 for well-behaved systems without series capacitors down to slightly below unity in difficult cases with series capacitors.

The solution parameters designating the maximum number of iterations, the convergence tolerance, the acceleration factors (including ACCM), and the blowup threshold can be changed using the same menu facility used for the standard Gauss solution method. (see Section 4.3.7.1).

4.3.8.3 Modified Gauss-Seidel Rules and Convergence Characteristics

The following rules and convergence characteristics apply to the Modified Gauss-Seidel solution method:

1. The presence of negative reactance branches connected to type two or three buses usually causes divergence.
2. Series capacitors may be represented between type one buses, as long as the level of compensation does not exceed about 80%.
3. The presence of very low impedance branches (e.g., jumpers with an impedance of j0.0001 pu) which are not being treated as zero impedance lines often results in slow convergence as the voltage adjustments get small, and in mismatches at the buses involved.
4. The number of iterations required to reach the convergence tolerance increases as the system size increases.
5. May be used if the initial voltage estimate is poor.
6. Is tolerant of reactive power problems.

7. Is tolerant of data errors and insoluble conditions in local areas of the network. It is generally well converged everywhere except in the problem areas.

8. The rate of convergence is very sensitive to the tuning of the acceleration factor ACCM. Modest deviation from the optimum value may result in poor convergence characteristics.

9. The Modified solution takes somewhat more time per iteration than does the standard Gauss-Seidel solution but generally requires fewer iterations.

4.3.9 Newton-Raphson Power Flow Solution Methods

The three Newton-Raphson iterative algorithms solve for the bus voltages needed to satisfy the bus boundary conditions contained in the working case. The solutions are launched from the ***Power Flow>Solution>Solve…*** option which in turn opens the Loadflow solutions dialog (see Figure 4-23). All three Newton-Raphson solution methods are available for selection on the Newton tab.

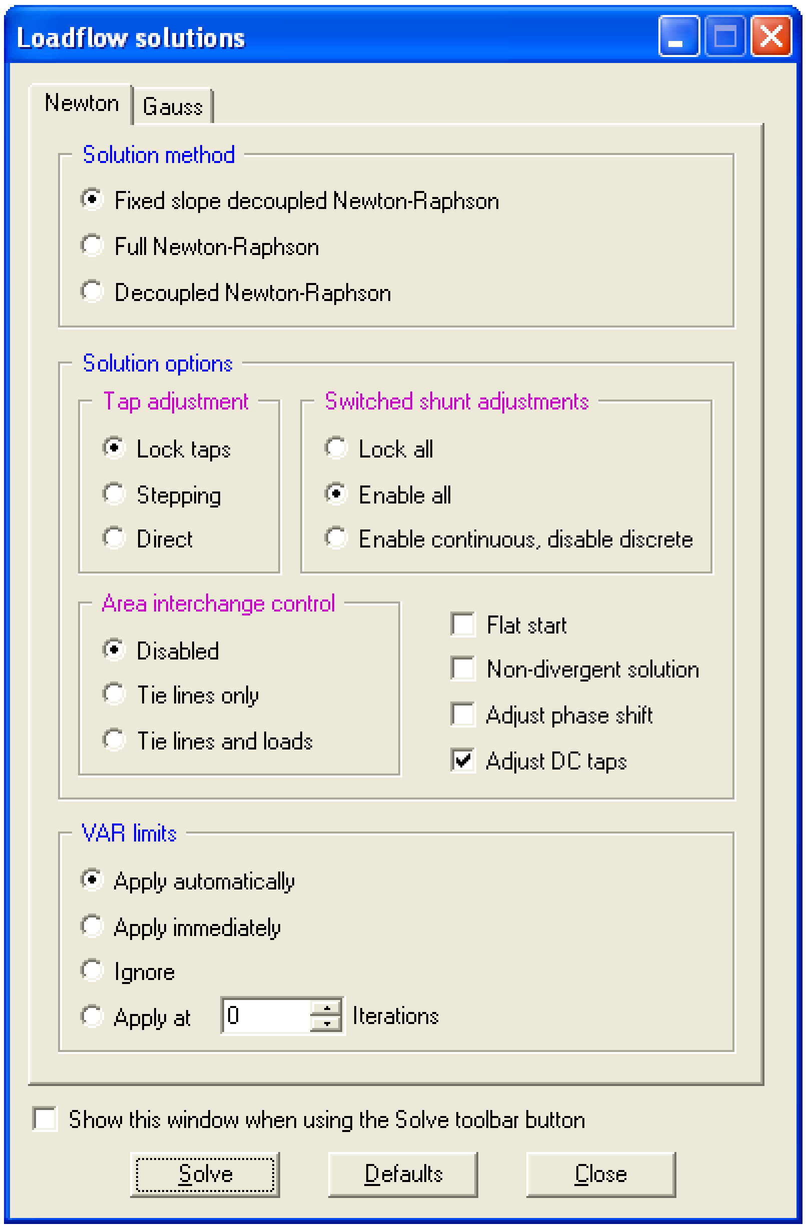


Figure 4-23. Loadflow Solution Dialog for Selection of Newton-Raphson Solutions

Alternatively, the solution can be launched using the ***Solve*** button. This will open the same selector dialog as shown in Figure 4-23, or it will automatically invoke the previously used solution method without offering the selector dialog.

For the Newton solution options, differences from the Gauss method are shown in Figure 4-23. They are:

- Tap and phase adjustment options are broken out to be independent.
- Imposition of VAR limits has more options.
- A non-divergent solution is available only for the full Newton and the fixed slope decoupled Newton solutions.

Following selection of any or all Solution Options, adjustments and/or Area Interchange Control options (see Section 4.3.12), the solution is initiated by clicking the ***Solve*** button in the dialog.

The Newton-Raphson solutions handle the network connectivity checking option, flat start solution, and load, generator, switched shunt, FACTS device, and DC line boundary conditions in the same way as do the Gauss-Seidel solutions. In addition to the interrupt control codes recognized by the Gauss-Seidel solution methods, however, the NC interrupt control code may be used to suppress the incorrect var limit tabulation printed at the termination of a Newton-Raphson solution (see Section 4.3.1).

The FACTS device monitor, DC transmission line monitors, largest mismatch tabulation, and swing bus summary are identical to those provided by the Gauss-Seidel solution method.

At each iteration, the convergence monitor (see Figure 4-24) tabulates:

- The iteration number.
- The largest active power mismatch in per unit on system MVA base and the bus at which it occurs.
- The largest reactive power mismatch in per unit on system MVA base and the bus at which it occurs.
- The largest voltage magnitude change in per unit and the bus at which it occurs.
- The largest phase angle change in radians and the bus at which it occurs.

Buses are identified in the convergence monitor by their bus numbers except for the star point buses of three-winding transformers which are identified by their transformer names.

```
 ITER     DELTAP     BUS      DELTAQ     BUS      DELTA/V/      BUS      DELTAANG      BUS
  0       1.6513     152      3.3331     202
                                                  0.02600       202      0.00977       202
  1       0.0479     202      1.4401     211
                                                  0.02646       211      0.00371       211
  2       0.0054     201      0.0713     211
                                                  0.00141       211      0.00020       211
  3       0.0000     201      0.0007     201


REACHED TOLERANCE IN    3 ITERATIONS

LARGEST MISMATCH:     0.00 MW     0.07 MVAR     0.07 MVA AT BUS     211 [HYDRO_G     20.000]
SYSTEM TOTAL ABSOLUTE MISMATCH:                 0.14 MVA

SWING BUS SUMMARY:
  BUS# X-- NAME --X BASKV       PGEN       PMAX      PMIN       QGEN       QMAX     QMIN
  3011 MINE_G       13.800      258.7      900.0      0.0       104.0      600.0   -100.0
```

Figure 4-24. Newton-Raphson Convergence Monitor (Fully Coupled)

4.3.9.1 Imposition of VAR Limits to Newton-Raphson Power Flow

Unlike the Gauss-Seidel solution method, the user has control over the number of iterations during which generator reactive power limits will first be applied (see Figure 4-25).

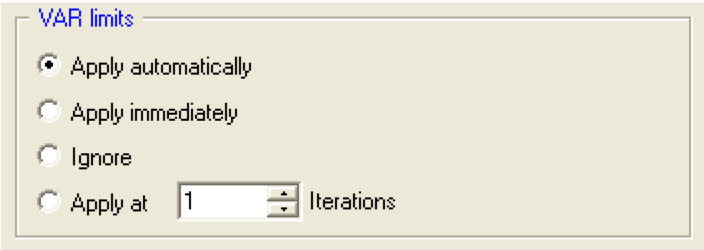


Figure 4-25. Selection of Imposition of Var Limits

- **Apply automatically:** Reactive power limits are to be ignored until the largest reactive power mismatch has been reduced to a preset multiple of the convergence tolerance.
- **Apply immediately:** Reactive power limits are to be recognized on the first mismatch calculation, preceding the first iteration.
- **Ignore:** Reactive power limits are to be ignored at all type two buses except those for which the upper and lower limits are equal.
- **Apply at:** Reactive power limits are to be applied either on iteration number "n" or when the largest reactive power mismatch is within a preset multiple of the tolerance, whichever occurs first.

The var limit logic of this solution method contains code to prevent the phenomenon of a setpoint mode voltage controlling device oscillating on and off a limit from one iteration to the next, or between high and low limits from one iteration to the next. This is accomplished by "looking back" to check the reactive power requirement and voltage magnitude on the previous iteration. Consequently, since the logic presumes the existence of a previous iteration for the conditions in the working case, the immediate application of generator reactive power limits should be specified only when *continuing* the solution of the system in the working case from a previous Gauss-Seidel or Newton-Raphson solution.

The application of generator reactive power limits on the first iteration following a network change *may* cause setpoint mode voltage controlling devices to be spuriously placed on a limit (e.g., a generator's reactive power set at the low limit but voltage magnitude less than scheduled voltage). Activity FNSL prints a summary of any such voltage controlling devices at the progress output device prior to returning control back to the activity selector.

The reactive power component limits of voltage controlling switched shunts, VSC converters, and shunt elements of FACTS devices are always recognized.

4.3.9.2 Newton-Raphson Solution Controls

The Newton-Raphson solution method has five available solution control parameters:

The user may modify any of these solution parameters by launching the Solution Parameters dialog (see Figure 4-26) from the ***Power Flow>Solution>Parameters…*** option. The available solution parameters are:

- ACCN - the acceleration factor
- TOL - the largest mismatch in MW and Mvar
- ITMXN - the maximum number of iterations
- DVLIM - the largest change in bus voltage
- NDVFCT - the non-divergent improvement factor
- VCTOLQ - the controlled bus Q mismatch convergence tolerance
- VCTOLV - the controlled bus voltage error convergence tolerance

The BLOWUP parameter, used for both Gauss and Newton solutions, is available on the General tab.

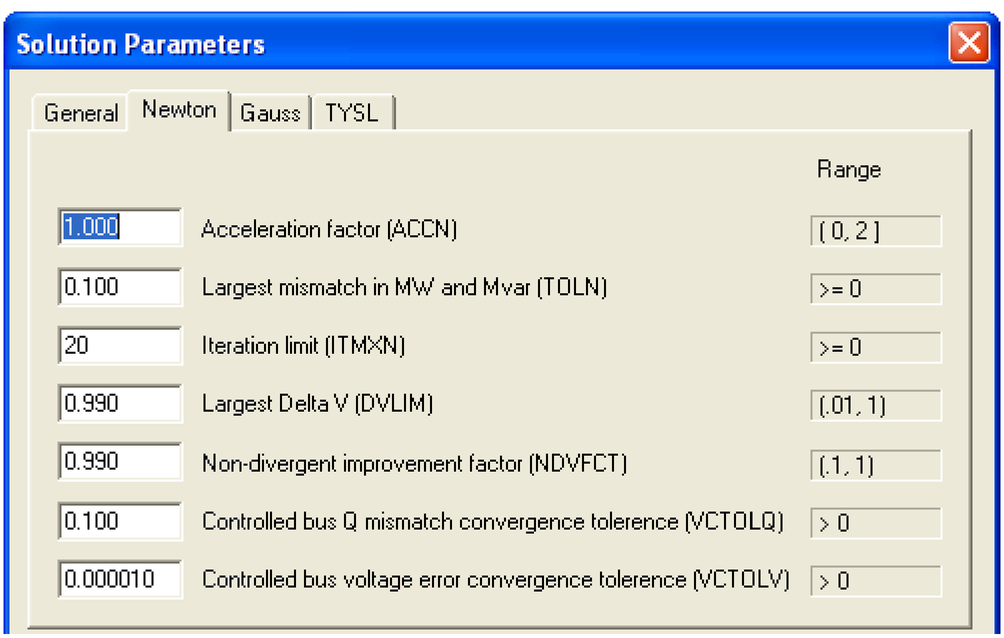


Figure 4-26. Newton-Raphson Solution Parameters

The Newton-Raphson solution methods apply an acceleration factor, ACCN, to the voltage adjustments made at setpoint mode voltage controlled buses. This is done to overcome the stability problems that can arise when the Newton method encounters reactive power limits. The normal value of this acceleration factor is unity, but in cases exhibiting oscillatory convergence, it may occasionally be advantageous to decrease the acceleration factor. It will rarely, if ever, be advantageous to set this acceleration factor greater than unity.

The Newton-Raphson solutions scale down the voltage magnitude and voltage angle change vectors if the most negative element of the "∆vmag / vmag" vector is less than or equal to -1.0. A more restrictive limit on the size of the largest voltage magnitude change which may be applied on any single iteration is provided by the solution parameter DVLIM; the element of the "∆vmag / vmag" vector with the largest magnitude is checked against DVLIM, and, if it exceeds DVLIM, the change vectors are scaled down such that the largest voltage magnitude change applied is of magnitude DVLIM. The default value of DVLIM is 0.99; reducing it to as low as 0.05 *may* improve convergence properties in difficult cases.

At the completion of the first iteration, the largest "∆vmag / vmag" change is checked against a "blowup" tolerance, BLOWUP, which has a default value of 5.0 pu; on subsequent iterations, the largest phase angle change as well as the largest voltage magnitude change are checked. The unscaled change vectors are used in the "blowup" check; i.e., the "blown up" condition is determined before any scaling down of the change vectors, as described in the preceding paragraph, is applied. If the largest change exceeds the "blowup" tolerance, an appropriate message is printed and the solution process is terminated. The "blowup" check is bypassed in the non-divergent Newton power flow solution (see Section 4.3.9.7).

The Newton-Raphson solutions have a default limit of 20 iterations (ITMXN). The tolerance, TOLN, applies to the largest bus mismatch during each iteration. Convergence is assumed when no active or reactive component of bus mismatch exceeds the tolerance. The default tolerance is 0.1 MW and Mvar, (0.001 pu on 100 MVA base) but a tolerance as large as 1 MW and Mvar can give acceptable power flow solutions for many purposes.

4.3.9.3 Fully Coupled Newton-Raphson Method Rules and Characteristics

The fully coupled Newton-Raphson solution continues its iterations until one of the following occurs:

1. No active or reactive component of bus mismatch exceeds the bus power mismatch convergence tolerance and all FACTS devices are satisfactorily solved.
2. The iteration limit is exceeded.
3. The non-divergent solution option is disabled and the "blown up" condition is detected.
4. The non-divergent solution option is enabled and applying the current iteration’s change vectors does not significantly reduce the system mismatch level.
5. The user issues the "AB" interrupt control code.
6. A diagonal element of the Jacobian matrix is near zero, indicating a singular matrix.

The following rules and convergence characteristics apply to Newton-Raphson solution methods but consideration should be given to the non-divergent solution (see Section 4.3.9.7):

1. The solution converges in a very few iterations on well-conditioned cases, achieving very small bus power mismatches.

2. Negative reactance branches are permitted in the network.

3. The presence of very low impedance branches (e.g., jumpers with an impedance of j0.0001) which are not being treated as zero impedance lines (seeSection 3.2.5.1) may result in the inability of the Newton-Raphson to reach the default convergence tolerance. Even with such a network, the solution is usually capable of reducing the largest bus power mismatch to less than 0.2 MVA.

4. The number of iterations required to reach the convergence tolerance is generally insensitive to system size.

5. The solution may diverge if the initial voltage estimate is poor.

6. Reactive power problems may cause poor convergence characteristics.

7. Applying generator reactive power limits "too soon" may cause the solution to diverge.

8. The solution is intolerant of data errors and insoluble conditions in local areas of the network.

9. When the solution diverges, it often fails catastrophically, giving no indication of where the problems are.

10. The Newton-Raphson solutions require the optimal ordering of network nodes. If a new ordering requirement is detected, a message is printed, and the ordering process is automatically executed at which point the solution continues.

11. The time per iteration of the solution is longer than that required for other power flow solution activities, but few iterations are usually needed.

4.3.9.4 Decoupled Newton-Raphson Solution Rules and Characteristics

The decoupled Newton-Raphson solution uses an iterative scheme in which the active power-angle calculation is decoupled from the reactive power-voltage adjustment. It is basically a Newton calculation in which each iteration consists of a pair of "half iterations"; first, with the voltage magnitudes held constant and new voltage phase angles determined, then with the phase angles fixed and new voltage magnitudes calculated.

The solution convergence monitor is similar to that of the fully coupled solution. Each iteration is identified in the ITER column with its main iteration number, followed by a decimal point, followed by either a zero (for the angle correction calculation) or a five (for the voltage magnitude correction calculation), see Figure 4-27.

```
ITER      DELTAP      BUS         DELTAQ      BUS       DELTA/V/      BUS       DELTAANG      BUS
  0.0       0.4265(      152    )    1.2845(      202    )
                                                            0.00000(            )   0.01098(      202    )
  0.5       0.0001(      154    )    1.3166(      202    )
                                                            0.02169(      202   )   0.00000(             )
  1.0       0.2135(      205    )    1.0963(      211    )
                                                            0.00000(            )   0.00173(      154    )
  1.5       0.0000(      205    )    1.0909(      211    )
                                                            0.02131(      211   )   0.00000(             )
  2.0       0.1691(      201    )    0.1693(      201    )
                                                            0.00000(            )   0.00295(      211    )
  2.5       0.0000(      201    )    0.1460(      211    )
                                                            0.00268(      211   )   0.00000(             )
  3.0       0.0216(      201    )    0.0401(      201    )
                                                            0.00000(            )   0.00036(      211    )
  3.5       0.0000(      201    )    0.0374(      201    )
                                                            0.00068(      211   )   0.00000(             )
  4.0       0.0055(      201    )    0.0096(      211    )
                                                            0.00000(            )   0.00009(      211    )
  4.5       0.0000(      211    )    0.0089(      201    )
                                                            0.00016(      211   )   0.00000(             )
  5.0       0.0013(      201    )    0.0022(      201    )
                                                            0.00000(            )   0.00002(      211    )
  5.5       0.0000(      211    )    0.0021(      211    )
                                                            0.00004(      211   )   0.00000(             )
  6.0       0.0003(      201    )    0.0005(      211    )

REACHED TOLERANCE IN   6 ITERATIONS

LARGEST MISMATCH:    -0.03 MW    0.05 MVAR     0.06 MVA AT BUS    201 [HYDRO       500.00]
SYSTEM TOTAL ABSOLUTE MISMATCH:               0.19 MVA

SWING BUS SUMMARY:
  BUS# X-- NAME --X BASKV      PGEN     PMAX     PMIN      QGEN     QMAX    QMIN
  3011 MINE_G       13.800     260.8    900.0     0.0      116.3    600.0  -100.0
```

Figure 4-27. Decoupled Newton-Raphson Convergence Monitor

The rules and characteristics governing the use of the decoupled solution are similar to those of the fully coupled solution. In addition to those rules, the following apply:

1. The decoupled solution converges well if fairly uniform X/R ratios are present throughout the network.
2. When the network contains branches with resistance close to or greater than the reactance, the iteration usually reaches some mismatch level and then begins to diverge, usually slowly.
3. As the mismatches are reduced, the rate of improvement on successive iterations is slowed.
4. The time per "half iteration" in the decoupled solution is roughly 1/4 of the time per fully coupled iteration.

4.3.9.5 Fixed-Slope Decoupled Newton-Raphson Rules and Characteristics

This flow solution uses a fixed-slope decoupled Newton-Raphson iterative algorithm in which the active power-angle calculation is decoupled from the reactive power-voltage adjustment. It is basically a Newton calculation in which each iteration consists of a pair of "half iterations"; first with the voltage magnitudes held constant and new voltage phase angles determined, then with the phase angles fixed and new voltage magnitudes calculated.

The method employs an approximation of the Jacobian matrix which is insensitive to bus voltages. Thus the matrix used in the active power-angle solution remains fixed throughout the solution, while the matrix used for the reactive power-voltage calculation changes only as voltage controlled buses switch between voltage regulating and reactive power limited boundary conditions.

The solution convergence monitor is similar to that of the decoupled solution. Each iteration is identified in the ITER column with its main iteration number, followed by a decimal point, followed by either a zero (for the angle correction calculation) or a five (for the voltage magnitude correction calculation).

In addition to those rules enumerated for the fully coupled solution, in Section 4.3.9.3), the following apply:

1. The fixed slope decoupled solution is much less sensitive to a poor initial voltage estimate than is the fully coupled solution.
2. As the mismatches are reduced, the rate of improvement on successive iterations may be slowed.
3. The time per "half iteration" with the fixed slope solution is roughly 1/5 of the time per fully coupled iteration. The "start-up" time is longer as the fixed matrices are calculated.

4.3.9.6 Non-Divergent Newton-Raphson Solution Option

When applying the Newton-Raphson algorithm or any of its variants to the power flow problem, one of the following results is usually observed:

- Bus power mismatches for all buses are within tolerance ("convergence").
- Increasing bus power mismatches, and usually increasing voltage and angle changes, are observed on successive iterations ("divergence"). A divergent solution is often characterized by unrealistically small or large voltage magnitudes and by very large bus power mismatches; it may be characterized by a Jacobian matrix that is singular or nearly so.
- Mismatch tolerances are not met, but the solution is neither converging nor diverging ("non-convergence"). This condition could be caused by a convergence tolerance which is beyond the precision limits of the combination of host computer and network impedances; it could also result from control ranges which are too narrow relative to the adjustment step (e.g., desired voltage range used by a voltage controlling transformer relative to the tap step) which results in oscillation of the controlling parameter from one adjustment cycle to the next (e.g., tap ratio increasing, then decreasing, then increasing, and so on), or by multiple controlling devices "fighting" each other.

The non-divergent Newton power flow solution option attempts to terminate the iterative procedure before divergent iterations have driven the voltage vector to a state where large power mismatches and unrealistic voltages are present. The resulting voltage vector, although not sufficiently accurate to provide a "converged" power flow solution, often provides a relatively good indication of the state of the network. In particular, voltage collapse situations can be identified by localized areas of bus power mismatches and low voltages, with the remainder of the network "converged".

The Non-divergent Solution option may be applied in the Fully Coupled and the Fixed Slope Decoupled Newton solutions. It also finds use in Automatic AC Contingency analysis (see Chapter 5). The ***Non-divergent solution*** option is selected in the Loadflow solutions dialog on the Newton tab (see Figure 4-28).

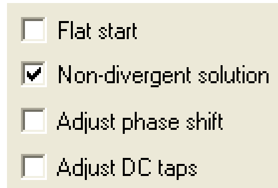


Figure 4-28. Selecting the Non-divergent Solution Option

The application of the Newton method to the power flow problem calculates a pair of change vectors: $\Delta\theta$ for voltage phase angles, and Δvmag / $vmag_{old}$ for bus voltage magnitudes. In its usual application, the bus voltages are updated using equations which may be written in the form:

$$\theta_{new} = \theta_{old} + (ACCFAC * \Delta\theta)$$

$$vmag_{new} = vmag_{old} * [1.0 + ACCFAC * (\Delta vmag / vmag_{old})]$$

where ACCFAC is equal to 1.0.

In the non-divergent solution scheme, ACCFAC is set to 1.0 at the start of each Newton iteration. If the mismatches that result from the new voltage and angle vectors indicate divergence, the value of ACCFAC is halved, θ_{new} and $vmag_{new}$ recalculated, and mismatches recalculated. This process is repeated until either:

- the indication of divergence is eliminated. In this case, the solution advances to its next iteration.
- ACCFAC has been reduced to a near zero value without eliminating the indication of divergence. In this case, the solution is terminated.

The divergence metric used in this "inner loop" voltage correction is the sum of squares of the MVA mismatches, expressed in per unit, at all in-service buses in the working case (SUMSQM). The non-divergent algorithm infers the elimination of divergence when the SUMSQM resulting from the application of a set of voltage magnitude and phase angle corrections is less than the SUMSQM at the start of the iteration multiplied by the improvement factor NDVFCT. That is, a new set of voltages is accepted if:

$$SUMSQM_{new} < NDVFCT * SUMSQM_{old}$$

The non-divergent improvement factor, NDVFCT, which has a default value of 0.99, should never be greater than 1.0 nor less than or equal to 0.0. With values very close to 1.0, The solution accepts small reductions in SUMSQM and goes on to the next Newton iteration. As NDVFCT is reduced, the Newton solution requires larger reductions in SUMSQM before inferring the elimination of divergence. The setting of NDVFCT is a trade-off between execution time and a possible incremental improvement in total system mismatch level.

Up to ten "inner loop" mismatch calculations are performed, and if SUMSQM has not improved sufficiently by the last attempt (with ACCFAC approximately 0.00195), the solution is terminated. The voltage vector is set to either its value at the completion of the prior Newton iteration, or to the value corresponding to the last "inner loop" mismatch calculation, whichever has the smaller value of SUMSQM.

4.3.9.7 Monitoring Non-Divergent Newton-Raphson Solution

When the ***Non-divergent solution*** option is enabled, the standard Fully Coupled Convergence Monitor (Figure 4-24) is augmented by two additional columns containing SUMSQM and ACCFAC. In addition, each "inner loop" mismatch calculation is reported. Figure 4-29 shows the convergence monitors for the attempted fully coupled solutions of a difficult case, first with the ***Non-divergent solution*** option disabled, and then with the option enabled. DVLIM and NDVFCT are both 0.99.

```
 ITER       DELTAP     BUS    DELTAQ     BUS    DELTA/V/     BUS   DELTAANG     BUS
  0         5.6995(    151)   1.2217(    151)    0.07177(   3008)   0.14024(    101)
  1         0.5073(    201)   0.6370(    206)    0.00591(    206)   0.00490(    201)
  2         0.0028(    152)   0.4046(    206)    0.00379(    206)   0.00034(    206)
  3         0.0001(    205)   2.4734(   3008)    0.03639(   3008)   0.00266(    206)
  4         0.0065(    154)   1.6332(    205)    0.03136(    205)   0.00779(    101)
  5         0.0253(    205)   0.8006(    201)    0.08905(    205)   0.03293(    101)
  6         0.2468(    205)   0.0599(    205)    0.17461(    205)   0.06537(    101)
  7         0.9226(    205)   0.2194(    205)    0.13294(    154)   0.04131(    101)
  8         0.3062(    205)   0.0904(    154)    0.13959(    205)   0.04873(    101)
  9         0.5686(    205)   0.1260(    205)    0.08090(    154)   0.03244(    101)
 10         0.2733(    205)   0.0589(    205)    0.82297(    205)   0.30216(    101)
 11         7.0235(    206)   7.6130(    102)    0.99000(    152)   4.91214(    206)


BLOWN UP AFTER  12 ITERATIONS

LARGEST MISMATCH:  495.60 MW 1025.72 MVAR  1139.18 MVA AT BUS   205 [SUB230  230.00]
SYSTEM TOTAL ABSOLUTE MISMATCH:            7280.85 MVA

SWING BUS SUMMARY:
  BUS X--- NAME ---X      PGEN     PMAX    PMIN      QGEN     QMAX    QMIN
```

a. Non-Divergent Solution Option Disabled

```
 ITER       DELTAP     BUS    DELTAQ     BUS    DELTA/V/     BUS   DELTAANG     BUS  SUMSQM       ACCFAC
  0         5.6995(    151)   1.2217(    151)                                          66.102       1.00000
  0.1       0.5073(    201)   0.6370(    206)                                          1.2214       1.00000
                                                 0.07177(   3008)   0.14024(    101)
  1         0.5073(    201)   0.6370(    206)                                          1.2214       1.00000
  1.1       0.0028(    152)   0.4046(    206)                                         0.16371       1.00000
                                                 0.00591(    206)   0.00490(    201)
  2         0.0028(    152)   0.4046(    206)                                         0.16371       1.00000
  2.1       0.0001(    205)   0.0388(    206)                                         0.15017E-02  1.00000
                                                 0.00379(    206)   0.00034(    206)
  3         0.0001(    205)   2.4734(   3008)                                          6.1193       1.00000
  3.1       0.0065(    154)   1.6332(    205)                                          2.7156       1.00000
                                                 0.03639(   3008)   0.00266(    206)
  4         0.0065(    154)   1.6332(    205)                                          2.7156       1.00000
  4.1       0.0253(    205)   0.8006(    201)                                         0.64587       1.00000
                                                 0.03136(    205)   0.00779(    101)
  5         0.0253(    205)   0.8006(    201)                                         0.64587       1.00000
  5.1       0.2468(    205)   0.0599(    205)                                         0.15622       1.00000
                                                 0.08905(    205)   0.03293(    101)
  6         0.2468(    205)   0.0599(    205)                                         0.15622       1.00000
  6.1       0.9226(    205)   0.2194(    205)                                          2.1249       1.00000
  6.2       0.3679(    205)   0.0859(    205)                                         0.33685       0.50000
  6.3       0.2479(    205)   0.0591(    205)                                         0.15538       0.25000
  6.4       0.2319(    205)   0.0560(    205)                                         0.13730       0.12500
                                                 0.02183(    205)   0.00817(    101)
  7         0.2319(    205)   0.0560(    205)                                         0.13730       1.00000
  7.1       7.9710(    206)   9.5520(    102)                                          357.47       1.00000
  7.2       3.6765(    206)   3.8054(    102)                                          60.676       0.50000
  7.3       1.5493(    205)   0.9314(    102)                                          8.2484       0.25000
  7.4       0.6542(    205)   0.1560(    205)                                          1.0698       0.12500
  7.5       0.3362(    205)   0.0800(    205)                                         0.28423       0.06250
  7.6       0.2556(    205)   0.0613(    205)                                         0.16584       0.03125
  7.7       0.2364(    205)   0.0570(    205)                                         0.14249       0.01563
  7.8       0.2323(    205)   0.0560(    205)                                         0.13773       0.00781
  7.9       0.2316(    205)   0.0559(    205)                                         0.13698       0.00391
  7.10      0.2316(    205)   0.0559(    205)                                         0.13701       0.00195
                                                 0.00193(    205)   0.00071(    101)


TERMINATED AFTER    8 ITERATIONS--NON-DIVERGENT OPTION COULD NOT REDUCE MISMATCH

LARGEST MISMATCH:    23.16 MW     5.59 MVAR    23.83 MVA AT BUS   205 [SUB230  230.00]
SYSTEM TOTAL ABSOLUTE MISMATCH:               93.62 MVA
```

b. Non-Divergent Solution Option Enabled

Figure 4-29. Fully Coupled Convergence Monitor

4.3.10 Combining Power Flow Solution Methods

In many power flow cases, the solution can be expedited by using two (or even more) iteration activities in succession in order to take advantage of the complementary strengths of the various iterative schemes. For example, if the starting voltage estimate is known to be poor, it is often advantageous to execute several Gauss-Seidel iterations and to switch over to the Newton-Raphson iterations once the voltage estimate has been brought into rough approximation to the true solution.

A simple approach is to allow a Gauss-Seidel solution to complete its maximum iterations and then select a Newton method and continue the solution from the same convergence point. (The starting voltage estimate for the Newton solution would be the last voltage vector estimated in the preceding execution of the Gauss solution.) At any time the solution can be changed back to a Gauss-Seidel solution or a different Newton method.

If the iterations are slow, it is possible to use the AB interrupt to cancel whichever solution method is in progress and, subsequently, select a different solution method to continue.

4.3.11 Using Acceleration Factors and Solution Tolerances

The five power flow solution activities use the acceleration factors listed in Table 4-3. Each acceleration factor is set to a default value based on general experience each time PSS™E is started up. The user should be prepared to tune these acceleration factors, particularly those used by the Gauss-Seidel solution, which is very dependent upon the acceleration of the voltage adjustment process.

The four acceleration factors listed in Table 4-3 are saved and retrieved with the power flow case. The power flow working case contains two tolerance values for use in convergence checking: a voltage change threshold for the Gauss-Seidel solutions, and a bus power mismatch tolerance for the Newton-Raphson solutions. These tolerances are set to default values of 0.0001 per unit and 0.001 per unit, (or 0.1 MW and Mvar on a 100 MVA system base) respectively, when PSS™E is started up.

Table 4-3. Power Flow Iteration Acceleration Factors

Iteration Type	Factors Used	Applied To
Gauss-Seidel	ACCP ACCQ	Real part of voltage change Imaginary part of voltage change
Modified Gauss-Seidel	ACCM ACCP ACCQ	Complex voltage change at Type 1 buses As for Gauss-Seidel at Type 2 buses
Newton-Raphson	ACCN	Magnitude of voltage change at Type 2 buses only

The convergence and tolerance data can be changed via the ***Power Flow>Solution>Parameters…*** option which opens up the Solution Parameters dialog. Figures 4-30 and 4-31 show the dialog open at the Newton and Gauss tabs respectively.

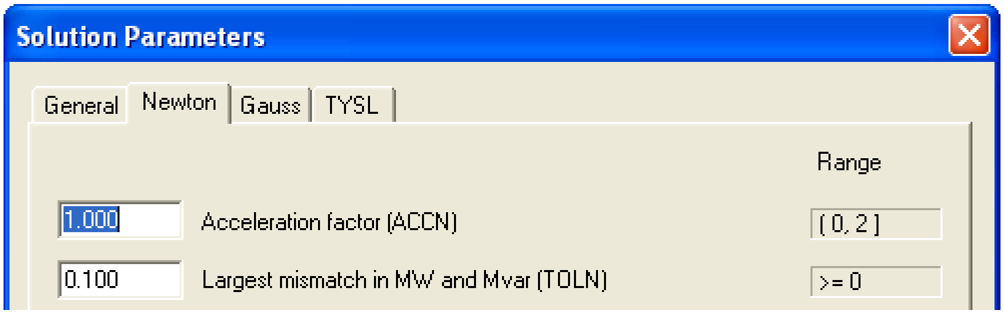


Figure 4-30. Changing Newton Acceleration Factor and Tolerance

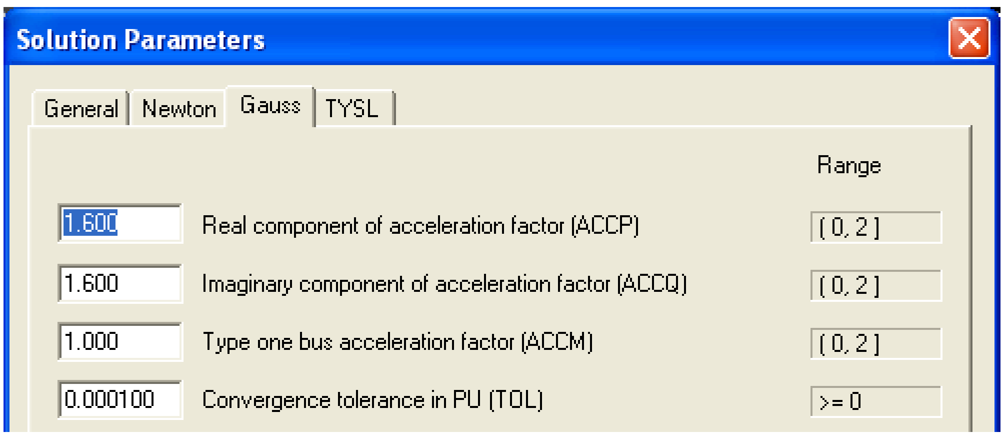


Figure 4-31. Gauss-Seidel Acceleration Factors and Tolerances

4.3.11.1 Using Acceleration Factors and Tolerances in Gauss-Seidel

The Gauss-Seidel solution uses separate acceleration factors (ACCP, ACCQ) for the real and reactive parts of the power balance equation. Typical values are (ACCP, ACCQ) = (1.6, 1.6), but ACCP need not be equal to ACCQ. The guide to the selection of ACCP and ACCQ should be based on the voltage change. If the voltage change in each iteration is oscillating in magnitude or sign, decrease acceleration. If the voltage change in each iteration is decreasing smoothly, convergence may be improved by increasing acceleration (see Figure 4-32).

ACCP and ACCQ values less than unity are perfectly permissible and will be required to achieve convergence in some difficult cases. The acceleration factor should never be set greater than 2, and the optimum value seldom exceeds about 1.8.

The normal tolerance value for the Gauss-Seidel solution is 0.0001 per unit. This tolerance is applied to the largest voltage change in each iteration and convergence is assumed when |ΔV| is less than this tolerance. The tolerance may be increased as far as 0.0005 per unit if only approximate power flows are needed. Reducing the tolerance as low as 0.00001 per unit is permissible to achieve reduced node mismatches, but such a small tolerance is not recommended because the convergence of the Gauss-Seidel method becomes very slow as the voltage changes fall below about 0.0001 per unit.

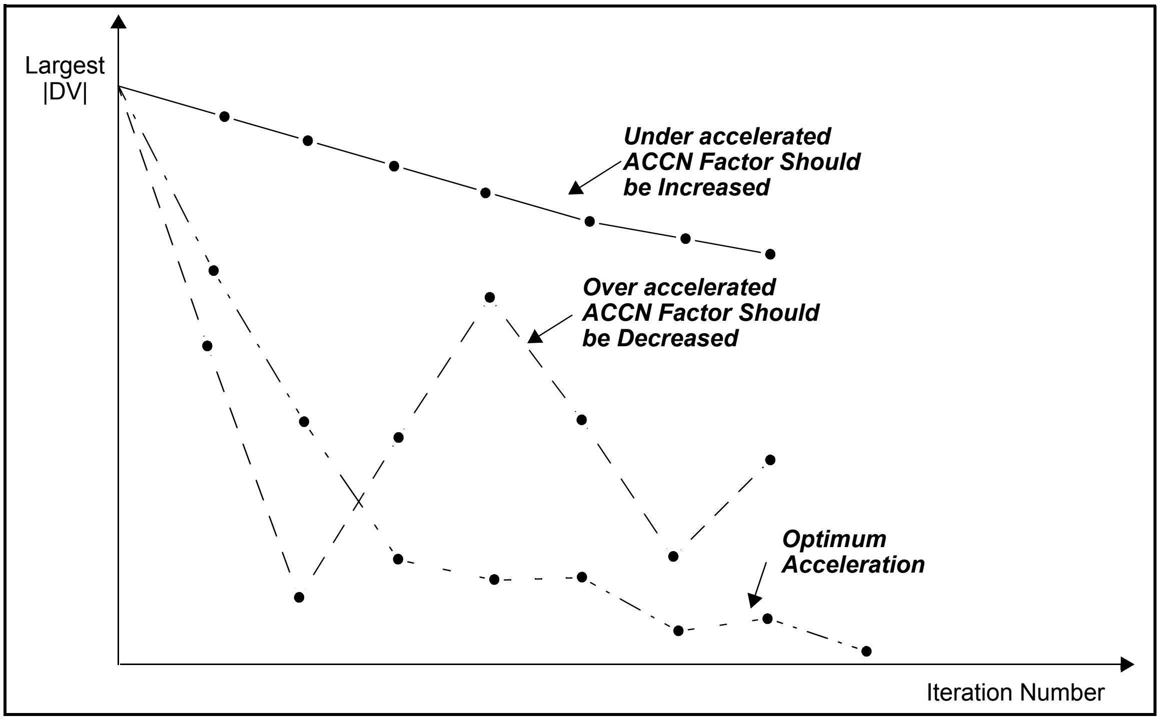


Figure 4-32. Dependence of Power Flow Convergence on Acceleration Factors

4.3.11.2 Using Acceleration Factors and Tolerances in Modified Gauss-Seidel

The Modified solution applies the standard Gauss-Seidel voltage adjustment formula at Type 2 buses and a modified formula at Type 1 buses to handle series capacitors connected between Type 1 buses. (The Modified solution usually *cannot* handle series capacitors connected to Type 2 or 3 buses.)

The Modified solution uses the Gauss-Seidel acceleration factors ACCP and ACCQ at Type 2 buses and a separate acceleration factor, ACCM at Type 1 buses. The principles for setting ACCM are the same as outlined above for setting ACCP, ACCQ. The convergence of the Modified solution is, however, very much more sensitive to the value of ACCM than is the standard Gauss-Seidel solution to the values of ACCP and ACCQ. Changing ACCP, ACCQ by 0.01 has very little effect on the convergence of either Gauss solution but the same change in ACCM may cause a major change in the convergence properties of the Modified version. Typical values for ACCM range from about 1.2 for well-behaved systems without series capacitors down to slightly below unity in difficult cases with series capacitors.

4.3.11.3 Using Acceleration Factors and Tolerances in Newton-Raphson

The Newton solutions apply an acceleration factor ACCN to the voltage adjustments made at voltage-controlled buses. This factoring overcomes stability problems that can arise when the Newton method encounters reactive power limits. The normal value of this acceleration factor is unity, but in extremely difficult cases it can be advantageous to set its value as low as 0.5. It will never be advantageous to set this acceleration factor greater than unity.

Convergence is assumed when no real or reactive component of bus power mismatch exceeds the tolerance. The typical tolerance value for Newton methods is 0.001 per unit (0.1 MW on 100-MVA base), but a tolerance as large as 0.01 per unit will give very acceptable power flow solutions for many purposes.

The Newton solutions might not be able to reduce mismatch to the 0.001 per-unit value because of the inherent computer precision limit.

Consider a branch with impedance of 0.0001 per unit and voltages close to unity at both ends. The maximum imprecision in calculation of power flow through the branch is approximately:

$$\Delta P = 2\frac{\Delta V}{Z} = 0.0025 \text{ per unit}$$

Since the bus mismatch imprecision is the sum of the imprecisions in flows into connected branches, a power flow case including such low-impedance branches is unlikely to reach the default tolerance of 0.001 per unit.

Branch impedances as low as 0.0001 per unit do not occur frequently, but can arise in star-equivalents of three-winding transformers and are sometimes used to represent jumpers between bus sections. When these low-impedance branches exist in a power flow case, it is often advisable to raise the zero-impedance branch threshold to represent these branches as zero-impedance lines and then remove the low-impedance branches by "joining" the terminal buses of the branch together. (This topological manipulation is described in Section 4.6.4). An alternative is to increase the tolerance to 0.0025 or 0.005 per unit.

A tolerance of 0.005 per unit on a 100-MVA system base represents a power flow solution imprecision of 0.5 MW, which is more than acceptable for the great majority of power flow cases.

4.3.12 Automatic Power Flow Solution Adjustments

Automatic adjustment options may be used in power flow solutions to allow maneuvering of the system to meet specified voltage, branch flow, and area net interchange schedules. Automatic adjustments can be enabled or disabled when setting program run-time options (see Section 1.6.4).

Alternatively the same adjustments can be enabled or disabled (to override the program run-time options), in the Loadflow Solutions dialog which is opened from the ***Power Flow>Solution>Solve*** option, (see Figure 4-21, for the Gauss solutions and Figure 4-23 for the Newton solutions). The Loadflow Solution dialog for the Newton solution is replicated in Figure 4-33.

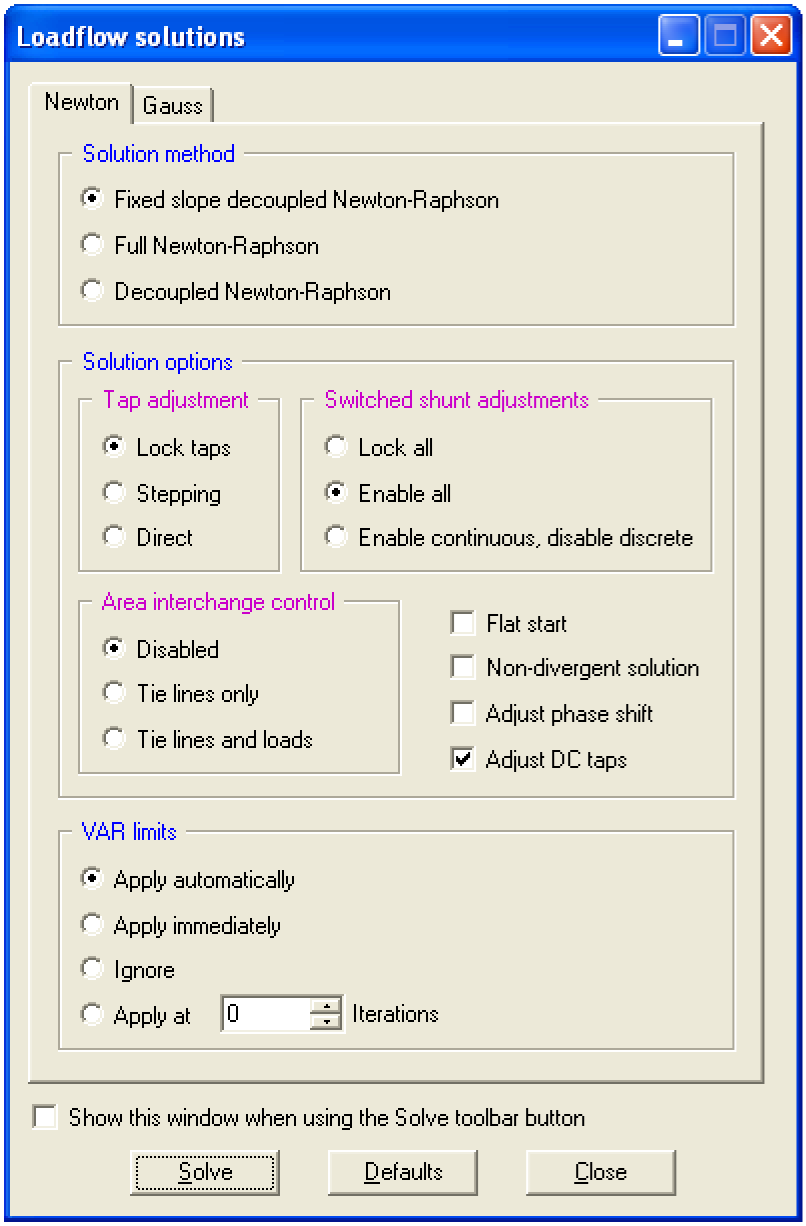


Figure 4-33. Solution Options and Adjustments for the Newton Solutions

The automatic adjustments available are specified in Table 4-4. In addition to the options listed in the table, the user has the option to start the power flow solution from a flat-start, as seen in Figure 4-33.

When enabled, an adjustment option is applied throughout the entire power flow case. However, it is important to recognize that the adjustment of any individual tap-changing transformer, phase shifter, or area net interchange can be suppressed by editing its adjustment parameters in such a way that no adjustment can occur. Those parameters are accessible in the spreadsheet.

Table 4-4. Available Automatic Adjustments

Type of Adjustment	Normal Default	Available In
Adjustment of transformer turns ratio in steps to hold voltage at a designated bus in specified band.	Disabled	GAUSS NEWTON
Direct adjustment of transformer turns ratio to hold voltage at a designated bus in specified band or to hold reactive power through transformer within specified band.	Disabled	NEWTON
Adjustment of area swing bus generator powers to hold area net interchange within specified band.	Disabled	GAUSS NEWTON
Adjustment of transformer phase shift to hold real power through transformer within specified band.	Disabled	NEWTON
Adjustment of converter transformers of DC transmission terminals to place rectifier delay angle and inverter margin angle within specified ranges.	Enabled	GAUSS NEWTON
Adjustment of switched shunt admittances to hold voltage at the bus as close to specified voltage as permitted by inductance/capacitor module size.	Enabled	GAUSS NEWTON

4.3.12.1 Adjusting Transformer Off-Nominal Tap Ratio

Depending on the solution technique chosen, transformer tap ratio adjustments can be made to control either voltage at a specified bus, a compensated voltage based on the transformer loading or to control Mvar flow at the tapped side of the transformer (see Table 4-5). Compensated voltage is often used on radial circuits when one wishes to remotely regulate a voltage but does not wish to install any communication links. Note that by controlling voltage using the Newton solution activities, the user may choose one of two adjustment techniques: discrete or direct tap adjustment. The Mvar control can be performed using direct tap adjustment only in Newton solutions.

With all solution activities, the request to adjust taps ratio automatically will not be honored until the voltage change is less than the adjustment threshold (ADJTR), a solution parameter with a default value of 0.005 per unit. With discrete tap adjustment, tap ratio will then be adjusted to a maximum of value of tap limit (TAPLIM), a solution parameter with a default value of 0.05 per unit, until tolerance is reached. With direct tap adjustment controlling voltage, tap ratio will be adjusted, as if the taps are continuous, from the iteration when tolerance is first reached through subsequent iterations until the tolerance is again reached. At that time, unless the tap ratio is zero, all taps will be set to the nearest step, locked, and additional iterations made to bring mismatch down to tolerance once again. Similarly, with direct tap adjustment controlling Mvar, adjustment will not be made until tolerance is reached and controlling logic is identical thereafter to that of direct tap adjustment controlling voltage.

The solution parameters ADJTR and TAPLIM can be changed in the Solution Parameters dialog, on the General tab, as previously shown in Figure 4-14.

Table 4-5. Transformer Tap Adjustment Options

Method	Availability of Voltage Control Adjustment	Availability of Voltage Control Via Direct Tap Adjustment	Availability of Mvar Control Via Direct Tap Adjustment
Gauss-Seidel	Yes	No	No*
Modified Gauss-Seidel	Yes	No	No*
Full Newton-Raphson	Yes	Yes	Yes
Decoupled Newton-Raphson	Yes	Yes	Yes
Fixed-slope, decoupled Newton-Raphson	Yes	Yes	Yes

Tap is assumed fixed.

4.3.12.2 Adjusting Transformer Voltage Control

Voltage control by transformer turns ratio adjustments, as described above, will only be made on transformers having the following conditions: a nonzero regulated bus number, IREG; and a value of 1 for the transformer enable flag, RF. The tap ratio of each transformer is adjusted to hold a voltage magnitude between the limits VMIN to VMAX. The voltage magnitude to be controlled is calculated as follows:

$$V_C = \left| V_{IREG} - I_{transformer}(CR + jCX) \right|$$

where:

CR + jCX	=	Compensating impedances input by the user.
$I_{transformer}$	=	Current in the transformer calculated on the IREG side of the transformer.

The recommended method for suppressing ratio adjustment is to set the transformer control flag to zero. Ratio adjustment may also be suppressed by setting IREG to 0.

The tap-step ratio should be properly coordinated with the acceptable voltage band (VMAX-VMIN) because the discrete steps of available tap ratio are recognized. The default tap-step ratio is 0.00625 per unit (0.625%). The band between VMAX and VMIN should normally be twice the transformer tap-step. A band of 2% is recommended for the normal case of 0.625% tap ratio steps. A value of 0 for tap-step should only be used to indicate continuously adjustable taps to the direct tap adjustment algorithm.

4.3.12.3 Adjusting Transformer Mvar

The tap ratio is adjusted to hold the Mvar on the tap side of the transformer between the limits VMIN-VMAX. As mentioned previously for voltage-controlling transformers, the user should coordinate tap-step and available range for Mvar-controlling transformers.

4.3.12.4 Adjusting Transformer Phase Shift Angle

The phase-shift angle of each phase shifter is adjusted, as necessary, to keep the real power flow through the phase shifter between the limits VMAX and VMIN.

Phase-shift adjustment is continuous and all adjustable phase shifters are adjusted simultaneously whenever the regulated real power flow of at least one of them falls outside its scheduled band. An unduly narrow band can cause non convergence of the power flow solution. A reasonable band is ± 5 MW of the target flow.

4.3.12.5 Adjusting Transformer Direct Current (DC) Converter Taps

The control logic adjusts the converter transformer tap positions to attempt to hold the bridge firing angles above minimum values and below maximum. The minimum values of the firing angles, α_{min} and γ_{min}, are firm limits; the bridges will not be operated in power flow solutions with firing angles below these values. The maximum values of the firing angles, α_{max} and γ_{max}, are objectives, but not firm limits; the converters may be operated in power flow solutions with firing angles above these limits if the converter transformer tap positions are at the ends of their ranges or if the desired angle ranges are narrow relative to the tap steps.

Converter taps are adjusted only until the corresponding bridge firing angles are between their specified maximum and minimum values; taps are not adjusted to minimize firing angles once they fall between their corresponding maxima and minima. Accordingly, the ranges of the bridge firing should be treated as the optimum bands for the various converters, with recognition that operation at a firing angle above the specified maximum value may be necessary for some combinations of scheduled DC power, DC voltage, and AC system conditions.

The AC solution options can be modified such that the adjustment of converter transformer ratios are *disabled*. This disabling applies to all DC transmission lines. Selective locking of DC converter transformer taps requires that their adjustment not be disabled via the AC solution options. The tap ratio of any individual converter transformer can be locked by using the program's data editing functions to set the DC converter tap limits and tap ratio equal to the desired value.

4.3.12.6 Adjusting Net Interchange

Each area of the power system may have one of its generators designated as an area-slack machine. Net interchange adjustment is implemented by manipulating the real power output of all area slack machines except those in areas containing system swing (Type 3) buses. Area slack machine adjustment may be suppressed for any individual area by setting the area slack bus number in the area interchange data category to 0. Area slack adjustment is continuous, but takes place only if the area net interchange falls outside the band for at least one area: (Scheduled interchange ± Interchange tolerance). An unduly small interchange tolerance can cause non convergence of the power flow solution.

The net interchange tolerance should be related to system interchange capability and system impedances. A typical tolerance for a large electric utility with capability for a 500 MW net interchange might be 10 MW, while an industrial plant with a maximum net interchange capability of 15 MW might be assigned a tolerance of 0.5 MW. The tolerance should be set in relation to interchange capability and remain fixed as the interchange schedule is varied.

4.3.12.7 Adjusting Switched Shunt Admittance

Automatically switched shunt devices are normally adjusted according to the rules given in Section 4.3.3. When this adjustment option is enabled, either all adjustable switched shunts (i.e., the control mode, MODSW, is not 0) are subject to adjustment, or only continuous mode switched shunts (i.e., MODSW is 1) are subject to adjustment. This adjustment is normally enabled in all power flow solutions. It can be suppressed, regardless of the values of MODSW in the Solution Options. Selective locking of automatically switched shunt devices must be handled by leaving the adjustment feature *enabled* in the power flow solution and setting MODSW to 0 at buses where locking is required.

4.4 Analyzing Power Flow Solution Results

PSS™E can generate a variety of output reports to provide:

- Comprehensive information on the power flow results
- Summaries of conditions in network subsystems
- Checks on system and equipment conditions

This section discusses the available reports, the means by which they are generated and, as appropriate, how to interpret the information presented.

Table 4-6 summarizes the available power flow reports and subsystems by which they can be limited.

Table 4-6. Summary of Available PSS™E Power Flow Reports

Function	Can be Selected by
Power Flow Results	
Comprehensive power flow output in tabular or graphical format.	AREA, OWNER, ZONE, KV
Multi-terminal DC line solution output	NONE
Summary Reports	
Summary of area, zone or owner totals of load, generation, net interchange, shunts and losses.	AREA, ZONE, OWNER
Summary of tie-line flows between areas.	AREA
Summary of tie-line flows between zones.	ZONE
Reports on Checking Limit	
Summary of branches exceeding specified percentage of selected rating.	AREA, OWNER, ZONE, KV
Summary of buses with voltage outside specified band.	AREA, OWNER, ZONE, KV
Summary of generator terminal loading conditions on either all, or only overloaded, generators.	AREA, OWNER, ZONE, KV
Summary of generator bus loading conditions on either all, or only var-limited, generators.	AREA, OWNER, ZONE, KV
Summary of controlling transformer's violations	AREA, OWNER, ZONE, KV
Generator reactive power capability	AREA, OWNER, ZONE, KV
Regulated bus violations and/or conflicts	AREA, OWNER, ZONE, KV

Power flow results can be provided either in a tabular format or in a graphical format using the one-line slider format.

In the tabular format, power flow output reports may be organized either numerically by ascending bus number, or alphabetically by bus name. Selection of ordering by numbers or names is made in the Program Settings (see Section 1.6.4.) where either the *Number* output option, or the *Extended Name* output option may be chosen. Changing between the *Number* and *Extended Name* input options has no effect on the ordering of power flow reports.

All reports, except those selected by the AREA, ZONE and OWNER criteria, are made with buses appearing in pure numeric or alphabetic order. Power flow results reports selected by these criteria order the buses numerically or alphabetically within groupings. As an example, if output is selected by AREA, with areas 2 and 6 selected, the report will list all buses in area 2 first and then all buses in area 6.

4.4.1 Obtaining Tabular Power Flow Reports

The report output process is launched from the ***Power Flow>Reports*** option (see Figure 4-34). Selecting ***Bus based reports…*** will open the dialog seen in Figure 4-35. Alternatively, selecting the ***Bus Based Reports*** toolbar button, highlighted in Figure 4-34 will also open the Bus Based Reports dialog.

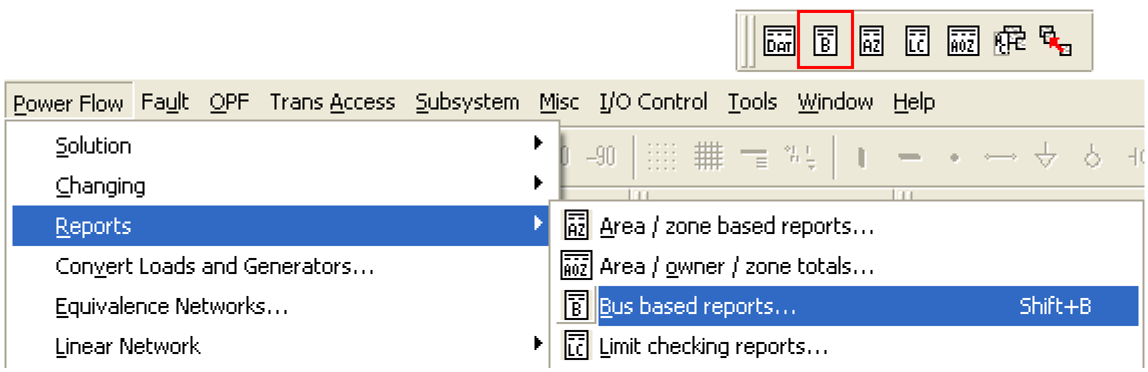


Figure 4-34. Selecting the Bus Based Reports

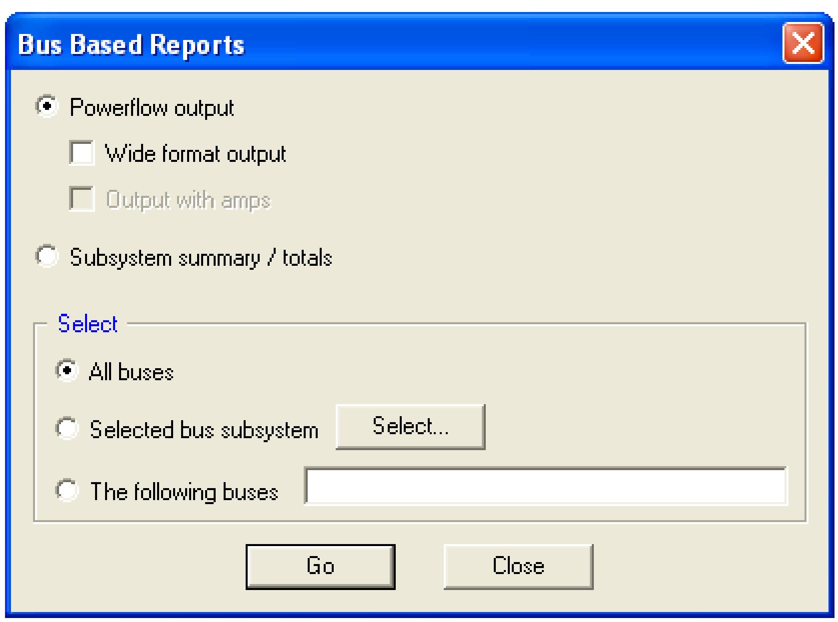


Figure 4-35. Bus Based Reports Dialog

The Bus Based Reports dialog shows options for selection of the "standard" output or a "Wide Format" output with or without the inclusion of branch and equipment currents (amperes) in the tabulation. The lower half of the dialog allows selection of output by Area, Zone, Owner, Base kV, Bus or any combination of those selection criteria.

4.4.1.1 Listing Bus Quantities in Power Flow Reports

The first line of the output block for each bus contains the bus number, name, and base voltage in the left portion of the line, column headings for the following data lines, the bus voltage (in pu), phase angle (in degrees), additional column headings for the LOSSES and the numbers and names of the AREAS and ZONES in which the listed buses reside. Either the bus number or the extended bus name is repeated at the end of the line, according to the bus output option currently in effect (see Figure 4-36).

The second line contains the bus voltage in kV if a base voltage was specified for the bus, followed by the MW and Mvar headings for the losses column. In addition, if the bus is a generator bus, the line contains the identifier GENERATION at the beginning and the plant active power, reactive power, and MVA output under the appropriate headings. This is followed by the percent MVA loading of the plant based on total plant MBASE. The plant reactive power output is followed by a single character flag, where "H" indicates that the plant reactive power output is at or beyond the total plant upper reactive power limit, "L" indicates that it is at or below the total plant lower reactive power limit, and "R" indicates that it is within limits.

Only plant conditions are tabulated. If more than one machine is modeled at the plant, individual machine conditions may be examined using the range checking facilities described in Section 4.4.5.

```
BUS    102 NUC-B       21.600 CKT     MW     MVAR     MVA  %I 1.0200PU  -30.81  X--- LOSSES ---X X---- AREA -----X X---- ZONE -----X    102
 FROM GENERATION                    750.0   344.5R  825.4  92 22.032KV                 MW     MVAR    1 FLAPCO          1 CENTRAL
 TO     151 NUCPLNT    500.00  1    750.0   344.6   825.4  65 1.0000UN               0.00    65.48    1 FLAPCO          1 CENTRAL

BUS    151 NUCPLNT     500.00 CKT     MW     MVAR     MVA  %I 1.0879PU   -5.07  X--- LOSSES ---X X---- AREA -----X X---- ZONE -----X    151
                                                              543.93KV                 MW     MVAR    1 FLAPCO          1 CENTRAL
 TO SHUNT                             0.0   710.1   710.1
 TO     101 NUC-A      21.600  1   -787.4  -276.2   834.4  61 1.1000HI   30.00LK     0.00    71.19    1 FLAPCO          1 CENTRAL
 TO     102 NUC-B      21.600  1   -750.0  -279.1   800.2  59 1.1000HI   30.00LK     0.00    65.48    1 FLAPCO          1 CENTRAL
 TO     152 MID500     500.00  1    444.7  -170.6   476.3  36                        4.37    77.37    1 FLAPCO          1 CENTRAL
 TO     152 MID500     500.00  2    444.7  -170.6   476.3  36                        4.37    77.37    1 FLAPCO          1 CENTRAL
 TO     201 HYDRO      500.00  1    648.1   186.5   674.4  52                        4.11    61.64    2 LIGHTCO         2 EASTERN

BUS    152 MID500      500.00 CKT     MW     MVAR     MVA  %I 1.0782PU  -15.07  X--- LOSSES ---X X---- AREA -----X X---- ZONE -----X    152
                                                              539.09KV                 MW     MVAR    1 FLAPCO          1 CENTRAL
 TO LOAD-PQ                        1200.0   360.0  1252.8
 TO LOAD-I                          936.2   280.9   977.4
 TO LOAD-Y                          973.9   292.2  1016.8
 TO SHUNT                             0.0  -930.0   930.0
 TO     151 NUCPLNT    500.00  1   -440.3   -46.3   442.7  34                        4.37    77.37    1 FLAPCO          1 CENTRAL
 TO     151 NUCPLNT    500.00  2   -440.3   -46.3   442.7  34                        4.37    77.37    1 FLAPCO          1 CENTRAL
 TO     153 MID230     230.00  1    701.9   255.0   746.8  28 1.0500HI               0.00    26.45    1 FLAPCO          1 CENTRAL
 TO     202 EAST500    500.00  1    119.0   161.5   200.5  16                        0.42     5.26    2 LIGHTCO         2 EASTERN
 TO    1403 WDUM       18.000  1  -1435.9  -152.6  1444.0  75 1.1000HI               0.00   176.88    5 WORLD           5 WESTERN
 TO    1404 EDUM       18.000  1  -1435.9  -152.6  1444.0  75 1.1000HI               0.00   176.88    5 WORLD           5 WESTERN
 TO    3004 WEST       500.00  1   -178.6   -21.8   179.9                            1.22    12.17    5 WORLD           5 WESTERN

BUS    153 MID230      230.00 CKT     MW     MVAR     MVA  %I 1.0150PU  -17.00  X--- LOSSES ---X X---- AREA -----X X---- ZONE -----X    153
                                                              233.45KV                 MW     MVAR    1 FLAPCO          1 CENTRAL
 TO LOAD-PQ                         200.0   100.0   223.6
 TO STATCON          FACTS DEV # 1    0.0    50.7    50.7 100
 TO     152 MID500     500.00  1   -701.9  -228.6   738.2  29 1.0000UN               0.00    26.45    1 FLAPCO          1 CENTRAL
 TO     154 DOWNTN     230.00  1    362.7    46.9   365.7 180                        6.52    58.65    1 FLAPCO          1 CENTRAL
 TO     154 DOWNTN     230.00  2    302.3    35.7   304.4 150                        5.43    48.88    1 FLAPCO          1 CENTRAL
 TO    3006 UPTOWN     230.00  1   -163.1    -4.7   163.2                            0.26     3.10    5 WORLD           5 WESTERN
```

Figure 4-36. Sample Standard Tabulated Power Flow Output

The first two lines for each tabulated bus are followed in turn by:

- Shunt elements connected to the bus
- FACTS devices
- DC lines
- AC branches terminating at the bus

4.4.1.2 Listing Shunt Elements in Power Flow Reports

These are the MW, Mvar and MVA values for constant power load, constant current load, constant admittance load, fixed shunt elements, and switched shunt at the bus, with the appropriate identifier at the left of each line. Note that only totals by load characteristic are tabulated. If more than one load is modeled at the bus, individual load quantities may be examined in detail as described in Section 3.2.3. Note that with the exception of the constant power loads, the power and reactive values are calculated on the basis of the bus voltage.

In Figure 4-36, on Bus 152, it can be seen that there are three connected loads, of different characteristics, and an 800 Mvar shunt capacitor. The capacitor is injecting 930 Mvar into the bus because of the elevated voltage at the bus (1.0782 pu).

4.4.1.3 Listing FACTS Devices in Power Flow Reports

In-service FACTS devices connected to the bus are reported in ascending FACTS device number order.

For each FACTS device for which the bus being reported is the sending end bus of an IPFC "master" or "slave" device, the following data pertaining to the device’s active power transfer to its companion IPFC device is printed:

1. An identifier indicating the type of the companion IPFC device ("IPFC MASTER" or "IPFC SLAVE").
2. The FACTS device number; this is printed in the circuit identifier column.
3. The active power flowing to the companion IPFC device. If the bus being reported is the IPFC "master" and the active power transfer is being held at its limit, its value is followed by the tag "HI".

Except for IPFC devices for which SHMX is 0.0, for each FACTS device for which the bus being reported is the sending end bus, the following data pertaining to the device’s shunt element are printed:

1. An identifier indicating the type of FACTS device shunt element and/or active power transfer being reported ("STATCON", "SSSC SHUNT", "UPFC SHUNT", or "IPFC SHUNT").
2. The FACTS device number; this is printed in the circuit identifier column.
3. Unless the device being reported is an IPFC, the active power being exchanged between the shunt and series element. If the active power is being held at its limit, its value is followed by the tag "HI".
4. The reactive power being absorbed by the shunt element.

5. The MVA corresponding to the active and reactive powers in (3) and (4) above, and the percent loading on the shunt element.

If the FACTS device contains a series element, the following data pertaining to it is printed in the output blocks of its sending and terminal end buses:

1. The number, name, and base voltage of the other endpoint bus ("to bus").
2. The FACTS device number; this is printed in the circuit identifier column.
3. The power flowing into the series element along with its percent loading at the "from bus" end.
4. The magnitude and phase of the series voltage. If the series voltage magnitude is being held at its limit (control modes 1, 5 and 6) or if the series voltage magnitude exceeds VSMX (control modes 2, 3, 4, 7 or 8), its value is followed by the tag "HI". Otherwise, the tag "RG" is printed.
5. The FACTS device losses calculated as the algebraic sum of the reactive power flowing into the series device from its endpoint buses.
6. The numbers and names of the area and zone in which the other endpoint bus ("to bus") resides.
7. An identifier indicating the type of FACTS device being reported ("SSSC", "UPFC", or "IPFC").

In Figure 4-36, it can be seen that on Bus 153, listed immediately after the 200 MW constant impedance load, there is a STATCON (identified as FACTS Device #1) absorbing 50 Mvar.

4.4.1.4 Listing DC Lines in Power Flow Reports

Output for DC transmission lines appears in the bus output block immediately following the bus and FACTS device output described above, and before output for AC branches. The order of printing is:

- Two-terminal lines, in ascending DC line number order
- Multi-terminal lines, in ascending DC line number order
- VSC DC line converters connected to the bus, in alphabetical VSC DC line name order.

The power flowing into a DC line is the apparent AC system complex load as seen at the converter bus.

The following data is printed in the output block of each two-terminal and multi-terminal DC line converter bus:

1. For two-terminal lines, the number, name, and base voltage of the other converter terminal bus ("*to bus*"). For multi-terminal lines, the identifier "MULTI-TERMINAL DC".
2. The DC line number; this is printed in the circuit identifier column.
3. The power flowing into the DC line.
4. The converter transformer off-nominal turns ratio, TAPR (or TAPI), followed by a two-character tag, which is either "HI" or "LO" if the ratio is at its high or low limit, respectively; "LK" if DC taps were locked during the last power flow solution activity, or if an

AC transformer (rather than this converter transformer) is controlling a DC line quantity; or "RG" if the ratio is in regulating range.

5. The value of converter angle followed by one of the tags "RG", "HI" or "LO" if the angle is within its limits, at or above its nominal high limit, or at or below its steady-state low limit, respectively.

6. DC line losses calculated as the algebraic sum of the powers flowing into the line from its converter buses.

7. For two-terminal lines, the numbers and names of the area and zone in which the other converter bus ("*to bus*") resides. For multi-terminal lines, the numbers and names of the area and zone in which the "DC bus" to which the AC converter bus is connected resides.

8. The identifier "RECTIFIER" (or "INVERTER"), which refers to the "*from bus*".

Figure 4-37 shows the output listing at a 765 kV Bus (1600) where there is a Generator (3,000 MW) feeding the rectifiers on the two DC lines to the 18 kV Buses 1403 and 1404. Each line is transmitting 1,500 MW. (Note that the LOSSES, AREA and ZONE columns are not shown.)

The converter transformer tap on DC line #1 is at its high limit (HI) and the firing angle, alpha is at 9.33^{o}, within its range (RG). On line #2, both the converter transformer and the firing angle are within regulating range (RG).

```
BUS    1600 NORTH        765.00 CKT     MW     MVAR     MVA  %I 1.0400PU    0.00  :
 FROM GENERATION                      3000.0   968.0R 3152.3  98 795.60KV
 TO    1403 WDUM         18.000 # 1   1500.0   454.7  1567.4     1.1000HI    9.33RG
 TO    1404 EDUM         18.000 # 2   1500.0   513.3  1585.4     1.0875RG   11.33RG
```

Figure 4-37. Two-terminal DC Line Output at Rectifier

In Figure 4-38 output for the inverter at Bus 1404 can be seen. It shows only 1435.9 MW arriving from the rectifier at Bus 1600, the converter transformer taps are locked (LK) and the firing angle, gamma, is at or above its high limit (HI) of 20^{o}.

```
BUS    1404 EDUM         18.000 CKT     MW     MVAR     MVA  %I 1.0000PU   -8.21  :
                                                                18.000KV
 TO SHUNT                               0.0  -800.0   800.0
 TO    1600 NORTH        765.00 # 2 -1435.9   834.2  1660.6     1.0000LK   26.92HI
 TO     152 MID500       500.00   1  1435.9   329.5  1473.2  83 1.0000UN
 TO    1402 ECOND        18.000   1     0.0  -363.7   363.7  36
```

Figure 4-38. Two-terminal DC Line Output at Inverter

For a bus with a VSC DC line connected to it, the following data is printed in the output block:

1. If the other converter terminal is in-service, the number, name, and base voltage of the other converter terminal bus ("*to bus*"), followed by the tag "VSC" in the circuit identifier column. If the other converter terminal is out-of-service, "VSC CONVERTER" is printed in these columns.

2. The AC power flowing into the DC converter.

3. The percent of MVA rating, where the rating is taken as the more restrictive of IMAX converted to MVA and SMAX.

4. DC line losses calculated as the algebraic sum of the powers flowing into the line from its converter buses.

5. The numbers and names of the area and zone in which the other converter bus resides if the other converter terminal is in-service; if it is out-of-service, these columns are left blank.

6. The VSC DC line name.

4.4.1.5 Listing Branch Quantities in Power Flow Reports

Following the output described above, flows for each in-service AC branch connected to the bus are tabulated, one per line. For non transformer branches and two-winding transformers, the output line contains the "*to bus*" number, name, and base voltage followed by the branch circuit identifier.

For three-winding transformers, the output line contains the string "3WNDTR" in the bus number column, the transformer name in the bus name column, and the winding number in the base voltage column, followed by the transformer circuit identifier.

The active and reactive power flow on the branch is printed as power leaving the "*from bus*" (i.e., positive for outgoing and negative for incoming); MVA flow is also printed. The percent current loading, based on the rating set established as the default rating in the run time options is then printed (see Sections 1.6.4, 3.2.5 and 3.2.6).

Branch losses which are printed are taken as I^2R and I^2X losses and *exclude* the line charging, line connected shunt, and magnetizing admittance components. For three-winding transformers, total losses on all three windings are printed.

The number and name of the area and zone in which the "*to bus*" resides are printed for non transformer branches and for two-winding transformers.

For transformers, the turns ratio of the winding connected to the "*from bus*" is printed following the percent loading. A two-character tag is printed adjacent to the ratio, which has the following significance:

HI	The "*from bus*" is connected to the winding one side of a regulating two-winding transformer or to a regulating winding of this three-winding transformer, and the off-nominal turns ratio is at or beyond its high limit.
LO	The "*from bus*" is connected to the winding one side of a regulating two-winding transformer or to a regulating winding of this three-winding transformer, and the off-nominal turns ratio is at or below its low limit.

RG	The "*from bus*" is connected to the winding one side of this regulating two-winding transformer or to a regulating winding of this three-winding transformer, its adjustment control mode is set to +1 or +2, the automatic tap ratio adjustment was enabled during the last power flow solution activity, and the off-nominal turns ratio is within its limits.
DC	The "*from bus*" is the winding one side of this two-winding transformer which is regulating alpha, gamma, or DC voltage of a DC line; its adjustment control mode is set to +4; DC tap adjustment was enabled during the last power flow solution activity; and the off-nominal turns ratio is within its limits.
LK	The "*from bus*" is connected to the winding one side of this two-winding transformer or to any winding of this three-winding transformer, and either this transformer winding is not a tap changing transformer winding, its adjustment control mode is to zero or negative, or the automatic tap ratio adjustment was disabled during the previous power flow solution activity.
UN	The "*from bus*" is not the winding one side of this two-winding transformer.

Except for the tags "DC" and "UN", phase shifters are handled in a similar manner. For single section two-winding transformers with non-zero phase shift angle on the winding one side, no indication of phase shift is printed in the output block of the winding two side bus.

When the multisection line reporting option is enabled (see Section 1.6.4), the far end "*to bus*" (rather than the closest "dummy" bus) of each multisection line connected to the "*from bus*" is shown as its "*to bus*". Multisection lines are identified with an ampersand ("&") as the first character of their branch identifiers in the circuit identifier column (e.g., "&1"). The sum of the losses on all of the line sections comprising the multisection line is shown as losses on the multisection line.

Finally, transformer information is shown only if the line section adjacent to the "*from bus*" is a transformer branch, and the data applies to the winding adjacent to the "*from bus*".

If any of the non transformer branches reported have a nonzero line shunt at the "*from bus*" end, or if any first winding of a transformer branch connected to the "*from bus*" has non-zero magnetizing admittance, and the line shunt reporting option is enabled (see Section 1.6.4), the branch output lines are followed by lines reporting powers corresponding to each of these admittances. Note that, regardless of the setting of this option, the branch flows reported always include these components.

Figure 4-39 shows a sample of the tabular output. It covers Buses 152 and 153 which are connected by a 500/230 kV transformer. It can be seen that the tap, at the Bus 152 side is at its high limit (HI) of 1.05 pu. At bus 153 it can be seen that this is not the winding one side of this two-winding transformer (UN).

The figure also shows three non transformer branches from Bus 153. They include circuits #1 and #2 to Bus 154 (DOWNTN), which are overloaded (at 180% and 150% of rating) and a single circuit to Bus 3006 (UPTOWN).

```
BUS     152 MID500      500.00 CKT     MW     MVAR     MVA  %I 1.0782PU  -15.07
                                                              539.09KV
  TO LOAD-PQ                         1200.0   360.0  1252.8
  TO LOAD-I                           936.2   280.9   977.4
  TO LOAD-Y                           973.9   292.2  1016.8
  TO SHUNT                              0.0  -930.0   930.0
  TO    151 NUCPLNT     500.00  1    -440.3   -46.3   442.7  34
  TO    151 NUCPLNT     500.00  2    -440.3   -46.3   442.7  34
  TO    153 MID230      230.00  1     701.9   255.0   746.8  28 1.0500HI
  TO    202 EAST500     500.00  1     119.0   161.5   200.5  16
  TO   1403 WDUM        18.000  1   -1435.9  -152.6  1444.0  75 1.1000HI
  TO   1404 EDUM        18.000  1   -1435.9  -152.6  1444.0  75 1.1000HI
  TO   3004 WEST        500.00  1    -178.6   -21.8   179.9

BUS     153 MID230      230.00 CKT     MW     MVAR     MVA  %I 1.0150PU  -17.00
                                                              233.45KV
  TO LOAD-PQ                          200.0   100.0   223.6
  TO STATCON         FACTS DEV # 1      0.0    50.7    50.7 100
  TO    152 MID500      500.00  1    -701.9  -228.6   738.2  29 1.0000UN
  TO    154 DOWNTN      230.00  1     362.7    46.9   365.7 180
  TO    154 DOWNTN      230.00  2     302.3    35.7   304.4 150
  TO   3006 UPTOWN      230.00  1    -163.1    -4.7   163.2
```

Figure 4-39. Power Flow Output for Branches

4.4.2 Obtaining Wide Format Power Flow Reports

This tabulated output presents the same information about the power flow solution as is seen in the standard output, with the addition of an option to print the branch currents (in amperes). Additionally, the rating sets in use are printed.

The layout of the information is different from the standard layout. Figure 4-40 shows the wide format output for the buses shown in Figure 4-36 for the standard output format.

```
X------- FROM BUS ------X AREA  VOLT            GEN    LOAD    SHUNT  X---------- TO BUS ----------X                          TRANSFORMER              RATING
  BUS# X-- NAME --X BASKV ZONE  PU/KV   ANGLE  MW/MVAR MW/MVAR MW/MVAR   BUS# X-- NAME --X BASKV AREA CKT    MW     MVAR   RATIO    ANGLE    AMPS  %I   SET A

   101 NUC-A        21.600     1 1.0200  -30.6   787.4      0.0      0.0 --------------------------------------------------------------------------------
                               1 22.032          347.4R     0.0      0.0    151 NUCPLNT      500.00    1  1   787.4  347.4 1.000UN          22553  68  1250M

   102 NUC-B        21.600     1 1.0200  -30.8   750.0      0.0      0.0 --------------------------------------------------------------------------------
                               1 22.032          344.5R     0.0      0.0    151 NUCPLNT      500.00    1  1   750.0  344.5 1.000UN          21629  65  1250M

   151 NUCPLNT      500.00     1 1.0879   -5.1     0.0      0.0      0.0 --------------------------------------------------------------------------------
                               1 543.93            0.0      0.0    710.1    101 NUC-A        21.600    1  1  -787.4 -276.2 1.100HI  30.0LK    886  61  1250M
                                                                            102 NUC-B        21.600    1  1  -750.0 -279.1 1.100HI  30.0LK    849  59  1250M
                                                                            152 MID500       500.00    1  1   444.7 -170.6                    506  36  1386A
                                                                            152 MID500       500.00    1  2   444.7 -170.6                    506  36  1386A
                                                                            201 HYDRO        500.00    2  1   648.1  186.5                    716  52  1386A
   152 MID500       500.00     1 1.0782  -15.1     0.0   3110.1      0.0 --------------------------------------------------------------------------------
                               1 539.09            0.0    933.0   -930.0    151 NUCPLNT      500.00    1  1  -440.3  -46.3                    474  34  1386A
                                                                            151 NUCPLNT      500.00    1  2  -440.3  -46.3                    474  34  1386A
                                                                            153 MID230       230.00    1  1   701.9  255.0 1.050HI            800  28  2500M
                                                                            202 EAST500      500.00    2  1   118.9  161.5                    215  16  1386A
                                                                           1403 WDUM         18.000    5  1 -1435.9 -152.6 1.100HI           1546  75  1780M
                                                                           1404 EDUM         18.000    5  1 -1435.9 -152.6 1.100HI           1546  75  1780M
                                                                           3004 WEST         500.00    5  1  -178.6  -21.8                    193
   153 MID230       230.00     1 1.0150  -17.0     0.0    200.0      0.0 --------------------------------------------------------------------------------
                               1 233.45            0.0    100.0      0.0 STATCON                        # 1     0.0   50.7                    126 100   126A
                                                                            152 MID500       500.00    1  1  -701.9 -228.6 1.000UN           1826  29  2500M
                                                                            154 DOWNTN       230.00    1  1   362.7   46.9                    905 180   502A
                                                                            154 DOWNTN       230.00    1  2   302.3   35.7                    753 150   502A
                                                                           3006 UPTOWN       230.00    5  1  -163.1   -4.7                    404
```

Figure 4-40. Wide Format Power Flow Output including Branch Currents

The main difference between the standard and wide format is that, in the former, the data categories are listed in vertical order while in the wide format they are printed from left to right. Those data categories are:

- Bus data
- Generators
- Load
- Shunts
- FACTS devices
- DC Lines
- Branches

The wide data format output is initiated in the same manner as the standard format. Selecting ***Wide format output*** provides the option to include currents in the tabulation (see Figure 4-41).

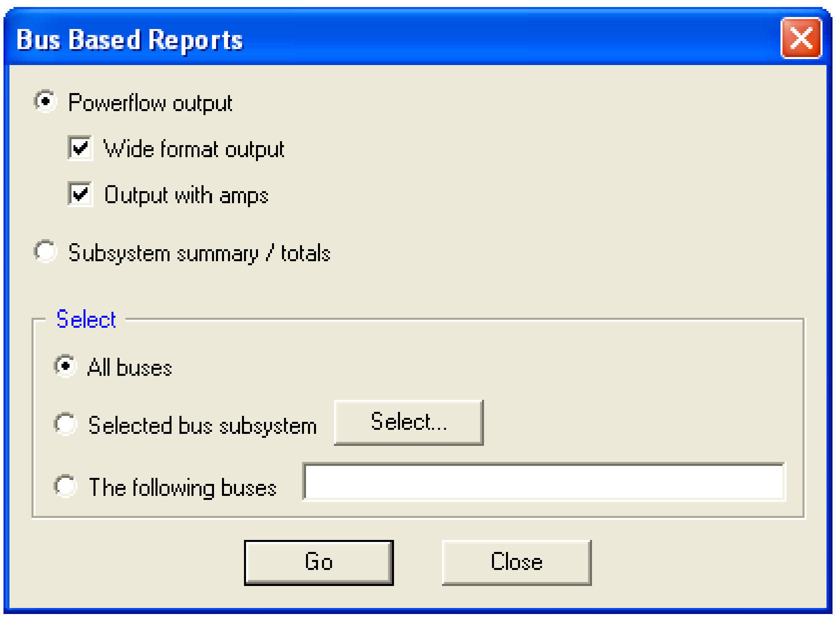


Figure 4-41. Selection of Wide Format Bus Based Report Output

4.4.3 Obtaining Graphical Power Flow Reports

Superimposing power flow results on a one-line diagram is an effective means of presentation. Section 2.5 describes the Diagram View and how to construct and manage the presentation of results (see Section 2.5.11.1). This section will highlight some of those features on the assumption that a diagram file (slider file type **.sld)* has previously been created. For the purposes of display, the *savnw.sav* and *savnw.sld* files will be used. These are found in the Example folder of the PSS™E installation.

4.4.3.1 Showing Results Information on the Diagram

A portion of the network power flow results can be seen in Figure 4-42. Here the annotation is selected to show:

- Bus name and number with voltages shown in pu and kV
- Branch flows at "to" and "from" end
- Transformer taps on both sides
- MW and Mvar flows on branches and in equipment
- Signs as opposed to arrows to show flow directions. Plus signs indicate flows out of a bus and minus signs indicate flows into a bus.

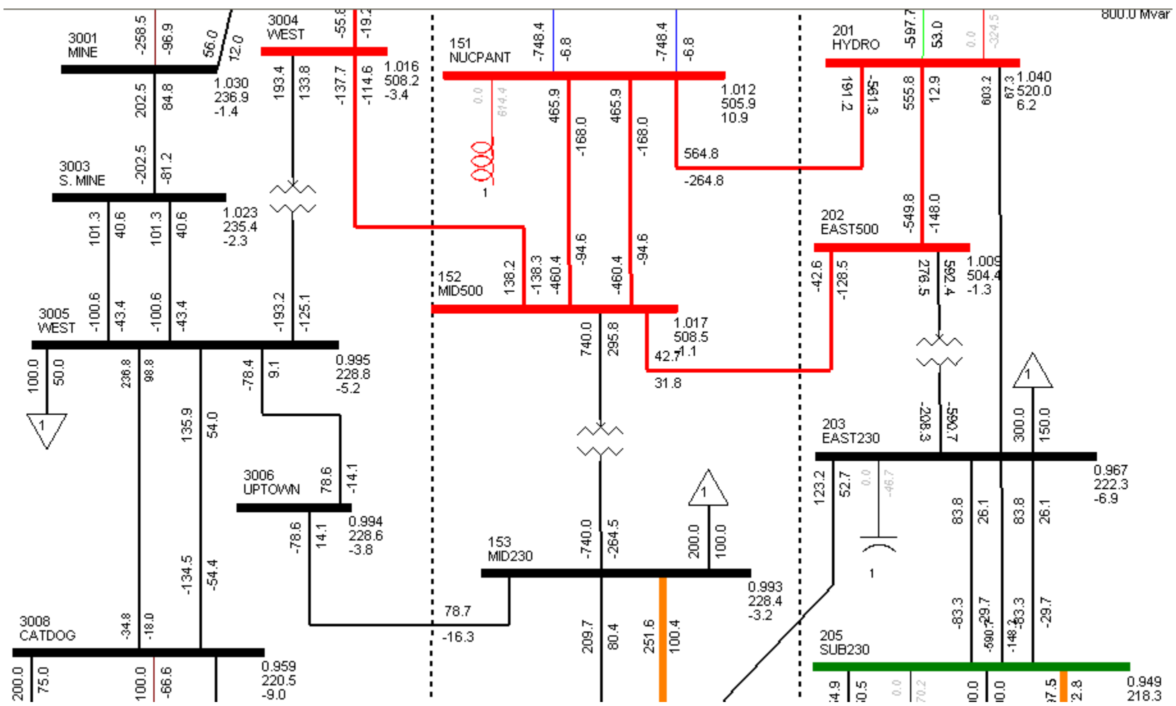


Figure 4-42. Power Flow Output Results in Diagram View

The user can choose to show all this information for all buses, branches and equipment, including generation, or to globally prevent showing of particular types of information (e.g., no branch flows on all branches) or to select particular buses, lines and equipment to have their annotation suppressed. Selecting the ***Diagram>Annotation…*** option will open the Powerflow Data Annotation dialog where selections can be made of which information to show. Right-clicking on the diagram or a network element in the diagram will give access to the same dialog (Figure 4-44). Right-clicking on a network element will make the **Item Annotation…** and **Diagram Annotation…** options available (Figure 4-43).

In the right hand diagram of Figure 4-43, the number of the bus (151) is shown. This is the item on which the right-click was performed. Note further that the Diagram Annotation toolbar button is indicated in the pop-up menu.

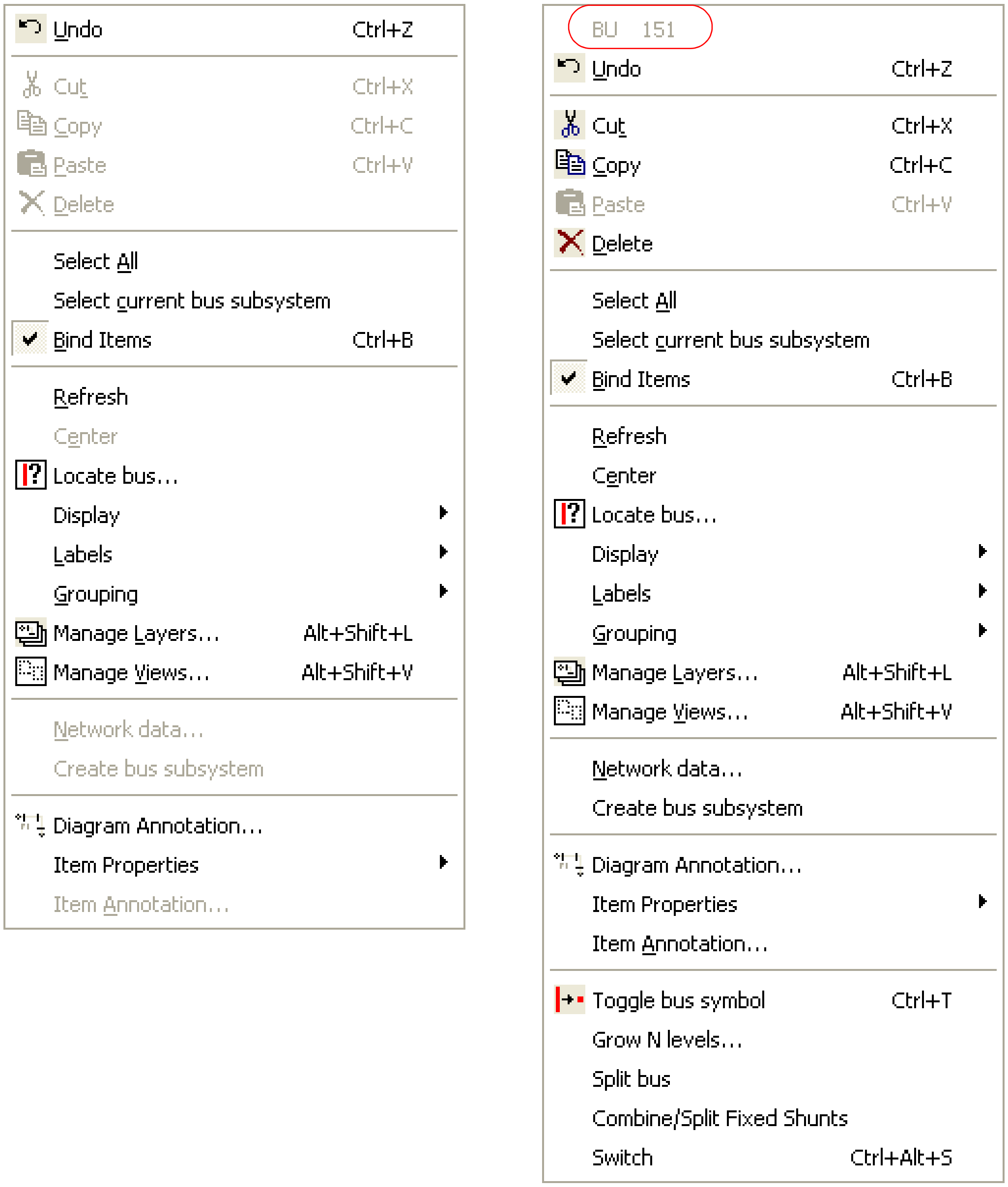


Figure 4-43. Selecting the Power Flow Data Annotation Dialog from the Diagram Right-click Pop-up Menu

The Powerflow Data Annotation dialog is shown in Figure 4-44. It can be seen that the annotations on the one-line diagram in Figure 4-42 are in accord with the selections shown for branch, bus, voltage, equipment and flow directions.

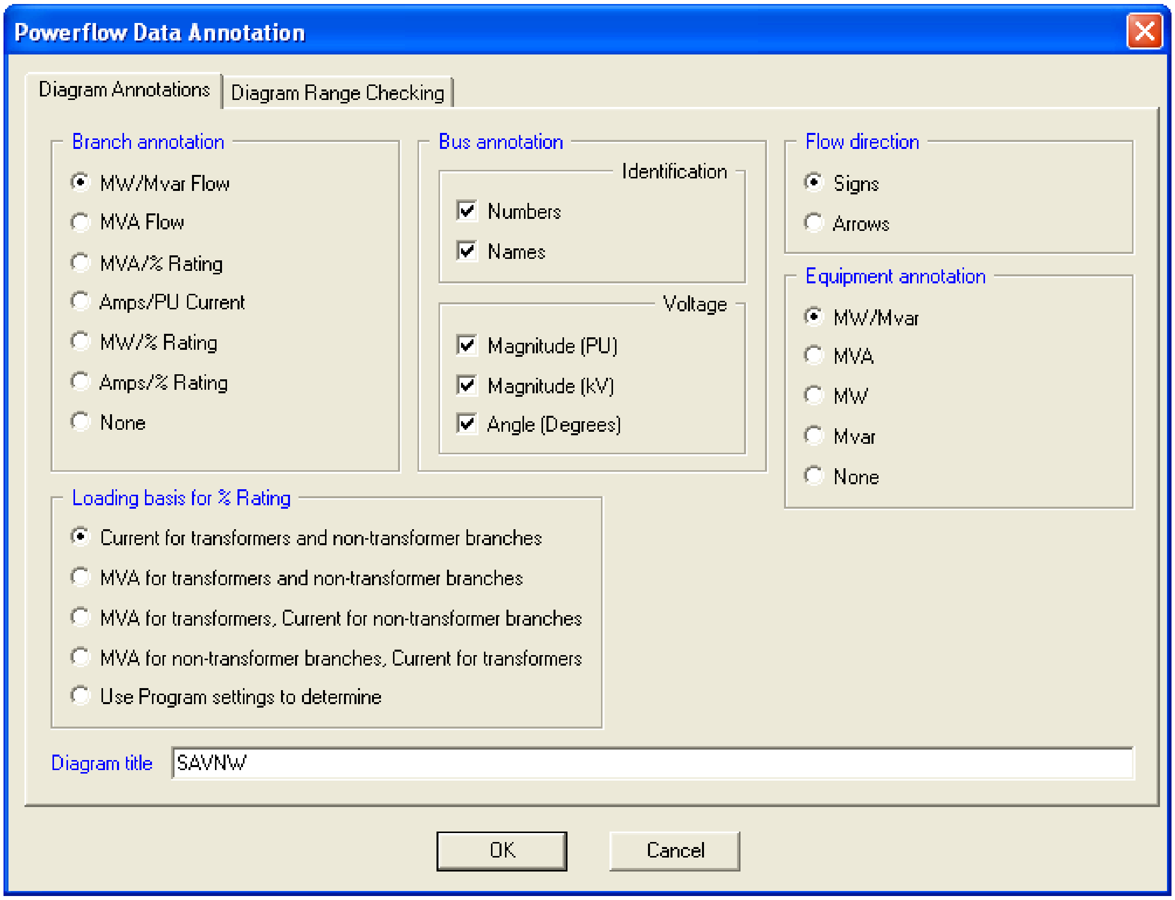


Figure 4-44. Power Flow Data Annotation Dialog: Diagram Annotations Tab

For each item (or network element) including generation, branch, equipment and bus, an Annotation Properties dialog will open particular to the item selected. Figure 4-45 shows the selections for a LOAD. More details on item annotation are discussed in Section 2.5.11.1.

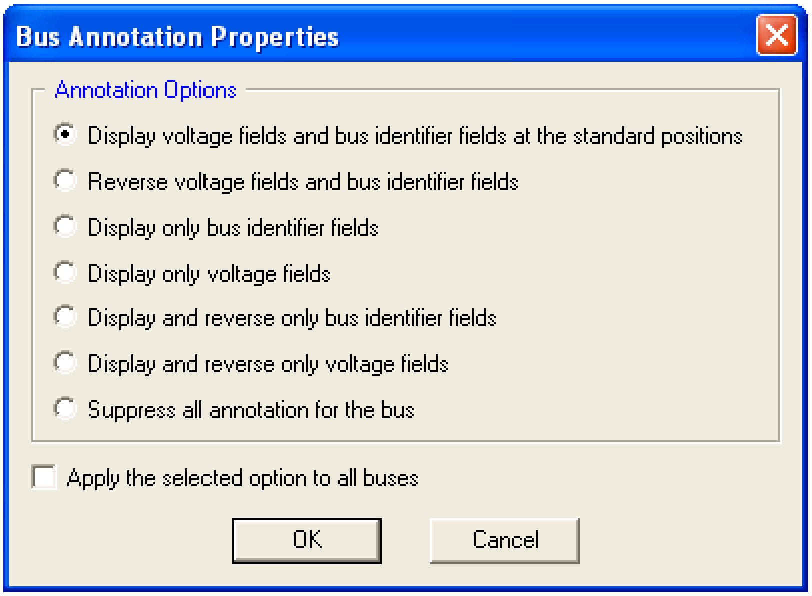


Figure 4-45. Load Annotation Properties Dialog

4.4.3.2 Color Coding Results on the Diagram

The Diagram View is useful for showing power flow conditions which are beyond selected limits. It is possible to highlight branches which are overloaded and bus voltages which are either higher than a selected high limit or lower than a selected low limit.

Figure 4-46 displays the Diagram Range Checking tab. Under Line Ratings, ***Use line ratings*** is selected to highlight lines loaded at 55% of the Rate A. In addition, the Bus Voltage Limits are selected to highlight buses with voltages higher than 1.01 pu or lower than 0.95 put

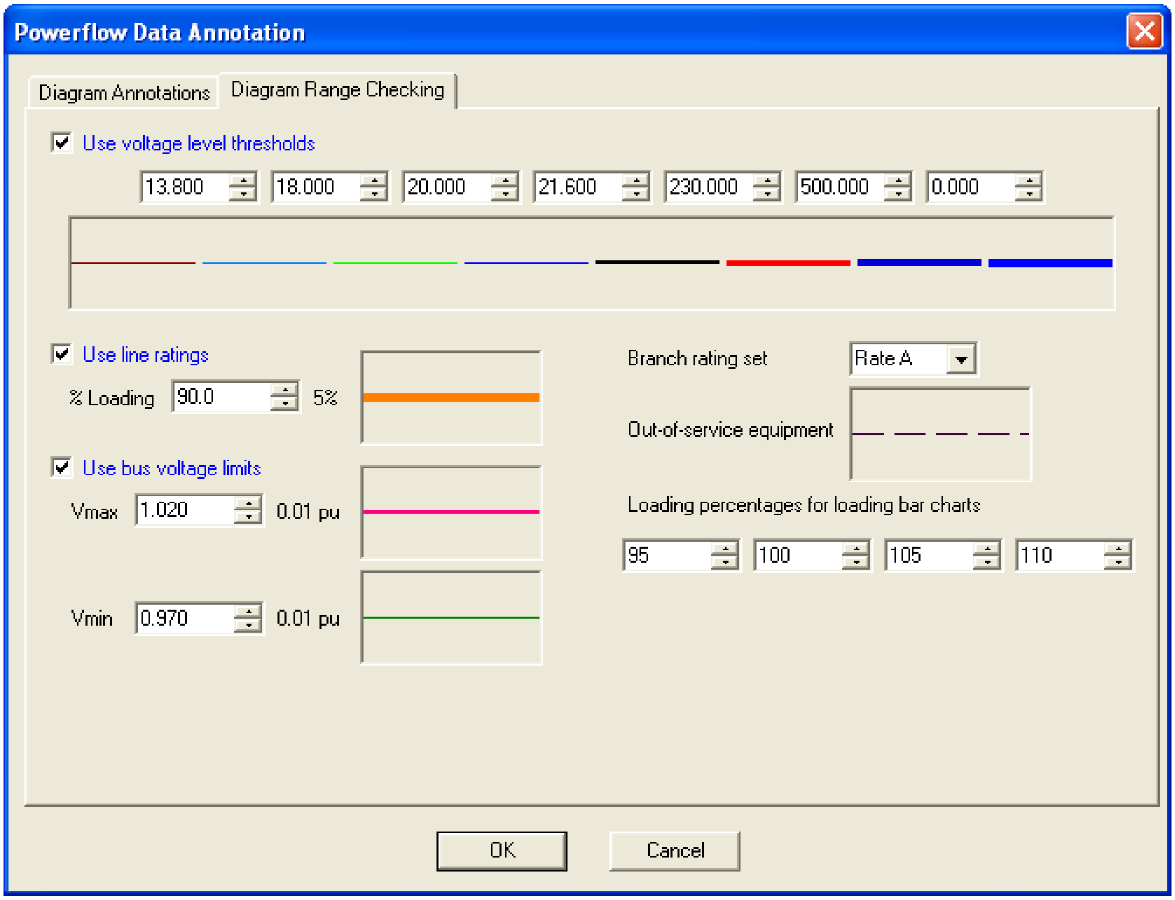


Figure 4-46. Selecting Line Ratings in the Diagram Range Checking Tab

With these Diagram Range Checking options selected, the power flow output shown in Figure 4-43 will change to show the buses and lines with voltages and loadings outside the ranges selected (see Figure 4-47).

It can be seen that buses 206 and 3018 (and others) are highlighted for having voltages in excess of the high limit, 1.02 pu. Bus 203 and 205 are highlighted for having voltages below the low limit, 0.97 pu.

The circuit one between buses 153 and 154 (and others) are highlighted to show their loading is in excess of 90% of their Rate A.

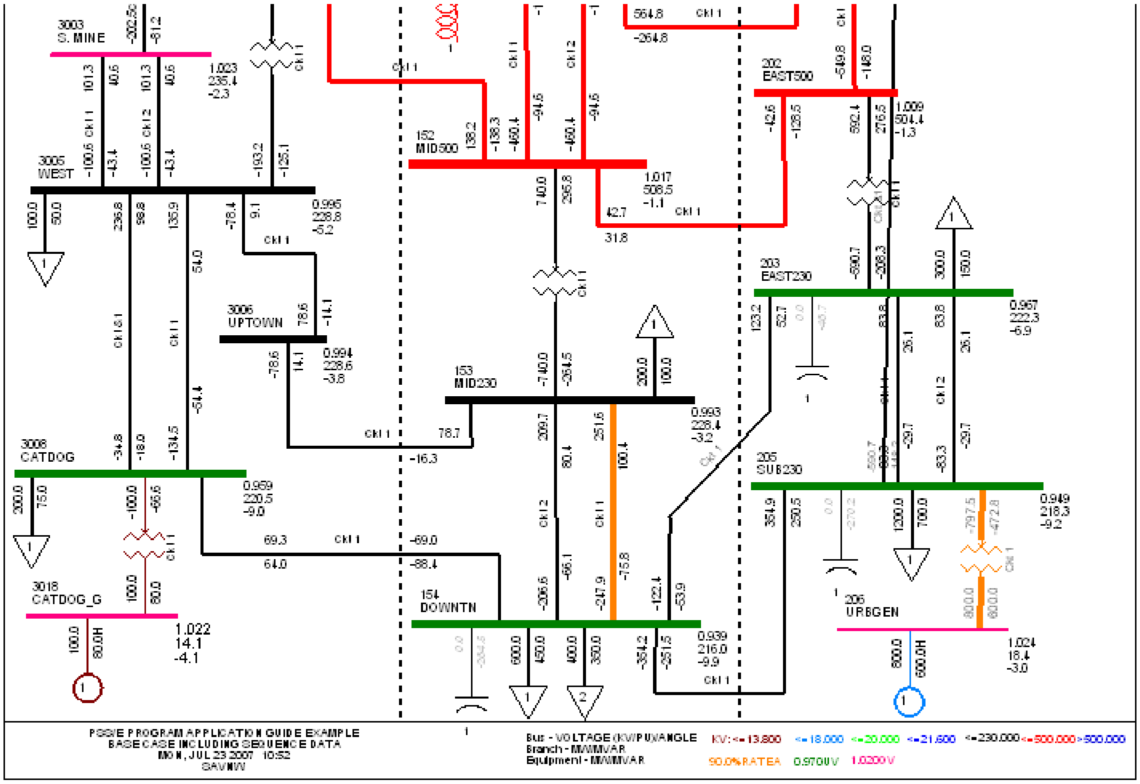
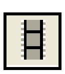


Figure 4-47. Power Flow Diagram showing Effect of Range Checking

4.4.3.3 Animating Flows on the Diagram



The Animate flows button is used to animate branch flows on the active Diagram View. The branch flows are animated using the flows from the last load flow solution (Figure 4-48).

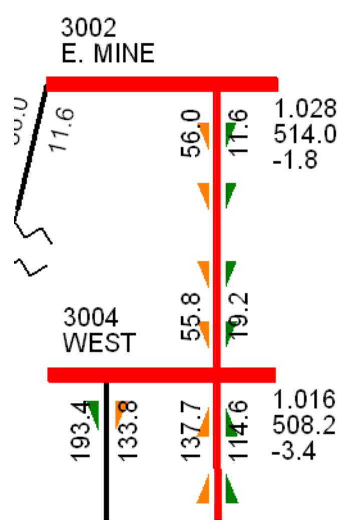
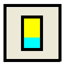


Figure 4-48. Animated Flows for MW and Mvar

4.4.3.4 Viewing Current Loadings on the Diagram



The Current loadings button is used to display line loading graphs. The graph values are set using values from the last load flow solution (Figure 4-49).

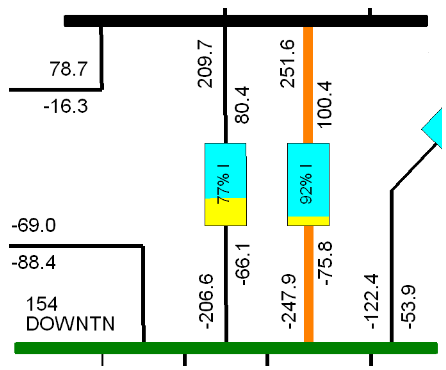


Figure 4-49. Current Loading Blocks Indicating Flow Levels

4.4.3.5 Exporting the Diagram to the Clipboard

All cutting, copying and pasting of diagram items in a Diagram View is done from the application diagram clipboard. Diagram items placed on the application diagram clipboard may only be used in other Diagram Views within the same invocation of PSS™E. To copy diagrams between applications, such as copying a diagram from PSS™E to Microsoft® Word, the system clipboard needs to be used. A Diagram View can be copied to the system clipboard by selecting ***Edit>Copy to clipboard*** from the Main Menu.

Another way to use a Diagram View in other applications is to export the Diagram View into either a JPEG (*.jpg) or Bitmap (*.bmp) image file. To export a Diagram View into an image file, select ***File>Export Diagram Image…*** from the Main Menu. A File dialog will appear prompting for a name to save the image file under. Select the image file format, either JPEG or Bitmap, by using the ***Save as type:*** field at the bottom of the dialog.

4.4.4 Power Flow System Summary Reports

Table 4-7 shows the information provided in the summary total reports for the three bases of Area, Zone and Owner. A "Y" indicates the information is provided. An "N" indicates the information is not provided or relevant.

Table 4-7. Information Provided in Summary Reports by Selection Criterion

Information	AREA	ZONE	OWNER
Generation (MW, Mvar)	Y	Y	Y
Load (MW, Mvar)	Y	Y	Y
Bus connected shunts including switched shunts and shunt elements of FACTS devices (MW, Mvar)	Y	Y	Y
Line connected shunt elements including magnetizing admittance of transformers (MW, Mvar)	Y	Y	Y
Line charging (Mvar)	Y	Y	Y
Net Interchange between areas or zones (MW, Mvar)	Y	Y	N
Losses (MW, Mvar)	Y	Y	Y
Desired net interchange between areas (MW)	Y	N	N

4.4.4.1 Reporting Totals by Area/Owner/Zone

Summary reports for areas/owners/zones are obtained by selecting ***Power Flow>Reports>Area / owner / zone totals...*** (Figure 4-50).

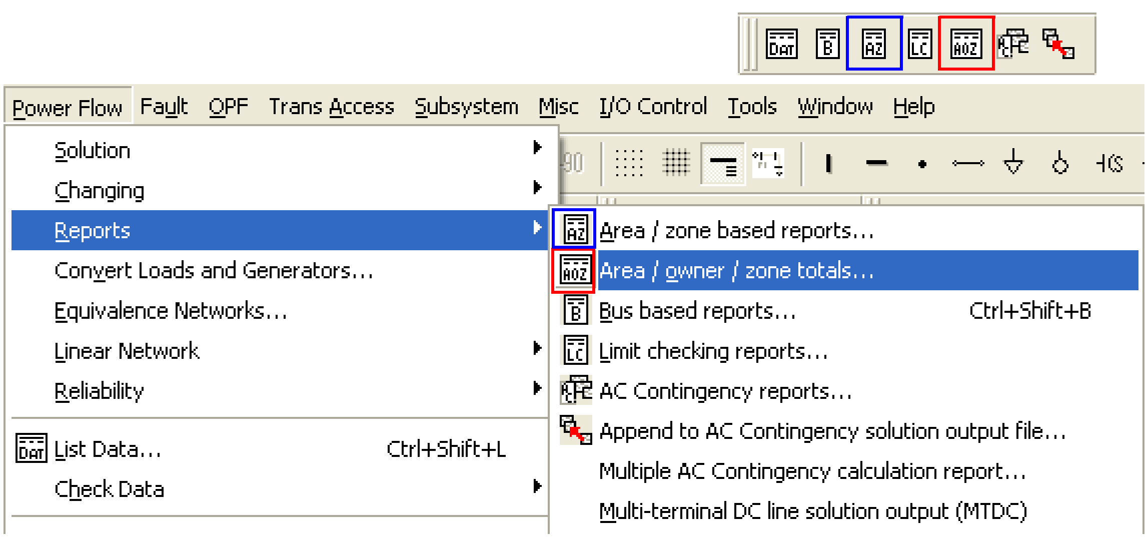


Figure 4-50. Accessing the Area, Owner, Zone Summary Reports

Area, zone and owner subsystem totals are selected in the **Area/Owner/Zone Totals** dialog (see Figure 4-51). The reports are generated, as specified, for all subsystems or for selected subsystems. The figure shows that Area totals have been indicated and that specific Areas will be selected. When the ***Select*** button is clicked, the Area Subsystem Selector dialog will be opened. Clicking ***Go*** generates the report.

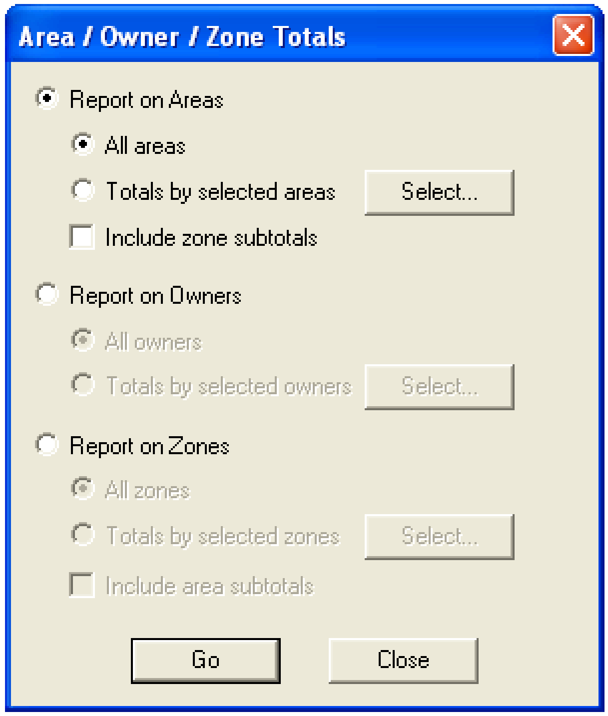


Figure 4-51. Selection of Area Totals Report by Selected Areas

4.4.4.1.1 Viewing Area Totals

The *savnw.sav* power flow case, which is provided in the Example subdirectory of the PSS™E installation, has three areas. For this power flow case, the Area totals are shown in Figure 4-52.

```
                      FROM       TO     TO BUS  TO LINE     FROM      TO              DESIRED
X-- AREA --X GENERATION    LOAD     SHUNT    SHUNT  CHARGING   NET INT    LOSSES  NET INT

    1             1500.0    200.0      0.0      0.0      0.0     278.7     21.3    250.0
FLAPCO             162.4    100.0    349.9      0.0    841.2    -684.6    438.3

    2             1400.0   2500.0      0.0      0.0      0.0    -130.8     30.8   -100.0
LIGHTCO            617.8   1650.0   -641.4      0.0    623.0     441.7    590.4

    5              358.7    500.0      0.0      0.0      0.0    -147.9      6.6   -150.0
WORLD              184.0    200.0      0.0      0.0    345.8     242.9     87.0

TOTALS            3258.7   3200.0      0.0      0.0      0.0       0.0     58.7      0.0
                   964.2   1950.0   -291.5      0.0   1810.1       0.0   1115.7
```

Figure 4-52. Area Total Results

A brief examination of the results shows:

- The FLAPCO area is transmitting power to the other two areas although it is exporting more (278.7 MW) than scheduled (250 MW). This is because the Area Interchange control was not enabled in the Loadflow Solutions window.
- LIGHTCO area is receiving 130.8 MW compared to a desired interchange of 100 MW.
- The FLAPCO area is receiving 684.6 Mvar from the other two areas.
- Total Real Power losses are 58.7 MW

4.4.4.1.2 Viewing Zone Totals

The *savnw.sav* power flow case, has four Zones. The Report on Zone totals is shown in Figure 4-53.

X-- ZONE --X	FROM GENERATION	TO LOAD	TO BUS SHUNT	TO LINE SHUNT	FROM CHARGING	TO NET INT	LOSSES
1	0.0	1200.0	0.0	0.0	0.0	-1218.0	18.0
FIRST	0.0	900.0	349.9	0.0	841.2	-698.2	289.6
2	1400.0	1500.0	0.0	0.0	0.0	-130.8	30.8
SECOND	617.8	850.0	-641.4	0.0	623.0	441.7	590.4
5	358.7	500.0	0.0	0.0	0.0	-147.9	6.6
FIFTH	184.0	200.0	0.0	0.0	345.8	242.9	87.0
77	1500.0	0.0	0.0	0.0	0.0	1496.7	3.3
PLANT	162.4	0.0	0.0	0.0	0.0	13.6	148.8
TOTALS	3258.7	3200.0	0.0	0.0	0.0	0.0	58.7
	964.2	1950.0	-291.5	0.0	1810.1	0.0	1115.7

Figure 4-53. Zone Totals Results

A brief examination of the results shows:

- Zone 1 (FIRST) has zero generation but a demand level of 1200 MW. It can be seen that its net interchange is 1218 MW which serves the load demand and the zone's losses of 18 MW. Note that there is no Zone interchange flow control available.
- Similarly, Zone 2 (SECOND) has 1400 MW of generation but 1500 MW of load. Its net interchange therefore is seen to be 130 MW which serves the deficit between generation and demand and the zone's real power losses of 30.8 MW.

4.4.4.1.3 Viewing Owner Totals

The *savnw.sav* power flow case, has seven Owners. The Report on Owner totals are shown in Figure 4-54.

```
                    FROM       TO     TO BUS  TO LINE     FROM
X- OWNER --X GENERATION     LOAD      SHUNT    SHUNT  CHARGING     LOSSES

    1              499.9     800.0       0.0      0.0       0.0      26.3
TRAN 1              54.1     550.0     349.9      0.0    1270.8     506.5

    2              560.0    1500.0       0.0      0.0       0.0       6.2
TRAN 2             247.1     850.0    -316.9      0.0      14.7     264.9

    5              124.0     500.0       0.0      0.0       0.0       5.4
TRAN 5              67.6     200.0       0.0      0.0      57.4      53.4

   11             1019.9       0.0       0.0      0.0       0.0       0.0
GEN 1              116.3       0.0       0.0      0.0       0.0       0.0

   22              899.7       0.0       0.0      0.0       0.0      19.5
GEN 2              394.7       0.0    -324.5      0.0     464.9     257.8

   55              155.0       0.0       0.0      0.0       0.0       0.2
GEN 5               84.5       0.0       0.0      0.0       0.0      24.6

  100                0.0     400.0       0.0      0.0       0.0       0.9
NO BUSES             0.0     350.0       0.0      0.0       2.3       8.5

TOTALS            3258.7    3200.0       0.0      0.0       0.0      58.7
                   964.2    1950.0    -291.5      0.0    1810.1    1115.7
```

Figure 4-54. Owner Totals Results

A brief examination of the results shows:

- The seven Owners have ownership of all the generators in this network (3258 MW). This can be compared with the Area totals.
- All the shunts in the network, whether they be FACTS devices, switched shunts or bus shunts are assigned to three Owners (TRAN 1, TRAN 2 and GEN 2).
- Three Owners (GEN 1, GEN 2 and GEN 5) supply a total of 19,196 MW of generation but have no ownership of demand.
- Note that there is no Owner interchange control available.

4.4.4.2 Reporting Interchange by Area/Owner/Zone

Table 4-8 shows the information provided in the interchange reports on the bases of area and zone.

Table 4-8. Information Provided in Interchange Reports for Areas and Zones

Information Provided	Area	Zone
Total interchange between Areas (MW, Mvar)	Y	-
Interchange flows on tie-lines between Areas (MW, Mvar)	Y	-
Total interchange between Zones (MW, Mvar)	-	Y
Interchange flows on tie-lines between Zones (MW, Mvar)	-	Y

The dialog for interchange reports are opened from the ***Power Flow>Reports>Area / zone based reports…*** or by clicking the ***Area/Zone*** button. The Area/Zone Base Reports dialog will be displayed (Figure 4-55).

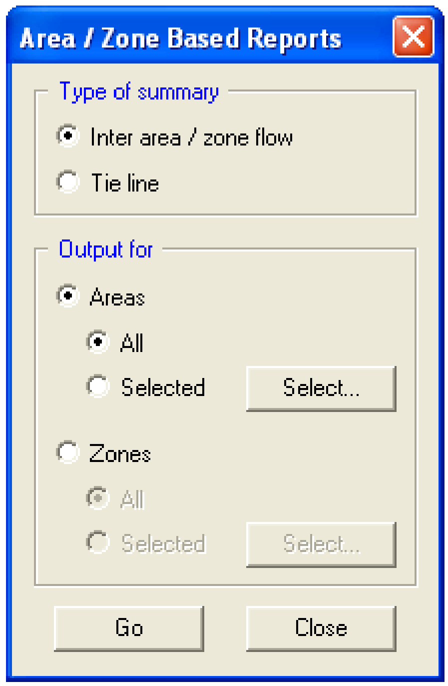


Figure 4-55. Area/Zone Based Reports Dialog

There are two types of summary reports: **Inter area/zone flow**, which provides total flows between Areas or Zones and **Tie line**, which provides detailed flows on the tie lines (branches) between the Areas or Zones.

The output is organized by Area or Zone such that all Areas or all Zones are reported or the Select… facility may be used to limit the output to selected Areas or Zones.

It is useful to note that the inter Area / Zone flow report can be compared to the Totals report described in Section 4.4.4.1.

4.4.4.2.1 Reporting Inter-Area/Inter-Zone Flow

The Inter-area summary report for the *savnw.sav* case is seen in Figure 4-56.

```
      TO AREA:     1     2     5
FROM AREA    *------------------
        1    *         131   148
FLAPCO       *        -442  -243
             *------------------
        2    *  -131
LIGHTCO      *   442
             *------------------
        5    *  -148
WORLD        *   243
             *------------------|
```

Figure 4-56. Inter-Area Flows by Area

This simple summary on inter-area flow can be compared with the Area Total report (see Figure 4-52). This report confirms the previously documented results which show that Area 1 is exporting 131 MW to Area 2 and exporting 148 MW to Area 5. Note that these numbers are rounded in comparison to results shown in Figure 4-52.

The Inter-zone summary report for the *savnw.sav* case is seen in Figure 4-57.

```
      TO ZONE:     1     2     5    77
FROM ZONE    *------------------------
        1    *         131   148 -1497
FIRST        *        -442  -243   -14
             *------------------------
        2    *  -131
SECOND       *   442
             *------------------------
        5    *  -148
FIFTH        *   243
             *------------------------
       77    *  1497
PLANT        *    14
             *------------------------|
```

Figure 4-57. Inter-Zone Flows by Zone

This simple summary on inter-zone flow can be compared with the Zone Total report (see Figure 4-53). This report confirms the previously documented results which show that Zone 1 is importing a total of 1218 MW from the other three zones.

4.4.4.2.2 Reporting Tie Line Flows

A portion of the Inter-area tie-line report for the *savnw.sav* case is seen in Figure 4-58. The report presents information in order of Area. The figure shows the tie-line flows from Area 1 to Areas 2 and 5. The total flows can be compared with the interchange totals shown in Figure 4-56 (inter-area flows) and Figure 4-52 (area totals report).

```
FROM AREA    1   FLAPCO

  TO AREA    2   LIGHTCO
  X---- FROM AREA BUS ----X   X----- TO AREA BUS -----X
    BUS# X-- NAME --X BASKV     BUS# X-- NAME --X BASKV  CKT      MW     MVAR
     151 NUCPANT     500.00*     201 HYDRO       500.00   1     564.8   -264.8
     152 MID500      500.00      202 EAST500     500.00*  1      42.6    128.5
     154 DOWNTN      230.00*     203 EAST230     230.00   1    -122.4    -53.9
     154 DOWNTN      230.00*     205 SUB230      230.00   1    -354.2   -251.5
  TOTAL FROM AREA    1 TO AREA    2                                                 130.8    -441.7

  TO AREA    5   WORLD
  X---- FROM AREA BUS ----X   X----- TO AREA BUS -----X
    BUS# X-- NAME --X BASKV     BUS# X-- NAME --X BASKV  CKT      MW     MVAR
     152 MID500      500.00*    3004 WEST        500.00   1     138.2   -138.3
     153 MID230      230.00*    3006 UPTOWN      230.00   1      78.7    -16.3
     154 DOWNTN      230.00*    3008 CATDOG      230.00   1     -69.0    -88.4
  TOTAL FROM AREA    1 TO AREA    5                                                 147.9    -242.9
                                                                                ---------  ---------
TOTAL FROM AREA    1   FLAPCO                                                       278.7    -684.6
```

Figure 4-58. Inter-Area Tie Line Report

A portion of the inter-zone tie-line report for the *savnw.sav* case is seen in Figure 4-59. The report presents information in order of Zone. The figure shows the tie-line flows from Zone 1 to Zones 2, 5 and 77. The total flows can be compared with the interchange totals shown in Figure 4-57 (inter-zone flows) and Figure 4-53 (zone totals report).

```
FROM ZONE    1   FIRST

  TO ZONE    2   SECOND
  X---- FROM ZONE BUS ----X   X----- TO ZONE BUS -----X
    BUS# X-- NAME --X BASKV     BUS# X-- NAME --X BASKV  CKT      MW     MVAR
     151 NUCPANT     500.00*     201 HYDRO       500.00   1     564.8   -264.8
     152 MID500      500.00      202 EAST500     500.00*  1      42.6    128.5
     154 DOWNTN      230.00*     203 EAST230     230.00   1    -122.4    -53.9
     154 DOWNTN      230.00*     205 SUB230      230.00   1    -354.2   -251.5
  TOTAL FROM ZONE    1 TO ZONE    2                                                 130.8    -441.7

  TO ZONE    5   FIFTH
  X---- FROM ZONE BUS ----X   X----- TO ZONE BUS -----X
    BUS# X-- NAME --X BASKV     BUS# X-- NAME --X BASKV  CKT      MW     MVAR
     152 MID500      500.00*    3004 WEST        500.00   1     138.2   -138.3
     153 MID230      230.00*    3006 UPTOWN      230.00   1      78.7    -16.3
     154 DOWNTN      230.00*    3008 CATDOG      230.00   1     -69.0    -88.4
  TOTAL FROM ZONE    1 TO ZONE    5                                                 147.9    -242.9

  TO ZONE   77   PLANT
  X---- FROM ZONE BUS ----X   X----- TO ZONE BUS -----X
    BUS# X-- NAME --X BASKV     BUS# X-- NAME --X BASKV  CKT      MW     MVAR
     151 NUCPANT     500.00*     101 NUC-A       21.600   1    -748.4     -6.8
     151 NUCPANT     500.00*     102 NUC-B       21.600   1    -748.4     -6.8
  TOTAL FROM ZONE    1 TO ZONE   77                                               -1496.7     -13.6
                                                                                ---------  ---------
TOTAL FROM ZONE    1   FIRST                                                      -1218.0    -698.2
```

Figure 4-59. Inter-Zone Tie Line Report

4.4.5 Viewing Network Limit Violations

PSS™E enables the user to develop seven different types of reports which can assist in rapidly identifying network conditions that are outside of required control limits or to indicate controlling equipment and possible violations and conflicts associated with those controls. The following summary reports are available:

- Summary of branches exceeding specified percentage of selected rating.
- Summary of buses with voltage outside specified band.
- Summary of generator terminal loading conditions on either all, or only overloaded, generators.
- Summary of generator bus loading conditions on either all, or only var-limited, generators.
- Summary of controlling transformers and violations.
- Generator reactive power and capability.
- Regulated buses, violations and/or conflicts.

The ***Power Flow>Reports>Limit checking reports…*** option opens the Limit Checking Reports dialog (see Figure 4-61). Alternatively, the Limit Checking toolbar button can be used (see upper right portion of Figure 4-60).

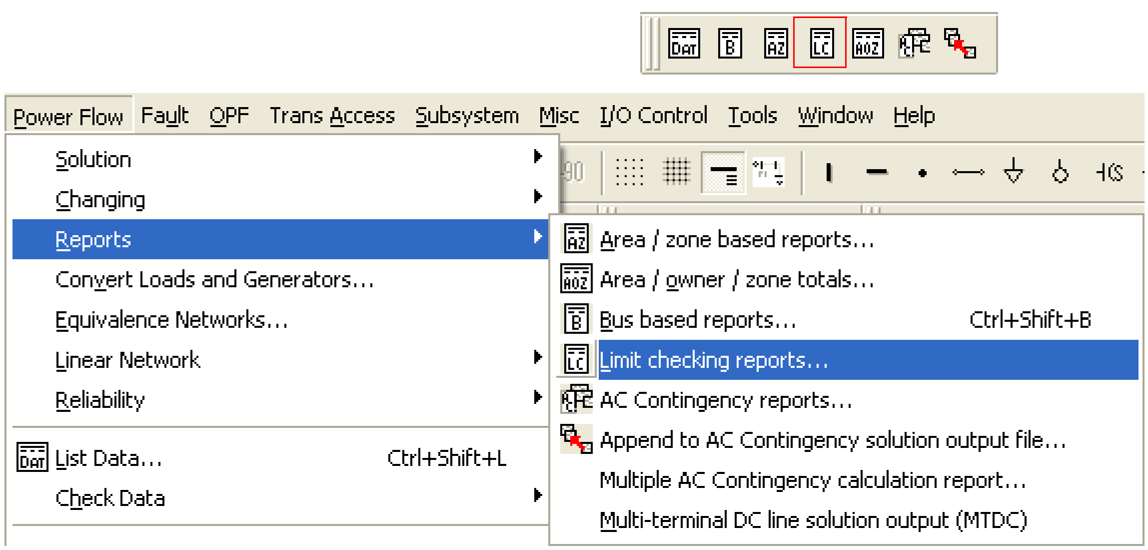


Figure 4-60. Accessing the Limit Checking Report Dialog

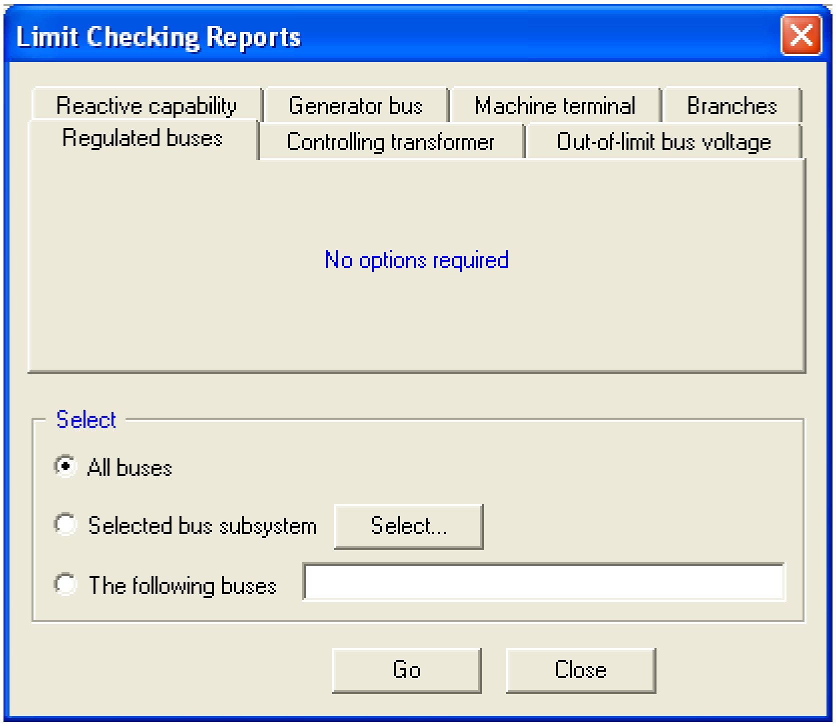


Figure 4-61. Limit Checking Reports Dialog

The seven available reports are accessed from the seven tabs shown in the Limit Checking Reports dialog. Note that each report can be selected by AREA, ZONE, OWNER, BASE KV and BUS, using the Select area of the dialog.

4.4.5.1 Viewing Branch Limits

Clicking on the ***Branches*** tab of the Limit Checking Reports dialog provides access to several types of branch loading checks:

- Branch overloads, based on current loading, for transformer and non-transformer branches
- Transformer overloads, based on MVA loading
- Transmission line (non-transformer branches) overloads based on current loading
- Branch current ratings (A, B and C) and percentage loading at each rating

For overload checking purposes, the user can select which of the three ratings is to be used, with the default being the rating set established in the program options (see Section 1.6.4). The default percentage of rating limit is 100%. This limit can be adjusted up or down in 5% steps.

Figure 4-62 shows the available reporting selections and the ratings selections on the Branches tab.

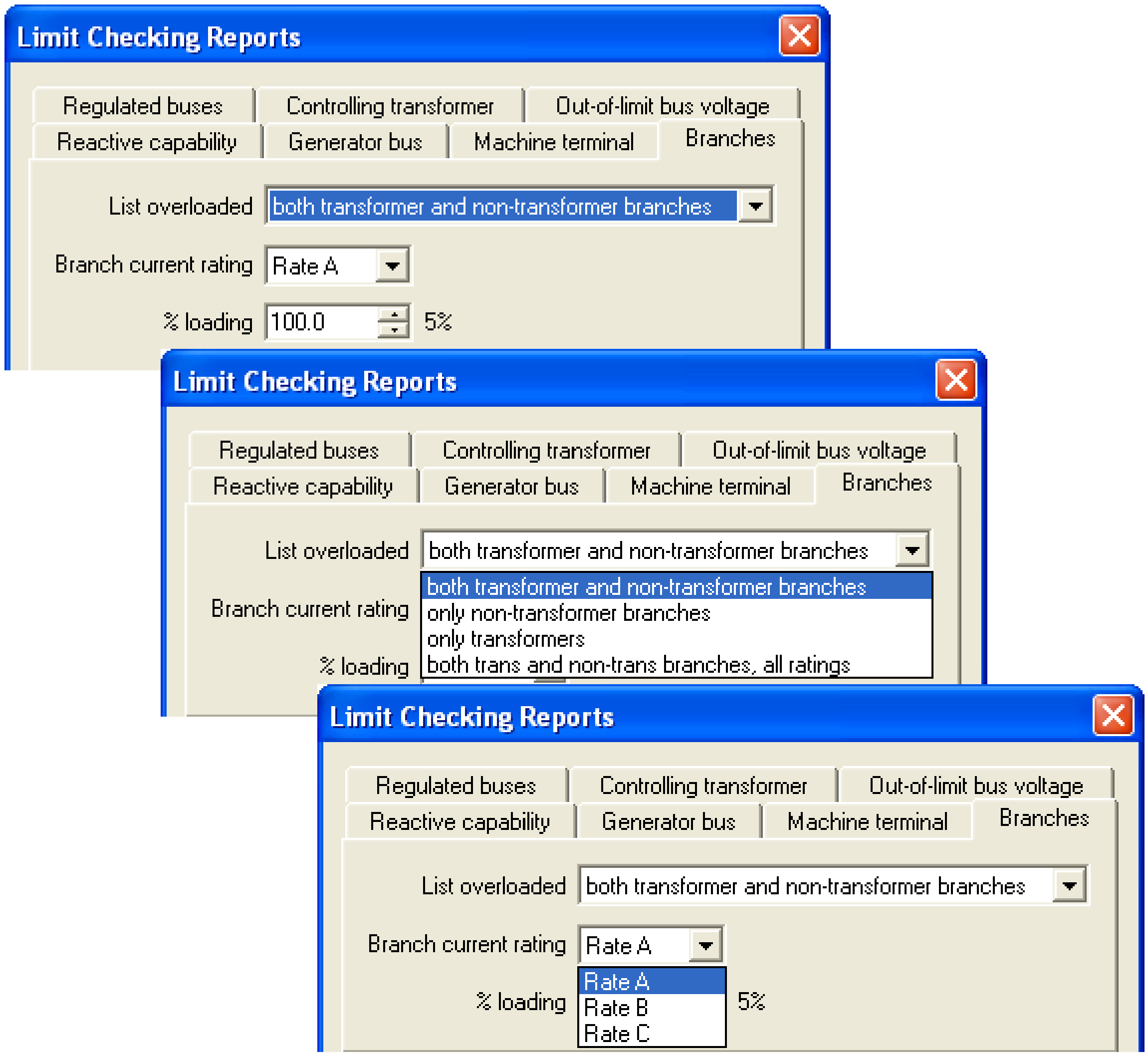


Figure 4-62. Selection of Branch Reports

4.4.5.1.1 Viewing Branch Overloads

When ***Branch currents*** is selected, each branch current loading is checked against designated branch ratings. Ratings are assumed to have been entered as:

$$MVA_{rated} = \sqrt{3} \times E_{base} \times I_{rated} \times 10^{-6}$$

where:

E_{base}	Is the base voltage in volts of the bus to which the terminal of the branch is connected.
I_{rated}	Is the rated phase current in amps.

Any checked branch whose *current* loading, including line charging, line connected shunt, and transformer magnetizing admittance components, exceeds the specified percentage of rating is reported. The default limit is 100%.

If the user specified a subsystem for reporting (for example, AREA, ZONE, etc.), the output is generated, with all branches having at least one endpoint bus in the specified subsystem being checked. It should be noted, however, that when subsystem selection is by OWNER, it is branch ownership rather than bus ownership which is used in determining which branches are contained in the specified subsystem. Any other selection criteria apply to the branch's endpoint buses.

Any branch whose corresponding rating is zero is not checked for overloading. Any branch whose current loading exceeds the designated percentage of rating is alarmed. The current is calculated at each end of the line and the number of the bus at which the current is higher is followed by an asterisk ("∗"). The branch current loading, rating, and percentage loading are tabulated.

For three-winding transformers, each winding is checked and reported separately. Only those windings connected to buses in the specified subsystems are processed. For each winding reported, the bus to which the winding is connected is shown as the "*from bus*", and the winding number and transformer name are listed as the "*to bus*".

The process of generating the report can be terminated with the AB interrupt control code.

Figure 4-63 shows a sample output from the *savnw.sav* case with a branch overload check performed on the basis of 80% of RATE A

The overload report lists branches in single entry list format ordered by "*from bus*". It can be seen that branches are also listed by AREA so that all branches overloaded in AREA 1 are listed first followed by branches in AREA 2 and AREA 5. Branches would also be listed by circuit number if appropriate.

In the table, the right most column shows the percentage loading on 100% of the RATE A level. Only one branch loading exceeds the 100% limit; the 230/18 kV transformer branch from Bus 205 to Bus 206. Four other branches are listed which have loadings less than 100% of RATE A but have loadings exceeding 80%.

```
     PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E      FRI, NOV 28 2003  12:28
PSS/E PROGRAM APPLICATION GUIDE EXAMPLE
BASE CASE INCLUDING SEQUENCE DATA

BRANCH LOADINGS ABOVE  80.0 % OF RATING SET A:

X--------- FROM BUS ----------X X---------- TO BUS -----------X       CURRENT(MVA)
  BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
   153 MID230      230.00    1     154 DOWNTN      230.00*    1  1    276.0   300.0    92.0
   202 EAST500     500.00*   2     203 EAST230     230.00     2  1    648.0   800.0    81.0
   204 SUB500      500.00    2     205 SUB230      230.00*    2  1    641.8   800.0    80.2
   205 SUB230      230.00    2     206 URBGEN      18.000*    2  1    976.9   900.0   108.5
  3008 CATDOG      230.00*   5    3018 CATDOG_G    13.800     5  1    125.3   150.0    83.6
```

Figure 4-63. Output Format for Branch Overloads Based on 80% of Rate A

4.4.5.1.2 Viewing Transformer Overloads

When ***Transformer MVA loadings*** is selected, each transformer branch MVA loading is checked against the designated branch ratings. Ratings are assumed to have been entered as MVA ratings. Any checked transformer branch whose MVA loading, including magnetizing admittance, exceeds the specified percentage of rating is reported.

If the user specified a subsystem for reporting (for example, AREA, ZONE, etc.), the output is generated with all transformer branches having at least one endpoint bus in the specified subsystem being checked. It should be noted, however, that when subsystem selection is by OWNER, it is transformer branch ownership rather than bus ownership which is used in determining which transformer branches are contained in the specified subsystem. Any other selection criteria apply to the branch's endpoint buses.

Any transformer whose corresponding rating is zero is not checked for overloading. Any transformer branch whose MVA loading exceeds the designated percentage of rating is alarmed. The loading is calculated at each end of the line and the number of the bus at which the loading is higher is followed by an asterisk ("*"). The branch MVA loading, rating, and percentage loading are tabulated.

For three-winding transformers, each winding is checked and reported separately. Only those windings connected to buses in the specified subsystem are processed. For each winding reported, the bus to which the winding is connected is shown as the "*from bus*", and the winding number and transformer name are listed as the "*to bus*".

The process of generating the report can be terminated with the AB interrupt control code.

Figure 4-64 shows a sample output from the *savnw.sav* case with the transformer overload check performed on the basis of 80% of RATE A.

The overload report lists transformer branches in single entry list format ordered by "*from bus*". Transformers are also listed by AREA so that all transformers overloaded in AREA 1 are listed first followed by transformers in AREA 2 and AREA 5. Transformers would also be listed by circuit number if appropriate. This report shows overloads only in AREAS 2 and 5.

In the table, the right most column shows the percentage loading on 100% of the RATE A level. Only one transformer loading exceeds the 100% limit. It is the 230/18 kV transformer branch from Bus 205 to Bus 206.

Two other branches are listed which have loadings less than 100% of RATE A but have loadings exceeding 80%.

```
     PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E      FRI, NOV 28 2003  12:42
PSS/E PROGRAM APPLICATION GUIDE EXAMPLE
BASE CASE INCLUDING SEQUENCE DATA

TRANSFORMER LOADINGS ABOVE  80.0 % OF RATING SET A:

X--------- FROM BUS ----------X X---------- TO BUS -----------X        MVA      MVA
  BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
   202 EAST500      500.00*    2    203 EAST230      230.00     2  1    653.7   800.0    81.7
   205 SUB230       230.00     2    206 URBGEN       18.000*    2  1   1000.0   900.0   111.1
  3008 CATDOG       230.00     5   3018 CATDOG_G     13.800*    5  1    128.1   150.0    85.4
```

Figure 4-64. Report on Transformer Overloads Based on 80% of RATE A

4.4.5.1.3 Viewing Transmission Line Overloads

When ***Transmission line currents*** is selected, the same report as for Branch Overloads is output (see Section 4.4.5.1.1) except that transformer branches are omitted from the overload checking.

Each non-transformer branch current loading is checked against designated branch ratings. Ratings are assumed to have been entered as:

$$MVA_{rated} = \sqrt{3} \times E_{base} \times I_{rated} \times 10^{-6}$$

where:

E_{base}	Is the base voltage in volts of the bus to which the terminal of the branch is connected.
I_{rated}	Is the rated phase current in amps.

Any checked branch whose *current* loading, including line charging and line connected shunt components, exceeds the specified percentage of rating is reported.

If the user specified a subsystem for reporting (for example, AREA, ZONE, etc.), the output is generated with all non-transformer branches having at least one endpoint bus in the specified subsystem being checked. It should be noted, however, that when subsystem selection is by OWNER, it is branch ownership rather than bus ownership which is used in determining which branches are contained in the specified subsystem. Any other selection criteria apply to the branch's endpoint buses.

Any branch whose corresponding rating is zero is not checked for overloading. Any non transformer branch whose current loading exceeds the designated percentage of rating is alarmed. The current is calculated at each end of the line and the number of the bus at which the current is higher is followed by an asterisk ("*"). The branch current loading, rating, and percentage loading are tabulated.

The process of generating the report can be terminated with the AB interrupt control code.

Figure 4-65 shows a sample output from the *savnw.sav* case with the transmission line (non-transformer branch) overload check performed on the basis of 75% of RATE A.

The overload report lists branches in single entry list format ordered by "*from bus*". As for Branch and Transformer overloads, branches are also listed by AREA so that all branches overloaded in AREA 1 are listed first followed by branches in AREA 2 and AREA 5. Branches would also be listed by circuit number if appropriate. This report shows overloads only in AREA 1.

In the table, the right most column shows the percentage loading on 100% of the RATE A level. It can be seen that no transmission lines have a loading in excess of 100% of RATE A. Three transmission lines are shown to have loadings in excess of 75% of RATE A. One line from Bus 153 to Bus 154 has two circuits listed in order of circuit number.

```
     PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E      FRI, NOV 28 2003  12:42
PSS/E PROGRAM APPLICATION GUIDE EXAMPLE
BASE CASE INCLUDING SEQUENCE DATA

TRANSMISSION LINE LOADINGS ABOVE  75.0 % OF RATING SET A:

X--------- FROM BUS ----------X X---------- TO BUS -----------X       CURRENT(MVA)
  BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
   153 MID230      230.00     1    154 DOWNTN      230.00*    1  1     276.0   300.0    92.0
   153 MID230      230.00     1    154 DOWNTN      230.00*    1  2     231.0   300.0    77.0
   154 DOWNTN      230.00*    1    205 SUB230      230.00     2  1     462.6   600.0    77.1
```

Figure 4-65. Report on Transmission Line Overloads

4.4.5.1.4 Viewing All Branch Current Ratings

Section 4.4.5.1.1 describes the method by which each branch current loading is checked against designated branch ratings. There the Branch Overloads are reported based on a selected Ratings set: RATE A, RATE B or RATE C.

When the ***Branch currents, all ratings*** report is selected, branch loadings are reported for all of the Rating sets, A, B and C.

Ratings are assumed to have been entered as:

$$MVA_{rated} = \sqrt{3} \times E_{base} \times I_{rated} \times 10^{-6}$$

where:

E_{base}	Is the base voltage in volts of the bus to which the terminal of the branch is connected.
I_{rated}	Is the rated phase current in amps.

Any checked branch whose current loading, including line charging, line connected shunt, and transformer magnetizing admittance components, exceeds the specified percentage of rating is reported.

If the user specified a subsystem for reporting (for example, AREA, ZONE, etc.), the output is generated with all branches having at least one endpoint bus in the specified subsystem being checked. It should be noted, however, that when subsystem selection is by OWNER, it is branch ownership rather than bus ownership which is used in determining which branches are contained in the specified subsystem. Any other selection criteria apply to the branch's endpoint buses.

Any branch whose corresponding rating is zero is not checked for overloading. Any branch whose current loading exceeds the designated percentage of rating is alarmed. The current is calculated at each end of the line and the number of the bus at which the current is higher is followed by an asterisk ("*").

The branch current loading, rating, and percentage loading are tabulated for each Rating Set.

Figure 4-66 shows a subset of the report for the *savnw.sav* power flow case. It demonstrates the manner in which the branches are listed in bus number, circuit and Area sequence.

The report shows only one branch is overloaded. It is the 230/18 kV transformer branch from Bus 205 to Bus 206 the loading of which is 108.5% of the RATE A level.

Note that a value for RATE C has been entered with a fictitious value of 1.0 MVA for most branches. The table therefore shows very high percentage loadings for that RATE.

PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E FRI, NOV 28 2003 12:45
PSS/E PROGRAM APPLICATION GUIDE EXAMPLE
BASE CASE INCLUDING SEQUENCE DATA

BRANCH LOADINGS ABOVE 100.0 % OF RATING:

X--------- FROM BUS	----------X			X--------- TO BUS	----------X				CURRENT (MVA)	RATING SET A		RATING SET B		RATING SET C	
BUS#	X-- NAME --X	BASKV	AREA	BUS#	X-- NAME --X	BASKV	AREA	CKT	LOADING	RATING	PERCENT	RATING	PERCENT	RATING	PERCENT
151	NUCPANT	500.00*	1	152	MID500	500.00	1	1	489.5	1200.0	40.8	1300.0	37.7	1.0	48948.1
151	NUCPANT	500.00*	1	152	MID500	500.00	1	2	489.5	1200.0	40.8	1300.0	37.7	1.0	48948.1
151	NUCPANT	500.00*	1	201	HYDRO	500.00	2	1	616.5	1200.0	51.4	1300.0	47.4	1.0	61647.2
152	MID500	500.00	1	202	EAST500	500.00*	2	1	134.2	1200.0	11.2	1300.0	10.3	1.0	13415.0
152	MID500	500.00*	1	3004	WEST	500.00	5	1	192.2	--	--	--	--	1.0	19223.4
153	MID230	230.00	1	154	DOWNTN	230.00*	1	1	276.0	300.0	92.0	350.0	78.9	1.0	27604.0
153	MID230	230.00	1	154	DOWNTN	230.00*	1	2	231.0	300.0	77.0	350.0	66.0	1.0	23096.7
153	MID230	230.00*	1	3006	UPTOWN	230.00	5	1	80.9	--	--	--	--	1.0	8088.9
154	DOWNTN	230.00*	1	203	EAST230	230.00	2	1	142.4	200.0	71.2	250.0	57.0	1.0	14244.1
154	DOWNTN	230.00*	1	205	SUB230	230.00	2	1	462.6	600.0	77.1	660.0	70.1	1.0	46264.6
154	DOWNTN	230.00*	1	3008	CATDOG	230.00	5	1	119.4	400.0	29.8	440.0	27.1	1.0	11938.8
201	HYDRO	500.00	2	202	EAST500	500.00*	2	1	564.4	1200.0	47.0	1300.0	43.4	1.0	56442.6
201	HYDRO	500.00	2	204	SUB500	500.00*	2	1	641.8	1200.0	53.5	1300.0	49.4	1.0	64175.1
203	EAST230	230.00	2	205	SUB230	230.00*	2	1	93.2	200.0	46.6	250.0	37.3	1.0	9320.5
203	EAST230	230.00	2	205	SUB230	230.00*	2	2	93.2	200.0	46.6	250.0	37.3	1.0	9320.5
205	SUB230	230.00	2	206	URBGEN	18.000*	2	1	976.9	900.0	108.5	1080.0	90.5	1350.0	72.4

Figure 4-66. Report for Branch Loadings, All Ratings

4.4.5.2 Viewing Out-of-limit Bus Voltages

Clicking the ***Out-of-limit bus voltage*** tab in the Limit Checking Reports dialog, will facilitate generation of a report which tabulates those buses whose voltage magnitude is outside a specified range (see Figure 4-67).

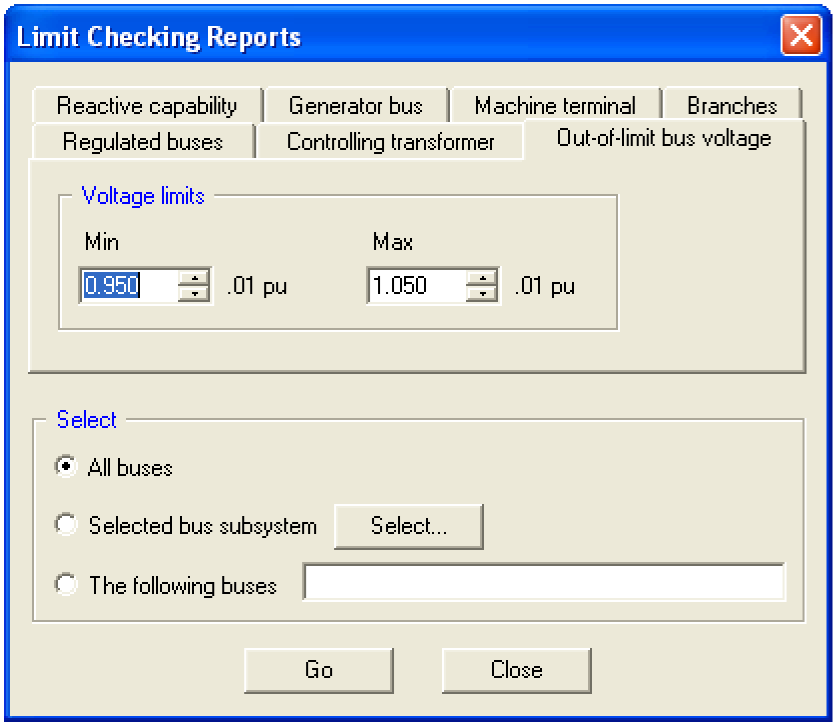


Figure 4-67. Limit Checking Reports Dialog: Out-of-limit Bus Voltage Tab

The voltage band is specified by selection of the Min and Max levels in pu. In Figure 4-67, the range is from 0.95 pu to 1.05 pu (the default level). Both limits can be adjusted in 0.01 pu increments in either direction. The Select facility is available for customizing the report to a particular subsystem.

The report generated by clicking the ***Go*** button produces a listing of those buses whose voltage magnitude is greater than VMAX, followed by a listing of buses whose voltage is less than VMIN. Both listings are in ascending numerical (under the "numbers" output option) or alphabetical (under the "names" output option) order. All buses except those whose type code is four are checked. The "star point" buses of three-winding transformers are neither checked nor reported.

The process of generating the report may be terminated with the AB interrupt control code.

Figure 4-68 shows the report generated for the *savnw.sav* case using a voltage range from 0.97 pu to 1.01 pu. It can be seen that the bus base voltage is listed together with the actual bus voltages in pu and kV. There are 13 buses with voltages greater than 1.01 pu and 5 buses with voltages less than 0.97 pu.

```
     PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E      FRI, NOV 28 2003  14:59
PSS/E PROGRAM APPLICATION GUIDE EXAMPLE
BASE CASE INCLUDING SEQUENCE DATA

BUSES WITH VOLTAGE GREATER THAN 1.0100:

  BUS# X-- NAME --X BASKV AREA  V(PU)  V(KV)      BUS# X-- NAME --X BASKV AREA  V(PU)  V(KV)
   101 NUC-A       21.600    1 1.0200 22.032       102 NUC-B       21.600    1 1.0200 22.032
   151 NUCPANT     500.00    1 1.0119 505.95       152 MID500      500.00    1 1.0171 508.54
   201 HYDRO       500.00    2 1.0400 520.00       206 URBGEN      18.000    2 1.0236 18.425
   211 HYDRO_G     20.000    2 1.0404 20.809      3001 MINE        230.00    5 1.0298 236.85
  3002 E. MINE     500.00    5 1.0279 513.96      3003 S. MINE     230.00    5 1.0233 235.36
  3004 WEST        500.00    5 1.0165 508.23      3011 MINE_G      13.800    5 1.0400 14.352
  3018 CATDOG_G    13.800    5 1.0218 14.100


BUSES WITH VOLTAGE LESS THAN 0.9700:

  BUS# X-- NAME --X BASKV AREA  V(PU)  V(KV)      BUS# X-- NAME --X BASKV AREA  V(PU)  V(KV)
   154 DOWNTN      230.00    1 0.9389 215.95       203 EAST230     230.00    2 0.9665 222.30
   205 SUB230      230.00    2 0.9490 218.27      3007 RURAL       230.00    5 0.9637 221.65
  3008 CATDOG      230.00    5 0.9586 220.48
```

Figure 4-68. Report for Voltages Out-of-limit

4.4.5.3 Viewing Reactive Capability

Clicking the ***Reactive capability*** tab in the Limit Checking Reports dialog, will facilitate generation of a report which tabulates machine loading and limit data. There is an option available to update the machine reactive power limits in the power flow case (see Figure 4-69).

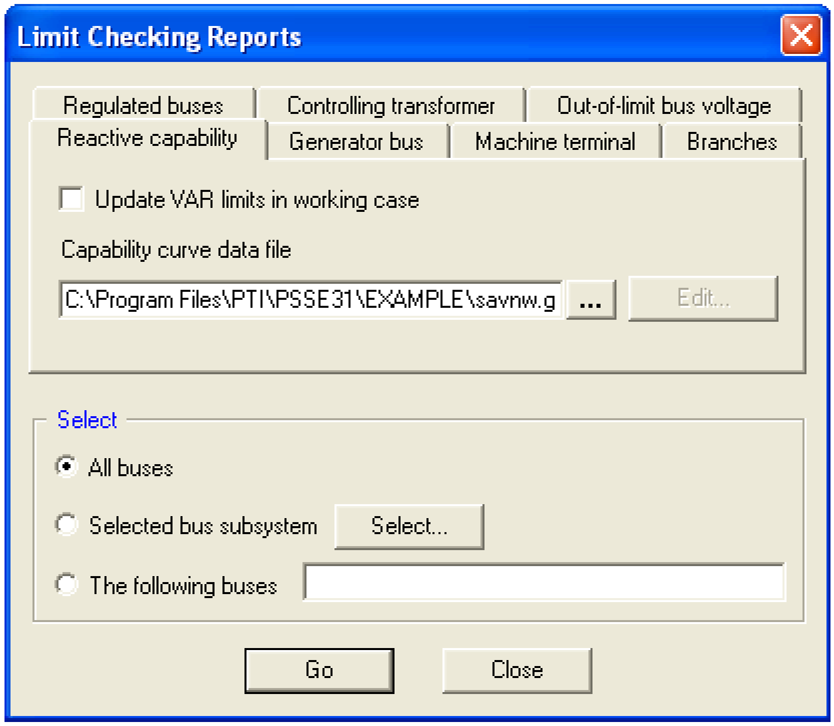


Figure 4-69. Limit Checking Reports Dialog: Reactive Capability Tab

As shown, there is a facility for specifying a Machine Capability Curve Data File and an option for updating Var limits in the power flow. The Select facility is also available for customizing the report to a particular subsystem.

4.4.5.3.1 Machine Capability Curve Data File

Any machine to be checked must have its capability curve specified in a Machine Capability Curve Data File. Each data record in this file has the following format:

```
I, ID, P1, QT1, QB1, P2, QT2, QB2, ... P10, QT10, QB10
```

where:

I	Bus number. Bus I must reside in the working case with a generator table entry assigned to it. No default is allowed.
ID	One- or two character machine identifier used to distinguish among multiple machines at a plant (i.e., at a generator bus). ID = ’1’ by default.
P_i	Generator active power output along the "MW" axis of the machine’s capability curve, entered in MW; no default allowed.

QT_i	Maximum (i.e., overexcited) reactive power limit at P_i MW, entered in Mvar. QT_i = 0.0 by default.
QB_i	Minimum (i.e., underexcited) reactive power limit at P_i MW, entered in Mvar. QB_i = 0.0 by default.

Up to 10 sets of points on the capability curve may be entered. When the machine is a generator, the P_i values must be in ascending order with P_1 greater than or equal to zero. When the machine is a motor, the P_i values must be in descending order with P_1 less than or equal to zero.

If P_1 is nonzero, an additional point is assumed at P = 0.0 with its QT and QB set equal to QT_1 and QB_1, respectively.

Data input is terminated with a record specifying a bus number of zero.

In the PSS™E EXAMPLE directory, there is an example capability curve established for the machines in the *savnw.sav* power flow case. The data file is *savnw.gcp*, and the contents of the file are listed in Figure 4-70. A generic plot of the reactive limits for the machine at bus 206 is shown.

I	ID	P1	QT1	QB1	P2	QT2	QB2	P3	QT3	QB3
101	1	0	800	-100	500	650	-100	900	0	0
102	1	0	800	-100	500	650	-100	900	0	0
206	1	100	600	0	500	400	0	1000	0	0
211	1	0	800	-100	500	750	-100	950	0	0
3011	1	100	200	-100	1000	600	-100			
3018	1	130	80	0						
0										

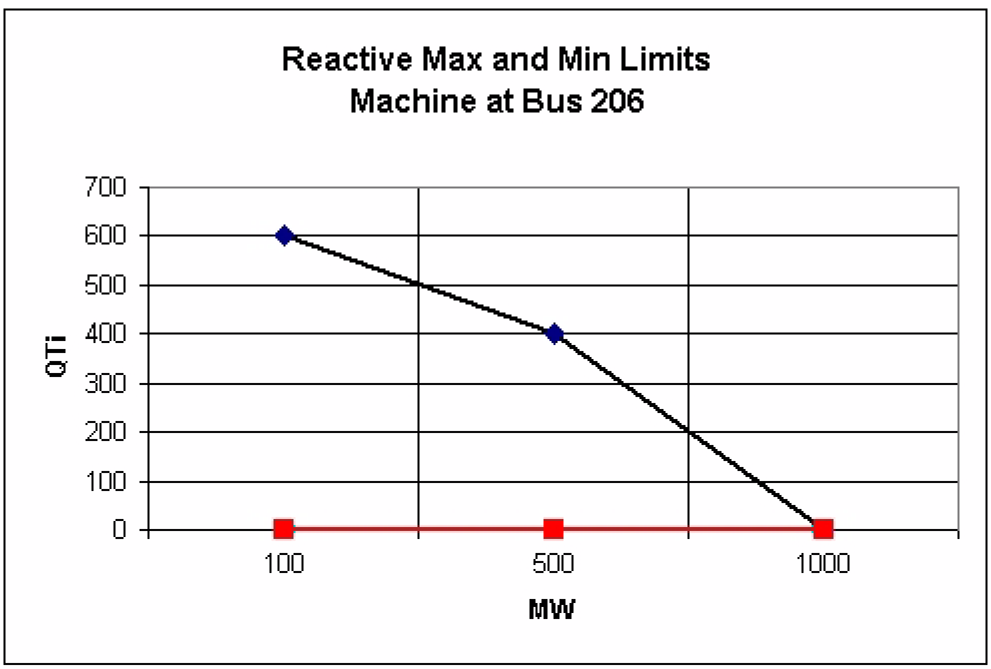


Figure 4-70. Capability Curve Example for savnw.sav Case

The report generated can be limited by employing the ***Select*** facility to include only machines in specific areas, owners, zones, base kV or at specific buses.

If selection is by OWNER, each machine wholly or partly owned by any of the owners specified and for which a data record was successfully read is processed. The owner assignment of the bus to which the machine is connected is not considered.

The report lists the following quantities:

1. Machine active and reactive power loading from the power flow case.
2. The Mvar limit settings on the capability curve corresponding to the machine's active power loading from (1).
3. The maximum active power loading from the capability curve (i.e., P_i from the last point entered for this machine).
4. The active and reactive power limits as contained in the working case.

If the machines' reactive power output in (1) is beyond the limits shown in (2), it is followed by an asterisk ("∗").

If the ***Update VAR limits in working case*** option is enabled, the update takes place after all reporting is complete or after interruption of the process via the AB interrupt control code for all machines that were reported.

It is important to note that the updating of reactive power limits is not reversible. It is recommended that, prior to generating the report with the option to update var limits enabled, the working file be preserved in a Saved Case File and that the new reactive power limit data be examined before permanently overwriting the original data.

Figure 4-71 shows the report generated for the *savnw.sav* working file. It clearly indicates that the machine at bus 206 has a reactive power output of 600 MW and a real power output of 800 MW. Based on its capability curve, the reactive power limit should be 160 Mvar based on the real power output of 800 MW. This is much less than the assumed limit of 600 Mvar. Examination of the capability curve plotted in Figure 4-70 confirms a reactive power limit of 160 Mvar with 800 MW generated.

```
     PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E      MON, DEC 01 2003   8:21
PSS/E PROGRAM APPLICATION GUIDE EXAMPLE
BASE CASE INCLUDING SEQUENCE DATA

CAPABILITY CURVE CHECK:
                                             X-- CAPABILITY CURVE --X X------- WORKING  CASE -------X
  BUS# X-- NAME --X BASKV ID    PGEN    QGEN     QMAX    QMIN  PLIMIT    QMAX    QMIN    PMAX    PMIN
   101 NUC-A       21.600 1    750.0    81.2    243.8   -37.5   900.0   600.0  -100.0   810.0     0.0
   102 NUC-B       21.600 1    750.0    81.2    243.8   -37.5   900.0   600.0  -100.0   810.0     0.0
   206 URBGEN      18.000 1    800.0   600.0*   160.0     0.0  1000.0   600.0     0.0   900.0     0.0
   211 HYDRO_G     20.000 1    600.0    17.7    583.3   -77.8   950.0   400.0  -100.0   616.2     0.0
  3011 MINE_G      13.800 1    258.7   104.0    270.5  -100.0  1000.0   600.0  -100.0   900.0     0.0
  3018 CATDOG_G    13.800 1    100.0    80.0     80.0     0.0   130.0    80.0     0.0   117.0     0.0
```

Figure 4-71. Report Output for Reactive Power Checking with Capability Curve

4.4.5.4 Viewing Generator Bus Limits

Clicking the ***Generator bus*** tab in the Limit Checking Reports dialog, will facilitate generation of a report which tabulates the loading and voltage conditions at generator buses (see Figure 4-72).

From the Generator bus tab, the following reports can be selected:

- VAR limited plants with unequal VAR limits
- All VAR limited plants
- On-line plants
- All plants

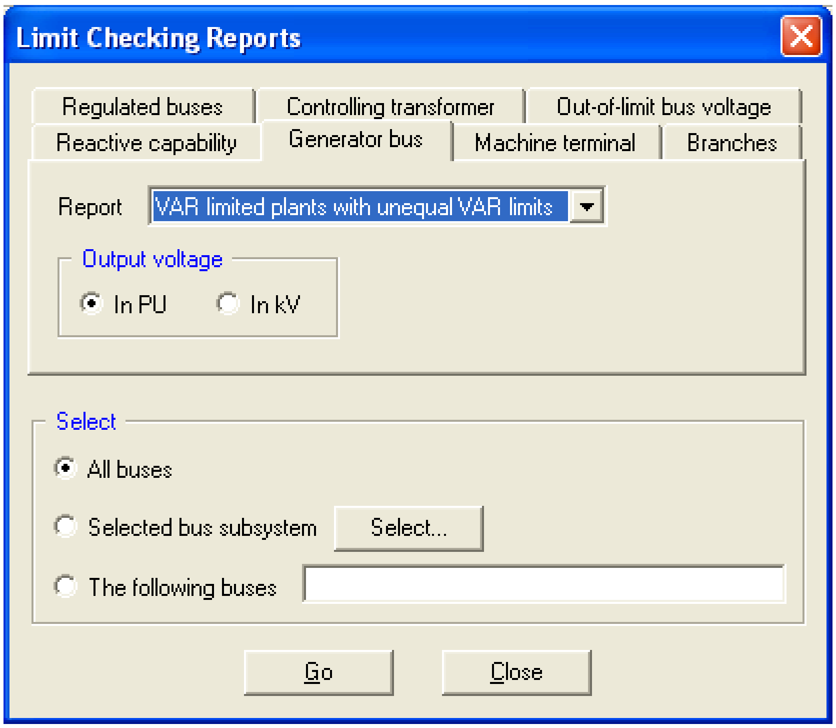


Figure 4-72. Limit Checking Reports Dialog: Generator Bus Tab

The **Output with voltage reversed** option allows the user to change the option to tabulate the results with voltage shown in pu or kV, depending on what the program option setting is (Section 1.6.4).

The report generated can be limited by the Select facility to include only machines in specific areas, owners, zones, base kV or at specific buses.

The report includes the bus number, name, base voltage, and type code, along with the number of machines modeled at the plant whose status flags are one, the number of machines whose status flags are zero, the total plant power outputs and reactive power limits, and scheduled and actual voltages.

If a plant regulates the voltage of a remote bus, the remote bus identifiers are printed and the actual voltage printed is that at the remote bus; if a plant regulates its own terminal voltage, the remote bus fields are blank. Total plant MBASE of machines at the bus whose status flags are one, along with the numbers of the zone and area in which the bus resides, are also printed.

Any plant that is either a system or area swing is identified with an appropriate tag at the end of the output line.

As the last line of each report, subsystem totals of plant power outputs, var limits, and MBASE are tabulated.

The generation of the report may be terminated by entering the AB interrupt control code.

Figure 4-73 shows a report for "All plants" from the *savnw.sav* working file.

From the report it can be seen that:

- Generators at buses 206, 211 and 3018 are regulating voltage at remote buses.
- Generator at buses 206 and 3018 are failing to meet scheduled voltages (VSCHED) at their remote buses. Their actual voltages (VACTUAL) at the remote buses are below scheduled because the machines have reached maximum reactive power limits. Under the TYP column, the machines at buses 206 and 3018 are indicated to be "-2"; the negative sign indicates that the machines are at a reactive power limit.
- The system swing bus is 3011 while the swing buses for Areas 1 and 2 are Buses 101 and 206 respectively.

```
PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E      MON, DEC 01 2003   9:16
PSS/E PROGRAM APPLICATION GUIDE EXAMPLE
BASE CASE INCLUDING SEQUENCE DATA
GENERATOR SUMMARY:
                          # MACH                                                                    X----- REMOTE BUS ------X
  BUS# X-- NAME --X BASKV ON/OFF TYP    MW     MVAR    QMAX    QMIN   VSCHED VACTUAL   BUS# X-- NAME --X BASKV  MVABASE ZONE AREA SWING
   101 NUC-A        21.600  1  0   2   750.0    81.2   600.0  -100.0  1.0200  1.0200                              900.0   77    1  AREA
   102 NUC-B        21.600  1  0   2   750.0    81.2   600.0  -100.0  1.0200  1.0200                              900.0   77    1
   206 URBGEN       18.000  1  0  -2   800.0   600.0   600.0     0.0  0.9800  0.9490    205 SUB230       230.00  1000.0    2    2  AREA
   211 HYDRO_G      20.000  1  0   2   600.0    17.7   400.0  -100.0  1.0400  1.0400    201 HYDRO        500.00   725.0    2    2
  3011 MINE_G       13.800  1  0   3   258.7   104.0   600.0  -100.0  1.0400  1.0400                             1000.0    5    5  SYST
  3018 CATDOG_G     13.800  1  0  -2   100.0    80.0    80.0     0.0  1.0200  0.9586   3008 CATDOG       230.00   130.0    5    5
SUBSYSTEM TOTALS                      3258.7   964.2  2880.0  -400.0                                             4655.0
```

Figure 4-73. Generator Bus Report

4.4.5.5 Viewing Machine Terminal Limits

Clicking the ***Machine terminal*** tab in the Limit Checking Reports dialog will facilitate generation of a report which tabulates machine loading and voltage conditions at the generator terminals of on-line machines at type two and three buses in the working case.

The user can select to report on all on-line machines or only those which are overloaded (see Figure 4-74).

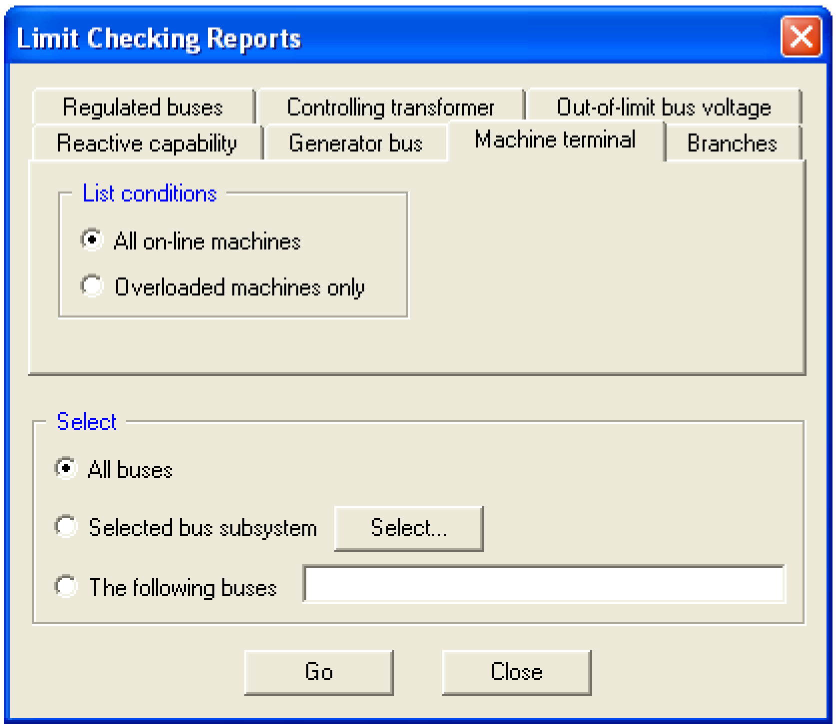


Figure 4-74. Limit Checking Reports Dialog: Machine Terminal Report Tab

4.4.5.5.1 Calculating Machine Overloads

When the machine step-up transformer is represented explicitly as a network branch, and hence the type two bus is the generator terminal bus, the overload check simply uses the boundary conditions at the bus in generating the report.

When the step-up transformer is modeled with the generator data (i.e., XTRAN is nonzero), the generator bus is the high side bus (refer to Section 3.2.4.1). In this case, the overload check calculates back through the step-up transformer impedance to determine the conditions that exist at the generator terminals.

The overload check assumes a machine capability curve as shown in Figure 4-75. The radius of the semicircle in the upper half plane, centered at the origin, is taken as:

$$\frac{MBASE}{E_t}$$

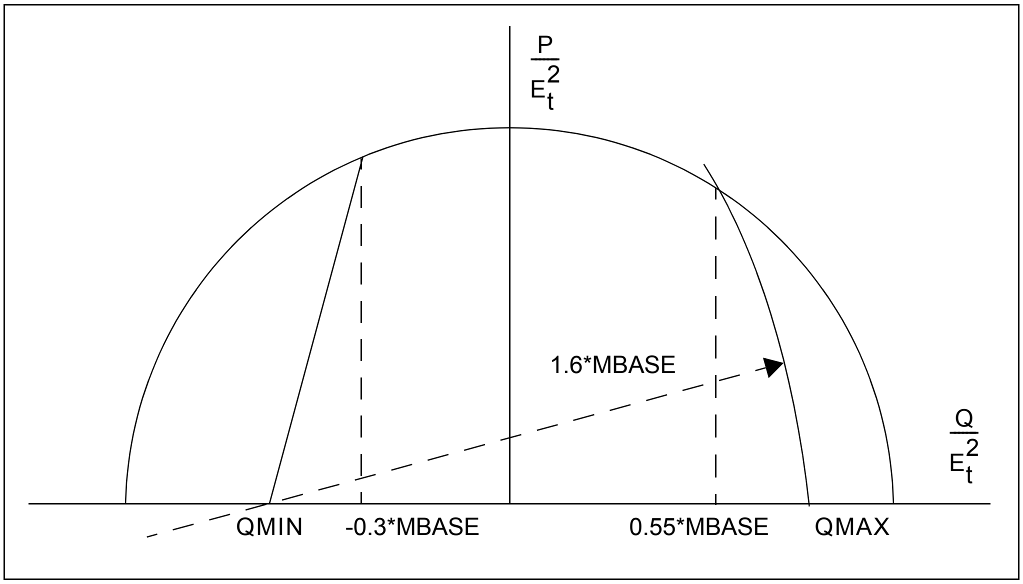


Figure 4-75. Assumed Capability Curve for Machine Overload Checking

When XTRAN is nonzero, the reactive power limits are modified to reflect these limits at the terminals by taking into account losses through the step-up transformer.

The assumed operating region in the capability curve of Figure 4-75 is bounded as follows:

1. On the bottom, by the "Q" axis.
2. On the top, by the semicircle in the upper half plane.
3. On the left, by the straight line connecting the point QMIN on the "Q" axis and the point on the upper half plane circle corresponding to an abscissa of -0.3∗MBASE. When QMIN is greater than -0.3∗MBASE, this bound is a line parallel to the "P" axis through the point QMIN on the "Q" axis.
4. On the right, by a circle of radius 1.6∗MBASE, with center at (0,Qmin) and passing through the point QMAX on the "Q" axis and the point on the upper half plane circle corresponding to an abscissa of 0.55∗MBASE. When QMAX is less than 0.55∗MBASE, this bound is a line parallel to the "P" axis through the point QMAX on the "Q" axis.

Any machine whose operating point is such that the quantity:

$$\frac{P_{gen} + jQ_{gen}}{(E_t)^2}$$

is outside this region is considered overloaded. Any machine absorbing active power is checked as if its active power is in the upper half plane.

For determining overloaded conditions, the value specified as MBASE for each machine must be the actual MVA base of the generator. The overload check is invalid for any machine for which the base is something other than this quantity, even if the base conversion has properly been taken into account in specifying ZSORCE and XTRAN.

When the **Overloaded machines only** option is enabled, only those machines considered overloaded under the criteria described above are reported. When the **All on-line machines** option is enabled (all machines in the case or only those within a specified subsystem), then those whose loading is outside the assumed capability curve have an asterisk ("*") printed following their current loading.

The report generated can be limited by the Select facility to include only machines in specific areas, owners, zones, base kV values or at specific buses.

If selection is by OWNER, each machine wholly or partly owned by any of the owners specified and for which a data record was successfully read is processed. The owner assignment of the bus to which the machine is connected is not considered.

Data presented includes the bus number, name, and base voltage, along with the machine identifier and the machine terminal conditions of power output, voltage, current, and power factor. Reactive power limits and the generator base, MBASE, are also printed, along with the step-up transformer impedance and off-nominal turns ratio if the transformer is represented as part of the generator model. The numbers of zone and area in which the bus resides are also printed, and machines at any plant which is either a system or area swing are identified with an appropriate tag at the end of the output line. Generators whose loading is outside the assumed capability curve have an asterisk ("∗") printed following their current loading.

As the last line of each report, subsystem totals of machine power outputs, reactive power limits, and MBASE are tabulated.

The generation of the report may be terminated by entering the "AB" interrupt control code.

Figure 4-76 shows the Machine Terminal report selected for "All on-line machines" in the *savnw.sav* power flow case.

It can be seen that machines at buses 206 and 3018 are overloaded based on the calculations conforming to the assumed capability curve in Figure 4-75.

It should be noted that the terminal voltages for those two machines, and the machine at bus 211, are higher than their scheduled voltages (VSCHED) because these machines are attempting to control voltage at remote buses rather than at the machine terminals. The Generator Bus report shows the scheduled voltages and the remote buses (see Figure 4-73).

```
PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E      MON, DEC 01 2003  10:08
PSS/E PROGRAM APPLICATION GUIDE EXAMPLE
BASE CASE INCLUDING SEQUENCE DATA

MACHINE SUMMARY:
  BUS# X-- NAME --X BASKV ID     MW     MVAR    QMAX    QMIN  ETERM CURRENT    PF   MVABASE   X T R A N   GENTAP ZONE AREA SWING
   101 NUC-A        21.600 1    750.0    81.2   600.0  -100.0 1.0200   739.6  0.9942   900.0                       77    1  AREA
   102 NUC-B        21.600 1    750.0    81.2   600.0  -100.0 1.0200   739.6  0.9942   900.0                       77    1
   206 URBGEN       18.000 1    800.0   600.0   600.0     0.0 1.0236   976.9* 0.8000  1000.0                        2    2  AREA
   211 HYDRO_G      20.000 1    600.0    17.7   400.0  -100.0 1.0404   576.9  0.9996   725.0                        2    2
  3011 MINE_G       13.800 1    258.7   104.0   600.0  -100.0 1.0400   268.1  0.9278  1000.0                        5    5  SYST
  3018 CATDOG_G     13.800 1    100.0    80.0    80.0     0.0 1.0218   125.3* 0.7809   130.0                        5    5
SUBSYSTEM TOTALS              3258.7   964.2  2880.0  -400.0                          4655.0
```

Figure 4-76. Report Tabulation for Machine Terminal Conditions in savnw.sav File

4.4.5.6 Viewing Voltage Controlled Buses

In large databases it is important to have the ability to easily identify which bus voltages are being regulated and which equipment is controlling the regulation. This helps to avoid situations in which there are potential regulation conflicts.

Clicking the ***Regulated buses*** tab in the Limit Checking Reports dialog will facilitate generation of a report which tabulates those buses whose voltages are controlled by generation, switched shunts, voltage controlling transformers, FACTS devices, and/or VSC DC line converters (see Figure 4-77).

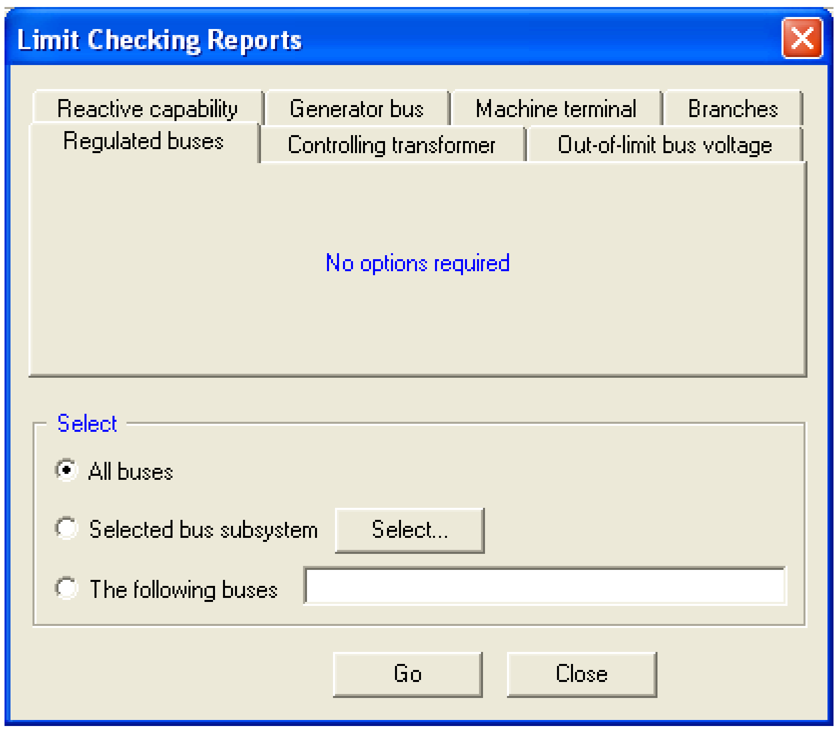


Figure 4-77. Limit Checking Reports Dialog: Regulated Buses Report Tab

Only in-service voltage controlled buses (i.e., buses whose type codes are less than four) are reported. The following lists the conditions under which the various voltage controlling equipment items are reported:

Generation	Bus type code is two or three, and at least one in-service machine is present.
Switched shunt	Bus type code is less than four and the control mode is 1 or 2.
Transformer	Branch is in-service and its adjustment control mode is set to +1.
FACTS device	Control mode is nonzero for sending bus end; control mode is one, five or seven for terminal bus end.
VSC DC converter	VSC DC line's control mode (MDC) is one, the VSC converter's AC control mode (MODE) is one, and the VSC converter's DC control code (TYPE) is not zero.

The report always displays voltage at the controlled bus. For any voltage controlling transformer whose load drop compensation impedance is nonzero, the controlled bus voltage (or, equivalently, the voltage limits) are compensated. Therefore, limits printed for such transformers are the compensated limits and the lower limit is preceded by an asterisk ("*"). Note that the calculation of these limits requires transformer current; hence, they are valid only if the report is generated from a solved system condition.

The generation of the report may be terminated by entering the AB interrupt control code.

The report generated can be limited by the Select facility to include only machines in specific areas, owners, zones, base kV or at specific buses.

Data presented includes the bus number, name, and base voltage of each regulated bus along with its present voltage magnitude. For each controlling equipment item, the desired voltage setpoint or voltage band, as appropriate, is listed along with any deviation between actual and scheduled voltages.

A Regulated Bus report from the *savnw.sav* power flow case is shown in Figure 4-78.

The report shows the following:

- Regulated buses 101, 102 and 3011 are generator terminal buses.
- Bus 154 is a type 1 bus whose voltage is regulated by the transformer in the branch from bus 152 to bus 153. Further the voltage control range of the transformer's tap changer is 0.98 to 1.0 pu but the controlled bus voltage is only 0.93892 pu. Consequently, a violation (or error) of -0.04108 pu is indicated.
- Bus 201 is a type 1 bus whose voltage is regulated by the remote generator at bus 211. The scheduled voltage of 1.04 pu has been met.
- Bus 205 is a type 1 bus whose voltage is regulated by the remote generator at bus 206 and the transformer tap changer in the transformer branch from the 500 kV bus 204 to the 230 kV bus 205. The generator is scheduled to control voltage at bus 205 to a level of 0.98 pu. The transformer tap changer has a voltage range between 0.98 pu and 1.0 pu and is controlling bus 205. The actual voltage on bus 205 is only 0.949 pu. Consequently, there is a violation indicated of 0.03098 pu.

```
PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E      MON, DEC 01 2003  12:27
PSS/E PROGRAM APPLICATION GUIDE EXAMPLE
BASE CASE INCLUDING SEQUENCE DATA

                            X--VOLTAGE--X X--SCHEDULED--X  X--VIOLATION--X
X---- REGULATED  BUS -----X   P.U.    KV      VOLTAGE        P.U.      KV   X------------------------ CONTROLLING  EQUIPMENT ------------X
   101 [NUC-A       21.600] 1.02000  22.0      1.02000                      LOCAL  GENERATION    101 [NUC-A     21.600]

   102 [NUC-B       21.600] 1.02000  22.0      1.02000                      LOCAL  GENERATION    102 [NUC-B     21.600]

   154 [DOWNTN     230.00] 0.93892 216.0 0.98000 1.00000 -0.04108    -9.45 XFRMER CKT 1  BUS     152 [MID500    500.00] TO 153 [MID230 230.00]

   201 [HYDRO      500.00] 1.04000 520.0      1.04000                      REMOTE GENERATION    211 [HYDRO_G  20.000]

   205 [SUB230     230.00] 0.94902 218.3      0.98000       -0.03098    -7.13 REMOTE GENERATION    206 [URBGEN    18.000]
                                           0.98000 1.00000 -0.03098    -7.13 XFRMER CKT 1  BUS     204 [SUB500    500.00] TO 205 [SUB230 230.00]

  3008 [CATDOG     230.00] 0.95861 220.5      1.02000       -0.06139   -14.12 REMOTE GENERATION   3018 [CATDOG_G 13.800]

  3011 [MINE_G      13.800] 1.04000  14.4      1.04000                      LOCAL  GENERATION   3011 [MINE_G    13.800]
```

Figure 4-78. Regulated Bus Report from the Savnw.sav Power Flow Case

4.4.5.7 Viewing Adjustable Transformers

Clicking the ***Controlling transformer*** tab in the Limit Checking Reports dialog will facilitate generation of a report which tabulates those transformers in the power flow case whose off-nominal turns ratio or phase-shift angle may be adjusted by the power flow solution activities (see Figure 4-79).

The user has the option of listing all adjustable transformers or of restricting the report to those whose controlled quantity is outside of its specified band. Further, the user can choose to reverse the voltage reporting from pu to kV, or vice versa, depending on the current program option setting (Section 1.6.4).

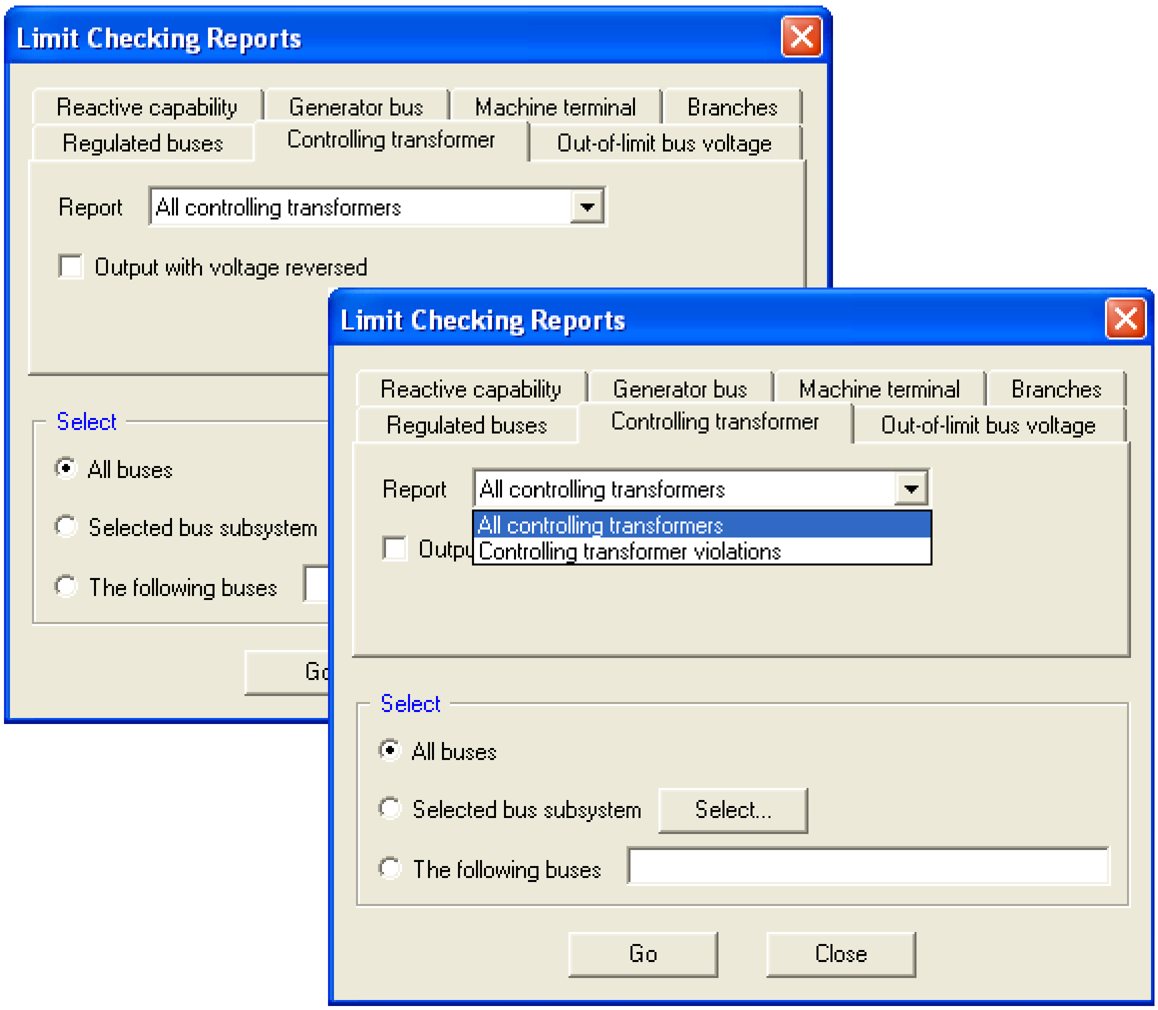


Figure 4-79. Limit Checking Reports Dialog: Controlling Transformer Tab

The report generated can be limited by the Select facility to include only transformers in specific areas, owners, zones, base kV or at specific buses. When subsystem selection by owner is in effect, branch ownership rather than bus ownership is used in determining which transformers are contained in the specified subsystem; any other selection criteria apply to the transformer's end-point buses.

Two-winding transformers are listed in the report with their winding one side bus first and with their winding two side bus as the "*to bus*". Three-winding transformer windings are listed in the report with their controlling winding side bus first and with their transformer name and winding number as the "*to bus*"; a three-winding transformer winding is processed if it is an adjustable winding and if the bus to which it is connected is in the specified subsystem.

Transformers are ordered in ascending numerical (under the "numbers" output option) or alphabetical (under the "names" option) order by controlling winding side bus, and, for each such bus, in ascending order by "*to bus*" field and circuit identifier.

The output report for each subsystem grouping is printed in up to four sections.

1. Those transformer windings whose tap ratio may be adjusted to control the voltage at a designated controlled bus are printed. The present controlled voltage and the desired voltage band are listed, along with the controlled bus, the tap ratio, the ratio limits, and the tap step. When the load drop compensating impedance is nonzero, the compensated voltage is printed preceded by an asterisk ("∗"); otherwise, the voltage at the controlled bus is reported.

2. A list of any transformer windings whose phase shift angle may be adjusted to control the active power flow through itself. The data tabulated for these includes the present active power flow through the phase shifter and the desired flow band, the phase shift angle, and the angle limits.

3. A list of any transformer windings whose ratio may be adjusted to control the reactive power flow through itself. The present reactive power flow and the desired flow band, the present tap ratio and its limits, and the tap step are tabulated.

4. A list of those two-winding transformers whose ratio may be adjusted to control the firing angle, extinction angle, or voltage of a DC line. Shown are the DC line number, type of quantity controlled, its present value and desired band, present tap ratio and its limits, and the tap step.

Any controlled quantity outside of its desired band is followed by the tag "HI" or "LO" as appropriate. Similarly, if the ratio or phase shift angle of a transformer is at or beyond one of its limits, the appropriate identifier is printed.

The generation of the report may be terminated by entering the AB interrupt control code.

See Figure 4-80 for an example of a Controlling Transformers report from the *savnw.sav* power flow case. Controlled buses at 154 and 205 show voltages below their transformers’ control range (indicated by "LO") and the Phase Shifting transformer controlling power flow shows a flow level above its control range (indicated by "HI").

```
PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E      MON, DEC 01 2003  13:59
PSS/E PROGRAM APPLICATION GUIDE EXAMPLE                            TRANSFORMER
BASE CASE INCLUDING SEQUENCE DATA                                    SUMMARY

                    ** TRANSFORMERS CONTROLLING VOLTAGE **

X--- ADJUSTABLE SIDE ---X X--------- TO ----------X                                X--- CONTROLLED BUS ----X
  BUS# X-- NAME --X BASKV   BUS# X-- NAME --X BASKV CKT     VOLT     MAX V   MIN V    BUS# X-- NAME --X BASKV   RATIO    MAX RAT MIN RAT NTAPOS
   152 MID500      500.00    153 MID230      230.00  1   0.93892LO 1.00000 0.98000    154 DOWNTN      230.00 1.01000   1.05000 0.95000     33
   204 SUB500      500.00    205 SUB230      230.00  1   0.94902LO 1.00000 0.98000    205 SUB230      230.00 1.00000   1.05000 0.95000     33

                   ** PHASE SHIFTERS CONTROLLING MW FLOW **

X--- ADJUSTABLE SIDE ---X X--------- TO ----------X
  BUS# X-- NAME --X BASKV   BUS# X-- NAME --X BASKV CKT     MW     MAX MW  MIN MW   ANGLE    MAX AN  MIN AN
   202 EAST500     500.00    203 EAST230     230.00  1    592.4HI   555.0   545.0    0.00     30.00  -30.00
```

Figure 4-80. Controlling Transformers Report for savnw.sav Power Flow Case

4.5 Modifying Load Characteristics

Normal practice in power flow work is to assume that distribution system tap changers and voltage regulators have brought customer voltages to nominal values and, hence, that load at the buses represented in the power flow case may be treated as a constant real and reactive power demand. It is generally recommended, therefore, that load is treated as constant MVA from one power flow case to the next.

This is particularly true of conventional planning studies where demand level is a given quantity which must be maintained under a variety of system normal and abnormal conditions. The Planners' job is to identify the lines and equipment required to sustain the defined demand levels; it is axiomatic that the demand level is a given (constant MVA).

In steady-state and quasi steady-state operation studies, it is reasonable to recognize the loads' dependence on voltage. Such studies include balanced switching (Chapter 8), short-circuit analysis (Chapter 7) and examination of potential voltage collapse or voltage instability. These are conditions under which voltage excursions can be significant.

Similarly, under dynamic conditions, which would be simulated with the PSS™E dynamic simulator, treating loads as purely constant MVA at the reference load value is not acceptable because time delays in distribution voltage-regulating devices prevent them from adjusting customer voltages in the period of interest. Further, loads have a frequency dependence. For dynamic studies, therefore, a variety of load models of varying complexity are available. These models recognize, in more detail, the specific characteristics of loads such as lighting, heating and motor loads. The PSS™E models available for dynamic simulations are discussed in detail in the *PSS™E Program Operation Manual*.

4.5.1 Basic Load Characteristics

The network solutions of PSS™E recognize load components with constant MVA, constant current, and constant admittance characteristics as discussed in Section 3.2.3.

The input functions of PSS™E (see Section 3.3) identify the load at each bus and allow the user to indicate the following components of each load.

PL	Real power, constant MVA load.
QL	Reactive power, constant MVA load.
IP	Real power, constant current load.
IQ	Reactive power, constant current load.
YP	Real power, constant admittance load.
YQ	Reactive power, constant admittance load.

All of these components are specified in MW and Mvar. The MW and Mvar values for the constant current and constant admittance components are the values that would be consumed by these loads when the bus voltage is unity per unit. The values of these components can be changed, using the editing facility in the Spreadsheet View or the load can be taken out of service by changing its status in the Spreadsheet View.

While it is possible to enter bus loads as combinations of constant MVA, constant current and constant admittance, it is preferable to enter the total load as constant MVA mainly because the majority of steady-state analysis will be performed at or close to nominal voltage and the total demand level is critical to the study at hand. It is a simple exercise to convert system loads from the constant MVA characteristic to either of the voltage dependent characteristics or a combination of all three depending on the type of analysis being carried out. It is equally simple to reconvert the loads to have their original characteristic or any other combination.

4.5.2 Converting Load Characteristics

The conversion process in PSS™E takes constant MVA load and reassigns it all or in part as constant current or constant admittance load. A fraction of the constant MVA load at each bus are transferred to each of the other two load characteristics, according to the following rules

$$S_I = S_i + \frac{aS_p}{v}$$

$$S_Y = S_y + \frac{bS_p}{v^2}$$

$$S_P = S_p \times (1 - a - b)$$

where:

S_p	=	Original constant MVA load.
S_i	=	Original constant current load.
S_y	=	Original constant shunt admittance load.
S_P	=	Final constant MVA load on bus (real, MW, or reactive, Mvar).
S_I	=	Final nominal constant current load on bus (real, MW, or reactive, Mvar).
S_Y	=	Final nominal constant shunt admittance load on bus (real or reactive).
a,b	=	Load transfer fractions, (a + b) < 1 (Real and reactive load may be allocated by different a and b values.)
v	=	Magnitude of bus voltage when load conversion is made.

The conversion and re-allocation process is diagrammed in Figure 4-81.

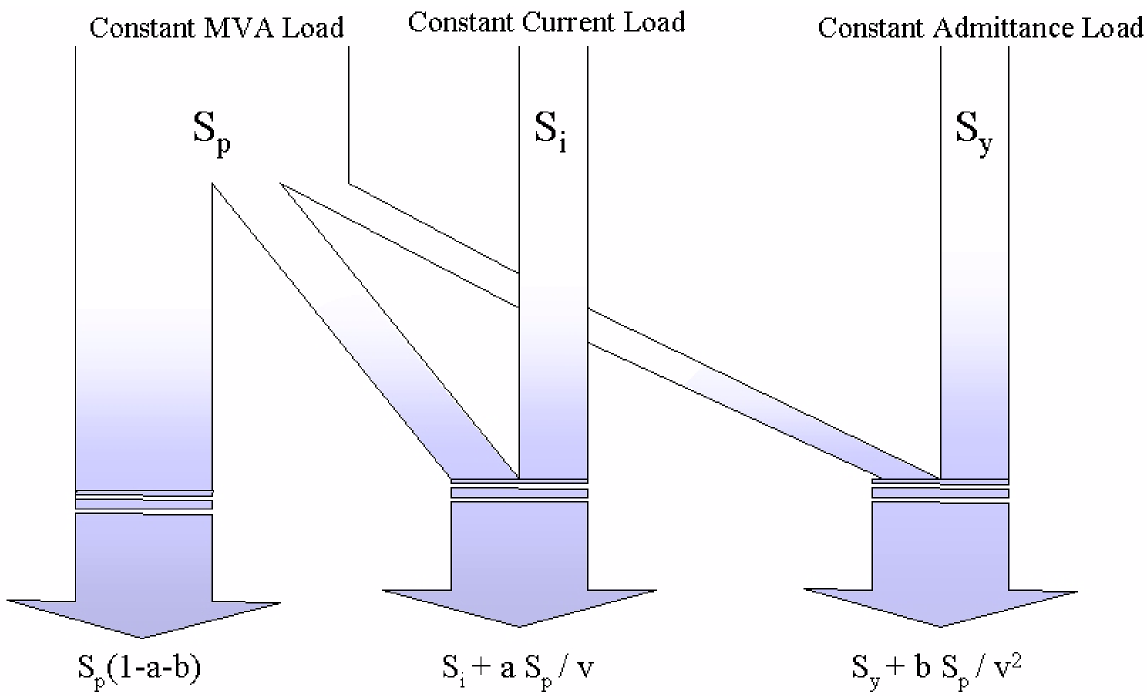


Figure 4-81. Re-allocation of Constant MVA Bus Load

It is useful to note the following points regarding the load conversions:

1. The conversion is performed only on the constant MVA load.
2. Load converted to constant current and constant admittance is added to any existing load represented by those characteristics.
3. The load is converted on the basis of the actual voltage at the network buses. Prior to conversion the working case should be solved to an acceptable mismatch level. Following conversion, the network is still in balance.
4. The split of load among the three characteristics may be different for the active and reactive components of load.
5. Admittance load is stored separately from the bus shunt.

Further, following conversion, only the new components are accessible for editing.

Load conversion is facilitated via the ***Power Flow>Convert Loads and Generators…*** option. This selection will display the Convert/Reconstruct Loads and Generators dialog where selections can be made on reallocations of constant MVA loads (see Figure 4-82).

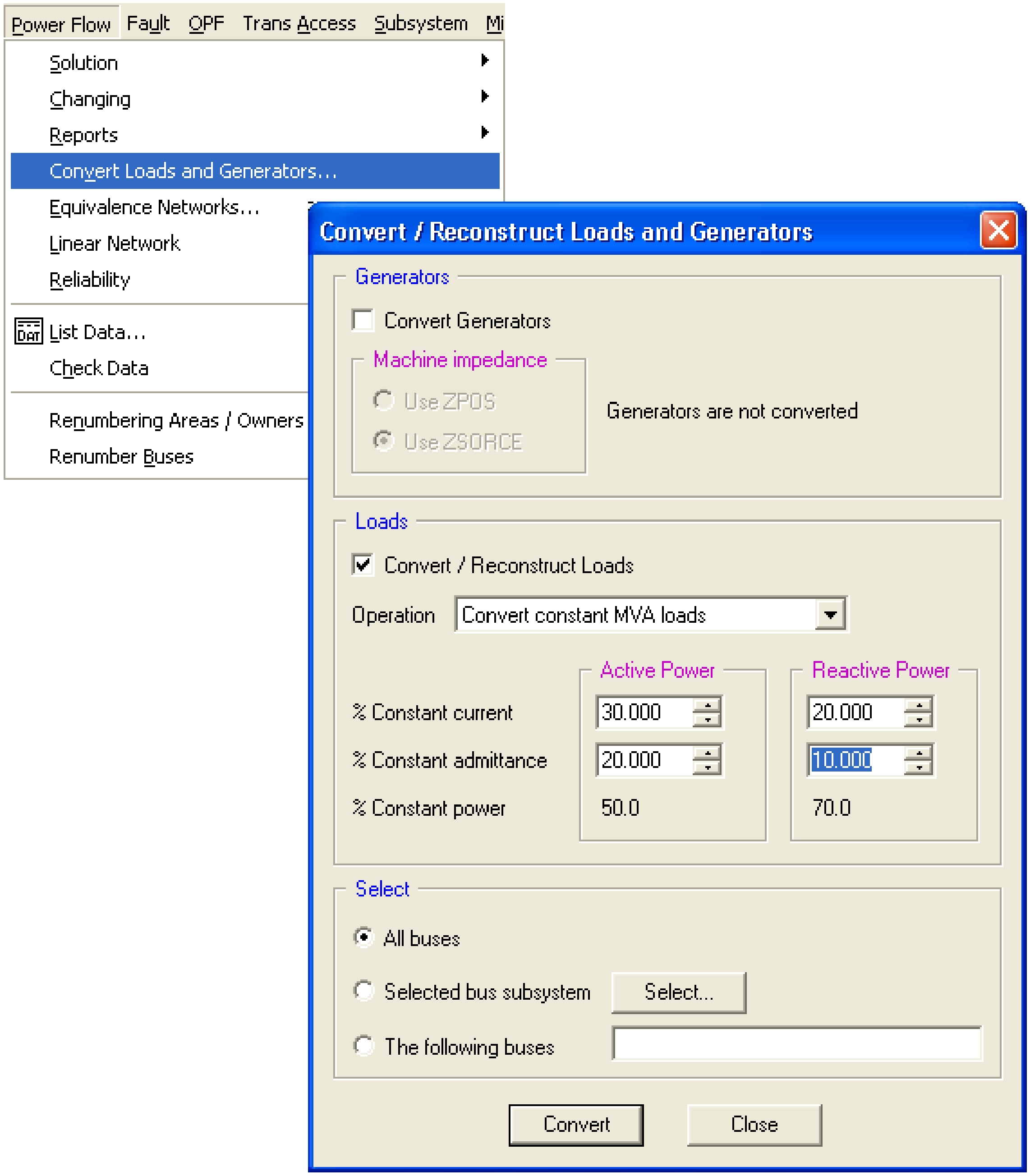


Figure 4-82. Convert/Reconstruct Loads and Generators Dialog

Figure 4-82 shows an example in which 30% of the Real part of the Constant MVA load is to be converted to constant current and 20% to constant admittance. For the imaginary component, the conversion is to 20% constant current and 10% constant admittance.

It can be seen further that the loads to be converted can be selected by the Area, Zone or Owner number to which the loads are assigned (NOT to the bus assignment to which the loads are connected). When selected by kV, all loads connected to buses with the selected voltage(s) will be converted in the loads' selected Areas, Zones and/or Owners.

Figure 4-83 shows the MVA loads in the *savnw.sav* power flow case, as initially defined. If the conversion selections shown in Figure 4-82 were chosen, the result would be to re-allocate the loads as shown in Figure 4-84. The conversion has been done, as can be seen, on all loads.

Note that conversion is done on the basis of the current load bus voltages in the power flow case. The user should be sure to solve the case to an acceptable tolerance before converting the loads.

Pload (MW)	Qload (MVAR)	Iload (MW)	Iload (MVAR)	Yload (MW)	Yload (MVAR)
200.0	100.0	0.0	0.0	0.0	0.0
600.0	450.0	0.0	0.0	0.0	0.0
400.0	350.0	0.0	0.0	0.0	0.0
300.0	150.0	0.0	0.0	0.0	0.0
1200.0	700.0	0.0	0.0	0.0	0.0
100.0	50.0	0.0	0.0	0.0	0.0
200.0	75.0	0.0	0.0	0.0	0.0
200.0	75.0	0.0	0.0	0.0	0.0

Figure 4-83. Reference Load Values in Savnw.sav Power Flow Case

Pload (MW)	Qload (MVAR)	Iload (MW)	Iload (MVAR)	Yload (MW)	Yload (MVAR)
100.0	70.0	60.4	20.1	40.6	-10.1
300.0	315.0	191.7	95.9	136.1	-51.0
200.0	245.0	127.8	74.6	90.7	-39.7
150.0	105.0	93.1	31.0	64.2	-16.1
600.0	490.0	379.3	147.5	266.5	-77.7
50.0	35.0	30.2	10.1	20.2	-5.1
100.0	52.5	62.3	15.6	43.1	-8.1
100.0	52.5	62.6	15.6	43.5	-8.2

Figure 4-84. Converted Loads Re-allocations as per Figure 4-82

4.5.3 Reconverting Load Characteristics

It is possible to reconstruct the constant MVA load from a mixture of the three load characteristics for selected network loads. Subsequently, it is possible to then convert the reconstructed constant MVA load to a different specified mixture of the constant MVA, constant current, and constant admittance load characteristics. The reconstruction process as illustrated in Figure 4-85. The process first collects all load back into a single constant MVA load and then reallocates it into constant MVA, constant current, and constant admittance components in the same manner as the conversion process.

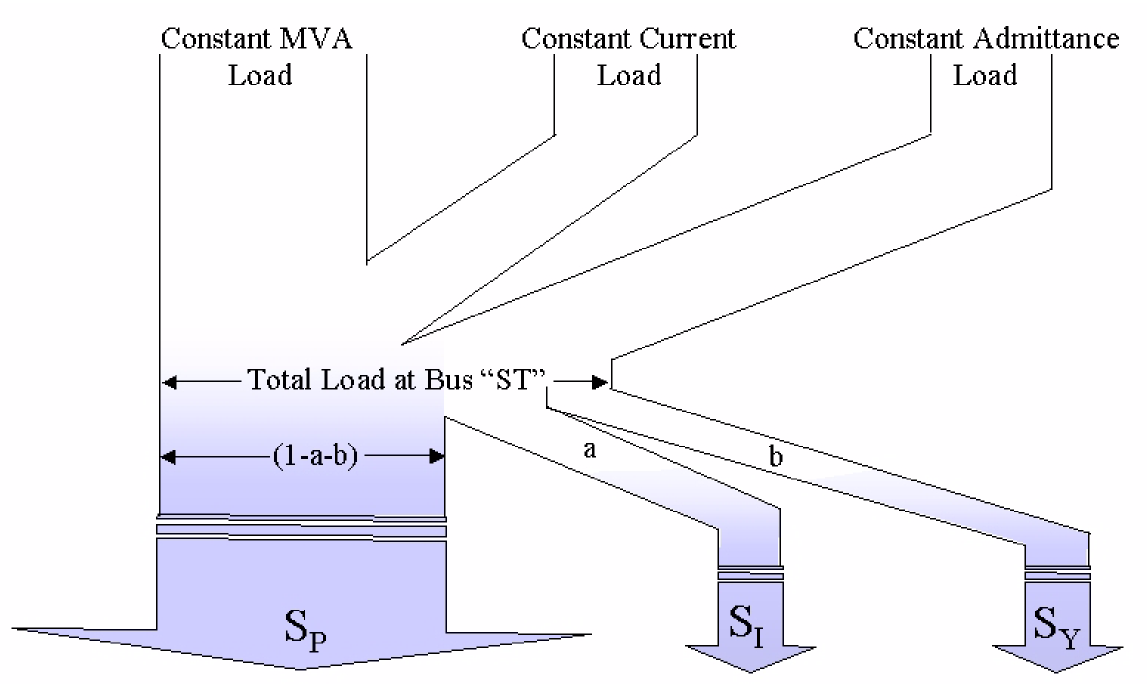


Figure 4-85. Load Collection and Re-allocation

There are two approaches to reconstruction and re-allocation of loads:

- Reconstruct MVA loads based on present bus voltage.
- Reconstruct MVA loads based on unity voltage.

When reconstructing MVA loads based upon present bus voltages, for each bus processed, the individual MVA loads represented by the three load characteristics are summed. This total load is then split among the three load characteristics as specified. Under this load reconstruction option, the network should be solved to an acceptable mismatch level before initiating the reconstruction process. The network will remain in balance at completion of this process.

This process first collects all load into the constant MVA component by

$$ST = S_p + vS_i + v^2 S_y$$

where ST is the total of the three load components and then reallocates it by the formula

$$S_I = \frac{aST}{v}$$

$$S_Y = \frac{bST}{v^2}$$

$$S_P = ST(1 - a - b)$$

The symbols used are defined in Section 4.5.2.

When reconstructing loads based on unity voltage, the three load components are summed assuming one per unit voltage, (v = 1.0) and this total load is split among the three load characteristics as specified. The network will normally not be in balance following this process with this load reconstruction option.

Load reconstruction is facilitated via the ***Power Flow>Convert Loads and Generators…*** option which displays the Convert/Reconstruct Loads and Generators dialog. To perform the load reconstruction, select the Convert / Reconstruct Loads option and select one of the "Reconstruct" options from the Operation menu.

In the this example the option to reconstruct using present voltage has been selected and the re-allocation is to 10% of total load for both real and reactive power for constant current and constant impedance loads (see Figure 4-86).

As for the conversion process, loads to be converted can be selected by the Area, Zone or Owner number to which the loads are assigned (NOT to the bus assignment to which the loads are connected) (see Figure 4-82). When selected by kV, all loads connected to buses with the selected voltage(s) will be converted in the loads' selected Areas, Zones and/or Owners.

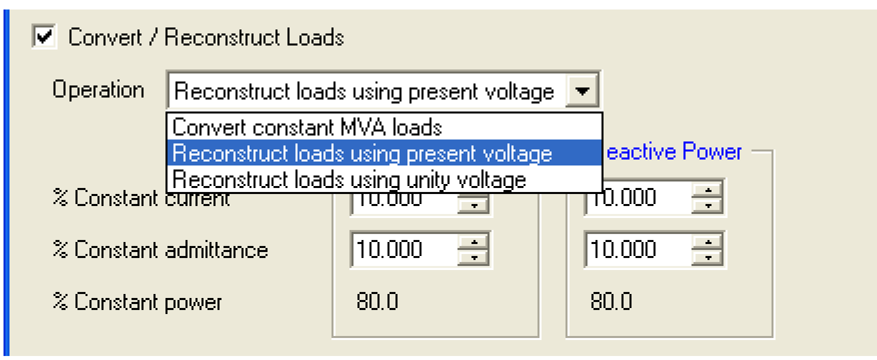


Figure 4-86. Reconstruction of Loads

Section 4.5.2 shows an example conversion process in which Figure 4-83 shows the MVA loads in the *savnw.sav* power flow case, as initially defined. That conversion example re-allocates the loads with the result shown in Figure 4-84. The conversion was done on all loads.

With that converted load as a starting point, the reconstruction can be done based on the reallocations shown in Figure 4-86 above. The result is shown in Figure 4-87.

Pload (MW)	Qload (MVAR)	Iload (MW)	Iload (MVAR)	Yload (MW)	Yload (MVAR)
160.0	80.0	20.1	10.1	20.3	-10.1
480.0	360.0	63.9	47.9	68.1	-51.0
320.0	280.0	42.6	37.3	45.4	-39.7
240.0	120.0	31.0	15.5	32.1	-16.1
960.0	560.0	126.4	73.8	133.2	-77.7
80.0	40.0	10.1	5.0	10.1	-5.1
160.0	60.0	20.8	7.8	21.5	-8.1
160.0	60.0	20.9	7.8	21.8	-8.2

Figure 4-87. Reconstruction of Loads Based on global 10% Reallocation

4.5.4 Scaling Loads and Generators

System planners and operators need the ability to analyze a wide range of demand and generation scenarios. Often the need is to study a variety of demand levels which cover a daily, weekly or a seasonal profile. To facilitate simple and rapid changes in load level, PSS™E provides a means by which not only loads but also generation can be "scaled". The process enables the user to uniformly increase or decrease any or all of the following quantities for a selected grouping of buses, loads, and machines:

- Load active power.
- Load reactive power.
- Active component of bus shunt admittance.
- Positive reactive component of bus shunt admittance (capacitors).
- Negative reactive component of bus shunt admittance (reactors).
- Generator active power output (positive generation).
- Motor active power output (negative generation).

The load and generation process is initiated with the ***Power Flow>Changing>Scale generation, load, shunt (SCAL)*** option (see Figure 4-88).

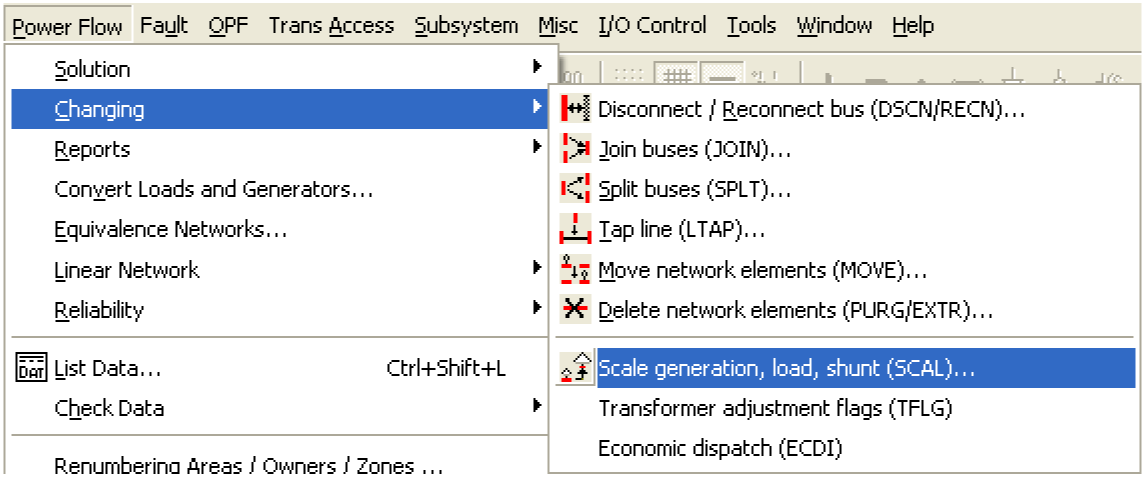


Figure 4-88. Scale Loads Menu Selection

The first requirement is to select loads and generators to be scaled. Selection is by Area, Zone, Owner, Base kV, combinations of these criteria, or by specific buses (see Figure 4-89).

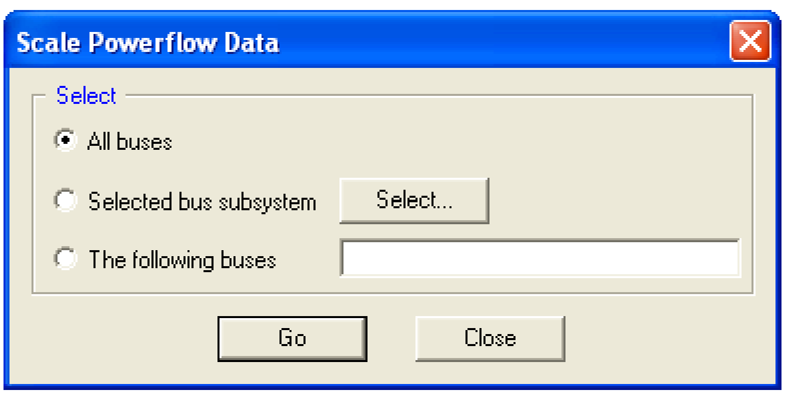


Figure 4-89. Scale Power Flow Data Dialog

Clicking the ***Go*** button in the Scale Powerflow Data dialog (see Figure 4-89) gives access to a second dialog where specific scaling selections can be made to loads and generation (see Figure 4-90).

Scaling Loads

It should be noted that selection by Area, Zone or Owner relates to the loads and not to the Area, Zone and Owner assignments of the buses to which the loads are connected.

In the scaling process, load totals include voltage dependency effects. The constant power characteristic holds the load power constant as long as the bus voltage exceeds the value specified by the solution parameter PQBRAK which is discussed in Section 4.2.4.1).

Further, the load totals are the sums of any constant power, current, and admittance components of those loads being scaled; all of these load components are scaled by the same factor.

Scaling Generators

For scaling purposes, machines with positive active power generation are included in the generator totals, and those with negative active power generation are included in the motor totals. The discussion below is in terms of generator totals, but the same approach is used for motor totals.

All in-service machines whose type code is two or three are included in the generation totals and subsequent scaling unless selection criteria limit the machines to be considered on the basis of Base kV, Area, Zone, Owner, a combination of those or by selection of specific buses. When the Owner criterion is employed, each machine wholly or partly owned by any of the owners specified is included. The owner assignments of buses are not considered.

In scaling generation, it is useful to remember the following points:

1. The scaling process is *not* a dispatch activity; it merely scales the existing active power output of online machines such that the ratio of machine to total power is retained. Machine power limits are recognized only if the user selects to enable the **Enforce machine power limits** option.

2. If a system swing (type three) bus is in the subsystem being scaled, the working case should be solved so that the swing power, which is included in the total generation, is reasonable.

If the total generation is being changed by a large amount, the new generator outputs, as set by the scaling process, should be examined to verify that machines are set at realistic operating points. (For these situations, the economic dispatch activity facility, as described in Section 4.8, might be more appropriate.)

Example data for the *savnw.sav* power flow case is presented in the Scale Powerflow Data dialog (see Figure 4-90). That data includes the total real load (3,200 MW), the total generation real power (3,258.7 MW) and the total reactive power for bus connected reactors and capacitor (600 Mvar and 950 Mvar, respectively). In addition the total reactive component of load is indicated to be 1,950 Mvar.

For scaling purposes, the real load and generation power can be changed by an absolute amount in 10 MW increments or by a percentage. Similarly, the bus connected reactive equipment can be scaled in the same manner.

For the reactive component of load, the scaling process provides three options:

- Change the absolute level of Load Mvar by 10 Mvar increments or by a percentage.
- Maintain a constant P/Q ratio as the real load component is changed.
- Select a load power factor, changeable in 0.01 increments.

Finally, the user can select to impose the generator and motor power limits indicated.

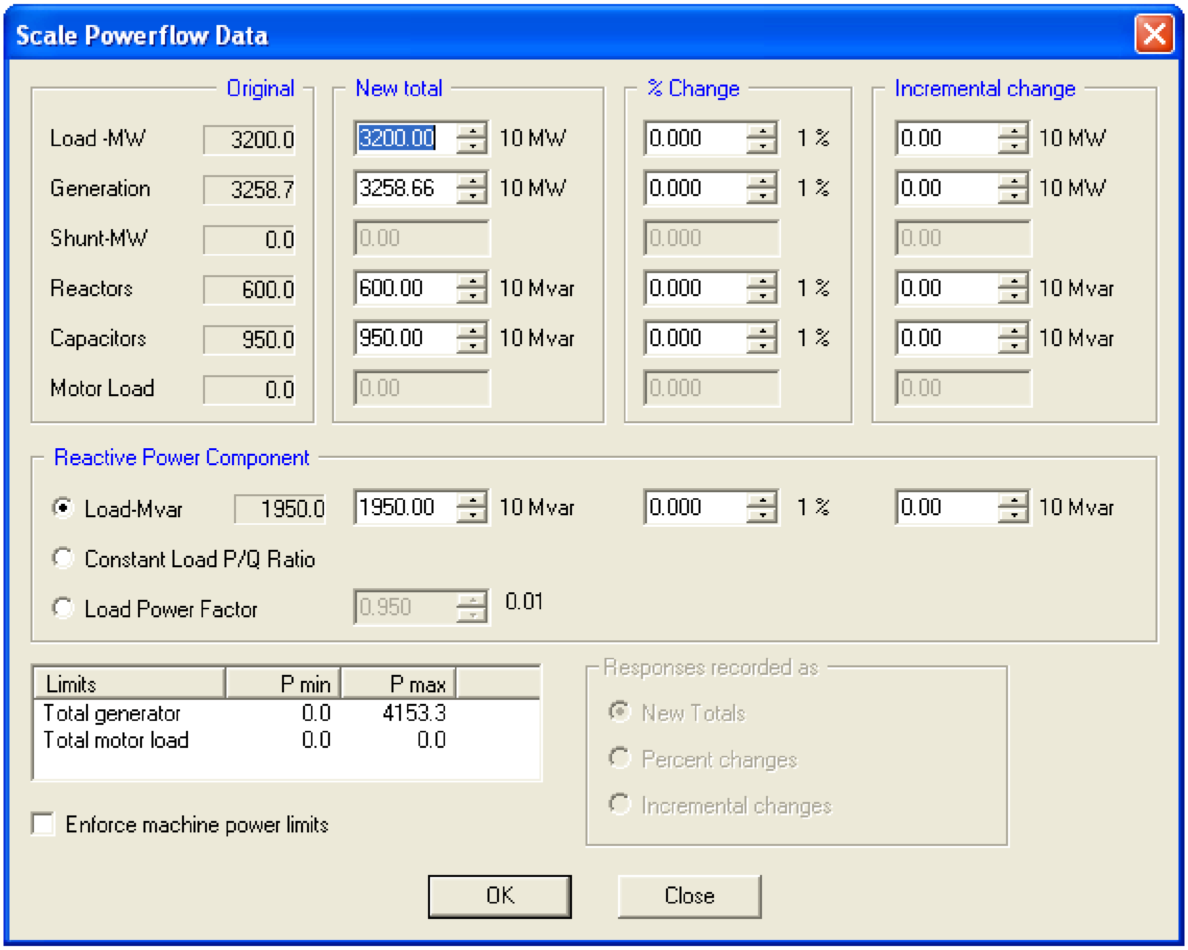


Figure 4-90. Dialog for Selecting Scaling Factors of Loads and Generation

Using the savnw.sav power flow case, an example can be shown of scaling all real load by + 2% while maintaining a constant P/Q ratio. No scaling will be imposed on real generation. Consequently, the swing bus will need to generate the extra power as well any additional system losses.

Figure 4-91 shows the total loads, the swing bus power and the system losses in the *savnw.sav* power flow case prior to scaling. Figure 4-92 shows the same data after scaling and resolving the case.

Pload (MW)	Qload (MVAR)	Iload (MW)	Iload (MVAR)	Yload (MW)	Yload (MVAR)
200.0	100.0	0.0	0.0	0.0	0.0
600.0	450.0	0.0	0.0	0.0	0.0
400.0	350.0	0.0	0.0	0.0	0.0
300.0	150.0	0.0	0.0	0.0	0.0
1200.0	700.0	0.0	0.0	0.0	0.0
100.0	50.0	0.0	0.0	0.0	0.0
200.0	75.0	0.0	0.0	0.0	0.0
200.0	75.0	0.0	0.0	0.0	0.0

```
TOTAL GENERATION PQLOAD    I LOAD    Y LOAD    SHUNTS  CHARGING   LOSSES     SWING
MW        3258.7   3200.0      0.0       0.0       0.0       0.0     58.7     258.7
MVAR       964.2   1950.0      0.0       0.0    -291.5    1810.1   1115.7     104.0
```

Figure 4-91. Pre-Scaling Load, Generation, Losses and Swing Bus Output

Pload (MW)	Qload (MVAR)	Iload (MW)	Iload (MVAR)	Yload (MW)	Yload (MVAR)
204.0	102.0	0.0	0.0	0.0	0.0
612.0	459.0	0.0	0.0	0.0	0.0
408.0	357.0	0.0	0.0	0.0	0.0
306.0	153.0	0.0	0.0	0.0	0.0
1224.0	714.0	0.0	0.0	0.0	0.0
102.0	51.0	0.0	0.0	0.0	0.0
204.0	76.5	0.0	0.0	0.0	0.0
204.0	76.5	0.0	0.0	0.0	0.0

```
TOTAL GENERATION PQLOAD    I LOAD    Y LOAD    SHUNTS  CHARGING   LOSSES     SWING
MW        3326.1   3264.0      0.0       0.0       0.0       0.0     62.1     326.1
MVAR      1087.5   1989.0      0.0       0.0    -276.1    1790.9   1165.5     131.8
```

Figure 4-92. Post-Scaling Load, Generation, Losses and Swing Bus Output

4.6 Modifying the Network

PSS™E allows the user to modify the original network model in a variety of ways. Network elements can be added and removed either on an individual basis or in bulk; network buses can be renumbered; transmission resistance elements can be updated; separate power flow files can be merged; generation dispatch can be based on economic data and the existing network topology can be modified.

This section will address a variety of procedures for modifying and manipulating network files, including:

- Disconnection and reconnection of network elements.
- Changing the network topology.
- Bus, Area, Zone and Owner renumbering.
- File merging.
- Developing an economic dispatch.

These procedures are accessed via the ***Power Flow*** menu and ***Power Flow>Changing*** option (see Figure 4-94). These procedures can also be accessed from the ***Topology*** toolbar buttons and the ***GEXM/GOUT*** toolbar button (see Figure 4-93).

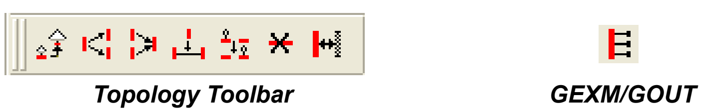


Figure 4-93. Toolbar Buttons for Changing Network Content and Topology

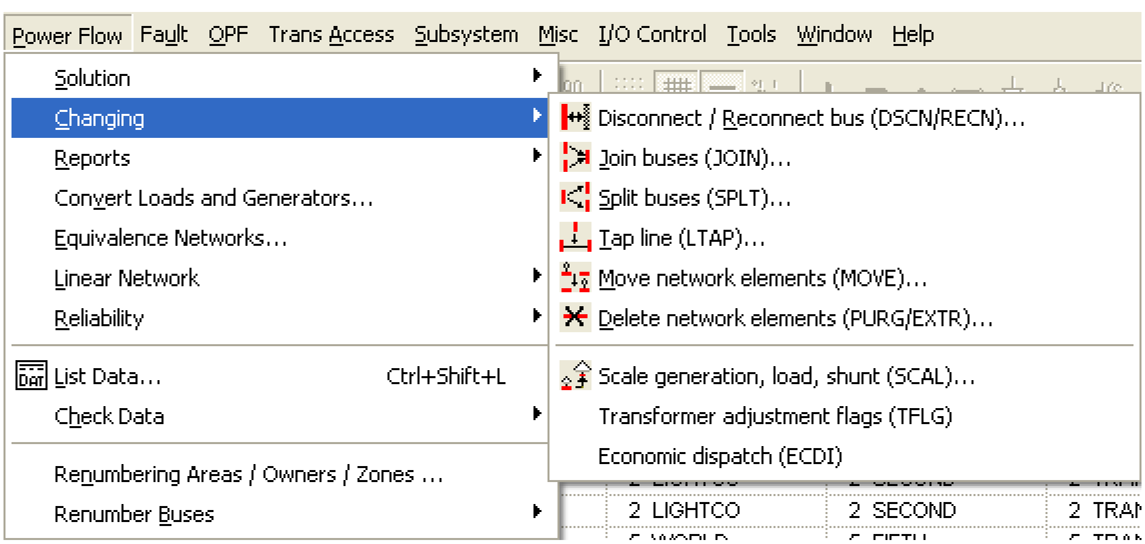


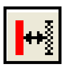
Figure 4-94. Accessing the Procedures for Changing Network Content and Topology

4.6.1 Disconnecting Buses

The bus disconnection procedure automates the data changes required to electrically isolate a bus. For each bus processed, its type code is set to four and all AC branches, DC lines, and series FACTS devices connected to the bus are set to out-of-service. A summary of branch status changes is printed in the Output Bar.

If the bus being processed is the endpoint bus of a multisection line grouping, the entire multisection line grouping is removed from service. If the bus being processed is a dummy bus of a multi- section line grouping, the multisection line is removed from service.

If a three-winding transformer is connected to the bus being processed, all three windings of the transformer are removed from service.



Clicking the ***Disconnecting Buses*** button or selecting the ***Power Flow>Changing>Disconnect/Reconnect bus (DSCN/RECN)...*** option will display the Disconnect / Reconnect Bus dialog (see Figure 4-95).

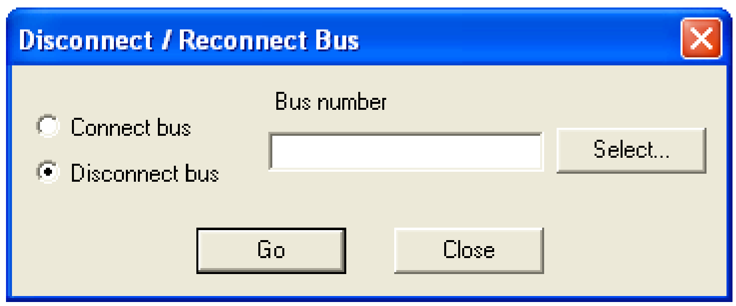


Figure 4-95. Disconnect/Reconnect Bus Dialog

The user has the choice of typing in a bus number or using the ***Select...*** button to display the Bus Selection dialog. The bus 154 DOWNTN in the *savnw.sav* power flow case has been selected (see Figure 4-96).

Clicking the ***OK*** button will revert back to the Disconnect / Reconnect Bus dialog (see Figure 4-95). Clicking the ***Go*** button will initiate the disconnection.

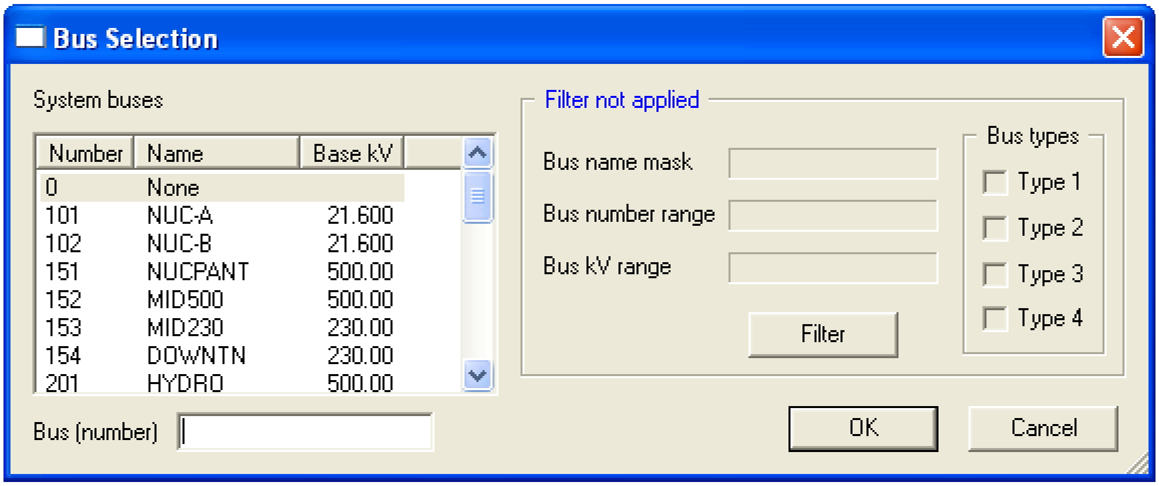


Figure 4-96. Bus Selection Dialog for Disconnection of Buses

This disconnection procedure will result in the printing of a summary of branch status changes in the Output Bar (see Figure 4-97).

```
TYPE CODE OF BUS    154 [DOWNTN      230.00] SET TO  4
AND STATUS OF FOLLOWING CONNECTED BRANCHES SET TO 0:
 CIRCUIT 1  TO BUS    153 [MID230      230.00]
 CIRCUIT 2  TO BUS    153 [MID230      230.00]
 CIRCUIT 1  TO BUS    203 [EAST230     230.00]
 CIRCUIT 1  TO BUS    205 [SUB230      230.00]
 CIRCUIT 1  TO BUS   3008 [CATDOG      230.00]
```

Figure 4-97. Summary of Disconnected Branches Output View

The output results shows that five circuits have been taken out of service. This summary, however, does not list the bus connected equipment which is taken out of service.

4.6.1.1 Using the Filter

When selecting a number or range of buses to be disconnected, a filter can be used. Clicking the ***Filter*** button in the Bus Selection dialog (see Figure 4-96) will display the Bus Filter dialog (see Figure 4-98).

The filter allows the selection of a range of buses, selected by type, bus number range, Base kV range and by name mask range. Following selection of the buses to be connected, clicking the ***OK*** button will revert back to the Bus Selection dialog.

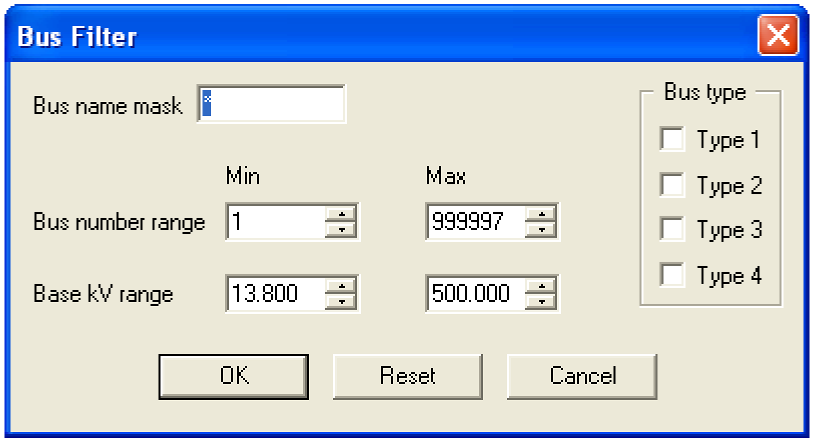


Figure 4-98. Bus Filter Dialog for Disconnecting Buses

4.6.1.2 Disconnecting a Bus using the Diagram View

With the Diagram View open it is possible to disconnect a selected bus, set its code to four and set all AC branches, DC lines, and series FACTS devices connected to the bus out-of-service. The users can right-click on the bus to be disconnected to display a pop-up menu (Figure 4-99). By selecting the ***Switch*** option, the disconnection will be made.

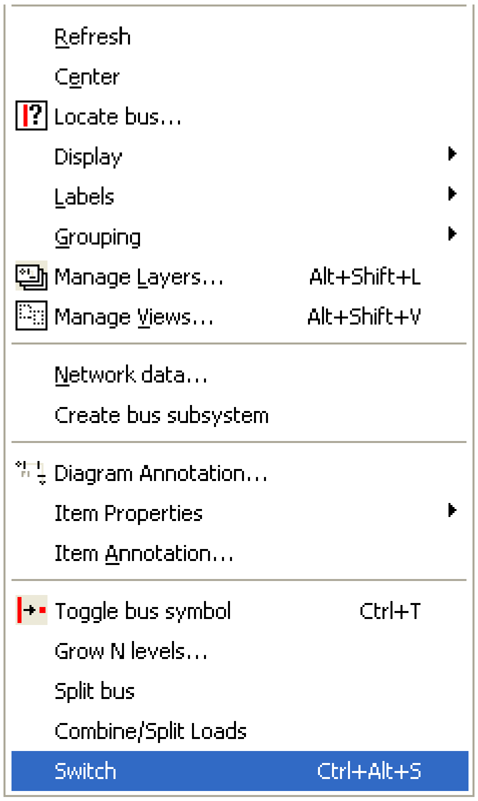


Figure 4-99. Accessing the Switch Process for Disconnecting Buses

When disconnecting in the Diagram View, the buses, lines and equipment notation will change to indicate their out of service condition. The line colors, width and style for out-of-service equipment is selected in the Diagram Range Checking tab in the Powerflow Data Annotation dialog (see Section 2.9.2). Further, the Output Bar will show a summary of the disconnected branches as shown in Figure 4-97.

In the example shown in Figure 4-100, a dashed black line has been selected for visually identifying out-of-service equipment. Using the *savnw.sav* power flow case, Bus 154 has been disconnected and it can be see that the diagram indicates all the branches and bus connected equipment are out of service.

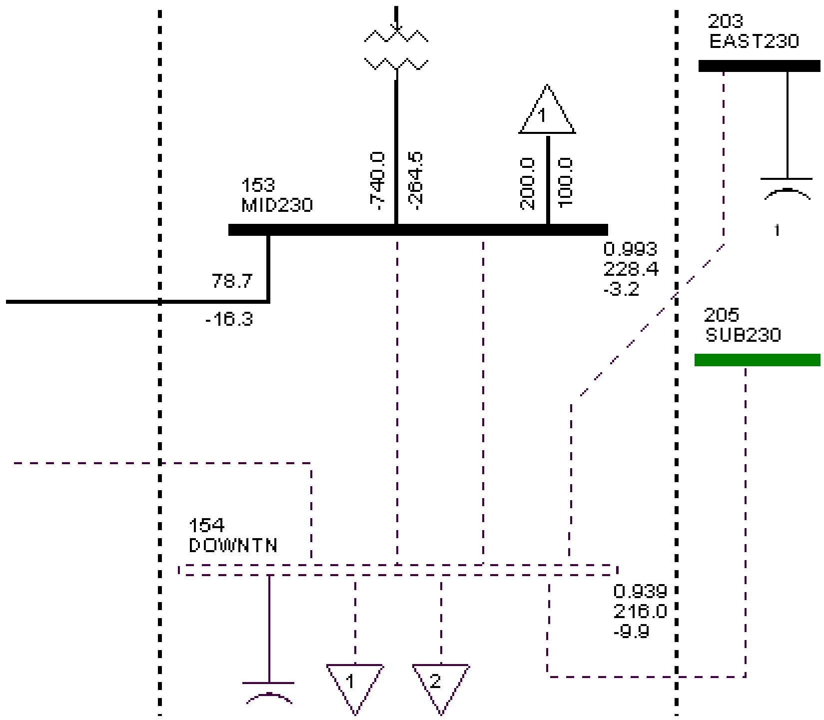


Figure 4-100. Diagram View of Disconnected Bus

4.6.2 Reconnecting Buses

The reconnection of isolated, out-of-service buses uses essentially the reverse procedure to that of disconnection of an in-service bus.

For each bus processed, if its type code is four, it is set to two if there is a plant table entry assigned to the bus or to one if no generator data is associated with the bus. Then, all branches connected to the bus for which the "*to bus*" is not a type four bus are set to in-service. All two-terminal and multi-terminal DC lines returned to service are placed in power control mode. All series FACTS devices returned to service have their control modes set to a positive value as described below. A summary of branch status changes is printed at the Output Bar.

If the bus being processed is the endpoint bus of a multisection line grouping, the entire multisection line grouping is returned to service as long as the type code of the other endpoint bus is not four; i.e., each line section is set to in-service and each dummy bus has its type code set to one (if there is no generator data for the dummy bus) or two (if there is a generator slot for the dummy bus).

If the bus being processed is a dummy bus of a multisection line grouping, the multisection line is set to in-service as long as the type codes of neither of the two end point buses is four.

If a three-winding transformer is connected to the bus being processed, all three windings of the transformer are set to in-service as long as the type codes of neither of the other two buses connected to the transformer is four.

Any series FACTS device returned to service has its control mode set as follows:

- To 3 if it was previously holding constant series impedance and then was disconnected as described in the previous section.
- To 4 if it was previously holding constant series voltage and then was disconnected as described in the previous section.
- To 5 through 8, as appropriate, if it was previously a series element of an IPFC and then was disconnected as described in the previous section.
- To 1 in all other cases.

Use of the menu options, toolbar buttons and the diagram view for selection and reconnection of buses are the same as for disconnecting buses as described in the previous section. The only difference is in selection of the Connect option rather than the Disconnect option (see Figure 4-101).

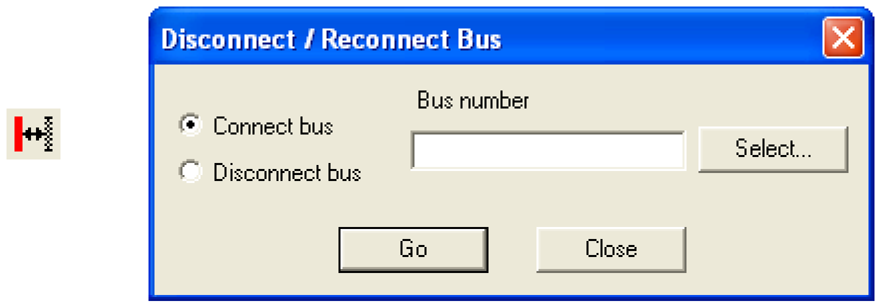


Figure 4-101. Disconnect/Reconnect Bus Dialog and Reconnect Toolbar Button

4.6.3 Removing Network Elements

PSS™E facilitates the users' ability to delete designated equipment items from the working file. Either individually specified equipment items can be removed or all outaged items of selected equipment categories can be removed.

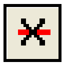
It is important to understand the difference between "deleting" network items and changing their service status. Network elements which are "flagged" as out of service are merely to be ignored during PSS™E network solution and reporting activities. The act of "deleting" permanently removes the equipment item and all its data from the power flow working file.

If all loads at a bus are removed, a message indicating that is printed to the Output Bar. Similarly, in deleting machines from the working case, if all machines at a bus (plant) are removed, an appropriate message is printed in the Output Bar and the plant data at the bus is also deleted.

If the plant entry of any area swing bus is deleted, an appropriate message is printed in the Output Bar and the area swing bus number is set to zero.

If a branch that is a member of a multisection line grouping is deleted, an appropriate message is printed and the multisection line grouping is deleted.

This deleting process *does not* check that the power flow data is in the form required by the power flow solution activities after deleting has taken place. The user should check for islands, system swing bus specification and area interchange control parameters before proceeding.



Using the ***Delete Network Elements*** button or selecting the ***Power Flow>Changing>Delete network elements (PURG/EXTR)...*** option will display the Delete network elements dialog where required deletions can be selected (see Figure 4-102). The user can either delete buses together with all their connected network elements or delete any equipment which is out-of-service.

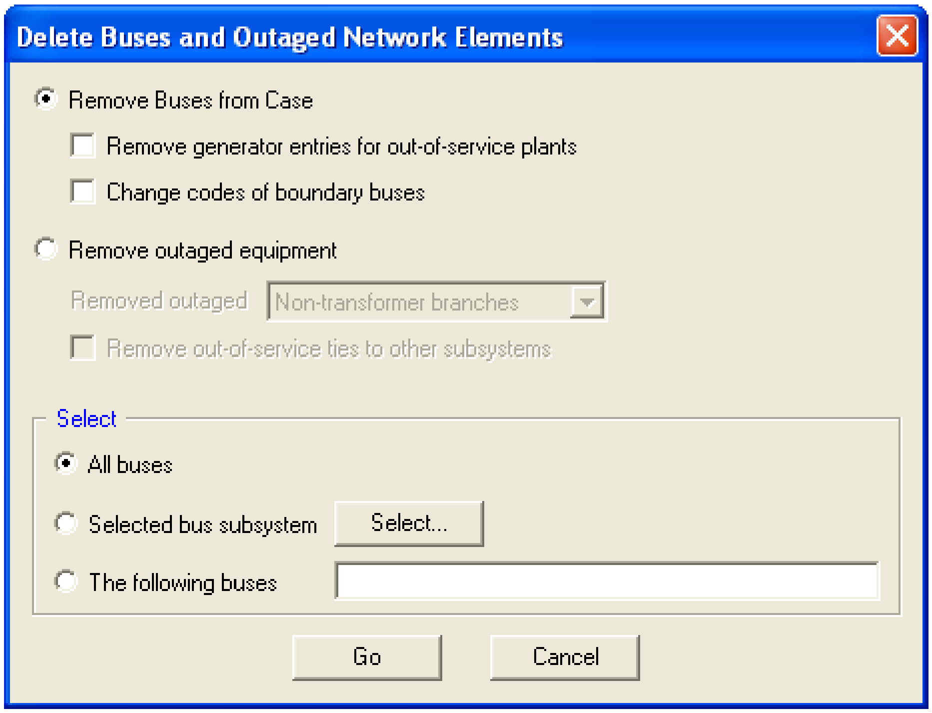


Figure 4-102. Deleting Network Elements Dialog

4.6.3.1 Removing Buses

By selecting the **Remove Buses from Case** option, all buses, together with all their connected lines and equipment can be deleted from the case whether or not they are in service. They can be selected for deletion on an individual basis or on a subsystem basis in the Select area of the dialog.

When deleting buses, the user has the option to **Remove generator entries for out-of-service plants**, (i.e., type one buses at which a plant is currently off-line). The proper selection for this option is dependent upon the application at hand. If the user is setting up the working file to build an equivalent of a subsystem contained within it, the usual procedure is to enable this option. For other applications, it is often desirable to retain these generator table allocations if the machines may subsequently be returned to service.

The other option available when deleting buses is to **Change codes of boundary buses**. This option will add four to the bus type codes of "boundary buses", which are retained in the working file following the deletion process. A "boundary bus" is defined as a bus to be retained in the working file which is connected to a bus to be deleted. The normal procedure is to disable this option unless some advanced equivalencing operation is to be performed with the retained data. See Chapter 9 for a description of these procedures.

As the deletion process proceeds, a summary of the number of buses deleted is shown in the Output Bar.

In the Diagram View, it is possible to see the buses and their associated lines and equipment which have been deleted (see Figure 4-103). The "unbound" items (items that exist in the diagram but not in the network data because of the deletion) are shown in the designated color selected in the Diagram Properties dialog, as described in Section 2.9.1. The diagram shows a partial view of the buses deleted from the FLAPCO area of the *savnw.sav* power flow case.

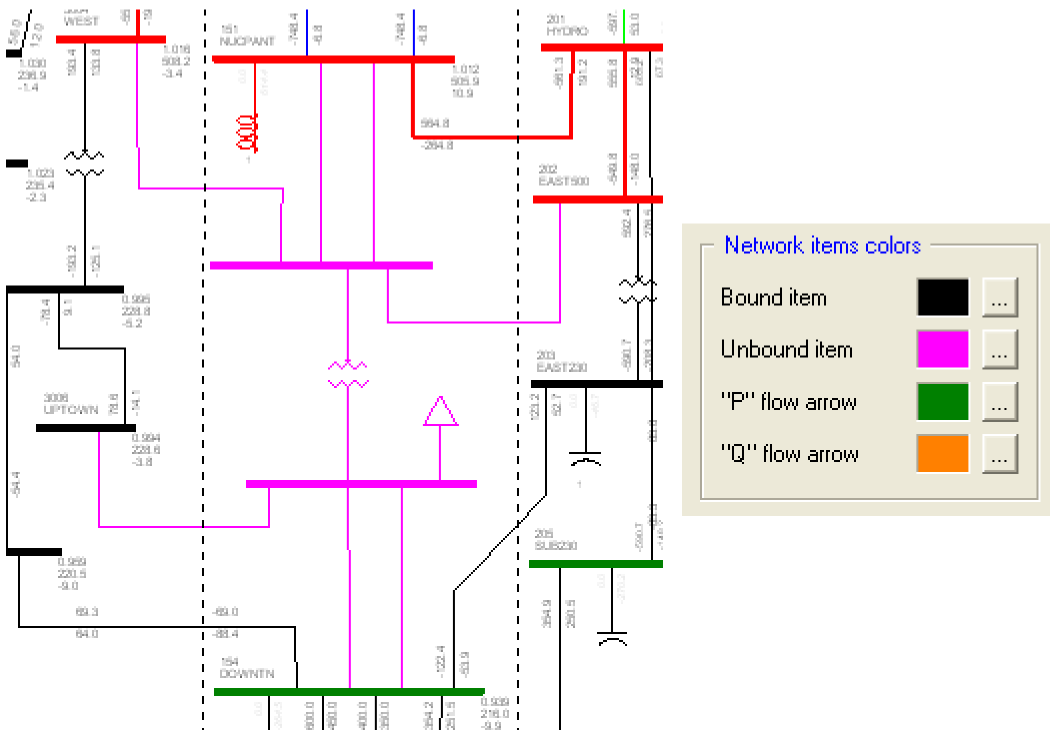


Figure 4-103. Diagram View of Deleted Buses and the Diagram Properties Options

4.6.3.2 Removing Outaged Equipment

Equipment which is out-of-service can be selected to be deleted from the working file. The selection criteria Area, Zone and or Owner assignments of buses are used to determine which equipment items are to be processed when subsystem selection by Area, Zone, and/or Owner is enabled. The Owner assignments of machines, AC branches, three-winding transformers, and FACTS devices, and the Area, Zone, and Owner assignments of loads, are not considered.

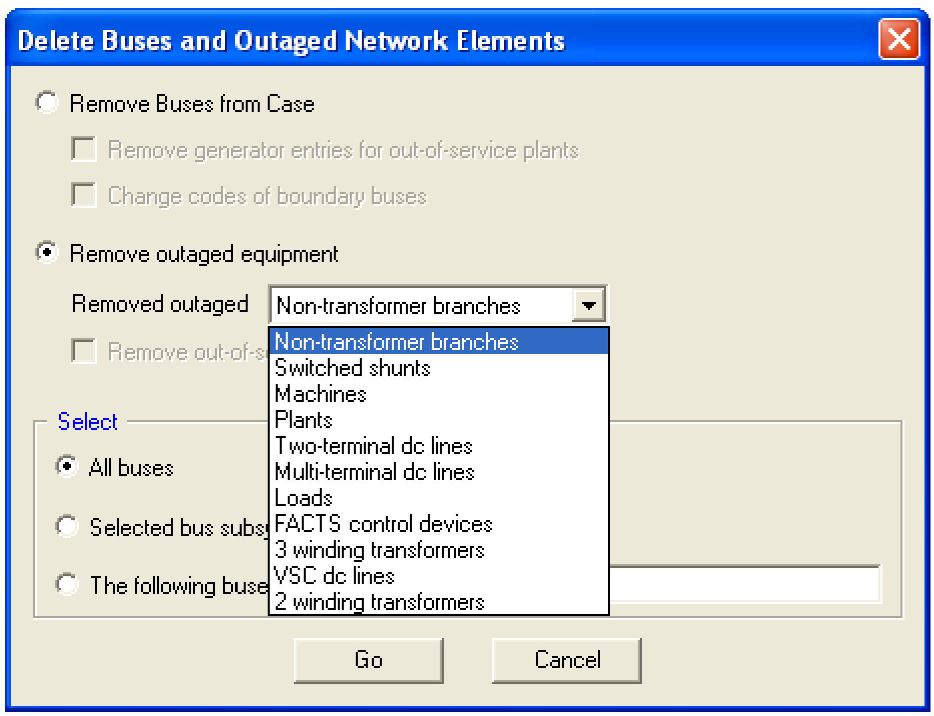
The deletion process operates on subsystem equipment items according to the following conditions:

AC branches	The branch status flag is zero or negative.
Switched shunts	The control mode is zero and no switched shunt blocks are switched on.
Machines	The machine status flag is zero or negative.
Plants	The bus type code is one or greater than three.

Loads	The load status flag is zero or negative.
DC lines	The control mode is zero.
FACTS devices	The control mode is zero.
Three-winding transformers	The status flag is zero.

In addition, the user can elect to **Remove out-of-service ties to other subsystems** when removing outages of AC branches, DC lines, FACTS devices, three-winding transformers and VSC DC lines. When making this election, any outaged branch with at least one bus in the specified subsystem is deleted. Otherwise, all buses connected by the branch must be in the specified subsystem. In the case of multi-terminal DC lines, only the AC converter buses are considered in determining if all buses are in the specified subsystem; specifically, the Area, Zone, and Owner assignments of the DC buses are not considered.

The data categories which can be processed for deletion are shown in the drop-down menu in Figure 4-104. In addition, the figure shows an example report following deletion of three AC lines in the *savnw.sav* case. These branches were taken out-of-service before attempting to delete them.



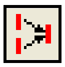

```
X------- FROM BUS ---------X X--------- TO BUS ----------X CKT
    151 [NUCPANT     500.00]    152 [MID500      500.00]  1
    151 [NUCPANT     500.00]    152 [MID500      500.00]  2
    151 [NUCPANT     500.00]    201 [HYDRO       500.00]  1

     3 BRANCHES DELETED
```

Figure 4-104. Selection of Non-transformer branches Data Category for Deletion and Output View

4.6.4 Joining Buses

The ***Join buses*** operation enables the user to combine pairs of buses, retaining the identity of one of the two buses. It is intended primarily to bolt together buses that are connected by a low impedance jumper branch. It is possible, however, to join together any pair of buses regardless of the impedance of any connecting branches or whether there is a branch between them at all.



Selecting the ***Power Flow>Changing>Join buses (JOIN)...*** option or clicking the ***Join Buses*** button on the toolbar opens the Join Buses dialog (see Figure 4-105). Within the dialog the user will identify the two buses to be joined. One of the buses will be retained and the other discarded. Additionally the user must decide how to treat the line shunts which are connected to any branch currently joining the two buses; either discard them or add them to the bus which is to be retained.

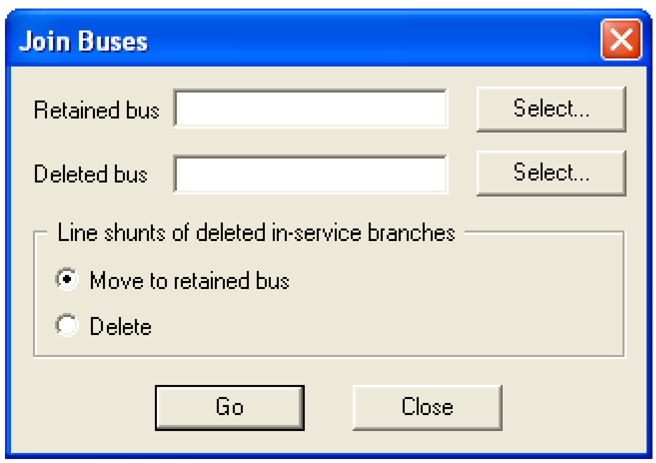


Figure 4-105. Join Buses Dialog

During the selection process an alarm will be issued if:

- Either of the specified buses is not contained in the working case
- The resulting retained bus would have more machines or loads than are able to be accommodated with unique identifiers
- Either has a type code of four or greater
- The two buses are connected by a three-winding transformer
- There is not enough room in the bus tables to handle the processing of three-winding transformers connected to the bus to be deleted. In these cases, the buses are not joined and a different selection must be made.

When the join is performed, the identity of the retained bus is preserved. This includes the bus attributes of number, name, base voltage, area, zone, and owner. Any shunt elements on the two buses are combined. Any branches between the buses being joined are removed from the working case, with line connected shunts and magnetizing admittances being added to the retained bus or discarded as indicated by the specification for the **Line shunts of deleted in-service branches** option.

All other branches originally emanating from the bus being removed are rerouted to the retained bus. If there are branches from the two specified buses to a common third bus with identical circuit identifiers, branches originally connected to the retained bus keep their original circuit identifiers and new identifiers are assigned to the rerouted circuits.

All loads at the bus being removed are transferred to the retained bus. In the case of conflicting load identifiers, those loads originally at the retained bus keep their original identifiers and new identifiers are assigned to the transferred loads.

If the retained bus is not a generator bus but the deleted one is, the plant and machine data of the removed bus is transferred to the retained bus. If both buses are generator buses, machines from the removed bus are transferred to the retained bus and plant totals are updated. In the case of conflicting machine identifiers, those machines originally at the retained bus keep their original machine identifiers and new identifiers are assigned to the transferred machines.

All changes to branch, load, and machine identifiers are reported in the Output Bar. The user has the option, however, of changing identifier settings in the spreadsheet before executing the Join Buses process.

If the retained bus does not have a switched shunt and the deleted one does, the switched shunt of the removed bus is transferred to the retained bus.

If both buses have switched shunts, the switched shunts are merged, with blocks being assigned in the following order:

1. Reactors from the removed bus.
2. Reactors from the retained bus.
3. Capacitors from the retained bus.
4. Capacitors from the removed bus.

Control parameters from the retained bus are kept unless the switched shunt at the retained bus controls the admittance setting of the switched shunt at the removed bus. In this case, the control parameter data items (MODSW, VSWHI, VSWLO, SWREM, RMPCT and RMIDNT) of the removed bus are transferred to the retained bus.

If either the retained bus or removed bus is involved in multisection line groupings, each such grouping is either:

- Redefined if the topology change results in a valid multisection line grouping.
- Deleted if the redefined grouping violates any of the requirements for multisection line groupings.

If sequence data is contained in the working case (see Section 7.2), it is handled appropriately, including the rerouting or removal of zero sequence mutuals. Zero sequence switched shunts and line shunts are treated in the same manner as they are in the positive sequence.

The Join Buses process is not sensitive to any interrupt control code options.

As an example, using the *savnw.sav* power flow case, the buses ’154 DOWNTN’ and ’3008 CATDOG’ will be joined. In Figure 4-106 it can be seen that bus 154 has two loads (600+j450 MVA and 400+j350 MVA) and bus 3008 has one load (200 + j75 MVA) at nominal voltage. The buses are joined by one 230 kV line without line shunts.

If bus 154 is the retained bus, the Join Buses process should move the load from bus 3008 to bus 154 and its identifier changed to '3'.

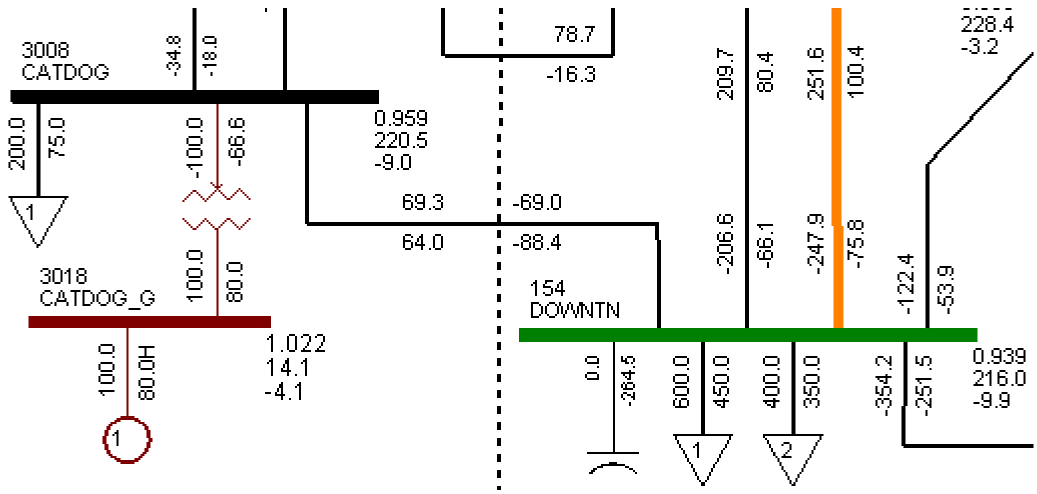


Figure 4-106. Buses 154 and 3008 to be Joined

In the Join Buses dialog, shown in Figure 4-105, clicking the ***Select...*** button will display the Bus Selection dialog (see Figure 4-107). The bus can be selected from the bus listing or the number can be typed in directly. For large cases, the filter can be used to limit the bus listing to a selected subsystem.

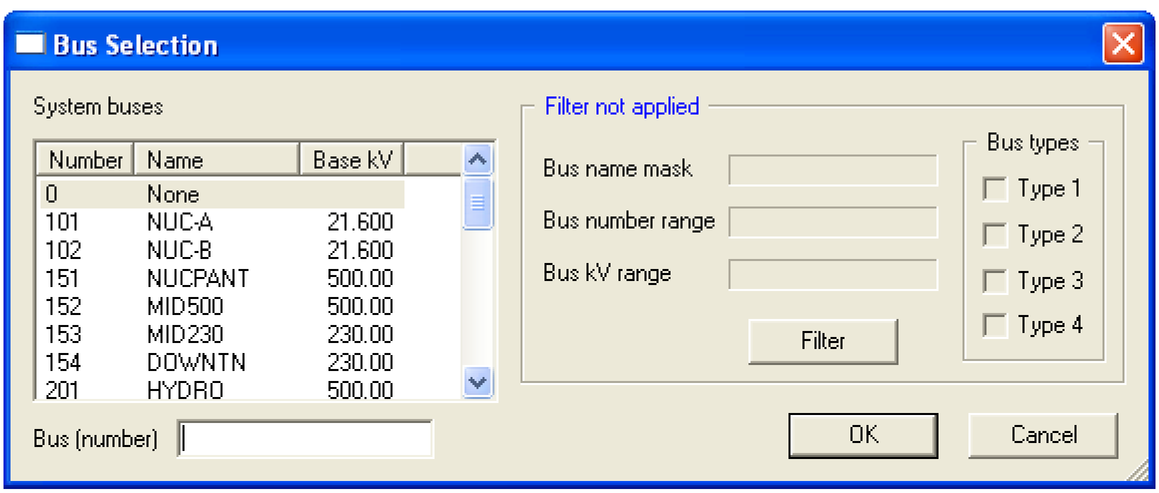
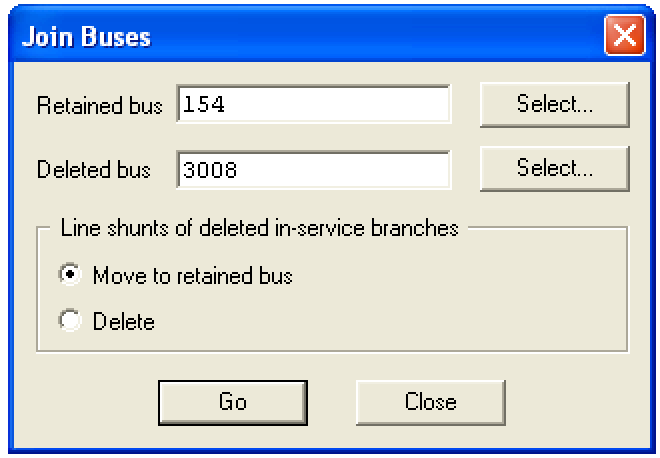


Figure 4-107. Selecting Buses for Joining

The result of the selection process will revert to the Join Buses dialog where the selected buses are indicated along with the choice of method of dealing with line shunts. Clicking the ***Go*** button shown in Figure 4-108 will complete the joining process and, for this example, result in a summary report in the Output Bar (the text of which is shown in the lower portion of Figure 4-108).




```
DUPLICATE LOAD IDENTIFIER 1
IDENTIFIER OF TRANSFERRED LOAD CHANGED TO 3
```

Figure 4-108. Join Buses Dialog and Summary Report on Relocation of Load

The summary report indicates that the load on Bus 3008, with identifier 1, was moved to bus 154 and its identifier changed to 3 so as to avoid conflict with two existing loads on that bus. Figure 4-110 shows the Diagram View of the retained bus #154. In the diagram it can be seen that there are now three bus loads on bus 154 and that the bus is now joined to buses 3005, 3007 and 3018, each of which were previously connected to bus 3008 (see Figure 4-109).

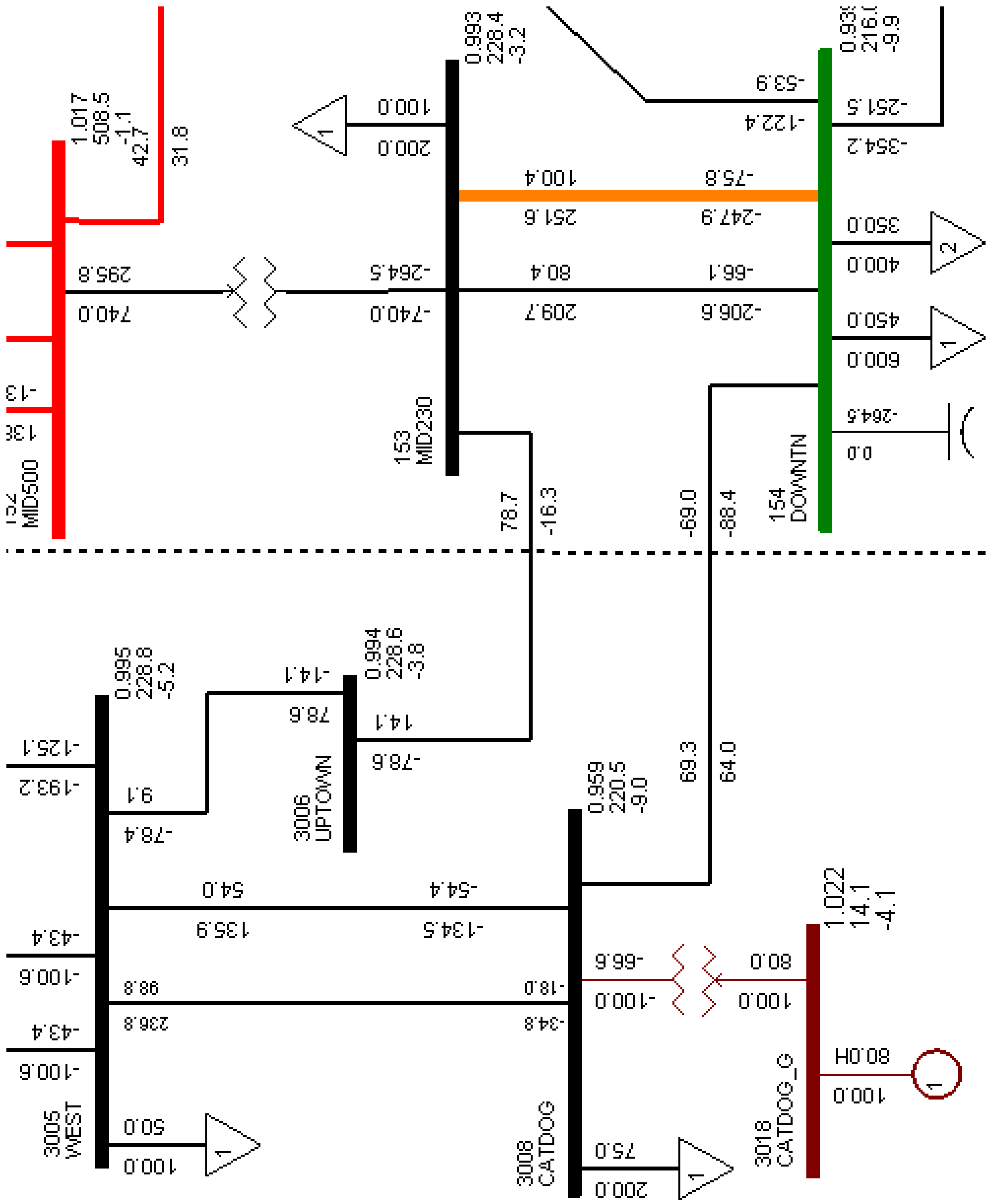


Figure 4-109. Original Topology at Bus 203

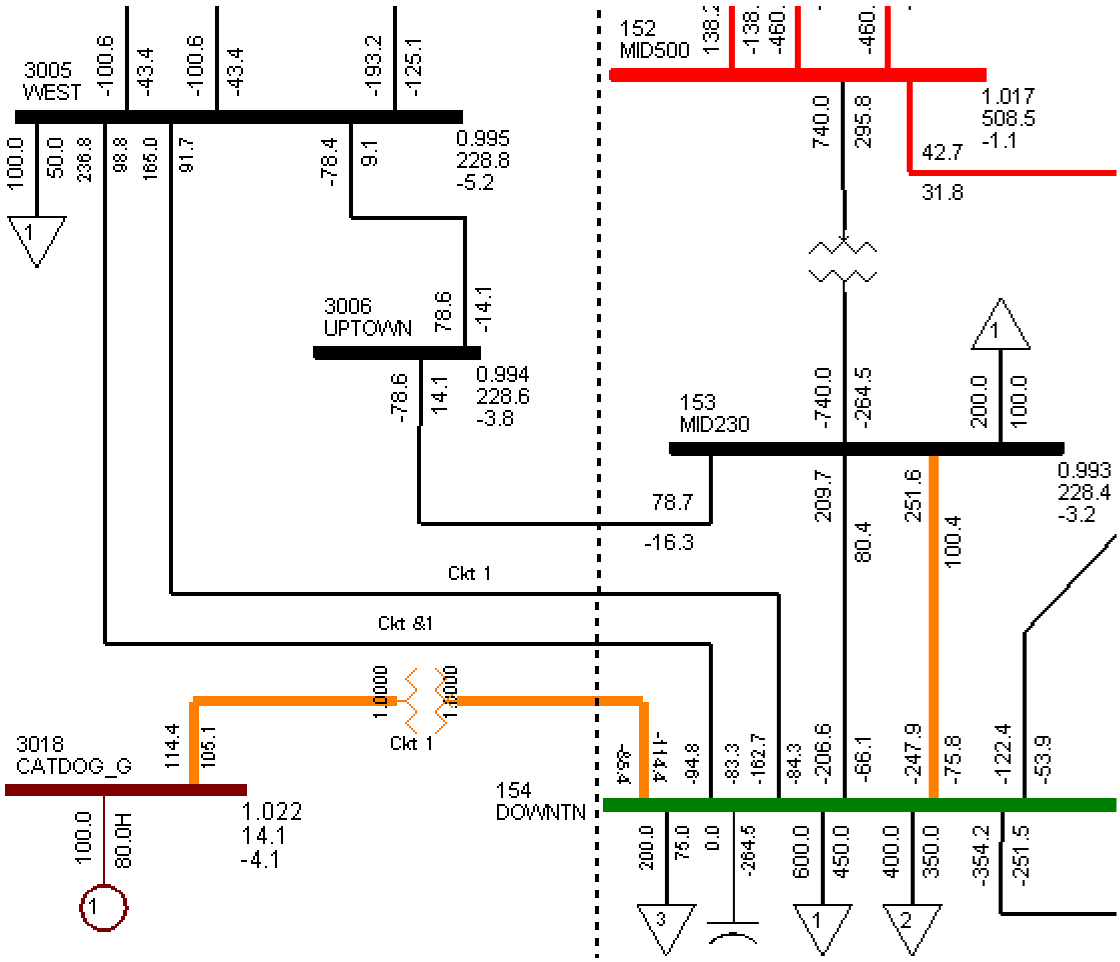
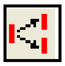


Figure 4-110. Revised Topology with Joined Buses

4.6.5 Splitting Buses

The ***Split buses*** operation enables the user to sectionalize buses into two buses connected by a branch. The procedure creates a new bus and allows the user to designate which of the branches connected to the original bus are to be rerouted to the new bus.



The process is initiated by selecting the ***Power Flow>Changing>Split buses (SPLT)...*** option from the Main Menu or the ***Split Bus*** button on the toolbar, which opens the Split Buses dialog (see Figure 4-111).

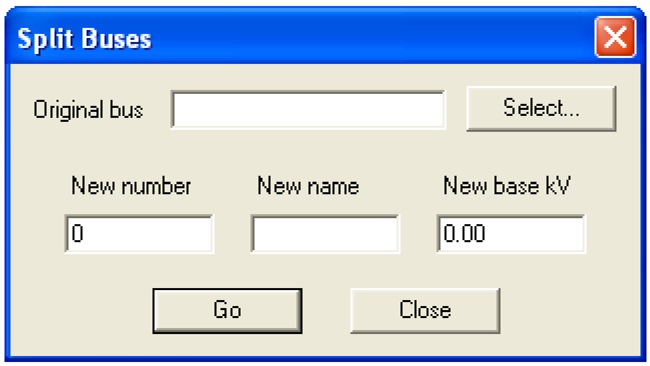


Figure 4-111. Initiating the Split Bus Process

In the Split Buses dialog, the user enters the bus to be split directly in the Original bus input field, or alternatively can click the ***Select...*** button which opens up the Bus Selection dialog. Having selected the bus, the user should provide a bus number, name and Base kV for the new bus. Clicking the ***Go*** button in the Split Buses dialog (Figure 4-111) will initiate the splitting process.

The user is now required to identify which network elements will be moved from the split bus and connected to the new bus. This selection is made in the Reassign Branches and Equipment dialog which opens when the splitting process is underway. Figure 4-112 shows a sample Reassign Branches and Equipment dialog which would display if bus 154 were selected to be split in the *savnw.sav* power flow case. Reassignment can be made for loads, switched shunts, machines and branches.

Finally, when the split is made, a new jumper branch is created to join the original and new buses together. See the notes in the next section.

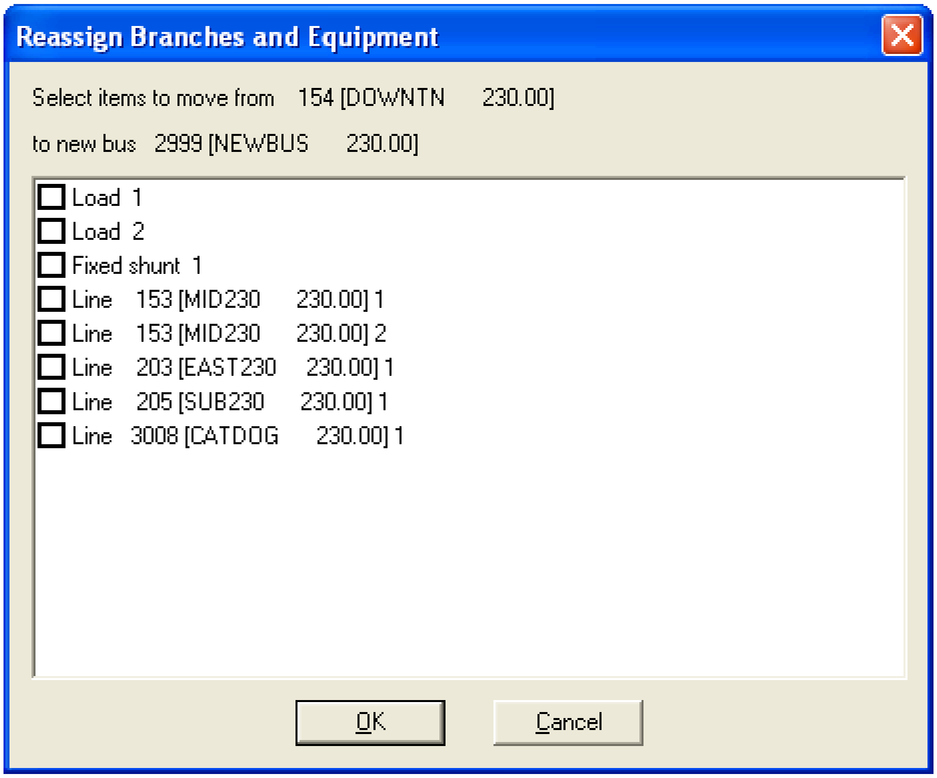


Figure 4-112. Reassign Branches and Equipment Dialog

The new bus is set up with no fixed shunt element, and is given the same area, zone, and owner assignments as the original bus. When generation is moved from the original bus to the new bus, the new bus is assigned the bus type code of the original bus; if all machines are moved to the new bus, the original bus is given a type code of one; if no machines are moved to the new bus, the original bus has its type code unchanged and the new bus becomes a type one bus with no generator entry.

If the zero impedance line threshold tolerance, THRSHZ, is greater than zero, the branch connecting the original and new buses is entered as a zero impedance line. Otherwise, a jumper branch with an impedance of j0.0001 is introduced between the original and new buses. The new branch is given the same owner as the original bus.

If the original bus is an endpoint bus of one or more multisection line groupings and the adjacent line section of a multisection line grouping is rerouted to the new bus, the new bus becomes the endpoint bus of the multisection line. If the original bus is a dummy bus of a multisection line grouping, the multisection line grouping is either:

- Redefined if exactly one of the two branches connected to the original bus is rerouted to the new bus.
- Deleted if neither or both are rerouted to the new bus.

The new bus is given a type code of one (or two or three if generation is moved to it) and the jumper branch between the original bus and the new bus is set to in-service *unless* the new bus becomes a dummy bus of an out-of-service multisection line grouping; in this case, the bus type code is set to four and the jumper branch is set to out-of-service.

If sequence data is contained in the working case (see Section 7.2), it is handled appropriately, including the rerouting of zero sequence mutuals. Branches introduced by the splitting process have their zero sequence impedances set to j0.0001.

Once the new bus has been created, the data associated with the new bus and branch may be modified just as any other bus and branch in the working case.

This splitting process is not sensitive to any interrupt control code options.

Using the *savnw.sav* power flow case, (see Figure 4-113) bus 3003 can be split and circuit 2 from bus 3005 reassigned to the new bus 3020.

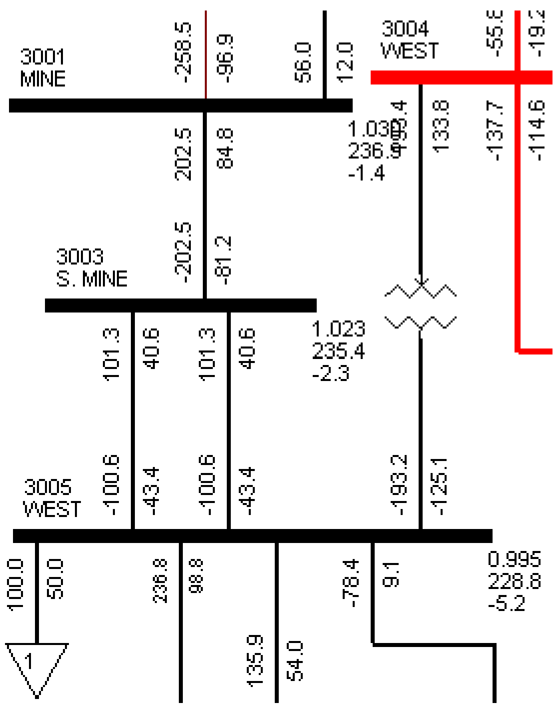
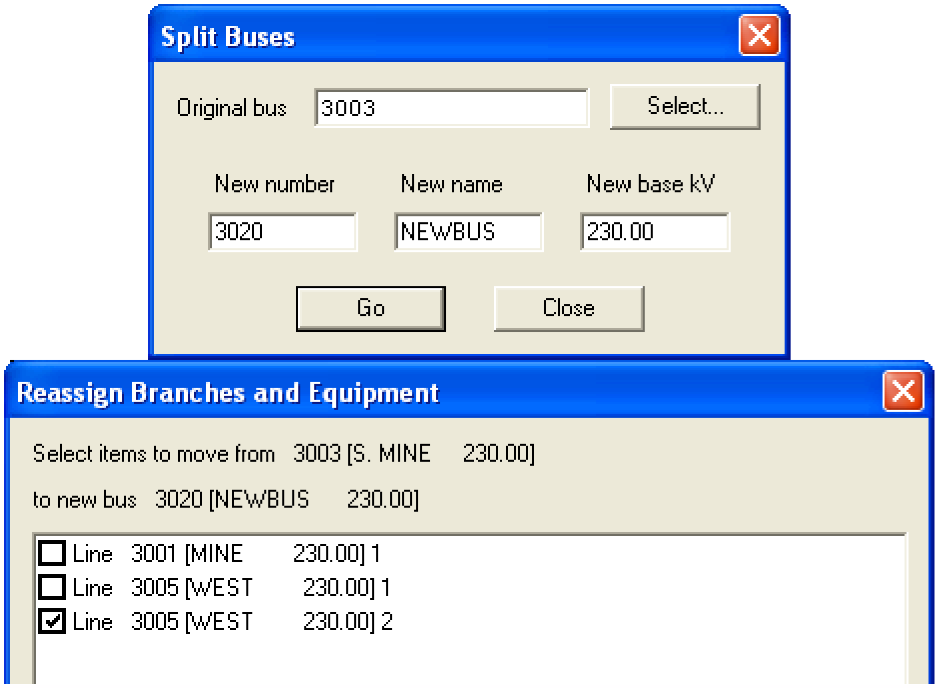


Figure 4-113. Bus 3003 to be Split

Selection of the bus to be split, its number, name and Base kV is done in the Split Buses dialog (see Figure 4-114). After clicking the ***Go*** button, the Reassign Branches and Equipment dialog displays the elements which can be selected to be moved to the new bus 3020. In the example, the option to move circuit 2 from bus 3005 to the new bus has been selected. Clicking the ***OK*** button in the Reassign Branches and Equipment dialog will complete the process. A summary of the changes is shown in the Output Bar (see the lower portion of Figure 4-114).




```
SPLITTING BUS   3003 [S. MINE     230.00]

CIRCUIT 2  FROM   3005 [WEST        230.00] TO   3003 [S. MINE     230.00] MOVED--IS NOW
CIRCUIT 2  FROM   3005 [WEST        230.00] TO   3020 [NEWBUS      230.00]
```

Figure 4-114. Bus Select, Reassign and Output Report Summary for Bus Split

The result of the splitting process can be seen in the Diagram View (see Figure 4-115). The diagram shows the new bus, 3020, the new branch from the new bus to the original bus and the new routing of circuit 2 from bus 3005 to the new bus.

A one-line Slider file conforming to the original topology will now show circuit 2 out-of-service. A modified Slider file will have to be generated to show the new topology.

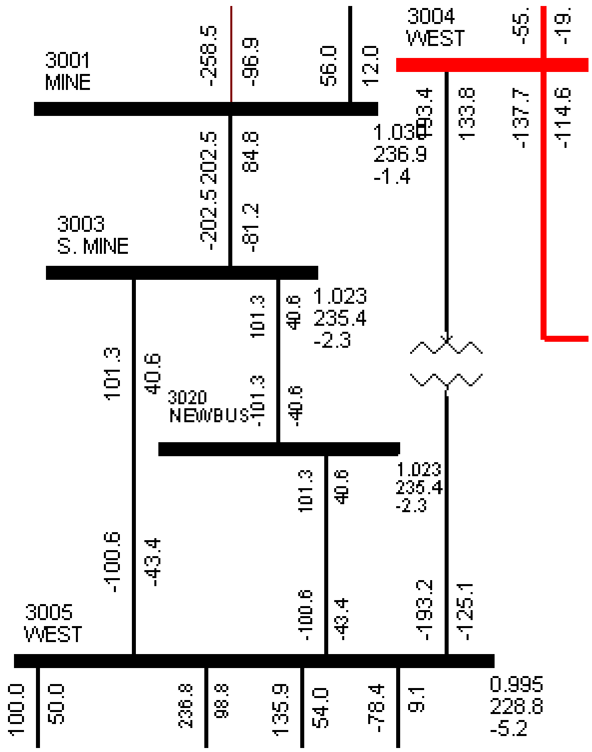
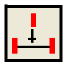


Figure 4-115. Diagram View of New Topology following Bus Split

4.6.6 Tapping a Line

The ***Tap line*** option enables the user to introduce a new bus into the working file at a designated location along a selected AC branch. Any non-transformer branch may be tapped.



The process is initiated by either selecting the ***Power Flow>Changing>Tap line (LTAP)…*** option or by clicking the ***Tap Line*** button. The Tap Line dialog is displayed (see Figure 4-116).

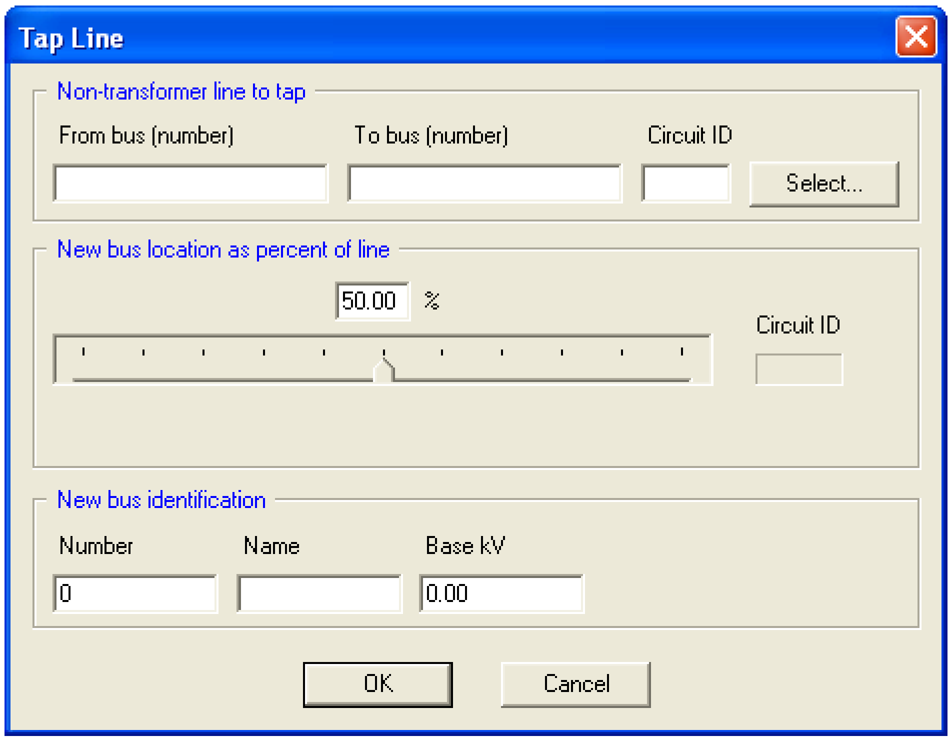


Figure 4-116. Tap Line Dialog

When the new bus is then introduced into the working file it is assigned to the area, zone, and owner of the nearer bus. The new bus is given a bus type code of one if the branch being tapped is in-service, or a type code of four if the branch is out-of-service. It is made a passive node with no load, generation, or shunt elements.

The original branch is split into two branches: one from the original "*from bus*" to the new bus, and one from the new bus to the original "*to bus*", both with appropriate fractions of the original branch impedance and charging. Line connected shunts on the new branches are set such that the line connected shunts from the original branch remain at the original "*from*" and "*to buses*". Circuit identifiers, ratings, status, metered ends, and ownership follow from the original branch.

If the original branch was a member of a multisection line grouping, the grouping's definition is modified to include the two new branches in place of the original branch.

If the working file contains sequence data (see Section 7.2), zero sequence branch parameters are handled in the same manner as their positive sequence counterparts. If the original branch is involved in a zero sequence mutual coupling, the mutual data arrays are modified and extended as appropriate. All mutual data changes are tabulated in the Output Bar.

The line tapping process is not sensitive to any interrupt control code options.

As an example, the branch from bus 3003 to 3005 circuit 1, in the *savnw.sav* power flow case, will be tapped at a point 40% of the distance from bus 3003. A new bus will be created with the number 3020, a name NEWBUS and a base voltage of 230 kV. Figure 4-117 shows the original topology in the Diagram View.

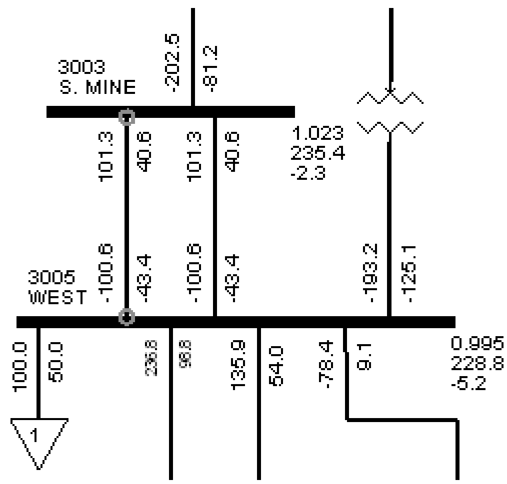


Figure 4-117. Line Selected to be Tapped

In the Tap Line dialog, shown in Figure 4-116, clicking the ***Select…*** button will display the Branch Selection dialog (see Figure 4-118). Selecting a bus in the From bus list will create a list of the To Buses having branches from that bus. The selection is completed by selecting a bus in the To bus list. If required, the filter can be used to reduce the listed buses to those in a specified subsystem.

In Figure 4-118, the branch from bus 3003 to bus 3005, circuit 1, has been selected. Clicking the ***OK*** button will revert the process to the Tap Line dialog.

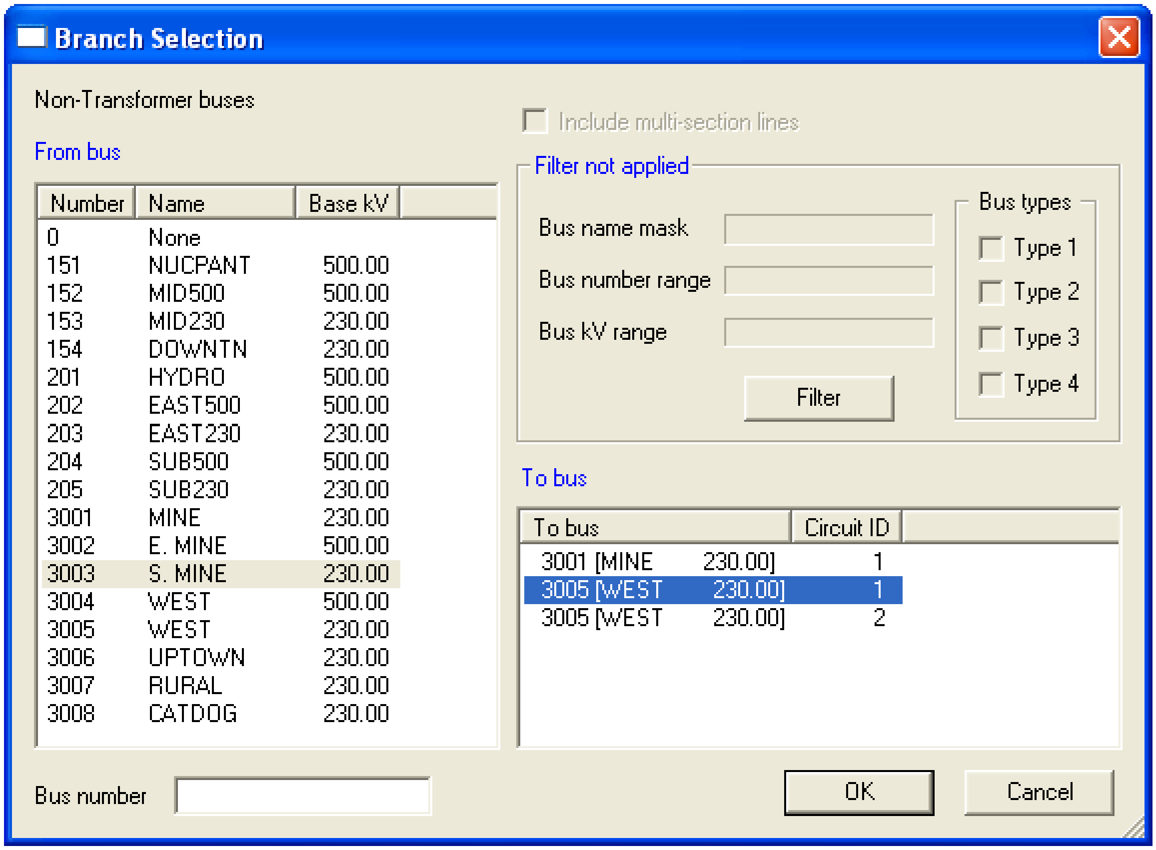
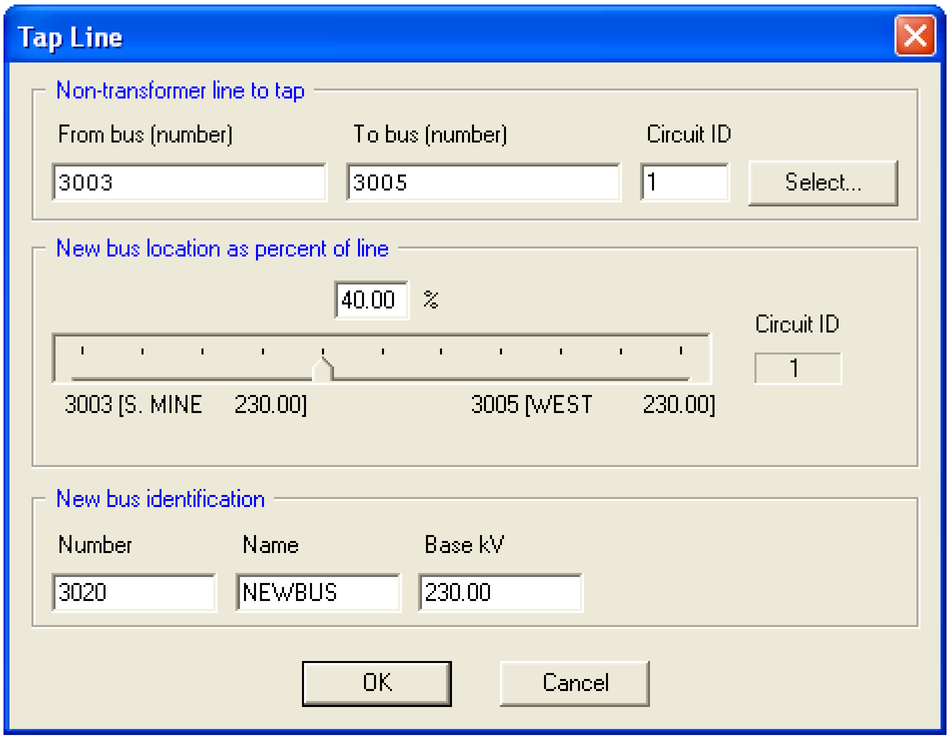


Figure 4-118. Selection of Branch for the Tap Line

In the Tap Line dialog, the tap position, 40% of the distance from bus 3003 and the new bus name, number and Base kV are identified as shown in Figure 4-119. Clicking the ***OK*** button will complete the process and generate a summary report of the action in the output window (see Figure 4-119).

The Output Bar summary report registers the tapping process and also indicates that the mutual coupling has been modified to take into account that the original line now comprises two lines.

At this point, any Slider diagram established for the original network topology will indicate that the tapped line is out-of-service. The one-line Slider diagram will need to be modified to show the new topology with the new bus. Figure 4-120 shows a modified Diagram View of the new topology around the new bus.




```
TAPPING CIRCUIT 1  FROM BUS   3003 [S. MINE     230.00] TO BUS   3005 [WEST

MUTUAL COUPLING RECORD:
  FROM      TO CKT    FROM      TO CKT  MUTUAL IMPEDANCE   BIJ1    BIJ2    BKL1    BKL2
  3003    3005  1     3003    3005  2    0.00250  0.02500 0.0000 1.0000 0.0000 1.0000
CHANGED TO:
  3003    3020  1     3003    3005  2    0.00100  0.01000 0.0000 1.0000 0.0000 0.4000
  3005    3020  1     3003    3005  2   -0.00150 -0.01500 0.0000 1.0000 0.4000 1.0000
```

Figure 4-119. Final Stage in Tap Line and Output View Summary

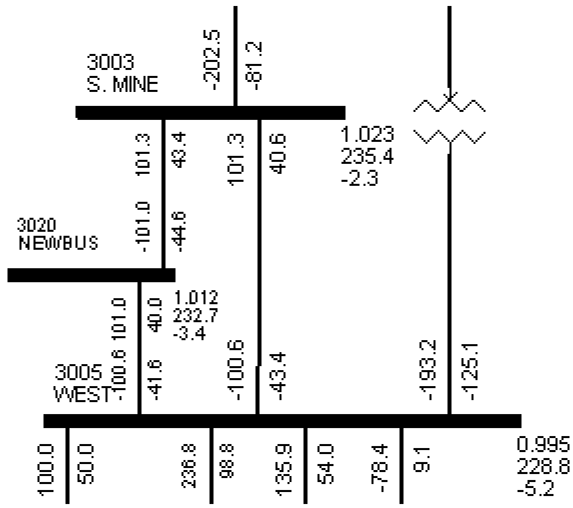
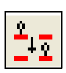


Figure 4-120. New Topology on Tapped Line

4.6.7 Moving Equipment

The ***Move network elements*** option enables the user to move selected switched shunts, loads, machines, and plants from one bus to another. It also provides for connecting the far end of selected branches and one winding of a three-winding transformer to different "*to buses*".



The process is initiated by selecting the ***Power Flow>Changing>Move network elements (MOVE)...*** option or by clicking the ***Move Network Elements*** button on the toolbar, either of which opens the Move network elements dialog (see Figure 4-121).

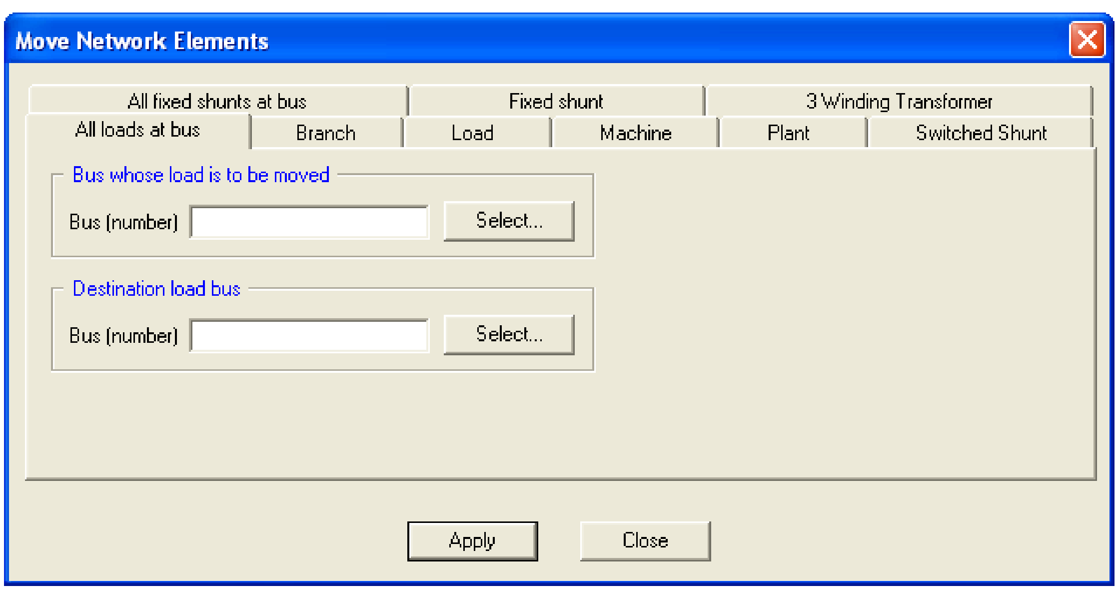


Figure 4-121. Move Network Elements Dialog

After selecting the equipment category by clicking on the corresponding tab, the user designates the individual equipment to be moved and the bus to which the equipment item is to be transferred. Finally, the ***Apply*** button is clicked to complete the transfer. A summary of the action taken is printed in the Output Bar.

4.6.7.1 Moving Branches and Transformers

When rerouting a branch whose circuit identifier matches that of a branch already existing between the "*from bus*" and the new "*to bus*", the existing branch keeps its original identifier and the user is asked to designate a new identifier for the rerouted branch. A similar approach is used in the rerouting of three-winding transformers.

In rerouting branches and three-winding transformers, if the new "*to bus*" is a dummy bus of a multi-section line grouping, that line grouping is deleted since the new "*to bus*" will have three branches connected to it following the rerouting.

If the branch being rerouted is a member of a multisection line grouping and the original "*to bus*" is a dummy bus, the multisection line grouping is deleted; if the original "*to bus*" is an endpoint bus of the multisection line grouping, either the grouping is deleted if the new "*to bus*" is the other endpoint bus, or the grouping is redefined.

In rerouting a branch that is involved in zero sequence mutual couplings, the mutual arrays are updated under the assumption that the rerouted branch retains the same couplings as the original branch.

4.6.7.2 Moving Switched Shunts

In moving switched shunts, if the destination bus does not have a switched shunt and the original one does, the switched shunt of the original bus is transferred to the destination bus. If both buses have switched shunts, the switched shunts are merged, with blocks being assigned in the following order:

1. Reactors from the original bus.
2. Reactors from the destination bus.
3. Capacitors from the destination bus.
4. Capacitors from the original bus.

Control parameters from the destination bus are kept unless the switched shunt at the destination bus controls the admittance setting of the switched shunt at the original bus. In this case, the control parameter data items (MODSW, VSWHI, VSWLO, SWREM, RMPCT and RMIDNT) of the original bus are transferred to the destination bus.

4.6.7.3 Moving Plants and Machines

When moving machines, if the destination bus is not a generator bus, the plant data of the original bus is copied to the destination bus prior to moving the machine. If both buses are generator buses, the machine is transferred to the designated bus and plant totals of both buses are updated. In the case of conflicting machine identifiers, those machines already at the destination bus keep their original machine identifiers and the user is asked to designate a new identifier for the moved machine. If all machines at a bus are moved to other buses, the original bus plant entry is removed.

In moving plants, the destination bus must not be a generator bus; all machines at a plant may be moved to another plant only by moving each individual machine.

In moving machines and plants, bus type codes are updated appropriately. If any moves result in the plant entry of an area swing being deleted, an appropriate message is printed. If the current destination bus is in the same area as the former area swing bus, it becomes the new area swing. Otherwise, the area swing bus number is set to zero.

4.6.7.4 Moving Loads

When moving individual loads, if both buses are load buses and a load with the same identifier as the load being moved is already present at the destination bus, the load previously at the destination bus keeps its original load identifier and the user is asked to designate a new identifier for the moved load. If all loads at a bus are moved to other buses, an appropriate message is printed. When moving all loads at a bus to another bus, the destination bus must not have any other loads; all loads at a bus may be moved to another load bus only by moving each individual load.

4.6.7.5 Notes and Example

The moving process *does not* check that the working file is in the form required by the power flow solution activities. The user is advised to check for islands, the system swing bus specification and the control parameters of merged plants and switched shunts before attempting to solve the modified case. Further, the process is not sensitive to any interrupt control code options.

Using the *savnw.sav* power flow case, the 500 kV line from bus 151, which terminates at bus 201 will be moved to terminate at bus 202. The original topology is shown in Figure 4-122.

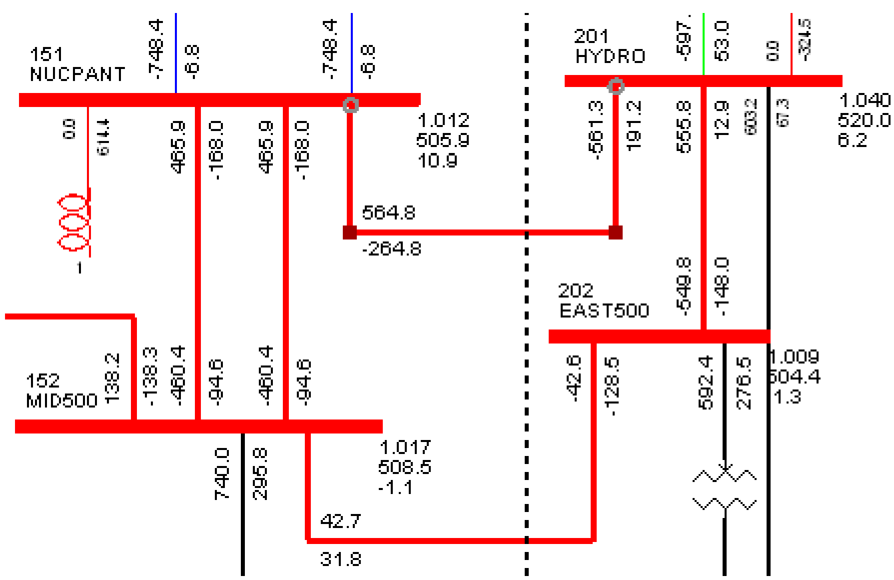


Figure 4-122. Original Topology before Moving Branch 151 - 201

On the Branch tab, in the Move network elements dialog, the original FROM and TO buses and the new TO bus are entered directly or by using the ***Select…*** button (see Figure 4-123).

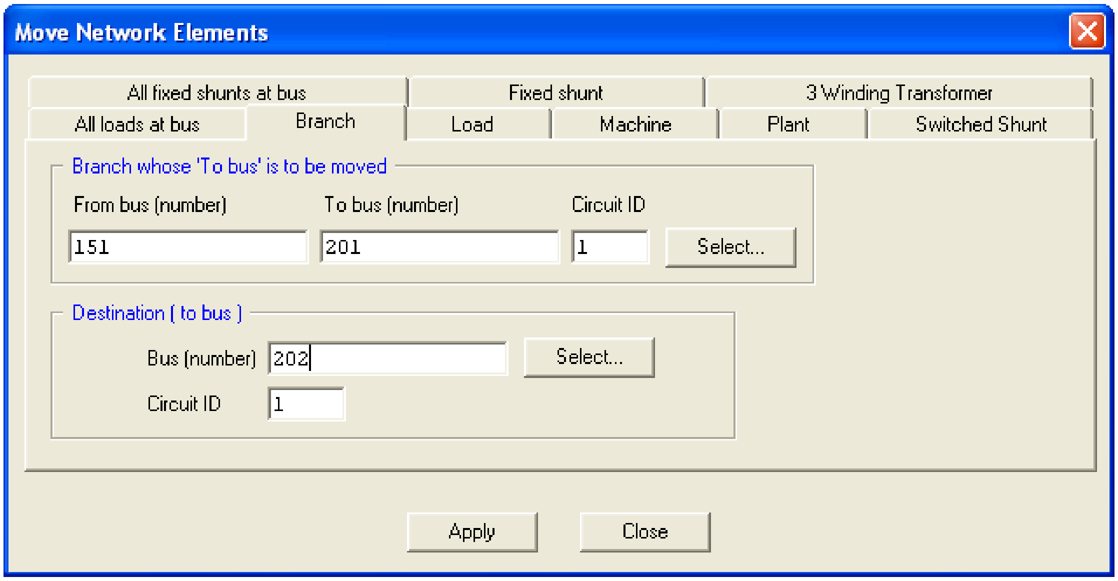


Figure 4-123. Selecting From and To Branch Information for Moving the To Bus

When using the ***Select*** facility, the Branch Selector dialog will display (see Figure 4-124). The selection of a From bus provides a list of available branches and circuits from which a To bus can be selected. A Filter facility is available to limit the available bus listings based on subsystem selection. Clicking the ***OK*** button takes the user back to the Move network elements dialog where the new To bus can be selected.

The terms "*From*" and "*To*" in this network element moving process are not related to the transformer and non-transformer data attributes which relate to windings and taps. Here the "*From"* and *"To"* are used merely to select branches, recognizing that the "*To*" end is the end which will be relocated. For three-winding transformers there are three buses to be selected; the *From, To* and *Last* bus. It is the *Last* bus which can be moved.

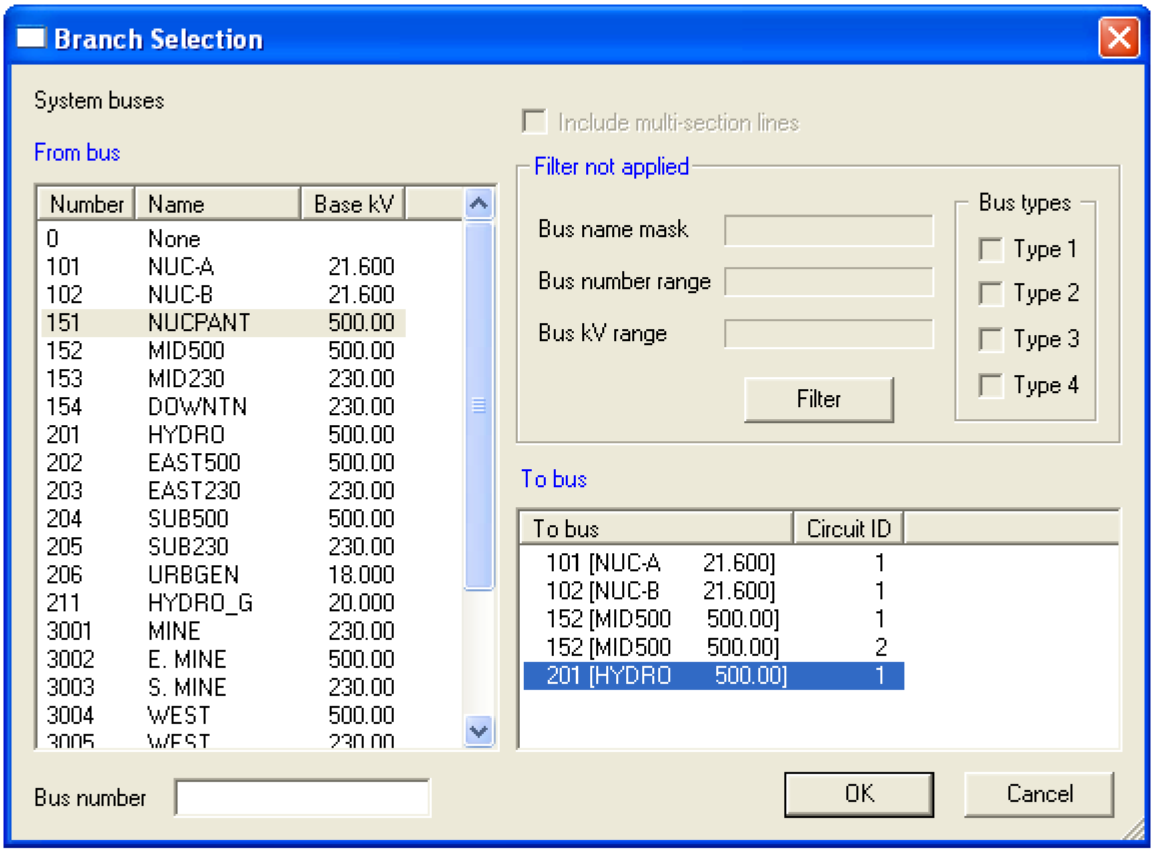


Figure 4-124. Branch Selection Dialog with Available Filter

When the moving process is complete, the original one-line Slider file will not be able to display the new topology. The branch which was moved (in the case of this example, the line from bus 151 to bus 201) will be indicated as out-of-service. The Slider file will need to be modified to display the new line termination. Figure 4-125 shows the new display with the new line location and the indicated "line out-of-service" from the original topology. That now non-existent branch can be deleted from the Slider file. It will no longer be in the network data and will not appear in the Spreadsheet View or Tree View.

The figure also show the summary of the moving action as printed in the Output Bar.

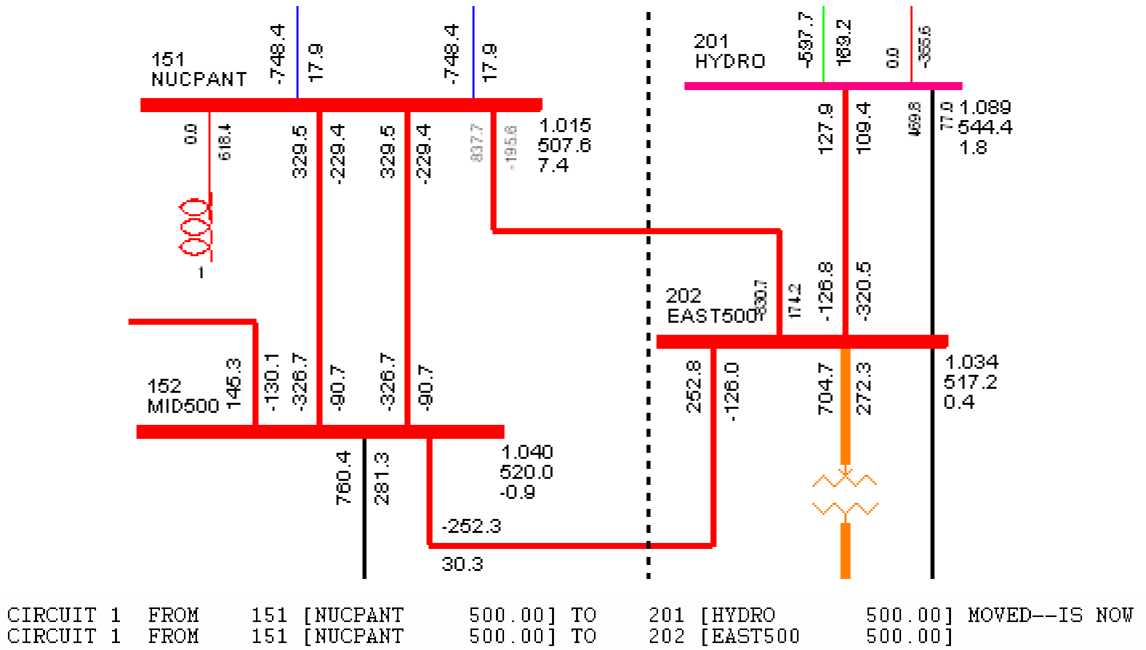
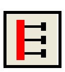


Figure 4-125. New Topology Following Branch Move and Output Report

4.6.8 Modifying the Network Using the Diagram View



Selecting the ***Diagram>Generate graphical power flow bus display (GOUT/GEXM)...*** option or clicking the GEXM/GOUT toolbar button, will initiate the generation of a Diagram View for a selected bus. From within the diagram a variety of operations can be performed. They include:

- Disconnection of buses and all associated data
- Reconnection of buses and all associated data
- Change of network element status
- Examination and changing of network element data
- Examination of power flow conditions

Clicking the GEXM/GOUT toolbar button will open the Select Bus dialog. The desired bus can either be entered directly in the input field provided, or clicking the ***Select...*** button will bring up the Bus Selection dialog from which a bus within the network can be chosen (see Figure 4-126). As is common for other operations or program procedures which require the selection of a bus, this Bus Selection dialog incorporates a Filter with which the user can produce a reduced listing of buses, from which the bus selection can be made. This is particularly helpful with large power flow cases.

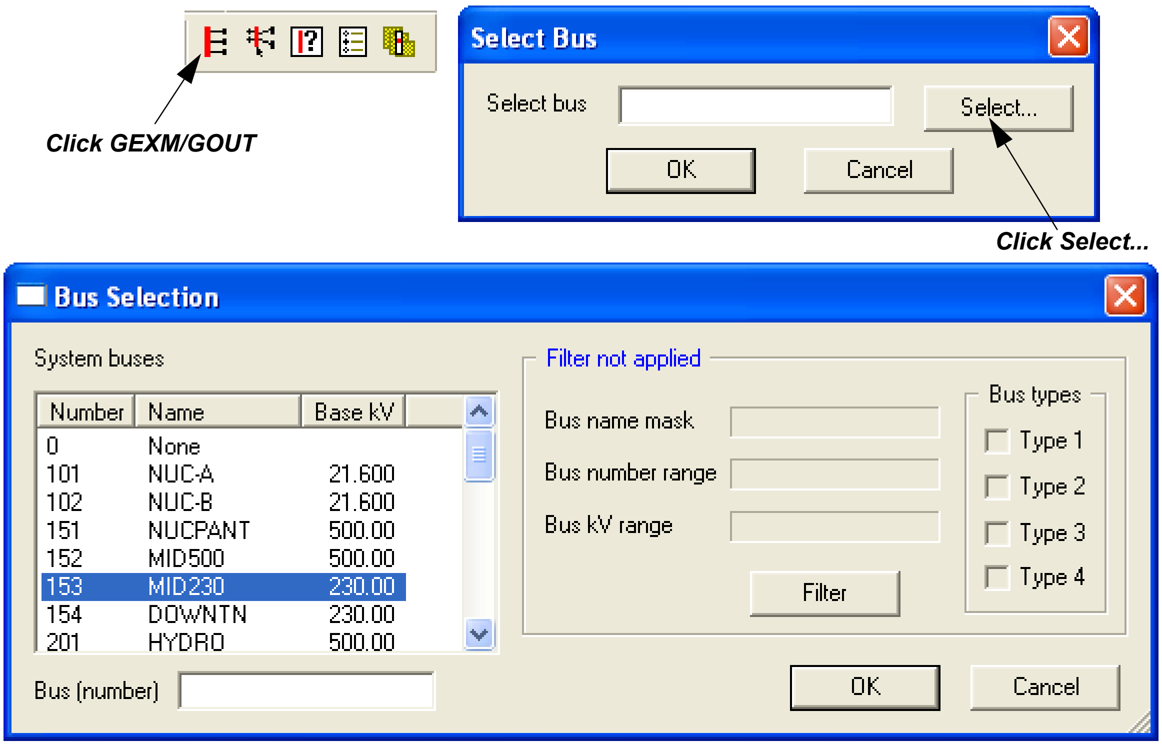


Figure 4-126. GEXM/GOUT Toolbar Button and Bus Selection for Bus 153 MID230

After bus selection a Diagram View will be generated for the selected bus showing associated lines and equipment and distant *"to buses"*. The default symbol for *"to buses"* is the node (see Figure 4-127 where one of the bus' symbols has been toggled to a scalable vertical type node). The user is able to perform the switching actions, data changes and examinations, as listed above, directly from this Diagram View.

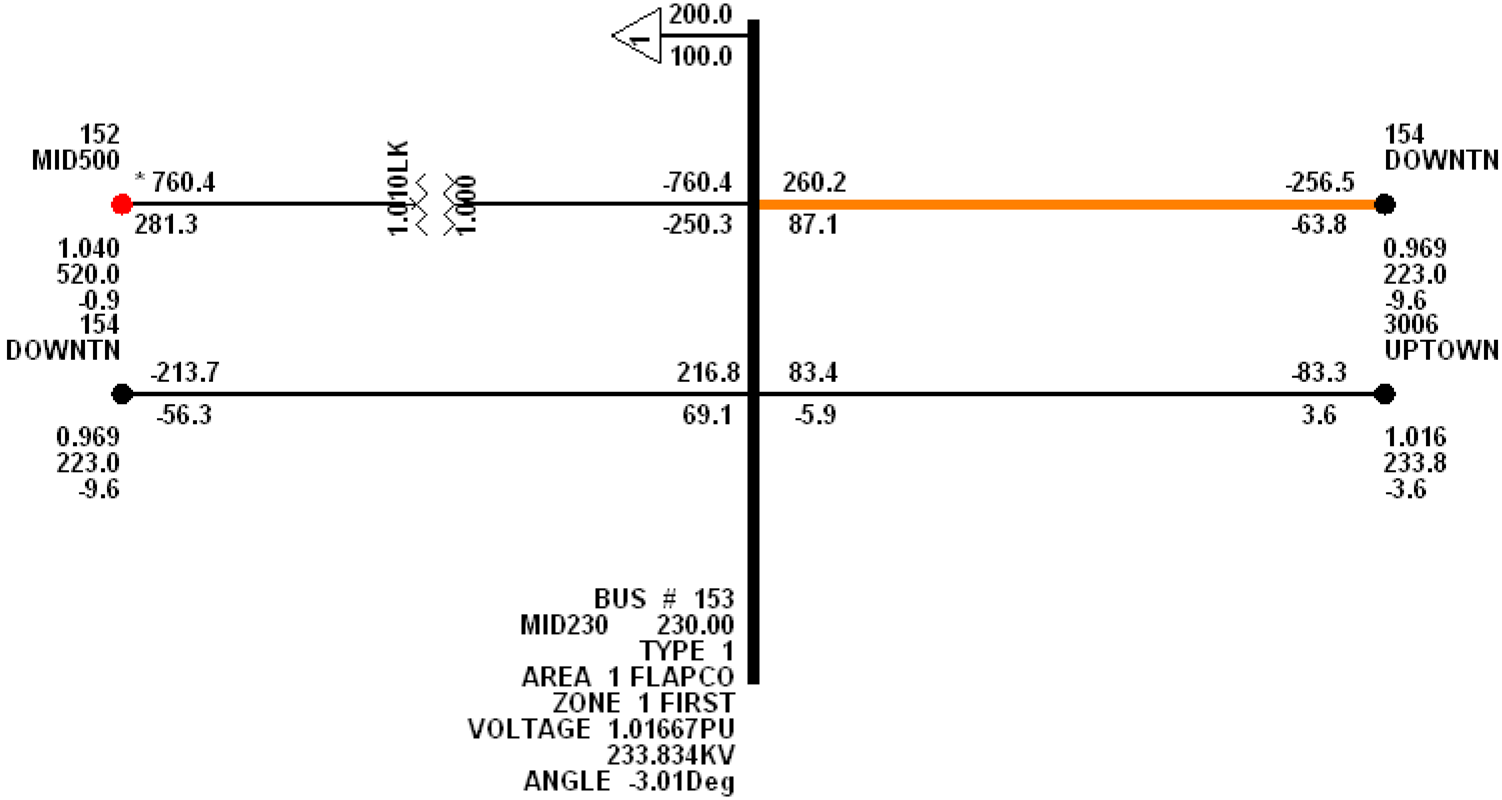


Figure 4-127. Diagram View for Selected Bus 153 MID230 from *Savnw.sav* case

Once the GEXM/GOUT bus is in the Diagram View, subsequently clicking on the "Display Powerflow results" LF toolbar button, will display powerflow results data on the diagram, including:

- Bus number, name, area, zone, voltage and angle.
- Flows to/from distant buses.
- Shunt connected equipment and loading.

Right-clicking on the diagram and selecting ***Diagram Annotation…*** will bring up the Powerflow Data Annotation dialog from which the above values can be selected for display, or hidden.

Clicking on the "Display Impedance data" DAT toolbar button, will display impedance and equipment rating data on the diagram instead of powerflow data (see Figure 4-128).

The view will return to the power flow view by clicking the ***LF*** button. It is useful to note, however, the user can perform switching and data changing operations from the diagram independent of the view.

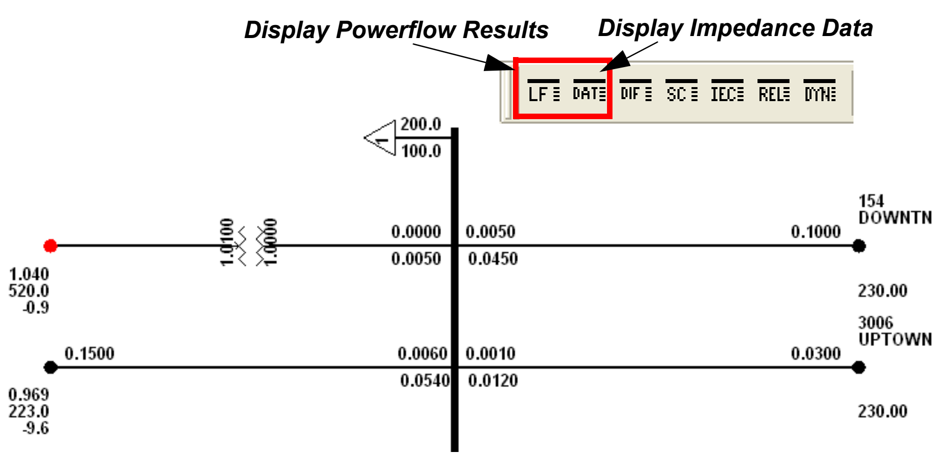


Figure 4-128. GOUT/GEXM View Displaying Impedance Data

4.6.8.1 Using the Data (GEXM) and Load Flow (GOUT) Views

For these notes, reference should be made to Figure 4-127 for the LF view and to Figure 4-128 for the DAT view.

If the selected bus is a generator bus controlling the voltage at a remote bus, the remote bus number, name, and base voltage will be tabulated with the other selected bus information. Further, if the active and reactive power mismatch at the bus exceed 0.5 MVA or kVA, according to the power output option in effect, the mismatch information will be listed.

Each machine at a selected bus is separately displayed with the machine identifier printed inside of the generator symbol. In the LF view, the machine loading is shown along with one of the "H", "L" and "R" flags indicating the current reactive loading condition (see Section 4.4.1.1). In the DAT view, the machine's defined power setting and reactive limits are shown.

Load and shunt elements are represented with actual loadings when shown in the LF view and ratings when shown in the DAT view. Load identifiers are shown within the symbol.

Branches are drawn from the top of the page in ascending "*to bus*" order (numeric or alphabetic according to the bus output option in effect). The "*to bus*" number and name are drawn on the extreme right of the branch line adjacent to the "*to bus*" busbar. Placing the cursor on the branch will pop up the line *from bus* and *to bus* numbers/names and the circuit identifier. In the LF view flows are shown as active and reactive power leaving the "*from bus*" (the selected bus) and as active and reactive power arriving at the *to bus* end. In the DAT view, the R, X and B data quantities are shown.

For two-winding transformer branches, two transformer symbols are drawn between the flow and the *"to bus"*. Off-nominal turns ratio and any nonzero phase shift angle are displayed between the flow and the first transformer symbol and between transformer symbols.

Any three-winding transformer connected to the bus is drawn similar to the two-winding transformer except one more branch and bus are displayed, and off-nominal turns ratio and any nonzero phase shift angle are shown only for the winding connected to the bus box.

When the multisection line reporting option is enabled (see Section 1.6.4), the far end "*to bus*" (rather than the closest "dummy" bus) of each multisection line connected to the bus being displayed is shown as its "*to bus*".

An asterisk ("∗") is drawn at the metered end of each branch. If a branch is a member of a multisection line grouping and the multisection line reporting option is enabled, the asterisk indicates the metered end of the line section adjacent to the bus being displayed and a plus sign ("+") designates the metered end of the multisection line grouping.

Any DC lines connected to the bus are drawn before any AC branches in ascending DC line number order, with two-terminal lines listed first, followed by any multi-terminal lines. Power flow conventions for DC lines are as in the Bus based report output format (see Section 4.2.3). Alpha, gamma, and the converter transformer off-nominal turns ratios are displayed and tagged as in the Bus base reports. For multi-terminal lines, no "*to bus*" end conditions are listed.

Any FACTS device with no series element which is connected to the selected bus is drawn to the left of the bus. It is illustrated with a straight line drawn from the displayed bus and connects to a rectangular box, which is attached to a shunt symbol. The rectangular box contains a power flow direction arrow pointing in the direction of the shunt. The FACTS device number is displayed above the device.

Any series FACTS device connected to the selected bus is drawn to the right of the bus with a line connecting that bus and its associated terminal/send bus. The series element is illustrated by a circle containing an embedded arrow and is located midway on the connecting line. The arrow indicates the power flow direction (sending end bus to terminal end bus direction). The FACTS device number is displayed to the right of the connected bus.

For series FACTS devices with non-zero shunt current and/or bridge active power transfer limits, when the selected bus is the sending end bus, two additional lines are drawn to represent the shunt and bridge element connections. The first line is drawn to the right of the sending end bus underneath the series element connecting line and stops at a point midway between the sending end bus and the terminal end bus. Another line is drawn from that point upward to the series element circle.

4.6.8.2 Disconnecting Buses in the Diagram View

Figure 4-127 shows bus 153 with its associated network elements comprising four non-transformer branches and a load. The LF view shows power flow results for that bus.

The bus along with its network elements can be disconnected directly from the diagram. This operation is initiated by right-clicking the bus to open the Bus Item pop-up menu and selecting the ***Switch*** option.

When disconnecting items in diagram views, the buses, lines and equipment notation will change to indicate their out-of-service condition. The line colors, width and style for out of service equipment are selected in the Diagram Range Checking tab in the Power Flow Data Annotation dialog (right-click on the diagram item and select ***Diagram Annotation…***; see Section 2.9.2).

If the switch operation is performed on bus 153, the diagram produced will indicate that the bus and its associated elements are out-of-service (see Figure 4-129). To reconnect the bus, perform the switch operation again.

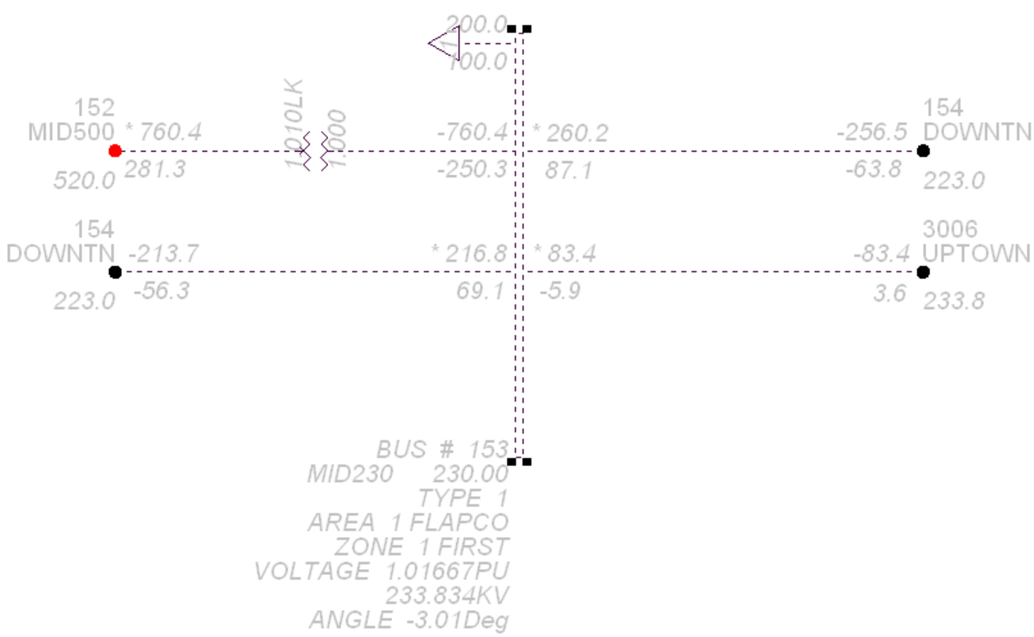


Figure 4-129. Disconnecting Bus from GOUT/GEXM Diagram View

4.6.8.3 Changing Network Equipment Data Using the Diagram View

Right-clicking on any item in the diagram will open that item's pop-up menu which will include, among others, options to change the item's data and/or status (see Figure 4-130).

Item status can be changed from in-service to out-of-service, or vice versa, by selecting the ***Switch*** option.

If the ***Network data*** option is selected, the user is taken directly to that item in the Spreadsheet View where the data changes can be made. Note also that changes in status can be made in the Spreadsheet View.

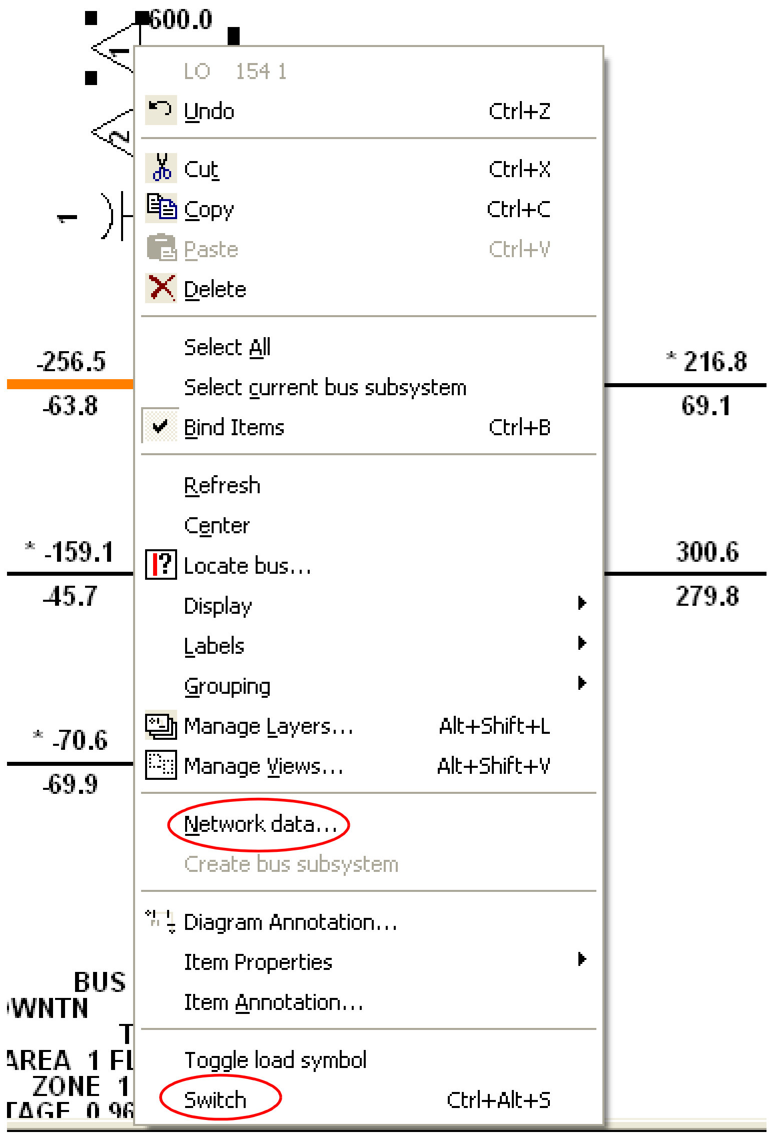


Figure 4-130. Right-Clicking on Load on Bus 154 to Open Item Pop-up Menu

4.6.8.4 Navigating the Network Using the GEXM/GOUT Diagram View

With the diagram opened via the ***GEXM/GOUT*** toolbar button, it is possible to "scroll" through the network to examine power flow conditions, data or to check topology.

To move from the initially selected bus to one of its *to buses*, all that is necessary is to double click the *to bus* node. That node/bus will become the "selected" bus. Figure 4-131 shows the result of double-clicking on to bus #154 from the diagram shown in Figure 4-127 where the selected bus was # 153.

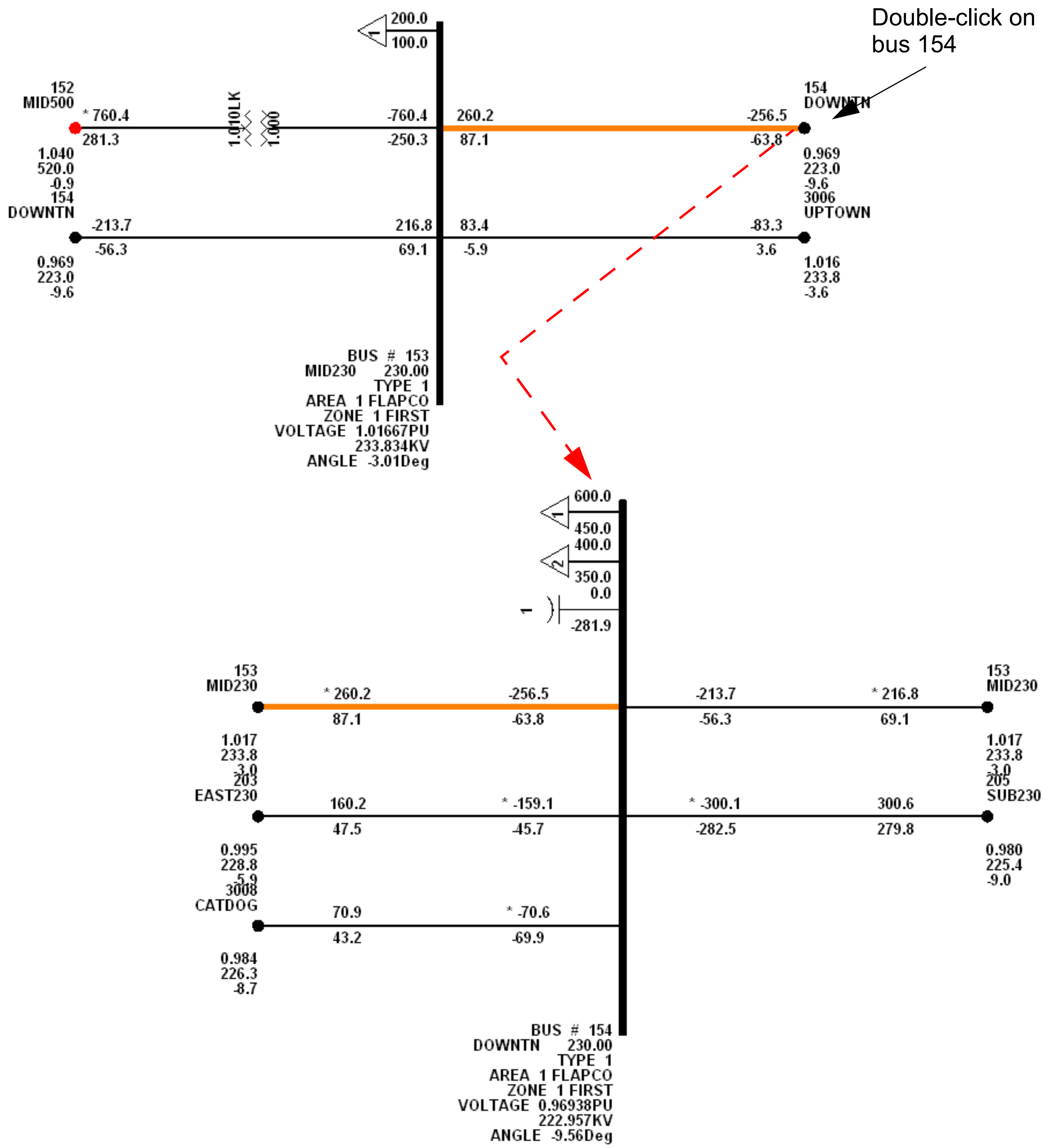


Figure 4-131. Scrolling through the Network

4.7 Renumbering Buses

The bus renumbering procedure, ***Power Flow>Renumber Buses***, enables the user to change the bus numbers of selected network buses in the working file and retain a tabulation of the bus number changes made.

When the renumbering procedure is initiated, the user is asked to specify the output destination, which can be the Output Bar or a file. The output tabulation consists of a series of records documenting those buses that have been assigned new numbers. The records are in the format:

```
old bus number   new bus number / bus name and base voltage
```

When directed to a file, denoted as a Bus Translation File, the output tabulation is useful for the situation where several power flow power flow Saved Cases of identical network topology but, for example, different loading levels are to be renumbered. The Bus Translation File may then be used as input in subsequent executions of the renumbering procedure for the other Saved Cases.

This procedure is not sensitive to any interrupt control code options.

The process is initiated via the ***Power Flow>Renumber Buses*** option (see Figure 4-132).

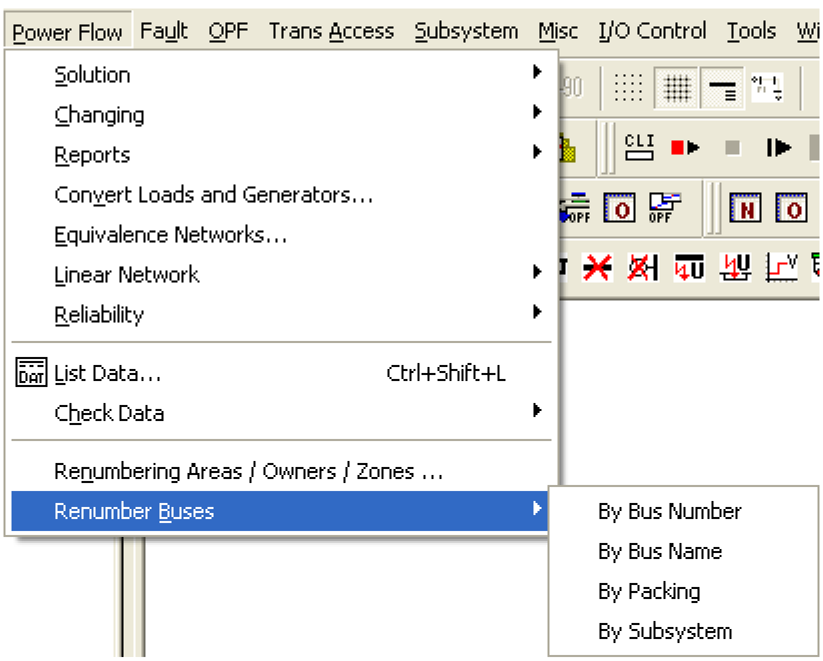


Figure 4-132. Initiating Bus Renumbering Procedure

Bus numbers can be renumbered by Number, Name, Packing and by Subsystem. These options are covered in more detail in the following sections.

4.7.1 Renumbering Buses by Name or Number

Selecting ***Power Flow>Renumber Buses>By Bus Number*** or ***By Bus Name*** will display a Renumber Buses by Bus Number or by Renumber Buses by Bus Name dialog (seeFigure 4-133).

Within the dialog a Bus Translation File can be specified that defines mappings from a series of old bus numbers/names to new bus numbers/names, or individual bus numbers/names can be entered directly in the input fields provided.

When specifying buses in the Old bus number/name and New bus number/name fields a single bus or a series of buses can be selected individually. Once the renumbering procedure is initiated the old and associated new bus numbers are output either to the Output Bar or a file selected by the user. Clicking the ***Go*** button will cause the bus numbers to be changed in the power flow working file. Clicking the ***Close*** button will close the dialog.

When specifying a Bus Translation File of type *.*trn* that file will have the same format as the Data file created by this bus renumbering process. Consequently, the user can create the "translation" file when renumbering buses and retain that information to repeat the process on other power flow data files having the same bus numbering. Specifying the translation file name will avoid having to repeat the bus selection process.

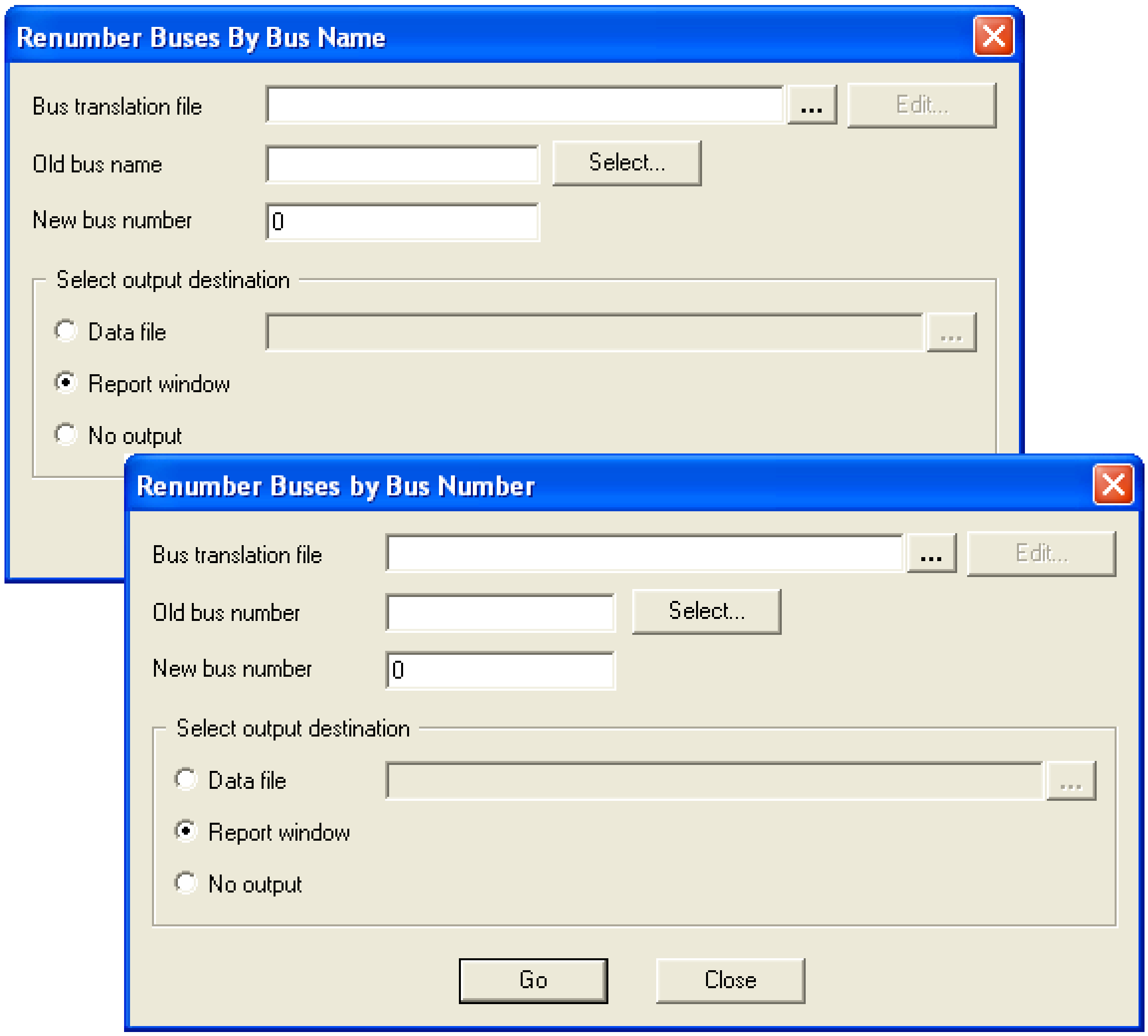


Figure 4-133. Renumber Buses Dialogs for Bus Name and Bus Number

The difference in selecting by number or name will be seen when the ***Select...*** button is clicked. That action will open up an additional dialog in which individual buses can be selected for the renumbering process. The buses will be listed in ascending order of bus number or alphabetical order of bus name. As is common with the PSS™E dialog, a filter is provided to reduce the range of buses from which to make the selection. This is particularly useful for very large data files. Figure 4-134 shows the different Bus Selection dialogs.

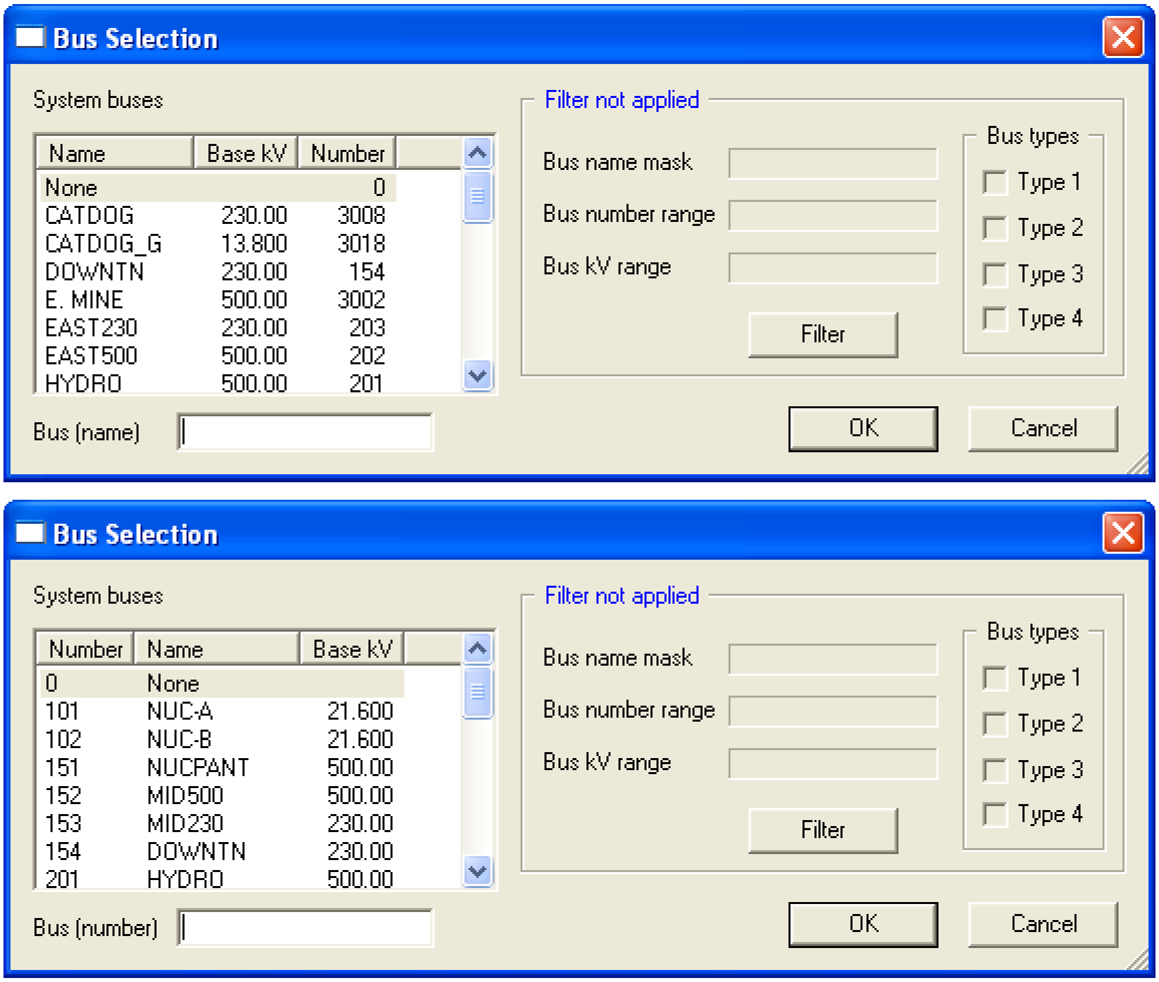


Figure 4-134. Dialogs for Selection by Number or Name

4.7.2 Renumbering Buses by Packing

Selecting ***Power Flow>Renumber Buses>By Packing*** allows the user to select a series of buses and to renumber them sequentially without spaces between numbers. When using this option the Renumber Numbers By Bus Packing dialog opens (see Figure 4-135).

It can be seen that the user can enter the starting and ending bus numbers of a selected series of buses to be packed. In Figure 4-135, buses from 101 to 160 have been selected for packing. There is no translation file facility. Again the output of the selection process can be sent to the Output Bar or a file.

If the ending bus number is less than the starting bus number or greater than 999997, an error message is generated and the input request remains open. If both the starting and ending numbers are valid, the bus numbers falling within the specified range are packed sequentially beginning with the starting bus number.

Following the completion of processing, the following message is printed:

```
n BUS NUMBER CHANGES MADE FOR SPECIFIED SUBSYSTEM
```

The packed buses and their old and new numbers will be listed in the Output Bar or in the selected output file.

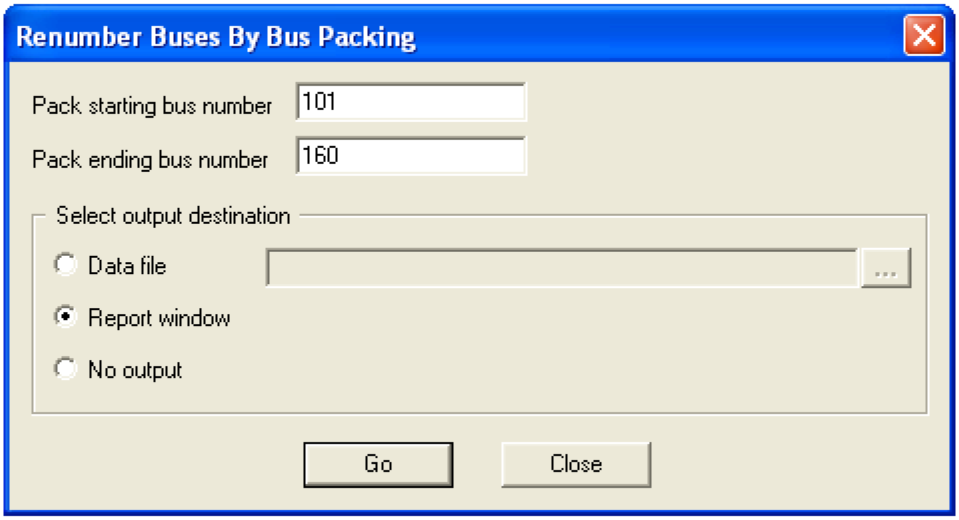


Figure 4-135. Renumber Buses By Bus Packing Dialog

Suppose for example, that bus packing is performed on the range shown in Figure 4-135, for the *savnw.sav* case. The original and resulting new bus numbers are shown in Figure 4-136. It can be seen that the original bus range from 101 to 154 has been packed to a range from 101 to 106.

Bus Number	Bus Name
101	NUC-A
102	NUC-B
151	NUCPANT
152	MID500
153	MID230
154	DOWNTN
201	HYDRO
202	EAST500
203	EAST230

Bus Number	Bus Name
101	NUC-A
102	NUC-B
103	NUCPANT
104	MID500
105	MID230
106	DOWNTN
201	HYDRO
202	EAST500
203	EAST230

Figure 4-136. Packing Bus Numbers

In the Output Bar the following message is printed indicating how many buses have been modified, along with a list of the old and new bus numbers. That list could have been sent to a specified output file.

```
4 BUS NUMBER CHANGES MADE FOR SPECIFIED SUBSYSTEM

--------------------------------------------------
    151     103  / NUCPANT      500.00
    152     104  / MID500       500.00
    153     105  / MID230       230.00
    154     106  / DOWNTN       230.00
```

Figure 4-137. Output Bar Indicating Number of Buses Modified

4.7.3 Renumbering Buses By Subsystem

The ***Power Flow>Renumber Buses>By Subsystem*** procedure facilitates the renumbering of buses by selected subsystems identified by Area, Owner, Zone, Base kV or Bus. Further, bus numbers in a selected subsystem can be packed in a specified range, or the original bus numbers can be incremented by a specified value in either a positive or negative direction. When choosing the procedure, the Renumber Buses By Subsystem dialog is activated (see Figure 4-138).

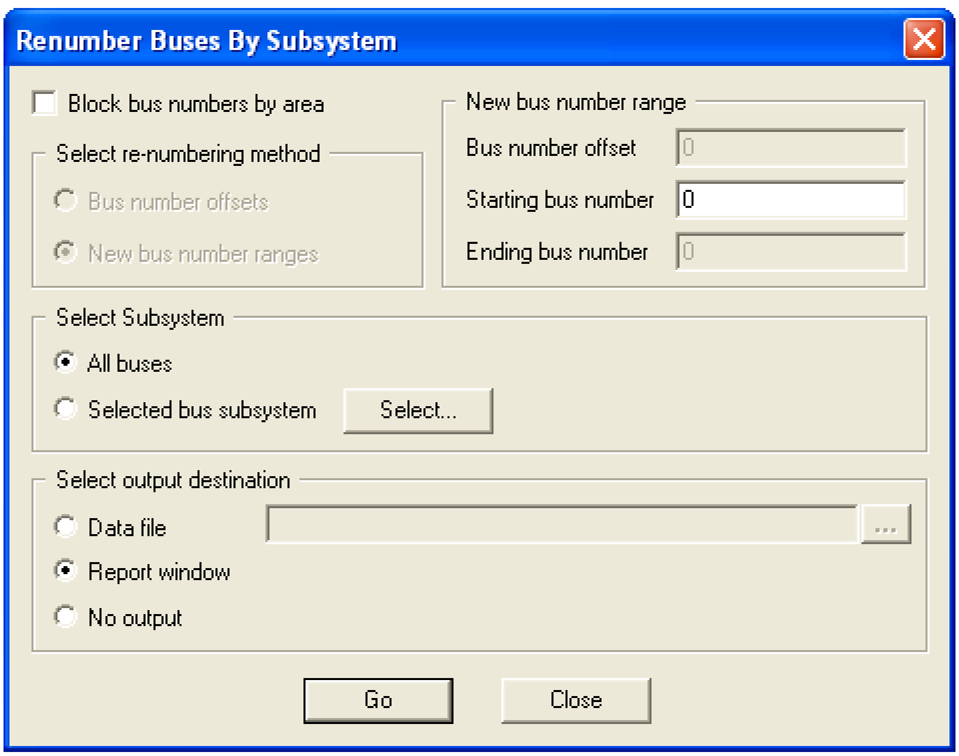


Figure 4-138. Renumbering Buses by Subsystem Dialog

If the user enables the **Block bus numbers by area** option, when ***Go*** is clicked the Block Numbers by Area dialog will open to facilitate the input of a new bus number range for each interchange area in the working file (see Figure 4-139).

No bus number changes are implemented until the new number range for each area in the working case is specified. Consequently, unless non-zero bus numbers are entered to indicate the bus number ranges for each area in the working file, the renumbering process will be terminated with the original numbering intact.

Within each area, the new bus number sequence corresponds to either the original bus number sequence or the bus name sequence, depending on the bus *output* option in force.

Block Numbers By Area

	Area # Name	Number of Buses	Starting Bus	Ending Bus
1	1 [FLAPCO]	6	1	99
2	2 [LIGHTCO]	7	100	199
3	5 [WORLD]	10	200	299

Figure 4-139. Renumber Buses by Area

Figure 4-140 shows the result of selecting this renumbering process using the *savnw.sav* power flow working file. Each of the three areas in the file will require a new bus number range.

In this example, the three area bus ranges are made consecutive. When the ***OK*** button is clicked in the Block Numbers by Area dialog the renumbering process will be completed and the original and new bus numbers will be listed in the Output Bar or the user's designated output file. Figure 4-140 shows the result of this renumbering example as shown in the Output Bar.

```
23 BUS NUMBER CHANGES MADE FOR SPECIFIED SUBSYSTEM
--------------------------------------------------

     101      1  / NUC-A       21.600
     102      2  / NUC-B       21.600
     151      3  / NUCPANT     500.00
     152      4  / MID500      500.00
     153      5  / MID230      230.00
     154      6  / DOWNTN      230.00
     201    100  / HYDRO       500.00
     202    101  / EAST500     500.00
     203    102  / EAST230     230.00
     204    103  / SUB500      500.00
     205    104  / SUB230      230.00
     206    105  / URBGEN      18.000
     211    106  / HYDRO_G     20.000
    3001    200  / MINE        230.00
    3002    201  / E. MINE     500.00
    3003    202  / S. MINE     230.00
    3004    203  / WEST        500.00
    3005    204  / WEST        230.00
    3006    205  / UPTOWN      230.00
    3007    206  / RURAL       230.00
    3008    207  / CATDOG      230.00
    3011    208  / MINE_G      13.800
    3018    209  / CATDOG_G    13.800
```

Figure 4-140. Result of Block Renumbering by Areas

In Figure 4-141 it can be seen that when buses within a selected subsystem are to be renumbered, the user has two options:

- Increment the bus numbers by a positive or negative value by selecting an "offset".
- Packing the buses in a new range identified by the "starting" and "ending" bus numbers.

The buses to be renumbered can be limited to a subsystem based on their Area, Owner, Zone and Base kV or merely by selection of individual buses.

As with other renumbering procedures, the result of renumbering can be shown in the Output Bar or output to a user designated file.

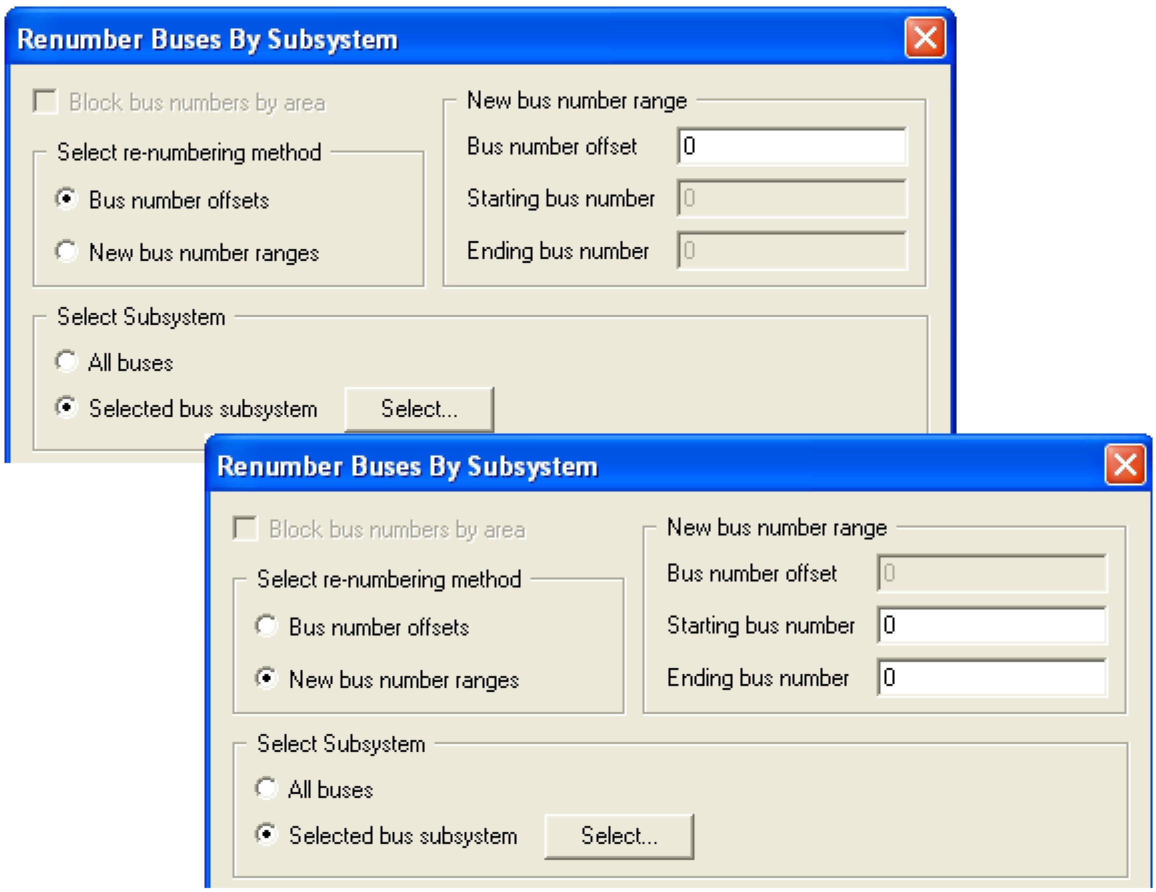


Figure 4-141. Alternative Methods of Renumbering Buses by Selected Subsystems

4.7.4 Renumbering Buses in Auxiliary Data Files

PSS™E employs a variety of data files associated with the power flow network data files used for steady-state analysis. If buses in the Power Flow Raw Data File are to be renumbered, it will be necessary to perform the same renumbering on the associated auxiliary data files in order for them to remain compliant.

The advantage of directing the output of the bus renumbering processes to a file, as described in the previous subsections, is that a record is available of which bus numbers were changed and what the new numbers are. The file can provide this information to the process for renumbering buses in the auxiliary file. Such a file is designated as a Bus Number Translation file and will have a "trn" extension.

Alternatively, a user-created Bus Number Translation File, containing data records of the following form, may also be used as the input to the process.

```
old bus number    new bus number
```

The process of renumbering buses in auxiliary files is initiated with the ***File>Renumber buses in auxiliary files (RNFI)…*** option (see Figure 4-142). The spreadsheet must be the active view for the option to appear.

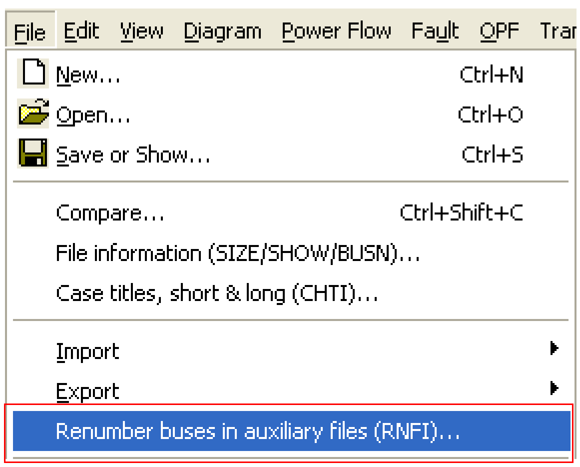


Figure 4-142. Menu for Renumbering Auxiliary Files

Selection of this option will display the Renumber Buses in Auxiliary Files dialog where the user will provide information on the type of auxiliary file to be processed, the Bus Number Translation File name, the specific auxiliary file to be processed and, if required, an output data file (see Figure 4-143).

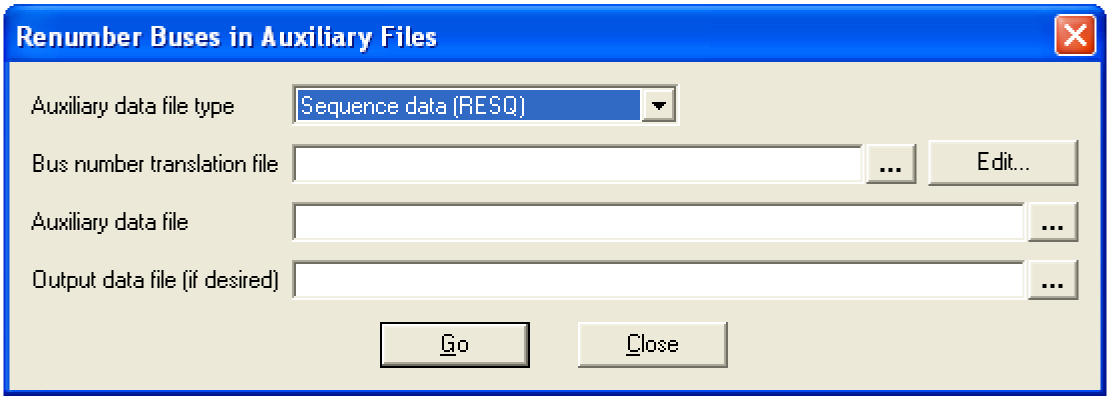


Figure 4-143. Renumber Buses in Auxiliary Files Dialog

There is a wide variety of auxiliary files used by PSS™E (see Figure 4-144). Each of these is discussed in detail in the appropriate sections in the PSS™E manuals.

The output data file is the final piece of information to be supplied by the user. While this is optional, it is most useful to identify an output file. This file will contain a copy of the processed auxiliary data file reconstructed with the new numbering. Consequently it will be immediately available for use with the renumbered Power Flow Data File. The alternative is to allow the reconstructed file to be printed in the Output Bar.

Note that this renumbering process is not sensitive to any interrupt control code options.

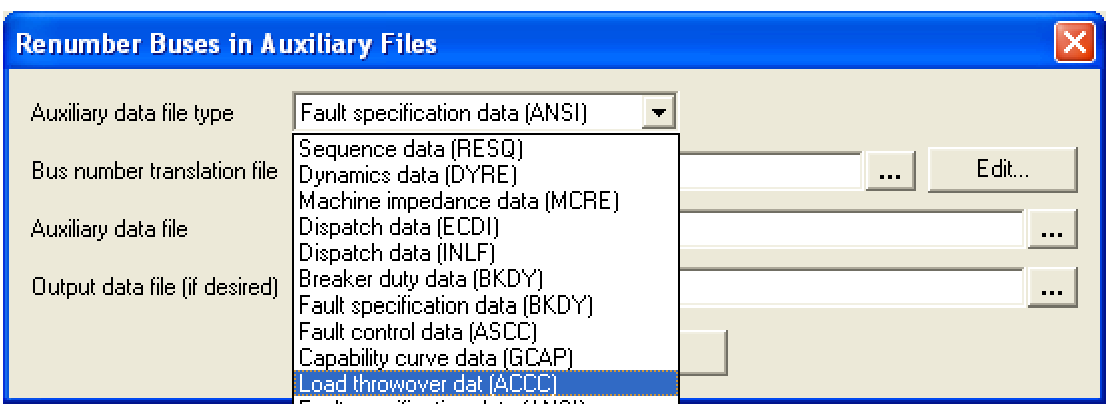


Figure 4-144. Available Auxiliary Files used by PSS™E

4.7.5 Renumbering Subsystem Groups (Area/Owner/Zone)

For the purposes of system analysis, for planning and operations, it is normal for users to take advantage of the PSS™E facility to assign buses and loads to specified areas and zones. In addition it is useful to be able to assign other network elements to specified owners. Assignments to ownership can be made not only for buses and loads but also for:

- Machines
- Branches
- FACTS devices
- VS DC lines

It should be noted that buses, loads and the elements listed above will be assigned by the user or will take on a default assignment when the power flow case is first set up. This means that there is always an existing assignment and that this renumbering process is one of changing assignments rather than providing an initial one.

PSS™E facilitates such renumbering or reassigning via the ***Power Flow>Renumbering Areas/Owners/Zones...*** option. Selection of that option will display the Renumbering Areas/Owners/Zones dialog (see Figure 4-145).

In this dialog, tabs may be selected for Area, Owner and Zone assignments. Within each of the tabs options are available for reassigning buses and loads, a listing of the Areas/Owners/Zones and their names which are already in use as well as the Areas/Owners/Zones which are not currently in use but available, and a subsystem selection utility. WIth this dialog it is possible to reassign to Areas, Owners or Zones which are already in use or those which are not.

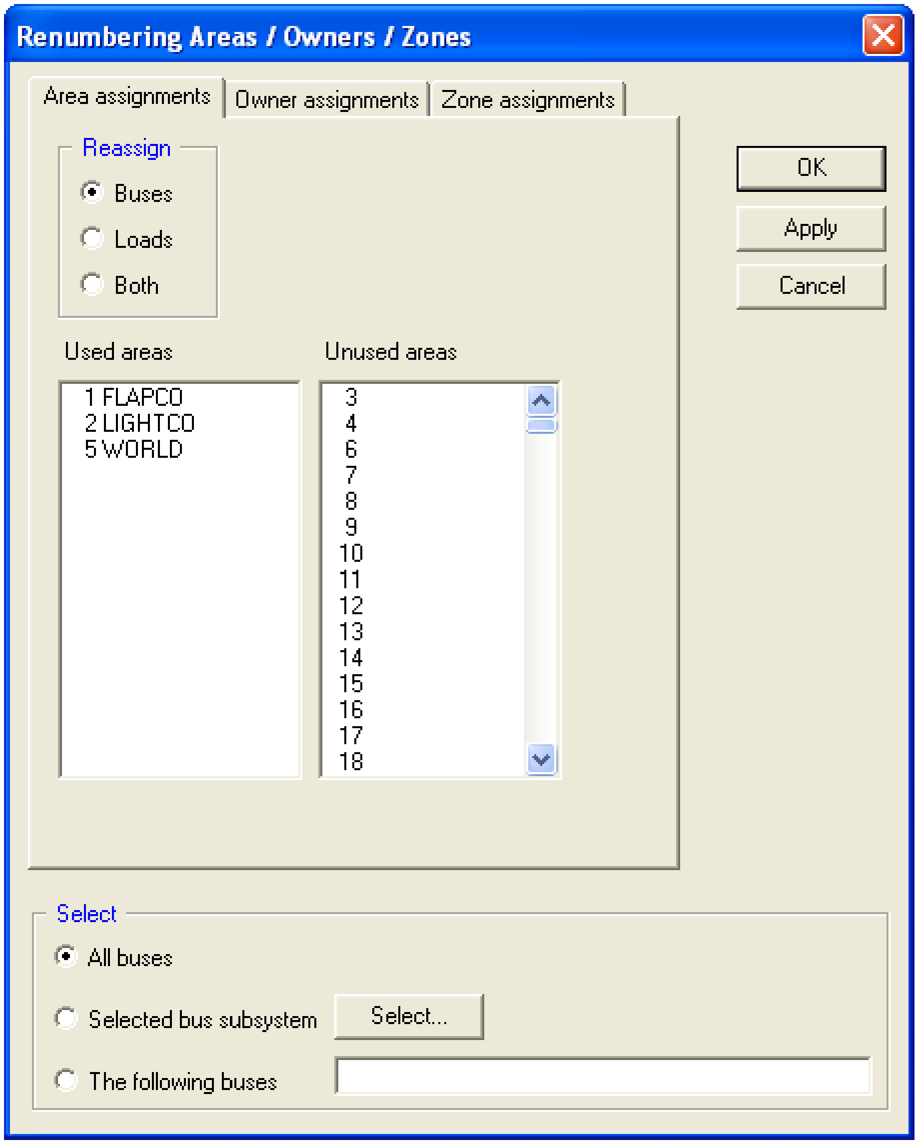


Figure 4-145. Renumbering Area/Owner/Zone Dialog

4.7.5.1 Renumbering Areas and Zones

Clicking on either the **Area assignments** or **Zone assignments** tab of the Renumbering Areas/Owners/Zones dialog window will produce essentially identical dialogs.

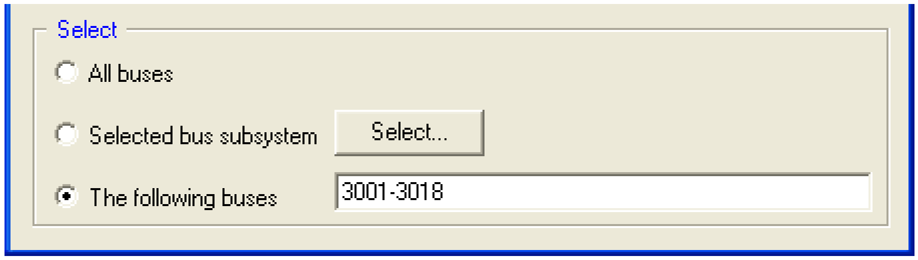
An example of area renumbering would best explain the process. Suppose that all buses in Area 5 (WORLD) in the *savnw.sav* power flow case needed to be reassigned to Area 2 (LIGHTCO). Before the reassignment it is useful to examine the Area information. Figure 4-146 shows via the Spreadsheet View that there are three Areas with a zero net interchange comprising four inter-area transactions from Area 1 (FLAPCO).

Area Number	Area Swing Bus	Desired Interchange	Tolerance (MW)	Area Name
1	1	250.00	10.00	FLAPCO
2	105	-100.00	10.00	LIGHTCO
5	208	-150.00	10.00	WORLD

From Area Number/Name	To Area Number/Name	Id	Transaction MW
1 FLAPCO	2 LIGHTCO	A	70.000
1 FLAPCO	2 LIGHTCO	B	30.000
1 FLAPCO	5 WORLD	A	100.000
1 FLAPCO	5 WORLD	B	50.000

Figure 4-146. Area and Inter-Area Interchange Information

The Select facility shown in Figure 4-145 allows selection of Area 5 as a subsystem or by identification of all buses in the Area to be re-numbered. In this example, let's select the ten buses residing in Area 5. Specify the bus number range in the "The following buses" field as "3001 -3018". Then highlight, in either the Used areas or Unused areas listing, the Area to which the buses will be reassigned. For this example, Area 2 was selected and ***OK*** was clicked. The results of this process is recorded in the Output Bar, at a printer or to a file of the user's choice (see Figure 4-147).




```
DUPLICATE INTER-AREA TRANSFER IDENTIFIER A
IDENTIFIER OF RE-ASSIGNED INTER-AREA TRANSFER CHANGED TO 1

DUPLICATE INTER-AREA TRANSFER IDENTIFIER B
IDENTIFIER OF RE-ASSIGNED INTER-AREA TRANSFER CHANGED TO 2

AREA ASSIGNMENT CHANGED FOR:
    10 BUSES

AREA     2 [LIGHTCO     ] CONTAINS:
  BUSES      LOADS  DC BUSES
     17          4         0

WARNING: BUS   3011 [MINE_G      13.800] IS A TYPE 3 BUS IN AREA    2 [LIGHTCO
         AREA    2 SLACK BUS IS BUS    206 [URBGEN      18.000]
```

Figure 4-147. Output Report on Reassignment

As shown in the output displayed in Figure 4-147, because Area 5 no longer has any buses assigned to it, the inter-area assignments have to be changed. It also indicates that Area 2 now has 17 buses and 4 loads, and that the system swing bus, 3011, now resides in Area 2 where that Area's slack bus, 206 already resides.

The modifications to network information will be indicated in the Spreadsheet View (see Figure 4-148). The inter-area transactions, which previously were identified for Area 5, as transactions A and B, have now been assigned to Area 2 as transactions 1 and 2 to avoid the conflict. This change was indicated in the Output Bar shown in Figure 4-147. The total transactions remain the same.

Area Number	Area Swing Bus	Desired Interchange	Tolerance (MW)	Area Name
1	101	250.00	10.00	FLAPCO
2	206	-250.00	10.00	LIGHTCO

From Area Number/Name	To Area Number/Name	Id	Transaction MW
1 FLAPCO	2 LIGHTCO	1	100.000
1 FLAPCO	2 LIGHTCO	2	50.000
1 FLAPCO	2 LIGHTCO	A	70.000
1 FLAPCO	2 LIGHTCO	B	30.000

Figure 4-148. Modified Area and Inter-Area Information following Reassignment

4.7.5.2 Renumbering Owners

When reassigning network elements by owner, the **Owner assignments** tab in the Renumbering Areas/Owners/Zones dialog gives the user access to reassigning ownership of machines, branches, VSC DC lines and FACTS devices (see Figure 4-149). Additional reassignment options are available for series elements.

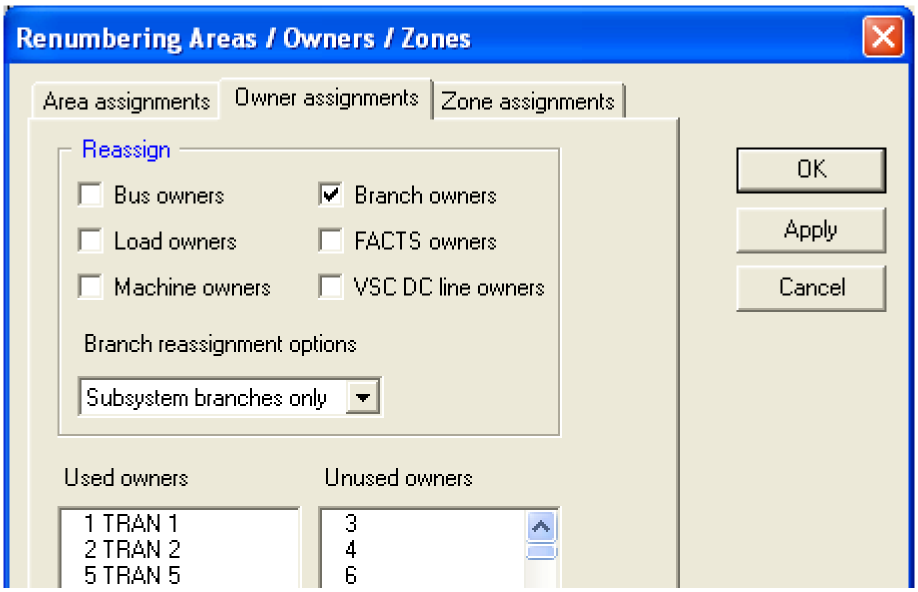


Figure 4-149. Renumbering Areas/Owners/Zones Dialog: Owner Assignments Tab

When one or more of the branch devices (Branch, FACTS or VSC DC lines) is selected, the Branch reassignment options field is active and a selection may be made (see Figure 4-150). The following branch reassignment options are available:

- Elements in the selected subsystem.
- Elements with terminals in the selected subsystem and a neighboring system, i.e. ties.
- Elements in the selected subsystem and the ties.

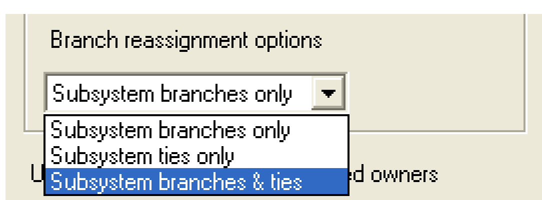


Figure 4-150. Selection Options for Series Elements (Branches)

The entire owner reassignment process entails:

- Selection of the network element type.
- Selection of the subsystem containing the elements to be reassigned.
- Selection of the owner number to which the elements will be reassigned.

Following the owner reassignment process, the following occurrences and conditions are logged in the dialog output device:

- The destination owner has a blank name and the reassignment process assigns to it the owner name from an owner which has a nonblank name and which is emptied during the owner reassignment process.
- An owner no longer has any equipment assigned to it.

The owner reassignment process then lists the number of buses, loads, machines, branches, FACTS devices, and/or VSC DC lines transferred to the destination owner, and the total number of buses, loads, machines, branches, DC buses, FACTS devices, and VSC DC lines now assigned to the owner, or, if no changes were made outputs:

```
NO OWNER ASSIGNMENT CHANGES FOR SELECTED SUBSYSTEM
```

To determine if an equipment item is processed in subsystem mode, for any active attribute (e.g., area), if the equipment item possesses the attribute (e.g., loads have an area attribute), it is used; otherwise (e.g., machines do not have an area attribute), the corresponding attribute of the bus is used.

When reassigning ownership for machines, branches, and VSC DC lines previously designated as having multiple owners, each ownership block is assigned to the new owner unless subsystem specification by owner is enabled. Under subsystem specification by owner, only those ownership blocks previously assigned to the specified owners are reassigned.

When reassigning ownership for FACTS devices, FACTS devices with no terminal bus specified (e.g., a STATCON) are not candidates for processing under the "subsystem ties only" series element renumbering option. Series FACTS devices are processed using the same criteria as AC branches and VSC DC lines (subsystem branches only, subsystem ties only, or subsystem branches and ties).

The owner reassignment process does not change the owner assignments of DC buses internal to multi-terminal DC lines.

The reassignment process is not sensitive to any interrupt control code options.

4.8 Economic Dispatch

The Economic Dispatch facility, accessed by selecting the ***Power Flow>Changing>Economic dispatch (ECDI)… option,*** provides a combined unit commitment and economic dispatch utility. This procedure places machines in a specified subsystem on or off line to satisfy a given subsystem minimum capacity. The in-service machines in the subsystem are then dispatched on the basis of equal incremental cost to meet a specified total subsystem generation.

The Economic dispatch process requires minimum and maximum outputs, incremental heat rates, fuel costs, and start-up priority rankings for all machines to be scheduled. This data should reside in source file form in an Economic Dispatch Data File (*.ecd), which is read at initiation of the procedure.

4.8.1 Creating the Economic Dispatch Data File

Each machine to be dispatched must have a dispatch data record specified for it in the Economic Dispatch Data File. The exceptions are those machines that are the "supplementary" units of a dispatch group. The following standard data record is applicable for all individual machines which will be dispatched and those machines which are the "principal" machines of a dispatch group. Data requirements for the supplementary machines in a dispatch group are shown in Section 4.8.1.2.

4.8.1.1 Standard Record Format

Each machine to be dispatched, except for those machines that are the "supplementary" units of a dispatch group, must have a data record specified for it in the Economic Dispatch Data File in the following format:

```
I,ID,PRIOR,FUELCO,PMAX,PMIN,HEMIN,X1,Y1,X2,Y2,X3,Y3,X4,Y4,X5,Y5,X6,Y6
```

where:

I	Bus number; bus I must be present in the working case and have a nonzero generator number assigned to it.
ID	One- or two-character machine identifier of the machine at bus I whose data is specified by this record. ID = '1' by default.
PRIOR	Priority ranking code ($\geq$ 0). Machines with a priority ranking of zero do not have their status changed during the unit commitment portion of the process. Machines with lowest positive priority ranking codes are switched in-service first even though machines with higher priority rankings may be more economical to run. Machines with highest priority ranking codes are switched out-of-service first even though machines with lower priority rankings may be more expensive to run. PRIOR = 0 by default.
FUELCO	Fuel cost for the machine in dollars per MBtu. No default is allowed.
PMAX	Maximum machine active power output; entered in MW. If this machine is the "principal" unit of a dispatch group, this is the sum of the maximum outputs of all machines in the dispatch group. If defaulted, PMAX **and PMIN** for this machine are set to the power limits currently in the power flow case (see Section 3.2.4).
PMIN	Minimum machine active power output; entered in MW. If this machine is the "principal" unit of a dispatch group, this is the sum of the minimum outputs of all machines in the dispatch group. If **PMAX** is defaulted, the value specified for PMIN is ignored and the one currently in the power flow working case is used; otherwise, no default is allowed.

HEMIN	Minimum heat input required by the machine when on-line; entered in MBtu/hr. If X_1 (see below) is greater than zero, HEMIN should be specified as the heat input required at "X_1" MW. No default is allowed.
X_i,Y_i	Points on the incremental heat rate curve; X_i values are entered in MW and Y_i values are entered in Btu/kWh. At least two points, and up to six points, may be entered. Both X and Y must be in ascending order, with $X_1 \geq$ PMIN and $X_n \leq$ PMAX. If this machine is the "principal" unit of a dispatch group, this curve is the combined curve of all machines in the dispatch group.

For the user's reference, the PSS™E EXAMPLE directory contains an economic dispatch file, *savnw.ecd*, which can be used in conjunction with the power flow case *savnw.sav*. A plot of those incremental heat rate curves is shown in Figure 4-151.

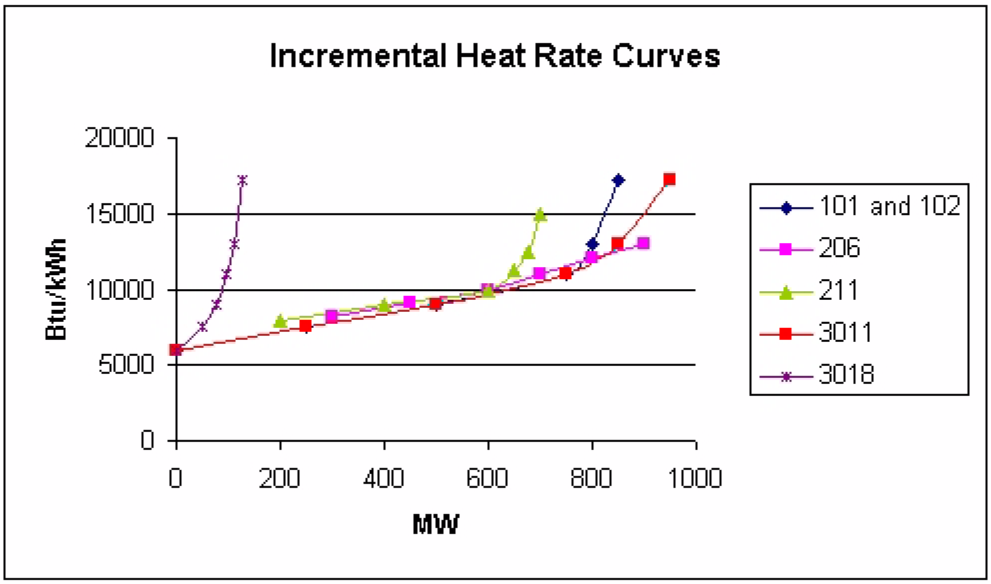


Figure 4-151. Incremental Heat Rate Curves Provided in the PSS™E savnw.sav Case

The auxiliary program PLINC may be used to plot the incremental heat rate curves of selected machines. Refer to *PSS™E Program Operation Manual,* Section 10.5 for details on its use.

4.8.1.2 Supplementary Unit Dispatch Groups

A special record format is recognized on which a "supplementary" unit of a dispatch group is specified. This record has the following format:

```
I,ID,PRIOR,FRACT,PRNBUS,PRNMAC,CODFRC
```

where:

I	Bus number; bus I must be present in the working case with a nonzero generator number assigned to it.
ID	One- or two-character machine identifier of the machine at bus I whose data is specified by this record. ID = ’1’ by default.
PRIOR	Priority ranking code (< 0). A negative priority ranking code signifies that this machine is a "supplementary" unit of a dispatch group. No default is allowed.
FRACT	When CODFRC is zero or negative, the fraction of the total power dispatched for the dispatch group to be assigned to the "principal" unit. When CODFRC is positive, the fraction of the total power dispatched for the dispatch group to be assigned to this "supplementary" unit. FRACT must be greater than zero and less than one. No default is allowed.
PRNBUS	Bus number of the "principal" machine associated with the dispatch group of which this "supplementary" unit is a member. No default is allowed.
PRNMAC	One- or two-character machine identifier of the "principal" machine at bus PRNBUS associated with the dispatch group of which this "supplementary" unit is a member. PRNMAC = ’1’ by default.
CODFRC	Defines the interpretation of FRACT on this record by the economic dispatch process. When CODFRC is zero or negative, FRACT is the fraction of the total power dispatched for the dispatch group to be assigned to the "principal" unit. When CODFRC is positive, FRACT is the fraction of the total power dispatched for the dispatch group to be assigned to this "supplementary" unit. CODFRC = 0 by default.

A Standard economic dispatch data record (see Section 4.8.1.1) must be included in the data input file for machine PRNMAC at bus PRNBUS. Its power output limits and incremental heat rate curve must be that corresponding to the combination of all machines in the dispatch group.

4.8.2 Application Notes

A dispatch group provides a means of handling a group of machines which are to be treated as a single entity in the unit commitment and economic dispatch calculations. A combined cycle plant, in which multiple steam units and combustion turbines are to be dispatched as one unit, may be handled as a dispatch group. The high pressure, low pressure pair of a cross compound unit may also be treated as a dispatch group.

To specify a dispatch group, any one (and only one) of the machines in the dispatch group must be designated on a standard Economic Dispatch Data File record (see Section 4.8.1.1); this machine is referred to as the "principal" unit of the dispatch group. The dispatch data specified on this data record must be that for the combination of all machines which are members of the dispatch group. Each of the remaining units in the dispatch, must be specified on a supplementary Economic Dispatch Data File record (see Section 4.8.1.2); these machines are referred to as the "supplementary" units of the dispatch group.

The sum of the FRACT values on all of the "supplementary" data records of a dispatch group must be less than one. When a dispatch group contains more than two machines, the data record for each of its "supplementary" machines must have CODFRC specified as a positive number, and FRACT as the fraction of total group power assigned to the "supplementary" machine. When a dispatch group contains exactly two machines, CODFRC for the "supplementary" machine may be specified as a positive or negative number or zero, and FRACT must be specified accordingly (see Figure 4-152).

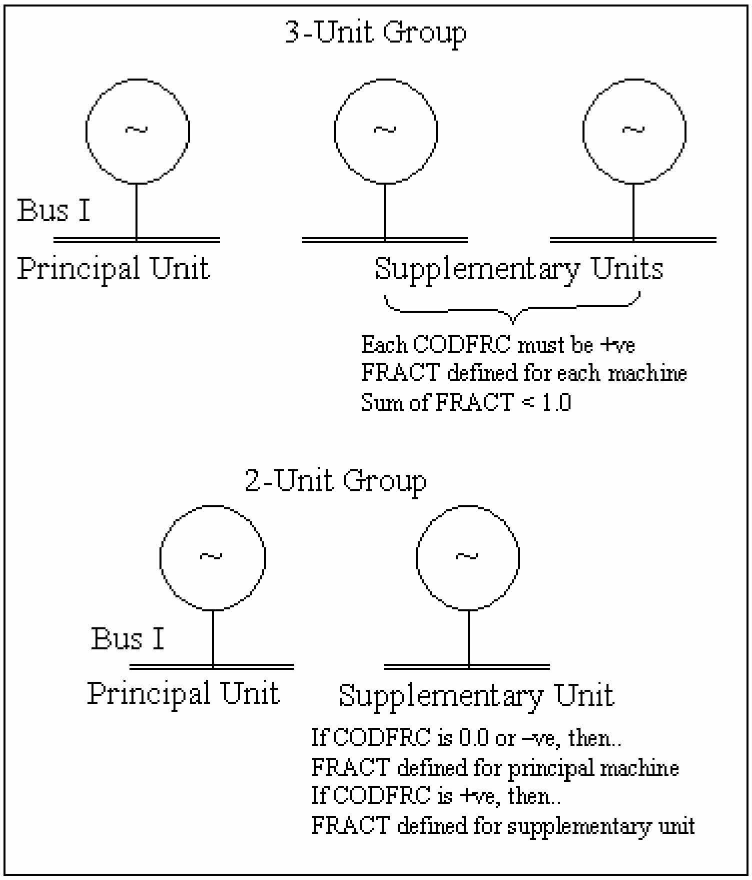


Figure 4-152. Assignments for Supplementary Machine Economic Dispatch

The initial service status of each machine in a dispatch group, as determined by the combination of the type code of the bus to which it is connected and its machine status flag, must be the same: either all in-service or all out-of-service. If the status of a dispatch group is switched during the unit commitment calculation, the status of each machine in the dispatch group is changed.

For a dispatch group, at the completion of the dispatch calculation, the dispatch group's total power output is split among the machines in the group according to the split fractions FRACT specified on the data records of the "supplementary" machines in the group (see Section 4.8.1.2).

When PMAX (and hence PMIN) are defaulted in the Economic Dispatch Data File, the machine limits contained in the working case are used as the dispatch limits (see Section 4.8.1.1). For a dispatch group, the sums of the limits of all machines in the group are used as the dispatch limits. In this case, it is possible to violate the individual machine limits as contained in the working case if FRACT is not coordinated with the individual machine limits.

When a subsystem of the power flow working case is being processed, the subsystem assignment of the "principal" unit of a dispatch group is taken as the subsystem assignment of the group. If the "principal" unit is in the subsystem being processed, its dispatch group is processed even if one or more of its "supplementary" units is not in the subsystem. Conversely, if the "principal" unit is not in the subsystem being processed, the dispatch group is not processed even if some or all of its "supplementary" units are in the subsystem.

When the subsystem to be processed is specified by owner, the owners to which machines (rather than buses) are assigned are used in defining the subsystem of machines to be processed. If a machine has multiple owners (see Section 3.2.4), the owner specified in the owner/fraction pair with the largest ownership fraction is assumed to have dispatch responsibility. If this largest ownership fraction is identical for two or more owners of a machine, the first one in the tables, as shown in the machine data listings is used.

The iterative dispatch calculation in the economic dispatch process is a binary search technique with an upper limit of 40 iterations. Convergence is assumed when the difference between dispatched power and desired power is less than 0.00001 times the desired power. Convergence failure, which is usually the result of precision limitations, is alarmed and the economic dispatch process continues as if convergence had been achieved.

4.8.3 Performing an Economic Dispatch

Selecting the ***Power Flow>Changing>Economic dispatch (ECDI)*** option will display the Economic Dispatch dialog (see Figure 4-153).

The subsystem selector is available for the user to identify which specific subsystems of the power flow case ("Area", "Zone", "Owner", "base kV") or which specific buses are to be processed. The dispatch is performed on only those machines in the specified subsystem for which valid dispatch data had been read. Other machines retain their initial status and power outputs.

The user is provided with the facility to identify the Economic Dispatch Data File (type **.ecd*) to be processed and to decide whether of not to base the subsequent dispatch on an existing unit commitment of a new one. If a new unit commitment is selected, all machines in the specified subsystem with a nonzero priority ranking for which dispatch data had been read are placed out-of-service prior to commencing the unit commitment calculation. Otherwise, the current unit commitment status profile is used as the starting point.

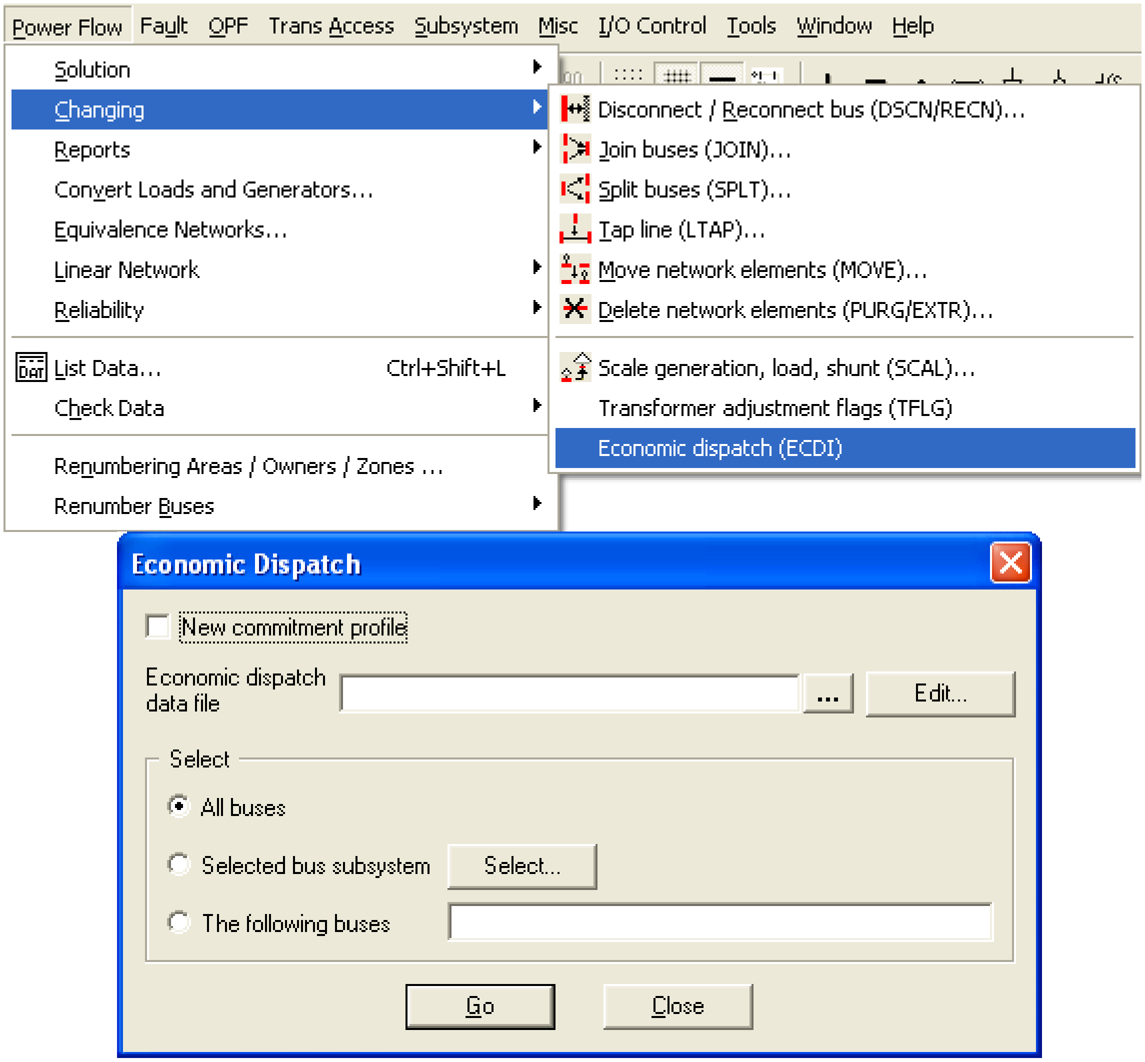


Figure 4-153. Launching the Economic Dispatch Procedure

After defining the subsystem to be processed and identifying the data file, clicking the ***Go*** button will invoke the process and output a summary of the predispatch condition to the Output Bar or output device of the user's choice.

```
PRE-DISPATCH PRODUCTION COST IS  15031.86 $/HR

PRESENT TOTAL GENERATION OF UNITS BEING DISPATCHED IS    3258.670
MAXIMUM GENERATION OF DISPATCHED UNITS NOW ON-LINE IS    4375.000
MINIMUM GENERATION OF DISPATCHED UNITS NOW ON-LINE IS    1800.000

PRESENT GENERATION OF SUBSYSTEM BEING DISPATCHED IS      3258.670
```

This is the result obtained using the *savnw.sav* power flow case and *savnw.ecd* file.

The first four quantities in the above summary are totals based upon the present power outputs and dispatch data specified in the data input file for those machines initially in-service in the subsystem to be processed. The final total is the sum of the present power outputs of those machines to be processed, and those machines in the specified subsystem for which no dispatch data was provided and whose outputs will not be changed by the economic dispatching process.

Following the summary of predispatch conditions, the process will prompt the user for additional information including the **Desired load** and **Desired minimum capacity** of units being dispatched (see Figure 4-154). The values specified for these two quantities should be entered as those applying to the machines to be dispatched. Specifically, they must not include the power outputs assigned to those machines within the specified subsystem for which dispatch data was not read.

In Figure 4-154, a new load level has been selected for the *savnw.sav* power case prior to performing the economic dispatch.

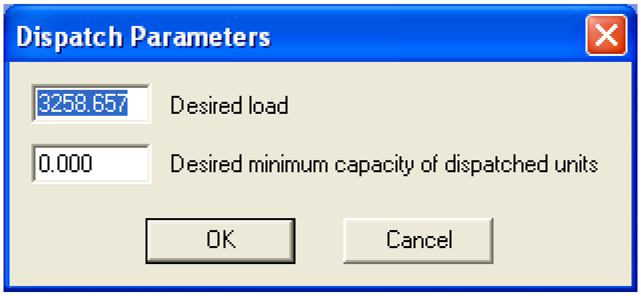


Figure 4-154. Redispatching Load and Generation

After clicking the ***OK*** button, the process commences the unit commitment portion of its calculation. Note again that the status of any machine with a priority ranking of zero is not changed during the unit commitment portion of the process but such machines are included in the economic dispatch calculation. Neither the status nor power outputs of machines for which either no dispatch data was provided or whose data was alarmed, and of machines outside of the specified subsystem, is changed during this process.

If the specified desired minimum capacity is greater than the sum of the maximum power outputs of the machines currently on-line, the unit commitment process places additional units on-line. Machines with lowest priority rankings are connected first, and, within a given priority ranking, units with the lowest full load average cost per MW are placed in-service first.

If the specified desired load is less than the sum of the minimum power outputs of the machines currently on-line, units are taken off-line. Machines with highest priority rankings are disconnected first, and, within a given priority ranking, units with the highest full load average cost per MW are placed out-of-service first.

Any time a machine status is changed, a message is printed at the Output Bar. Any processing errors encountered are alarmed and the user is asked to respecify the desired load and minimum capacity.

Once a commitment profile satisfying the desired load and capacity constraints has been successfully determined, the power outputs of the machines to be dispatched are calculated. Power outputs are set on the basis of equal incremental costs subject to the machine power output limits.

The dispatch calculation uses an iterative approach and, at the end of each iteration a convergence monitor is printed which tabulates:

- The iteration number.
- The total power mismatch.
- The incremental cost.
- The change in incremental cost.

Following the dispatch calculation, the production cost and the incremental cost along with the post-dispatch totals of dispatched power, capacity limits of the dispatched machines, and subsystem generation are tabulated. Plant power outputs and reactive power limits are updated to reflect the commitment and dispatch calculation results.

Results are summarized in the Output Bar or output device selected by the user. For the example shown in Figure 4-154, using the *savnw.sav* power flow case, the results summary and convergence monitor are shown in Figure 4-155.

```
   1     239.876       7.982       2.04675
   2    -364.735       5.935       1.02338
   3      73.860       6.958       0.51169
   4    -127.351       6.446       0.25584
   5     -20.627       6.702       0.12792
   6      26.617       6.830       0.06396
   7       2.995       6.766       0.03198
   8      -8.816       6.734       0.01599
   9      -2.911       6.750       0.00800
  10       0.042       6.758       0.00400
  11      -1.435       6.754       0.00200
  12      -0.696       6.756       0.00100
  13      -0.327       6.757       0.00050
  14      -0.143       6.758       0.00025
  15      -0.050       6.758       0.00012
  16      -0.004       6.758       0.00006

 REACHED TOLERANCE IN  16 ITERATIONS

 TOTAL MISMATCH IS    -0.0042 MEGAWATTS
 PRODUCTION COST IS  19483.91 $/HR
 INCREMENTAL COST IS     6.76 $/MW-HR

 PRESENT TOTAL GENERATION OF UNITS BEING DISPATCHED IS    3999.996
 MAXIMUM GENERATION OF DISPATCHED UNITS NOW ON-LINE IS    4375.000
 MINIMUM GENERATION OF DISPATCHED UNITS NOW ON-LINE IS    1800.000

 PRESENT GENERATION OF SUBSYSTEM BEING DISPATCHED IS      3999.996
```

Figure 4-155. Summary Results of the Economic Dispatch Process

The dispatch data as read from the Economic Dispatch Data File is not retained with the working case file following termination of the process. A data input file is required for each new execution.

The dispatch process responds to the following interrupt control codes:

AB	Abandon following the completion of the next dispatch iteration.
NC	Suppress the dispatch convergence monitor.

4.8.4 Viewing Economic Dispatch Results

Following completion of the dispatch calculation, the plant power outputs and reactive power limits outputs are updated to reflect the commitment and dispatch calculation results. One means to examine the results is to use the Limit Checking report to look at machine terminal conditions. In Figure 4-156 those conditions can be seen for the savnw.sav power flow case before and after the economic dispatch calculation example described here.

```
     PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E
PSS/E PROGRAM APPLICATION GUIDE EXAMPLE
BASE CASE INCLUDING SEQUENCE DATA

MACHINE SUMMARY:
  BUS# X-- NAME --X BASKV ID     MW     MVAR    QMAX
   101 NUC-A       21.600 1    750.0    81.2   600.0
   102 NUC-B       21.600 1    750.0    81.2   600.0
   206 URBGEN      18.000 1    800.0   600.0   600.0
   211 HYDRO_G     20.000 1    600.0    17.7   400.0
  3011 MINE_G      13.800 1    258.7   104.0   600.0
  3018 CATDOG_G    13.800 1    100.0    80.0    80.0
SUBSYSTEM TOTALS              3258.7   964.2  2880.0
```

```
     PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E
PSS/E PROGRAM APPLICATION GUIDE EXAMPLE
BASE CASE INCLUDING SEQUENCE DATA

MACHINE SUMMARY:
  BUS# X-- NAME --X BASKV ID     MW     MVAR    QMAX
   101 NUC-A       21.600 1    808.3    81.2   600.0
   102 NUC-B       21.600 1    808.3    81.2   600.0
   206 URBGEN      18.000 1    870.5   600.0   600.0
   211 HYDRO_G     20.000 1    666.0    17.7   400.0
  3011 MINE_G      13.800 1    847.0   104.0   600.0
SUBSYSTEM TOTALS              4000.0   884.2  2800.0
```

Figure 4-156. Before and After Machine Terminal Conditions for Economic Dispatch Example

Chapter 5

Contingency Analysis

5.1 Overview: Contingency Analysis

Contingency analysis covers a variety of analytical investigations performed by both system planners and operators. The system planner's objective is to identify the network elements which will be required to maintain system operation within planning criteria. The general requirement is to identify capital investments and operating costs for long term future developments.The system operators' objective is to identify the manner in which the system must be operated to maintain system security both in the near term (days, weeks, months) with existing network elements or the medium term (one to three years) during which a limited amount of equipment could be installed.

The basic approach to contingency analysis is to:

- Establish generation/demand base case scenarios which are to be tested.
- Identify variations of generation and demand for the base cases for the time period of development or operation.
- Identify the tests (contingencies) to be performed for both steady-state and dynamic analysis and the system conditions which are acceptable or required prior to and during such contingencies. The tests and required post-contingency conditions are generally described by "Reliability Criteria".
- Perform the tests.

5.1.1 Reliability Testing Criteria for Contingency Analysis

Criteria describe tests to be performed and required conditions prior to and during the test conditions. While there may be variations in criteria between electric power utilities, regions and countries, there is significant commonality.

Typical steady-state tests can include:

- Base case with all elements in service.
- Single contingencies (N-1). Loss of any transmission line or transformer or generator. These are often termed 'probable' or 'credible' contingencies.
- Double contingencies (N-2). Simultaneous loss of two single-circuit transmission lines, a double-circuit line or DC bipole. Variations on these contingencies exist worldwide specifically with respect to the definition of "double" circuit and the option of non-simultaneity of loss (N-1-1). These too are 'credible' or 'probable' contingencies.

- Less probable contingences and/or extreme contingencies can include loss of entire substations or multiple generators.

Typical dynamic testing will include the same family of contingencies and are augmented by representation of the severity of the initiating disturbance which results in the loss of system elements (three-phase and single-phase faults with normal or delayed clearing times for example).

Acceptable system conditions prior to and subsequent to the contingencies depend on the severity of the contingency and include:

- Voltages within defined normal or emergency limits.
- Changes in voltage within defined limits.
- Branch loadings within normal or emergency loading limits.
- Maintenance or loss of limited amounts of load.
- Maintenance of system integrity or breakdown into viable sections.
- Maintenance of transient and dynamic stability.

Such criteria are deterministic in the sense that the scenario being tested must comply with the acceptable system conditions or is considered to have failed the test. A failure implies the need for additional system elements (for planning) or an adjustment of precontingency test conditions (for operations).

An overview of deterministic reliability tests is summarized in Table 5-1.

Table 5-1. Deterministic Reliability Tests

Overview of Deterministic Reliability Tests			
Reliability Test Criteria for Transmission Expansion	**Test Conditions**	**Analysis**	**Acceptable Conditions**
	Normal Steady-State conditions	Steady-State Power Flow	System within normal loading and voltage limits
	Single Contingencies (Credible - more probable)	Steady-State Power Flow	System within emergency loading and voltage limits immediately after outage and within normal limits after system adjustments
		Dynamic Analysis	Transiently and dynamically stable
	Double Contingencies (Credible - more probable)	Steady-State Power Flow	System within emergency loading and voltage limits after system adjustment.
		Dynamic Analysis	Transiently and dynamically stable
	Less Probable Contingencies Supplementary Tests	Steady-State Analysis	No voltage collapse or overload cascading
		Dynamic Analysis	Transiently and dynamically stable
	Extreme Contingencies Supplementary Tests	Steady-State and Dynamic Analysis	Avoidance of widespread load interruptions, uncontrolled cascading and black-outs

5.1.2 Applying Deterministic Criteria

This type of study comprises the outage of system elements and an examination of voltage and loading conditions both prior to and subsequent to the outage (contingency).

Generally, for the normal condition (base case with all elements in service) the user is establishing acceptable normal conditions of voltage and loading of lines, transformers and generators. Under these conditions the user will normally solve the power flow with control options activated for transformer taps, switched shunts and other devices. Under contingency conditions, depending on the criteria in use, the user will often block control actions as a function of how equipment in the user's system operates.

The basic process is one of:

- Disconnecting a system element.
- Solving the new power flow.
- Examining system conditions using PSS™E reporting facilities.

The user's response to the results of contingency cases will depend on the study objectives.

A limited system analysis can be performed merely by manually performing the steps outlined in the 'basic process'. A more detailed analysis, specifically of a large system can involve the simulation and examination of thousands of contingencies. For this, PSS™E provides procedures for automatic testing and reporting. These procedures are described in this chapter.

5.1.2.1 Applying Transmission Transfer Limit Analysis

For economic or market requirements, the user will often need to identify the maximum level of power which can be transferred across a network; often from identified sending and receiving areas or systems. Limits are usually identified for both normal and contingency conditions.

As power transfers are increased across a network, limits will be reached when the thermal loading of network elements is exceeded or when voltages fall outside acceptable levels; usually during contingencies. The procedures for identifying transfer limits, available in PSS™E, are described in Chapters 6 and 11.

5.1.2.2 Applying Voltage Stability Analysis

This type of analysis is similar to transfer limit analysis but is specifically concerned with situations where voltage control becomes the major factor in determining the power transfer capabilities of a network. Voltage stability is a phenomenon concerning the eventual collapse of voltage as system loading is increased and/or power transfers are increased.

Widely accepted measures of a networks vulnerability to voltage instability or collapse are:

- Power - Voltage curves (P-V) which identify voltage levels within a system as power transfers increase.
- Reactive - Voltage curves (Q-V) which identify reactive margins versus system voltage levels.

Both P-V and Q-V curves show limiting operating conditions within a network for both normal and contingency conditions. The procedures for analyzing these conditions with PSS™E are described in Chapter 11.

5.1.3 Applying Probabilistic Reliability Criteria

The behavior of power systems is probabilistic. Loads are always uncertain. The events that cause the outages my vary, but are always in the form of unplanned events such as lightning strikes, falling tree limbs, human errors, and so on; these events are thus of a random nature. The weakness of deterministic reliability analysis is that it does not reflect the probabilistic nature of power system behavior, but treats every contingency tested equally significant. In deterministic reliability analysis, every contingency being tested must comply with the acceptable system conditions or is considered to have failed the test. A failure implies the need for additional system elements (for planning) or an adjustment of precontingency test conditions (for operations). It is impossible to have zero risk of system failures in power systems because contingencies are uncontrollable. tn many cases, a decision must be made to accept a risk as long as it can be technically and financially justified, in other words keeping risk of system failures within a acceptable range. on the other hand, customers have the rights to know how often, for how long these outages cause discontinuity of load supply. Probabilistic reliability assessment (see Section 5.8) is provided to answer these questions. The module uses contingency enumeration technology and consists of a calculation part, which evaluates each contingency and models predefined tripping and corrective action sequences, and an analysis part, which conducts a detailed analysis on the basis of the evaluated contingency sequences to calculated following probabilistic indices:

- Probabilistic indices of flow overloads
- Probabilistic indices of voltage violations
- Expected unserved energy
- Interrupted power

The basic procedure to perform probabilistic reliability study is:

- perform a contingency analysis following the procedure for contingency analysis discussed in the above section
- prepare outage statistic data
- perform probabilistic reliability assessment

5.2 Performing AC Contingency Analysis

This network contingency calculation function calculates full AC power flow solutions for the user's specified set of contingency cases, monitors voltage and loading conditions and stores the results in a binary file. Subsequently, this file can be processed to produce a variety of reports of voltage and loading violations, loadings and available capacity. This feature is a powerful approach for testing large systems with many possible contingencies specifically where the user wishes to monitor specific branches, interfaces or network areas for problems.

One role of the AC contingency calculation is that of a screening tool whose purpose is to focus attention on those contingency cases which deserve closer study.

A useful feature is the ability to produce reports in a format appropriate for import to a spread sheet program.

5.2.1 Setting Up for AC Contingency Analysis

To launch the contingency calculation solution process select the ***Power Flow>Solution>AC contingency solution (ACCC)*** option. This will open the AC Contingency Solution dialog (see Figure 5-1).

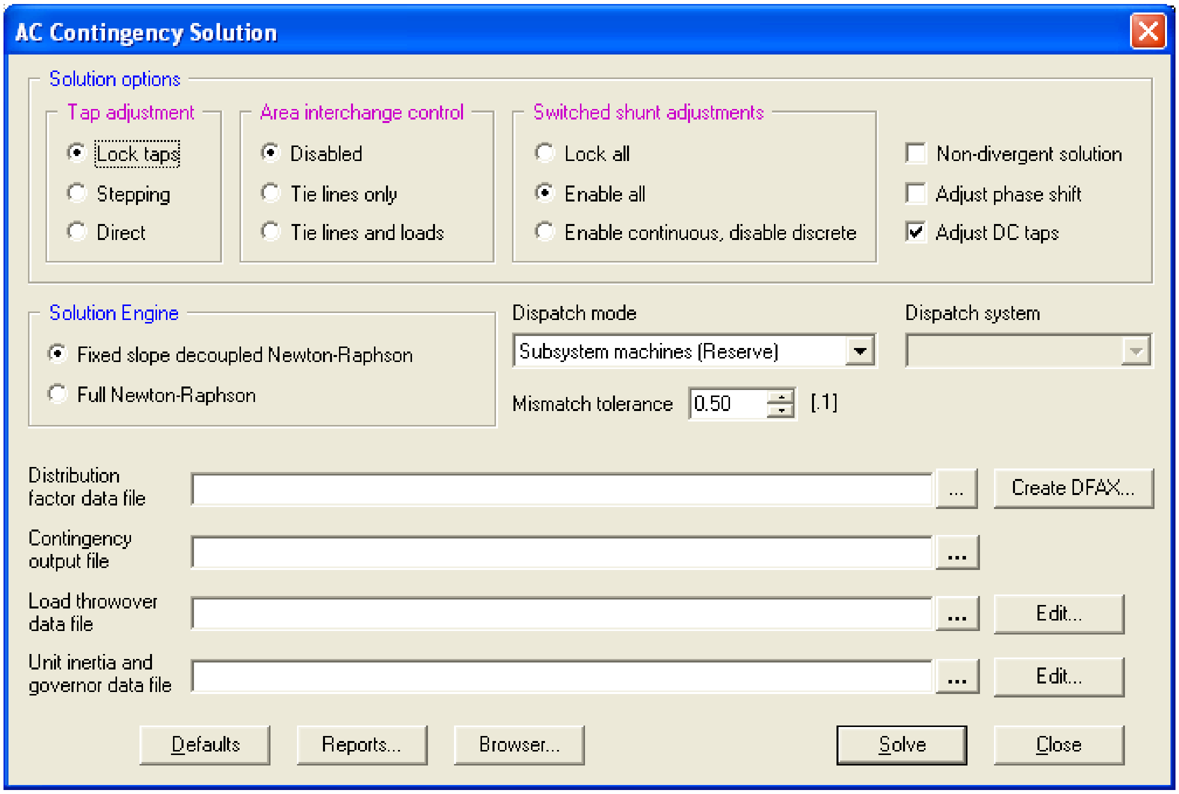


Figure 5-1. AC Contingency Solution Dialog

5.2.1.1 Setting AC contingency analysis options

Solution options: Select the desired solution options to be applied during load flow calculations for obtaining post-contingency states (see Chapter 4).

Solution Engine: Select the desired load flow solution engine to be used in obtaining post-contingency states (see Chapter 4).

Dispatch Mode: Dispatch codes for generation dispatch calculations in ACCC analysis.

- **Subsystem machines (Reserve):** Participating machines are connected to dispatch subsystem buses and have positive active power generation. Each machine's participation factor is its reserve (PT-PG or PG-PB) with positive values. If a Unit Inertia and Governor Data File is specified, machine active power limits are taken from it; otherwise, the machine active power limits in the working case are used. In generation dispatch analysis, generator active power limits are adjusted by the following rules. If PT had been defaulted, the larger value of PG (its existing MW output) and machine power base (MVA base) will be used as PT; If PT of a machine is less than its PG, the

PT is set equal to the PG. If PB of a machine had been defaulted, it is set to zero; if PB of a machine is less than its PG, the PB is set equal to the PG.

- **Subsystem machines (Pmax):** Participating machines are connected to dispatch subsystem buses and have positive active power generation. Each machine's participation factor is its maximum active power generation with positive values. If a Unit Inertia and Governor Data File is specified, maximum machine active power limits are taken from it; otherwise, the maximum machine active power limits in the working case are used. PT is adjusted by the rules discussed in Dispatch Mode of Machine Reserve.
- **Subsystem machines (Inertia):** Participating machines are connected to dispatch subsystem buses and have positive active power generation. Each machine's participation factor is its inertia constant. For machines for which no data record is successfully read, an inertia constant of 4.0 on machine base is used.
- **Subsystem machines (Governor droop):** Participating machines are connected to dispatch subsystem buses and have positive active power generation. Each machine's participation factor is its governor permanent droop. For machines for which no data record is successfully read, a droop constant of 0.05 on machine base is used.

Dispatch system: Select the subsystem for the generation dispatch. The subsystem is predefined in a subsystem description file. All subsystem buses with one or more in-service machines whose active power generation is positive are participating in the generation dispatch. If several islands exist in the system, participating machines for each island are connected to dispatch subsystem buses within the island.

Mismatch tolerance: Specify mismatch tolerance. This tolerance will be used to check for the largest initial active or reactive power mismatch. If exceeded, the process is terminated. This value is also used as the convergence tolerance in the power flow solution of each contingency case (see Chapter 4)

5.2.1.2 About Generation Dispatch

Outages of generator units, the separation of the network into islands, the shedding of load, and other contingency events can lead to imbalances in the power resources and demand for interconnected AC systems. One way to keep balances is to include DISPATCH keyword at the end of data records that specify a boundary change contingency in the Contingency Description Data File (see Section 5.2.3.1), the change in the boundary condition is allocated among participating generators selected in the dispatch group. When dispatch mode is disabled, if non-boundary change contingencies and boundary change contingencies without optional keyword DISPATCH specified cause imbalances in the power resources and demands, these imbalances are totally absorbed by the swing bus within the island; any island without the swing bus is shut down.

To provide a more realistic model of the post-contingency states, one of four dispatch modes and a proper dispatch subsystem should be selected. Imbalances are then apportioned among machines within the dispatch subsystem in specified participation factors. For islands without the swing bus, the bus with largest generation capacity is designated as the island swing bus. When there is insufficient capacity available from the reserves, load is shed. Reactive power loads are shed in proportion to real power loads to retain the power factor at affected buses. The following describes the computation procedures.

1. Identify all islands within the network using a tree searching technique.
2. For each island, assure that a swing bus exists. If there is no existing swing bus, the bus with the largest generation capacity within the island is chosen as the swing bus. If no such bus can be found, the entire island is shut down and all load shed.

3. Sum the present generator output and generation requirement to find if there is a MW imbalance. The generation requirement in the island is given by the total of all bus loads, active power bus shunts, and active power losses, including dc lines.

4. If generation deficiency, DEF, exists, it is met by increasing the present generation of participating machines in the island by an amount proportional to the given participation factors. If DEF still exists after the active power reserves of participating machines are exhausted, all on-line machines in the island are participating in the generation dispatch to meet generation deficiency in the specified dispatch mode.

   $$PGEN_i^1 = PGEN_i^0 + p_i \times DEF$$

   where:

   $PGEN_i^0$ is the present dispatch of unit *i*,

   $PGEN_i^1$ is the new dispatch of unit *i*, and

   p_i is the participating factor of unit *i.*

5. Load shedding will take place if the sum of the maximum generation of all on-line machines is insufficient to cover the generation requirements. In such cases, load at all buses is shed proportionately until a load/generation balance is attained. Bus shunts and bus losses will not be shed.

   $$PLOAD_i^1 = PLOAD_i^0 + \frac{PLOAD_i^0}{\sum(PLOAD_i^0)} \times DEF$$

   where:

   $PLOAD_i^0$ is the present load at bus *i*,

   $PLOAD_i^1$ is the new load at bus *i.*

6. Similarly, if generation excess, EXC, exists, it is corrected by reducing the dispatch of participating machines within this island proportional to their given participation factors. If generation excess still exists after all on-line machines have been reduced to their minimum generation limits, the island will be shut down, and all load shed.

   $$PGEN_i^1 = PGEN_i^0 + p_i \times EXC$$

   where p_i is the participating factor of unit *i*.

Steps three through six in the above list are repeated for each island in the network until a load/generation balance is attained.

5.2.2 Input Data Files for AC Contingency Analysis

There are four main files used for contingency analysis in PSS™E:

- **Distribution Factor Data:** This must be created using the ***Build*** facility found in the ***Power Flow>Linear Network*** option (see Section 5.2.3.2).
- **Contingency Output:** This is a required file designated by the user as the destination for the results of the contingency calculations.
- **Load throwover Data:** This is an optional file, created by the user, that contains data records of the following form:

  ```
  IBUS, JBUS
  ```

  where IBUS and JBUS are bus numbers. If branch outage contingency events isolate bus IBUS, the user can elect to move the load to bus JBUS. Bus IBUS and/or JBUS may be a dummy bus of a multi section line grouping. Data records may be input in any order. Input is terminated with a record specifying an "IBUS" value of zero.
- **Unit Inertia and Governor Data File:** This is an optional file, created by the user, that contains generator inertia and governor response data (see Section 5.6.1).

5.2.2.1 About the Distribution Factor File

The Distribution Factor File setup activity reads a set of Linear Network Analysis Data Files and reflects their contents in a Distribution Factor Data File in preparation for performing automatic AC contingency analysis as well as a variety of other analyses including DC contingency testing, generator contingency analysis and transfer limit identification.

Input for the process of creating the Distribution Factor file is contained in three data files:

- **Subsystem** Description Data file; relevant subsystems of the working case are specified in this *.sub file.
- **Monitored Element** Data file; network elements to be monitored for problems are specified in this *.mon file.
- **Contingency** Description Data file; contingencies to be tested are specified in this *.con file.

5.2.2.2 Data File Conventions

The three data files are governed by notational conventions which are identified in the following list:

CAPITALS	Keyword that must be specified exactly as shown. No keyword abbreviations are allowed.
[…]	Items enclosed in square brackets are optional keywords and/or values.
|A| or A|B |B|	Specify one from the list separated by, or enclosed in, the vertical bars.
bsid	Bus identifier; this data value **must** be a bus number when the numbers input option is in effect, and an extended bus name (twelve character name plus bus base voltage) when the names input option is in effect. If an extended bus name contains blanks or special characters, it must be enclosed in single quotes.
ckid	One- or two-character circuit identifier.

mcid	One- or two-character machine identifier.
devid	FACTS device or dc line name; up to twelve characters. If a device name contains blanks or special characters, it must be enclosed in single quotes.
i	An integer value.
r	A floating point value; the decimal point is optional when specifying a whole number (e.g., 10, 10., and 10.0 all specify the floating point number ten).
file	A filename.
label	A 12-character label identifier. If a label contains blanks or special characters, it must be enclosed in single quotes.

Keywords and data values must be separated by one or more blanks.

Special Data Records

The following record types are allowed in each of the Linear Network Analysis Data Files:

TRACE	Enables or disables input tracing. When enabled, each line read from the input file is written to the dialog output device (normally the user's terminal) and is initially disabled.
ECHO file	Outputs each input line to a designated file of the user's choice. If the filename specification contains any blanks or slashes ("/"), it must be enclosed in single quotes. This writing of input records is useful when they are being input interactively and the same set of input records will be used in subsequent construction of a Distribution Factor file.
COM	Designates a comment line which is ignored during input processing. Any meaningful comments may be placed on a comment line following the COM keyword.
END	End of block structure or end of data input, as appropriate.

In addition, blank lines may be included anywhere in the file. These are ignored during the input file processing.

5.2.2.3 About the Subsystem Description Data file

Subsystems of the working case are defined via the Subsystem Description Data File. While format details differ, the subsystem definition provided is functionally identical to the specification of subsystems via the bus subsystem selector window.

The portion of the working case to be contained in each subsystem being defined is specified in the following SUBSYSTEM block structure:

```
SUBSYSTEM|SYSTEM [label]
(subsystem specification data record)
.
.
(subsystem specification data record)
END
```

The subsystem specification data records allowed are as described below.

The optional subsystem labels are used on several record types in the Monitored Element and Contingency Description Data Files. If no label is specified on a SUBSYSTEM record, the label "UNNAMED n" is assigned to the subsystem, where "n" is a unique integer. Up to one hundred subsystems may be specified in a Subsystem Description Data File, and each subsystem must be defined within a single SUBSYSTEM block structure.

Subsystem Specification Data Records

Buses can be selected to be in included in a SUBSYSTEM or SYSTEM using a series of criteria; that is selecting by BUS, AREA, ZONE, OWNER and KV. Further, buses can be selected on an individual basis or in groups.

Selecting buses by number requires data records of the following form:

```
BUS bsid
BUSES bsid bsid
```

The BUSES record is valid only when the numbers input option is in effect and assigns the designated buses, as well as all buses whose bus numbers fall between the two bus numbers specified, to the subsystem being defined. For example, the data record "BUSES 15 77" may be used to select all buses with numbers from 16 to 76, inclusive.

Selecting buses by area requires data records of the following form:

```
AREA i
AREAS i i
```

where "i" is an area number. The AREAS record type assigns all buses in a range of area numbers to the subsystem being defined. For example, the data record "AREAS 5 7" may be used to assign all buses in areas five, six, and seven to the subsystem.

Similarly, all buses in selected zones and owners may be assigned to a subsystem with data records of the following form:

```
ZONE i
ZONES i i
OWNERS i
OWNERS i i
```

Buses at designated voltage levels may be assigned to a subsystem with records of the following form, where, as above, the KVRANGE record defines a range of voltage levels:

```
KV r
KVRANGE r r
```

Note that, in specifying ranges of bus numbers, areas, zones, owners, and voltage levels, the second value specified **must not** be preceded with a minus sign. The second number specified **must** be greater than the first.

In addition, a "join group" block structure provides for the specification of a group of buses through the logical "anding" of two or more of the five selection criteria described above. A "join group" has the following block structure:

```
JOIN [label]
(subsystem specification data record)
.
.
(subsystem specification data record)
END
```

where each subsystem specification data record is one of the simple record types (BUS, AREA, ZONE, OWNER, KV, or the corresponding "range of" records) described above. The optional JOIN group label is for the user’s convenience and is neither used in the distribution factor calculations nor preserved in the Distribution Factor Data File.

Each join group block structure must appear within the subsystem block structure described above. Both JOIN group block structures and the simple record types may be included within a SUBSYSTEM block structure.

The following example defines the subsystem "MY COMPANY", which consists of all buses in area five, along with all buses in area six which are in zones eight through ten:

```
SUBSYSTEM 'MY COMPANY'
AREA 5
JOIN 'GROUP 1'
 AREA 6
 ZONES 8 10
 END
END
```

Several transmission transfer limit analyses require the prior calculation of a Distribution Factor Data file Those analyses modify the generation/load profile within designated SUBSYSTEMS to determine transfer capability. The user can specify which buses are to participate in the generation/load shift, along with their participation factors. The participation factors determine how the change in subsystem power injection is to be shared among the designated buses. To establish the participating buses and their participation factors, the PARTICIPATE block structure is used.

The form of the participation block structure is:

```
PARTICIPATE
 BUS bsid r
  .
  .
 BUS bsid r
END
```

The "r" values are nonzero participation factors which are normally expressed in percent or per unit of the total SUBSYSTEM generation shift. While individual "r" values may be negative, the sum of the "r" values within a participate block structure must be positive.

Each participation block structure must appear within the SUBSYSTEM block structure described above, and **must follow** the simple record types and/or join group block structures defining the SUBSYSTEM; that is, it must be the last data record block in the SUBSYSTEM specification.

Each bus specified must reside in the subsystem being processed. Any bus which violates this requirement or which is disconnected (i.e., its type code is four or greater) is alarmed and ignored.

5.2.3 About the Monitored Element Data File

This file identifies those elements, or groups of elements that are to be monitored for flow violations and those buses which are to be monitored for voltage violations.

Flow Monitoring Records

Each monitored element may consist of either a single branch or a group of branches (an "interface"), where the flow on an interface is taken as the sum of the flows on the branches comprising the interface.

Up to 1,000 interfaces are allowed, and the total of single branches plus branches contained in all interfaces may not exceed the number of branches for which PSS™E is dimensioned. Only in-service branches are added to the monitored element list.

To specify a single branch for monitoring, the following data record may be used:

```
[MONITOR] |BRANCH| FROM BUS bsid TO BUS bsid ⎡|CIRCUIT| ckid⎤
          |LINE  |                           ⎣|CKT    |     ⎦
```

To specify one winding of a three-winding transformer for monitoring, the bus to which the winding is connected must be the first bus specified in the following data record:

```
[MONITOR] |BRANCH| FROM BUS bsid TO BUS bsid TO BUS bsid ⎡|CIRCUIT| ckid⎤
          |LINE  |                                       ⎣|CKT    |     ⎦
```

If the optional circuit identifier keyword and data value are omitted, a circuit identifier of '1' is assumed.

As a convenience to save typing, the following block structure may be used to designate a series of single branches for monitoring where, as above, the default circuit identifier is '1'. Three-winding transformers cannot be specified using this block structure.

```
[MONITOR] |BRANCHES|
          |LINES   |
bsid bsid [ckid]
.
.
bsid bsid [ckid]
END
```

In specifying a branch with the above records, if it is already in the monitored element list in the specified direction, an appropriate message is printed and the record is ignored. If a branch is included in the monitored element list in both directions, the same results are shown in both directions.

When the ***Multi Section Line Reporting*** option is enabled, in-service multi section line groupings may be specified with the above records. If an in-service member of a multi section line grouping is specified, the multi section line (rather than the specified member) is added to the monitored element list in the same direction as the specified member. When the ***Multi Section Line Reporting*** option is disabled, multi section line groupings may not be specified in the above records; in-service members of multi section line groupings may be designated and are added as specified to the monitored element list.

The following four record types provide for the addition of a group of branches to the monitored element list with a single record. Any branch that is included in the subset specified by the following records, but which is already included in the monitored element list in either direction, is skipped.

For these record types, when the ***Multi Section Line Reporting*** option is enabled, multi section line groupings within the specified subset, but not the individual members of such groupings, are added to the monitored line list. When the ***Multi Section Line Reporting*** option is disabled, members of multi section line groupings within the specified subset, but not the multi section line groupings, are added to the monitored line list.

To place all branches in the monitored element list, the following data record may be used:

```
[MONITOR] ALL |BRANCHES|
              |LINES   |
```

Branches are entered into the monitored element list in single entry form, with the lower ordered bus (number or name, according to the bus output option currently in effect) as the "*from bus*".

The following data record may be used to select for monitoring all branches connected to a specified bus:

```
[MONITOR] |BRANCHES| FROM BUS bsid
          |LINES   |
```

The following data record may be used to select all branches within a specified subsystem.

```
[MONITOR] |BRANCHES| IN |AREA i         |
          |LINES   |    |ZONE i         |
                        |OWNER i        |
                        |KV r           |
                        |SYSTEM label   |
                        |SUBSYSTEM label|
```

In using the SYSTEM or SUBSYSTEM keywords, the "label" must correspond to a subsystem label specified in a previously accessed Subsystem Description Data File. For a three-winding transformer to be included, all of its in-service windings must be connected to subsystem buses; for any such three-winding transformer, all of its in-service windings are added to the monitored element list.

Finally, the following record provides for the monitoring of all ties from a specified subsystem, or all ties between a pair of subsystems:

```
[MONITOR] TIES FROM |AREA i         | ┌TO |AREA i         |┐
                    |ZONE i         | │   |ZONE i         |│
                    |OWNER i        | │   |OWNER i        |│
                    |KV r           | │   |KV r           |│
                    |SYSTEM label   | │   |SYSTEM label   |│
                    |SUBSYSTEM label| └   |SUBSYSTEM label|┘
```

For a three-winding transformer to be included, at least one of its in-service windings must be connected to a subsystem bus, and at least one of its in-service windings must be connected to a bus which is either not in the subsystem or in the "*to subsystem*", as appropriate; for any such three-winding transformer, all of its in-service windings connected to subsystem buses are added to the monitored element list.

For a tie branch between a pair of subsystems to be added to the monitored element list, both of the following must be satisfied:

1. One bus is in the "*from subsystem*".

2. Another bus is in the "*to subsystem*", and it is not in the "*from subsystem*".

For the case of disjoint subsystems (e.g., TIES FROM AREA 1 TO AREA 2), the selection of tie branches is clear and unambiguous. However, in the case of overlapping subsystems (e.g., TIES FROM AREA 1 TO ZONE 5), the user must be aware of the above rules in specifying "TIES" records. The possibility exists that, in applying the above criteria, the set of branches included as ties may not be the same if the "*from*" and "*to subsystems*" are interchanged. Consider, for example, the following area and zone assignments:

Bus	Area	Zone
1	1	10
2	1	5
3	2	5
4	1	5

Further, assume that a branch exists between each pair of buses. The record "TIES FROM AREA 1 TO ZONE 5" would include the branches 1-3, 2-3, and 4-3, but not 1-2, 1-4, or 2-4. Conversely, the record "TIES FROM ZONE 5 TO AREA 1" would include the branches 2-1, 3-1, and 4-1, but not 2-3, 2-4, or 3-4.

When the ***Multi Section Line Reporting*** option is enabled, the subsystem assignments of the "dummy buses" of each multi section line grouping are ignored; a multi section line grouping is treated as a tie branch if and only if its endpoint buses satisfy items (1) and (2) above. When the ***Multi Section Line Reporting*** option is disabled, the multi section line grouping definitions are ignored and any member of a multi section line grouping satisfying items (1) and (2) above is considered a tie branch.

An INTERFACE is defined using the following block structure:

```
[MONITOR] INTERFACE label È|RATING r [MW]      |
                          Î|RATINGS r r r [MW]|°
(branch specification record; see below)
.
.
(branch specification record; see below)
END
```

The branch specification records may specify sets of tie lines, individual branches or individual three-winding transformers.

For specifying sets of tie lines the following data specification record is used:

```
[MONITOR] TIES FROM |AREA i          | ⎡TO |AREA i          |⎤
                    |ZONE i          | ⎢   |ZONE i          |⎥
                    |OWNER i         | ⎢   |OWNER i         |⎥
                    |KV r            | ⎢   |KV r            |⎥
                    |SYSTEM label    | ⎢   |SYSTEM label    |⎥
                    |SUBSYSTEM label| ⎣   |SUBSYSTEM label|⎦
```

For specifying three-winding transformer windings, the following specification record is used:

```
[MONITOR] |BRANCH| FROM BUS bsid TO BUS bsid TO BUS bsid ⎡|CIRCUIT| ckid⎤
          |LINE  |                                       ⎣|CKT    |     ⎦
```

For specifying individual branches, the following data specification record is used:

```
[MONITOR] |BRANCH| FROM BUS bsid TO BUS bsid ⎡|CIRCUIT| ckid⎤
          |LINE  |                           ⎣|CKT    |     ⎦
```

or, simply:

```
bsid bsid [ckid]
```

The 12-character interface labels are used to identify interfaces in the output reports. As with AC branches, provision is made for three interface ratings. When the first form of the INTERFACE record above is used (i.e., the token RATING and a single value are specified), the designated value is used for each of the three interface ratings.

When the second form of the INTERFACE record is used (i.e., the token RATINGS and three values are specified), the designated values are used as the interface's A, B, and C ratings, respectively. Interface ratings, which are entered as zero, are based on the default rating set indicated by the program run-time options.

If the optional specification of ratings is omitted, the sum of the appropriate rating set values of each of the interface members is taken as the interface rating. It is important to note that an interface rating is usually specified as something other than a thermal limit; for example, contractual or stability considerations may determine the interface rating to be used.

Voltage Monitoring Records

Buses which are to be monitored for voltage violations are specified in the Monitored Element Data File. Two types of voltage violations may be detected.

The following data record defines a voltage band along with a set of buses whose voltages are to be checked against the band.

```
[MONITOR] VOLTAGE RANGE |ALL BUSES      | r [r]
                        |AREA i         |
                        |ZONE i         |
                        |OWNER i        |
                        |KV r           |
                        |SYSTEM label   |
                        |SUBSYSTEM label|
                        |BUS bsid       |
```

where the first "r" value is the lower bound of the per unit voltage band and the optional second "r" value is the upper bound. If the upper bound is omitted, the upper end of the band is not checked.

The following data record defines voltage drop and voltage rise deviation thresholds along with a set of buses whose voltage changes in contingency cases from their base case values are to be checked.

```
[MONITOR] VOLTAGE DEVIATION |ALL BUSES      | r [r]
                            |AREA i         |
                            |ZONE i         |
                            |OWNER i        |
                            |KV r           |
                            |SYSTEM label   |
                            |SUBSYSTEM label|
                             |BUS bsid       |
```

where the first "r" value is the magnitude of voltage drop in per unit and the optional second "r" value is the magnitude of voltage rise. If the voltage rise threshold is omitted, the voltage rise check is omitted.

5.2.3.1 About the Contingency Description Data File

Contingency cases are designated in a Contingency Description Data File and can consist of up to sixteen "events". Contingencies can comprise switching network elements and generation in and out of service, moving generation, load and shunt locations, redispatching generation and changing load and shunt levels.

The Contingency Description Data File provides two means by which contingency cases may be specified. First, individual contingency cases consisting of single or multiple events involving bus boundary condition and/or branch status changes may be specified in a contingency case block structure.

Second, the selection of a group of single or double line outage contingency cases may be specified with a single data record.

Contingency Case Block Structure

In this method, a contingency case is defined in a block structure as follows:

```
CONTINGENCY label [f d]
(contingency event specification record; see below)
.
.
(contingency event specification record; see below)
END
```

The 12-character contingency label is printed in output reports to identify each contingency. ’f’ and ’d’ are frequency and duration of user specified outages respectively for probabilistic reliability assessment.

There is a variety of supported contingency event specifications record formats available. They are described in the remainder of this section.

The outaging of an in-service non transformer branch or two-winding transformer is specified with the following record where the default circuit identifier is '1'.

```
|DISCONNECT| |BRANCH| FROM BUS bsid TO BUS bsid ⌈|CIRCUIT| ckid⌉
|OPEN      | |LINE  |                          ⌊|CKT    |     ⌋
|TRIP      |
```

Similarly, an out-of-service non transformer branch or two-winding transformer may be placed in-service with a record of the form:

```
CLOSE |BRANCH| FROM BUS bsid TO BUS bsid ⌈|CIRCUIT| ckid⌉
      |LINE  |                          ⌊|CKT    |     ⌋
```

When the ***Multi Section Line Reporting*** option is enabled, multi section line groupings may be specified with the above records. If a member of a multi section line grouping is specified, switching the entire multi section line (rather than the specified member) is treated as the contingency event.When the ***Multi Section Line Reporting*** option is disabled, multi section line groupings may not be specified in the above records. In this situation; members of multi section line groupings may be designated on OPEN and CLOSE records but only the specified member is switched.

The outaging of an in-service three-winding transformer is specified with the following record where the default circuit identifier is '1' if this specification is omitted:

```
|DISCONNECT| |BRANCH| FROM BUS bsid TO BUS bsid TO BUS bsid ⌈|CIRCUIT| ckid⌉
|OPEN      | |LINE  |                                      ⌊|CKT    |     ⌋
|TRIP      |
```

Similarly, all windings of an out-of-service three-winding transformer may be placed in-service with a record of the form:

```
CLOSE |BRANCH| FROM BUS bsid TO BUS bsid TO BUS bsid ⌈|CIRCUIT| ckid⌉
      |LINE  |                                      ⌊|CKT    |     ⌋
```

The outaging of one winding of a three-winding transformer is specified with the following record where the default circuit identifier is ’1’ if this specification is omitted:

```
|DISCONNECT| |THREEWINDING| AT BUS bsid TO BUS bsid TO BUS bsid ⌈|CIRCUIT| ckid⌉
|OPEN      |                                                   ⌊|CKT    |     ⌋
|TRIP      |
```

Similarly, one winding of a three-winding transformer my be placed in-service with a record of the form:

```
|CLOSE| |THREEWINDING| AT BUS bsid TO BUS bsid TO BUS bsid ⌈|CIRCUIT| ckid⌉
                                                          ⌊|CKT    |     ⌋
```

The winding to be opened or closed is the one connected to ’AT BUS’ end. When opening one winding of a three-winding transformer, all three windings of the three-winding transformer must be in-service; when closing one winding of a three-winding transformer, the other two windings of the three-winding transformer must be in-service.

The outaging of all in-service branches connected to a bus may be specified with a record of the form:

```
|DISCONNECT|BUS bsid
|OPEN      |
|TRIP      |
```

This command is converted to as many OPEN BRANCH commands as are required before it is passed to the Distribution Factor Data File.

When the ***Multi Section Line Reporting*** option is enabled, each in-service multi section line connected to the specified bus is switched out as a unit. If the specified bus is a dummy bus of a multi section line, this command is converted to a single OPEN BRANCH command that outages the corresponding multi section line. When the ***Multi Section Line Reporting*** option is disabled, only the line section adjacent to the specified bus is outaged for each multi section line connected to the bus.

The next four record types allow the user to specify contingency events in which the load and generation boundary conditions may be changed at a selected bus. Load and shunt are synonymous in the linearized network model, and specifying either results in identical contingency events. When changing generation, the bus must have in-service generation connected to it and it may not be a swing bus.

The first data record of this type uses the following data record to set the load or generation at a bus either to a designated value or to a specified percentage of its initial value:

```
SET BUS bsid |GENERATION| TO r |MW      | [DISPATCH]
             |LOAD      |      |PERCENT|
             |SHUNT     |
```

The number "r" specified must not be a negative number when the PERCENT keyword is used.

When the optional keyword DISPATCH is included at the end of the SET record, the user may designate how the change in the bus boundary condition is to be apportioned among selected network buses rather than having it all assigned to the system swing bus(es). In this case, the SET data record **must** be followed by records of the form:

```
BUS bsid r
.
.
BUS bsid r
END
```

The "r" values are positive participation factors which are normally expressed in percent or per unit of the total MW change specified by the contingency event specification record.

The second data record of this type uses the following data record to change the load or generation at a bus either by a designated amount or by a specified percentage of its initial value:

```
|CHANGE| BUS bsid |GENERATION| BY r |MW      | [DISPATCH]
|ALTER |          |LOAD      |      |PERCENT|
|MODIFY|          |SHUNT     |
```

When the PERCENT keyword is specified, the magnitude of the initial value of the quantity to be modified is used to determine the amount of the change; i.e.,

$$P_{new} = P_{orig} + \frac{r \times |P_{orig}|}{100.}$$

In changing either by PERCENT or MW, when the quantity to be modified is initially positive and the change is a reduction (i.e., "r" is negative), a negative result is treated as an error condition.

The presence of the optional keyword DISPATCH is handled as described above for the SET data record.

The third and fourth data records of this type are similar to the CHANGE record, except the direction of the change is defined by the first keyword, and "r" must be a positive number:

```
|INCREASE| BUS bsid |GENERATION| BY r |MW     | [DISPATCH]
|RAISE   |          |LOAD      |      |PERCENT|
                    |SHUNT     |

|DECREASE| BUS bsid |GENERATION| BY r |MW     | [DISPATCH]
|REDUCE  |          |LOAD      |      |PERCENT|
                    |SHUNT     |
```

The presence of the optional keyword DISPATCH is handled as described above for the SET data record.

To transfer load or generation from one bus to another, the following data record is used:

```
MOVE r |MW     | |GENERATION| FROM BUS bsid TO BUS bsid
       |PERCENT| |LOAD      |
                 |SHUNT     |
```

When transferring MW, the power shift, P_{sh}, is set to "r"; when the PERCENT keyword is specified, the power shift is calculated as:

$$P_{sh} = \frac{r \times |P_{orig}|}{100.}$$

where P_{orig} is initial load or generation, as appropriate, at the "*from bus*". The power shift is then subtracted from the original power at the "*from bus*" and added to the original power at the "*to bus*". When the quantity to be modified at the "*from bus*" is initially positive, a negative post-shift power at the "*from bus*" is treated as an error condition.

When generation is being transferred, the "*from bus*" must have in-service generation. If the "*to bus*" is not a generator bus, an appropriate message is printed and the power shift is treated as negative load at the "*to bus*". Either of the two buses may be a swing bus.

An in-service machine may be removed from service using the following data record:

```
REMOVE |MACHINE| mcid FROM BUS bsid [DISPATCH]
       |UNIT   |
```

Similarly, an out-of-service machine may be placed in-service with a record of the form:

```
ADD |MACHINE| mcid TO BUS bsid [DISPATCH]
    |UNIT   |
```

The presence of the optional keyword DISPATCH is handled as described above for the SET data record. The machine status contingency events are not permitted at swing buses.

In-service DC lines and FACTs devices can be blocked using the following data record:

```
BLOCK |TWOTERMDC   | devid
      |MULTITERMDC|
      |VSCDC       |
      |FACTS       |
```

where the four tokens in the selection list allow access to two-terminal dc lines, multi-terminal dc lines, VSC dc lines, and FACTS devices, respectively.

Automatic Single and Double Line Outage Contingency Specification

A series of single line outage contingency cases are designated with the following data record.

```
SINGLE |BRANCH| FROM BUS bsid
       |LINE  |
```

Each in-service branch connected to the designated bus is outaged, one at a time.

A series of double line outage contingency cases are designated with the following data record.

```
DOUBLE |BRANCH| FROM BUS bsid
       |LINE  |
```

This record generates contingencies such that each branch connected to the designated bus is outaged in turn with every other branch connected to the same bus.

All branches within a specified subsystem, can be outaged, either singly or in pairs, by using the following data record.

```
|SINGLE    | |BRANCH| IN |AREA i          |
|DOUBLE    | |LINE  |    |ZONE i          |
|BUSDOUBLE|              |OWNER i         |
|PARALLEL |              |KV r            |
                         |SYSTEM label    |
                         |SUBSYSTEM label|
```

The DOUBLE, BUSDOUBLE, and PARALLEL contingency specification records all generate contingency cases consisting of two simultaneous line outages. The DOUBLE record generates all combinations of double line outage contingencies for all branches whose endpoint buses are contained in the specified subsystem. That is, each branch in the subsystem is outaged in turn with every other branch in the subsystem. DOUBLE may be viewed as considering independent events causing simultaneous outages.

The BUSDOUBLE record is more restrictive than the DOUBLE record. For each bus in the specified subsystem, it generates all combinations of double line outage contingencies for all branches between that bus and other subsystem buses. BUSDOUBLE may be viewed as considering single events in substations which affect pairs of branches connected to a substation.

The PARALLEL record is more restrictive than the BUSDOUBLE record. It generates double line outage contingencies only for parallel branches (i.e., for each contingency case, the two branches being outaged connect the same pair of subsystem buses). Three-winding transformer contingencies are not generated by the PARALLEL record. PARALLEL may be viewed as considering single events on rights-of-way which affect pairs of branches on a right-of-way.

In using the SYSTEM or SUBSYSTEM keywords, the "label" must correspond to a subsystem label specified in a previously accessed Subsystem Description Data File (see Section 5.2.2.3).

Finally, the following data record provides for the outaging, either singly or in pairs, of all ties from a specified subsystem or all ties between a pair of subsystems:

```
|SINGLE| TIE FROM |AREA i           | ÈTO |AREA i           |
|DOUBLE|          |ZONE i           | Í   |ZONE i           |Ž
|BUSDOUBLE|       |OWNER i          | Í   |OWNER i          |Ž
|PARALLEL|        |KV r             | Í   |KV r             |Ž
                  |SYSTEM label     | Í   |SYSTEM label     |Ž
                  |SUBSYSTEM label| Î   |SUBSYSTEM label|°
```

The selection of tie branches in the case of overlapping subsystems is handled using the criteria given in Section 5.2.3 for the monitoring of ties.

For these record types, when the ***Multi Section Line Reporting*** option is enabled, the outaging of a multi section line grouping within the specified subset is treated as a contingency event; the entire multi section line is outaged. When the ***Multi Section Line Reporting*** option is disabled, individual members of multi section line groupings within the specified subset (rather than entire multi section line groupings) are outaged.

The SKIP block structure is used to specify individual branches which are to be excluded from outaging in contingencies generated as a result of subsequent SINGLE, DOUBLE, BUSDOUBLE, and PARALLEL contingency specification records. Each SKIP block structure is specified as follows:

```
SKIP
(branch specification record; see below)
.
.
(branch specification record; see below)
END
```

Non-transformer branches and two-winding transformers are specified on branch specification records using the following record format:

```
bsid TO bsid ⌈|CIRCUIT| ckid⌉
             ⌊|CKT    |     ⌋
```

Three-winding transformers are specified on branch specification records using the following record format:

```
bsid TO bsid TO bsid ⌈|CIRCUIT| ckid⌉
                     ⌊|CKT    |     ⌋
```

The default circuit identifier is ’1’ if this specification is omitted.

Branches specified in a SKIP block structure apply only to SINGLE, DOUBLE, BUSDOUBLE, and PARALLEL contingency specification records which are below it in the Contingency Description

Data File. Multiple SKIP block structures are allowed, and each SKIP block structure appends to the list of branches to be omitted from outaging as a result of subsequent automatic contingency specification records.

When the multi-section line reporting option is enabled and a branch which is a member of a multi-section line is specified, the multi-section line is excluded from outaging. When the multi-section line reporting option is disabled and a multi-section line is specified, an error message is printed and the record is ignored.

5.2.3.2 Building the AC Contingency Analysis Distribution Factor File

To launch the building process, use the ***Power Flow>Linear Network>Build Distribution Factor data file (DFAX…*** option (see Figure 5-2) to open the Building Distribution Factor Data File dialog.

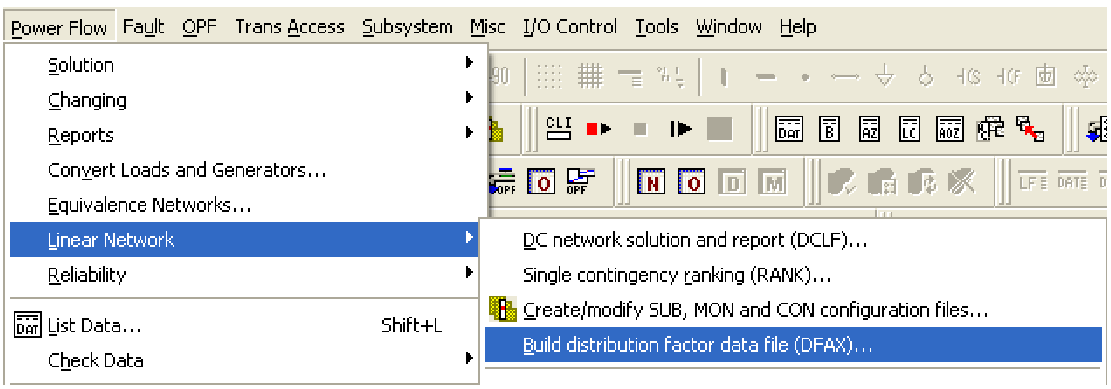


Figure 5-2. Building the Distribution Factor Data File

In the dialog (Figure 5-3), the data files available in the PSS™E EXAMPLE directory have been selected. They can be used for testing the process. The other file required is the user's destination file for the output. This can be a new file or a previously built file which can be written over. It will be a **.dfx* type file.

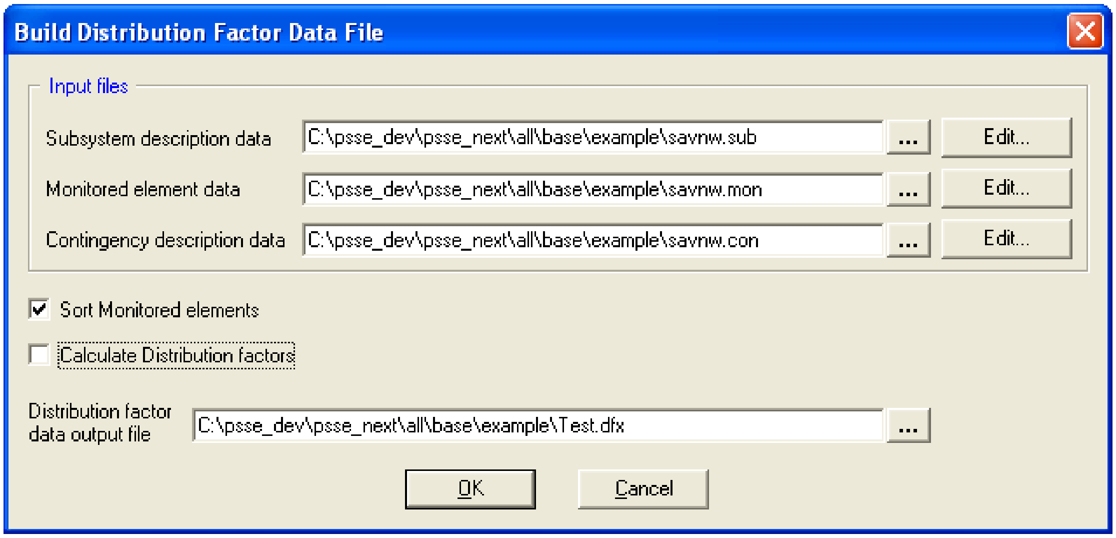


Figure 5-3. Building Distribution Factor Data File Dialog

The building process reads the Contingency Description Data File, updating internal arrays and transferring the contingency definitions into the Distribution Factor Data File. Any contingency case specifications in which errors are detected are alarmed and skipped.

The first check box gives the user the option of having the branches in the monitored element list sorted in the contingency analysis report. If the box is checked, branches are sorted in ascending numerical or alphabetical order according to the bus output option currently in effect. Branches are sorted by "*from bus*", and, for each "*from bus*", by "*to bus*" and circuit identifier. If the box is not checked, monitored branches remain in the same order in which they were specified in the Monitored Element Data File. In either case, interfaces are reported after all monitored branches in the order in which they were specified in the Monitored Element Data File.

For AC Contingency analysis, the second check box should remain unchecked and the process terminated with the ***OK*** button. Such a Distribution Factor Data File is specified not only for AC contingency analysis but also in transmission access analyses described in Chapter 10.

The second check box should be checked to build a distribution factor file suitable for DC contingency testing (Section 5.5.2) and linearized transfer limit analyses discussed in Chapter 6.

Since the information stored in the Distribution Factor Data File are a function of data organization and network topology in the working case, it follows that it must be re-executed before performing the AC contingency analysis any time one or more of the following occurs:

- Change of bus type code.
- Change of machine, load or branch status.
- Change of branch reactance.
- Change in the group of branches modeled as zero impedance lines.
- Change of metered end of a multi section line when the ***Multi Section Line Reporting*** option is enabled.

- Addition or removal of buses, branches, machines or loads.
- Change of any bus attributes by which subsystems, monitored elements, and/or contingencies are specified (e.g., area assignments, base voltages, etc.).
- Change to any of the Linear Network Analysis Data Files.

The distribution factor file building process is sensitive to the Multi Section Line Reporting option. That option setting, at the time of building, is saved in the Distribution Factor Data File and overrides the option setting in subsequent executions of the AC contingency analysis.

The distribution factor file building process is sensitive to the Bus Input option. That option setting is, at the time of building governs the manner in which buses **must** be identified (i.e., either bus numbers or extended bus names) in the Linear Network Analysis Data Files which are used in the building process. The setting of the Bus Input option in subsequent executions of the AC contingency analysis **must** be identical to that which existed when the distribution factor file was built.

A Distribution Factor Data File, and therefore the corresponding Monitored Element Data File, must specify at least one monitored branch. This applies even if one or more interfaces are specified or if the Distribution Factor Data File is to be used only for AC contingency calculations and only voltage violations are of interest.

Care should be taken not to include unnecessary END statements in the Linear Network Analysis Data Files. END statements are used to indicate the termination of block structures as well as the termination of the data input stream. Improperly placed END statements are often interpreted by activity DFAX as an end of input data signal. Symptoms of these conditions can occur during the execution of activities that use such a Distribution Factor Data File; they include monitored elements that are omitted from output reports and contingency cases that are skipped.

Activity DFAX is not sensitive to any interrupt control code options.

5.2.4 Ranking AC Contingencies by Severity

In large systems with many possible contingencies, especially single branch outages, it is often useful to minimize the computational and subsequent analyses by identifying the most severe contingencies prior to performing the contingency analysis. PSS™E facilitates the "ranking" of designated single branch outage contingencies and builds a Contingency Description Data File with contingencies specified in decreasing order of their estimated severities. Contingency rankings using two different performance criteria may be calculated. Additionally, contingencies which create "swingless islands" can be included.

5.2.4.1 About the AC Contingency Ranking Process

The process of ranking contingencies in order of severity involves the following:

1. Establish the criteria to be considered in formulating the ranking (e.g., overloading, voltage collapse, etc.).
2. For each criterion established in (1), define a scalar mathematical function which has a large value for contingencies which stress the system relative to that criteria, and a small value for those which do not; this function is called a "performance index". The performance index should be such that contingencies resulting in system conditions yielding large valued performance indices are considered more severe than system conditions with smaller performance indices.

3. Derive an efficient and accurate procedure for calculating these performance indices for a large number of possible contingencies.

The ranking process in PSS™E is able to calculate contingency rankings based on either or both of the following criteria:

1. An overload criteria measuring branch loadings relative to their ratings.
2. A voltage depression criteria which indicates increased reactive power consumption by estimating increases in reactive losses due to increased line loadings.

In the overload ranker, the performance index, PI, is defined as:

$$PI = \sum_{i=1}^{L} \left(\frac{P_i}{PMAX_i} \right)^2$$

where:

P_i	=	the active power flow on branch "i".
$PMAX_i$	=	the rating of branch "i".
L	=	the set of monitored branches contributing to PI.

Clearly, PI has a small value for system conditions when branch loadings are light and a large value when lines exceed their limits. An increase in PI following a contingency indicates that overall loading on the branches contributing to PI has increased.

The set of monitored branches in the overload ranker is as defined in a Monitored Element Data File. This is normally the same set of monitored elements which are specified in the building of a Distribution Factor Data File, as described previously in Section 5.2.2.1.

In the voltage ranker, the performance index is defined as:

$$PI = \sum_{i=1}^{L} X_i P_i^2$$

where:

X_i	=	the reactance of branch "i".
P_i	=	the active power flow on branch "i".
L	=	the set of monitored branches contributing to PI.

PI gives an indication of reactive power losses under different system conditions. As line loadings increase, their I^2X losses also increase. This increase in reactive demand generally results in a depression of system voltages.

The set of monitored branches in the voltage ranker is normally all branches in the working case. The user may elect to omit those branches for which no rating is specified in a selected rating set.

The performance indices are calculated in PSS™E using the ranking algorithm described in *An Advanced Contingency Selection Algorithm* by T.A. Mikolinnas and B.F. Wollenberg, IEEE Transactions on Power Apparatus and Systems, Vol. PAS-100, No. 2, February, 1981, pp. 608-617. This algorithm provides for the evaluation of the performance indices described above without requiring post-contingency branch flows.

5.2.4.2 Launching the AC Contingency Ranking Process

To initiate the ranking process, use the ***Power Flow>Linear Network>Single-line contingency ranking (RANK)…*** option (see Figure 5-4).

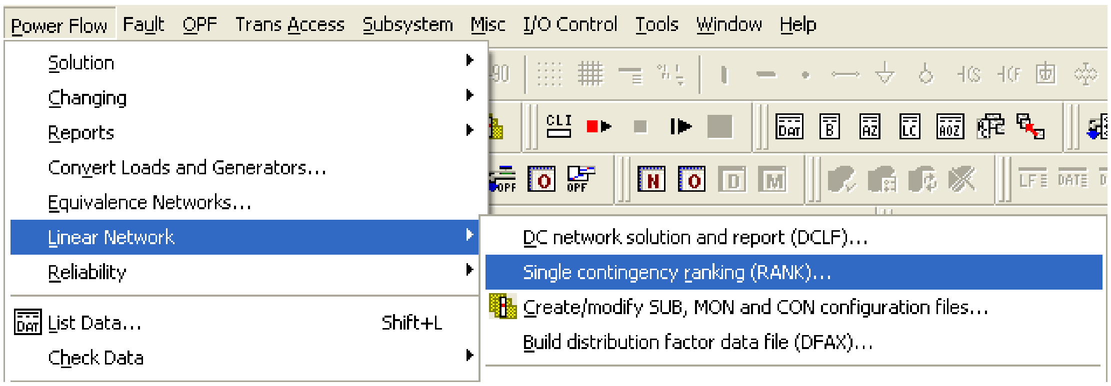


Figure 5-4. Launching the Ranking Process

5.2.4.3 Setting AC Contingency Analysis Solution and Control Parameters

When the ranking process is launched, the Single Line Contingency Ranking dialog is displayed. It displays its default solution and output control parameters and gives the user the opportunity to change any of these parameters, see Figure 5-5.

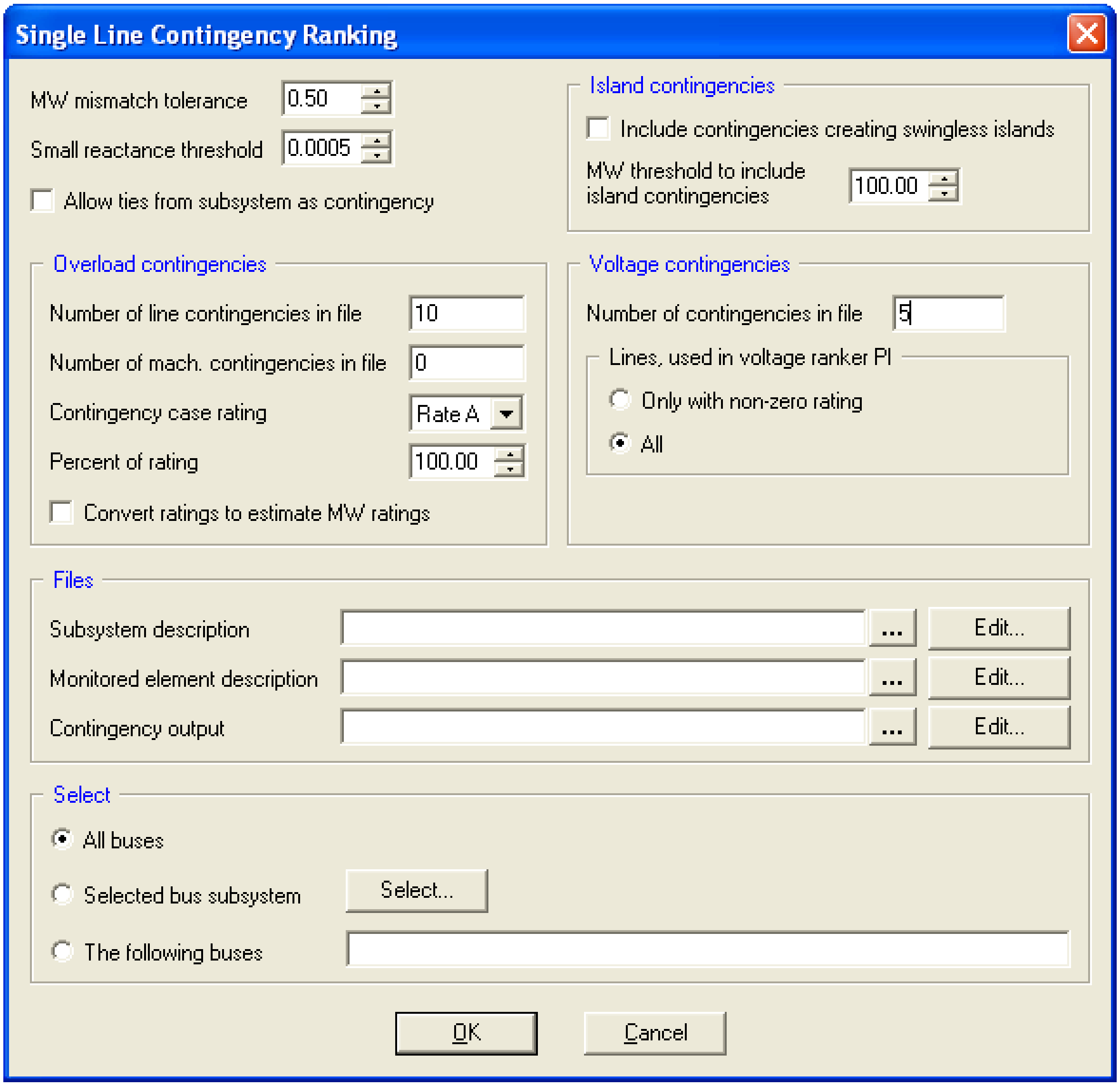


Figure 5-5. Single Line Contingency Ranking Dialog

MW mismatch tolerance: If the largest initial active power mismatch exceeds the specified MW mismatch tolerance, the user is given the opportunity to terminate the ranking process.

Small reactance threshold: The "performance index" calculation used in ranking is inaccurate for the outaging of branches with "small" reactances. All branches from the list of contingencies created by the ranking process whose magnitude of reactance is less than or equal to this threshold have their performance indices explicitly calculated. The contingency list is created based on the user’s subsystem selection, (see below).

Allow ties from subsystem as contingency: The group of branches which may be outaged are defined according to the subsystem selected by the user in the Select facility of the dialog. The box, if checked, will allow the inclusion in the contingency list, of both the selected subsystem branches and ties from the subsystem to other buses in the network. If the box is not checked, only branches from within the designated subsystem will be included.

Number of contingencies in file: This defines the number "n" of line outages from the overload ranking to be included in the output of the ranking process. A value of zero for this solution parameter causes the process to bypass the overload ranking calculation.

Number of mach. contingencies in file: This defines the number "m" of machine outages from the overload ranking to be included in the output of the ranking process. The overload ranker is applied to generating machine outages by assuming that the generation deficiency is redispatched among remaining machines and that the new dispatches cause changes in branch loading. The dispatch is always based on reserve. A value of zero for this solution parameter causes the process to bypass the machine overload ranking calculation.

Contingency case rating and percent of rating: These define the loading limits to be used in calculating overload performance indices. The default rating set is the one established as the default rating set program option setting.

Convert ratings to estimate MW ratings: If this is checked, ratings of monitored branches are converted to estimated MW ratings based upon each monitored line's Mvar loading at the metered end in the base case AC solution.

Number of (voltage) contingencies in file: This defines the number "k" of voltage contingencies to be included in the output of the ranking process. A value of zero for this solution parameter causes the process to bypass the voltage ranking calculation.

Lines used in voltage ranker PI: This defines the network branches which are to contribute to the voltage ranker performance index. Either all network branches are used or only those branches having a nonzero value in the designated case rating set.

Include contingencies creating swingless islands, and, MW threshold: Contingencies which result in the formation of an island of one or more buses, without a swing bus, are omitted from both the overlaid and voltage ranking process if this box is not checked. If the box is checked, the output of such contingencies is enabled in the ranking process, if the active power flow on such a branch exceeds the MW threshold tolerance specified. The tolerance is applied to the base case DC power flow.

5.2.4.4 Terminating Rules of the AC Ranking Process

The process will be terminated, following the user’s modifications to the solution and control parameters if:

- The number of overload and voltage contingencies are both zero and contingencies resulting in islands are not included.
- Generators have been converted.
- Any non type four bus is not connected to a type three bus through an in-service branch
- largest active power mismatch corresponding to the present AC solution voltage vector in the working case is greater than the MW mismatch tolerance solution parameter specified above.

5.2.4.5 Constructing an AC Contingency List by Subsystem

The ranking process constructs a contingency list as the basis for ranking, based on the user's subsystem selection. A subset of the Single Line Contingency Ranking dialog is shown in Figure 5-6. It shows the commonly used Select facility.

The user has the option of limiting the contingency list by Area, Owner, Zone, BasekV and Buses or including all branches. The ranking process will assume the user's designated subsystem as a basis for construction of the contingency list to be ranked.

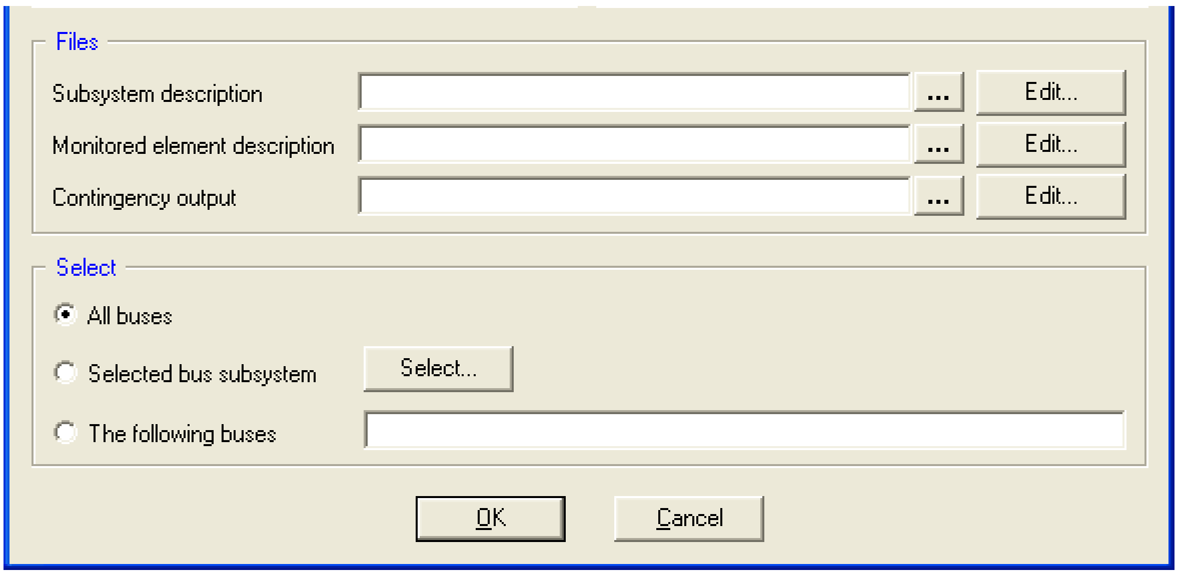


Figure 5-6. Selection of Subsystem for Construction of Contingency List

In Figure 5-6, the user can supply Subsystem and Monitored Element Description Data Files. That facility is available, however, only if overload ranking is enabled.

The ranking process establishes subsystem definitions and constructs a monitored branch list from these two files, respectively. It should be noted, however, that the ranking process excludes from the monitored branch list any branch with a zero (or negative) rating in the rating set specified. It also ignores any interface definitions.

The contingency ranking algorithm is unable to handle zero impedance lines as contingent or monitored branches. Consequently, if any zero impedance lines are present in the contingency list, the monitored element list for the overload ranker (if overload ranking is enabled) or the monitored element list for the voltage ranker (if voltage ranking is enabled), zero impedance line modeling is temporarily disabled and a new ordering of network buses is determined automatically. The optimal ordering process in PSS™E is used to determine an ordering of the network buses such that sparsity is maintained as the Jacobian matrix is triangularized for AC network solutions or the system admittance matrix is decomposed into its triangular factors in activities for linearized network analyses.

5.2.4.6 Analyzing AC Contingency Ranking Results

In the dialog, shown in Figure 5-5, the user supplies the name of an output file (type **.con*) to which the contingency specification records are to be deposited. If no file name is supplied, the results are written to the Output Bar.

If overload ranking is enabled, the "n" contingencies with the largest performance indices are output in the form of Contingency Description Data File records. Similarly, if voltage depression ranking is enabled, the "m" contingencies with the largest performance indices are output in the form of Contingency Description Data File records. Finally, if islanding contingency output is enabled, any contingency which results in the formation of a swingless island and whose base case DC power flow loading exceeds the threshold specified is output in the form of Contingency Description Data File records.

Figure 5-7 shows a subset of the Contingency Description Data file produced by the ranking process using the *savnw.sav* power flow case. It can be seen that each contingency included in the ranked set is identified with either an overload or a voltage label and independently numbered.

5.2.4.7 Application Notes on AC Contingency Ranking Process

Activity RANK derives performance indices and establishes severity rankings using the same linearized network model used in DC analogy network solutions as described in Section 5.5. This level of modeling is well suited for the main objective of the ranking process which is to select system conditions deserving further study. Contingencies enumerated by the overload rank can be examined further with DC power flow contingency analyses (see Section 5.5) or with AC power flow analyses described here in Section 5.2. Contingencies output by the voltage ranker are normally analyzed with AC power flow solution activities.

The use of a single number to characterize a system condition is convenient for ranking purposes. It does, however, have its limitations. For example, it is possible for a contingency which results in a number of heavily loaded lines but no overloaded lines to be ranked equally with a contingency which produces one or two overloaded lines with other lines being relatively lightly loaded. This is not necessarily a deficiency; it is quite appropriate to conclude that both of these system conditions deserve further study.

The performance indices defined above, and hence the severity rankings which are based on them, are dependent both on (1) network topological and parametric data and (2) the system operating point. New ranking should be performed if any of the following network changes are made:

- Change of bus type code.
- Change of machine, load or branch status.
- Change of branch reactance or change in the group of branches modeled as zero impedance lines.
- Change of metered end of a multi section line when the ***Multi Section Line Reporting*** option is enabled.
- Addition or removal of buses, branches, machines or loads.
- Change of any bus attributes by which subsystems, monitored elements, and/or contingencies are specified (e.g., area assignments, base voltages, etc.).
- Change to any of the Linear Network Analysis Data Files.

```
WORKING CASE HAS LARGEST MISMATCH OF      0.02 MW AT    154 [DOWNTN      230.00]

 PROCESSING THE SUBSYSTEM DESCRIPTION FILE...

 PROCESSING THE MONITORED ELEMENT DESCRIPTION FILE...
CONTINGENCY 'OVRLOD 1     '
OPEN LINE FROM BUS    154 TO BUS    205 CKT 1   / PI=    2.3194 'DOWNTN      230.00' TO 'SUB230      230.00'
END
CONTINGENCY 'OVRLOD 2     '
OPEN LINE FROM BUS    151 TO BUS    152 CKT 1   / PI=    1.0727 'NUCPANT     500.00' TO 'MID500      500.00'
END
CONTINGENCY 'OVRLOD 3     '
OPEN LINE FROM BUS    152 TO BUS   3004 CKT 1   / PI=    1.0685 'MID500      500.00' TO 'WEST        500.00'
END
CONTINGENCY 'OVRLOD 4     '
OPEN LINE FROM BUS    154 TO BUS   3008 CKT 1   / PI=    1.0465 'DOWNTN      230.00' TO 'CATDOG      230.00'
END
CONTINGENCY 'VLTAGE 1     '
OPEN LINE FROM BUS    201 TO BUS    204 CKT 1   / PI=   12.9703 'HYDRO       500.00' TO 'SUB500      500.00'
END
CONTINGENCY 'VLTAGE 2     '
OPEN LINE FROM BUS    152 TO BUS    153 CKT 1   / PI=   12.3183 'MID500      500.00' TO 'MID230      230.00'
END
CONTINGENCY 'VLTAGE 3     '
OPEN LINE FROM BUS    151 TO BUS    201 CKT 1   / PI=   12.1484 'NUCPANT     500.00' TO 'HYDRO       500.00'
END
CONTINGENCY 'VLTAGE 4     '
OPEN LINE FROM BUS    202 TO BUS    203 CKT 1   / PI=   12.0872 'EAST500     500.00' TO 'EAST230     230.00'
END
CONTINGENCY 'VLTAGE 5     '
OPEN LINE FROM BUS    201 TO BUS    202 CKT 1   / PI=   11.8464 'HYDRO       500.00' TO 'EAST500     500.00'
END
```

Figure 5-7. Typical Contingency Description File from the Contingency Ranking Process

Further, boundary condition changes (e.g., changes to loads, machine loadings, etc.), while not invalidating a Distribution Factor Data File, may affect the contingency rankings. Boundary condition changes which have only a minor impact on line loadings are not likely to significantly affect the rankings; changes such as increasing an area's load by ten percent or tripping a large unit and dispatching its previous power output among other machines in the system are likely to have a significant effect on line flows which in turn could significantly alter the contingency rankings.

The contingency ranking algorithm is not able to accurately calculate performance indices for branches with "small" reactances. For any branch in the contingency list whose reactance magnitude is less than or equal to the reactance threshold (see Figure 5-5 where the default value of 0.0005 is shown), the standard calculation is bypassed and its performance indices are explicitly calculated. The small reactance threshold value should always be at least as large as the zero impedance line threshold tolerance (see Section 3.2.5.1). Experience to date indicates that the default value is conservative and for most systems it could safely be reduced. For systems with small impedance lines, one could test the adequacy of this threshold by calculating two sets of overload rankings using different threshold values. If the performance indices for the outaging of small reactance branches are essentially the same, the smaller threshold value may be used.

When the ***Multi Section Reporting*** option is enabled, the subsystem assignments of the two endpoint buses of each multi section line are considered (rather than those of any of its dummy buses) in adding the branch to the contingency list. If a multi section line is added to the contingency list, the line section at the metered end of the multi section line is considered to be the outaged element. The performance indices which result are correct *unless* there is any load or generation present at any of the dummy buses of the multi section line.

For each three-winding transformer in the contingency list, performance indices are calculated for the outaging of each in-service winding in turn, and the largest of these is taken as the performance index for the entire transformer.

In constructing the contingency list, parallel lines between the same pair of buses which have identical impedances, loss estimates, and line shunt and phase shift active power injections (i.e., they are identical in the linear network model used by the ranking process) are not all included in the contingency list. Only one from among such a group of lines is needed. The ranking process does not check for identical three-winding transformers connecting the same three buses.

If both overload and voltage depression rankings are being determined in the same execution of the ranking process, the overload rankings are calculated first and any branch which is output by the overload ranker is removed from the contingency list prior to calculating the voltage rankings.

The Contingency Description Data File constructed by the ranking process is a standard source file which may be edited by the user prior to its being used in the building of a Distribution Factor file. Bus identifiers are written as bus numbers when the ***Numbers Input*** option is in effect, and as extended bus names when the ***Names Input*** option is in effect. That is, when the Contingency Description Data File produced by the ranking process is submitted for building the Distribution Factor File along with the same Subsystem Description and Monitored Element Data Files which were used for ranking, the files are compatible with each other.

5.2.5 Running AC Contingency Analysis

The network contingency calculation function calculates full AC power flow solutions for a specified set of contingency cases. Results are stored in a binary file. This file is subsequently processed to produce reports of violations, loadings and available capacity.

As shown in Section 5.2.1, in order to launch the contingency calculation solution process select the ***Power Flow>Solution>AC contingency solution (ACCC)*** option. This will open the AC Contingency Solution dialog shown in Figure 5-1 which is reproduced here for reference.

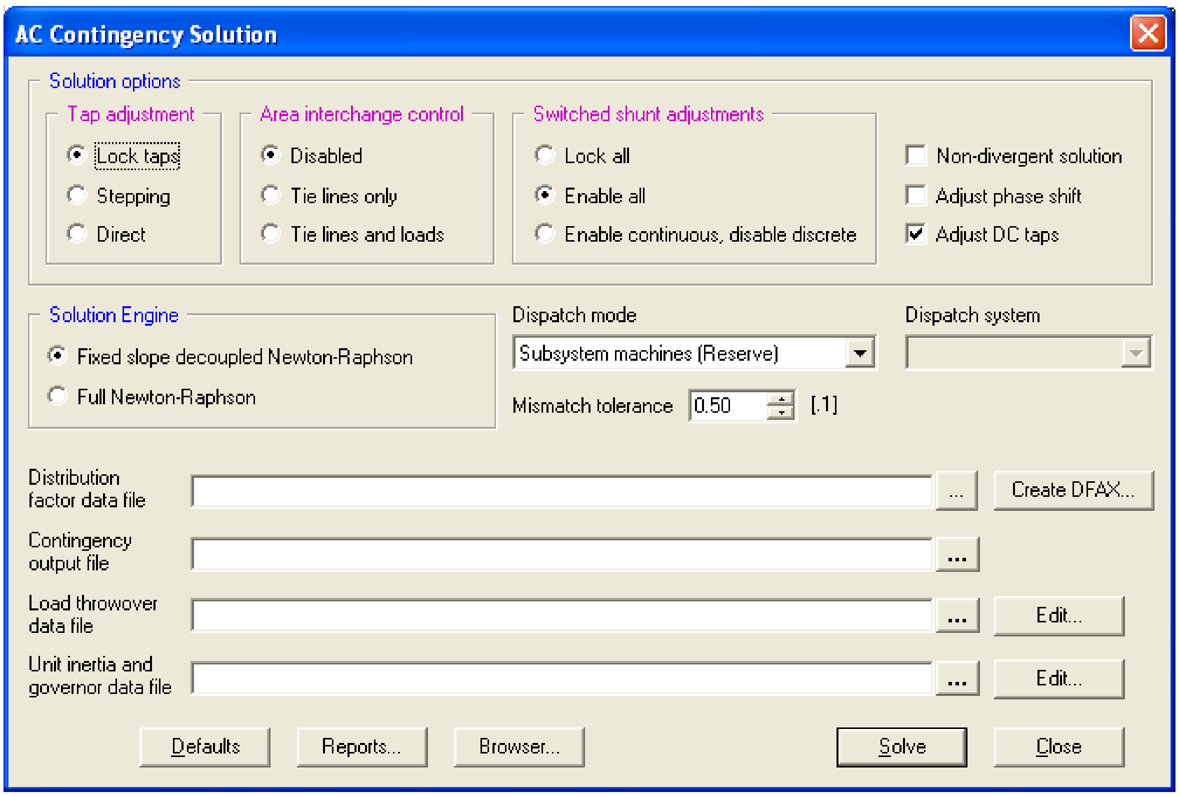


Figure 5-8. Showing AC Contingency Solution Dialog

When selected this process will alarm and terminate if generators are converted. It then checks that each non type four bus is connected back to a type three (swing) bus through the in-service AC network. If any violations are detected, an appropriate message is printed and the process is terminated.

As noted, the dialog prompts the user for various inputs, including: a mismatch tolerance, Newton solution parameters, a choice between two Newton type solutions, and the names of three files. Selecting the ***Close*** button terminates the process.

The user is required to enter the name of the Distribution Factor file which is build using the process described previously in Section 5.2.1 and select a Contingency Output file to which the results of the contingency analyses will be written. The Load Throwover Data file (Section 5.2.2) is optional.

Once the control and solution options together with the required filenames have been specified, select the ***Solve*** button to initiate the calculations.

The AC contingency solution process then sets up PSS™E working memory, the working files and temporary scratch files in preparation for the contingency case power flow solutions. This process uses either the fixed slope decoupled Newton-Raphson iterative power flow solution algorithm or the full Newton-Raphson method.

The contingency label and contingency events of each contingency case are logged at the progress output device as the solution process encounters it. A message identifies any network conditions that fail to converge or which are skipped.

The AC contingency solution process responds to the following interrupt control codes:

AB	Abandon the process following completion of the next iteration.
CM	Print the convergence and automatic adjustment monitors.
NM	Suppress any automatic adjustment monitors (only used with CM interrupt control code).
DC	Tabulate conditions for each DC line after each iteration.
FD	Tabulate conditions for each FACTS device after each iteration.

5.2.6 Viewing AC Contingency Analysis Reports

The AC Contingency Solution function calculates contingency solution results (loadings on monitored branches and interfaces, and bus voltage magnitudes) and places them into the specified AC Contingency Solution Output File. These results may then be tabulated using any or all of three output processing functions.

- The AC Contingency Single Run Report function (see Section 5.2.6.1) may be used to produce a variety of tabular and spreadsheet output reports of results from a single AC Contingency Solution Output File.
- The AC Contingency Multiple Run Report function (see Section 5.2.6.2) may be used to produce a variety of tabular reports of results from up to nine AC Contingency Solution Output Files.
- The auxiliary program AcccBrwsGrid (see Section 5.2.6.3) may be used to perform spreadsheet-like manipulations of the results from a single AC Contingency Solution Output File.

5.2.6.1 AC Contingency Single Run Report

To launch the AC contingency calculation report process select the ***Power Flow>Report>AC contingency report*** option. This will open the AC Contingency Reports dialog where the AC Contingency Solution Output file, the binary file into which the solution results have been deposited, can be identified. In addition, the dialog displays the default control parameters and provides the opportunity to change these parameters (see Figure 5-9).

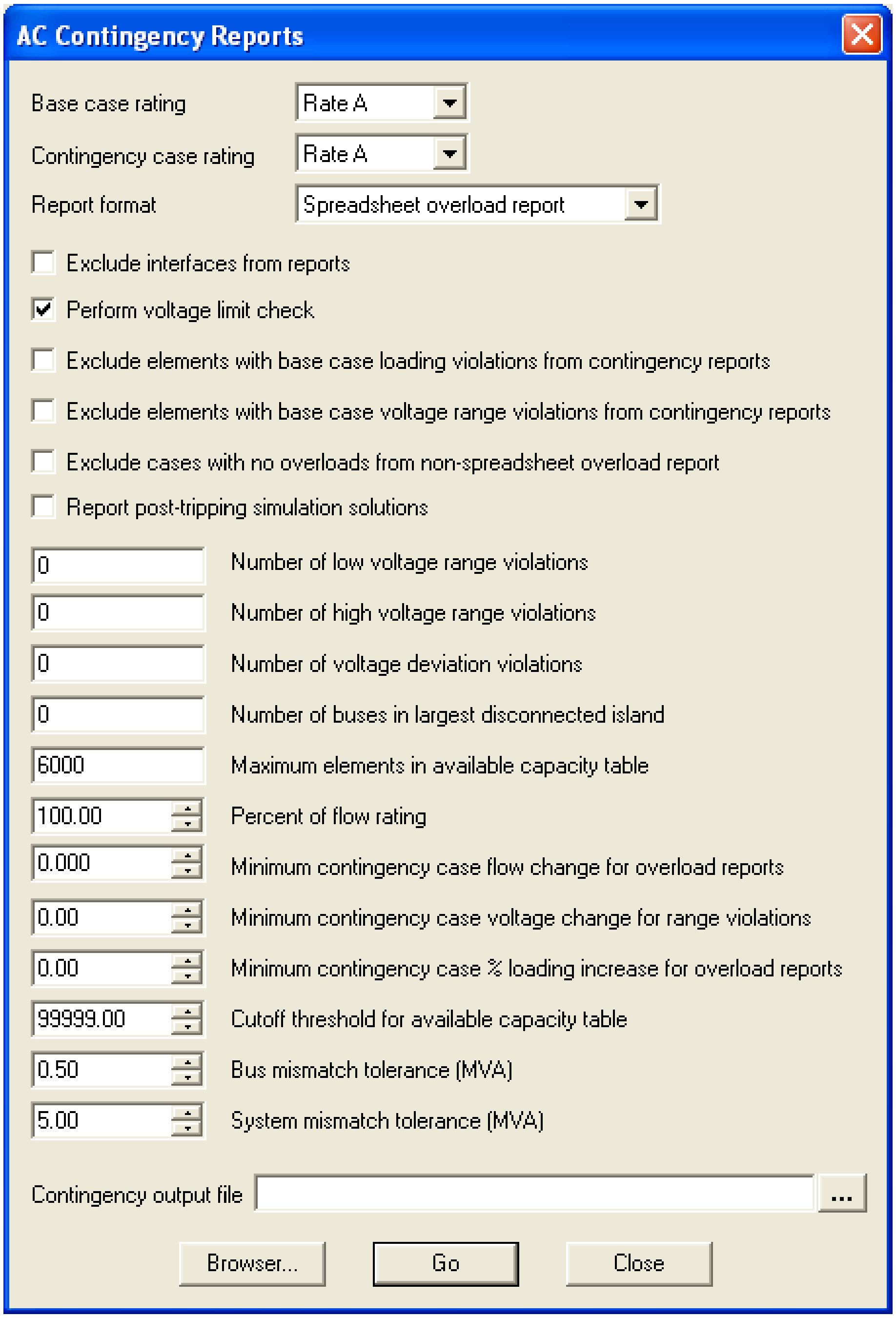


Figure 5-9. AC Contingency Reports Dialog

The contingency analysis report options can be specified on the AC Contingency Reports Dialog. The options are described as follows:

Base Case Rating and Contingency Case Rating: Base case and contingency case rating and the Percent of flow rating define the line loading limits used in determining overloads in base case and contingency cases respectively. Defaults are the default rating set program option (see Section 1.6.4).

Report format: The available options list allow the user to select from among:

- An overload report having a format appropriate for import to a spread sheet program.
- A loading table having a format appropriate for import to a spread sheet program.
- An available capacity table formatted for import to a spread sheet program.
- An overload report having a format appropriate for visual inspection (non-spread sheet).
- A loading table having a format appropriate for visual inspection (non-spread sheet).
- A report of the non-converged network conditions in a format appropriate for import to a spread sheet program.
- A report of overloads and voltage violations in each network condition which corrective actions are specified to alleviate the violations, overloads and voltage violations in corresponding post-corrective action network condition, as well as specified corrective actions, having a format appropriate for visual inspection (see Section 5.3.8 for corrective action analysis).

Exclude interfaces from report: Interface loadings may be excluded from all reports by checking this box.

Perform voltage limit check: Voltage limit checking may be enabled by checking this box. The user selects those subsystems whose bus voltages are to be monitored, the types of voltage check (voltage band or deviation from base case values), and threshold values by specifying records in the Monitored Element Data File (see Section 5.2.3). In the dialog, however, is the facility to specify the Minimum contingency case voltage change for range violations. If voltage checking is enabled, buses whose out-of-limits voltages in contingency cases differ from their base case voltages by less than this minimum change parameter are omitted from any voltage range checking reports.

Exclude elements with base case loading violations from contingency reports: To include or exclude monitored branches and interfaces which experience loading violations in the base case from being checked and reported in overload reports of contingency cases.

Exclude elements with base case voltage violations from contingency reports: To include or exclude monitored buses which experience voltage range violations in the base case from the corresponding check in contingency case reports. This flag applies only to the voltage range violation checks of the overload reports.

Exclude cases with no overloads from non-spreadsheet overload: This box can be checked to limit the number of records appearing in the non-spread sheet overload report. If the box is not checked, the report will identify all network conditions and it may indicate that some network conditions have no overloaded monitored elements.

Report post-tripping simulation solutions: By checking the box, each post-tripping network condition which satisfies the filter criteria is included in reports from 1 to 6, otherwise post-tripping network conditions are excluded from reports from 1 to 6 (see Section 5.3.6 for tripping simulation).

Filter Criteria: The converged network conditions included in a report may be limited by filter criteria. Only those contingencies that satisfy the filter criteria are reported. The following filter criteria are user assigned:

- Number of low voltage range violations
- Number of high voltage range violations
- Number of voltage deviation violations
- Number of buses in largest disconnected island

When voltage limit checking is enabled, a network condition is included in the report if the following conditions are satisfied:

- The number of buses in the largest disconnected island is greater than or equal to the threshold.
- The number of violations of all three voltage violation categories is greater than or equal to each respective threshold.

When voltage limit checking is disabled a network condition is included in the report if the number of buses in the largest disconnected island is greater than or equal to the threshold.

Maximum elements in available capacity table: This limits the total number of records (monitored elements) which may appear in the table, and the Cutoff threshold for available capacity table parameter excludes any monitored element whose available capacity exceeds this threshold.

Minimum contingency case flow change for overload report: Overloaded branches in contingency cases whose contingency case flows differ from their base case flows by less than this parameter are omitted from the overload report.

The ***Non-converged networks*** selection from the Report format field will identify the network conditions that fail the convergence criteria. The convergence criteria conditions include:

- an AC contingency solution process termination for the network condition of: "MET CONVERGENCE TOLERANCE", or "ITERATION LIMIT EXCEEDED", or "TERMINATED BY NON-DIVERGENT OPTION",
- a largest bus mismatch magnitude that is less than the Bus mismatch tolerance,
- and a system mismatch magnitude that is less than the System mismatch tolerance.

The AC contingency report process responds to the following interrupt control codes:

AB	Abandon the process following completion of the current system condition.

5.2.6.2 AC Contingency Multiple Run Report

The AC Contingency Multiple Run Report function is used to report the results of up to nine executions of the AC Contingency Solution function. It is initiated by selecting the ***Power Flow>Report>Multiple AC Contingency calculation report*** menu entry, which brings up the AC Multiple Contingency Run Report dialog (see Figure 5-10). This dialog is used to specify:

- the names of up to nine AC Contingency Solution Output Files;
- which of the optional reports are to be produced; and
- various reporting options and tolerances.

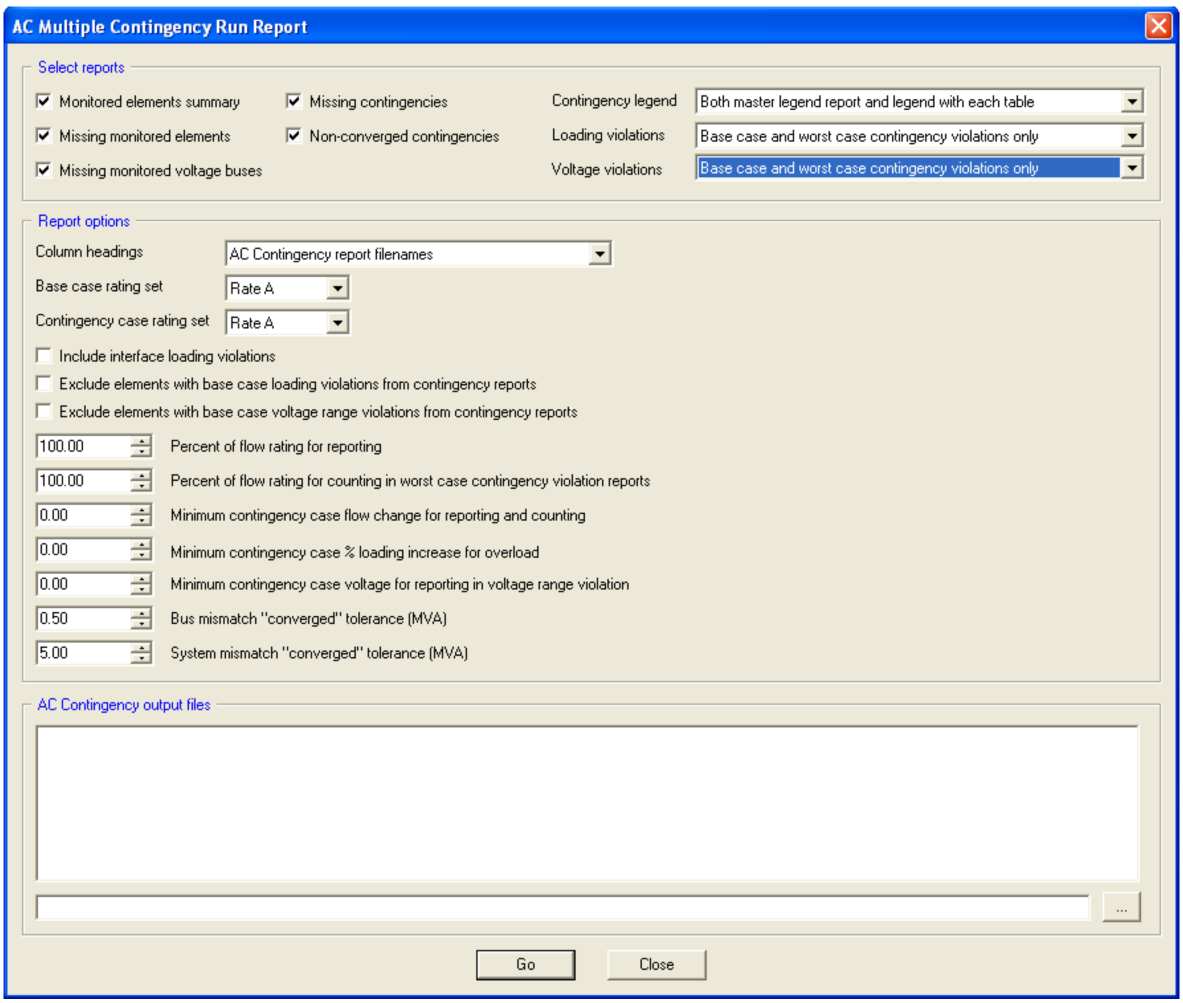


Figure 5-10. AC Multiple Contingency Run Report Dialog

Details on the significance of the input parameters to the AC Contingency Multiple Run Report function and on the operation of the AC Contingency Multiple Run Report function are given in Section Section 4.114.5 of the *PSS™E Program Operation Manual*. Details on the content of the reports which can be produced by the AC Contingency Multiple Run Report function are given in Section 4.114.6 of the *PSS™E Program Operation Manual*.

5.2.6.3 AC Contingency Post Processor

The AcccBrwsGrid program is used to perform spreadsheet-like manipulations on the results contained in an AC Contingency Solution Output File. It executes outside of PSS™E, and is initiated by selecting the ACCC Post Processor (AcccBrwsGrid) entry from the Windows® ***Start>Programs>PSSE 31>PSS™E Utilities*** menu. AcccBrwsGrid is documented in its "Help" files.

5.2.6.4 AC Contingency Result Retrieval Routines

A family of retrieval routines is provided to extract the results in contingency analysis output files and return arrays in FORTRAN format. These return values can then be used to create customized reported. These routines can be called from Python files (see Chapter 13).

5.2.7 Analyzing AC Contingency Analysis Results

To perform AC contingency analysis there are several steps:

1. Select ***Power Flow>Linear network>Build distribution factor file (DFAX)*** to produce the Distribution Factor file from the **.sub*, **.mon*, **.con* files.

2. Select ***Power Flow>Solution>AC contingency solution (ACCC)*** to produce the Contingency Output file using the Distribution Factor file.

3. Select ***Power Flow>Reports>AC contingency reports*** to produce the selected report using the Contingency Output file.

The process and file path are shown in Figure 5-11. Remember that the **.con* file can be partially constructed using the Ranking process in Section 5.2.4.

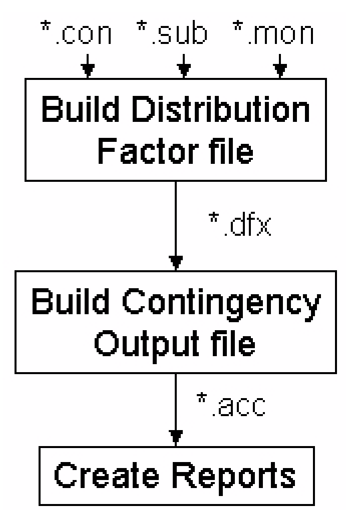


Figure 5-11. File Path and Process for AC Contingency Analysis

5.2.7.1 AC Contingency Analysis Report Conventions

For branches, loadings printed are MVA loadings. For each monitored non-transformer branch, the percent loading is either the percent current or the percent MVA loading, according to the non-transformer branch percent loading units program option setting (see *PSS™E Program Operation Manual* Sections 3.11 and 6.10), and both the MVA loading and percent loading are taken from the end of the branch with the larger current loading. An asterisk ("∗") is printed between the bus number and name of the bus at the end of the branch with the larger current loading.

For monitored transformers, the percent loading is either the percent current or the percent MVA loading, according to the transformer percent loading units program option setting. For monitored three-winding transformer windings, both the MVA loading and percent loading are calculated at the winding bus. For monitored two-winding transformers, both the MVA loading and percent loading are taken from the end of the branch with the larger MVA loading. An asterisk ("∗") is printed between the bus number and name of the bus at the end of the transformer with the larger MVA loading.

During the construction of the Distribution Factor Data File, when the ***Multi Section Line Reporting*** option is enabled, all members of each monitored multi section line are checked for overloading. For each such line section reported, both the branch itself and the multi section line of which it is a member are identified in the overload report.

The flow across an interface is taken as the sum of the MW flows of its members. For three-winding transformer windings, the MW loading is calculated at the winding bus as power flowing into the transformer. For other members, the MW flow is calculated at its metered end in the "*from bus*" to "*to bus*" direction. The percent loading for each interface is its percent MW loading based on its MW loading and its interface MW rating from the selected rating set.

The percent of flow rating does not affect the values printed as monitored element ratings in all report formats.

If a line outage contingency forms an island with no type three (swing) bus, a singular sub matrix is formed. In the overload report, any monitored branch which resides in the swingless island, as well as any interface which includes such a branch as a member, is omitted. In the loading table, such monitored elements have zero reported as their flows. Any bus in a swingless island is omitted from the voltage report.

5.2.7.2 Viewing the AC Contingency Analysis Overload Report

Each converged network condition which satisfies the filter criteria described in Section is included in the overload report. A branch or interface is reported if the following conditions are satisfied:

- Its rating from the selected rating set is nonzero.
- Its loading exceeds the specified percentage of the selected rating.
- For contingency cases, the difference in loading between the base and contingency cases exceeds the Minimum contingency case flow change for overload report tolerance.

In the non-spread sheet overload report, for each monitored element printed, the pre-contingency and post-contingency loadings, the rating and the post-contingency percent loading are listed. In the spread sheet overload report, for each monitored element printed, the post-contingency loading, the rating and the post-contingency percent loading are listed.

When the ***Perform voltage limit check*** is enabled, the overloaded monitored element report for each system condition is followed by the voltage violation report. The voltage violations report is presented in groups corresponding to the voltage monitoring data records specified in the Monitored Element Data File.

Each "voltage range" record results in a tabulation of those buses from the set of buses defined on the data record whose voltage is below the low voltage threshold (i.e., the first "r" value on the data record), followed by the list of buses whose voltage is above the high voltage threshold (i.e., the second "r" value on the data record). For contingency cases, if the voltage change at a bus from its value in the base case is less than the minimum contingency case voltage change for range violations parameter, the bus is omitted from the report.

Each "voltage deviation" record results in a tabulation of those buses from the set of buses specified on the data record whose voltage drop from their base case values exceeds the voltage drop threshold (i.e., the first "r" value on the data record), followed by the list of buses whose voltage rise exceeds the voltage rise threshold (i.e., the second "r" value on the data record).

For each bus printed, both its contingency case and base case values are printed. Report blocks are printed in the order in which the Monitor Voltage data records are contained in the Monitored Element Data File. Any report block for which no violations are detected is omitted from the report.

An example spreadsheet overload report is shown, partially in Figure 5-13a and 5-13b overleaf.

The report shows initially the rating set and percentage used for checking overloads, followed by the files used to perform the contingency analysis.

The overload report lists the monitored elements which suffer overloads and the name of the contingency causing the overload. To the right of that listing is the branch Rating, the post-contingency Flow and the post-contingency flow’s percentage of rating. It should be noted that the first branch listed, which is from bus 153 to bus 154 has a rating of 350 MVA, an post-contingency flow of 343.2 MVA and a percentage loading of 117%. While the MVA flow is apparently less than the branch rating, it must be remembered that the rating is based on branch current capacity and 100% voltage.

Ratings are assumed to have been entered as:

$$MVA_{rated} = \sqrt{3} \times E_{base} \times I_{rated} \times 10^{-6}$$

where:

E_{base}	=	the base voltage in volts of the bus to which the terminal of the branch is connected.
I_{rated}	=	the rated phase current in amps.

For this contingency, the MVA flow shown is concurrent with a voltage of 0.832 pu. This corresponding level of current is 17% higher than the branches current capacity.

The monitored interface listed as suffering an overload is identified in the *jdmsavnw.mon* file, indicating that the interface comprises the three branches shown (see Figure 5-12).

```
MONITOR INTERFACE WEST RATING 200 MW
3004 152
3006 153
3008 154
END
```

Figure 5-12. Sample Monitored Interface Description

```
ACCC OVERLOAD REPORT: MONITORED ELEMENTS LOADED ABOVE 100.0 % OF RATING SET B
INCLUDES VOLTAGE REPORT

DISTRIBUTION FACTOR FILE:     C:\Program Files\PTI\PSSE30\EXAMPLE\ac-contingency.dfx
SUBSYSTEM DESCRIPTION FILE:   C:\Program Files\PTI\PSSE30\EXAMPLE\jdmsavnw.sub
MONITORED ELEMENT FILE:       C:\Program Files\PTI\PSSE30\EXAMPLE\jdmsavnw.mon
CONTINGENCY DESCRIPTION FILE: C:\Program Files\PTI\PSSE30\EXAMPLE\jdmsavnw.con

<------------------ MONITORED BRANCH ------------------> CONTINGENCY    RATING     FLOW       %
   153 MID230       230.00     154*DOWNTN       230.00 1  TRIPLINE6        350.0     343.2     117.9
   203 EAST230      230.00     154*DOWNTN       230.00 1  TRIPLINE6        250.0     345.0     165.9
       INTERFACE WEST                                     TRIP1NUCLEAR     200.0     582.3     291.1
   153 MID230       230.00     154*DOWNTN       230.00 1  LOSE2LINEEA      350.0     470.6     162.8

MONITORED VOLTAGE REPORT:
SYSTEM                         CONTINGENCY  <--------- B U S --------->   V-CONT    V-INIT    V-MAX     V-MIN
ALL                      RANGE TRIPLINE2       154 DOWNTN      230.00  0.92754   0.93892   1.50000   0.93000
ALL                      RANGE TRIPLINE3       154 DOWNTN      230.00  0.90864   0.93892   1.50000   0.93000
```

a.)

```
CONTINGENCY LEGEND:
LABEL          EVENTS
TRIPLINE2    : TRIP LINE FROM BUS 152 [MID500      500.00] TO BUS 202 [EAST500     500.00]
TRIPLINE3    : TRIP LINE FROM BUS 153 [MID230      230.00] TO BUS 154 [DOWNTN      230.00]
TRIPLINE6    : TRIP LINE FROM BUS 154 [DOWNTN      230.00] TO BUS 205 [SUB230      230.00]
TRIP1NUCLEAR: REMOVE UNIT 1 FROM BUS 101 [NUC-A        21.600]
LOSE2LINEEA  : TRIP LINE FROM BUS 151 [NUCPANT     500.00] TO BUS 201 [HYDRO       500.00]
               TRIP LINE FROM BUS 152 [MID500      500.00] TO BUS 202 [EAST500     500.00]
```

b.)

Figure 5-13. Overload Report from AC Contingency Analysis

Following the overloaded element list, the report shows buses where voltage falls outside the specified range which has an upper threshold of 1.50 pu (a value of 1.05 is more adequate) and a lower threshold of 0.93 pu. The contingency initiating the voltage reduction is indicated by the bus number. Note that the list of buses outside the range is limited for only two in Figure 5-13.

Finally, following the listing of the overloaded elements and buses outside Range, the report presents a legend indicating for each contingency name, the details of the disturbance.

In the non-spread sheet overload report, for each monitored element printed, the pre-contingency and post-contingency loadings, the rating and the post-contingency percent loading are listed.

5.2.7.3 Viewing the AC Contingency Analysis Loading Report

Each converged network condition which satisfies the filter criteria is included in the loading table. For each monitored element, the selected rating, loading and percent loadings are reported.

In the non-spread sheet format, results are reported in tabular form with four contingency cases per table. Each group of contingency cases contains a page summarizing the contingency cases performed. For each contingency, the contingency label and the events defining the contingency are listed.

The summary page is followed by the loading table. For each monitored element, this table lists its rating, loading, and percentage loading in the base case network solution, and the loading and percentage loading for each of the contingency cases reported. MVA loadings are printed for branches and MW loadings reported for interfaces. Percentage loadings are calculated as described above. Any percentage loading above the specified percentage threshold is followed by an asterisk ("∗"). When the ***Multi Section Line Reporting*** option is enabled, all members of each monitored multi section line are reported.

In the spread sheet format, the monitored flow results are reported in a table that include the following fields: the monitored element description, the network condition label, the element’s rating, the element’s flow, and the element’s percent loading. A subsequent table identifies event descriptions for each network condition label.

Single branches are listed first, either in the order in which they were specified in the Monitored Element Data File, or in ascending numerical or alphabetical order, according to the option selected during the building process of the distribution factor file. Unless excluded, interfaces are listed in the order in which they were specified.

If ***Perform voltage limit check*** is enabled, the loading table is followed by voltage violation report blocks corresponding to the voltage monitoring data records specified in the Monitored Element Data File. In the non-spread sheet format, the report is limited to only those buses with voltage violations. In the spread sheet format, the report includes all buses identified by the monitoring data records.

Figure 5-14 shows a partial sample of a loading report obtained using the *savnw.sav* power flow case.

```
ACCC LOADING REPORT: RATING SET B
INCLUDES VOLTAGE REPORT

DISTRIBUTION FACTOR FILE:     C:\Program Files\PTI\PSSE30\EXAMPLE\ac-contingency.dfx
SUBSYSTEM DESCRIPTION FILE:   C:\Program Files\PTI\PSSE30\EXAMPLE\jdmsavnw.sub
MONITORED ELEMENT FILE:       C:\Program Files\PTI\PSSE30\EXAMPLE\jdmsavnw.mon
CONTINGENCY DESCRIPTION FILE: C:\Program Files\PTI\PSSE30\EXAMPLE\jdmsavnw.con

 <------------------ MONITORED BRANCH ------------------> CONTINGENCY    RATING     FLOW       %
     151*NUCPANT     500.00    152  MID500      500.00 1  BASE CASE      1300.0     495.3     37.7
     153 MID230      230.00    154*DOWNTN       230.00 1  BASE CASE       350.0     259.2     78.9
     201 HYDRO       500.00    151*NUCPANT      500.00 1  BASE CASE      1300.0     623.8     47.4
     202*EAST500     500.00    152  MID500      500.00 1  BASE CASE      1300.0     135.3     10.3
     203 EAST230     230.00    154*DOWNTN       230.00 1  BASE CASE       250.0     133.7     57.0
     205 SUB230      230.00    154*DOWNTN       230.00 1  BASE CASE       660.0     434.4     70.1
    3004 WEST        500.00    152*MID500       500.00 1  BASE CASE         0.0     195.5
    3006 UPTOWN      230.00    153*MID230       230.00 1  BASE CASE         0.0      80.3
    3008 CATDOG      230.00    154*DOWNTN       230.00 1  BASE CASE       440.0     112.1     27.1
         INTERFACE WEST                                   BASE CASE       200.0    -147.9     74.0
         INTERFACE EAST                                   BASE CASE       350.0    -130.8     37.4
     151*NUCPANT     500.00    152  MID500      500.00 1  TRIPLINE2      1300.0     487.2     37.0
     153 MID230      230.00    154*DOWNTN       230.00 1  TRIPLINE2       350.0     272.9     84.0
     201 HYDRO       500.00    151*NUCPANT      500.00 1  TRIPLINE2      1300.0     638.5     48.5
     202*EAST500     500.00    152  MID500      500.00 1  TRIPLINE2      1300.0       0.0      0.0
     203 EAST230     230.00    154*DOWNTN       230.00 1  TRIPLINE2       250.0     118.5     51.1
     205 SUB230      230.00    154*DOWNTN       230.00 1  TRIPLINE2       660.0     412.9     67.4
    3004 WEST        500.00    152*MID500       500.00 1  TRIPLINE2         0.0     195.6
    3006 UPTOWN      230.00    153*MID230       230.00 1  TRIPLINE2         0.0      82.3
    3008 CATDOG      230.00    154*DOWNTN       230.00 1  TRIPLINE2       440.0     126.0     30.9
         INTERFACE WEST                                   TRIPLINE2       200.0    -146.3     73.1
         INTERFACE EAST                                   TRIPLINE2       350.0    -131.9     37.7
```

Figure 5-14. Sample Loading Report

It can be seen in the report that there are eleven monitored elements two of which are defined interfaces. Their ratings, flow and percentage loadings are listed for the base case and subsequently for each contingency for which a converged case was obtained.

5.2.7.4 Viewing the AC Contingency Analysis Available Capacity Report

The available capacity report provides a "worst case" summary over all converged system conditions which satisfy the filter criteria. In this report, each monitored element with a nonzero rating in the specified rating set is printed no more than once: for the system condition (base case or contingency case) in which its "available capacity" index is smallest.

The two parameters which may be assigned to control the contents of the available capacity table are the:

- **Maximum elements in available capacity table** parameter may be used to restrict the table to the "n" monitored elements with the smallest "available capacity" indices.
- **Cutoff threshold for available capacity table** parameter may be used to restrict the table to those monitored elements whose "available capacity" indices are less than the specified "cutoff" threshold.

For each monitored element reported, this table lists: its rating; its base case loading; its "worst case" loading, percentage loading, "available capacity" index, and the system condition (the contingency case label or "BASE CASE") under which the "worst case" loading occurs. The report indicates the number of "other" system conditions under which the monitored element has the same "available capacity" index as in the tabulated "worst case", and the "impact" on the monitored element.

Base case (the column headed BASE) and worst case (MAXIMUM) loadings are MVA loadings for branches and MW loadings for interfaces,. Worst case percentage loadings are calculated as described above for the overload report. For non transformer branches, current loadings, calculated as in Section 4.4.5.1.3, are listed in the column headed "IMPACT". For transformer branches the IMPACT is MVA loading and for interfaces the IMPACT is MW loading. An "available capacity" index (the column labeled AVAILABLE) is listed for each tabulated monitored element. The "available capacity" index is the difference between the RATING and the IMPACT.

In the available capacity report, monitored elements are printed in order of increasing "available capacity" index. Clearly, elements with negative indices are overloaded in the "worst case" system condition.

This report is terminated with descriptions of those contingency cases which were identified as "worst case" system conditions for one or more monitored elements. This contingency case summary lists contingency cases in the order in which they were calculated.

Figure 5-15 shows the capacity report for the *savnw.sav* power flow case. It can be seen that the Interface West suffers the greatest capacity deficiency, followed by the branches from bus 154 to buses 153 and 203. Other listed branches and interface show, for the contingencies tested (and converged) an available capacity for increased flow.

```
ACCC AVAILABLE CAPACITY REPORT: RATING SET B

DISTRIBUTION FACTOR FILE:      C:\Program Files\PTI\PSSE30\EXAMPLE\ac-contingency.dfx
SUBSYSTEM DESCRIPTION FILE:    C:\Program Files\PTI\PSSE30\EXAMPLE\jdmsavnw.sub
MONITORED ELEMENT FILE:        C:\Program Files\PTI\PSSE30\EXAMPLE\jdmsavnw.mon
CONTINGENCY DESCRIPTION FILE:  C:\Program Files\PTI\PSSE30\EXAMPLE\jdmsavnw.con

<------- F R O M -------> <--------- T O --------->CKT CONTINGENCY  OTHERS    BASE  MAXIMUM   IMPACT   RATING  PERCENT  AVAILABLE
       INTERFACE WEST                                  TRIP1NUCLEAR     0    147.9    582.3    582.3    200.0    291.1    -382.3
   153 MID230       230.00    154 DOWNTN      230.00 1 LOSE2LINEEA      0    259.2    470.6    570.0    350.0    162.8    -220.0
   203 EAST230      230.00    154 DOWNTN      230.00 1 TRIPLINE6        0    133.7    345.0    414.8    250.0    165.9    -164.8
   205 SUB230       230.00    154 DOWNTN      230.00 1 LOSE2LINEEA      0    434.4    497.5    602.5    660.0     91.3      57.5
  3008 CATDOG       230.00    154 DOWNTN      230.00 1 LOSE2LINEEA      0    112.1    265.3    321.3    440.0     73.0     118.7
       INTERFACE EAST                                  LOSE2LINESWE     0    130.8    138.3    138.3    350.0     39.5     211.7
   151 NUCPANT      500.00    152 MID500      500.00 1 LOSE2LINEEA      0    495.3    734.2    816.9   1300.0     62.8     483.1
   201 HYDRO        500.00    151 NUCPANT     500.00 1 LOSE2LINESWE     0    623.8    676.3    672.4   1300.0     51.7     627.6
   202 EAST500      500.00    152 MID500      500.00 1 LOSEEASTBIGT     0    135.3    448.0    459.8   1300.0     35.4     840.2

CONTINGENCY LEGEND:
LABEL         EVENTS
TRIPLINE6   : TRIP LINE FROM BUS 154 [DOWNTN      230.00] TO BUS 205 [SUB230      230.00]
TRIP1NUCLEAR: REMOVE UNIT 1 FROM BUS 101 [NUC-A       21.600]
LOSEEASTBIGT: TRIP LINE FROM BUS 151 [NUCPANT     500.00] TO BUS 201 [HYDRO       500.00]
LOSE2LINESWE: TRIP LINE FROM BUS 3004 [WEST        500.00] TO BUS 152 [MID500      500.00]
              TRIP LINE FROM BUS 3006 [UPTOWN      230.00] TO BUS 153 [MID230      230.00]
LOSE2LINEEA : TRIP LINE FROM BUS 151 [NUCPANT     500.00] TO BUS 201 [HYDRO       500.00]
              TRIP LINE FROM BUS 152 [MID500      500.00] TO BUS 202 [EAST500     500.00]
|
```

Figure 5-15. Sample Capacity Report from the savnw.sav Power Flow Case

5.2.7.5 Viewing the AC Contingency Analysis Non-Converged Network Report

The report identifies each network condition that fails to meet the convergence criteria. The report format is suitable for import into a spread sheet program.

The user selected values of ***Bus mismatch tolerance*** and ***System mismatch tolerance*** are identified following the report title. A table of non-converged networks is presented that identifies: the network condition label, the largest bus mismatch magnitude, the system mismatch magnitude and the termination condition from the AC contingency solution process. A subsequent table identifies event descriptions for each network condition label.

For the *savnw.sav* power flow case, Figure 5-16 shows the Report. It can be seen that five contingencies have failed to converge. The user, at this point has the option of re-testing the AC contingencies using the non-divergent power flow solution with this automated approach or to examine each contingency heuristically using a variety of solution methods and solution controls. Often the problem is a lack of voltage support.

```
ACCC NON-CONVERGED NETWORK REPORT:
BUS MISMATCH TOLERANCE=  0.5000 MVA
SYSTEM MISMATCH TOLERANCE=  5.0000 MVA

DISTRIBUTION FACTOR FILE:     C:\Program Files\PTI\PSSE30\EXAMPLE\ac-contingency.dfx
SUBSYSTEM DESCRIPTION FILE:   C:\Program Files\PTI\PSSE30\EXAMPLE\jdmsavnw.sub
MONITORED ELEMENT FILE:       C:\Program Files\PTI\PSSE30\EXAMPLE\jdmsavnw.mon
CONTINGENCY DESCRIPTION FILE: C:\Program Files\PTI\PSSE30\EXAMPLE\jdmsavnw.con

CONTINGENCY  X--- MISMATCH (MVA) ----X
X- LABEL --X X-- BUS ---X X- SYSTEM -X TERMINATION CONDITION
TRIPLINE1      10147.       27161.     BLOWN UP
TRIP2NUCLEAR   797.99       3173.8     BLOWN UP
ADDLARGELOAD   795.39       3657.2     BLOWN UP
LOSEEASTLOAD   2496.2       17064.     BLOWN UP
XFMR204-205    797.23       3537.0     BLOWN UP

CONTINGENCY LEGEND:
LABEL         EVENTS
TRIPLINE1   : TRIP LINE FROM BUS 151 [NUCPANT 500.00] TO BUS 152 [MID500  500.00]
TRIP2NUCLEAR: REMOVE UNIT 1 FROM BUS 101 [NUC-A       21.600]
              REMOVE UNIT 1 FROM BUS 102 [NUC-B       21.600]
ADDLARGELOAD: INCREASE BUS 154 [DOWNTN      230.00] LOAD BY 50 PERCENT
LOSEEASTLOAD: SET BUS 205 [SUB230      230.00] LOAD TO 0 MW
XFMR204-205 : DISCONNECT BRANCH FROM BUS 201 [HYDRO500.00] TO BUS 205 [SUB230 230.00] CKT &1
```

Figure 5-16. Non-Converged Network Report Example

5.2.7.6 Viewing the AC Contingency Analysis Corrective Action Report

To have corrective action reports, contingency analysis output file must be produced by multiple level contingency analysis initiated with perform corrective actions (see Section 5.3).

Each network condition that satisfies two conditions is included in the non-spread sheet corrective action report. One is that a network condition causes violations, and corrective actions are specified for the network condition to relieve the violations. After each network condition is solved, flow overloads and bus voltage violations are identified by the operating limits specified prior to multiple level contingency analysis. Flow limits are ***Contingency case rating and percent of rating*** specified in Multiple Contingency Analysis Tab prior to multiple level contingency analysis; 100.0 percent of ***rating set program settings*** by default. Voltage limits are taken from Monitored Element Data File. Another condition is that network conditions must satisfy the filter criteria.

The corrective actions results also depend on running mode specified prior to multiple contingency analysis. The running mode is specified according to selections of three options in contingency analysis: perform multiple contingency analysis, perform tripping simulation (see Section 5.3.6) and perform corrective actions (Section 5.3.8). When contingency analysis is initiated with perform tripping simulation, flows and voltages in post-tripping network conditions are checked against limits, corrective actions are then specified to alleviate flows and voltages violations if any.

To reproduce the complete sequences that had been simulated, and present corrective actions and violations that had been identified and activated corrective actions during contingency analysis, some options in **AC Contingency Single Run report** are not allowed to select, but set by programs when the report option is corrective action report. ***Exclude interfaces from report*** is not checked, and the box of ***Perform voltage limit check*** is checked. Boxes of ***Exclude elements with base case loading violations from contingency reports***, ***Exclude elements with base case voltage range violations from contingency reports*** and ***Exclude cases with no overloads from non-spreadsheet overload report*** are unchecked. ***Report post-tripping simulation solutions*** is checked. ***Base case rating*** and ***Contingency rating*** and ***percent of flow rating*** are taken from the rating set specified prior to contingency analysis.

In the summary page, input files and options used in contingency analysis are presented. For each network condition that satisfies conditions, post-contingency solution is reported first, then followed by post-tripping solution and post-corrective action solution. Each solution is presented in the format similar to non-spread sheet overload report format. For each monitored element printed, the pre-contingency loading, one of post-contingency, post-tripping and post-corrective action loading, the rating and the corresponding percent loading are listed. For each bus printed, voltage in one of post-contingency, post-tripping and post-corrective action solutions, base case voltage are printed.

Violations in solutions are followed by correctives actions specified for the network condition. Corrective actions are grouped into three groups: generation dispatch, load shedding and phase shift angle adjustment. For generator dispatch, active power outputs prior to corrective action analysis and changes in active power outputs in MW are reported. For load shedding, active power loads prior to corrective actions and load curtailments in MW are reported. For phase shifter angle adjustments, phase shifter angles prior to corrective actions and angle adjustments in degrees are reported.

Figure 5-17 shows a partial sample of a corrective action report. In the sample, contingency '1_5' causes an interface flow overloading and two bus voltage violations. In post-corrective action solution, the loading of the interface is decreased to 100.2 percent of rating A and two bus voltage violations still exist. The corrective actions involved are generation re-dispatch of five generators, load shedding at four buses and one phase shift angle adjustment.

```
<----------- C O N T I N G E N C Y   E V E N T S ----------><--------- O V E R L O A D E D   L I N E S ----------> <- MVA(MW|FLOW ->
      <----------- MULTI-SECTION LINE GROUPINGS -----------> <------- F R O M -------> <--------- T O --------->CKT  PRE-CNT  POST-CNT  RATING  PERCENT
 REMOVE UNIT 1 FROM BUS 101 [NUC-A       21.600]            -------------------------------------------------------------------------- CONTINGENCY 1_5
 TRIP LINE FROM BUS 151 [NUCPANT     500.00] TO BUS 201 [HYDRO       500.00]
                                                                   INTERFACE WEST                                    -147.9    425.0    200.0    212.5

                                                       X-------- B U S --------X  V-CONT  V-INIT  X-------- B U S --------X  V-CONT  V-INIT
          AREA 2 BUSES WITH VOLTAGE GREATER THAN 1.0600:    201 HYDRO       500.00 1.09500 1.04000     211 HYDRO_G     20.000 1.07232 1.04042

 <---------------- POST - CORRECTIVE ACTIONS -----------------><--------- O V E R L O A D E D   L I N E S ----------> <- MVA|MW)FLOW ->
      <----------- MULTI-SECTION LINE GROUPINGS -----------> <------- F R O M -------> <--------- T O --------->CKT  PRE-CNT  POST-COR  RATING  PERCENT
 ----------------------------------------------------------------------------------------------------------------POST-CORRECTIVE ACTIONS
                                                                   INTERFACE WEST                                    -147.9    200.5    200.0    100.2

                                                       X-------- B U S --------X  V-CORR  V-INIT  X-------- B U S --------X  V-CORR  V-INIT
          AREA 2 BUSES WITH VOLTAGE GREATER THAN 1.0600:    201 HYDRO       500.00 1.09923 1.04000     211 HYDRO_G     20.000 1.07668 1.04042

 <----------- C O N T R O L   A D J U S T M E N T S --------->
               *** GENERATION  DISPATCH (MW) ***            X-------- B U S --------X  PGEN-INIT  PGEN-DELT
                                                               102 NUC-B       21.600     803.9        6.1
                                                               206 URBGEN      18.000     889.9       10.1
                                                               211 HYDRO_G     20.000     614.6        1.6
                                                              3011 MINE_G      13.800     833.1     -115.1
                                                              3018 CATDOG_G    13.800     115.3     -115.3
               *** LOAD SHEDDING (MW) ***                   X-------- B U S --------X  LOAD-INIT  LOAD-DELT
                                                               153 MID230      230.00     200.0       40.0
                                                               154 DOWNTN      230.00    1000.0       60.0
                                                               203 EAST230     230.00     300.0       40.0
                                                               205 SUB230      230.00    1200.0       66.1
               *** PHASE SHIFTER ADJUSTMENT ***             <------- F R O M -------> <--------- T O --------->CKT  PHAS-INIT  PHAS-DELT
                                                               203 EAST230     230.00    202 EAST500     500.00 1          0.0       -2.6
```

Figure 5-17. Sample Corrective Action Report

5.2.8 Appending to the AC Contingency Solution Output File

The Append ACCC function is used to output system conditions of a contingency case solution, as contained in a designated Saved Case File, in the form of an AC Contingency Solution Output File. This is useful for the situation in which the specification and/or solution of a contingency case exceeds the capability of the AC Contingency Solution function, but the user wishes to have the contingency case reported along with, and in the same format as, the contingency cases calculated by the AC Contingency Solution function.

The Append ACCC function is initiated by selecting the ***Power Flow>Report>Append to AC Contingency solution output file*** menu entry, which brings up the Append to AC Contingency Solution Output File dialog (see Figure 5-18). This dialog is used to specify:

- the label by which the contingency is to be identified;
- up to sixteen lines of text describing the contingency;
- an option to append to an existing AC Contingency Solution Output File or to create a new one; and
- the names of four files.

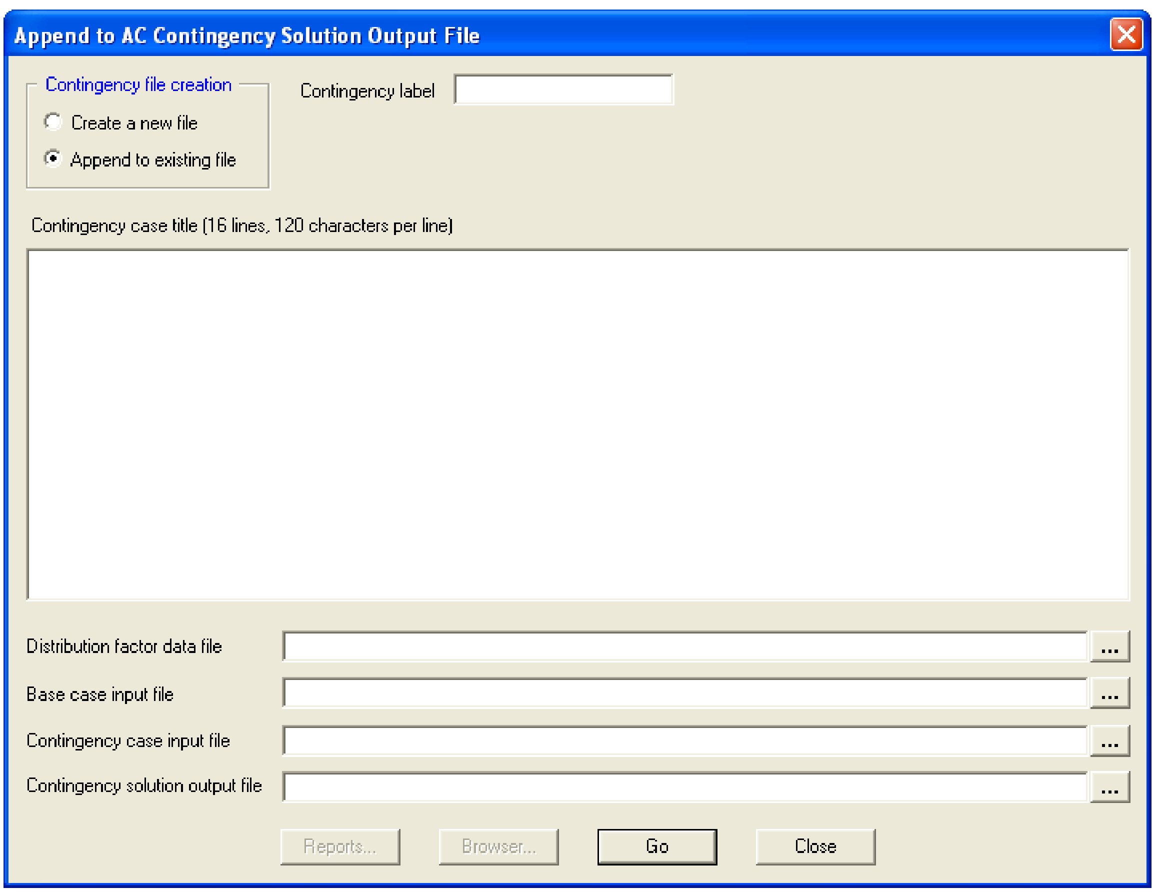


Figure 5-18. Append to AC Contingency Solution Output Dialog

Details on the significance of the input parameters to the Append ACCC function and on the operation of the Append ACCC function are given in Section 4.114.7 of the *PSS™E Program Operation Manual*.

5.2.9 Implement Generation Dispatch Algorithm in Contingency Analysis

For each contingency, automatic contingency analysis imposes the contingency, implements generation re-dispatch if generation dispatch mode is enabled (see Section 5.2.1.2), and solves AC load flow solution sequentially. To know how system operation condition is changed by a contingency, such as bus disconnection, line open/close and changes in bus boundary condition, and how the imbalances caused by the contingency is apportioned by means of generation dispatch algorithms, the Implement Generation Dispatch feature is used to impose a contingency and/or implement generation dispatch, and **DIFF** activity can then be used to check the changes made by Implement Generation Dispatch to working case. The modified case can then be solved by load flow solution.

Select ***Power flow >Solution>Implement Generation Dispatch*** to launch the Implement Generation Dispatch dialog (see Figure 5-19).

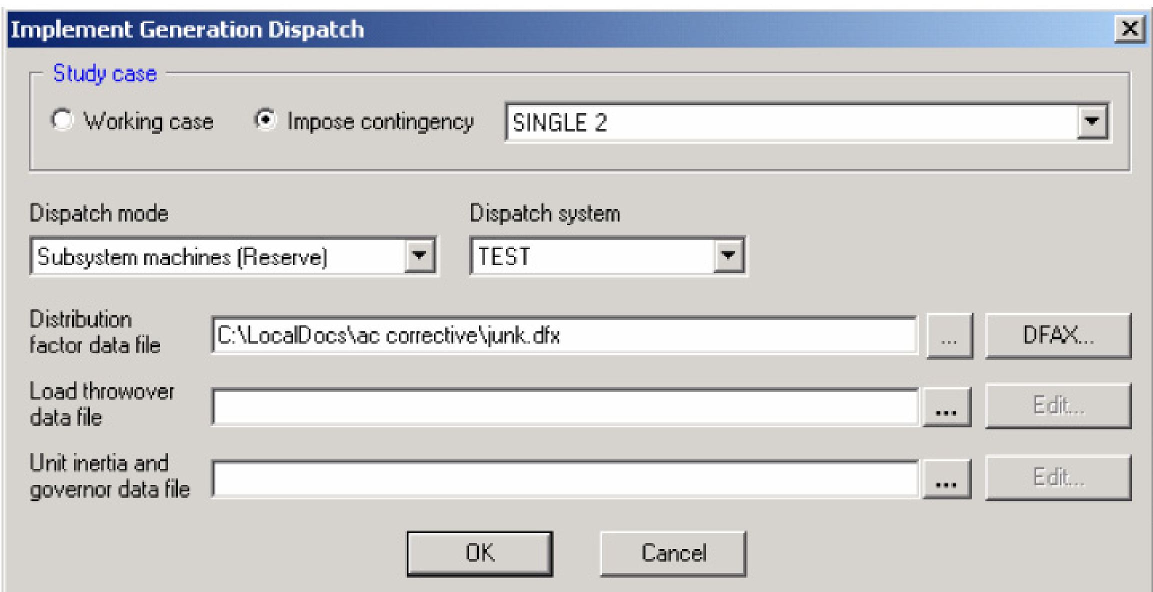


Figure 5-19. Implement Generation Dispatch Algorithm

Study case: Select to impose a contingency from the contingency list specified in Contingency Description Data File or to use working case

Dispatch Mode and Dispatch system: Specify generation dispatch mode and dispatch subsystem. If Dispatch mode is disabled, buses that are not connected to a swing bus will be disconnected and imbalances are absorbed by the swing bus within the island.

There are three input Files:

Distribution Factor Data File: it is a required file, that contains contingency descriptions and subsystem specifications.

Load Throwover Data File: It is an optional file, that contains load throwover data.

Unit Inertia and Governor Data File: it is an optional file, that contains generator inertia and governor response data.

5.2.10 Application Notes for AC Contingency Analysis

One role of the AC contingency calculation is that of a screening tool whose purpose is to focus attention on those contingency cases which deserve closer study. In this mode, it is often appropriate to use a looser convergence tolerance than is used in other power flow solution applications.

If any line outage contingency cases form one or more swingless islands, any DC line having at least one converter station bus in such an island is blocked for that contingency case solution. Similarly, any FACTS device having at least one of its buses in such an island removed from service for that contingency case solution. Any such DC line or FACTS device which is a tie branch between a swingless island and the remaining system is alarmed.

When the SET, CHANGE, INCREASE, DECREASE or MOVE contingency records operate on LOAD, the specified buses must have one or more in-service connected loads. For the MOVE event, in-service connected load must exist at both the FROM and TO buses. When these events employ the PERCENT keyword, the connected bus load MVA magnitudes are adjusted. The reactive power to active power ratio remains constant, and the relative proportions of constant MVA, constant current and constant admittance load components remain constant. When these events employ the MW keyword and the bus demand includes a non-zero active power component, the bus load MVA is adjusted by the ratio of the specified MW value to the initial active power bus load (or this ratio plus 1.0 if the specified value is incremental load). This initial active power bus load is computed using nominal (i.e., not voltage adjusted) values for constant current and constant admittance load components, and recognizing the affect of any load multiplier associated with an Optimal Power Flow (see the *PSS™E OPF Manual*) adjustable bus load table. When these events employ the MW keyword and the initial bus active power load is zero, the specified MW value is assigned to the bus as a constant MVA component active power load and the reactive power bus load is unaltered.

When the SET, CHANGE, INCREASE, DECREASE or MOVE contingency records operate on SHUNT and employ the PERCENT keyword, the bus SHUNT MVA magnitude is adjusted. When these events employ the MW keyword and the initial active power component of shunt admittance is non-zero, the bus shunt MVA is adjusted by the ratio of the specified MW value to the initial active power component of shunt admittance (or this ratio plus 1.0 if the specified value is incremental load). When these events employ the MW keyword and the initial active power component of shunt admittance is zero, the specified MW value is assigned to the active power component of shunt admittance and the reactive power component of shunt admittance is unaltered.

When the SET, CHANGE, INCREASE, DECREASE or MOVE contingency records operate on GENERATION, the specified buses must have one or more in-service connected machines. For the MOVE event, an in-service connected machine must exist at both the FROM and TO buses. The value specified, whether PERCENT or MW, affects the magnitude of the bus active power generation only.

If the DISPATCH option is included on a SET, CHANGE, INCREASE, DECREASE, ADD or REMOVE contingency record, the opposite change in the active power boundary condition is distributed among the type two and three buses specified. Note that only type two and three buses are allowed to participate in picking up the active power boundary condition change imposed by the contingency event. Any other buses specified as participating are alarmed and omitted from the power dispatch calculation. If only non type two or three buses are specified, the system swing bus(es) pick up all of the active power change.

The AC contingency calculation detects the specification of duplicate single- and double-line outage contingencies and calculates the contingency case solution only for the first specification of such a contingency. Any contingency cases involving bus boundary condition contingency events or more than two-line outage contingency events are not checked for duplication.

It is required that the working case be solved to an acceptable mismatch tolerance prior to executing the AC contingency calculation solution process.

5.3 Performing Multiple Level AC Contingency Analysis

Multiple level AC contingency analysis provides a comprehensively featured function for testing deterministic reliability as discussed in Section 5.1.2. It features easy configuration, built-in contingency ranking function to automatically select contingencies, tripping simulation of post-contingency conditions and corrective action analysis to relieve flow overloads and voltage violations caused by a contingency. The procedure of evaluating a single contingency with multiple level contingency analysis is shown in Figure 5-20.

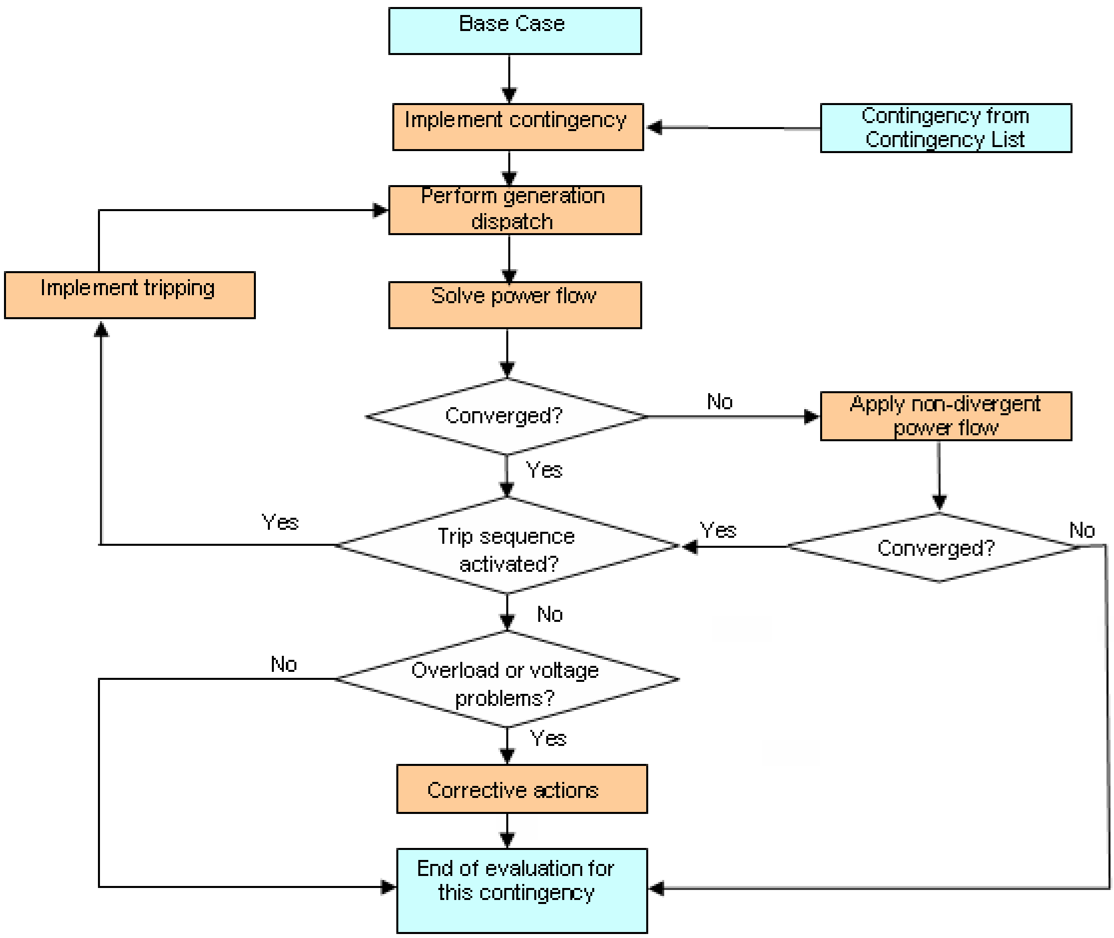


Figure 5-20. Outline of Evaluation Procedure Using AC Power Flows for a Single Contingency

Multiple level AC contingency analysis calculates full AC power flow solutions for the user specified and automatically selected single or multiple contingencies, monitors voltage and loading conditions and stores the results in a binary file. It will accept a user-specified list of contingencies to be included in a contingency study as defined in a Contingency Description Data File (see Section 5.2.3.1). Each of these specified contingencies may consist of a combination of generation and transmission outages. In addition, contingencies may be selected by built-in automatic contingency rankers. Two such rankers, for branch overload and voltage collapse contingencies (see Section 5.2.4), are integrated within multiple level contingency analysis. There is full flexibility in defining contingency subsystem; i.e., you can define in which portion of the system you will allow contingencies automatically selected by rankers. A contingency sub-system may comprise of specific equipment, a combination of control areas or zones, or the whole database (see Section 5.2.1).

The multiple contingency solution function performs deterministic reliability assessment for up to three levels, namely N-1, N-2 and N-3 criterion. User specified and automatically selected contingencies are evaluated individually and in combination with each other as overlapping outages up to the specified evaluation level. When used in conjunction with the automatic contingency ranker, a stopping criterion (non-failure cutoff) is applied at each level. This provides the opportunity for enormous savings in computational evaluation of contingencies. Furthermore, PSS™E has built-in logic that identifies if a given set of outages has already been evaluated as a contingency, thus ensuring that an automatic contingency analysis run is comprised only of unique contingencies.

Multiple level AC contingency analysis models special relay actuation schemes designed to trip or reconnect a generator or a circuit, and shed or transfer load in response to specified low voltage, line flow, interface flow, generator output, or line and generator service status. During contingency analysis, switching will be automatically performed and new load flow solutions obtained whenever trip/reconnect relaying sequences are triggered. The tripping simulation can simulate cascading outages from contingencies.

Multiple Level Ac contingency analysis performs corrective action analysis to eliminate flow overloads and voltage violations caused by a contingency with the objective of minimizing control adjustments including: re-dispatch of generations, curtailment of loads and adjustment of phase-shifting transformers. This can help translate system related reliability measures, such as the location and magnitude of branch overloads and bus voltage violations, to customer-impact indices in terms of the potential amount of service interruptions, which are critical indices in probabilistic reliability assessment.

5.3.1 Setting-Up for Multiple Level AC Contingency Analysis

To launch multiple level contingency calculation solution process select the ***Power Flow>Solution>Multiple AC contingency solution*** option. This will open the Multi-Level AC Contingency Solution dialog (see Figure 5-21). There is a series of tabs at the top of the dialog, they are Power Flow Control, Multiple Contingency Analysis, Tripping Simulation and Corrective Actions; each tab prompts the users to set-up one function of the multiple level contingency analysis.

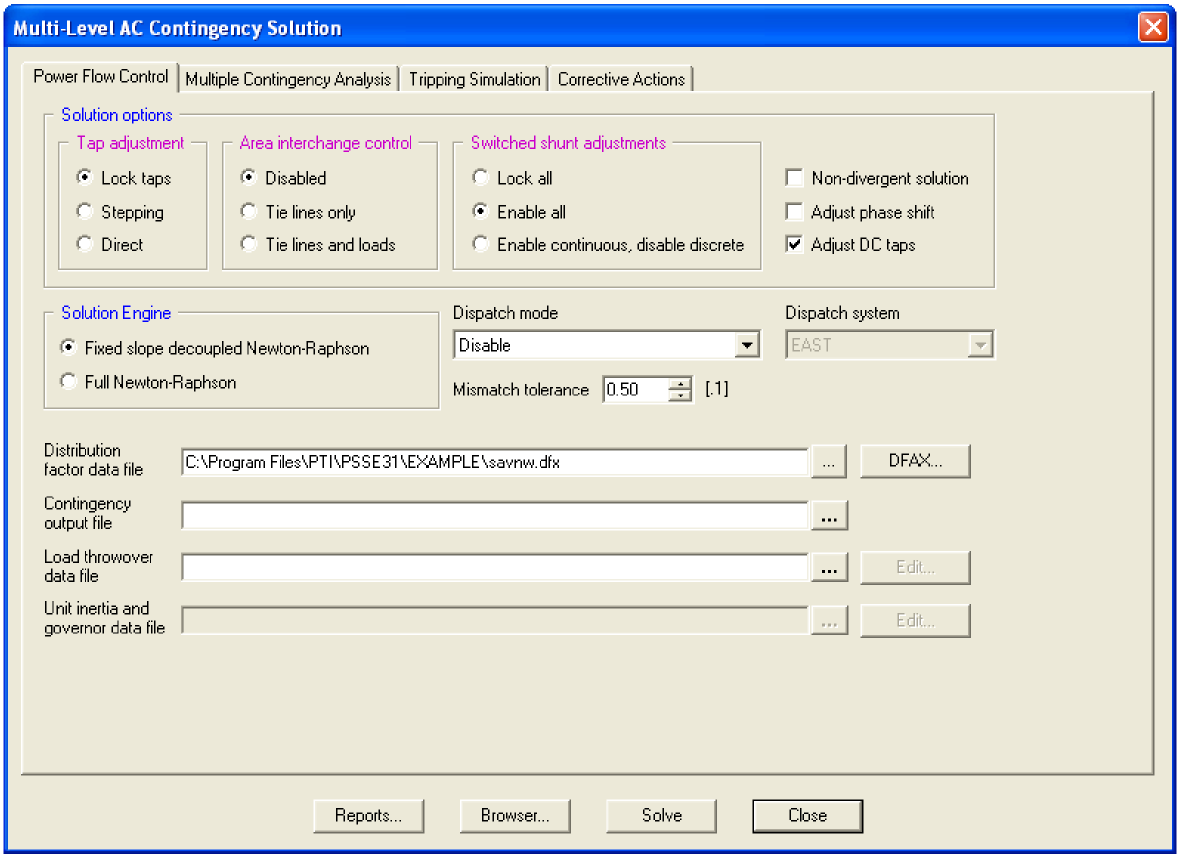


Figure 5-21. Multi-Level AC Contingency Solution Dialog – Power Flow Control Tab

5.3.1.1 Setting AC Power Flow Options

When the Power flow Control tab is selected, the dialog appears as shown in Figure 5-21.

Solution options: Select the desired solution options to be applied during load flow calculations (see Chapter 4).

Solution Engine: Select the desired load flow solution engine to be used (see Chapter 4).

Dispatch mode: Dispatch codes for generation dispatch calculations in contingency analysis (see Section 5.2.1.1).

Dispatch system: Select the subsystem for the generation dispatch (see Section 5.2.1.1).

Mismatch tolerance: Specify mismatch tolerance. This tolerance will be used to check for the largest initial active or reactive power mismatch. If exceeded, the process is terminated. This value is also used as the convergence tolerance in power flow solution (see Chapter 4).

5.3.1.2 Input Data Files

There are five files used for multiple level contingency analysis:

- **Distribution Factor Data:** This must be created using the ***Build*** facility found in the ***Power Flow>Linear Network*** option (see following Section 5.2.3.2).
- **Contingency Output:** This is a required file designated by the user as the destination for the results of the contingency calculations.
- **Load throwover Data:** This is an optional file that contains load throwover data (see Section 5.2.2).
- **Unit Inertia and Governor Data:** This is an optional file, created by the user, that contains generator inertia and governor response data (see following Section 5.6.1).
- **Tripping data:** if multiple level contingency analysis is initiated with tripping simulation, this file is required, created by the user, that contains tripping data (see following Section 5.3.7.2). The tripping Data File is specified in tripping simulation tab.

5.3.1.3 Setting Multiple Level Contingency Options

When the Multiple Contingency Analysis tab is selected, the dialog for setting multiple level contingency analysis is shown in Figure 5-22.

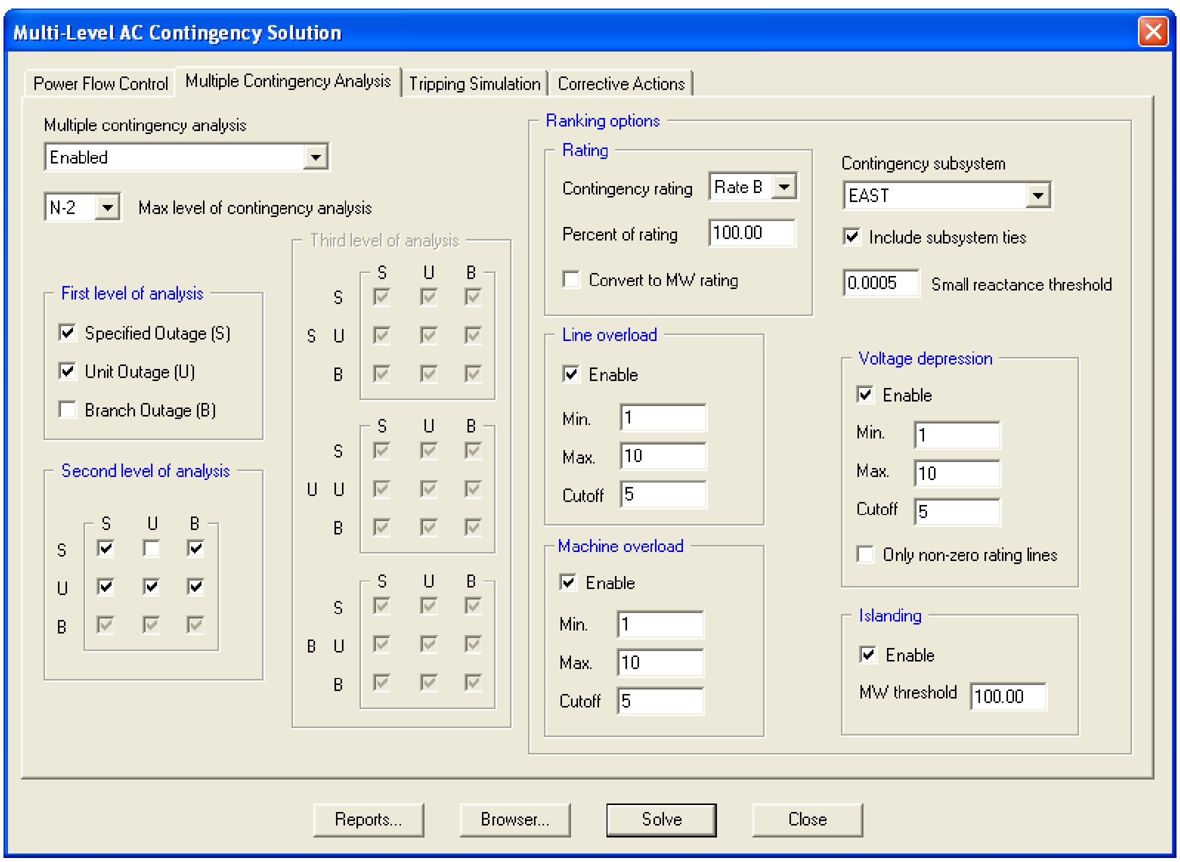


Figure 5-22. Multi-Level AC Contingency Solution Dialog – Multiple Contingency Analysis Tab

Perform multiple contingency analysis: When perform multiple contingency analysis is disabled, all other options in this dialog are disabled; when perform multiple contingency analysis is enabled, the next-level contingencies (e.g. secondary contingencies of a primary contingency) of each non-failure contingency (see Section 5.3.3) are to be evaluated; when perform multiple contingency analysis is enabled with failure cutoff disabled, the next-level contingencies of each failure and non-failure contingency will be evaluated.

Max level of contingency analysis: Select the level of multiple contingency analysis up to three. This option enables the contingency combination selections at less or equal levels.

First level analysis: Select the contingency groups included in the primary contingency list (see Section 5.3.4). There are three groups of contingencies to choose, namely S, U and B. S represents user specified outages, U and B are machine outages and branch outages respectively. When the ranked contingencies are included in the primary list, the ranking solution is performed on the base power flow case using a linearized network model. The number of ranked contingencies of each group included in the list is determined by the min, max, cutoff values of the ranker.

Second level analysis: Select the contingency groups included in the secondary contingency list for each primary contingency. Nine N-2 contingency combinations are represented with a matrix. Each row represents one type of first-level contingencies which the secondary contingency list is generated based on existing system condition after solving. The name of contingency type is dictated by the letter at the beginning of each row; three elements of a row represent the same categories (S, U, B) in secondary contingency list. When an element is selected, the corresponding N-2 contingency will be evaluated. If one group of contingencies is not specified in primary contingency list, its secondary list is empty and the corresponding row will be disabled.

Third level analysis: Select the contingency groups included in the tertiary contingency list for each first-level and second-level contingency. There are 27 N-3 contingency combinations for the tertiary contingency; each combination is comprised of one of each of three contingency event types for each level. These combinations are represented with three matrices; each of them has nine elements. Each matrix represents one group of first-level contingency cases and is dictated by the letter at the first column; each row of a matrix represents one type of second-level contingencies and is indicated by the letter at the second column. Three elements of a row of a matrix represent categories S, U and B in tertiary contingency list. The tertiary contingency list is built based on existing system condition after solving first and second level contingencies. Similarly, tertiary contingency list may exist if and only if its corresponding first and second level contingencies have been tested. That is if one group of contingency is not included in primary list, all following lists are empty and the corresponding matrix is disabled; if one group of contingency is not tested at level 2, the corresponding row is disabled and the tertiary list is empty.

Ranking options: Select contingency rankers and specify the number of each group of contingencies to be included in the list (for contingency ranking, see Section 5.2.4).

Machine overload ranking: has four control parameters.

- **Enable:** Include single machine outages from branch overload ranking in the contingency list.
- **Min.:** The minimum of single machine outages from the overload ranking to be tested in the list.
- **Max.:** The maximum of single machine outages from the overload ranking to be tested in the list.

- **Cutoff:** The number of consecutive single machine outages from the overload ranking that are non-failure.

Line overload: has four control parameters.

- **Enable:** Include single branch outage that causes overloading in the contingency list.
- **Min.:** The minimum of single branch outages from the overload ranking to be tested in the list.
- **Max.:** The maximum of single branch outages from the overload ranking to be tested in the list.
- **Cutoff:** The number of consecutive single branch outages from the overload ranking that are non-failure.

Voltage depression: has four control parameters.

- **Enable:** Include single branch outage that causes voltage collapse in the contingency list.
- **Min.:** The minimum of single branch outages from the voltage collapse ranking to be tested in the list.
- **Max.:** The maximum of single branch outages from the voltage collapse ranking to be tested in the list.
- **Cutoff:** The number of consecutive single branch outages from the voltage collapse ranking that are non-failure.

Islanding ranking: has two control parameters.

- **Enable:** Include single branch Contingencies which result in the formation of an island of one or more buses, without a swing bus, in the contingency list.
- **MW threshold:** The minimum of active power flow on such branches.

Contingency case rating and percent of rating: These define the loading limits to be used in calculating overload performance indices. By default, contingency case rating is rating set program option setting and percent of rating is 100 percent. They are also used to determine flow overloads in post-contingency solutions and classify the post-contingency solutions into either failure or non-failure groups, and if Perform corrective actions option is enabled, then corrective actions are specified to remove the flow overloads.

Contingency subsystem: Select the subsystem where contingencies will be automatically selected by rankers.

See Section 5.2.4 for options of Convert ratings to estimate MW ratings, Small reactance threshold, and Allow ties from subsystem as contingency.

5.3.2 Terms Used in Multiple-Level Contingency Analysis

Multiple level contingency analysis can perform both simple and complex contingency analysis. Certain terms used in the implementation and documentation are specific to multiple contingency analysis use and may not necessarily reflect those of local electric power analysis practice. Some key definitions of terms applied to multiple contingency analysis are identified as following:

Contingency element: A major component in the network whose operation status or setpoints can be changed, e.g., one transmission circuit outage, one machine out-of-service, one transmission circuit reclosing, a change in load or generation at a bus.

Contingency event: The contingency of one or more elements originating from a single cause, e.g., each contingency case defined with a block structure in a contingency description file is considered as one contingency event.

Contingency: A contingency condition simulated by PSS™E made up of one or more contingency events.

Level: The number of contingency events within a contingency studied by PSS™E. "Level" may also be viewed as the number of independent causes studied in a contingency; e.g., N-1, N-2 and N-3.

Contingency events include:

- Single contingency elements, e.g., one transmission circuit outage, and
- Multiple contingency elements, e.g., a combination of circuits and, or machines out-of-service at the same time.

Examples of the latter include outages of multiple circuits terminating at the same bus caused by bus failures and outages of two circuits on the same right-of-way caused by ROW failure.

When multiple events are combined within a contingency, they are assumed to be occurring simultaneously but originating from independent causes, i.e., one event does not trigger the others. Multiple level contingency analysis is deigned to model up to three events per contingency.

5.3.3 Classification of Contingency Analysis Results

There are two cutoffs to control the level of multiple contingency analysis and number of contingencies to be evaluated at each level during analysis: failure cutoff and non-failure cutoff.

The failure cutoff is enabled by selecting ’Enable’ for multiple contingency analysis option, the next-level contingencies of a failure contingency that results in operating limit violations will be skipped. It is most likely that under a failure contingency condition any next-level contingencies will result in operating limit violations too, so there is no need to apply more contingencies to failure cases. Enabling failure cutoff can reduce the set of tested contingencies and concentrate studies on more probable contingencies. To evaluate complete multiple event contingencies for the specified level, the failure cutoff must be disabled by selecting ’Enable with failure cutoff disabled’ for ***Perform multiple contingency analysis*** option. After completion of a contingency analysis, only non-failure cases could be used as base cases for next-level contingency analysis. The failure cutoff is applied to both user specified contingencies and ranked contingencies. For example, multiple level contingency analysis is initiated with level 2 and failure cutoff enabled, user specified contingencies for N-1 and combinations SS and SB for N-2 (SS consists of two different user specified contingencies in the user specified contingency list, and SB consists of a user specified contingency and a ranked single branch outage), if all user specified contingencies are failure cases based on the failure criteria in Table 5-3, namely all N-1 cases are failure cases, all N-2 contingencies are skipped.

The non-failure cutoff is specified by cutoff numbers within each ranker. If the number of consecutive non-failure contingencies from the ranker is more than the cutoff, it is assumed that the rest contingencies from the same ranker will not lead to violations and be skipped. This section discusses internal the failure criteria to classify a contingency solution.

At the completion of a contingency evaluation, the contingency may be classified according to solution characteristics of the last power flow solution performed on the contingency. This classification is shown in Table 5-2.

Table 5-2. Classification of Contingency Evaluation Based on Power Flow Solution

Category I	Converged and maximum bus mismatch within tolerance
Category II	Voltage Collapse solution stopped by non-divergent power flow
Category III	Not Converged

Category I contingencies are those whose power flow solutions have a maximum bus mismatch less than the mismatch tolerance. Category I contingencies are further classified into: failures and non-failures. A Category I contingency is classified as a failure if the contingency results in problems listed in Table 5-3 or if specific events occur during the contingency. The classifications are applied only to internal programs. The failure status of the contingency is used only as stopping criteria for failure and non-failure cutoff algorithms. You can make your failure criteria more stringent in order to obtain a reduced set of tested contingencies; however only monitored flows and voltages specified in monitored element data file of tested contingencies are saved in results files and can be post-processed to generate the different reports. In order to test more contingencies, you have to repeat contingency analysis with new selections of failure criteria (see Section 5.3.5). The failure status of a contingency is not stored in result files.

Table 5-3. Types of problem that would Qualify a Category I Contingency as a Failure

Problem	Description	Default Criteria
OVERLOAD	Circuit or interface loading above a specified multiplier of a specified rating (A, B or C).	Specified rating multiplied by a percent factor from GUI, by default, 100 percent of rating set program option setting is used.
HIGH VOLTAGE	Bus voltage above the high voltage limit.	Upper limit defined in monitored element file.
LOW VOLTAGE	Bus voltage below the low voltage limit.	Lower limit defined in monitored element file.
VOLTAGE DEVIATION	Bus voltage change (absolute value) between pre- and post-contingency conditions exceeds the Deviation criterion	Variation defined in monitored element file

The detected overloaded branches are different with those in post-processed report files where the different ratings of loading may be applied.

An islanding event occurs when a contingency causes a physical separation of a bus or group of buses from the base case network. The outage of a radial branch will automatically result in islanding of a radial bus. If the contingency is a multiple element outage, it may cause multiple islands. When dispatch mode and dispatch subsystem are specified, contingency analysis will process islanding events via generation redispatch (see Section 5.2.1.2), otherwise those islands without a swing bus will be shut down. The islanding problem has been removed from the failure criteria since PSS™E-30.3.

The types of events (as differentiated from troubles) occurring during contingency evaluation that would qualify a contingency as a failure, include:

- TRIPPING – A contingency where at least one trip specification is actuated (see Section 5.3.6).

Power flow cases with solutions that are classified as either voltage collapse (Category II) or not converged (Category III) are excluded from tests of failure.

5.3.4 About Contingency List

Multiple contingency analysis functions work with a contingency event list, also referred to as a contingency list. The list provides a sequence for evaluating contingencies. However, the true power of this list lies in the fact that not all contingencies included in it are evaluated by multiple contingency analyses.

It is useful to think of the contingency list as further divided into contingency groups. Contingency groups are shown in Table 5-4. The graphic equivalent of this table is shown in Figure 5-23.

Table 5-4. Groups within Contingency List

Group	Contents
S	Specified contingencies.
U	Outages of single machines, ranked according to impact on thermal loading of branches.
B1	Outages of single branches that result in separation (islanding) of the network.
B2	Outage of single branches ranked according to impact on thermal loading of branches.
B3	Outage of single branches ranked according to impact on voltage collapse.

In group S, the contingencies are taken directly from a dfax file which is generated with a Contingency Description File (see Section 5.2.3.1). These can be viewed as must-test contingencies; i.e., no matter how system conditions change, it is important to the reliability assessment to consider these contingencies. The Contingency Description File may be:

- Created by the user based on previous operating or planning experience with a system, reliability criteria guidelines or some other arbitrary method. The file is thus one that is created outside of PSS™E, with a text editor.
- Produced by pre-screening contingencies using activity RANK (refer to Section 5.2.4).

Groups U, B1, B2 and B3 are comprised of ranked contingencies from the contingency subsystem, each group is based on different methods of ranking.

Things to note about the contingency list and its groups:

- Within each ranked group, there is internal ordering from most severe to least severe contingencies.
- Contingencies are evaluated according to the sequence of groups.

- If a contingency has been evaluated in an earlier group, the same contingency in a later group will be skipped.

Each contingency evaluation constitutes a Power Flow solution resulting in a post-contingency system state. Conditions in the post-contingency state are then checked against the specified failure criteria.

Ranked contingencies are tested one by one in sequence until an unbroken series of N non-failure contingencies. The stopping criterion (non-failure cutoff) of "N contingencies in a row" is applied here. The evaluation of a ranked contingency group is complete when all contingencies are exhausted or the stopping criterion is met.

Groups B1, B2 and B3 may be comprised of the same contingencies, albeit with different ranking. Some of these contingencies may also be included in group S.

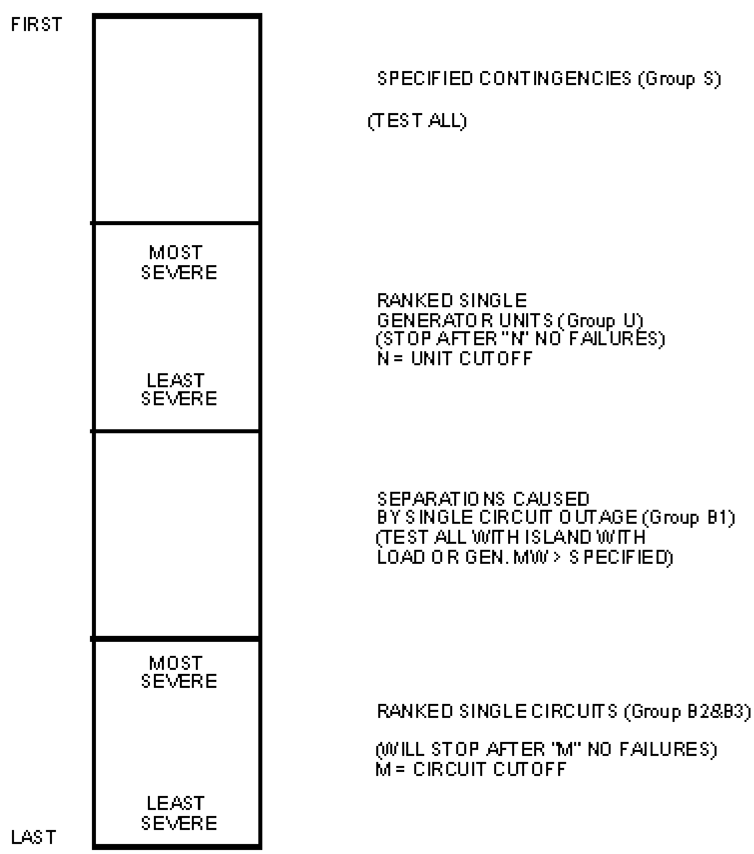


Figure 5-23. Contingency List

5.3.5 Wind Chime Algorithm for Multiple Level Contingency Analysis

If a one-level contingency analysis is specified, all must-test events (group S) are evaluated first. Those of ranked individual machine outages (group U) follow this. These ranked machine outages will be tested one by one until an unbroken sequence of N contingencies without any system problems has been detected or the maximum of contingencies of group U has been tested. When the testing of machine outages is complete, either because the list has been exhausted, or because the stopping criterion has been met, the branch outage events causing system separations (group B1) are evaluated. A simple screening algorithm that searches for continuity can also automatically select these events. The final two groups of events in the list are the ranked branch outages from overload (group B2) and voltage collapse ranking (group B3). These are tested in a similar fashion as the ranked machine outages, in which the individual branch outages are tested one by one and the list is truncated after the corresponding stopping criterion is met. Groups B1, B2 and B3 may be comprised of the same contingencies, albeit with different ranking. Some of these contingencies may also be included in group S.

The multiple contingency solution procedure is given by the example of a two-level contingency analysis. If a two-level contingency analysis is to be performed, a newly ordered event list is built after solving each first-level contingency Power Flow. These secondary ordered event lists may contain the same categories of outage events as those in the first-level list, with the exclusion of the initial outage event. New rankings are determined based on the system conditions existing after each first-level contingency using a linearized network model. This approach is called Wind Chime approach.

Figure 5-24 illustrates the Wind Chime approach for a two-level contingency run using a contingency level of 2; some other options specified for this run are ’Enabled with failure cutoff disabled’ for ***Perform multiple contingency analysis*** option, B for the first level and BB for the second level analysis, as well as only single branch outages from overload ranking with non-failure cutoff of 2.

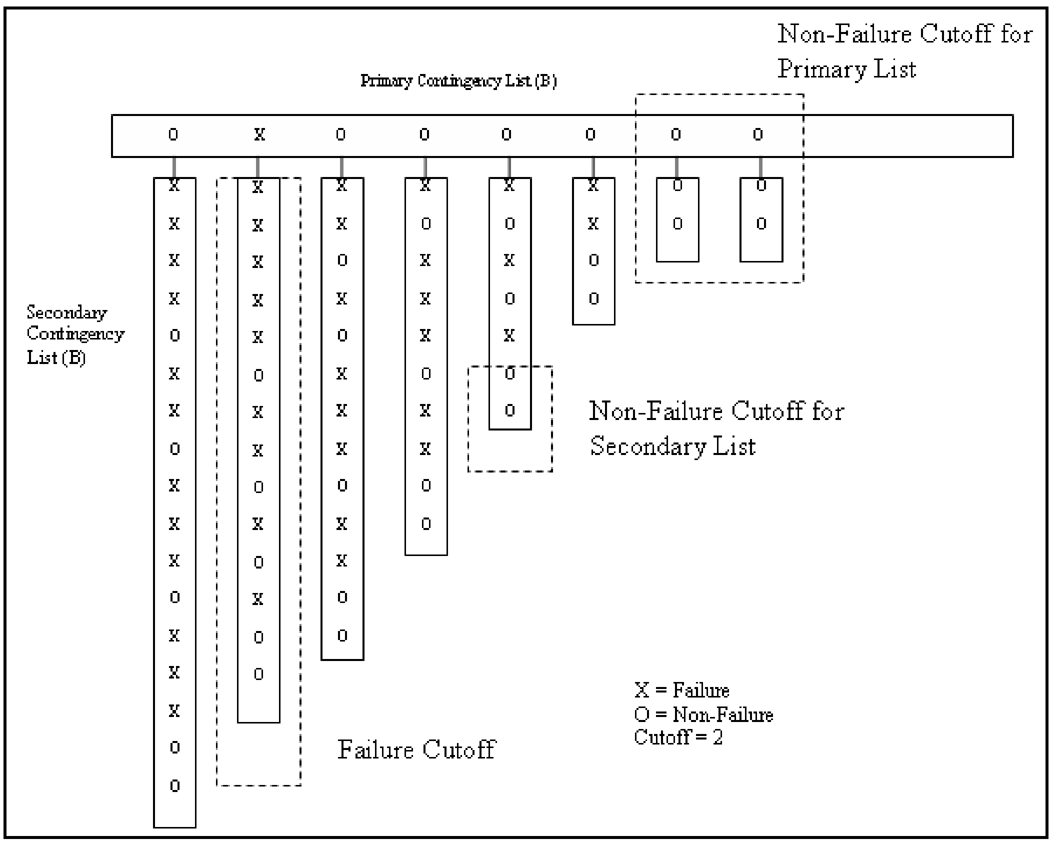


Figure 5-24. Wind Chime Approach for 2 Level

In Figure 5-24, the initial first-level contingency is a non-failure. That is, it does not have any criteria violations in Table 5-3 and trigger any failure events. A number of second-level contingencies are then run until two consecutive second-level contingencies are non-failures. The next first-level contingency is evaluated and is classified as a failure case; because failure cutoff is disabled, it is followed by second-level contingencies until two consecutive second-level contingencies are non-failures. This procedure continues until the top two second-level contingencies are non-failures for two consecutive first level contingencies.

This process can be duplicated for any level of automatic contingency analysis. If third-level contingencies are requested, a ranking is done for each second-level contingency and the tertiary contingencies are run until the maximum is reached or the cutoff criterion is satisfied.

The contingency evaluation functions contain logic to efficiently check whether a contingency consisting of a combination of branchess and machines has already been tested. In this way, any particular branch or machine outage combination, whether it originates from one multiple element event or from two or more single element events, will be tested only once. Also, elements that are ranked higher in the primary event list than the present primary contingency will not be included in the present and subsequent secondary ranking lists. This assumes that all two level events associated with those primary events would have been evaluated, either explicitly by power flow solutions or implicitly by ranking list truncation. The ranking algorithm also takes into account the outages of identical machines located at the same bus. Since the impact of these outages on the system will be identical, it is necessary to test only one of such machine outages per contingency level.

The program can still test multiple levels of machines of the same size.

5.3.6 About Tripping Sequence

A contingency analysis my be followed by tripping simulations within multiple level contingency analysis. Tripping sequences are simulations of events ensuing from automatic monitoring equipment such as relays, and automatic circuit breaking and making equipment such as circuit breakers and switchers. These sequences are important in order for multiple contingency analysis to obtain the right post-contingency state. Examples of tripping sequences are:

- Transfer of load to another bus on loss of power on a transmission branch.
- Switching of lines following outage or overload of another.
- Tripping of transmission circuits following extreme overloads.

Tripping sequences may also be used to model other automatic actions such as remedial action schemes (RAS), special protection schemes (SPS) and operating guides.

5.3.7 Setting-Up for Tripping Simulation

To initiate multiple level contingency analysis with tripping simulation, select ***Power Flow>Solution>Multi_Level AC Contingency Solution***, and select the Tripping Simulation tab, the dialog for setting tripping simulation options is shown in Figure 5-25.

5.3.7.1 Setting Tripping Simulation Options

Perform tripping simulation: Select to perform tripping simulation for post-contingencies states.

Number of trip events per load flow: After a contingency power flow solution, tripping conditions that trigger tripping sequences are checked in the order in which tripping events are specified in

Tripping Element Data File (Section 5.3.7.2). There may be more than one instance of tripping sequences that are activated. The number of trip events that are activated prior to the next power flow solution is set by number of trip events per load flow.

Number of load flows per contingency: When a new power flow solution is performed following activation of one or more tripping sequences, the trip triggers are reset and all the remaining trip sequences are checked for the new power flow solution. If one or more remaining tipping sequences satisfy conditions, a new power flow is performed with activation of these tripping sequences up to Number of trip events per load flow. This process continues till the number of load flows following a contingency power flow reaches the number of load flows per contingency.

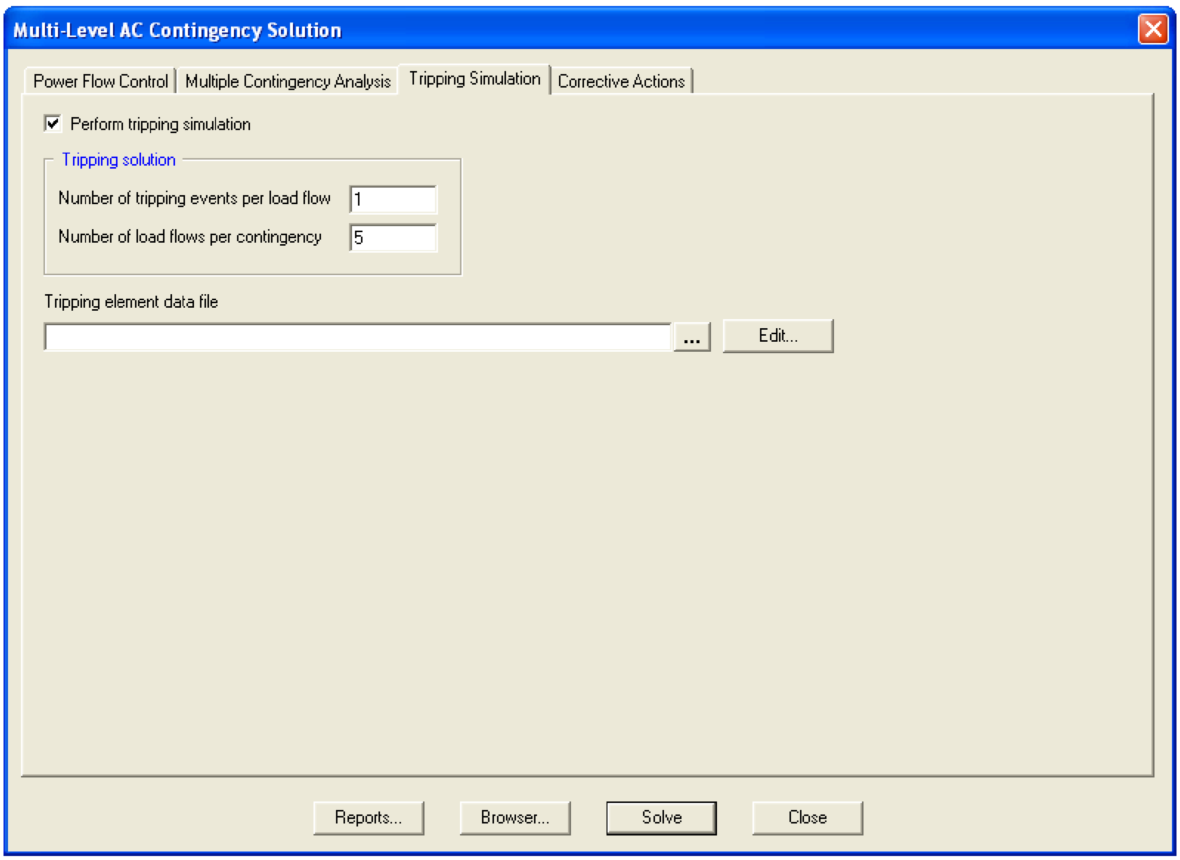


Figure 5-25. Multi-Level AC Contingency Solution Dialog – Tripping Simulation Tab

5.3.7.2 About Input Tripping Element Data File

The tripping events are defined via the tripping data file (see Section 5.2.2.2 for conventions in tripping data file). Each specification block structure is comprised of a trip descriptor and one of each of two categories of data records - monitored equipment, trip equipment. The former includes circuit/transformer/interface flows, generator output, bus voltage, the operating status of monitored elements. The latter includes circuit/transformer/unit outages, load shedding, bus outage, and circuit reclosing. The tripping event is defined in a block structure as follows:

Tripping Label

```
(monitor element)...
(trip element)
End
```

The 12-character contingency label is used to identify each tripping event.

5.3.7.3 Monitored Equipment

The monitored elements include buses, lines, transformers, interfaces and machines. In a block structure of tripping condition definition, there may be several individual conditions up to 10; each condition has its monitored element specification and tripping rating. If the value of logical OR of these conditions is TRUE, tripping actions defined within this block are triggered.

Voltage Monitoring Records

The following data record defines a voltage band with a single bus whose voltage is to be checked against the band:

```
[MONITOR]  VOLTAGE RANGE   BUS bsid  TR   r [r]
```

where the first "r" value is the lower bound of the per unit voltage band and the optional second "r" value is the upper bound. If the upper bound is omitted, the upper end of the band is not checked. Token TR is key word for trip rating.

Flow Monitoring Records

The data record format defines a non-transformer branch or two-winding transformer for monitoring. The 'r' value is the tripping rating in specified unit with one of token 'MW/MVA/ MVAR/AMPS/PERCENT'. The monitored flow direction is dictated by FROM bus to TO bus specifications. If the trip rating is a positive number, trip will occur if the monitored flow exceeds this number, if it is a negative number, trip will occur if the monitored flow is below the absolute value of this number. A trip rating of 0 means that tripping should take place if the monitored element is out of service.

```
[MONITOR]|BRANCH| FROM BUS bsid TO BUS bsid [|CIRCUIT| ckid]  TR r |MW      |
         |LINE  |                            |CKT    |            |MVA     |
                                                                  |MVAR    |
                                                                  |AMPS    |
                                                                  |PERCENT| OF |A|
                                                                               |B|
                                                                               |C|
```

To specify one winding of a three-winding transformer for monitoring, the bus to which the winding is connected must be the first bus specified in the following data record:

```
[MONITOR]|BRANCH| FROM BUS bsid TO BUS bsid TO BUS bsid [|CIRCUIT |] ckid TR r|MW      |
         |LINE  |                                        |CKT     |          |MVA     |
                                                                             |MVAR    |
                                                                             |AMPS    |
                                                                         |PERCENT| OF |A|
                                                                                      |B|
                                                                                      |C|
```

When flow monitoring records employ keyword ’PERCENT’, one of rating sets ’A/B/C’ must be specified. Percent loadings of monitored elements based on ratings are specified as either Current or MVA percent loadings by percent units program settings (see Section 1.6.4).

Unit Monitoring Record

The data record defines a single machine for monitoring:

```
[MONITOR]|UNIT    | MCID AT BUS bsid TR r|MW |
         |MACHINE|                      |MVA|
         |MVAR    |
         |AMPS    |
```

Interface Monitoring Record

```
[MONITOR] INTERFACE label TR r |MW/MVA/ MVAR/AMPS|
(branch specification record, see below)
.
.
(branch specification record, see below)
END
```

where r is trip rating for the monitored interface, if the sum of MW/MVA/ MVAR/AMPS flows at the ’*From bus*’ end of specified branches is greater than r, trip actions occur. A rating of zero will disable the monitored interface flow condition. The branch specification record may specify individual two-winding or non-transformer branches or individual three-winding transformers.

For specifying a two-winding or non-transformer branch the following data specification record is used:

```
|BRANCH| FROM BUS bsid TO BUS bsid [|CIRCUIT| ckid]
|LINE  |                            |CKT    |
```

For specifying a three-winding transformer the following data specification record is used:

```
|BRANCH| FROM BUS bsid TO BUS bsid TO BUS bsid |CIRCUIT| ckid
|LINE  |                                       |CKT    |
```

5.3.7.4 Trip Equipment

Up to 16 tripping actions may be specified in a tripping event definition block structure. If any one of tripping conditions is satisfied, all given tripping actions might be enforced to post-contingency cases. The tripping actions are defined using following data records.

The outaging of an in-service non-transformer branch or two-winding transformer is specified with the following record:

```
|DISCONNECT||BRANCH| FROM BUS bsid TO BUS bsid [|CIRCUIT| ] ckid
|OPEN      ||LINE  |                            |CKT    |
|TRIP      |
```

An out-of-service non-transformer branch or two-winding transformer may be placed in-service with a record of the form:

```
CLOSE |BRANCH| FROM BUS bsid TO BUS bsid  [|CIRCUIT| ] ckid
      |LINE  |                             |CKT     |
```

The outaging of a three-winding transformer is specified with the following record:

```
|DISCONNECT||BRANCH| FROM BUS bsid TO BUS bsid TO BUS bsid [|CIRCUIT| ] ckid
|OPEN      ||LINE  |                                        |CKT     |
|TRIP      |
```

An out-of-service three-winding transformer may be placed in-service with a record of the form:

```
CLOSE |BRANCH| FROM BUS bsid TO BUS bsid TO BUS bsid  [|CIRCUIT| ] ckid
      |LINE  |                                         |CKT     |
```

The next four record types allow the user to specify contingency events in which the load and generation boundary conditions may be changed at a selected bus. When changing generation, the bus must have in-service generation connected to it and it may not be a swing bus.

The first data record of this type uses the following data record to set the load or generation at a bus either to a designated value or to a specified percentage of its initial value:

```
SET BUS bsid |GENERATION| TO r |MW     |
             |LOAD      |      |PERCENT|
             |SHUNT     |
```

The number "r" specified must not be a negative number when the PERCENT keyword is used.

The second data record of this type uses the following data record to change the load or generation at a bus either by a designated amount or by a specified percentage of its initial value:

```
|CHANGE| BUS bsid |GENERATION| BY r |MW     |
|ALTER |          |LOAD      |      |PERCENT|
|MODIFY|          |SHUNT     |
```

The third and fourth data records of this type are similar to the CHANGE record, except the direction of the change is defined by the first keyword, and "r" must be a positive number:

```
|INCREASE| BUS bsid |GENERATION| BY r |MW     |
|RAISE   |          |LOAD      |      |PERCENT|
|SHUNT   |

|DECREASE| BUS bsid |GENERATION| BY r |MW     |
|REDUCE  |          |LOAD      |      |PERCENT|
|SHUNT   |
```

To transfer load or generation from one bus to another, the following data record is used:

```
MOVE r |MW     | |GENERATION| FROM BUS bsid TO BUS bsid
       |PERCENT| |LOAD      |
                 |SHUNT     |
```

See Section 5.2.3.1 for details.

An in-service machine may be removed from service using the following data record:

```
REMOVE |MACHINE| mcid FROM BUS bsid
       |UNIT   |
```

Similarly, an out-of-service machine may be placed in-service with a record of the form:

```
ADD |MACHINE| mcid TO BUS bsid
    |UNIT   |
```

5.3.7.5 Automatic Single Tripping Record

A series of tripping events is specified with a record of the form:

```
SINGLE LINE IN | AREA i          | TR r PERCENT OF |A|
               | ZONE i          |                 |B|
               | OWNER i         |                 |C|
               | KV r            |
               | SYSTEM label    |
               | SYBSSYTEM label|
```

In each tripping event, a single branch within a given subsystem is monitored. For non-transformer branches and two-winding transformers, a branch is tripped when flow at either one of its two bus ends exceeds the tripping rating. For three-winding transformers, a three-winding transformer is outaged when the flow at any one of its three winding buses exceeds the tripping rating.

5.3.8 Setting Up Corrective Action Analysis

When multiple level contingency analysis is initiated with corrective action analysis, if there are operating limit violations in post-contingency solutions, or in post-tripping contingency solutions if tripping simulation is enabled and tripping events are activated following a contingency, corrective actions will be specified to relieve these violations. Flow limits are contingency case rating and percent of rating specified in **Multiple Contingency Analysis Tab**; voltage limits are taken from Monitored Element Data File. To initiate multiple level contingency analysis with corrective action analysis, select ***Power Flow>Solution>Multi_Level AC Contingency Solution***, and select the Corrective Actions tab, the dialog for setting corrective actions options is shown in Figure 5-26.

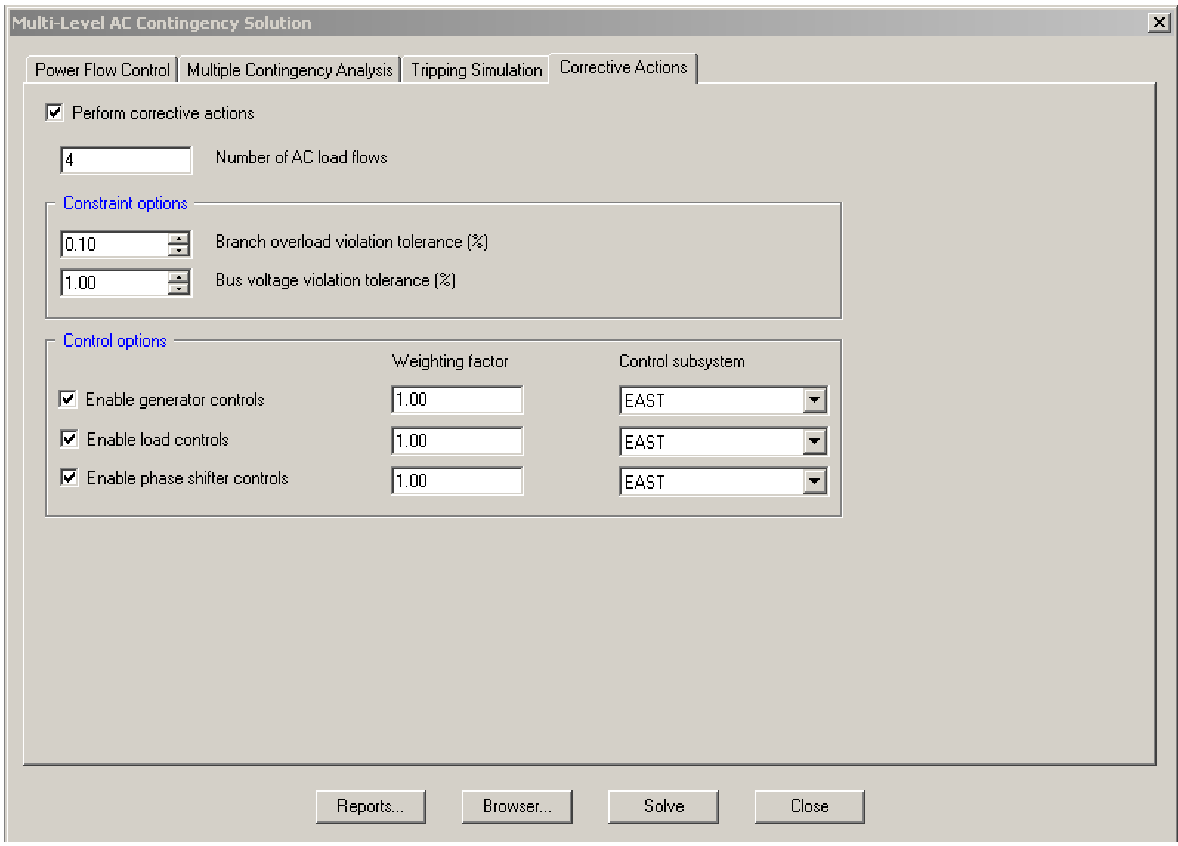


Figure 5-26. Multi-Level AC Contingency Solution Dialog - Corrective Actions Tab

5.3.8.1 Setting Corrective Action Analysis Options

Perform Corrective Actions: Select to perform corrective action analysis, otherwise all other options in this dialog are disabled.

Number of AC load flows: Select the desired number of iterations between execution of the linear programming engine to identify corrective actions and subsequent AC load flow solution to verify the feasibility of those actions. The specified number of iterations can be between 1 and 10. Note that, even if a feasible solution appears to have been found, i.e., the identified corrective actions appear to have been successful, the iteration between linear programming computation and AC power flow solution may continue in an attempt to further optimize the solution if not exceeding the iteration limit.

Branch overload violation tolerance: The percent of flow rating used in linear programming engine can be adjusted by specifying a branch overload violation tolerance. e.g., if branch overload violation tolerance is specified as 0.1% and percent of flow rating is 100%, percent of rating of 100.1% is used in determination of overload violations in linear programming algorithm.

Bus voltage violation tolerance: The limits of bus voltages used in linear programming engine can be adjusted by specifying bus voltage violation tolerance. The voltage violation tolerance is applied to both upper and lower voltage limits, if applicable. e.g., if bus voltage violation tolerance is specified as 0.1%, lower and upper limits of bus voltages are 0.95 and 1.05 in pu respectively. The adjusted voltage limits are 0.949 and 1.051 respectively.

Control options: Select types of control adjustments and specify weighting factors for each type.

Enable generator controls: Real power generation dispatch controls can be included by checking this box. The adjustable range is from PT to PB of each participating machine. Generator active power limits are taken from a Generator Inertia and Governor Response Data File (see Section 5.6.1) if the file is specified, otherwise the values in base case are used. In corrective action analysis, generator active power limits are adjusted by the following rules. If PT had been defaulted, the larger value of PG (its existing MW output) and machine power base (MVA base) will be used as PT; If PT of a machine is less than its PG, the PT is set equal to the PG. If PB of a machine had been defaulted, it is set equal to 0; if PB of a machine is less than its PG, the PB is set equal to the PG. A machine will be excluded from the controls if its PT is equal to its PB.

Generator weighting factors: Weighting factors of generation dispatch adjustments are used to adjust cost factors in the objective function. The internal cost factors for real power generation dispatch control specified in the programs are shown in Table 5-5; the actual cost factors are equal to internal factors multiplied by the user defined generator weighting factors. e.g., if weighting factor of generation dispatch control is set as 1.0, the cost for generation dispatch of 100 MW will be 1.0.

Generator control subsystem: Select the subsystem in which all in-service generators with valid range of adjustments will participate in corrective action analysis.

Enable load controls: Load shedding controls can be included by checking this box. The loads with negative MW values will be excluded from the controls. While performing load curtailment, the algorithm maintains a constant power factor at the buses where load curtailment occurs.

Load weighting factors: Weighting factors of load curtailments are used to adjust cost factors in the objective function. The internal cost factors for load curtailments defined in the programs are shown in Table 5-5; the actual cost factors are equal to internal factors multiplied by the user-defined weighting factors. e.g., if weighting factor of load curtailments is set as 1.0, the cost for load shedding of 100 MW will be 100.0.

Load control subsystem: Select the subsystem in which all in-service loads will participate in corrective action analysis. Loads with negative real power will not be included as candidates for load curtailments.

Enable phase shifter controls: Phase shifter controls can be included by checking this box. To be adjustable as a phase shifter, transformers must be operated under MW control mode. The adjustable range of a participating phase shifter is from Rmax to Rmin.

Phase shifter weighting factors: Weighting factors of phase shifter angle adjustments to be used to adjust cost factors in the objective function. The internal cost factors for phase shifter angle adjustments defined in the programs are shown in Table 5-5; the actual cost factors are equal to internal factors multiplied by the user-defined weighting factors. e.g., if weighting factor of phase shifter angle adjustment is 1.0, the cost of phase shifter angle adjust em nt of 100 degrees is 3.5.

Phase shifter subsystem: Select the subsystem in which all in-service phase shifters will participate in corrective actions.

5.3.9 Running Multiple Contingency Analysis

As discussed in Section 5.3.1, in order to launch multiple level contingency calculation solution select ***Power Flow>Solution>Multiple AC contingency solution*** option. This will open the Multi-Level Contingency Solution dialog shown in Figure 5-21. From multiple level contingency analysis windows, users can specify the following running mode to perform the specific study.

When options of perform multiple contingency analysis, perform tripping simulation and perform corrective actions are disabled, the user will perform single AC contingency analysis (see Section 5.2) by pressing ***Solve*** button after options together with required filenames in the tab for power flow control have been specified. Only user specified contingencies defined in contingency description file are tested.

When perform multiple contingency analysis option is disable while perform tripping simulation enabled, after options with required filenames in tabs for power flow control and tripping simulation have been specified, AC contingency analysis will be performed to all user specified contingencies with tripping simulations. All converged post-contingency states will be checked against the tripping conditions. If tripping actions are activated, the post-tripping condition at the last stage of tripping simulation will be saved in the output file.

When perform multiple contingency analysis is enabled while perform tripping simulation disabled, multiple level contingency analysis is performed using wind chime algorithm after options together with filenames in tabs for power flow control and multiple contingency analysis have been specified.

When both perform multiple contingency analysis and perform tripping simulation are enabled, multiple level contingency analysis with tripping simulation is performed after options together with filenames in all three tabs have been specified. Each post-contingency condition will be checked against the tripping conditions. If tripping actions are activated, post-tripping condition at the last stage of tripping simulation will be saved in the output file. Tripping events activated following a contingency will qualify the case as failure, so that its next-level contingencies are skipped if failure cutoff is enabled.

Corrective action analysis can be enabled or disabled for any above running mode.

The contingency label and contingency events of each contingency case are logged at the progress output device as the solution process encounters it. A message identifies any network conditions that fail to converge or which are skipped. The duplicate contingencies at secondary and tertiary levels will not be presented in the progress windows.

The AC contingency solution process responds to the following interrupt control codes:

AB – Abandon the process following completion of the next iteration.

CM – Print the convergence and automatic adjustment monitors.

NM – Suppress any automatic adjustment monitors (only used with CM interrupt control code).

DC – Tabulate conditions for each DC line after each iteration.

FD – Tabulate conditions for each FACTS device after each iteration.

5.3.10 View the Contingency Analysis Results

The multiple level AC Contingency Solution function calculates post-contingency, post-tripping and post-corrective actions contingency solution results (loadings on monitored branches and interfaces, and bus voltage magnitudes) and places them into the specified AC Contingency Solution Output File. These results may then be tabulated using any or all of three output processing functions: the AC Contingency Single Run Report function; the AC Contingency Multiple Run Report function; the auxiliary program AcccBrwsGrid (see Section 5.2.6).

5.3.11 Application Notes on Multiple Contingency Analysis

In the output file, the contingency label of automatically selected contingencies generated by the programs reflects its level and position in the contingency list at each level. The label of the first level ranked contingencies, consists of the name of the ranker from which it is generated and the sequence number in the contingency list, e.g., contingency 'OVRLOD 2' is from overload ranking and is the second contingency in the list. the other ranker names are 'UNIT', 'VLTAGE' and 'ISLAND'. The labels of multiple contingencies are comprised of sequence number at each level separated by '_', e.g., "12_14", the first number represents the 12th contingency in the first level contingency list, 14th is the number in the secondary contingency list. Another example is "15_16_17", the first number represents the 15th contingency in the first level contingency list, 16th is the number in the secondary contingency list, the 17th is the number in the tertiary contingency list.

Post-tripping solutions at the last stage of tripping simulation for each contingency that triggers tripping events are saved into output files in the same format as contingency cases. The label of a post-tripping solution is generated by the programs, and is comprised of the first ten letters of the label of the contingency activating tripping actions and ended with a "/T" which identifies the case as a post-tripping case. Normally contingency legends for a tripping solution will include tripping labels, description of the monitored element which trigger the tripping activities and description of tripping activities, due to limited space to save the legends, when the number of tripping activities and monitored elements in a tripping solution is more than 16, only tripping labels are saved as contingency legends.

The post-corrective action solution and activated corrective actions are stored into output files if ***Perform corrective action analysis*** is enabled.

The maximum number of contingencies that can be tested in a multiple level contingency analysis is 100,000.

5.4 AC Corrective Action Analysis

A power flow may have any number of operating limit violations, and these problems can be alleviated by corrective actions. The AC corrective action analysis is formulated as an optimal power flow problem with the objective of minimizing load curtailment, MW generation re-dispatch, and transformer phase angle adjustment. It includes a standard ac power flow solution with local automatic adjustments, power system network linearization, and a linear programming solution to relieve the overload and voltage limit violations.

Recognizing that thermal ratings and voltage limits in a power system may sometimes be treated as soft limits, the algorithm relaxes the hard limits on the constraints in case of infeasibility, and returns a solution with some minor violations. Hence, incorporation of the soft limits reduces the likelihood of infeasible solutions, which is particularly useful during contingency analysis when a large number of corrective action solutions may need to be performed automatically.

5.4.1 Setting-up for AC corrective action analysis

To launch AC corrective action solution, select the ***power flow>solution>AC corrective actions*** option. This will open the AC corrective actions menu shown in Table 5-27.

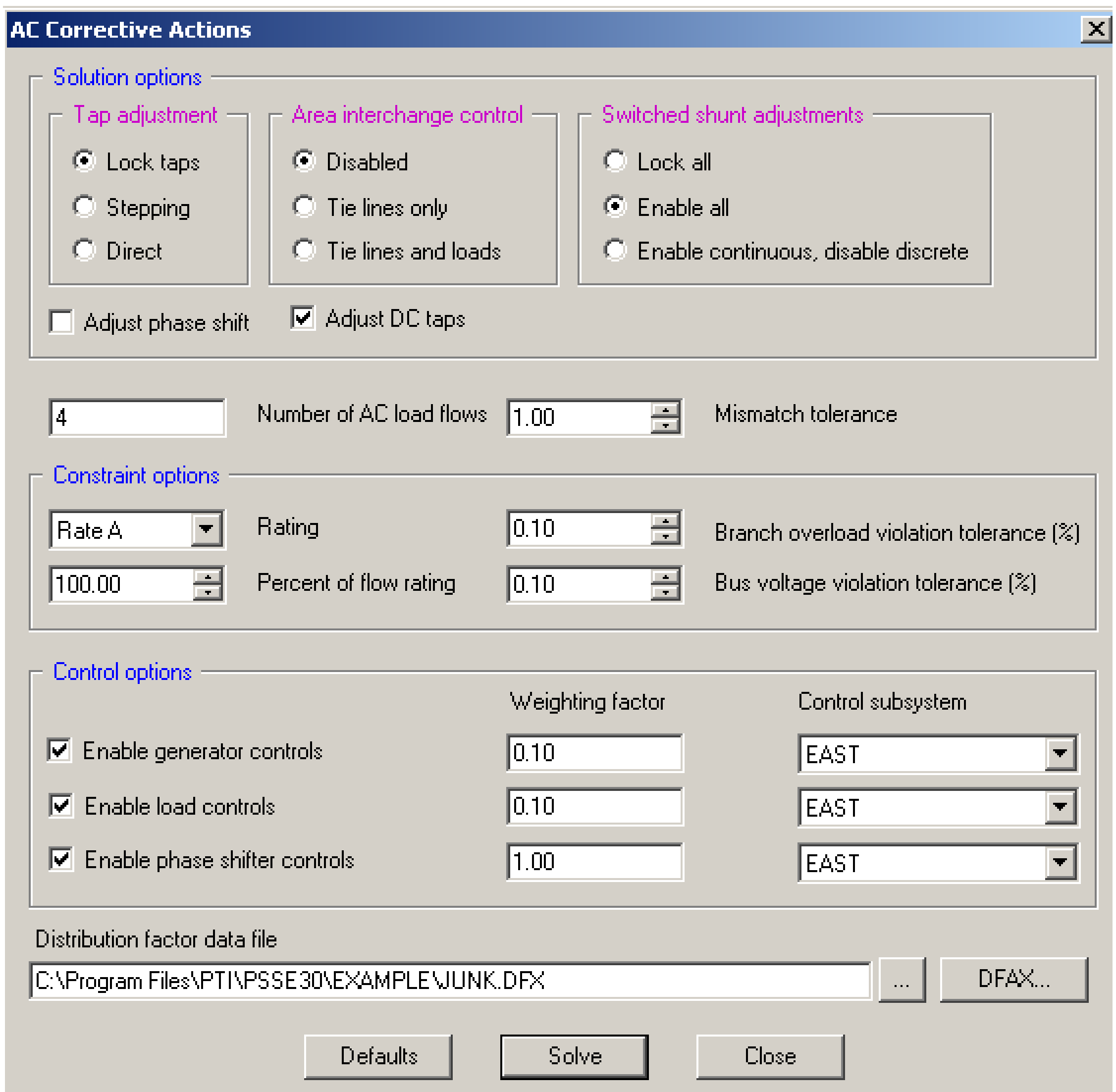


Figure 5-27. Launch AC Corrective Action Analysis Dialog

5.4.1.1 Setting AC Corrective Action Options

The following options are available in the AC corrective actions menu.

Solution options: Select the desired solution options to be applied during load flow calculations within corrective actions (see Chapter 4).

Number of AC load flows: Select the desired number of iterations between execution of the linear programming engine to identify corrective actions and subsequent AC load flow solution to verify the feasibility of those actions. The specified number of iterations can be between 1 and 10. Note that, even if a feasible solution appears to have been found, i.e., the identified corrective actions appear to have been successful, the iteration between linear programming computation and AC power flow solution may continue in an attempt to further optimize the solution if not exceeding the iteration limit. The user needs to select this parameter carefully, based on experience. On the other hand, if a solution fails at the nth iteration because the AC load flow diverges, the user may obtain an approximate solution by specifying the number of AC load flows as n-1 and repeating the calculations.

Mismatch tolerance: This tolerance will be used to check for the largest active or reactive power mismatch in the power flow case prior to the start of the AC corrective actions computation. If this tolerance is exceeded, the process is terminated. This value is also used as the convergence tolerance for the AC load flow solution embedded in AC corrective action analysis.

Constraint options: Select branch flow rating set, and limit tolerances for monitored elements.

Rating and percent of flow rating: Specify rating and percent of rating to be used in determination of branch and interface flow overloads.

Branch overload violation tolerance: The percent of flow rating used in linear programming engine can be adjusted by specifying a branch overload violation tolerance. e.g., if branch overload violation tolerance is specified as 0.1% and percent of flow rating is 100%, percent of rating of 100.1% is used in determination of overload violations in linear programming algorithm.

Bus voltage violation tolerance: The limits of bus voltages used in linear programming engine can be adjusted by specifying bus voltage violation tolerance. The voltage violation tolerance is applied to both upper and lower voltage limits, if applicable. e.g., if bus voltage violation tolerance is specified as 0.1%, lower and upper limits of bus voltages are 0.95 and 1.05 in pu respectively. The adjusted voltage limits are 0.949 and 1.051 respectively.

Control options: Select types of control adjustments and specify weighting factors for each type.

Enable generator controls: Real power generation dispatch controls can be included by checking this box. The adjustable range is from PT to PB of each participating machine. Generator active power limits are taken from a Generator Inertia and Governor Response Data File (see Section 5.6.1) if the file is specified, otherwise the values in base case are used. In corrective action analysis, generator active power limits are adjusted by the following rules. If PT had been defaulted, the larger value of PG (its existing MW output) and machine power base (MVA base) will be used as PT; If PT of a machine is less than its PG, the PT is set equal to the PG. If PB of a machine had been defaulted, it is set equal to 0; if PB of a machine is less than its PG, the PB is set equal to the PG. A machine will be excluded from the controls if its PT is equal to its PB.

Generator weighting factors: Weighting factors of generation dispatch adjustments are used to adjust cost factors in the objective function. The internal cost factors for real power generation dispatch control defined in the programs are shown in Table 5-5; the actual cost factors are equal to internal factors multiplied by the user defined generator weighting factors. e.g., if weighting factor of generation dispatch control is set as 1.0, the cost for generation dispatch of 100 MW will be 1.0.

Generator control subsystem: Select the subsystem in which all in-service generators with valid range of adjustments will participate in corrective action analysis.

Enable load controls: Load shedding controls can be included by checking this box. The loads with negative MW values will be excluded from the controls. While performing load curtailment, the algorithm maintains a constant power factor at the buses where load curtailment occurs.

Load weighting factors: Weighting factors of load curtailments are used to adjust cost factors in the objective function. The internal cost factors for load curtailments defined in the programs are shown in Table 5-5; the actual cost factors are equal to internal factors multiplied by the user-defined weighting factors. e.g., if weighting factor of load curtailments is set as 1.0, the cost for load shedding of 100 MW will be 100.0.

Load control subsystem: Select the subsystem in which all in-service loads will participate in corrective action analysis. Loads with negative real power will not be included as candidates for load curtailments.

Enable phase shifter controls: Phase shifter controls can be included by checking this box. To be adjustable as a phase shifter, transformers must be operated under MW control mode. The adjustable range of a participating phase shifter is from Rmax to Rmin.

Phase shifter weighting factors: Weighting factors of phase shifter angle adjustments to be used to adjust cost factors in the objective function. The internal cost factors for phase shifter angle adjustments defined in the programs are shown in Table 5-5; the actual cost factors are equal to internal factors multiplied by the user-defined weighting factors. e.g., if weighting factor of phase shifter angle adjustment is 1.0, the cost of phase shifter angle adjust em nt of 100 degrees is 3.5.

Phase shifter subsystem: Select the subsystem in which all in-service phase shifters will participate in corrective actions.

Table 5-5. Weighting Functions and Factors of Controls

Control	Weighing Function	Internal Weight
Phase Angle	V-Curve	2 per 57.4 degrees (0.035 per degree)
MW Generation	V-Curve	1 per 100 MW * (0.01 per MW)
Load Curtailment	Linear	10 per 100 MW * (1.0 per MW)

5.4.1.2 Input Data File

The Distribution Factor Data File is used to provide monitored elements, bus voltage limits and control subsystems. When creating a Distribution Factor Data File for corrective action analysis, a Contingency Description Data File where no contingencies are specified is allowed.

5.4.2 About Corrective Action Analysis

The corrective actions are modeled as an optimal power flow problem. The objective function is to minimize the control adjustments needed to remove limit violations in the power system. The constraints include equality and inequality constraints, namely power flow equations and limits of controls and operation conditions.

5.4.2.1 Constraints and Controls

The corrective action algorithm recognizes several types of constraints and controls. Constraints are operating limits imposed on bus voltages, branch flows, or power transfers over interfaces. The system problems identified in a contingency analysis are the violations of such constraints. Controls include generator active powers, phase shifter angles, and bus load curtailments. The objective of the corrective action algorithm is to observe all constraints while minimizing the weighted sum of control adjustments within their upper and lower bounds. The priorities of control actions are: (1) phase shifter adjustment, followed by (2) generator active power shift, and, if required, (3) load curtailment generally. This priority order is maintained by assigning a higher cost to the lower priority controls.

Constraints are the power system operating limits that need to be observed. The corrective action algorithm allows three types of constraints that are defined in the Distribution Factor Data File:

- **Branch flows:** Branch flow limits are obtained from the designated rating set, adjusted by a specified multiplying factor. Percent loadings of monitored elements based on ratings are specified as either Current or MVA percent loadings by percent units program settings (see Section 1.6.4), and used in determination of overloading. Any branch whose rating in the designated rating set is zero is excluded from the set of constraint; zero impedance lines are also excluded from the set of constraints in the correction actions solution.
- **Interface MW flows:** Interface flow is defined as the sum of MW flow of its members. Each interface is specified in terms of the "from" bus, "to" bus and circuit identifier of each of its members. Flow is computed at the "from" bus end of each circuit in the interface. If an interface consists of one or more zero impedance branches, or its rating in the designated rating set is zero, it will be excluded from constraints.
- **Bus voltages:** High and low voltage limits for each bus are defined in per unit. Voltage limits can be specified on a system-wide basis, for the study area only, or for individual areas, zones and buses. If a bus voltage is monitored by several sets of upper and lower limits, the maximum of upper limits of all sets is selected as the upper limit and the minimum of lower limits of all sets is selected as the lower limit for the bus voltage respectively. Note that voltage deviation limits are not checked in corrective action calculations. For a generator bus, if the generator has sufficient reactive power generation to maintain its scheduled voltage, the generator bus is excluded from the constraint set.

Controls are the actions that can be taken to correct branch loading, bus voltage and interface flow limit violations in a power system. There are three categories of controls modeled in the corrective actions computation:

- **Generator real power output:** Generators located at buses with zero impedance lines are excluded from the control set.
- **Phase shifter angle:** The desired MW flow values in the power flow database for individual phase shifters are ignored in the corrective action analysis.
- **Load shedding:** Bus real power load can be curtailed as needed to correct system problems. The reactive power load is adjusted accordingly to maintain a constant power factor of load at the bus. Loads located at buses with zero impedance lines are excluded from the control set.

5.4.2.2 Weighting and Penalty Functions

The corrective action algorithm finds an optimal solution by minimizing the weighted sum of the individual controls. The weight for each control is given by its weighting function. The corrective actions are influenced by these weighting functions and the relative effectiveness of the respective controls in eliminating the system problems.

Two types of weighting functions for controls are used: V-curves for MW generation and phase shifter angle; and a linear function for load shedding, as shown in Figure 5-28, Figure 5-29 and Figure 5-30.

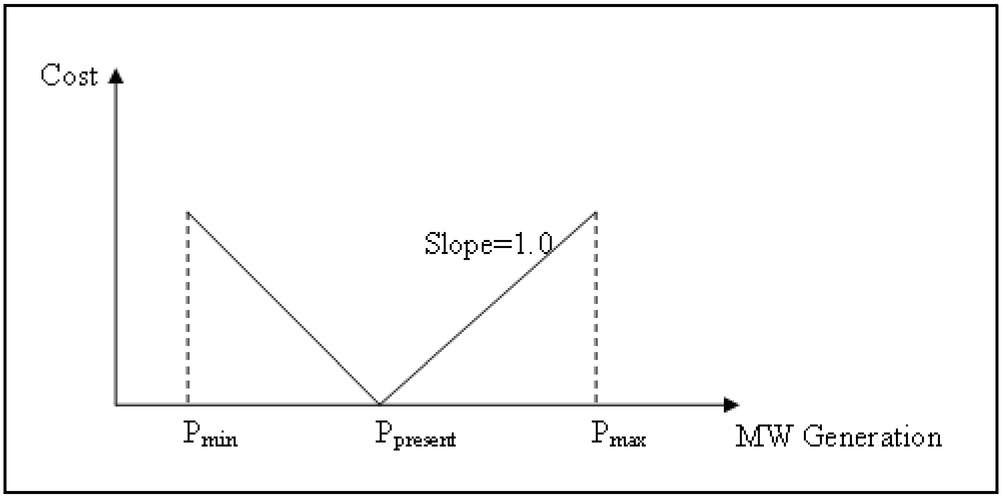


Figure 5-28. Real Power Generation Control Default Weighting Function

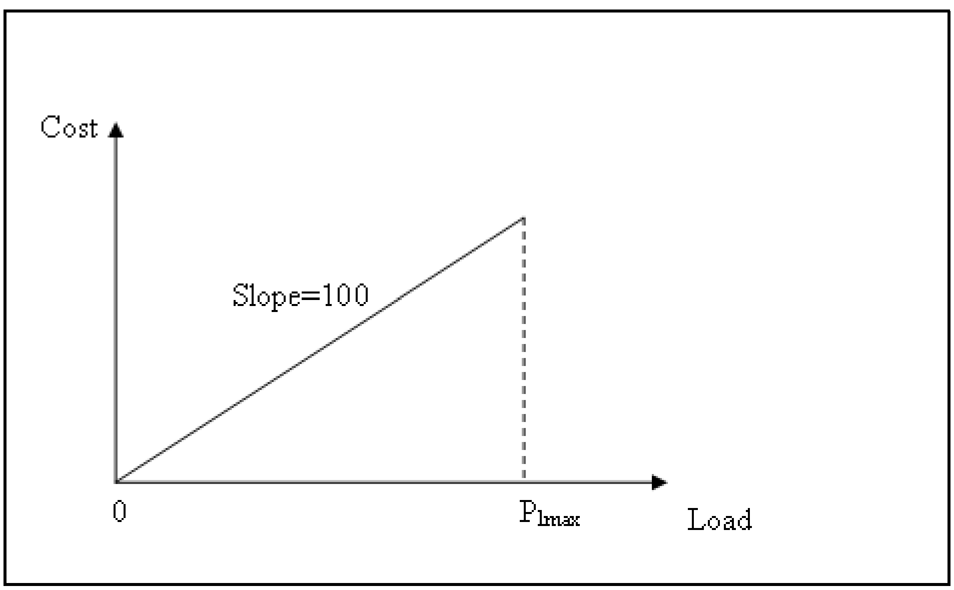


Figure 5-29. Load Shedding Control Default Weighting Function

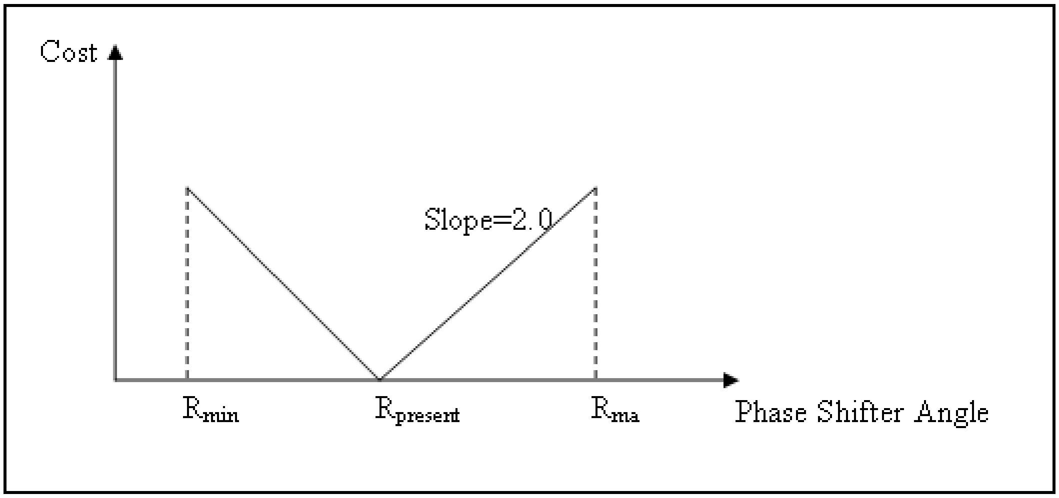


Figure 5-30. Phase Shifter Angle Control Default Weighting Function

Load shedding should be assigned a much higher weight than generator real power dispatch to prevent unnecessary load shedding when generation rescheduling is adequate in relieving the system problems. Moderate changes of the weights from the default values generally have little influence on the corrective actions since the sensitivities expressing the effectiveness of individual actions tend to dominate. A large weighting factor discourages the control from being adjusted. Therefore, you can favor certain controls over others by specifying smaller external weights. However, please note that extremely large or small weights may cause solution problems. For this reason, it is recommended that weights be limited to the range from 0.1 to 10.

If the limit violations in the power system cannot all be eliminated using the basic control actions, it may be preferable sometimes to accept certain degree of limit violations instead of applying extreme and ineffective control adjustments. This strategy can be represented by applying soft penalties to the constraints.

The penalties for constraint violations are represented by multi-segment linear functions. The internal penalties for the first two segments for branch loading and bus voltage constraints are 1000 and 10000, respectively, as shown in Figure 5-31 and Figure 5-32. These penalties cannot be adjusted.

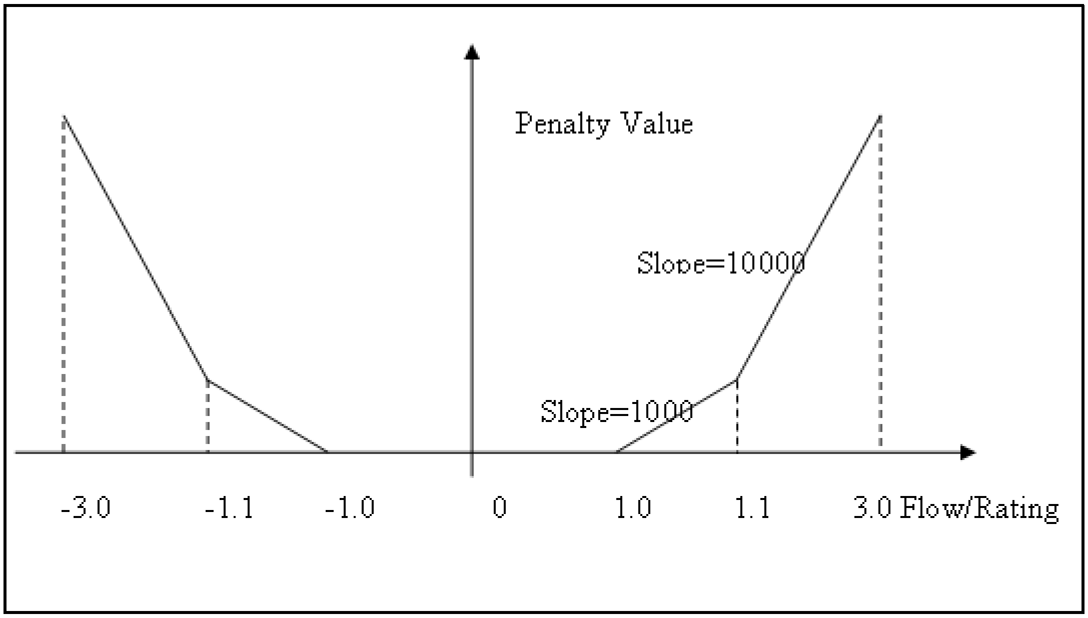


Figure 5-31. Branch/Interface Flow Overload Penalty Function

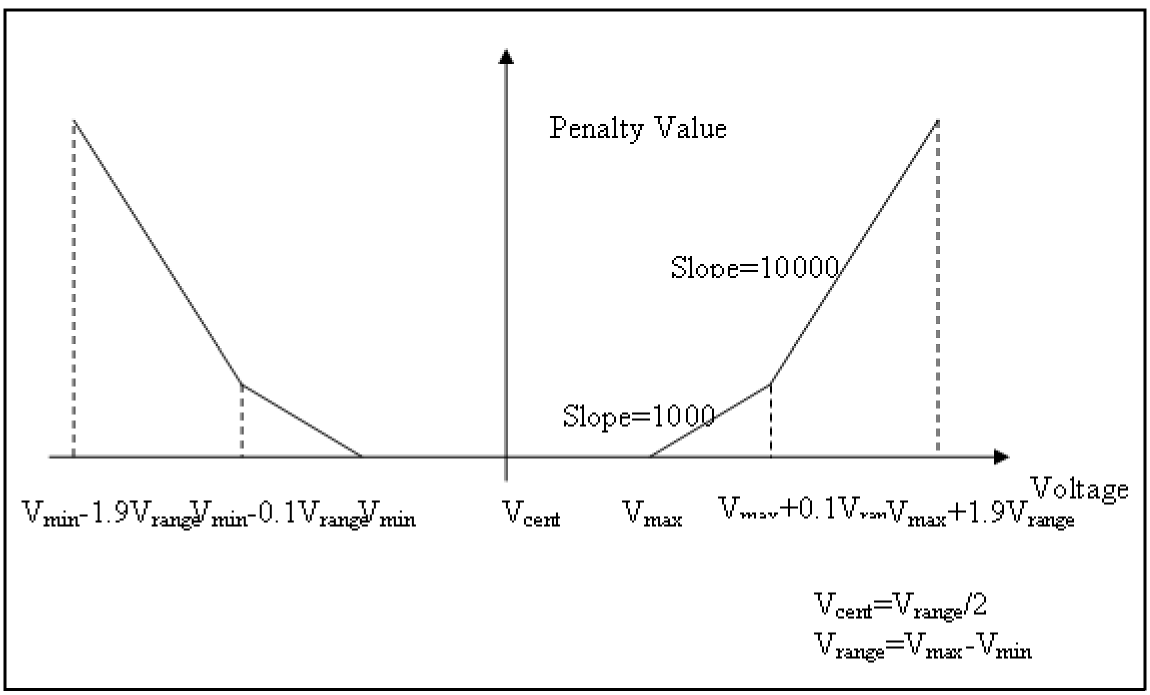


Figure 5-32. Bus Voltage Violation Penalty Function

5.4.3 Running AC corrective actions

To launch AC corrective action solution, select ***power flow>solution>AC corrective actions***. After finishing the selection of options, choose the solve button to initiate the AC corrective actions computation.

5.4.4 Viewing AC Corrective Actions Results.

After AC corrective actions solution is performed successfully, a corrective action analysis report is produced. In the report, files used in the analysis, and numbers of constraints and controls are presented first. Flow overloads and bus voltage violations prior to and post corrective action analysis are reported. Specified corrective actions are presented in the order of generation dispatch, load shedding and phase shifter angle adjustment. For each control adjustment, the initial and new values, as well as the change are reported. Figure 5-33 shows the results of AC corrective actions applied to an example system (savnw case). In this run, percent MVA and percent CURRENT units are specified for monitored transformer and non-transformer branches respectively. 8 branches, 2 interfaces and 6 bus voltages are selected as constraints from monitored elements, 6 generator buses, 7 load buses, as well as 1 phase shifter are selected as controls from components in specified subsystems. In the report, the base case is found to have four flow violations above 60% of rating A (as an illustration) including flow overloading on Interface 'WEST', which is 171% of its normal limit. The report also shows that, after corrective actions have been applied, flows on two branches are slightly higher than their limits.

```
                    PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E
AC CORRECTIVE ACTIONS RESULTS:% LOADING VALUES ARE % MVA FOR TRANSFORMERS AND % CURRENT FOR NON-TRANSFORMER BRANCHES
-------------------------------------------------------------------------------
Case file:                          C:\Program Files\PTI\PSSE30\EXAMPLE\savnw.sav
Distribution factor file:           C:\Program Files\PTI\PSSE30\EXAMPLE\corrective-actions.dfx
Subsystem description file:         C:\Program Files\PTI\PSSE30\EXAMPLE\savnwl.sub
Monitored element file:             C:\Program Files\PTI\PSSE30\EXAMPLE\savnw.mon
Contingency description file:       C:\Program Files\PTI\PSSE30\EXAMPLE\savnw.con
*** Constraints ***
No. of monitored flows:             8
No. of monitored interfaces:        2
No. of monitored voltages:          6
*** Controls ***
No. of Generators:                  6         In Subsystem:  LODSUB
No. of Load Shedding:               7         In Subsystem:  LODSUB
No. of Phase Shifters:              1         In Subsystem:  LODSUB
-------------------------------------------------------------------------------
BASE CASE OVERLOAD REPORT: MONITORED BRANCHES LOADED ABOVE  60.0 % OF RATING SET A
INCLUDES BUS VOLTAGE VIOLATION REPORT
<---------- O V E R L O A D E D   L I N E S ---------->     FLOW   RATING       %
<------ F R O M --------> <-------- T O ----------> CKT   MVA/MW     MVA
   203 EAST230      230.00    154 DOWNTN      230.00  1     137.7    200.0    71.22
   205 SUB230       230.00    154 DOWNTN      230.00  1     439.0    600.0    77.11
  3018 CATDOG_G      13.800   3008 CATDOG      230.00  1     122.8    150.0    85.38
WEST                                                        343.4    200.0   171.70
-------------------------------------------------------------------------------
POST-CORRECTIVE ACTIONS OVERLOAD REPORT/ INCLUDES BUS VOLTAGE VIOLATION REPORT
<---------- O V E R L O A D E D   L I N E S ---------->     FLOW   RATING       %
<------ F R O M --------> <-------- T O ----------> CKT   MVA/MW     MVA
   205 SUB230       230.00    154 DOWNTN      230.00  1     374.3    600.0    66.23
  3018 CATDOG_G      13.800   3008 CATDOG      230.00  1      89.1    150.0    62.53
-------------------------------------------------------------------------------
BUSES WITH REAL POWER GENERATION ADJUSTMENTS (MW)
<-------- B U S -------->    GEN-INI    GEN-NEW    GEN-ADJ
   101 NUC-A        21.600      750.0      610.6    -139.4
   102 NUC-B        21.600      750.0      630.0    -120.0
   206 URBGEN       18.000      800.0      840.0      40.0
   211 HYDRO_G      20.000      600.0      616.2      16.2
  3011 MINE_G       13.800      258.7      505.9     247.2
  3018 CATDOG_G     13.800      100.0       48.9     -51.1

PHASE SHIFTER ADJUSTMENTS (DEGREE)
<----------- P H A S E   S H I F T E R -----------> CKT  PHASE-INI PHASE-NEW PHASE-ADJ
   203 EAST230      230.00    202 EAST500      500.00  1        0.00      9.55      9.55

===== END OF REPORT ====================================================================
```

Figure 5-33. Sample Report from Corrective Action Analysis

5.4.5 Application Notes on AC Corrective Action Analysis

The corrective actions solution algorithm does not place a limit on the numbers of controls and constraints that can be modeled. The computation time of corrective actions solution is approximately proportional to size of the power system and the number of constraints. Since local controls are generally more effective in removing violations, it may be preferable to choose the subsystems in which control actions are allowed to be the same as that in which elements are monitored.

Operating limit violations caused by incorrect limit settings may have a significant impact on the optimal solution found. Hence, suspicious limits should be verified and corrected, if necessary, or even removed from the solution.

Two methods can be used to excluded controls from the corrective actions solution. One is to set the upper and lower limits of a control identical; another is by specifying a control subsystem that does not include controls that are not desired in a particular application

Since the optimization engine is based on a linear power flow, the result from the linear programming solution is iterated with a standard AC power flow solution until one of following conditions occurs:

- all overloads and voltage violations are resolved,
- the adjustable controls are exhausted,
- the number of AC power flow solutions reaches the specified value,
- the difference of the values of objective function between two consecutive iterations is less than a tolerance
- the AC load flow diverges during the process

When AC corrective actions computation fails because of AC load flow divergence, warning messages in the progress window indicate at which step the AC load flow diverges. The user may obtain an approximately optimal solution by specifying the number of AC load flow in AC corrective actions input menu as one less than the step in the solution failure occurs. Or, if the user finds that the computation may require more iterations to reach an optimal solution, the desired iteration number may be increased.

The AC corrective actions computation is not sensitive to any interrupt codes.

5.5 DC Linearized Network Solutions

During the early stages of the planning process, when identifying feasible, alternative expansion plans, it may be acceptable to use approximate, computationally more efficient, power flow models. For example, in the daily operation of a power system, the user may be presented, from an online system, a model of the expected load, generation, and transmission system for the day. For this system condition, the user may want to perform a quick analysis of transfer limits for the base case and several contingencies. Because the results may go back to the online system, a computationally more efficient model is needed. One very widely used approximation is the linearized or DC power flow, which converts the nonlinear AC problem into a simple, linear circuit analysis problem. The advantage of this approach is that efficient, non iterative numerical techniques can be used to compute an approximate power flow solution. Many alternatives or contingencies can be investigated with the same computer effort that would be expended to calculate one AC power flow solution.

The DC power flow model is useful for rapid calculation of real power flow. It ignores reactive power flow and changes in voltage magnitudes, and assumes that, for most circuits, $X_{ij} >> r_{ij}$ and the angle between two buses is small. These assumptions result in the power flow from bus i to bus k simplifying to

$$P_{ij} = \frac{\theta_i - \theta_j}{X_{ij}} \tag{5.1}$$

where:

θ_i = Angle at bus i.

θ_j = Angle at bus j.

X_{ij} = Reactance between bus i and bus j.

The power injected into a single bus i is just the sum of the power on all circuits into the bus or

$$P_i = \sum_{j=1}^{n} P_{ij} = \sum_{j=1}^{n} \frac{\theta_i - \theta_j}{X_{ij}} \tag{5.2}$$

shown in matrix form as

[P] = [B][θ] for a system of n buses.

Note that this equation is linear and that the admittance matrix [B] is sparse since there are only several transmission lines connected to each bus. The solution of this system of equations can be accomplished efficiently by the numerical technique of triangular factorization. The power injections, [P], are known, and the phase angles, [θ], are computed. Once the phase-angle solution has been determined, the real power flows can be computed using (5.1).

5.5.1 Performing a DC Linearized Network Solution

The linearized network solution applies the DC analogy network solution algorithm to the network modeled in the working case. Optionally, the solution method may also be applied to that network with the status of a specified AC branch changed. The base case and change case solutions are then tabulated in a single report.

The DC network solution provides only *approximate* power flow solutions. The simplified branch flow equations on which its algorithm is based inherently result in phase angles and branch flows that are *different* from the AC power flow solution, even when the starting point is a fully solved power flow case. Further, they lead to the assumption that bus voltage magnitudes and line losses remain constant as a branch is placed in- or out-of-service. It has the advantage, though, that it is substantially faster than a full AC power flow solution. Thus, its proper role is that of a screening tool to indicate which cases deserve further attention.

The "linearized" or "DC" power flow model used by the DC network solution process approximates the nonlinear AC power flow with a simplified non iterative calculation. In this method, the matrix equation,

$$[P] = [B][\theta]$$

expresses net bus power injections as linear functions of bus phase angles.

The DC network solution is launched with the ***Power Flow>Linear Network>DC network solution and report (DCLF)*** option as seen in Figure 5-34. This selection will display the DC Network Solution and Report dialog (Figure 5-35)

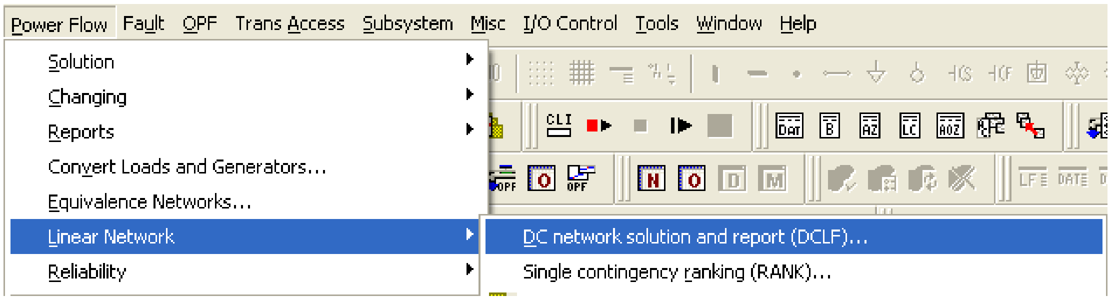


Figure 5-34. Launching the DC Network Solution and Report Dialog

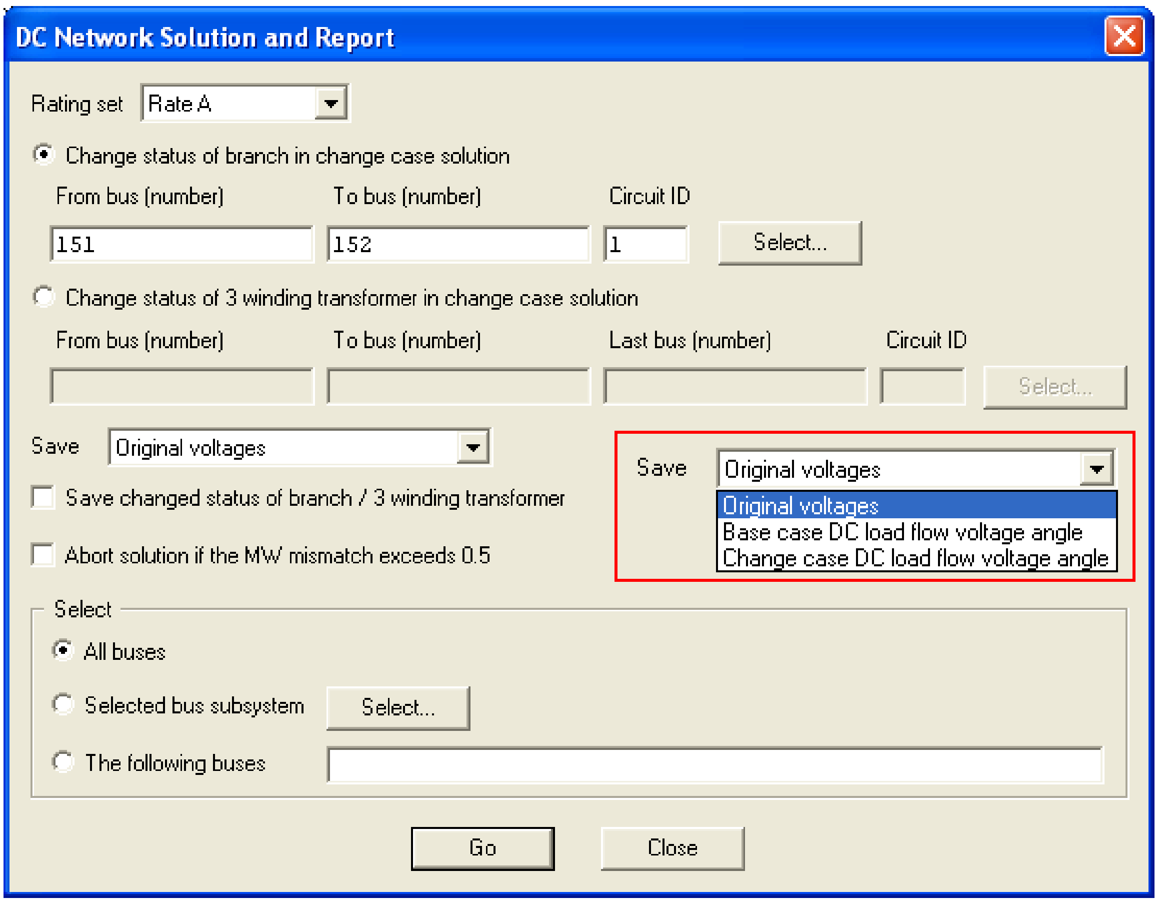


Figure 5-35. DC Network Solution and Report Dialog

The user can select, which of the three ratings are to be used in tabulating line loading percentages in the output report. The default will be the rating set established as the default rating set program options, a change case involving outage of a non-transformer branch or two-winding transformer, or a change case involving outage of a three-winding transformer.

Following the solution, the user has the option of modifying the voltage vector to incorporate the phase angle vector calculated for either the base case or change case DC power flow solution. As shown in Figure 5-35, the choices are:

- Original voltages
- Base Case DC load flow voltages
- Change case DC load flow voltages

If ***Original*** is selected, the voltage vector remains the same as it was prior to launching the DC network solution process and the following message is printed in the Output Bar:

```
ORIGINAL VOLTAGES RETAINED
```

If either the ***Base Case*** or ***Change Case*** is selected, the network solution process sets the voltage at each bus to its voltage magnitude as contained in the working case at a phase angle corresponding to its phase angle in the selected DC solution. An appropriate message is printed:

```
BASE CASE DC LOAD FLOW VOLTAGES SAVED
```

or:

```
CHANGE CASE DC LOAD FLOW VOLTAGES SAVED
```

The status of the changed branch or three-winding transformer can be retained if the user checks the ***Save changed status*** box.

Finally, the user can, with the Select facility in the dialog choose the buses to be included in the output report with the usual selection by Area, Owner, Zone BasekV and Bus options.

With the selection shown in Figure 5-35, the process, when the ***Go*** button is selected, will show the following information in the Output Bar.

```
WORKING CASE HAS LARGEST MISMATCH OF 0.02 MW AT 154 [DOWNTN 230.00]
CIRCUIT 1  FROM 151 [NUCPANT  500.00] TO 152 [MID500   500.00] IS NOW IN
NEW STATUS OF CKT 1  FROM 151 [NUCPANT  500.00] TO 152 [MID500  500.00] IS OUT
ORIGINAL VOLTAGES RETAINED
ORIGINAL BRANCH STATUS RESTORED
```

5.5.1.1 Application Notes for the DC Linearized Network Solution

- The DC network solution process will check that each non type four bus is connected back to a type three (swing) bus through the in-service AC network. If any violations are detected, an appropriate message is printed and process is terminated.
- Next the largest active power mismatch corresponding to the present AC solution voltage vector in the working case is calculated and printed. If this largest mismatch is greater than 0.5 MW, the user the user has the option of continuing or terminating:
- If a branch outage separates the system such that an island with no type three (swing) bus remains, an appropriate message is printed.
- When the multi section line reporting option is **enabled**, and either an in-service multi section line grouping or an in-service member of such a grouping is specified, the entire

grouping is switched. If the specified multi section line grouping or member is initially out-of-service, the DC network solution process does not allow it to be switched. In outaging a multi section line grouping, the type codes of the interior "dummy" buses are automatically changed as required. When the multi section line reporting option is **disabled**, neither multi section line groupings nor members thereof may be switched.

- If an out-of-service three-winding transformer is specified as the branch whose status is to be changed, it is not allowed to be switched.

5.5.1.2 Viewing the DC Linearized Network Solution Report

The general form of the output report is similar to the Wide Format output listing used for AC power flow reporting, described in Section 5.2.6. An example of the output for the network solution as set up in the example of Figure 5-35 can be seen in Figure 5-36.

The bus information presented includes the number of the area in which the bus resides, the bus voltage phase angles for the base case and change case DC power flow solutions, generator MW, and load MW. The value printed as load includes the active power components of the bus shunt and all in-service loads connected to the bus on the basis of the voltage magnitude at the bus at the DC network solution is initiated.

The load also includes the power entering or leaving the bus through any DC lines, VSC DC lines or FACTS devices connected to the bus. If the DC line, VSC DC line or FACTS device power arrays are zero (e.g., if a power flow network raw data file had just been opened and no AC power flow solution attempted), an estimate of the DC or VSC DC line and FACTS device powers is used based upon the scheduled power or current. Otherwise, regardless of the quality of the AC solution upon entry to the DC network solution process, the powers contained in the working case are used. In any case, DC lines, VSC DC lines and FACTS devices are not separately reported here.

The "star point" buses of three-winding transformers are not reported.

For non transformer branches and for two-winding transformers listed, the number, name, base voltage, and area of the "*to bus*" is printed, along with the circuit identifier; for three-winding transformers, the output line contains the string "3WNDTR" in the bus number column, the transformer name in the bus name column, and the winding number in the base voltage column, followed by the transformer circuit identifier. The active power flowing into the line at the "*from bus*" and the corresponding percentage of the selected rating are printed for both the base and change case DC solutions. The selected line rating and the difference in line flow between the base case and change case solutions are also tabulated.

If the current execution of the DC network solution includes only a base case DC solution, the change case columns of the report are blank. If a change case solution was calculated, a description of the change case is included in the banner at the top of each page of output. In addition, in the bus output block for the "*from*" and "*to bus*es" of the branch whose status was changed, the branch output line for this branch is preceded by the character string "**--->**".

If the change case is a line outage which results in the creation of an island without a swing bus, change case phase angles and line flows from within the swingless island are not tabulated; dashes are printed in the output report where these values would normally be shown.

```
                    PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E      TUE, FEB 10 2004  14:29
                           PSS/E PROGRAM APPLICATION GUIDE EXAMPLE
                           BASE CASE INCLUDING SEQUENCE DATA
               CHANGE CASE: CIRCUIT 1  FROM    151 [NUCPANT     500.00] TO    152 [MID500      500.00] IS OUT

X--------- FROM BUS ---------X   BASE CHANGE    GEN.    LOAD X---------- TO BUS ----------X        BASE CASE     RATE    CHANGE CASE    DELTA
  BUS# X-- NAME --X BASKV AREA  ANGLE  ANGLE     MW      MW    BUS# X-- NAME --X BASKV AREA CKT     MW      %      MVA      MW      %       MW
   101 NUC-A       21.600    1   16.6   21.8   750.0     0.0 ----------------------------------------------------------------------------
                                                                151 NUCPANT    500.00   1  1    750.0   60.0  1250.0   750.0   60.0     0.0
   102 NUC-B       21.600    1   16.6   21.8   750.0     0.0 ----------------------------------------------------------------------------
                                                                151 NUCPANT    500.00   1  1    750.0   60.0  1250.0   750.0   60.0     0.0
   151 NUCPANT     500.00    1   10.7   15.9     0.0     0.0 ----------------------------------------------------------------------------
                                                                101 NUC-A      21.600   1  1   -748.4   59.9  1250.0  -748.4   59.9     0.0
                                                                102 NUC-B      21.600   1  1   -748.4   59.9  1250.0  -748.4   59.9     0.0
                                                         --->   152 MID500     500.00   1  1    469.0   39.1  1200.0    XXXX          -463.5
                                                                152 MID500     500.00   1  2    469.0   39.1  1200.0   679.5   56.6   210.5
                                                                201 HYDRO      500.00   2  1    558.7   46.6  1200.0   811.7   67.6   253.0
   152 MID500      500.00    1   -1.5   -1.8     0.0     0.0 ----------------------------------------------------------------------------
                                                         --->   151 NUCPANT    500.00   1  1   -463.5   38.6  1200.0    XXXX           463.5
                                                                151 NUCPANT    500.00   1  2   -463.5   38.6  1200.0  -674.0   56.2  -210.5
                                                                153 MID230     230.00   1  1    744.1   29.8  2500.0   678.6   27.1   -65.5
                                                                202 EAST500    500.00   2  1     50.8    4.2  1200.0  -121.7   10.1  -172.5
                                                               3004 WEST       500.00   5  1    132.2                  117.2           -15.0
   153 MID230      230.00    1   -3.6   -3.8     0.0   200.0 ----------------------------------------------------------------------------
                                                                152 MID500     500.00   1  1   -744.1   29.8  2500.0  -678.6   27.1    65.5
                                                                154 DOWNTN     230.00   1  1    253.9   84.6   300.0   222.5   74.2   -31.4
                                                                154 DOWNTN     230.00   1  2    211.6   70.5   300.0   185.4   61.8   -26.2
                                                               3006 UPTOWN     230.00   5  1     78.6                   70.6            -7.9
   154 DOWNTN      230.00    1  -10.1   -9.4     0.0  1000.0 ----------------------------------------------------------------------------
                                                                153 MID230     230.00   1  1   -250.1   83.4   300.0  -218.7   72.9    31.4
                                                                153 MID230     230.00   1  2   -208.4   69.5   300.0  -182.3   60.8    26.2
                                                                203 EAST230    230.00   2  1   -122.4   61.2   200.0  -124.5   62.2    -2.0
                                                                205 SUB230     230.00   2  1   -356.1   59.4   600.0  -434.6   72.4   -78.4
                                                               3008 CATDOG     230.00   5  1    -62.9   15.7   400.0   -39.9   10.0    22.9
```

Figure 5-36. Sample Output Listing for the DC Network Solution Including Change Case

When the multi section line reporting option is enabled, the interior "dummy" buses of multi section line groupings are not reported. In reporting branches, the far end "*to bus*" (rather than the closest "dummy" bus) of each multi section line connected to the "*from bus*" is shown as its "*to bus*". Mid-section lines are identified with an ampersand ("&") as the first character of their line identifiers in the branch circuit identifier column (e.g., "&1").

5.5.1.3 Application Notes on the DC Linearized Network Solution Report

The line loading percentages tabulated in the solution report should be used with caution since reactive power flows are neglected in the DC analogy solution. These percentages are calculated based only on the MW loading of the line as determined by the DC analogy solution.

The active power components of any line connected shunts in the working case are treated in the same manner that bus shunts are as far is the DC network solution is concerned. Here, they are reported as part of the line flow rather than as load at the bus; that is, they are reported in the same manner as for AC solutions. If the change case is a branch outage, its line shunts are removed from the solution along with the branch. If the change case places a branch in-service, its line shunt components are not added with the branch.

The mathematics of a standard DC analogy network solution neglects line losses. That is, in applying such a method, generation and load exactly balance. The DC network solution employed by PSS™E, on the other hand, approximates the effect of line losses on its DC analogy solutions with the following approach for each branch: From the voltage vector in the working case, it calculates the losses on the branch. Then, during the network solutions, the line losses at the "sending end" of the branch, as determined from the initial voltage vector, are injected as load.

In the output report, these loss injections *are not* included in the bus loads tabulated. Rather, their effect is included in the line flows printed for each branch. Thus, instead of having equal flows with opposite signs at the two ends of a branch, the flows as tabulated here differ by the line loss estimate.

The same loss estimate vector is used in both the base case and change case DC analogy solutions. If the change case is a branch outage, its loss estimate is not removed from the solution along with the branch; it remains as an "invisible" load at the "sending end" bus described above. If the change case places a branch in-service, no loss estimate is added with the branch.

If the multi section line reporting option is enabled, the losses from the members of each in-service multi section line are equivalenced to its endpoint buses. Thus, if the change case calculation is the outaging of a multi section line, all of its losses remain as "invisible" load.

Similarly, any loss estimate that would normally be injected at the "star point" bus of a three-winding transformer are equivalenced to its endpoint buses, and remain as "invisible" load if the change case calculation is the outaging of a three-winding transformer.

From the foregoing discussion, then, it is **strongly** recommended that when using the DC network solution, to check branch outage cases, the network be solved to an acceptable mismatch tolerance with a full AC solution prior to launching the DC solution. While it does not require a solved system condition, the *only* time an unsolved starting point should be provided is when using the DC solution as a "bootstrap" to obtain an estimate of phase angles for a full AC power flow solution.

5.5.2 Checking Linear Network DC Contingencies

The previous section on the DC network solution process described the means by which a linearized base case solution could be obtained along with one change case. Such change case could be considered a contingency. The linearized network contingency calculation process described here, extends the process and facilitates the estimation of the flows on a set of monitored elements for the base case and for a specified set of contingency cases. Either an overload report or a loading table giving results of each case may be tabulated.

The DC contingency analysis process is launched by selecting the ***Power Flow>Linear Network> DC contingency checking (DCCC)*** option. This option will open the DC Contingency Checking dialog (see Figure 5-37). This figure shows drop-down menus for the Output code, the Line flow code and the Contingency case rating selections.

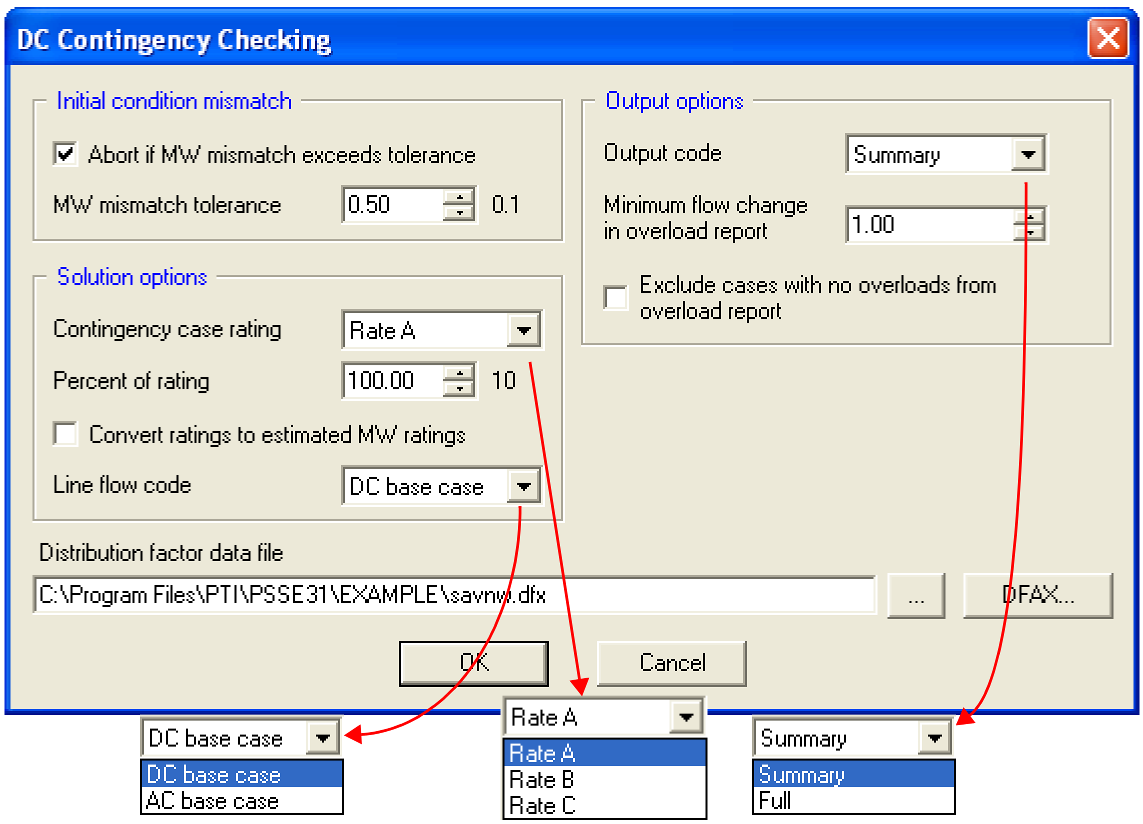


Figure 5-37. DC Contingency Checking Dialog

5.5.2.1 Setting Initial Condition Mismatch for the Linear Network DC Contingency Checking

If the largest initial active power mismatch exceeds the specified MW mismatch tolerance, the user is given the opportunity to terminate the contingency checking process. Note that the user can modify the tolerance in steps of 0.1.

5.5.2.2 Setting Solution Options for the Linear Network DC Contingency Checking

Contingency case rating: This set and the percentage thereof, define the line loading limits used in determining overloads. The default rating set is the one established as the default rating set program option.

Convert ratings code: If the convert ratings code box is checked, ratings of monitored branches are converted to estimated MW ratings based upon each monitored line's Mvar loading at the metered end in the base case AC solution.

Line flow code: Defines the base flow to be used in deriving contingency case flow estimates. The user can select the AC or the DC base case conditions.

5.5.2.3 Setting Linear Network DC Checking Output Options

Output code: This allows the user to select either an overload summary report or a loading table.

Minimum flow change: Overloaded branches in contingency cases whose contingency case flows differ from their base case flows by less than the minimum contingency case flow change parameter are omitted from the summary overload report.

Exclude cases: If this box is checked, those cases for which no overloads are detected are omitted from the summary overload report.

5.5.2.4 Using the Distribution Factor Data File in Linear Network DC Solutions

In Figure 5-37, that the user must supply the name of a distribution factor data file which corresponds to the current network condition and to the desired Linear Network Analysis Data Files. The process of building a distribution factor file for AC contingency analysis was discussed in Section 5.2.7. The building process for building a file suitable for linearized network analyses (such as this DC contingency calculation process) is initially the same but requires the "base case" susceptance matrix to be constructed and the calculation of the line outage distribution factors corresponding to line outage contingency events contained in the Contingency Description Data File.

Note that, whenever a line outage contingency results in the presence of a swingless island, an appropriate message is printed prior to calculating the corresponding distribution factor vector.

As described in Section 5.2.7, to launch the building process, use the ***Power Flow>Linear Network>Build Distribution Factor data file (DFAX)*** option, to open the dialog. As seen in Figure 5-38, it is necessary to check the ***Calculate Distribution Factors*** box to build the distribution factor file suitable for linear analyses as opposed to AC analysis.

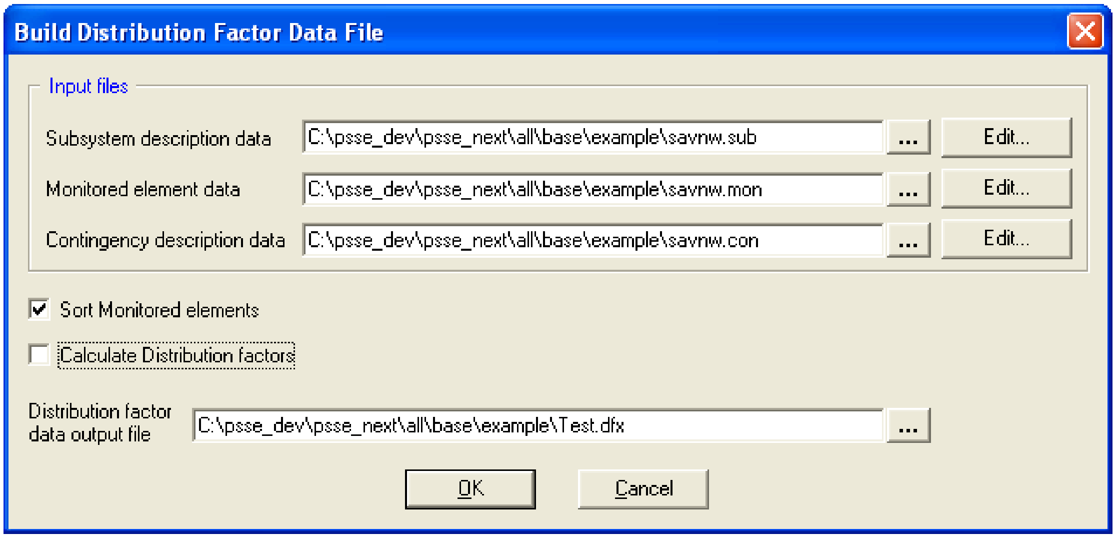


Figure 5-38. Build Distribution Factor Data File for Linear Analyses

Returning to Figure 5-37, the user, once having made the selections for Solutions and Output and having identified the appropriate distribution factor file will select the ***OK*** button in the dialog.

The DC contingency checking process checks that generators are not "converted" and that each non type four bus is connected back to a type three (swing) bus through the in-service AC network. If any violations are detected, an appropriate message is printed and the process is terminated.

The Distribution Factor Data File is read, and, if the convert ratings option was enabled at the start of the process, ratings from the selected rating set of those monitored branches having a nonzero rating are modified. For each such branch, the Mvar loading is calculated and a MW rating is determined under the assumption that the Mvar loading is unchanged under contingency conditions.

Finally, the "base case" DC load flow solution is calculated followed by the processing of the designated contingency cases. If a line outage contingency forms an island with no type three (swing) bus, a singular submatrix is formed. Such islands are omitted from the contingency checking process.

This DC contingency checking process may be terminated by entering the AB interrupt control code.

5.5.2.5 Estimating DC Linear Network Contingency Checking Case Flows

One of two calculation sequences is used for calculating monitored element flow estimates for each contingency case. For contingency cases involving no line closure contingency events, no three-winding transformer outages, and no more than two line outage contingency events, the following calculations are performed:

1. The contingency case flow estimates are initialized to either the flows given by the base case DC network solution or the base case AC flows, according to the line flow code solution parameter selected.
2. If any bus boundary condition contingency events have been specified as part of the contingency case, the incremental form of the DC power flow equation:

   $$[\Delta P] = [B][\Delta\theta]$$

   is solved for the corresponding phase angle changes, and the resulting incremental line flows are calculated and added to the contingency case flow estimate vector initialized in (1).
3. If one (or two) line outage contingency events have been specified as part of the contingency case, the corresponding vector(s) of line outage distribution factors is (are) retrieved from the Distribution Factor Data File. The contingency case flow estimate vector is updated to reflect the first (or only) line outage.
4. If two line outage contingency events have been specified as part of the contingency case, the vector of distribution factors for the second outage is updated to reflect the prior outage of the branch processed in (3). The contingency case flow estimate vector is again updated to reflect the second line outage.

For contingency cases involving either line closure contingency event(s), three-winding transformer outages, or more than two line outage contingency events, full DC network solutions are calculated. If the line flow code selection is for the DC base case, contingency case flows are taken as those from the contingency case DC network solution; if the line flow code selection was for the AC base case, the changes in flows between the base case and contingency case DC network solutions are added to the base case AC flows to establish the contingency case flow estimates.

In applying the first method described above (the "distribution factor method") for contingency cases involving two line outages, if the simultaneous outages create a swingless island which neither of the two outages individually creates, the distribution factor method is abandoned and the second method described above, the full DC network solution, is used.

In either of the two calculation methods, whenever a line outage contingency results in the presence of a swingless island, an appropriate message is printed prior to calculating the contingency case flow estimates.

5.5.2.6 Viewing the Linear Network DC Overload Report

In the overload report, each network condition (i.e., the base case and each contingency case) is reported immediately after its calculation. A branch or interface is reported if the following conditions are satisfied:

- Its rating from the selected rating set is nonzero.
- Its loading estimate exceeds the specified percentage of the selected rating.
- For contingency cases, the difference in loading between the base and contingency cases exceeds the minimum contingency case flow tolerance.

For each monitored element printed, the pre-contingency and post-contingency MW loadings, the rating and the post-contingency percent loading are listed. Any monitored branch which resides in a swingless island, as well as any interface which includes such a branch as a member, is omitted from the overload report.

For three-winding transformer windings, flow estimates are calculated at the winding bus end as power flowing into the transformer. For other AC branches, flow estimates are calculated at the metered end in the "*from bus*" to "*to bus*" direction. The flow across an interface is taken as the sum of the flows of its members. For three-winding transformer windings, the flow is calculated at the winding bus as power flowing into the transformer. For other members, the flow is calculated at its metered end in the "*from bus*" (i.e., the first bus specified in entering the branch) to "*to bus*" direction.

Single branches are listed first, either in the order in which they were specified in the Monitored Element Data File, or in ascending numerical or alphabetical order, according to the option selected during the building of the distribution factor file. These are followed by the interfaces in the order in which they were specified.

If the convert ratings option was selected at the start of this DC contingency checking process, the values printed as line ratings are the estimated MW ratings; otherwise, the ratings as contained in the power flow case are printed. In either case, the values printed are not modified by any percentage of rating parameter specified at the start of this contingency checking process.

An example DC contingency check run using the *savnw.sav*, *savnw.sub*, *savnw.mon* and *savnw.con* files will produce the Overload/ Summary Report (see Figure 5-38).

It can be seen that four contingencies result in overload conditions. The description of the contingencies are listed at the left hand side of the report. Centered are shown the lines and interfaces which are subjected to overload conditions during each listed contingency. At the right of the table are listed, under the "Name" of the contingency condition, the:

- Pre-contingency power flow
- Post contingency power flows
- Rating and percent loading based on that rating

```
     PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E   WED, FEB 11 2004  12:39
PSS/E PROGRAM APPLICATION GUIDE EXAMPLE                              PAGE 1
BASE CASE INCLUDING SEQUENCE DATA
DCCC OVERLOAD REPORT: MONITORED ELEMENTS LOADED ABOVE 100.0 % OF RATING SET B

DISTRIBUTION FACTOR FILE:      C:\Program Files\PTI\PSSE30\EXAMPLE\dc-contingency.dfx
SUBSYSTEM DESCRIPTION FILE:    C:\Program Files\PTI\PSSE30\EXAMPLE\savnw.sub
MONITORED ELEMENT FILE:        C:\Program Files\PTI\PSSE30\EXAMPLE\savnw.mon
CONTINGENCY DESCRIPTION FILE:  C:\Program Files\PTI\PSSE30\EXAMPLE\savnw.con

                                                   <------- O V E R L O A D E D   L I N E S ------>  <--- MW FLOW --->
<---- C O N T I N G E N C Y   E V E N T S--------><------- F R O M -------> <------- T O ----->CKT  PRE-CNT  POST-CNT  RATING  PERCENT
REMOVE UNIT 1 FROM BUS 101 [NUC-A 21.600]           ------------------------------------------------------- CONTINGENCY TRIP1NUCLEAR
                                                              INTERFACE WEST                          -147.9    602.1    200.0    301.0
REMOVE UNIT 1 FROM BUS 101 [NUC-A 21.600]           -------------------------------------------------------- CONTINGENCY TRIP2NUCLEAR
REMOVE UNIT 1 FROM BUS 102 [NUC-B 21.600]
                                                       3008 CATDOG   230.00    154 DOWNTN  230.00 1     62.9    465.4    431.0    108.0
                                                              INTERFACE WEST                          -147.9   1352.1    200.0    676.0
INCREASE BUS 154 [DOWNTN230.00] LOAD BY 50 PERCENT   -------------------------------------------------------- CONTINGENCY ADDLARGELOAD
                                                              INTERFACE WEST                          -147.9    352.1    200.0    176.0
SET BUS 205 [SUB230230.00] LOAD TO 0 MW              -------------------------------------------------------- CONTINGENCY LOSEEASTLOAD
                                                         205 SUB230    230.00    154 DOWNTN 230.00 1    356.1   1198.2    610.2    196.3
                                                              INTERFACE WEST                          -147.9  -1347.9    200.0    674.0
                                                              INTERFACE EAST                          -130.8   1069.2    350.0    305.5
```

Figure 5-39. Summary Contingency Report from the DC Contingency Checking Process

5.5.2.7 Viewing the Linear Network DC Loading Report

In the loading table, results are reported in tabular form with four contingency cases per table. Each group of contingency cases contains a page summarizing the contingency cases performed. For each contingency, the contingency label and the events defining the contingency are listed. The contingency case summary page is followed by the loading table. For each monitored element, this table lists its rating, MW loading and percentage loading in the base case network solution, and the MW and percentage loadings for each of the contingency cases reported. Percentage loadings are shown as positive numbers. Any percentage loading above the specified percentage threshold is followed by an asterisk ("∗").

An example DC contingency check run using the *savnw.sav*, *savnw.sub*, *savnw.mon* and *savnw.con* files will produce the Loading Report partially shown in Figure 5-40.

It should be noted that the cases marked with an asterisk, are summarized on the overload report typical of which is that shown in Figure 5-39.

Any monitored branch which resides in a swingless island, as well as any interface which includes such a branch as a member, has dashes printed in place of its flow in the loading table.

```
     PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E   WED, FEB 11 2004  12:38
PSS/E PROGRAM APPLICATION GUIDE EXAMPLE                               PAGE 1
BASE CASE INCLUDING SEQUENCE DATA
                       *** DCCC CONTINGENCY SUMMARY ***

DISTRIBUTION FACTOR FILE:      C:\Program Files\PTI\PSSE30\EXAMPLE\dc-contingency.dfx
SUBSYSTEM DESCRIPTION FILE:    C:\Program Files\PTI\PSSE30\EXAMPLE\savnw.sub
MONITORED ELEMENT FILE:        C:\Program Files\PTI\PSSE30\EXAMPLE\savnw.mon
CONTINGENCY DESCRIPTION FILE:  C:\Program Files\PTI\PSSE30\EXAMPLE\savnw.con

<-CONTINGENCY-> <-----------------------------------------------------CONTINGENCY DESCRIPTION--------------------------------------

  TRIP1NUCLEAR   REMOVE UNIT 1 FROM BUS 101 [NUC-A       21.600]

  TRIP2NUCLEAR   REMOVE UNIT 1 FROM BUS 101 [NUC-A       21.600]
                 REMOVE UNIT 1 FROM BUS 102 [NUC-B       21.600]

  ADDLARGELOAD   INCREASE BUS 154 [DOWNTN      230.00] LOAD BY 50 PERCENT

  LOSEWESTGEN    REMOVE UNIT 1 FROM BUS 3018 [CATDOG_G    13.800]
     PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E   WED, FEB 11 2004  12:38
PSS/E PROGRAM APPLICATION GUIDE EXAMPLE                               PAGE 2
BASE CASE INCLUDING SEQUENCE DATA
   DCCC LOADING TABLE: * FOR MONITORED ELEMENTS ABOVE 100.0 % OF RATING SET B

                                             CONTINGENCY LABEL-->     BASE CASE      TRIP1NUCLEAR    TRIP2NUCLEAR    ADDLARGELOAD
                                                                       MW     %        MW     %        MW     %        MW     %
<-------- F R O M --------> <---------- T O ---------->CKT RATING  --------------  --------------  --------------  --------------
   201 [HYDRO       500.00]    151 [NUCPANT     500.00] 1  1272.7   -558.7  43.9    -248.6  19.5      61.4   4.8    -595.8  46.8
   202 [EAST500     500.00]    152 [MID500      500.00] 1  1293.6    -50.7   3.9    -161.6  12.5    -272.5  21.1    -156.0  12.1
   203 [EAST230     230.00]    154 [DOWNTN      230.00] 1   244.1    122.4  50.2      90.7  37.1      58.9  24.1     160.8  65.8
   205 [SUB230      230.00]    154 [DOWNTN      230.00] 1   610.2    356.1  58.4     188.8  30.9      21.4   3.5     460.2  75.4
  3004 [WEST        500.00]    152 [MID500      500.00] 1 -NONE-    -132.2   ---     190.1   ---     512.5   ---      40.8   ---
  3006 [UPTOWN      230.00]    153 [MID230      230.00] 1 -NONE-     -78.6   ---     147.8   ---     374.3   ---      50.2   ---
  3008 [CATDOG      230.00]    154 [DOWNTN      230.00] 1   431.0     62.9  14.6     264.1  61.3     465.4 108.0*    261.1  60.6
       INTERFACE WEST                                      200.0   -147.9  74.0     602.1 301.0*  1352.1 676.0*    352.1 176.0*
       INTERFACE EAST                                      350.0   -130.8  37.4    -130.8  37.4    -130.8  37.4    -130.8  37.4
```

Figure 5-40. Loading Report from the DC Contingency Checking Process

5.5.3 Perform DC Corrective Action Analysis

DC corrective actions computation represents the transmission system by means of a linear model, and is modeled as an optimal power flow problem solved with a linear programming method. It identifies the necessary adjustments to loads, phase-shifter angles and active power generations to eliminate branch loading violations.

5.5.3.1 Setting-up for DC Corrective Action Analysis

To launch DC corrective action analysis, select ***Power Flow>Linear Network>DC Corrective Actions***. This will open DC corrective actions dialog (see Table 5-41).

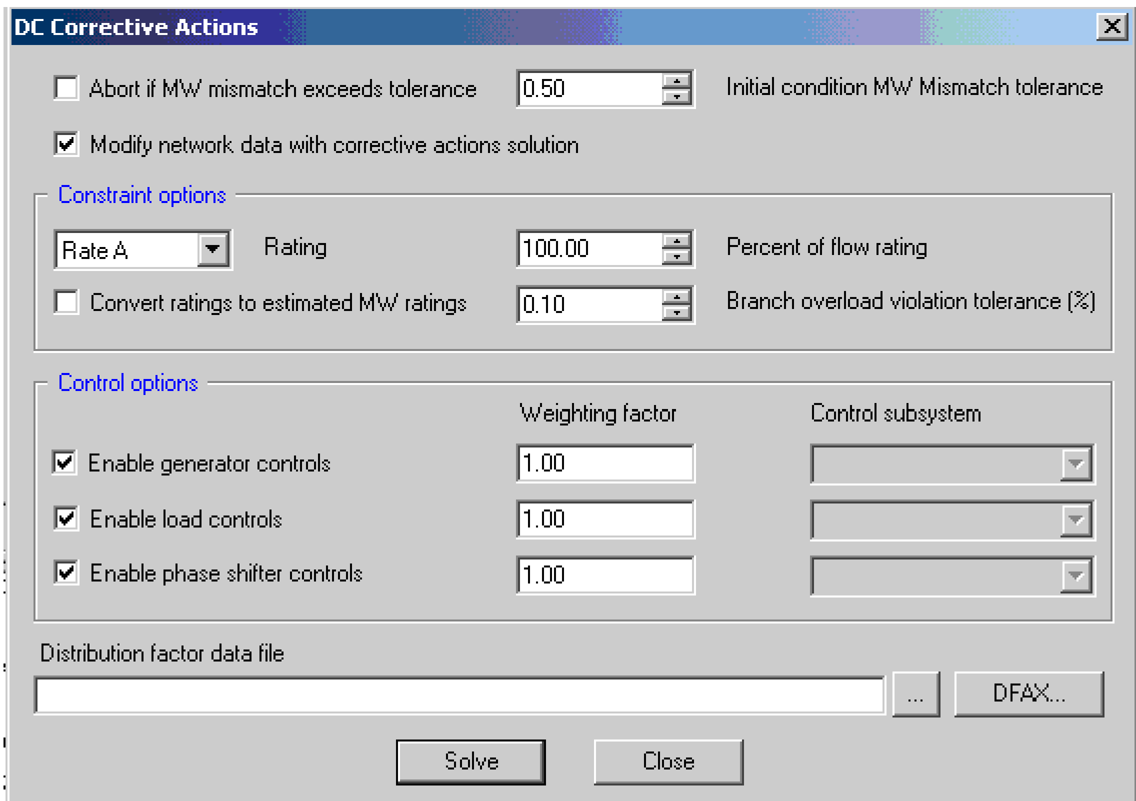


Figure 5-41. DC Corrective Action analysis Dialog

5.5.3.2 Setting DC Corrective Action Analysis Options

Abort if MW mismatch exceeds tolerance: Check the box to abort DC corrective action analysis if the largest initial active power mismatch exceeds the specified Initial Condition MW Mismatch Tolerance. Otherwise continue to perform DC corrective action analysis.

Modify network data with corrective action solution: select to modify generation, load and phase shifter angle to incorporate adjustments of control components involved in corrective actions and modify bus voltages to incorporate bus voltage phase angle vectors calculated from corrective actions.

Constraint options: Select branch flow rating set and limit tolerance for monitored branches and interfaces.

Rating and percent of flow rating: Define branch rating set and percent of rating. The limits are equal to the specified rating multiplied by percent of flow rating.

Convert ratings to estimated MW ratings: If the convert ratings code box is checked, ratings of monitored branches are converted to estimated MW ratings based upon each monitored line's MVAR loading at the metered end in the base case AC solution.

Branch overload violation tolerance: Specify branch loading limit tolerance for adjustment of load limits to be used in linear programming engine. For example, if the tolerance is 0.1% and the selected flow rating is 100% of Rate A, the linear programming algorithm will consider the solution feasible if the loading of a branch has been reduced within 100.1% of the rating.

Control options: Select types of control adjustments and specify weighting factors for each type (see Section 5.4.1.1).

5.5.3.3 Input Data File

The Distribution Factor Data File is used to define branch and interface flow constraints and control subsystems. When creating a Distribution Factor Data File for DC corrective action, a Contingency Description Data File which specifies no contingencies is allowed.

5.5.3.4 About DC Corrective Action Analysis

The mathematical model is presented in section 5.3.1. The DC corrective actions algorithm differs from that in the AC corrective actions in that it represents the transmission system by means of a linear model. Control adjustments are computed using a linear programming algorithm, whose objective is to minimize the cost of generation re-dispatch, phase-shifter angle changes and load shedding. DC corrective actions focus on branch and interface overloads, and MW flows are used to determine circuit loadings. Bus voltage constraints are not taken into account in DC corrective actions. DC corrective actions use the same weighting functions for MW generation, phase angle, and load curtailment as discussed in AC corrective actions (see Section 5.4.2.1). The penalty functions for soft constraints for branch flows and interface flows are also the same as those discussed in AC corrective actions.

5.5.3.5 Running DC corrective actions

To launch DC corrective actions solution, select ***Power Flow>Linear Network>DC Corrective Actions***. After finishing the selection of options, click the solve button to perform DC corrective actions.

5.5.3.6 View the DC corrective action results.

After a DC corrective actions solution is performed successfully, the program lists monitored branches that are overloaded, before and, if any, after the corrective actions solution. In the second part of the report, initial and new values of the controls, as well as changes in controls are reported also. Figure 5-42 is the sample result of DC corrective actions applied to an example system. Two branches and an interface flow overloads in the working case are removed by corrective actions, which involve the adjustments of the phase shifter between buses 203 and 202, and generation at two generator buses.

```
                   PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E
                              DC CORRECTIVE ACTIONS RESULTS

 -------------------------------------------------------------------------------

  Case file:                              C:\Program Files\PTI\PSSE30\EXAMPLE\savnw.sav
  Distribution factor file:               C:\Program Files\PTI\PSSE30\EXAMPLE\corrective-actions.dfx
  Subsystem description file:             C:\Program Files\PTI\PSSE30\EXAMPLE\savnwl.sub
  Monitored element file:                 C:\Program Files\PTI\PSSE30\EXAMPLE\savnw.mon
  Contingency description file:           C:\Program Files\PTI\PSSE30\EXAMPLE\savnw.con
  *** Constraints ***
  No. of monitored flows:                 8
  No. of monitored interfaces:            2
  *** Controls ***
  No. of Generators:                      6          In Subsystem:  LODSUB
  No. of Load Shedding:                   7          In Subsystem:  LODSUB
  No. of Phase Shifters:                  1          In Subsystem:  LODSUB

 -------------------------------------------------------------------------------

  BASE CASE OVERLOAD REPORT: MONITORED BRANCHES LOADED ABOVE  60.0 % OF RATING SET A

  <---------- O V E R L O A D E D   L I N E S ---------->     FLOW   RATING       %
  <------ F R O M --------> <-------- T O ----------> CKT       MW      MVA
     203 EAST230      230.00     154 DOWNTN      230.00  1     122.4    200.0    61.22
    3018 CATDOG_G     13.800    3008 CATDOG      230.00  1     100.0    150.0    66.64
  WEST                                                         343.4    200.0   171.70

 -------------------------------------------------------------------------------

  POST-CORRECTIVE ACTIONS OVERLOAD REPORT

  <---------- O V E R L O A D E D   L I N E S ---------->     FLOW   RATING       %
  WEST                                                         120.0    200.0    60.00

 -------------------------------------------------------------------------------

  BUSES WITH REAL POWER GENERATION ADJUSTMENTS (MW)
  <-------- B U S --------->   GEN-INI   GEN-NEW   GEN-ADJ
     211 HYDRO_G      20.000     600.0     614.7      14.7
    3018 CATDOG_G     13.800     100.0      83.6     -16.4

  PHASE SHIFTER ADJUSTMENTS (DEGREE)
  <----------- P H A S E   S H I F T E R -----------> CKT  PHASE-INI PHASE-NEW PHASE-ADJ
     203 EAST230      230.00     202 EAST500     500.00  1       0.00     14.45     14.45

  ===== END OF REPORT ====================================================================
```

Figure 5-42. Sample Output of DC Corrective Action Analysis

5.5.3.7 Application notes on DC corrective action

The corrective actions solution algorithm does not place a limit on the number of controls and constraints that can be modeled. The computation time of a corrective actions solution is approximately proportional to the number of constraints. Since local controls are generally more effective in removing violations, it may be preferable to choose the subsystem in which control actions are allowed to be the same as that in which elements are monitored.

Operating limit violations caused by incorrect limit settings may have a significant impact on the optimal solution found. Hence, suspicious limits should be verified and corrected, if necessary, or even removed from the solution.

Two methods can be used to excluded controls from the corrective actions solution. One way is to set the upper and lower limits of a control equal; another is to carefully define the control subsystem to exclude those controls that are not desired in a particular application.

The DC corrective actions computation is not sensitive to any interrupt codes.

5.6 Generator Contingency Analysis

The Gauss-Seidel and Newton-Raphson power flow solutions take advantage of the swing bus to absorb all changes in system losses, changes in load and generation dispatch. These assumed "steady state" solutions do not account for owner flow conditions immediately following a disturbance or system change that modifies the power balance, such as:

- Sudden loss of load, which would be redistributed in the transient period immediately following the disturbance among generators
- Sudden loss of generation which would be redistributed among all other generators
- System break-up into islands each with its own frequency deviation.

An "Inertial" power flow represents the effects of governor action and other effects which might stress the system. Following the loss of generation, addition of significant demand or the splitting of a network, conditions can be such that there is a demand resource unbalance. The result is a change in frequency and an adjustment of generator output. Generator output will be controlled initially by machine inertia and fast acting controls, such as excitation and voltage regulators. As time extends beyond the disturbance, the generator governors will have more influence.

PSS™E provides two power flow solutions with inertia/governor re-dispatch to enable the user to examine system conditions and to obtain a revised generator dispatch for the conditions under which machine inertia plays the major role in modifying generator output and under which governors play a more significant role.

The **Inertial Power Flow** solution gives a quick approximation to system effects in the first 0.5 seconds following a disturbance, during which governor effects are minimal. Generator powers are principally influenced by machine inertias

The **Governor Response** solution represents the system several seconds after an event when governors and exciters have brought the system back to steady-state. The new generator powers are determined by governor droop and load damping characteristics.

The inertial and governor response power flow solutions both use a Newton-Raphson iterative algorithm to solve for the bus voltages needed to satisfy the bus boundary conditions contained in the working case. The power flow case is assumed to have appropriate data changes corresponding to some event imposed upon the solved pre-event power flow case.

Data required for the generation dispatch are specified in an Inertia and Governor Response Data File. Island average frequencies are estimated and network parameters are made frequency sensitive.

5.6.1 Creating the Generator Inertia and Governor Response Data File

The input data stream consists of a series of records in the following format:

```
I, ID, H, PMAX, PMIN, R, D
```

where:

I	Bus number. Bus I must reside in the working case with a generator table entry assigned to it. No default is allowed.
ID	One- or two-character machine identifier used to distinguish among multiple machines at a plant (i.e., at a generator bus). ID = ’1’ by default.
H	Machine inertia; entered in pu on MBASE base. H = 4.0 by default.
PMAX	Maximum machine active power output; entered in pu on MBASE base. If defaulted, PMAX and PMIN for this machine are set *to the active power limits contained in the power flow case for any machine for which a data file record was successfully read but PMAX was defaulted.*
PMIN	Minimum machine active power output; entered in pu on MBASE base. If PMAX is defaulted, the value specified for PMIN is set *to the active power limit contained in the power flow case*; otherwise, PMIN = 0.0 by default.
R	Governor permanent droop; entered in pu on MBASE base. R = 0.05 by default.
D	Turbine damping factor; entered in pu on MBASE base. D = 0.0 by default.

Data records may be input in any machine order. Input is terminated with a record specifying an "I" value of zero.

Any machine for which PMAX = PMIN in the Inertia and Governor Response Data File is treated as non dispatchable. Its active power remains at its initial value from the working case when its island’s swing bus generation change is dispatched among the in-service machines in the island.

In the inertial power flow, except for the use of "PMAX" and "PMIN" to categorize machines as either dispatchable or non dispatchable, only "H" is used. In the governor response power flow, "R", "D", "PMAX", and "PMIN" are used.

5.6.2 About the Generator Inertial Power Flow

The inertial power flow solution is intended to indicate system conditions that would exist half a second after the initiation of an event on a steady state system condition. In this time frame, it is assumed that generator over current protection and governor effects are minimal, and that changes in generator powers are influenced principally by machine inertias.

In this solution, generator scheduled voltages at those generator buses which are initially at a reactive power limit are set to their predisturbance (i.e., initial working case) voltages. The default response to the var limits selection is to ignore reactive power limits. By default, tap adjustment and phase shift angle adjustment are disabled, DC converter taps are locked, and switched shunts are active. Area interchange control and the non-divergent solution option are always disabled.

For machines for which no data record is successfully read (e.g., if no data file is specified, or if it does not contain data records for all in-service machines), a machine inertia constant of 4.0 on machine base (i.e., on MBASE base), is used. Clearly, the proper specification of MBASE for any machine using default data is essential.

Speed deviation and frequency of each machine are estimated according to the equations:

$$\frac{P_t - P_e}{1 + n} = 2H\frac{dn}{dt} \tag{5.3}$$

$$n = 0.5\frac{dn}{dt} \tag{5.4}$$

$$f = 1 + n \tag{5.5}$$

where:

P_t	=	Turbine power; assumed to be initial machine power.
P_e	=	Machine power.
H	=	Machine inertia.
n	=	Machine speed deviation.
f	=	Machine terminal frequency.

Equation (5.4) assumes that the rate of change of frequency is linear over the half second time frame.

5.6.3 About the Governor Response Solution

The governor response power flow solution is intended to indicate system conditions that would exist at least several seconds after the initiation of an event on a steady-state system condition. In this time frame, it is assumed that voltage regulator and turbine governor effects are influential in bringing the system to a new steady-state condition, and that changes in generator powers are determined by governor droop and damping characteristics.

In this solution, generator scheduled voltages are unchanged except as described below, and the default response to the var limit selection is to honor generator reactive power limits. By default, tap adjustment by the stepping method and phase shift angle adjustment are enabled, DC taps are unlocked, and switched shunts are active. These settings may be overridden by the user when initiating the solution. Area interchange control and the non-divergent solution option are always disabled.

A generator bus that is selected as an island swing by the solution process and that was initially at a reactive power limit is alarmed and its scheduled voltage is set to its predisturbance (i.e., initial power flow case) voltage.

Speed deviation and frequency of each machine are estimated according to the equations:

$$n = \frac{P_t - P_e}{D + (1/R)} \tag{5.6}$$

$$f = 1 + n \tag{5.7}$$

where D and R are as defined in Section 5.6.1, and P_t, P_e, n, and f are as defined in Section 5.6.2.

If, during the solution, the total generation requirement in an island drives all generators in the island to their high or low power output limits, an appropriate message is printed and the solution process is terminated.

5.6.4 Launching the Inertial/Governor Response Solution

Both the Inertial Power Flow and Governor Response solutions are launched by selecting the ***Power Flow>Solution>N-R solution with inertial governor dispatch (INLF)*** option. This option will display the N-R Solution with Inertial/Governor Redispatch dialog (see Figure 5-43).

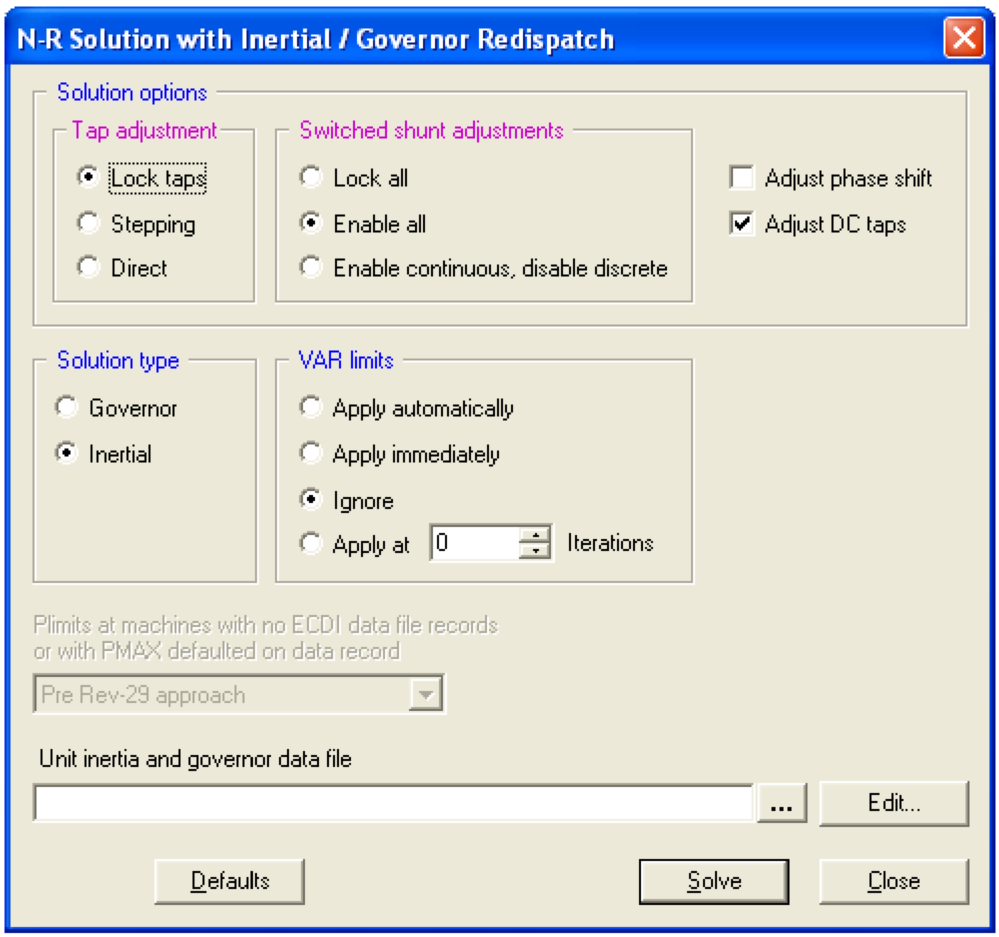


Figure 5-43. Launching the Inertial/Governor Response Power Flow Solutions

In the dialog shown in Figure 5-43, the user's minimum requirements are to supply the Unit Inertia and governor data file and to select the ***Inertial*** Solution type. Note that the figure shows default values for Solution options, Tap adjustments and Var limits. Remember that Area interchange control and the non-divergent solution option are always disabled in this solution.

In reading the input file, gross data errors (e.g., H = 0.0) are alarmed and the corresponding record is ignored. Data inconsistencies (e.g., PMAX less than initial machine power) are alarmed, "fixed", and used.

The power flow process, when initiated, checks each island for a swing bus. One (and only one) swing bus must be specified in each island, and, if no swing bus exists in an island, the program assigns the self-regulating generator bus with the largest inertial or governor response, as appropriate, as the island swing. The process will alarm and terminate if:

- Any island contains more than one type three bus
- A type three bus has no dispatchable in-service machines
- An island without a type three bus contains no dispatchable self-regulating generator buses
- An island contains no dispatchable machines.

The inertial power flow solution functions in a manner similar to the fully coupled Newton-Raphson solution. It handles treatment of generator reactive power limits, load, generator, switched shunt, FACTS device, VSC DC lines, and DC line boundary conditions, the "blowup" check, scaling of the voltage magnitude change vector, acceleration, and interrupt control codes in the same way. The selection and application of automatic adjustments is identical except that the area interchange control and the non-divergent solution options are not available. The basic solution convergence monitor, FACTS device monitor, DC transmission line monitors, largest mismatch tabulation, and swing bus summary too are identical.

The solution parameters designating the maximum number of iterations, acceleration, convergence tolerance, and maximum voltage magnitude change are shared with fully coupled Newton-Raphson solution and the blowup threshold and constant power voltage breakpoint are shared among all power flow solutions. The user may modify any of these solution parameters.

The inertial power flow solution objective is to provide for the redispatch of generator powers to allow proper load sharing in a power unbalance condition. This occurs whenever the largest angle change in radians during an iteration is less than the automatic adjustment threshold tolerance, ADJTHR, *and* any island swing bus power has changed by more than the convergence tolerance since the last dispatch. The largest swing bus power change is tabulated prior to each dispatch calculation.

Island average frequency estimates are updated during the dispatch calculation; they are set to the average of the dispatchable machine frequencies. All bus and line shunts, admittance loads, line charging capacitances and line impedances are modified to reflect their dependency on frequency. Prior to terminating, the solution process tabulates the frequency estimate and swing bus of each island.

5.6.5 Example of a Generator Contingency Analysis Solution

An example Inertial solution can be run using the savnw.sav power flow case found in the ***PSSE30>EXAMPLE*** directory.

The test will be to trip the machine at bus 101 in the power flow. That unit is generating 750 MW. The inertial data file to be used assumes the following information contained in Table 5-6.

Table 5-6. Inertial Power Flow Solution Data File

I	ID	H	PMAX	PMIN	R	D
101	**1**	**4**	**0.9**	**0**	**0.05**	**0**
102	**1**	**4**	**0.9**	**0**	**0.05**	**0**
206	**1**	**4**	**0.9**	**0**	**0.05**	**0**
211	**1**	**5**	**0.85**	**0**	**0.05**	**0**
3011	**1**	**4**	**0.9**	**0**	**0.05**	**0**
3018	**1**	**4**	**0.9**	**0**	**0.05**	**0**

Running the Inertial and Governor power flow solutions will result in a summary of network conditions and a convergence monitor in the Output Bar (see Figure 5-44).

```
REACHED TOLERANCE IN   9 ITERATIONS

LARGEST MISMATCH: 0.00 MW -0.01 MVAR  0.01 MVA AT BUS 211 [HYDRO_G     20.000]
SYSTEM TOTAL ABSOLUTE MISMATCH:               0.03 MVA

SWING BUS SUMMARY:
  BUS# X-- NAME --X BASKV      PGEN     PMAX    PMIN      QGEN     QMAX    QMIN
  3011 MINE_G      13.800     446.5    900.0     0.0     109.7    600.0  -100.0

FREQUENCY FOR ISLAND  1 IS 59.287 HERTZ
  SWING BUS FOR THIS ISLAND IS 3011 [MINE_G  13.800]
```

Inertial Response

```
REACHED TOLERANCE IN  10 ITERATIONS

LARGEST MISMATCH: 0.00 MW  -0.04 MVAR   0.04 MVA AT BUS 3008 [CATDOG 230.00]
SYSTEM TOTAL ABSOLUTE MISMATCH:               0.08 MVA

SWING BUS SUMMARY:
  BUS X--- NAME ---X      PGEN     PMAX    PMIN     QGEN     QMAX    QMIN
 3011 MINE_G  13.800     809.4    900.0     0.0     77.9    600.0  -100.0

FREQUENCY FOR ISLAND  1 IS 59.478 HERTZ
  SWING BUS FOR THIS ISLAND IS  3011 [MINE_G  13.8]
```

Governor Response

Figure 5-44. Progress Reports for Inertial and Governor Power Flow Solutions

It can be seen in Figure 5-44 that the frequency in the inertial response, shortly after the disturbance has fallen to 59.287 Hz while following governor action it has recovered to 59.478 Hz. Further, following governor action the swing bus has an increased power generation at 809 MW.

To further examine the solution it is useful to look at the redispatches. In Figure 5-45 the dispatches are shown for the Base case, the situation subject to inertial redispatch and the situation subject to governor action.

Inertial redispatch is not controlled by governor action. The amount of power from each unit is a function of its inertia and it can be seen that some units are outputting power above PMAX. This will slow down the units. Following governor action, machine powers have been reduced to levels at or within their maximum capabilities.

Bus number	Bus name	Id	Status	Pgen (MW)	Pmax (MW)
101	NUC-A 21.60	1	☑ In	750.00	810.0
102	NUC-B 21.60	1	☑ In	750.00	810.0
206	URBGEN 18.00	1	☑ In	800.00	900.0
211	HYDRO_G 20.00	1	☑ In	600.00	616.3
3011	MINE_G 13.80	1	☑ In	258.66	900.0
3018	CATDOG_G 13.80	1	☑ In	100.00	117.0

Base Case

Bus number	Bus name	Id	Status	Pgen (MW)	Pmax (MW)
101	NUC-A 21.600	1	☑ In	750.00	810.0
102	NUC-B 21.600	1	☑ In	919.04	810.0
206	URBGEN 18.000	1	☑ In	987.83	900.0
211	HYDRO_G 20.000	1	☑ In	770.22	616.3
3011	MINE_G 13.800	1	☑ In	446.49	900.0
3018	CATDOG_G 13.80	1	☑ In	124.42	117.0

Inertial

Bus number	Bus name	Id	Status	Pgen (MW)
101	NUC-A 21.60	1	☑ In	750.00
102	NUC-B 21.60	1	☑ In	810.00
206	URBGEN 18.00	1	☑ In	900.00
211	HYDRO_G 20.00	1	☑ In	616.25
3011	MINE_G 13.80	1	☑ In	809.44
3018	CATDOG_G 13.80	1	☑ In	117.00

Governor

Figure 5-45. Initial Dispatch Compared to Inertial and Governor Power Flow Redispatch Levels

5.6.5.1 Application Notes on Generator Inertial and Governor Redispatch

It may often be appropriate to precede the redispatch calculation with a conversion of load boundary conditions from the typical constant MVA characteristic used in conventional power flow calculations to a representation suitable for network conditions involving abnormally low or high voltages.

All frequency-sensitive data items are modified in the power flow case at the completion of this redispatch process. Therefore, standard power flow reporting activities such as the Bus based, Area based and Subsystem based implicitly calculate results at off-nominal frequencies, even though island frequencies are not preserved. As a result of this, and the possible modification of generator scheduled voltages described above, it is **strongly** recommended that care be taken in saving the new power flow condition. In particular, the user should not overwrite the Saved Case File containing the pre-event network solution, or any milestone Saved Case File preserved prior to running the inertial or governor response power flow solutions.

These power flow solutions might require more iterations than the Newton-Raphson solutions activity, particularly when the system, or an island thereof, is under severe stress. The iteration limit ITMXN may be increased via the solution parameters data editor window.

Should the inertial or governor response power flow solutions fail to converge in an islanding situation, inspection of solution results may indicate that all islands except one are "solved." Such a solution may be adequate for the application at hand. Note that in an islanding case, those islands that are not of particular interest may be disconnected. This should be done after implementing the data changes required to model the event being studied, and before running the power flow solutions.

Just as in a conventional power flow solution, selection of a swing bus for each island can have an effect on the solution convergence properties for that island. Proper selection of island swing buses requires a "feel" for the system. The user may find it helpful to make several attempts at solution for a particularly troublesome island, each with a different island swing bus.

It is good practice to save the working case in a Saved Case File before running either the inertial or governor response power flow solution. This is useful for the situation in which either of them fails to converge. The Saved Case may be restored, changes made (e.g., different load characteristics, different island swing buses, or other techniques described above) and a new solution attempted without having to re-specify the data changes required to model the event under study.

Note again that the data items described earlier in Section 5.6.1 are specified on machine base.

5.7 Calculating Distribution Factors

It is possible for the user to print the distribution factors from the linearized network model Distribution Factor file built as described in Section 5.2.2 but only for single event line outage contingencies. Distribution factors for other types of single contingency events are calculated as needed.

Because the linearized network model is the basis of the calculation of distribution factors, it is necessary to recognize that their use provides approximate results useful for estimating conditions during contingencies.

5.7.1 Uses of Distribution Factors

In both large and small network models, the factors are useful for the user to make quick estimates of changes in line flows during contingencies which result in:

- Loss of a single line element
- Increase or decrease in generation at a bus
- Increase of decrease of load at a bus

Line closure distribution factors are generally not very useful and are supported only for compatibility with other linear analyses. They are equal in magnitude to those of the corresponding line outage contingency but with the opposite sign.

Each distribution factor is a sensitivity coefficient describing the effect of the corresponding contingency on the set of monitored elements. A distribution factor is defined as the ratio of the change in flow on the monitored element in the pre-contingency and post-contingency DC power flow solutions to the DC power change on the element involved in the contingency:

$$\text{D.F.} = \frac{(\text{MW in contingency case}) - (\text{MW in base case})}{\text{Power Shift}}$$

Distribution factors are usually used to *estimate* post-contingency line flows when only pre-contingency ("base case") conditions are known:

$$P_{new} = P_{base} + (\text{D.F.} \times \Delta P)$$

Figure 5-46 is an example that shows the outage of a line carrying 100 MW in the base case. If the distribution factor for that specific outage is denoted as "FIJ" for the line from Bus I to Bus L and its value is equal to 0.05, then the line from Bus I to Bus L will have an increased loading equal to the 100 MW lost from the outaged line multiplied by "FIJ", that is 5 MW.

For bus boundary condition contingencies, the distribution factors are expressed relative to a change in power withdrawn at the bus. Thus, they are identical for increases in generation, decreases in generation, increases in load and decreases in load. A load increase and a generation decrease both have a positive "ΔP", while a load decrease and a generation increase both have a negative "ΔP" in deriving post-contingency monitored line flows with the above formula.

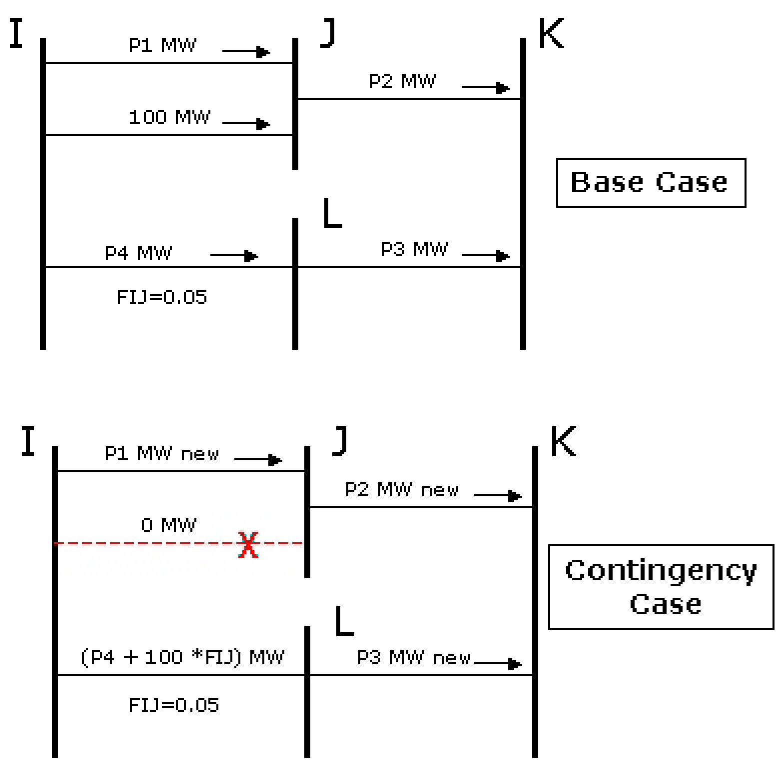


Figure 5-46. Application of Line Outage Distribution Factor

5.7.2 Performing the Distribution Factor Calculation

To initiate the process and output of results the user should select ***Power Flow>Linear network>Calculate and print distribution factors (OTDF)*** option. This will open a dialog where the distribution factor data file, which corresponds to the current network condition, can be selected (see Figure 5-47).

The program will check that generators are not "converted" and that each non type four bus is connected back to a type three (swing) bus through the in-service AC network. If any violations are detected, an appropriate message is printed and the process terminated. Next the largest active power mismatch corresponding to the present AC solution voltage vector in the working case is calculated and printed.

The Distribution Factor Data File is read, and the "base case" DC load flow solution is calculated followed by the processing of the designated contingency cases. Only single event contingencies are allowed. Changing the status of a three-winding transformer is considered a multiple event contingency; disconnecting a bus is often a multiple event contingency. Any multiple event contingencies are alarmed and ignored.

The calculation and printing process may be terminated by entering the AB interrupt control code.

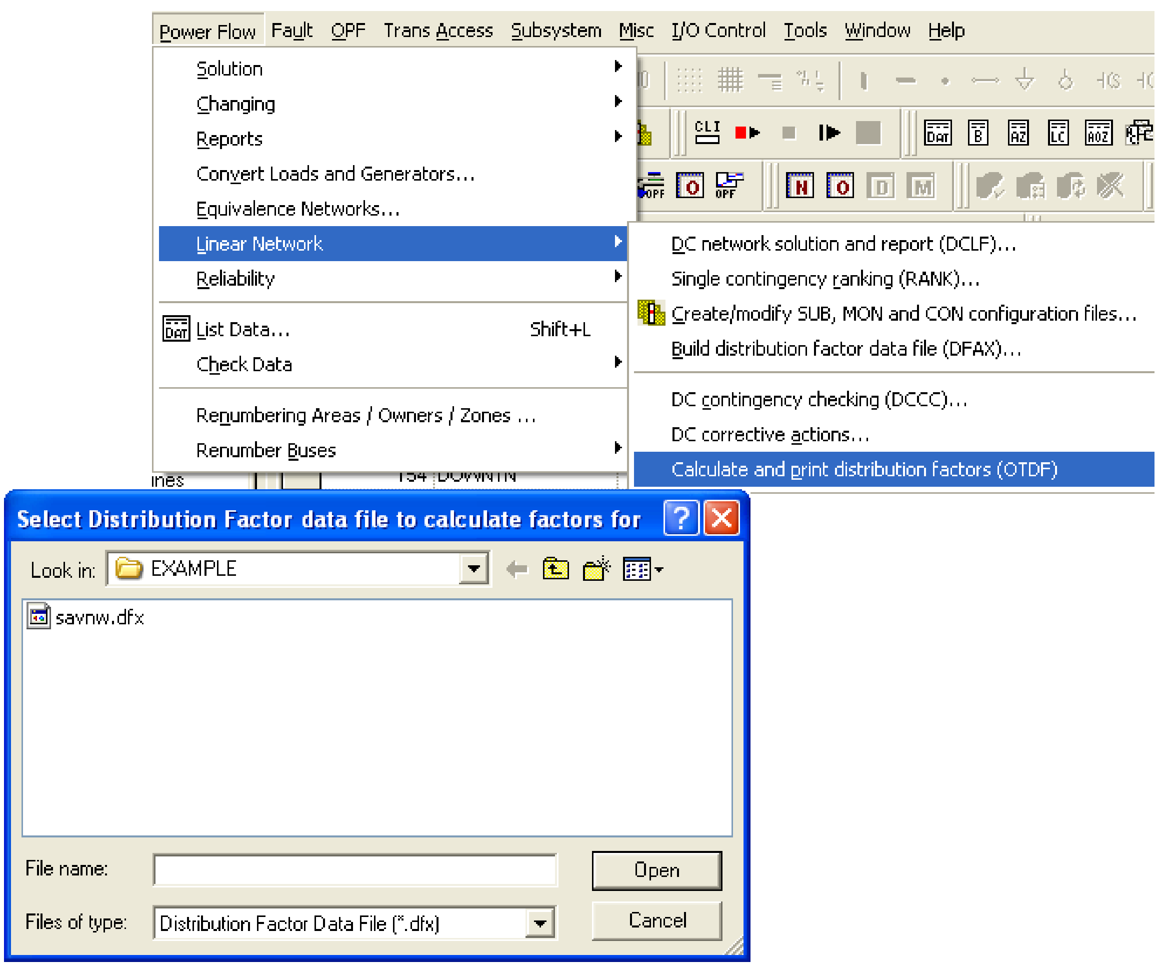


Figure 5-47. Launching the Distribution Factor Output Process

5.7.3 Viewing the Distribution Factor Report

Results are reported in tabular form, with six contingency cases per table. Each group of contingency cases contains a page summarizing the contingency cases performed. For each contingency, the contingency label and the data record defining the contingency are listed, along with the change in power of the affected element ("MW shift"). For line outage contingencies, the quantity shown is the base case AC active power flow at the metered end of the line in the "*from bus*" to "*to bus*" direction.

The summary page is followed by the distribution factor table. For each monitored element, this table lists its active power loading in the base case AC network solution; its loading in the base case DC analogy network solution, along with the distribution factor for each of the contingency cases reported.

Single branches are listed first, either in the order in which they were specified in the Monitored Element Data File or in ascending numerical or alphabetical order, according to the option selected during the building of the distribution factor file. These are followed by the interfaces in the order in which they were specified.

If a line outage contingency forms an island with no type three (swing) bus, a singular submatrix is formed. Any monitored branch which resides in the swingless island has dashes printed in place of its distribution factor. Similarly, any interface which includes such a member has its distribution factor printed as dashes.

Because the distribution factor output process uses the same linearized network model as is used in the DC analogy network solution method for the DC load flow, only *approximate* power flow solutions are obtained. The simplified branch flow equations inherently result in phase angles and branch flows that are *different* from the AC power flow solution, even when the starting point is a fully solved power flow case. Further, they lead to the assumption that bus voltage magnitudes and line losses remain constant as a branch is placed in- or out-of-service. It has the advantage, though, that it is substantially faster than a full AC power flow solution. Thus, its proper role is that of a screening tool to indicate which cases deserve further attention.

The process described here will detect the specification of duplicate single line outage contingencies and prints the distribution factor vector only for the first specification of such a contingency. Any contingency cases involving bus boundary contingency events or line closure contingency events are not checked for duplication.

It is recommended that the network be solved to an acceptable mismatch tolerance prior to launching this reporting process, otherwise, while the distribution factors would be valid, the base case line flows printed would not.

In using distribution factors, the flow directions of "P_{base}" and "ΔP" used in the above equation must be consistent with those assumed when the distribution factors were calculated.

A line outage distribution factor reflects the outage of the series reactance element only and not the removal of the branch's loss estimate and line shunt components. Further, neither line outage nor line closure distribution factors for a multi section line reflect the removal of any generation or load that may be present at its dummy buses.

A partial report is shown in Section 5-48 which is curtailed to show only three of the first six contingencies. Note that the reports shows the data files uses and lists each single contingency considered prior to listing the distribution factors for each of the lines and interfaces monitored, for each contingency. The files used are the *savnw.con*/*mon*/*sub* files from the PSS™E EXAMPLE directory.

As an example, it can be seen the if the nuclear plant at bus 101 is tripped, the SHIFT will be 750 MW, (the units output), and the line from Bus 201 to 151 will experience a power flow reduction of 310 MW (which is equal to 750 MW x 0.41339). The base case flow is shown as negative value of 564.8 MW at the Bus 201 end. This is the receiving end of the line. Consequently, the 750 MW shift coupled with a positive distribution factor will result in a reduce flow towards Bus 201. An AC solution shows the flow reduces to 255.9 MW. The calculation (-564.8 + 310) gives -254.8 MW (error less than 0.43%).

```
PSS/E PROGRAM APPLICATION GUIDE EXAMPLE                              PAGE 1
BASE CASE INCLUDING SEQUENCE DATA
                       *** OTDF CONTINGENCY SUMMARY ***

DISTRIBUTION FACTOR FILE:     C:\Program Files\PTI\PSSE30\EXAMPLE\dc-contingency.dfx
SUBSYSTEM DESCRIPTION FILE:   C:\Program Files\PTI\PSSE30\EXAMPLE\savnw.sub
MONITORED ELEMENT FILE:       C:\Program Files\PTI\PSSE30\EXAMPLE\savnw.mon
CONTINGENCY DESCRIPTION FILE: C:\Program Files\PTI\PSSE30\EXAMPLE\savnw.con

<-CONTINGENCY-> <-MW SHIFT-> <---------------------------------------------CONTINGENCY DESCRIPTION---------

  TRIP1NUCLEAR      750.0     REMOVE UNIT 1 FROM BUS 101 [NUC-A       21.600]

  ADDLARGELOAD      500.0     INCREASE BUS 154 [DOWNTN      230.00] LOAD BY 50 PERCENT

  LOSEWESTGEN       100.0     REMOVE UNIT 1 FROM BUS 3018 [CATDOG_G    13.800]

  LOSEWESTBIGT     -138.2     TRIP LINE FROM BUS 3004 [WEST        500.00] TO BUS 152 [MID500      500.00]

  LOSEEASTBIGT      564.8     TRIP LINE FROM BUS 151 [NUCPANT     500.00] TO BUS 201 [HYDRO       500.00]

  LOSEEASTLOAD    -1200.0     SET BUS 205 [SUB230      230.00] LOAD TO 0 MW

-------------------------------------------------------------------------------

     PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E   MON, FEB 16 2004   8:44
PSS/E PROGRAM APPLICATION GUIDE EXAMPLE                              PAGE 2
BASE CASE INCLUDING SEQUENCE DATA
                    *** OTDF DISTRIBUTION FACTOR TABLE ***

                                  CONTINGENCY LABEL--> BASE CASE MW TRIP1NUCLEAR ADDLARGELOAD  LOSEWESTGEN
                                   POWER SHIFT (MW)-->    AC     DC      750.0        500.0        100.0
<-------- FROM ---------> <---------- TO ---------->CKT <----> <----><----------> <----------> <---------->
   201 HYDRO       500.00    151 NUCPANT     500.00 1  -564.8 -558.7   0.41339     -0.07415     -0.04159
   202 EAST500     500.00    152 MID500      500.00 1   -42.6  -50.7  -0.14785     -0.21055     -0.11808
   203 EAST230     230.00    154 DOWNTN      230.00 1   122.4  122.4  -0.04237      0.07663      0.04298
   205 SUB230      230.00    154 DOWNTN      230.00 1   354.2  356.1  -0.22317      0.20808      0.11669
  3004 WEST        500.00    152 MID500      500.00 1  -138.2 -132.2   0.42977      0.34592      0.21485
  3006 UPTOWN      230.00    153 MID230      230.00 1   -78.7  -78.6   0.30190      0.25751      0.11931
  3008 CATDOG      230.00    154 DOWNTN      230.00 1    69.0   62.9   0.26833      0.39657     -0.33416
       INTERFACE WEST                                  -147.9 -147.9   1.00000      1.00000      0.00000
       INTERFACE EAST                                  -130.8 -130.8   0.00000      0.00000      0.00000
```

Figure 5-48. Example Report Listing Distribution Factors

5.8 Perform Probabilistic Reliability Assessment

The applications of probabilistic methods can provide points of view from transmission planners and operators, focusing on the frequency and duration of system problems, or from customers focusing on the impact of unreliability on load curtailments. Typically probabilistic reliability assessment is applied to:

- Calculation of reliability indices;
- Weak points analysis, i.e. components most affected by outages;
- Comparisons between different operating conditions, network structure as well as planning alternatives.;
- Analysis of effectiveness of corrective actions

The transition from deterministic contingency analysis to probabilistic assessment for system problems is an easy one. Probabilistic reliability analysis is provided via an additional post-processing function to calculate probabilistic indices for local and system problems with given outage statistics for each contingency. The reliability assessment package as shown in Figure 5-49 consists of a calculation part, which evaluates each contingency and models predefined tripping and corrective action sequences, and an analysis part, which conducts a detailed analysis on the basis of the evaluated contingency sequences.

The results are referred to as "probabilistic indices". They are composite probabilities of problems given in terms of frequency and duration indices, and determined by probabilities of transitions from 'success' operating conditions to 'failure' operating conditions. Generally, outage statistics are given in terms of frequencies and duration to reflect the probability that a transmission element will be forced out-of-service, and to calculate transition probabilities.

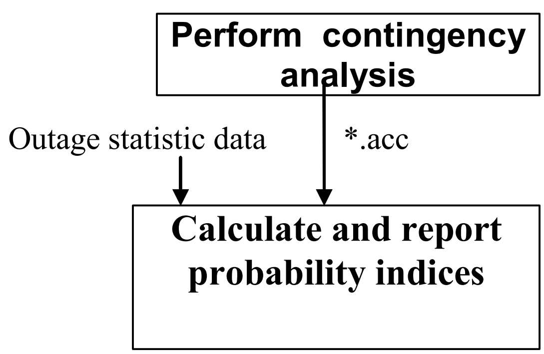


Figure 5-49. Process of Probabilistic Reliability Assessment

5.8.1 Setting-up for Probabilistic Reliability Assessment

To launch the probabilistic reliability assessment calculation, select the ***Power flow > Reliability > probabilistic reliability assessment*** option from menu entry. This will open the Probabilistic reliability assessment dialog (see Figure 5-50).

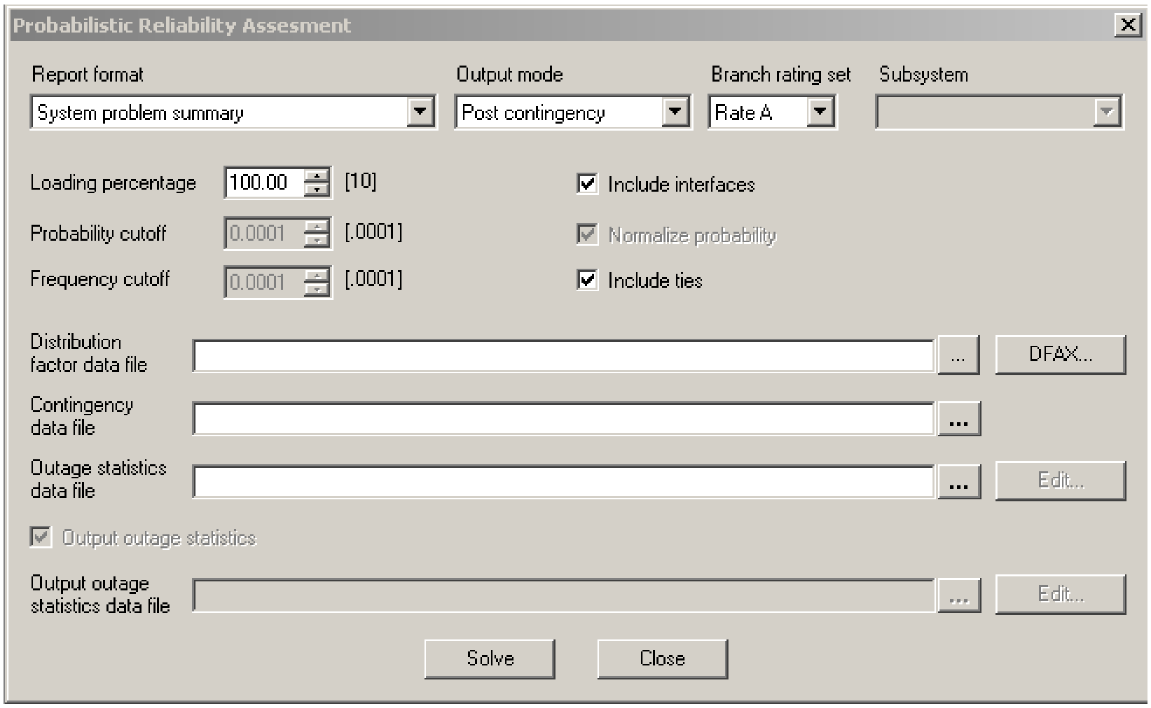


Figure 5-50. Probabilistic Reliability Assessment Dialog

5.8.1.1 Setting Probabilistic Reliability Assessment Options

Report format: the available options list allows the user to select from among the following reports:

- system problem summary
- system loss of load
- bus loss of load
- branch flow overloading
- bus voltage violations
- contingency summary for
- system problem probabilistic indices
- system load curtailment probabilistic indices
- bus load curtailment probabilistic indices
- branch flow overloading probabilistic indices
- bus voltage violation probabilistic indices
- contingency summary with probabilistic indices

When no probabilistic data is available or the studies are limited in deterministic reliability area, the users can produce the first six reports for deterministic reliability analysis, and each contingency will have identical statistic data.

Output mode: Probabilistic reliability analysis can be performed in one of three modes, they are post-contingency, post-tripping and post-corrective action, subject to the corresponding running mode is specified during contingency analysis.

- **post-contingency mode:** Select the post-contingency solutions as the states in the determination of system and component problems
- **post-tripping mode:** Select the solutions after tripping events as the states for calculations of probabilistic indices. If contingency analysis has been initiated without tripping simulation, post-tripping solution of a contingency is identical to its post-contingency solution.
- **post-corrective action mode:** Select the solutions after corrective action analysis for probabilistic reliability analysis. If contingency analysis has been initiated without corrective actions; post-corrective action solution of a contingency is identical to its post-contingency solution if tripping simulation enabled in contingency analysis, or to its post-contingency solution if tripping simulation disabled. Under this mode, a contingency and complete sequences following it are taken account into probabilistic reliability assessment.

Branch rating set and loading percentage: Define branch loading limits to be used. The limits are equal to the specified rating multiplied by percent of flow rating.

Subsystem: Define the study subsystem where the probability indices are calculated. There is a 'Entire system' subsystem set by the programs, when selected, analysis is performed within entire system. Probabilistic Indices can also be obtained for a specific subsystem predefined in Subsystem Description Data File (see Section 5.2.2.3). When a subsystem is designated, only monitored elements in the subsystem are checked against failure criteria to determine whether a contingency solution has problems. For bus voltages being checked, buses must belong to the subsystem; for line flows being checked, both of ends of a line must be in the subsystem.

Include interfaces: Interfaces do not belong to any subsystems. if the box of including interfaces is checked, then the impacts of interfaces on probability indices of the specified subsystem will be accumulated.

Include ties: Check the box to include the impacts of tie lines on probability indices of the specified subsystem.

Probability and frequency cutoffs: A contingency may be of low probability or frequency that the risk to the system is low, and evaluation is superfluous. Probability and frequency cutoffs are used to exclude contingencies from probabilistic reliability analysis whose probability and frequency are less than these threshold values.

5.8.1.2 Input Data Files

There are four main files used by probabilistic reliability assessment:

Distribution Factor Data File: It is a required file, and is the one used when performing contingency analysis (see Section 5.2.3.2).

Contingency Solution Output File: it is a required file, and is created with the current base case and above Distribution Factor Data File. It is recommended that the file been generated by multiple level contingency analysis function (see Section 5.3), When the file is generated by plain ACCC, analysis is limited to deterministic reliability assessment.

Outage Statistic Data File: It contains outage statistics of user specified contingencies and individual components (see Section 5.8.1.3), it is required when performing probabilistic reliability assessment.

Output Outage Statistic Data File: It is required when output statistic data file option is selected. The file is used to convert generic statistics to specific statistics for individual components, then the resulting file can be edited and modified for future use. It has the same format as Outage Statistic Data File.

5.8.1.3 Outage Statistic Data File

The Outage Statistic Data File is used to specify frequencies and durations for individual element outages and user specified contingencies. Outage statistics for individual elements, including non-transformer branches, transformers and machines, must be specified. They are also used to calculate outage statistics of multiple independent element contingencies whose statistics are not specified. Statistics for user specified outages can be defined in Outage Statistic Data File or in the Contingency Description Data File; when both files contain statistics for a user specified contingency, values are taken from Outage Statistic Data File. When no statistic data inputs for a multiple element contingency, the contingency is treated as a multiple independent element outage and its statistics are calculated on the basis of outage statistics of each single element within it. If a user specified contingency contains one or more FACTs device outages, closing events, or boundary condition change events, its statistics are zeros if not specified. Contingencies generated automatically by the multiple level contingency analysis are treated as independent multiple element contingencies, their outage statistics are thus calculated. The following examples illustrate how to specify outage statistics.

Example 1: There is no need to specify outage statistics of contingencies created by global command 'DOUBLE', each double branch contingency is treated as a multiple independent outage and its outage statistics are calculated from frequency and duration of two branches within it.

Example 2: Contingency A has branch B outage. Statistics for contingency A can be specified in the Outage Statistic Data File or in the Contingency Description Data File. Otherwise its statistics are equal to the statistics for the outage of branch B. If no invalid outage statistic data record is read for branch B in Outage Statistic Data File, outage statistics of contingency A are zero.

Example 3: Contingency A has branches B and C outages. Statistics for contingency A can be specified in the Outage Statistic Data File or in the Contingency Description Data File. If no statistics are specified for contingency A, its statistics are equal to frequency and duration of the multiple independent outaging of branches A and B. If no invalid outage statistic data records are read for either branch B or C, outage statistics of contingency A are zero.

Example 4: Contingency A has branch B and FACTs device C outages. Statistics for contingency A can be specified in the Outage Statistic Data File or in the Contingency Description Data File. If no statistics are specified for contingency A, its statistics are zeros.

There are two types of data records in the Outage Statistic Data File: one is generic outage statistic data and the other is specific outage data. The following data record defines a set of non-transformer branches that have the same outage statistics:

```
|LINES   |  |IN    |  |AREA  i          |  xm, bm, ft, dt, fmt, dmt
|BRANCHES|  |FROM  |  |ZONE  i          |
                      |OWNER i          |
                      |KV  r            |
                      |SYSTEM    label  |
                      |SUBSYSTEM label  |
```

Where: "xm" is branch reactance (ohm/mile), "bm" is branch charging susceptance (mh./mile), "ft" is outage frequency for terminal caused single circuit outages (occurrences/year), "dt" is repair time for terminal caused single circuit outages (hours), "fmt" is outage frequency for single circuit outages (occurrences/year-mile), and "dmt" is outage durations for single circuit outages (hours). In using "system" or "subsystem" keywords, the "label" must correspond to a subsystem label specified in a previously accessed Subsystem Description Data File. In using "in" keyword, both bus ends of a non-transformer branch must belong to a specified subsystem to be included. In using "From" keyword, either end of a non-transformer branch belongs to a specified subsystem to be included. The frequency and duration of a single line outage is calculated as:

F=len*fmt+ft
D=(mft*dmt*len+ft*dt)/F

Where len is the length of the branch. When length of the branch is not specified in working case, it is estimated by its reactance X: len=X/xm. For example, if the branch from bus i to bus j is 10 miles and statistics of the branch are ft=0.01, dt=10, fmt=0.02, dmt=20, then F and D of this single branch outage is:

```
F=(10*0.02+0.01)=0.21 (Occurrences/year)
D=(0.02*20*10+10*0.01)/0.21=19.5 (hour)
```

The following data record defines a set of transformers that have the same statistic data.

```
TRANSFORMERS |IN  |  |AREA i          |  ftr, dtr
             |FROM|  |ZONE i          |
                     |OWNER i         |
                     |KV  r           |
                     |SYSTEM    label |
                     |SUBSYSTEM label |
```

Where: ftr is outage frequency for transformer on site outages (occurrences/year), dtr is outage duration for transformer on site outages (hours). In using 'in' keyword, for a three winding transformer to be included, all of its in-service windings must be connected to subsystem buses. In using 'from' keyword, for a three winding transformer to be included, one of its in-serve winding must be connected to a subsystem bus.

The following data record defines generic statistic data for a set of machines.

```
|UNITS    | min_size, max_size, in |AREA i         |  fmt, dmt
|MACHINES |                        |ZONE i         |
                                   |OWNER i        |
                                   |KV r           |
                                   |SYSTEM    label|
                                   |SUBSYSTEM label|
```

Where: min_size and max_size are minimum and maximum size of generators in the set, the MBASE of generators are checked against the limits. Fmt is frequency of unit outage (occurrences/year), dmt is duration of unit outage (hours)

The following records define statistic data for a specific user specified contingency:

```
CONTINGENCY 'LABEL' f d
```

Where: ’f’ and ’d’ are frequency and duration of user specified outages respectively. As discussed before, statistics of user specified contingencies can be specified in .con file or in statistic data file in above format, if both files have statistics for the same user specified contingencies, the values in outage statistic data file will be applied.

The following data record defines statistic data for a non-transformer branch or two winding transformer.

```
|LINE   |  FROM BUS I TO BUS J |CKT    | CKTID F D
|BRANCH|                       |CIRCUIT|
```

Where: F is frequency of line outage (occurrences/year), D is duration of line outage (hours)

Similarly the following data record defines statistic data for a three-winding transformer:

```
|LINE   | FORM BUS I TO BUS J TO BUS K |CKT     | CKTID F D
|BRANCH|                               |CIRCUIT |
```

The following data record defines statistic data for a machine

```
|UNIT    | MACID AT BUS I P D
|MACHINE|
```

Where P is probability of machine outage, D is duration of machine outage.

When the multi-section reporting option is enabled, the frequency and probability of a multi section line is equal to the sum of frequencies and probabilities of all its members.

5.8.2 Performing Probabilistic Reliability Assessment

The procedure of performing probabilistic reliability analysis consists of three steps:

- Perform contingency analysis. The contingency screening results (.acc output files) are required to computed reliability indices.
- select the ***Power flow > Reliability > probabilistic reliability assessment*** option, after setting up options and specifying input files, perform reliability assessment. If deterministic reliability indices are computed, Outage Statistic data File is not required.
- Analyzing the results

5.8.3 Analyzing Probabilistic Assessment Results

For each monitored non-transformer branch, the percent loading is either the percent current or the percent MVA loading, according to the non-transformer branch percent loading units program option setting (see *PSS™E Program Operation Manual* Sections 3.11 and 6.10) specified when performing contingency analysis to create contingency output files. For monitored transformers, the percent loading is either the percent current or the percent MVA loading, according to the transformer percent loading units program option setting.

Three output modes are available when reporting results: post-contingency, post-tripping simulation, and post-corrective actions. Each output mode corresponds to one stage in the evaluation of a contingency. When performing multiple level contingency analysis (see Section 5.3), a running mode is specified according to selections of options of perform multiple contingency analysis, perform tripping simulations and perform corrective actions. The running mode determines how many stages in a contingency analysis are involved. e.g. if all three options are selected, a contingency and its following sequences: tripping events and corrective actions are simulated and then each contingency may have one load flow solution with respect to each option stored in the Contingency Analysis Output File, the solution after a contingency being imposed, the one after simulating tripping events triggered by the contingency, and the last one is after applying corrective actions that are specified to relieve violations in the second solution. In other words, a contingency analysis consists of three stages. By specifying output mode option, users have access to power flow solutions at each stage. If power flow solutions for an output mode do not exist in the output files, load flow solutions at previous stage will be used for the output mode. e.g., tripping simulation option is disabled prior to contingency analysis, therefore there are no post-tripping solutions in result files. If output mode is set as post-tripping, reliability results under post-tripping mode are identical to those under post-contingency mode.

When calculating probabilistic load curtailment indices, results may be quite different under different output mode, since load curtailments may be caused by contingencies, tripping events, generation dispatch and corrective actions.

In order to better understand the output, several examples are developed with the savnw.sav power flow case. The .sub, .mon, and .con files for contingency analysis and an example outage statistic data file .prb for reliability assessment are provided in the example directory. Contingency analysis is performed by multiple level contingency analysis function with simulations of tripping and corrective actions sequences.

5.8.3.1 System Probabilistic Index Summary

Figure 5-51 shows the system reliability indices summary report under post-contingency output mode. The frequency, average duration and probability for each type of problems are calculated. Impact indices of overloads and bus voltage violations with respect to voltage limits 'AREA 2 BUSES WITH VOLTAGE LESS THAN 0.940 (PU)' and 'AREA 2 BUSES WITH VOLTAGE GREATER THAN 1.060 (PU)' are also given. For each type of problems, the number of contingencies causing the problem, the worst violation as well as the contingency causing the worst violation are reported. The study subsystem is 'Entire system', study system total indices are reported at the end. The results under post-corrective actions mode are shown in Figure 5-52. The load curtailments are found in the post-corrective actions solutions, while voltage violations and overloads are alleviated by corrective actions. From a system point of view, reliability indices, frequency, average duration and probability, are almost the same under the two stages. Furthermore, the results under post-contingency mode provides reliability indices for system problems, and the results under post-corrective actions mode provide impacts of system problems on electricity customers.

<-- F A I L U R E C R I T E R I A -->	FREQ. (OC/Y)	DURATION (HOURS)	PROB. (H/Y)	IMPACT	NO. OF CONT.	WORST VIOL.	WORST
AREA 2 BUSES WITH VOLTAGE LESS THAN 0.940 (PU)	11.9176	10.0	119.1	1.53	13	0.875	17_17
ZONE 5 BUSES WITH VOLTAGE DROP BEYOND 0.060 (PU)	0.3369	10.0	3.4	0.18	2	0.084	14_20
AREA 2 BUSES WITH VOLTAGE GREATER THAN 1.060 (PU)	8.9740	10.0	89.6	0.27	10	1.106	17_17
OVERLOAD (%)	0.4113	9.1	3.7	3.68	6	211.905	14_20
NOT CONVERGE	0.0511	5.0	0.3		6		
ENTIRE SYSTEM TOTAL	12.3048	10.0	122.7		20		

Figure 5-51. System Reliability Indices Summary Under Post-Contingency Mode

<-- F A I L U R E C R I T E R I A -->	FREQ. (OC/Y)	DURATION (HOURS)	PROB. (H/Y)	IMPACT	NO. OF CONT.	WORST VIOL.
AREA 2 BUSES WITH VOLTAGE LESS THAN 0.940 (PU)	1.7018	9.9	16.8	0.29	5	
AREA 2 BUSES WITH VOLTAGE GREATER THAN 1.060 (PU)	1.7198	9.8	16.9	0.07	7	
ZONE 5 BUSES WITH VOLTAGE RISE BEYOND 0.055 (PU)	0.0043	5.0	0.0	0.00	2	
OVERLOAD (%)	0.3361	10.0	3.4	2.49	1	
LOSS OF LOAD (MW)	10.5780	10.0	105.8	14026.67	11	
NOT CONVERGE	0.0511	5.0	0.3		6	
ENTIRE SYSTEM TOTAL	12.3048	10.0	122.7		20	

Figure 5-52. System Reliability Indices Summary Under Post-Corrective Action Mode

5.8.3.2 System Loss of Load Report

The cumulative system loss of load summary provides detailed indices of loss of load for outages in which one or more buses are separated from the remainder of the network, or load shedding is performed at certain buses. The cumulative loss of load index represents the amount, frequency and energy of load lost as given in increments, and accumulated. Incremental step size is 10 MW; for load curtailment in excess of 1000 MW, it is grouped as one set.

Figure 5-53 shows system loss of load report under post-corrective actions mode. System load curtailments results are dependent on the options used in the multiple level contingency analysis. The sum of frequency, average duration and probability causing the corresponding amount of load curtailments are reported. The interrupted power I.P. and Expected Unserved Energy E.U.E. are provided. Note for E.U.E, the duration is one year (8760 hours). The study subsystem is specified as 'ENTIRE SYSTEM'

```
<--  LOAD CURTAILMENTS -->    FREQ.  DURATION  PROB.   I.P.     E.U.E  NO. OF   WORST CONT.
<-----      (MW)      ----->   (OC/Y)   (HOUR)  (H/Y)  (MW/Y)   (MWH/Y)  CONT.
 80.0 --  90.0                 3.6272    10.0   36.4   290.17   2911.76     2     OVRLOD  14
160.0 -- 170.0                 6.8657    10.0   68.9  1098.51  11029.22     2     OVRLOD  17
ENTIRE SYSTEM                 10.4928    10.0  105.3  1388.68  13940.98     4
```

Figure 5-53. System Load Curtailment Probabilistic Indices

5.8.3.3 Branch Flow Overloading Indices

Figure 5-54 shows the branch flow overload deterministic reliability results, where no outage statistics are required and all contingencies are assumed to have equal statistics. The following items are calculated: average overload and maximum loading of the overloaded circuit, the number of contingencies which result in overload of this circuit, and the contingency causing maximum overload.

Figure 5-55 shows overload probabilistic indices for each circuit and for the study subsystem. Specifically, the sum of frequency, average duration and probability of all contingencies resulting in a circuit overload are reported. The system overload impact index is equal to the sum of overload impact indices of all circuits. As we can see, the total number of contingencies that result in overload problem in Figure 5-54 is much bigger than that in Figure 5-55; this is because some contingencies with overload problems had zero statistics or statistics less than cutoff values.

```
<----- O V E R L O A D E D  L I N E S -----> AVG.OVRLOD  MAX.LOADING  NO. OF   WORST CONT.
<------F R O M ------> <------ T O ----->CKT       (%)          (%)      CONT.
 ENTIRE SYSTEM                                                             49
  203 EAST230   230.00   154 DOWNTN  230.00      92.55        244.85       11    5_9
  205 SUB230    230.00   154 DOWNTN  230.00       9.01        120.68        8    15_22
       INTERFACE WEST                           193.29        296.76       35    1_12
```

Figure 5-54. Branch Flow Overloading Probabilistic Indices

```
<------ O V E R L O A D E D  L I N E S ------->   FREQ.    DURATION   PROB.  IMPACT  MAX VIO.   NO. OF   WORST CONT.
<------ F R O M ------> <------ T O ---- -->CKT   (OC/Y)    (HOUR)    (H/Y)   (PU)     (%)      CONT.
 ENTIRE SYSTEM                                    0.4113       9.1      3.7   3.68      0.00        6
  203 EAST230  230.00    154 DOWNTN  230.00       0.3518       9.8      3.4   3.62    211.90        3   14_20
  205 SUB230   230.00    154 DOWNTN  230.00       0.0744       5.0      0.4   0.06    120.68        4   15_22
```

Figure 5-55. Branch Flow Overloading Probabilistic Indices

5.8.4 Viewing Graphical Output of Reliability Assessment Results

With a diagram view open, it is possible to show the reliability results on the diagram. To enable reliability diagram, it is necessary to perform a reliability assessment calculation by selecting ***Power Flow > Reliability > Reliability Assessment*** first to prepare reliability results, then select ***Diagram >Results >Reliability Analysis*** results as shown in Figure 5-56 to initiate the reliability diagram view.

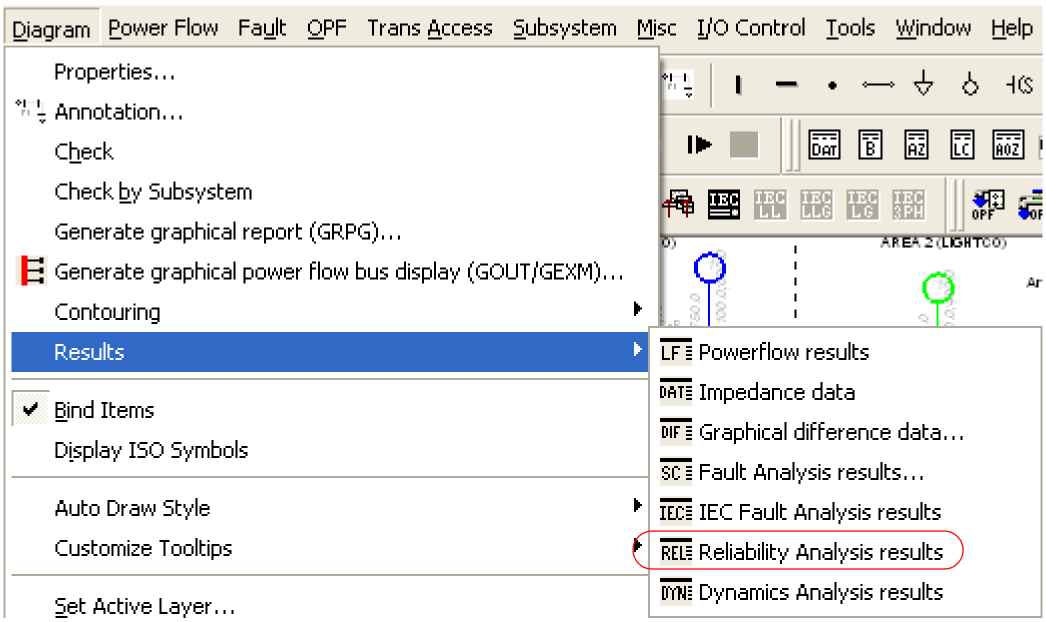


Figure 5-56. Select Graphical Report of Reliability Analysis

With reliability diagram annotation, one of three data categories can be displayed one a time on the reliability diagram; they are contingency solution, deterministic reliability results, and probabilistic reliability results. Under each data category, several data quantities are available. When a data category does not exist in the reliability assessment analysis, the corresponding option is disabled. Note to display bus voltage violations, a voltage limit record and either its lower or upper limit must be specified. On the diagram voltage violations for one monitored voltage limit record are shown at a time.

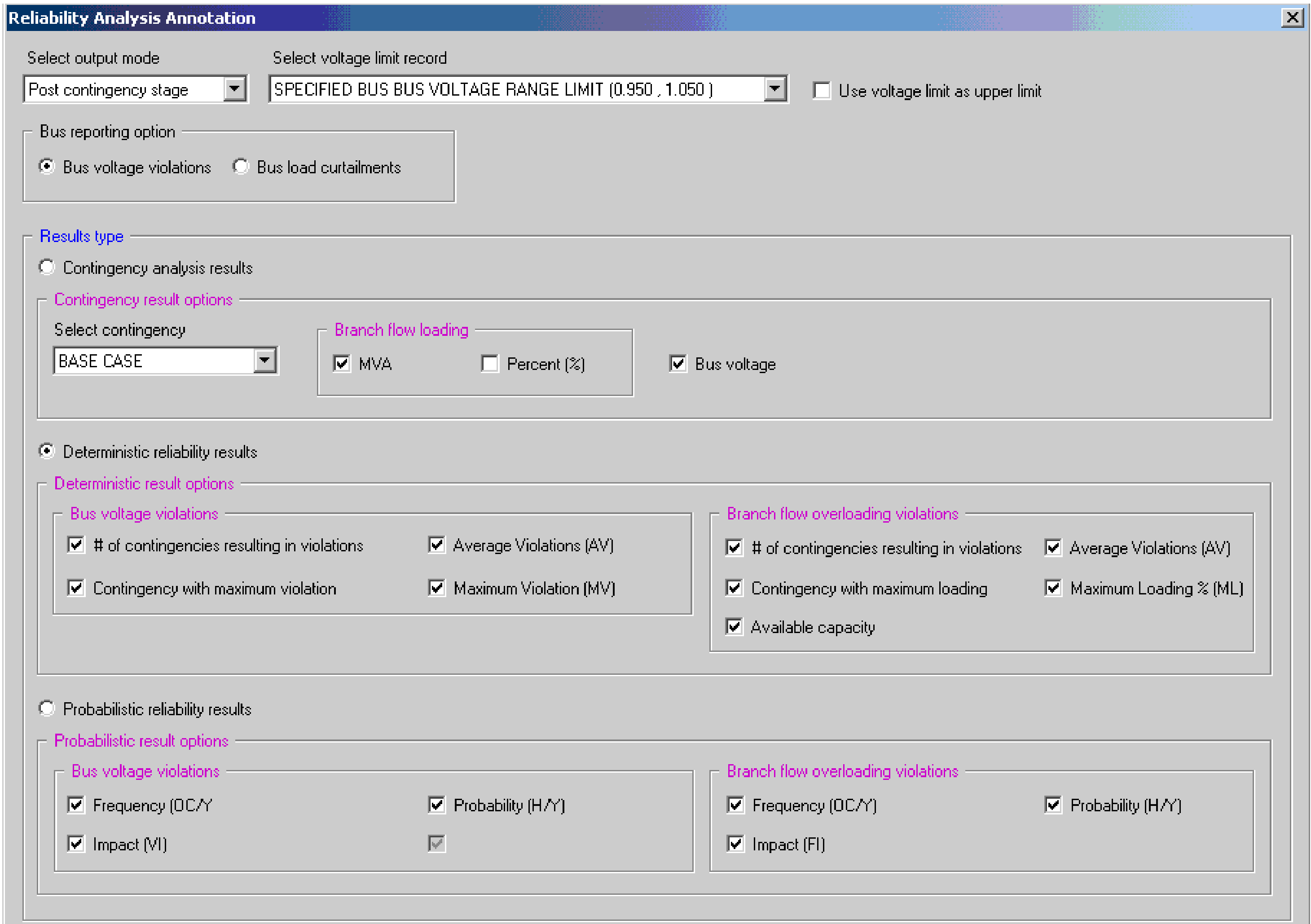


Figure 5-57. Reliability Diagram Annotation

Figure 5-58 shows branch flow overloads. Only monitored branches have values and are shown in the diagram. Overloaded circuits are branches from bus 154 to bus 203 and from bus 154 to bus 205. Note that the results shown in the diagram are calculated on the basis of contingency analysis results and specified options in reliability assessment. (e.g rating set, percent loading, cutoff values of frequency and probability). In this example, branch flow overloading probabilistic indices are on the basis of 100% of rating A. If users want to change the results in the diagram by changing the rating set, then a reliability assessment analysis has to be redone. Following are parameters whose change requires redoing reliability assessment to refresh the diagram view.

- Normalizing probability option
- Rating set
- Cutoff values of frequency and probability
- Outage statistic data
- Similarly, for voltage violations and load curtailment results, reliability assessment should be performed again if any of following parameters are changed:
- Normalizing probability option
- Cutoff values of frequency and probability
- Outage statistic data

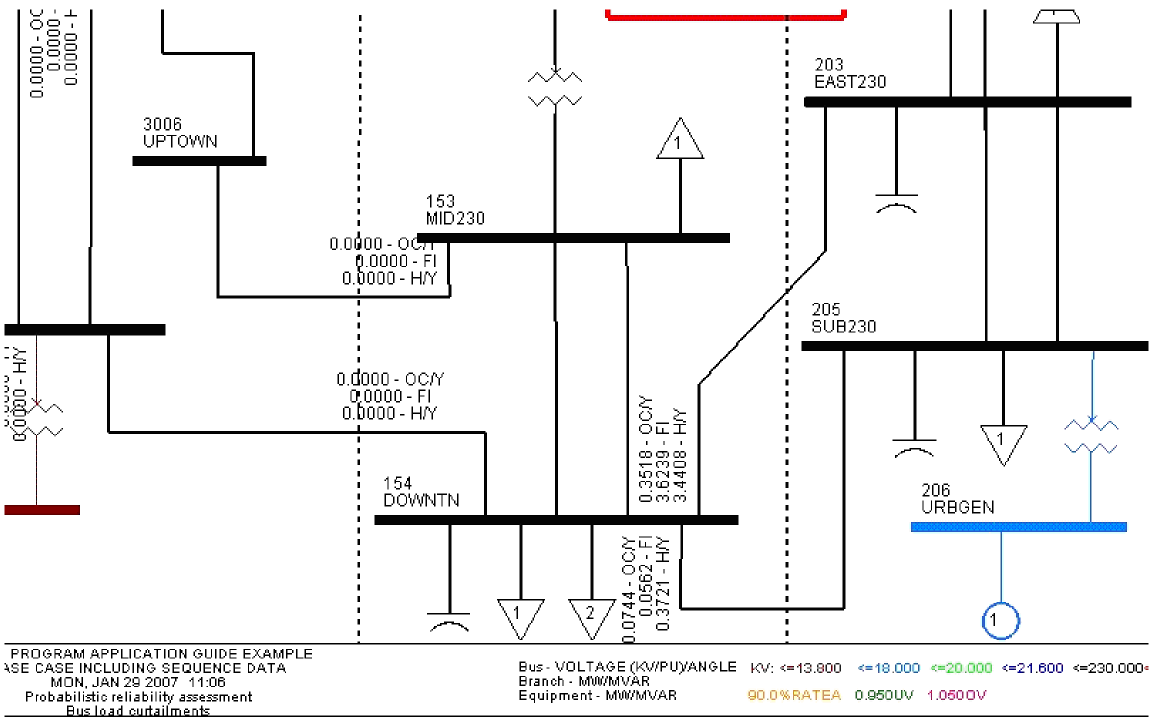


Figure 5-58. Branch Flow Overloading Probabilistic Reliability Results

Figure 5-59 shows bus load curtailment probabilistic results. Expected Unserved Energy at buses 153 and 154 are 5546.6 MWH/Y and 8480.8MWH/Y respectively.

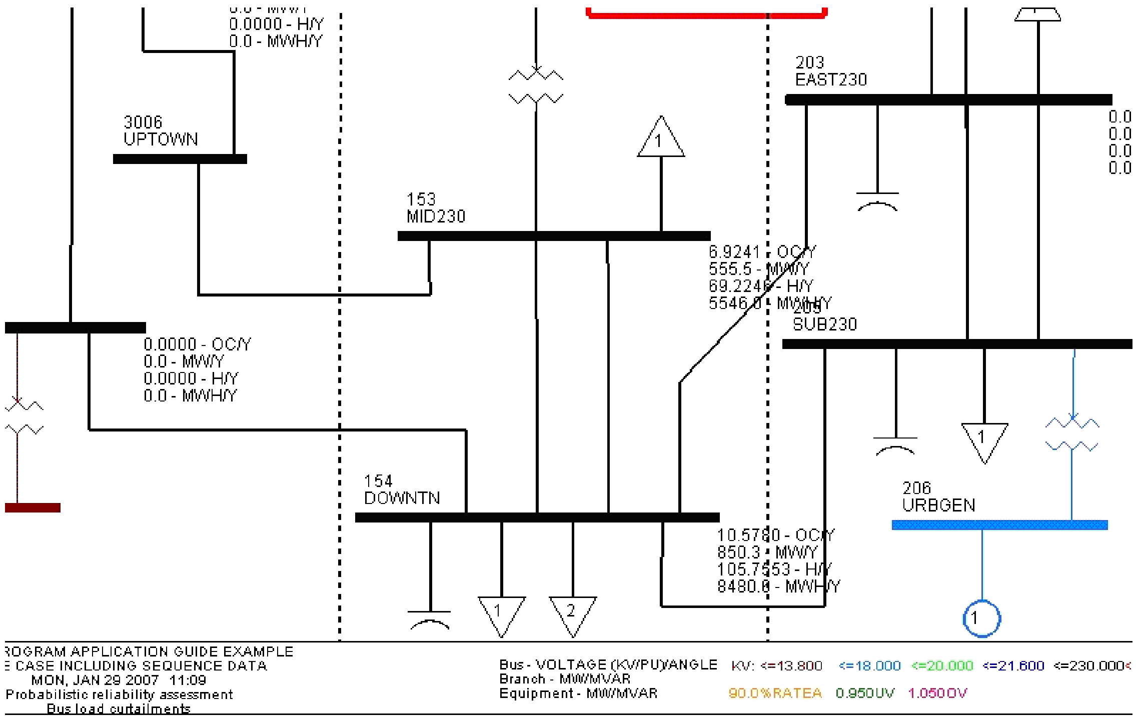


Figure 5-59. Bus Load Curtailment Results

5.8.5 Application Notes

The probabilistic reliability assessment requires a Contingency Solution Output File and a Distribution Factor Data File. It is required that the working case contain the same network representation (i.e., the same Saved Case) on which the contingency analysis calculation was based, and that the same Distribution Factor Data File that was used in contingency analysis be specified; otherwise, the probabilistic assessment function will terminate. When the base case remains unchanged, but the Monitored Element Data File and/or the Contingency Description Data File (and therefore the Distribution Factor Data File) are changed, the contingency analysis must be performed again before selecting the reliability assessment function. When adding new subsystems in the Subsystem Description Data File (see Section 5.2.2) without any changes in the Monitored Element Data File and the Contingency Description Data File, only the Distribution Factor Data File needs to be rebuilt, the reliability assessment can be performed with the newly created DFAX file without redoing contingency analysis.

The Contingency Solution Output File must be created by the multiple level contingency analysis function in PSS™E-31 or later to compute probabilistic reliability indices.

Contingencies with frequencies and probabilities of zeros have no impact on probability indices. When a user specified contingency does not have statistics specified, it is treated as a multiple independent outage and its statistic data is determined on the basis of the individual outages of which it consists. In case any one among them has unknown or zero frequency or duration, its statistics will be zeros. For contingencies consisting of closing outages, FACTs device outages and boundary condition changes (specified by keywords SET/CHANGE/INCREASE/ DECREASE /MOVE), since statistics of these outages can not be defined in outage statistic data file, statistics of such contingencies then can not be calculated must be given explicitly in outage statistics data file or in Contingency Description Data File, otherwise their statistics are zeros.

The multiple level contingency analysis function can simulate a contingency and event sequences following the contingency. For a contingency, there may be three solutions: post-contingency, post-tripping, and post-corrective actions solutions. It is important to properly select the stage at which the reliability assessment will be performed. When analysis is performed on solutions at the stage which does not exist in Contingency Analysis Output File, the solutions at previous stage will be used.

Reliability measures can be obtained as a function of the severity of problems without repeating the contingency analysis. For example, PSS™E can be used to compute failure indices for 10%, 20%, and more severe levels of overloads. Such computations can be done entirely within activity RELIND by adjusting the overload failure criterion and obtaining the reliability index output corresponding to each overload rating. The procedure to change voltage limits is to edit voltage monitor records in Monitored Element Data File (only the values of limits can be changed), and then recreate the Distribution Factor Data File. The reliability assessment can then be performed with newly created DFAX file without redoing contingency analysis. However, when other changes are made to Monitored Element Data File and Contingency Description Data File, the whole procedure must be gone through to perform probabilistic reliability assessment.

Reliability calculations can be obtained for different outage statistics without repeating the contingency analysis. This can be done by preparing two or more sets of outage statistics, and simply repeating the reliability calculations in RELIND after each set of outage data has been read into the program. This feature is useful for studying the impact of severe weather conditions and to determine the sensitivity of results to specific outages and to uncertainties in outage statistics.

If there are violations in the base case with specified failure criteria, all other states will result in system problems on the basis of the second assumption of the algorithm in PSS™E, and then the probability of system problems should be equal to 1; in other words, system problems always exist. In this case, PSS™E will neglect the probability of the base case, and add up probabilities of all outages with system problems to calculate probabilistic indices. However, the double counting problem is more prominent because it is most likely that tested outages have system problems if the base case has problems.

When probabilistic indices are used to compare the relative performance of the system under different operating conditions or with different system configurations, a contingency analysis must be performed for each initial system condition (base case). The different operating conditions can be simulated by means of load or dispatch adjustments, or by outages of specific network elements in the pre-disturbance condition. Different system configurations can be represented using appropriate system adjustment activities within PSS™E, such as CHNG activity.

Chapter 6

Transmission Transfer Limit Analysis

6.1 Overview: Transmission Transfer Limit Analysis

In the day-to-day operation of interconnected networks, bulk power transfer is often constrained by the ability of transmission elements to withstand thermal effects for various normal and contingency conditions. More recently this bulk power transfer is often constrained by stability limits. If sufficient stability analysis has been performed, megawatt limits can be assigned to elements or groups of elements. Since the transfers of power amount to thousands of megawatts for many hours in every single day, the determination of the ability of the transmission system to support the power transfers is a vital consideration to assure that the interconnected network is operated in a secure and reliable manner.

As shown in Section 5.5 a DC technique gives a quick solution. A common approach used to find a limiting solution is to start with a base case and calculate the sensitivity of flow in monitored elements or groups of elements to a variation in interchange. This technique is often referred to as a distribution factor technique. Once the sensitivity of elements is known, linear projections can be used to estimate permissible interchanges based on thermal limits. P_1, P_2 and P_3 represents linear line flow functions of the net import. The horizontal line rating intersects P_1 impassing a limit or net import restriction. Figure 6-1 graphically shows this technique.

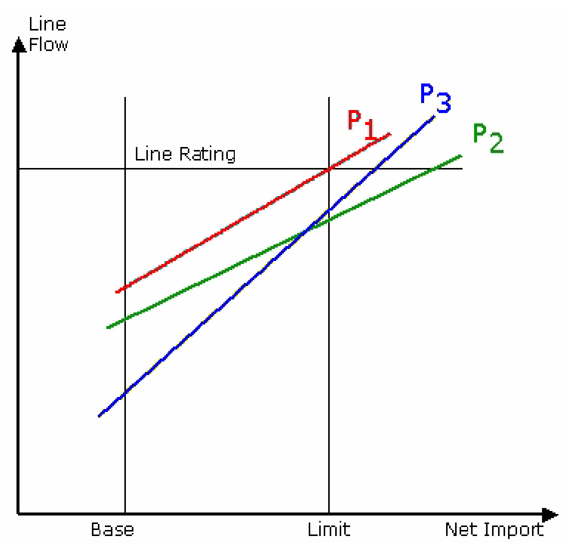


Figure 6-1. Linear Projection Technique Used in Transfer Limit Analysis

6.2 Calculating Transmission Transfer Limits

The transmission interchange limit calculation, estimates the import or export limits of a specified subsystem of the working case using a linearized network model. The user designates this "study system" in which the total power injection is to be increased (for export limits) or decreased (for import limits). An opposite change in the total power injection is made in a designated "opposing system." The calculation uses the sensitivity type analysis described in Section 6.1.

Power transfer distribution factors relating changes in branch and interface flows to a change in study system interchange are determined. The maximum study system export or import is then derived by extrapolation subject to the constraint that no monitored elements exceed a specified percentage of a selected rating. This process may be repeated for a designated set of user specified contingency cases.

The process will perform all the contingencies identified in the contingency description file processed when building the distribution factor file. Further, the process uses the monitored list file, which allows the lines to be monitored and interfaced. This feature is important because these interfaces often define stability limits.

Note that any two subsystems identified in the **.sub* file can be used for the transfer analysis. Further, however, it should be noted that the limits will be found based on **only** those elements (lines and interfaces) which are monitored, i.e., included in the **.mon* file.

In Figure 6-2 it can be seen that Areas A and C form the "study" and "opposing" system, respectively. Transfers take place directly and via Area B. It is important therefore to monitor lines within Area B or interfaces between Area B and the other two areas to ensure that the correct limits are identified.

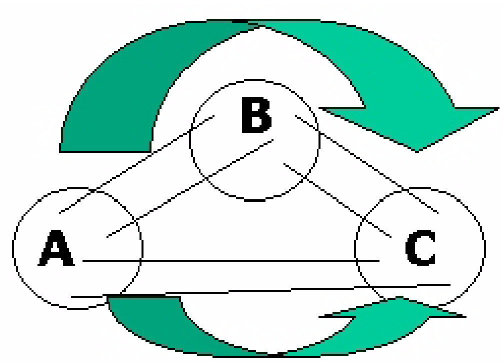


Figure 6-2. Study System (A) and Opposing System (C). Area B Potentially Limiting

The interchange limits calculation is launched using the ***Power Flow>Linear network>Transmission interchange limits calculation (TLTG)*** option. This option will display the Transmission interchange limits calculation dialog, shown in Figure 6-3 with default values.

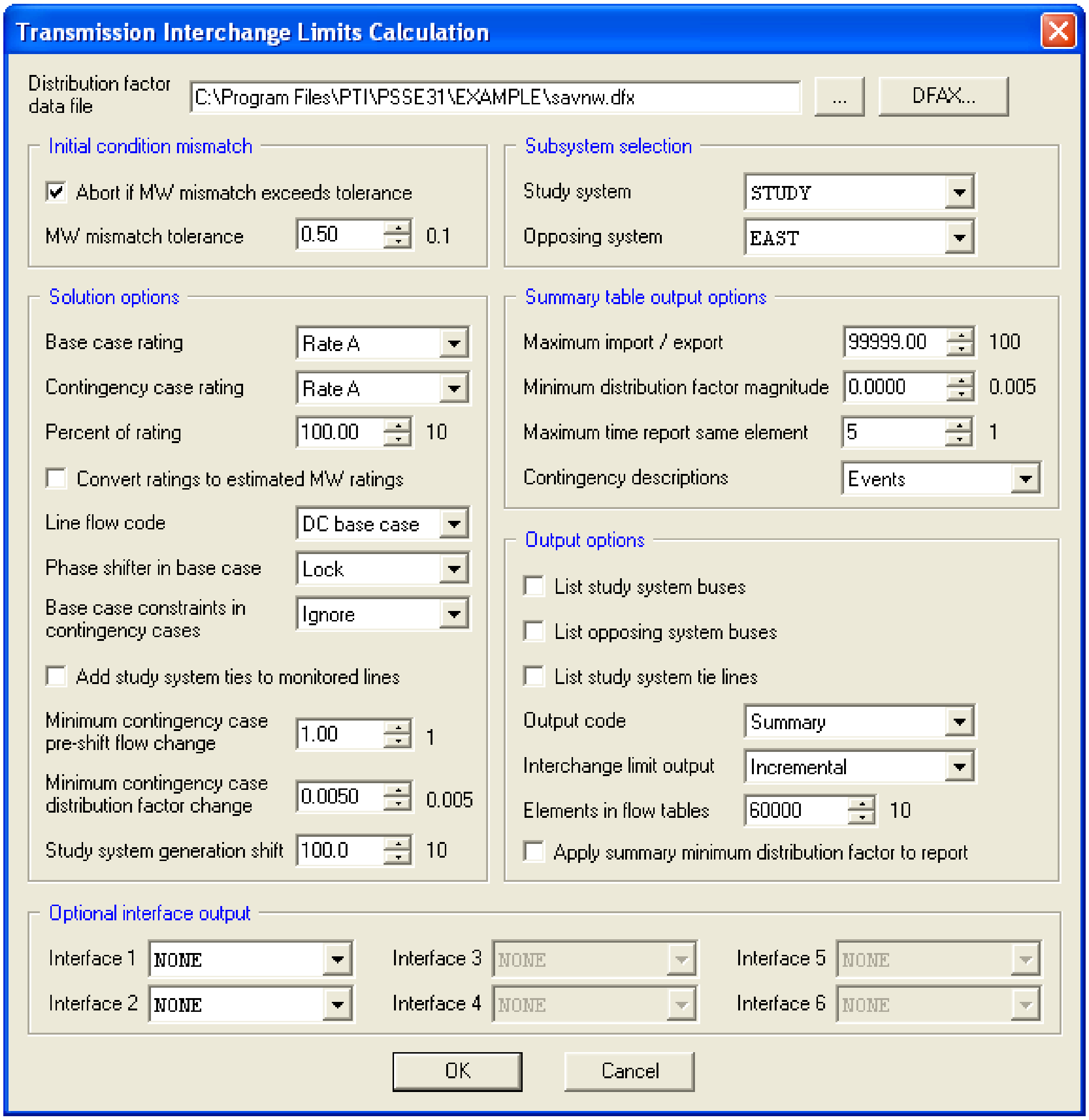


Figure 6-3. Two-Area Transmission Limit Calculation Dialog

The first requirement is for the user to identify the linearized network model Distribution Factor file built as described in Section 5.2.1.

6.2.1 Specifying Transfer Limit Analysis Options

The second requirement is to make the necessary and appropriate selections for the subsystems to be tested and the solution and output options discussed below.

6.2.1.1 Setting the Transfer Limit Initial Condition Mismatch

If the largest initial active power mismatch exceeds the specified MW mismatch tolerance, the user is given the opportunity to terminate the calculation process. Note that the user can modify the tolerance in steps of 0.1.

6.2.1.2 Setting the Transfer Limit Solution Options

Base and contingency case rating: This set, and the percentage thereof, define the line loading limits used in determining overloads. The default rating set is the one established as the default rating set program options.

Convert ratings code: If the convert ratings code box is checked, ratings of monitored branches are converted to estimated MW ratings based upon each monitored line’s Mvar loading at the metered end in the base case AC solution.

Line flow code: This defines the base flow to be used in deriving branch flow estimates. The user can select the AC or the DC base case conditions.

Phase shifter in base case: This can be set to "Lock" or "Regulate" If set to regulate any regulating phase shifter whose adjustment control mode COD n is set to +3 holds its base case flow in all base case shift solutions. Otherwise, all phase shift angles are locked at their base case settings.

Base case constraints in contingency cases: The user can choose to recognize, "include", both the base case and contingency case flow constraints in calculating the pre-contingency interchange limits for each contingency case. Otherwise, "ignore" the base case constraints and consider only the contingency case loadings (see Section 6.2.3.3).

Add study system ties to monitored lines: The user can check this box to have study system tie lines included as monitored elements.

Minimum contingency case pre-shift flow change and **Minimum contingency case distribution factor change:** These provides a means of ignoring those monitored elements which, in a contingency case, are not significantly affected by the contingency. If the magnitude change in pre-shift flow from the base case value is less than this minimum flow change threshold and the magnitude change in the power transfer distribution factor from the base case value is less than the distribution factor change threshold, the monitored element is ignored.

Study system generation shift: This is the value of change in total generation in the study system. If the value entered is positive, export limits are to be determined; otherwise, import limits are to be calculated. The "generation shift" is apportioned among generator and load buses in the "study" and "opposing" systems in proportion to the participation factors specified in the "participation block structure" of the Subsystem Description Data file. Alternatively the "shift" is shared among generator buses in proportion to their plant MBASEs (i.e., the sum of the MBASEs of in-service machines with positive active power output at the bus). In this case, there must be at least one in-service machine with a positive MBASE in the subsystem.

The setting of participation factors is described in Section 5.2.2.3.

6.2.1.3 Setting the Transfer Limit Subsystem Selection

Study System: This is the network subsystem in which the total power injection is to be increased (for export limits) or decreased (for import limits). The choices available are those listed in the *.sub type file.

Opposing System: This is the network subsystem in which an opposite change, from that in the "Study" system, is made.

6.2.1.4 Setting the Transfer Limit Summary Table Output Options

Maximum import/export: This is the first of three "cutoff" thresholds for including monitored elements in the summary report.

Minimum distribution factor: This is the second of three "cutoff" thresholds for including monitored elements in the summary report. For small distribution factors, with levels below this threshold, there will be no reporting for the related element.

Maximum time report samet: This is the third of three "cutoff" thresholds for including monitored elements in the summary report. This will limit the number of times an element is reported in the same report.

Contingency descriptions: The user can select the manner in which contingency cases are identified in the summary report. The options are to use the 12-character contingency case label or the events comprising the contingency case or both the contingency label and the contingency events description.

6.2.1.5 Setting the Transfer Limit General Output Options

List study system buses: The user can check this box to provide for a listing of "study" system buses in the output report.

List opposing system buses: The user can check this box to provide for a listing of "opposing" system buses, in the output report.

List study system tie lines: The user can check this box to provide for a listing of study system tie lines in the output report.

Output code: This provides for a selection of either a "Summary" report of all cases considered or a "Full" report which will comprise a monitored element flow table for each case considered followed by a summary report of all cases considered

Interchange limit output: This output code provides for selection of either "incremental transfer capability" or "total transfer capability" as the desired output quantity.

Elements in flow tables: This is the number of elements to include in flow tables allowing the user to limit the flow table for each case reported to the "n" most restrictive monitored elements.

Apply summary minimum distribution factor to report: If checked, this will cause the limitation of reported output to only those elements whose distribution factors are greater than the "Minimum distribution factor magnitude" referred to in Section 6.2.1.4.

6.2.1.6 Setting Transfer Limit Optional Interface Output

The user is given the option of having the summary report repeated with interface transfer limits and distribution factors for a selected interface listed rather than study system transfer limits and distribution factors. The "interface" distribution factors listed on the "interface" summary report are measures of the changes in monitored element flows to a change in base case interface flow.

6.2.2 Performing Transfer Limit Analysis

When the user has identified the information required in the dialog of Figure 6-3, clicking ***OK*** will complete the process during which the program will:

- Check for and warn against unacceptable conditions.
- Perform the required calculations.
- Summarize the test conditions.
- Output the result to a report to the Output Bar or to a file selected by the user.

The program will check that generators are not "converted" and that each non type four bus is connected back to a type three (swing) bus through the in-service AC network. If any violations are detected, an appropriate message is printed and the process is terminated.

The program will check to ensure that there are no buses which are members of both of the selected subsystems. If any such buses are found, they are alarmed and the process is terminated.

The largest active power mismatch corresponding to the present AC solution voltage vector in the working case is calculated and printed.

If the convert ratings option was enabled, ratings from the selected rating set(s) of those monitored branches having nonzero rating(s) are modified. For each such branch, the Mvar loading is calculated and MW rating(s) are determined under the assumption that the Mvar loading is unchanged under power transfer and contingency conditions.

Using the incremental form of the DC power flow equation (see Section 5.5) and the power shift vector, phase angle changes are calculated, followed by incremental line flows for all monitored lines and interfaces. These are transformed into a vector of base case power transfer distribution factors, and the interchange limit is determined by extrapolation such that all monitored elements satisfy their rating constraints.

The "base case" DC network solution is calculated and the solution summarized as in the following example:

```
STUDY SYSTEM GENERATION IS        1500.0 MW
OPPOSING SYSTEM GENERATION IS     1748.9 MW
STUDY SYSTEM NET INTERCHANGE IS    282.8 MW
```

The "base case" solution is then reported, followed by processing of the designated contingency cases with contingency case flow estimates calculated using the methodology given in Section 5.5.2.5. Prior to terminating, an ordered summary report from among all the cases calculated is tabulated.

In listing study system buses, opposing system buses, and study system tie lines, the tabulation may be terminated by entering the AB interrupt control code. In this case, the interrupt is cleared and processing continues. Once the interchange limit calculations have started, the process may be terminated by entering the AB interrupt control code.

6.2.3 Analyzing Transfer Limit Results

The results of running an example case will be presented to assist in understanding the Report format. The example will be based on the files available in the PSS™E EXAMPLE directory; those being:

- *savnw.sav* – the power flow case
- *savnw.sub* – subsystem definitions
- *savnw.con* – contingency description file
- *savnw.mon* – the monitored element file

To further help clarify the power flow condition, Figure 6-4 shows the inter-area flows and the subsystem definition file, savnw.sub. There it can be seen that the subsystem named "STUDY" comprises Area 1 of the power flow case and the subsystem named "EAST" comprises Area 2. Further, Area 1 has a net export of 131 MW + 148 MW; a total of 279 MW

```
SUBSYSTEM STUDY
AREA 1
END
SUBSYSTEM EAST
AREA 2
END
SUBSYSTEM WEST
AREA 5
END
END
```

savnw.sub file

```
            TO AREA:     1      2      5
FROM AREA        *-------------------
         1       *            131    148
FLAPCO           *           -442   -243
                 *-------------------
         2       *  -131
LIGHTCO          *   442
                 *-------------------
         5       *  -148
WORLD            *   243
                 *-------------------
```

Inter-Area Flows in Base Case

Figure 6-4. Subsystem file and Power Flow Condition for Transfer Analysis

6.2.3.1 Viewing the Transfer Limit Analysis Base Case Conditions Report

Base case conditions are reported first. The report lists the study system generation, the opposing system generation, and the study system net interchange corresponding to the network solution before and after applying the generation shift. This is followed by a tabulation of the pre-shift and post-shift generation at those study system and opposing system buses participating in the generation shift. Loadings on monitored elements are then reported, sorted such that the most restrictive elements are listed first. Either incremental or total pre-contingency transfer limits, as appropriate, are listed.

Flow estimates are listed for each of three interchange schedules: with the original generation profile, with the specified generation shift, and at the generation shift corresponding to the transfer level limit required for the most restrictive monitored element (i.e., the one listed first). Any flow at or above the selected percentage of the appropriate rating is followed by an asterisk ("*"). The power transfer distribution factor relating the change in flow on the monitored element to a change in study system net interchange is also tabulated, along with the rating of the monitored element; for branches, this *is not* the percentage of the rating used in determining the interchange limit, but either the value of rating entered as raw data and the data editor windows, or, if the convert ratings option was selected at the start of this transfer analysis calculation, the estimated MW ratings.

Figure 6-5 shows the report obtained using the example files (*savnw.**) from which was built the *dc-contingency.dfx* distribution factor file. The file names are listed in the report as shown.

The pre- and post-shift generation levels and the net interchange are listed for the "Study" and "Opposing" systems. In this example, a shift of 100 MW is assumed. The generators which participate in both systems to make the ± 100 MW shift are listed. They are the nuclear plants at buses 101 and 102 in the "Study" system and the generators at buses 206 and 211 in the "Opposing" system.

```
      *** TLTG EXPORT LIMIT OUTPUT FOR BASE CASE                ***

DISTRIBUTION FACTOR FILE:     C:\Program Files\PTI\PSSE30\EXAMPLE\dc-contingency.dfx
SUBSYSTEM DESCRIPTION FILE:   C:\Program Files\PTI\PSSE30\EXAMPLE\savnw.sub
MONITORED ELEMENT FILE:       C:\Program Files\PTI\PSSE30\EXAMPLE\savnw.mon
CONTINGENCY DESCRIPTION FILE: C:\Program Files\PTI\PSSE30\EXAMPLE\savnw.con

                                PRE-SHIFT    DELTA  POST-SHIFT
STUDY SYSTEM MW GENERATION:       1500.0     100.0    1600.0
OPPOSING SYSTEM MW GENERATION:    1400.0    -100.0    1300.0
STUDY SYSTEM NET INTERCHANGE:      278.7     100.0     378.7

<---------------- STUDY SYSTEM -----------------> <--------------- OPPOSING SYSTEM --------------->
                         <---- GENERATOR MW ---->                                   <---- GENERATOR MW ---->
  BUS# X-- NAME --X BASKV     BASE   SHIFT  CHANGE   BUS# X-- NAME --X BASKV     BASE   SHIFT  CHANGE
   101 NUC-A        21.600   750.0   800.0    50.0    206 URBGEN       18.000   800.0   742.0   -58.0
   102 NUC-B        21.600   750.0   800.0    50.0    211 HYDRO_G      20.000   600.0   558.0   -42.0

LOADINGS AT OR ABOVE 100.0 %                                    <------------- BASE CASE ------------->
OF RATING ARE MARKED WITH '*'                             TOTAL          PRE-    POST-   LIMIT
                                                          TRANS RATING  SHIFT   SHIFT    CASE     DISTR.
<------- F R O M -------> <--------- T O ---------> CKT   CAPAB   A       MW      MW       MW     FACTOR
       INTERFACE EAST                                     497.9   350  -130.8  -230.8  -350.0  -1.00000
   201 HYDRO        500.00    151 NUCPANT      500.00  1  1330.4  1200  -558.7  -619.7  -692.4  -0.60981
   205 SUB230       230.00    154 DOWNTN       230.00  1  3370.1   600   356.1   325.2   288.3  -0.30929
  3008 CATDOG       230.00    154 DOWNTN       230.00  1  4734.9   400    62.9    70.4    79.4   0.07566
   202 EAST500      500.00    152 MID500       500.00  1  9483.9  1200   -50.7   -63.2   -78.1  -0.12486
```

Figure 6-5. Base Case Results for Two Area Transfer Limit Calculation

For the base case condition, it can be seen that the element which is most restrictive for transfers is the "INTERFACE EAST". This interface comprises 4 branches which tie the Study and Opposing systems. Consequently, all transfer takes place across these branches. This is why the Distribution factor has a value of 1.0. This means that 100% of any generation shift will flow on this interface.

The flow in the PRE-SHIFT condition is 130.8 MW on the interface. If a 100 MW shift is imposed, the POST-SHIFT flow on the interface will increase by 100 MW to 230 MW as shown. The shift can be increased until the flow on the interface is 350 MW, its thermal limit. this is the "LIMIT" case.

It can be seen that the flow on the limiting interface can increase by 220 MW (350-131) before reaching its thermal limit. Consequently, the "TOTAL" transfer limit will be the pre-shift flow of 278.7 MW plus the possible 220 MW increase. As the report shows, therefore, the transfer limit for the base case condition is 497.9 MW and is caused by the thermal limit on the "INTERFACE EAST".

As the listing shows, the next most restrictive element is the branch from Bus 201 to Bus 151. The results are showing that, if the "INTERFACE EAST" thermal limit were removed (by upgrading or other means), this branch would create the limit; in this case it is 1,330 MW.

How is the 1,330 MW Calculated?

Branch 201 to 151 has a thermal limit of 1,200 MW. The pre-shift flow on the branch is only 558.7 MW. Consequently, the branch has a capacity for an additional flow of 641.3 MW (1200 - 558.3). To increase the flow on this branch by 641.3 the generation shift would have to be 1,051.6 MW because the distribution factor for this branch is 0.60981, i.e. only about 60% of the generation shift will flow on this branch. Given a generation shift of 1,051 MW, on top of the pre-shift inter-area flow of 278.7 MW, the total transfer limit is 1,330 MW.

Similar calculations can be done to check the other, less restrictive limits shown in the report listing. Note that the limit imposed by the branch from Bus 205 to Bus 154 is marginally more complicated to check because the generation shift actually decreases flow on this branch. It is necessary to consider the flow direction on the branches (*to* and *from*) and the sign of the distribution factors.

Three-Winding Transformers

For monitored three-winding transformer windings, flow estimates are calculated at the winding bus end as power flowing into the transformer. For other monitored branches, flow estimates are calculated at the metered end in the "*from bus*" to "*to bus*" direction. The flow across an interface is taken as the sum of the flows of its members. For three-winding transformer windings, the flow is calculated at the winding bus as power flowing into the transformer. For other members, the flow is calculated at its metered end in the "*from bus*" (the first bus specified in entering the branch) to "*to bus*" direction.

6.2.3.2 Viewing Transfer Limit Analysis Flows For Contingency Cases

When reporting flows for contingency cases, the events comprising the contingency are listed followed by flows on the monitored elements sorted as described above. The flow table includes both the contingency case flows in the same form as the base case report described above, as well as the base case flows at the transfer level required for the most restrictive monitored element. Note that if the user so selects (see Section 6.2.1.2), only the contingency case constraints are considered in calculating the transfer limit; in this case, base case flows at the transfer limit may be shown as overloaded since the corresponding constraints are ignored in the transfer limit calculation.

An curtailed example of the report listing for the contingency cases is shown in Figure 6-6.

A summary report tabulates the number of system condition solutions attempted and the number for which there exists no interchange schedule at which the rating constraint can be satisfied for all monitored elements.

This is followed by a tabulation of monitored elements for all system conditions which were calculated, in order of increasing incremental or total transfer capability, as appropriate. The limiting element is listed along with its power transfer distribution factor, its pre-shift contingency case flow, its rating, and a description of the system condition.

Only those monitored elements satisfying the "cutoff" threshold solution parameters set by the user are included in the summary. Once an element has been listed the maximum number of times "n", its "nth" occurrence includes an asterisk ("*") before its description, and further reporting of the element is suppressed.

This summary report is reprinted for each selected interface with interface transfer limits and distribution factors rather than study system interchange limits and distribution factors tabulated. All distribution factors on the interface transfer limits summary report describe changes in monitored element flow relative to a change in interface flow. The branches which form the interface are listed on the first page of an interface's transfer limit summary report.

The final page of the summary report lists those elements which were reported "n" times, sorted by the number of times they would have been reported.

If a line outage contingency forms an island with no type three (swing) bus, a singular submatrix is formed. Any monitored branch which resides in the swingless island, as well as any interface which includes such a branch as a member, has dashes printed where its contingency case results would normally be printed.

How is the negative transfer limit obtained?

In Figure 6-6 it can be seen that the most severe contingency identifies a negative transfer limit of -56.5 MW. The contingency is loss of the two units at Buses 101 and 102. In the pre-shift condition, in which there is a transfer of 278 MW, the branch from Bus 3008 to Bus 154 has a loading of 465 MW but has a thermal capacity of only 440 MW. This loading has to be reduced by 25.4 MW to keep the branch within its capacity.

The distribution factor is 0.07566. Consequently the transfer has to be reduced by 335 MW (that is 25.4 MW divided by 0.07566) from its current level of 278.7 MW. This, rounding off, is 57 MW less than the base case (pre-shift) transfer.

6.2.3.3 Application Notes for Transfer Limit Analysis

Since this transfer limit calculation process uses the linearized network model, note should be taken of the approximate nature of the solution. The proper role of this analysis, therefore, should be to focus attention on those system conditions which deserve more detailed study.

The process detects the specification of duplicate single and double line outage contingencies and calculates the contingency case solution only for the first specification of such a contingency. Any contingency cases involving bus boundary contingency events, line closure contingency events, or more than two line outage contingency events are not checked for duplication.

The values shown as monitored element flows are set as described in Section 5.5.2.5. The user selects the base flow value to be used by setting the line flow code solution parameter at the start of the process.

```
CONTINGENCY TRIP2NUCLEAR:
    REMOVE UNIT 1 FROM BUS 101 [NUC-A       21.600]
    REMOVE UNIT 1 FROM BUS 102 [NUC-B       21.600]

INSOLUBLE CASE: OVERLOAD IN PRE-SHIFT SOLUTION INSENSITIVE TO INTERCHANGE LEVEL

LOADINGS AT OR ABOVE 100.0 %                                <--------- CONTINGENCY CASE ----------> <-BASE CASE->
OF RATING ARE MARKED WITH '*'                         TOTAL          PRE-    POST-   LIMIT                      LIMIT
                                                      TRANS  RATING  SHIFT   SHIFT   CASE     DISTR.  RATING    CASE
<------- F R O M -------> <--------- T O ---------> CKT  CAPAB   B       MW      MW      MW     FACTOR    A        MW
  3008 CATDOG       230.00    154 DOWNTN       230.00  1    -56.5   440   465.4*  472.9*  440.0*  0.07566   400     37.5
   205 SUB230       230.00    154 DOWNTN       230.00  1   2481.7   660    21.4     -9.5   125.1  -0.30929   600    459.8
   201 HYDRO        500.00    151 NUCPANT      500.00  1   2511.2  1300    61.4      0.4   265.8  -0.60981  1200   -354.3
   203 EAST230      230.00    154 DOWNTN       230.00  1   4626.3   250    58.9     63.3    44.2   0.04396   200    107.7
   202 EAST500      500.00    152 MID500       500.00  1   8508.6  1300  -272.5   -284.9  -230.6  -0.12486  1200     -8.8
  3004 WEST         500.00    152 MID500       500.00  1  >99999.  NONE   512.5    507.5   529.0  -0.04947  NONE   -115.6
  3006 UPTOWN       230.00    153 MID230       230.00  1  >99999.  NONE   374.3    371.6   383.0  -0.02619  NONE    -69.8
       INTERFACE WEST                                     >99999.   200  1352.1* 1352.1* 1352.1*  0.00000   200   -147.9
```

Typical output for Contingency case. Most restrictive transfer limit is negative due to overload prior to shift during contingency.

```
SOLUTION OF  11 SYSTEM CONDITIONS ATTEMPTED      4 INSOLUBLE SYSTEM CONDITIONS

 TOTAL                                                         PRE- RATING
 TRANS <----------------- LIMITING ELEMENT ----------------->  DISTR.  SHIFT BAS/CNT
 CAPAB <------- F R O M -------> <--------- T O --------->CKT  FACTOR    MW     A/B  <------------------ CONTINGENCY DESCRIPTION ------------------->
 -56.5   3008 CATDOG       230.00    154 DOWNTN       230.00 1  0.07566  465.4  440.0 REMOVE UNIT 1 FROM BUS 101 [NUC-A        21.600]
                                                                                      REMOVE UNIT 1 FROM BUS 102 [NUC-B        21.600]
 497.9        INTERFACE EAST                                  -1.00000 -130.8  350.0 BASE CASE
 887.8    205 SUB230       230.00    154 DOWNTN       230.00 1 -0.88160 -123.0  660.0 OPEN 151 [NUCPANT     500.00] TO 201 [HYDRO       500.00] CKT 1
                                                                                      OPEN 152 [MID500      500.00] TO 202 [EAST500     500.00] CKT 1
 992.0   3008 CATDOG       230.00    154 DOWNTN       230.00 1  0.28513  236.6  440.0 OPEN 151 [NUCPANT     500.00] TO 201 [HYDRO       500.00] CKT 1
                                                                                      OPEN 152 [MID500      500.00] TO 202 [EAST500     500.00] CKT 1
1035.4    203 EAST230      230.00    154 DOWNTN       230.00 1  0.06321  202.2  250.0 OPEN 201 [HYDRO       500.00] TO 205 [SUB230      230.00] CKT &1
1330.4    201 HYDRO        500.00    151 NUCPANT      500.00 1 -0.60981 -558.7 1200.0 BASE CASE
```

Partial Summary Listing showing Contingency Testing results in order of Increasing Transfer Capability

Figure 6-6. Partial Listing of Report for Two Area Transfer Limits for Contingency Cases

In the contingency case monitored flow tables, transfer limits may be calculated using either of the following approaches:

1. Both pre-contingency and post-contingency flows must satisfy their appropriate rating constraints (i.e., both the base case and the contingency case must have no overloads).

2. Only post-contingency constraints need be satisfied.

The user selects the method to be used by selecting or not to ignore the base case constraints. This selection has no effect on the summary report. For contingency cases, the transfer capability shown is always that at which the monitored element is at its limit in the contingency case. Thus, the selection is meaningful only if the full output option is selected.

When the ***Apply summary minimum distribution factor to Report*** box is checked and the ***Minimum distribution factor Magnitude*** is set to greater than zero, monitored elements with distribution factor magnitudes below the threshold are ignored in calculating the corresponding monitored element flow table as well as being omitted from the summary report.

If the ***Convert ratings to estimated MW Ratings*** box is checked, any percentage of rating parameter is applied after the conversion to estimated MW ratings. Interface ratings are not affected by the convert ratings solution parameter.

Line loss estimates and line shunts of outaged lines are handled as in the DC Load Flow solution process.

It is required that the working case be solved to an acceptable mismatch tolerance prior to initiating this transfer limit analysis.

It is entirely possible that, for a given system condition, there is no interchange schedule at which the linearized network model results in all monitored elements satisfying their rating constraints. This could occur, for example, if the pre-shift solution had two overloaded branches, and one required an increase in interchange to relieve its overload while the other required a decrease in interchange.

The settings of the ***Minimum contingency case pre-shift flow Change*** and the ***Minimum contingency case distribution factor Change*** solution options may be used to exclude from consideration in a contingency case those monitored elements which are not greatly affected by the contingency. This could result in a situation in which none of the remaining monitored elements have nonzero ratings. Such insoluble conditions are described in the output block for that condition when full output is selected; when the summary report is chosen, such cases are identified.

When specifying a rating percentage of other than one hundred percent, note that interface ratings are also scaled by the specified percentage in checking their flows to determine maximum interchange.

6.3 Factoring Generation Participation in Transfer Limit Analysis

The sequential participation transmission interchange limit analysis calculation estimates the import or export limits of a specified subsystem of the working case using a linearized network model. The user designates this "study system" in which the total power injection is to be increased (for export limits) or decreased (for import limits). An opposite change in the total power injection is made in a designated "opposing system." The calculation uses the sensitivity type analysis described in the previous Section 6.1.

It is clear that this analysis is similar to that described in Section 6.2, the difference here being that the shifts in export or import are defined on the basis of specific participating elements in the "study" and "opposing" systems.

The process described here accesses a Distribution Factor Data File to pick up subsystem, monitored element and contingency definitions. In addition, however, it accesses a Subsystem Participation Data File in which alternative participation data may be provided for the study and/or opposing systems.

Power transfer distribution factors relating changes in branch and interface flows to a change in study system interchange are determined. The maximum study system export or import is then derived by extrapolation subject to the constraint that no monitored elements exceed a specified percentage of a selected rating. This process may is then repeated for a designated set of user specified contingency cases.

The process will perform all the contingencies identified in the contingency description file processed when building the distribution factor file. Further, the process uses the monitored list file, which allows the lines to be monitored and interfaced. This feature is important because these interfaces often define stability limits.

Note that any two subsystems identified in the *.sub file can be used for the transfer analysis. Further, however, it should be noted that the limits will be found based on **only** those elements (lines and interfaces) which are monitored, i.e. included in the *.mon file.

6.3.1 Creating the Subsystem Participation Data File

This data file is used to define "participation blocks" for one or more of the subsystems which are defined in the Distribution Factor Data File built using the data supplied in the subsystem description data file (type *.sub), the monitored element file (type *.mon) and the contingency description file (type *.con) (see Section 5.2.2). The subsystems of interest here would have been defined in that subsystem description data file. The participation data defined in the Subsystem Participation Data File provides for:

- Up to five participation blocks per subsystem.
- For each participation block, the fraction of the maximum permissible power shift which is to be assigned to the block.
- For each participation block, the list of buses which are to be included in the block and their block participation factors.

The Subsystem Participation Data File consists of one or more sets of subsystem data with a line containing a zero or blanks following the last set of subsystem data. The file format will appear as shown here:

```
set of data for a subsystem

set of data for another subsystem

.
.
.

set of data for another subsystem

0
```
End of participation data

Each set of data for a subsystem contains the subsystem label enclosed in single quotes (see Section 5.2.2.3), followed by data for up to five participation blocks, followed by line containing a zero:

```
'label'

data for participation block 1

.
.
.

data for participation block n

0
```
End of participation data for subsystem 'label'

The format of records for each participation block is as follows:

```
BLOCKF
IBUS PF
.
.
.
IBUS PF
0
```
End of participation block

where:

BLOCKF	Is a positive value defining the block participation factor. BLOCKF is typically expressed in percent or per unit of the maximum permissible power shift which is to be assigned to the participation block.
IBUS	Is the bus number of a bus assigned to subsystem "label". A subsystem bus may be a member of no more than one participation block.
PF	Is a nonzero value defining the bus participation factor. PF is typically expressed in percent or per unit of the power shift assigned to this participation block. While individual PF value may be negative, the sum of PF factors within each participation block must be positive.

Following is an example of a Subsystem Participation Data File.

```
'SUBSYS A' <---- Start of participation data for subsystem 'SUBSYS A'
   .2 <---- Start of participation block 1 for subsystem 'SUBSYS A'
   101 1
   0 <---- End of participation block 1 for subsystem 'SUBSYS A'
   .8 <---- Start of participation block 2 for subsystem 'SUBSYS A'
   102 1
   0 <---- End of participation block 2 for subsystem 'SUBSYS A'
 0 <---- End of participation data for subsystem 'SUBSYS A'
'SUBSYS B' <---- Start of participation data for subsystem 'SUBSYS B'
  4 <---- Start of participation block 1 for subsystem 'SUBSYS B'
   201 .725
   206 1.0
   0 <---- End of participation block 1 for subsystem 'SUBSYS B'
   6 <---- Start of participation block 2 for subsystem 'SUBSYS B'
   211 .3
   264 .6
   0 <---- End of participation block 2 for subsystem 'SUBSYS B'
 0 <---- End of participation data for subsystem 'SUBSYS B'
0 <---- End of participation data
```

6.3.2 Calculating Interchange Limits

The interchange limits calculation is launched using the ***Power Flow>Linear network>Sequential participation interchange limit (SPIL)*** option. This option will display the Sequential participation interchange limit dialog shown in Figure 6-7 with its default values.

The first requirement is for the user to identify the linearized network model Distribution Factor file built as described in Section 5.2.3.2 and the Subsystem participation data file.

The second requirement is to make the necessary and appropriate selections for the subsystems to be tested and the solution and output options discussed below.

6.3.2.1 Setting Interchange Limit Initial Condition Mismatch.

If the largest initial active power mismatch exceeds the specified MW mismatch tolerance, the user is given the opportunity to terminate the calculation process. Note that the user can modify the tolerance in steps of 0.1.

6.3.2.2 Setting Interchange Limit Solution Options

Base and contingency case rating: This set, and the percentage thereof, define the line loading limits used in determining overloads. The default rating set is the one established as the default rating set program options.

Convert ratings code: If the convert ratings code box is checked, ratings of monitored branches are converted to estimated MW ratings based upon each monitored line's Mvar loading at the metered end in the base case AC solution.

Line flow code: This defines the base flow to be used in deriving branch flow estimates. The user can select the AC or the DC base case conditions.

Phase shifter in base case: This can be set to "Lock" or "Regulate" If set to regulate any regulating phase shifter whose adjustment control mode COD n is set to +3 holds its base case flow in all base case shift solutions. Otherwise, all phase shift angles are locked at their base case settings.

Add study system ties to monitored lines: The user can check this box to have study system tie lines included as monitored elements is checked.

Minimum contingency case pre-shift flow change and **Minimum contingency case distribution factor change:** These provides a means of ignoring those monitored elements which, in a contingency case, are not significantly affected by the contingency. If the magnitude change in pre-shift flow from the base case value is less than this minimum flow change threshold *and* the magnitude change in the power transfer distribution factor from the base case value is less than the distribution factor change threshold, the monitored element is ignored.

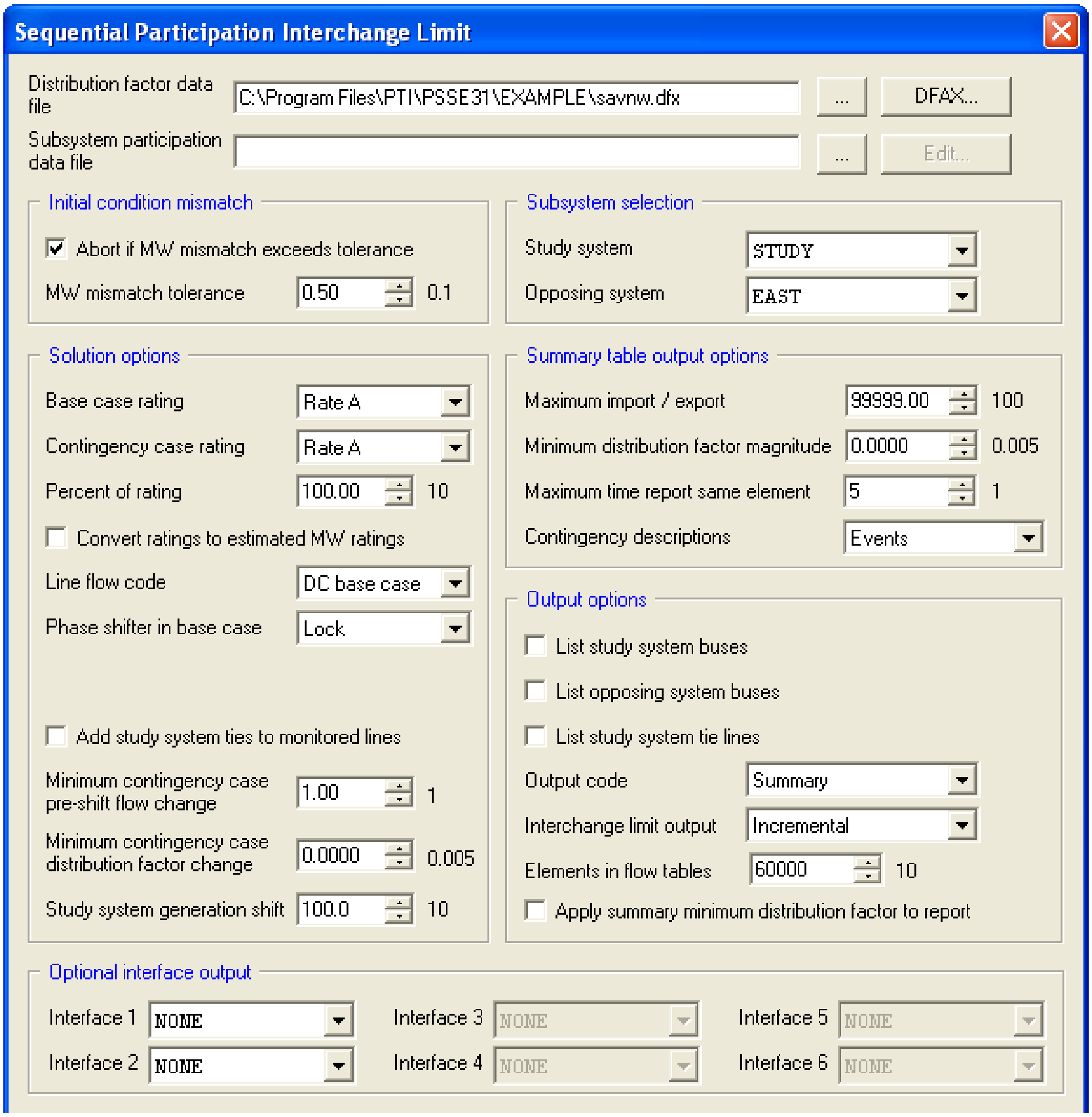


Figure 6-7. Sequential Participation Interchange Limit Selector Window

Study system generation shift: This is the value of change in total generation in the study system. If the value entered is positive, export limits are to be determined; otherwise, import limits are to be calculated. The "generation shift" is apportioned among generator and load buses in the study system in proportion to the participation factors specified in the "participation block structure" of the Subsystem Description Data file (see Section 6.3.1) or in a series of sequential shifts as defined in the Subsystem Participation Data file described above. If no participation block was entered for the study system in either file, the generation shift is shared among generator buses in proportion to their plant MBASEs (i.e., the sum of the MBASEs of in-service machines with positive active power output at the bus). In this case, there must be at least one in-service machine with a positive MBASE in the subsystem. Similar opposite "generation shifts" are applied to buses in the opposing system, again according to their participation factors or MBASEs.

Using the incremental form of the DC power flow equation (see Section 5.5) and the generation shift vectors, phase angle changes are calculated, followed by incremental line flows for all monitored lines and interfaces. These are transformed into vectors of base case power transfer distribution factors, and the interchange limit is determined by extrapolation such that all monitored elements satisfy their rating constraints.

6.3.2.3 Setting Interchange Limit Subsystem Selection

Study System: This is the network subsystem in which the total power injection is to be increased (for export limits) or decreased (for import limits). The choices available are those listed in the *.sub type file.

Opposing System: This is the network subsystem in which an opposite change, from that in the "Study" system, is made.

6.3.2.4 Setting Interchange Limit Summary Table Output Options

Maximum import/export: This the first of three "cutoff" thresholds for including monitored elements in the summary report.

Minimum distribution factor: This the second of three "cutoff" thresholds for including monitored elements in the summary report. For small distribution factors, with levels below this threshold, there will be no reporting for the related element.

Maximum time report same element: This the third of three "cutoff" thresholds for including monitored elements in the summary report. This will limit the number of times an element is reported in the same report.

Contingency descriptions: The user can select the manner in which contingency cases are identified in the summary report. The options are to use the 12-character contingency case label or the events comprising the contingency case or both the contingency label and the contingency events description.

6.3.2.5 Setting Interchange Limit General Output Options

List study system buses: The user can check this box to provide for a listing of "study" system buses in the output report.

List opposing system buses: The user can check this box to provide for a listing of "opposing" system buses, in the output report.

List study system tie lines: The user can check this box to provide for a listing of study system tie lines in the output report.

Output code: This provides for a selection of either a "Summary" report of all cases considered or a "Full" report which will comprise a monitored element flow table for each case considered followed by a summary report of all cases considered

Interchange limit output: This output code provides for selection of either "incremental transfer capability" or "total transfer capability" as the desired output quantity.

Elements in flow tables: This is the number of monitored elements to include in flow tables allowing the user to limit the flow table for each case reported to the "n" most restrictive monitored elements.

Apply summary minimum distribution factor to report: If checked this will cause the limitation of reported output to only those elements whose distribution factors are greater than the "Minimum distribution factor magnitude" referred to in Section 6.3.2.4.

6.3.2.6 Setting Interchange Limit Interface Output Option

The user is given the option of having the summary report repeated with interface transfer limits and distribution factors for a selected interface listed rather than study system transfer limits and distribution factors. The "interface" distribution factors listed on the "interface" summary report are measures of the changes in monitored element flows to a change in base case interface flow.

6.3.3 Running Interchange Limit Analysis

When the user has identified the information required in the dialog of Figure 6-7, clicking ***OK*** will complete the process during which the program will:

- Check for and warn against unacceptable conditions
- Perform the required calculations
- Summarize the test conditions
- Output the result to a Report to the Output Bar or to a file selected by the user.

The program will check that generators are not "converted" and that each non type four bus is connected back to a type three (swing) bus through the in-service AC network. If any violations are detected, an appropriate message is printed and the process is terminated.

The program will check to ensure that there are no buses which are members of both of the selected subsystems. If any such buses are found, they are alarmed and the process is terminated.

The largest active power mismatch corresponding to the present AC solution voltage vector in the working case is calculated and printed.

If no subsystems are defined an appropriate error message is printed and the interchange calculation process is terminated. If only one subsystem is defined, a second subsystem ("WORLD") is assumed containing those buses in the power flow case which are not assigned to the specified subsystem.

If the convert ratings option was enabled, ratings from the selected rating set(s) of those monitored branches having nonzero rating(s) are modified. For each such branch, the Mvar loading is calculated and MW rating(s) are determined under the assumption that the Mvar loading is unchanged under power transfer and contingency conditions.

Using the incremental form of the DC power flow equation (see Section 5.5) and the power shift vector, phase angle changes are calculated, followed by incremental line flows for all monitored lines and interfaces. These are transformed into a vector of base case power transfer distribution factors, and the interchange limit is determined by extrapolation such that all monitored elements satisfy their rating constraints.

The "base case" DC network solution is calculated and the solution summarized as in the following example:

```
STUDY SYSTEM GENERATION IS         1500.0 MW
OPPOSING SYSTEM GENERATION IS      1748.9 MW
STUDY SYSTEM NET INTERCHANGE IS     282.8 MW
```

The "generation shift" is apportioned among generator and load buses in the study system in a series of sequential shifts as defined in the Subsystem Participation Data File described above.

The "base case" solution is then reported, followed by processing of the designated contingency cases with contingency case flow estimates. Prior to terminating, an ordered summary report from among all the cases calculated is tabulated.

The user is given the option of having the summary report repeated with interface transfer limits and distribution factors for a selected interface (as indicated in Section 6.3.2.6) mentioned in Listed rather than study system transfer limits and distribution factors. The "interface" distribution factors listed on the "interface" summary report are measures of the changes in monitored element flows to a change in base case interface flow.

In listing study system buses, opposing system buses, and study system tie lines, the tabulation may be terminated by entering the AB interrupt control code. In this case, the interrupt is cleared and processing continues. Once the interchange limit calculations have started, the interchange calculation process may be terminated by entering the AB interrupt control code.

6.3.4 Analyzing Interchange Limit Results

The significant difference between this Sequential Participation Interchange Limit calculation and the Two-area Transmission Interchange Limit calculation, described in Section 6.2, is that the generation shift here is established by sequential participation of specific buses each with its own participation factor.

When multiple participation blocks are specified in the Subsystem Participation Data File for the study and/or opposing systems, the study system generation shift and the block participation factors specified in the Subsystem Participation Data File are used to allocate portions of the specified shift sequentially among the participation blocks. Within each participation block, its allocation is assigned to the block's participating buses in proportion to their bus participation factors. Thus, the sensitivity of each monitored element's flow to an incremental change in study system interchange is defined by a set of power transfer distribution factors which vary according to the current level of study system interchange.

6.3.4.1 Viewing the Interchange Limit Base Case Conditions Report

Base case conditions are reported first. The report lists the study system generation, the opposing system generation, and the study system net interchange corresponding to the network solution before and after applying the generation shift. This is followed by a tabulation of the pre-shift and post-shift generation at those study system and opposing system buses participating in the generation shift. Loadings on monitored elements are then reported, sorted such that the most restrictive elements are listed first. Either incremental or total pre-contingency transfer limits, as appropriate, are listed.

Flow estimates are listed for each of three interchange schedules: with the original generation profile, with the specified generation shift, and at the generation shift corresponding to the transfer level limit required for the most restrictive monitored element (i.e., the one listed first). Any flow at or above the selected percentage of the appropriate rating is followed by an asterisk ("*"). The power transfer distribution factor relating the change in flow on the monitored element to a change in study system net interchange is also tabulated. When multiple participation blocks were specified for either the study or opposing system, the power transfer distribution factors printed are those that apply at the transfer level required for the most restrictive monitored element.

For each monitored element reported, its rating is listed; for branches, this *is not* the percentage of the rating used in determining the interchange limit, but either the value of rating entered as raw data and the data editor windows, or, if the convert ratings option was selected at the start of this transfer analysis calculation, the estimated MW ratings.

Figure 6-9 shows the report obtained using the example files (*savnw.**) from which was built the *dc-contingency.dfx* distribution factor file. The example data files used (*.*sub*, *.*mon*, *.*con*) can be seen listed at the top of the report listing. They are available in the PSS™E EXAMPLE directory.

As an example, a Subsystem Participation Data file was prepared for the two study areas "STUDY" and "EAST" identified in the *savnw.sub* file. The file is shown in Figure 6-8 where it can be seen that generators at Buses 101 and 102, in the "STUDY" subsystem are identified as participating at 20% and 80% respectively. In the "EAST" subsystem, the "opposing" system, there are two participation blocks, one of which has a participation of 30% and the other which participation of 70%. Each block has a participating generator and load bus.

For the purposes of running and example case, a total shift of 100 MW is assumed. In the Report listing, Figure 6-9, it can be seen that this shifts in the "study" and "opposing systems are apportioned as defined by the participation block ratios as identified in Figure 6-8.

```
'STUDY'
0.2
101 1
0
0.8
102 1
0
0
'EAST'
0.3
205 0.7
206 1
0
0.7
211 0.3
203 0.6
0
0
0
```

Figure 6-8. Participation Factors

```
       *** SPIL EXPORT LIMIT OUTPUT FOR BASE CASE                ***

DISTRIBUTION FACTOR FILE:      C:\Program Files\PTI\PSSE30\EXAMPLE\dc-contingency.dfx
SUBSYSTEM DESCRIPTION FILE:    C:\Program Files\PTI\PSSE30\EXAMPLE\savnw.sub
MONITORED ELEMENT FILE:        C:\Program Files\PTI\PSSE30\EXAMPLE\savnw.mon
CONTINGENCY DESCRIPTION FILE:  C:\Program Files\PTI\PSSE30\EXAMPLE\savnw.con

                                PRE-SHIFT    DELTA   POST-SHIFT
STUDY SYSTEM MW GENERATION:       1500.0     100.0     1600.0
OPPOSING SYSTEM MW GENERATION:    1400.0    -100.0     1300.0
STUDY SYSTEM NET INTERCHANGE:      278.7     100.0      378.7

<---------------- STUDY SYSTEM -----------------> <--------------- OPPOSING SYSTEM --------------->
                         <---- GENERATOR MW ---->                          <---- GENERATOR MW ---->
  BUS# X-- NAME --X BASKV     BASE   SHIFT  CHANGE   BUS# X-- NAME --X BASKV     BASE   SHIFT  CHANGE
   101 NUC-A       21.600    750.0   770.0    20.0    203 EAST230     230.00      0.0   -46.7   -46.7
   102 NUC-B       21.600    750.0   830.0    80.0    205 SUB230      230.00      0.0   -12.4   -12.4
                                                      206 URBGEN      18.000    800.0   782.4   -17.6
                                                      211 HYDRO_G     20.000    600.0   576.7   -23.3

LOADINGS AT OR ABOVE 100.0 %                                     <------------- BASE CASE ------------->
OF RATING ARE MARKED WITH '*'                              TOTAL          PRE-    POST-   LIMIT
                                                           TRANS RATING  SHIFT    SHIFT    CASE    DISTR.
<------- F R O M -------> <--------- T O ---------> CKT   CAPAB    A      MW       MW      MW      FACTOR
       INTERFACE EAST                                     497.9   350  -130.8   -230.8  -350.0* -1.00000
   201 HYDRO        500.00    151 NUCPANT     500.00  1  1387.8  1200  -558.7   -614.4  -683.6  -0.58028
   203 EAST230      230.00    154 DOWNTN      230.00  1  3241.7   200   122.4    117.0   103.8  -0.11072
   202 EAST500      500.00    152 MID500      500.00  1  5146.4  1200   -50.7    -70.1   -98.4  -0.23699
  3008 CATDOG       230.00    154 DOWNTN      230.00  1  6713.6   400    62.9     69.9    76.2   0.05210
   205 SUB230       230.00    154 DOWNTN      230.00  1 13389.1   600   356.1    336.7   328.2  -0.07200
  3004 WEST         500.00    152 MID500      500.00  1 >99999.  NONE  -132.2   -136.8  -140.9  -0.03407
  3006 UPTOWN       230.00    153 MID230      230.00  1 >99999.  NONE   -78.6    -81.0   -83.2  -0.01803
       INTERFACE WEST                                   >99999.   200  -147.9   -147.9  -147.9   0.00000
```

Figure 6-9. Sequential Participation Interchange Limit Output for Base Case

It can be seen that the transfer capabilities and participation factors are different from those shown in Figure 6-5 where sequential participation factors were not used. There, the power shift is apportioned relative to the MBASE value for the machines in the two participating systems.

Three-Winding Transformers

For monitored three-winding transformer windings, flow estimates are calculated at the winding bus end as power flowing into the transformer. For other monitored branches, flow estimates are calculated at the metered end in the "*from bus*" to "*to bus*" direction. The flow across an interface is taken as the sum of the flows of its members. For three-winding transformer windings, the flow is calculated at the winding bus as power flowing into the transformer. For other members, the flow is calculated at its metered end in the "*from bus*" (the first bus specified in entering the branch) to "*to bus*" direction.

6.3.4.2 Viewing Interchange Limit Contingency Cases

When reporting flows for contingency cases, the events comprising the contingency are listed followed by flows on the monitored elements sorted as described above. The flow table includes both the contingency case flows in the same form as the base case report described above, as well as the base case flows at the transfer level required for the most restrictive monitored element. Only the contingency case constraints are considered in calculating the transfer limit; base case flows at the transfer limit may be shown as overloaded since the corresponding constraints are ignored in the transfer limit calculation.

A summary report tabulates the number of system condition solutions attempted and the number for which there exists no interchange schedule at which the rating constraint can be satisfied for all monitored elements. This is followed by a tabulation of monitored elements for all system conditions which were calculated, in order of increasing incremental or total transfer capability, as appropriate. The limiting element is listed along with its power transfer distribution factor, its pre-shift contingency case flow, its rating, and a description of the system condition.

Only those monitored elements satisfying the "cutoff" threshold solution parameters set by the user when launching the calculation process are included in the summary. Once an element has been listed the maximum number of times "n", its "nth" occurrence includes an asterisk ("*") before its description, and further reporting of the element is suppressed.

This summary report is reprinted for each selected interface with interface transfer limits and distribution factors rather than study system interchange limits and distribution factors tabulated. All distribution factors on the interface transfer limits summary report describe changes in monitored element flow relative to a change in interface flow. The branches which form the interface are listed on the first page of an interface's transfer limit summary report.

The final page of the summary report lists those elements which were reported "n" times, sorted by the number of times they would have been reported.

If a line outage contingency forms an island with no type three (swing) bus, a singular submatrix is formed. Any monitored branch which resides in the swingless island, as well as any interface which includes such a branch as a member, has dashes printed where its contingency case results would normally be printed.

Reference can be made to Figure 6-6 which shows the report listing for the two-area Transmission Interchange Limit calculation. The format for this two area calculation, using sequential participation factors, is the same. The results, however, will show different interchange limits and distribution factors.

6.3.4.3 Application Notes for Interchange Limit Analysis

When multiple participation blocks are specified in the Subsystem Participation Data File for the study and/or opposing systems, the study system generation shift and the block participation factors specified in the Subsystem Participation Data File are used to allocate portions of the specified shift sequentially among the participation blocks. Within each participation block, its allocation is assigned to the block's participating buses in proportion to their bus participation factors. Thus, the sensitivity of each monitored element's flow to an incremental change in study system interchange is defined by a set of power transfer distribution factors which vary according to the current level of study system interchange.

Since this transfer limit calculation process uses the linearized network model, note should be taken of the approximate nature of the solution. The proper role of this analysis, therefore, should be to focus attention on those system conditions which deserve more detailed study.

The process detects the specification of duplicate single and double line outage contingencies and calculates the contingency case solution only for the first specification of such a contingency. Any contingency cases involving bus boundary contingency events, line closure contingency events, or more than two line outage contingency events are not checked for duplication.

The values shown as monitored element flows are set as described in Section 6.3.1. The user selects the base flow value to be used by setting the line flow code solution parameter at the start of the process; see above.

In the contingency case monitored flow tables, transfer limits are calculated such that only post-contingency constraints need be satisfied.

When the ***Apply summary minimum distribution factor to Report*** box is checked and the ***Minimum distribution factor Magnitude*** is set to greater than zero, monitored elements with distribution factor magnitudes below the threshold are ignored in calculating the corresponding monitored element flow table as well as being omitted from the summary report.

If the ***Convert ratings to estimated MW Ratings*** box is checked, any percentage of rating parameter is applied after the conversion to estimated MW ratings. Interface ratings are not affected by the convert ratings solution parameter.

Line loss estimates and line shunts of outaged lines are handled as in the DC Load Flow solution process.

It is required that the working case be solved to an acceptable mismatch tolerance prior to initiating this transfer limit analysis.

It is entirely possible that, for a given system condition, there is no interchange schedule at which the linearized network model results in all monitored elements satisfying their rating constraints. This could occur, for example, if the pre-shift solution had two overloaded branches, and one required an increase in interchange to relieve its overload while the other required a decrease in interchange.

The settings of the Minimum contingency case pre-shift flow Change and the Minimum contingency case distribution factor Change solution options may be used to exclude from consideration in a contingency case those monitored elements which are not greatly affected by the contingency. This could result in a situation in which none of the remaining monitored elements have nonzero ratings. Such insoluble conditions are described in the output block for that condition when full output is selected; when the summary report is chosen, such cases are identified.

When specifying a rating percentage of other than one hundred percent, note that interface ratings are also scaled by the specified percentage in checking their flows to determine maximum interchange.

6.4 Calculating Transfer Limits with Three Participating Areas

As for the two-area solution described in Section 6.3, this transmission interchange limit analysis estimates the import or export limits of a specified subsystem of the working case using a linearized network model. The user designates this "study system" in which the total power injection is to be increased (for export limits) or decreased (for import limits).

This interchange analysis differs from the two-area calculation, however, in that it considers simultaneous power injection shifts in two "opposing systems" in maximizing "study system" import or export.

Two sets of base case power transfer distribution factors are determined: one set relating changes in branch and interface flows to a change in study system interchange against the first opposing system, and another relating changes in flows to a change in study system interchange against the second opposing system. The maximum study system export or import is then derived by a linear program subject to the constraint that no monitored elements exceed a specified percentage of a selected rating. This process may then be repeated for a designated set of user specified contingency cases.

Results are presented in tabular and, optionally, graphical forms.

The data used here is the same at that used for the two-area calculation, i.e a distribution factor data file is required to be constructed as described in Section 5.2.2.

6.4.1 Performing Interchange Limit Analysis (Two Opposing Systems)

To launch the calculation process it necessary to select the ***Power Flow>Linear networks>Interchange limits with two opposing systems (POLY)*** option. This option will display the Interchange limits with two opposing systems dialog (see Figure 6-10).

The user is required to identify the Distribution factor data file and to identify the name of an output file to which the information will be written for current or later plotting of the graphical display of results. The file is of type **.pol*.

The remaining task is to make the selections for solution options, output options and graphical output parameters.

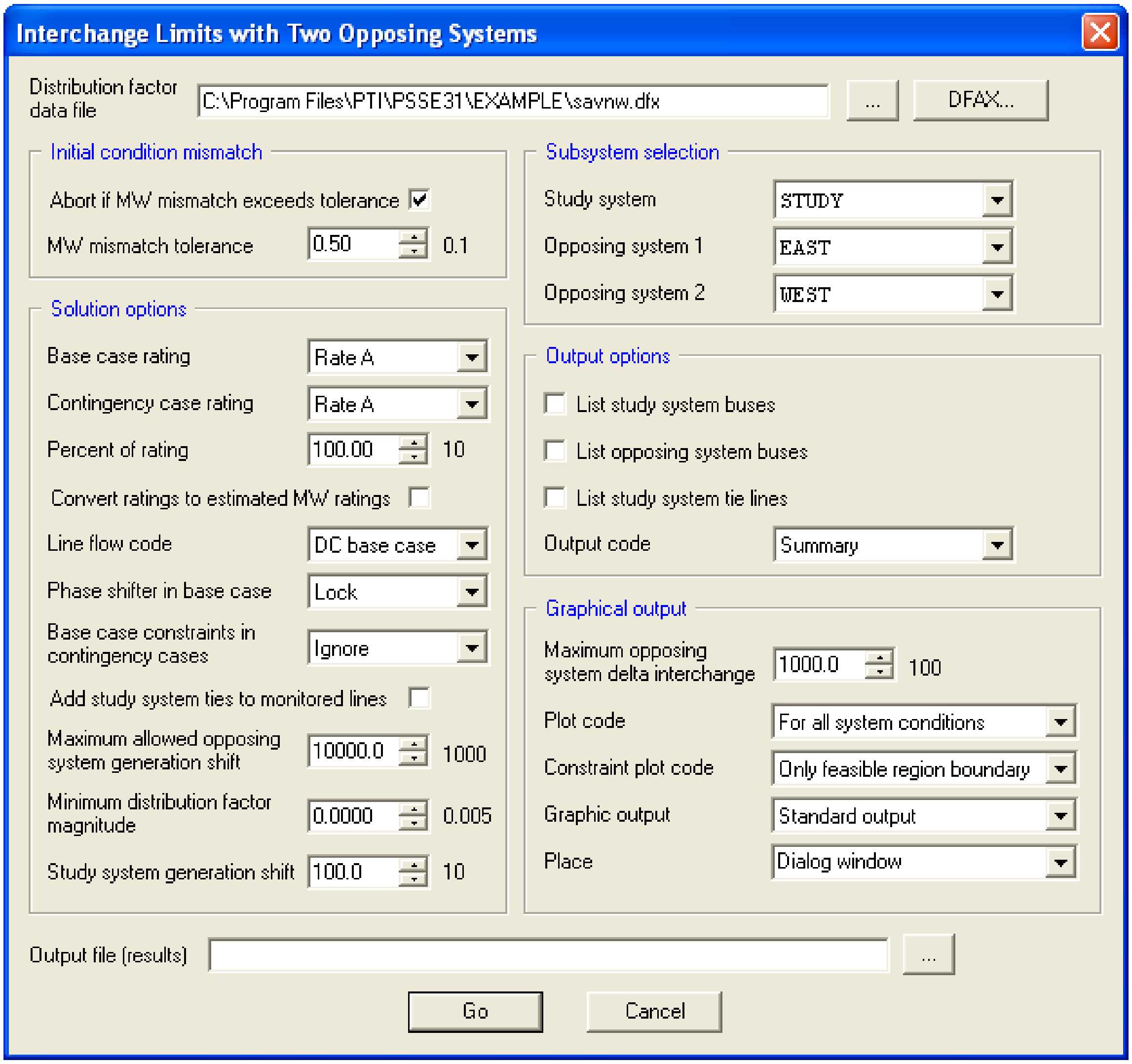


Figure 6-10. Dialog for Three-area Interchange Calculation

6.4.1.1 Setting the Interchange Limit (Two-Opposing Systems) Initial Condition Mismatch Option

If the largest initial active power mismatch exceeds the specified MW mismatch tolerance, the user is given the opportunity to terminate the calculation process. Note that the user can modify the tolerance in steps of 0.1.

6.4.1.2 Setting Interchange Limit (Two-Opposing Systems) Solution Options

Base and contingency case rating set: This set, and the percentage thereof, define the line loading limits used in determining overloads. The default rating set is the one established as the default rating set program options.

Convert ratings code: If the convert ratings code box is checked, ratings of monitored branches are converted to estimated MW ratings based upon each monitored line's Mvar loading at the metered end in the base case AC solution.

Line flow code: This defines the base flow to be used in deriving branch flow estimates. The user can select the AC or the DC base case conditions.

Phase shifter in base case: This can be set to "Lock" or "Regulate" If set to regulate any regulating phase shifter whose adjustment control mode COD n is set to +3 holds its base case flow in all base case shift solutions. Otherwise, all phase shift angles are locked at their base case settings.

Base case constraints in contingency cases: The user can choose to recognize, "include", both the base case and contingency case flow constraints in calculating the pre-contingency interchange limits for each contingency case. Otherwise, "ignore" the base case constraints and consider only the contingency case loadings.

Add study system ties to monitored lines: The user can check this box to have study system tie lines included as monitored elements is checked

Maximum allowed opposing system generation shift: Places a bound on the permissible generation shift for each of the opposing systems.

Minimum distribution factor magnitude: This defines the minimum distribution factor magnitude threshold for including monitored elements in the transfer limit calculation and report. Any monitored element for which both of its power transfer distribution factor magnitudes are below this threshold is ignored during the processing and reporting of the corresponding system condition.

Study system generation shift: The "generation shift" is apportioned among generator and load buses in the study system in proportion to the participation factors specified in the "participation block structure" of the Subsystem Description Data File. If no participation block was entered for the study system, the generation shift is shared among generator buses in proportion to their plant MBASEs (i.e., the sum of the MBASEs of in-service machines with positive active power output at the bus). In this case, there must be at least one in-service machine with a positive MBASE in the subsystem. The opposite "generation shift" is applied to buses in the first opposing system, again according to their participation factors or MBASEs.

6.4.1.3 Setting Interchange Limit (Two-Opposing Systems) Subsystem Selection

Study System: This is the network subsystem in which the total power injection is to be increased (for export limits) or decreased (for import limits). The choices available are those listed in the *.sub type file.

Opposing System 1 and **Opposing System 2:** These are the network subystems in which an opposite change, from that in the "Study" system, is made.

6.4.1.4 Setting Interchange Limit (Two-Opposing Systems) Output Options

List study system buses: The user can check this box to provide for a listing of "study" system buses in the output report.

List opposing system buses: The user can check this box to provide for a listing of "opposing" system buses, in the output report.

List study system tie lines: The user can check this box to provide for a listing of study system tie lines in the output report.

Output code: The output code allows the user to select either a summary report of all cases considered, or a monitored element flow table for each case considered followed by a summary report of all cases considered.

6.4.1.5 Setting Interchange Limit (Two-Opposing Systems) Graphical Output Options

Maximum opposing system delta interchange: When the graphical display of results is selected, a graph is produced for either each optimal solution calculated or for only the combined case solution; see below. Change in interchange in the first opposing system is plotted along the "x-axis," and change in interchange in the second opposing system is plotted along the "y-axis." The plotting scales are set according to this parameter.

Plot Code: The user can select to produce graphical output only for the combined case or for all cases.

Constraint plot code: The user can select to include on each plot for which a transfer limit exists either all constraint lines or only those which form the boundary of the polygon which encloses the feasible region.

Graphic output: This allows the user to include both the graph and the letter code key on the same plot or on separate plots.

Place: The user can select to place the graphic results on the monitor or send to a printer.

6.4.2 Calculating the Interchange Limit (Two-Opposing Systems)

Once the user has identified all the required information, all that is required is to select ***Go*** in the dialog.

Prior to calculation, the program will check that generators are not "converted" and that each non type four bus is connected back to a type three (swing) bus through the in-service AC network. If any violations are detected, an appropriate message is printed and the process is terminated.

Next, the largest active power mismatch corresponding to the present AC solution voltage vector in the working case is calculated. If this largest mismatch is greater than the MW mismatch tolerance, the user is given the option of continuing or terminating: the process.

The program will check to ensure that there are no buses which are members of two or all three of the selected subsystems. If any such buses are found, they are alarmed and the process is terminated.

If the convert ratings option was enabled at the start of the process ratings from the selected rating set(s) of those metered branches having nonzero rating(s) are modified. For each such branch, the Mvar loading is calculated and MW rating(s) are determined under the assumption that the Mvar loading is unchanged under power transfer and contingency conditions.

The "base case" DC network solution is then calculated summarized as in the following example:

```
STUDY SYSTEM GENERATION IS        1500.0 MW
OPPOSING SYSTEM 1 GENERATION IS   1400.0 MW
OPPOSING SYSTEM 2 GENERATION IS    348.9 MW
STUDY SYSTEM NET INTERCHANGE IS    282.8 MW
```

Using the incremental form of the DC power flow equation (see Section 5.5) and the power shift vector, phase angle changes are calculated, followed by incremental line flows for all monitored lines and interfaces. These are transformed into a vector of base case power transfer distribution factors. A second set of power transfer distribution factors describing the effect on the monitored elements of an interchange shift between the study system and the second opposing system is calculated.

Based on the two sets of power transfer distribution factors, the "study" system interchange limit is determined by a linear programming technique such that all monitored elements satisfy their rating constraint. The "base case" solution is reported, followed by processing of the designated contingency cases.

One final optimal solution is calculated for a "combined case". This solution calculation includes constraints for all system conditions (i.e., the base case and all contingency cases) for which an individual optimum solution was found. This calculation therefore determines the maximum study system export (or import, as appropriate) schedule such that no monitored element is overloaded in the base case or under contingency conditions.

The "combined case" solution is then reported and, prior to the process terminating, the calculated interchange limits for the base case, for all contingency cases, and for the combined case are summarized.

In listing study system buses, opposing system buses, and study system tie lines, the tabulation may be terminated by entering the AB interrupt control code. In this case, the interrupt is cleared and processing continues. Once the interchange limit calculations have started, the process may be terminated by entering the AB interrupt control code.

6.4.3 Analyzing Interchange Limit (Two-Opposing Systems) Results

6.4.3.1 Viewing the Interchange Limit (Two-Opposing Systems) Tabular Report

In reporting the base case solution, the program lists the generation in the study and opposing systems and the study system net interchange corresponding to the network solution before applying any generation shift and in the two generation shift cases. This is followed by a tabulation of the pre-shift and post-shift generation at those study system and opposing system buses participating in the generation shifts.

The "generation shifts" required to achieve the interchange limit (import or export, as appropriate) are then listed, along with the limiting lines and/or interfaces and their ratings (see Figure 6-11).

For monitored three-winding transformer windings, flow estimates are calculated at the winding bus end as power flowing into the transformer. For other monitored branches, flow estimates are calculated at the metered end in the "*from bus*" to "*to bus*" direction. The flow across an interface is taken as the sum of the flows of its members. For three-winding transformer windings, the flow is calculated at the winding bus as power flowing into the transformer. For other members, the flow is calculated at its metered end in the "*from bus*" (i.e., the first bus specified in entering the branch; to "*to bus*" direction.

Loadings on monitored elements are then reported. The flow estimates are listed for each of four interchange schedules: with the original generation profile; with the specified generation shift in the study system and the opposite shift in the first opposing system; with the specified generation shift in the study system and the opposite shift in the second opposing system; and in the case with maximum import or export, as appropriate, in which no monitored elements exceed the specified percentage of the selected rating. Any flow at or above the selected percentage of the appropriate rating is followed by an asterisk ("∗"). The power transfer distribution factors relating the change in flow on the monitored element to a change in study system net interchange with the opposite change in the two opposing systems in turn are also tabulated, along with the rating of the monitored element; for branches, this *is not* the percentage of the rating used in determining the interchange limit, but either the value of rating as entered with the raw data or as modified with the program editor or, if the convert ratings option was selected at the start of this interchange calculation, the estimated MW ratings (see Figure 6-11).

When reporting results for contingency cases, the events comprising the contingency are listed, followed by the "generation shifts" required to achieve the transfer limit for the contingency case being reported, along with the limiting elements. The flow table includes both the contingency case flows in the same form as the base case report described above, as well as the base case flows at the transfer limit. Note that if the user has so selected, only the contingency case constraints are considered in calculating the transfer limit; in this case, base case flows at the transfer limit may be shown as overloaded since the corresponding constraints were ignored in the transfer limit calculation.

When reporting results for the "combined case", the program tabulates the "generation shifts" required to achieve the interchange schedule which results in maximum import (or export, as appropriate) while simultaneously avoiding overloading in all system conditions for which individual optima were found. The limiting elements are listed along with the system condition in which they are limiting. The combined case flow table includes only those elements which are part of the border of the feasible region of a successfully solved system condition. Flows are reported in the same form as the base case report described above, and the system condition to which they apply is shown at the right side of each output line.

A summary page tabulates the number of optimal solutions attempted, and the number for which there exists no interchange schedule at which the rating constraint can be satisfied for all monitored elements. Then, for each case processed, the interchange limit is listed along with the corresponding generation shifts required in the two opposing systems.

If a line outage contingency forms an island with no type three (swing) bus, a singular submatrix is formed. Any monitored branch which resides in the swingless island, as well as any interface which includes such a branch as a member, has dashes printed where its contingency case results would normally be printed.

```
        *** POLY EXPORT LIMIT OUTPUT FOR BASE CASE                ***

DISTRIBUTION FACTOR FILE:      C:\Program Files\PTI\PSSE30\EXAMPLE\dc-contingency3.dfx
SUBSYSTEM DESCRIPTION FILE:    C:\Program Files\PTI\PSSE30\EXAMPLE\savnw.sub
MONITORED ELEMENT FILE:        C:\Program Files\PTI\PSSE30\EXAMPLE\jdmsavnw.mon
CONTINGENCY DESCRIPTION FILE:  C:\Program Files\PTI\PSSE30\EXAMPLE\savnw2.con

                                            X- SHIFT CASE 1 -X  X- SHIFT CASE 2 -X
                                PRE-SHIFT    DELTA  POST-SHIFT   DELTA  POST-SHIFT
STUDY SYSTEM MW GENERATION:       1500.0     100.0    1600.0     100.0    1600.0
OPPOSING SYSTEM 1 MW GENERATION:  1400.0    -100.0    1300.0       0.0    1400.0
OPPOSING SYSTEM 2 MW GENERATION:   358.7       0.0     358.7    -100.0     258.7
STUDY SYSTEM MW NET INTERCHANGE:   278.7     100.0     378.7     100.0     378.7

<---------------- STUDY SYSTEM -----------------> <------------ FIRST OPPOSING SYSTEM ------------> <------- SECOND OPPOSING SYSTEM ------->
                           <---- GENERATOR MW ---->                           <---- GENERATOR MW ---->                <---- GENERATOR MW ---->
  BUS# X-- NAME --X BASKV     BASE    SHIFT  CHANGE   BUS# X NAME X BASKV     BASE   SHIFT  CHANGE   BUS# X-NAME -X BASKV  BASE    SHIFT  CHANGE
   101 NUC-A       21.600    750.0    800.0    50.0    206 URBGEN   18.000    800.0  742.0  -58.0   3011 MINE_G    13.800  258.7   170.2  -88.5
   102 NUC-B       21.600    750.0    800.0    50.0    211 HYDRO_G  20.000    600.0  558.0  -42.0   3018 CATDOG_G 13.800  100.0    88.5  -11.5

                                BASE CASE INCREMENTAL   TOTAL
STUDY SYSTEM GENERATION MW         1500.0    1450.3    2950.3
OPPOSING SYSTEM 1 GENERATION MW    1400.0    -181.9    1218.1
OPPOSING SYSTEM 2 GENERATION MW     358.7   -1268.4    -909.8
STUDY SYSTEM MW NET INTERCHANGE     278.7    1450.3    1729.0

LIMITING MONITORED ELEMENTS LOADED AT 100.0 % OF RATING:
<-------- F R O M --------> <---------- T O ----------> CKT   RATING
   201 [HYDRO       500.00]    151 [NUCPANT     500.00]  1    1200.0
   205 [SUB230      230.00]    154 [DOWNTN      230.00]  1     600.0

LOADINGS AT OR ABOVE 100.0 %                           <--------------------- BASE CASE ---------------------->
OF RATING ARE MARKED WITH '*'                            PRE- GEN SHIFT CASES   LIMIT            DISTRIBUTION
                                                        SHIFT  OPSYS1  OPSYS2    CASE  RATING       FACTORS
<------- F R O M -------> <--------- T O ---------> CKT   MW      MW      MW      MW      A      OPSYS1   OPSYS2
   151 NUCPANT     500.00    152 MID500      500.00  1   469.0   488.5   498.1   873.5   1200   0.19509  0.29091
   153 MID230      230.00    154 DOWNTN      230.00  1   253.9   264.2   255.1   288.5    300   0.10346  0.01247
   201 HYDRO       500.00    151 NUCPANT     500.00  1  -558.7  -619.7  -600.5  -1200.*  1200  -0.60981 -0.41817
   202 EAST500     500.00    152 MID500      500.00  1   -50.7   -63.2   -37.3    96.9   1200  -0.12486  0.13426
   203 EAST230     230.00    154 DOWNTN      230.00  1   122.4   126.8   127.2   190.4    200   0.04396  0.04731
   205 SUB230      230.00    154 DOWNTN      230.00  1   356.1   325.2   379.8   600.0*   600  -0.30929  0.23660
       INTERFACE WEST                                   -147.9  -147.9  -247.9  -1416.   2000   0.00000 -1.00000
       INTERFACE EAST                                   -130.8  -230.8  -130.8  -312.6   1600  -1.00000  0.00000
```

Figure 6-11. Typical Output from Interchange Calculation for Two Opposing System

6.4.3.2 Viewing the Interchange Limit (Two-Opposing Systems) Graphical Output

When the graphical display of results is selected, a graph is produce for either each optimal solution calculated or for only the combined case solution. Change in interchange in the first opposing system is plotted along the "x-axis," and change in interchange in the second opposing system is plotted along the "y-axis." The plotting scales are set according to the user's selection of the Maximum opposing system delta interchange parameter.

For each monitored element, a pair of straight lines is plotted indicating the set of interchange schedule changes for which that element is exactly at its rating constraint. Moving to any point on one side of any "limit line" brings the loading on the element below its limit; points on the other side result in a limit violation. On the "violation" side of the "limit line," the background is shaded blue (see Figure 6-13).

When all monitored elements are so plotted, the region of interchange schedule changes at which no monitored element violates its rating constraint is shown as the "clean" portion of the graph. If the point of maximum transfer (export or import, as appropriate) exists for a given system condition, it occurs at the intersection of a pair of "limit lines," and is enclosed in a square. In Figure 6-13 this is where the interchange with the EAST system is 434 MW and -226 MW with the WEST.

A single-letter code is printed at each end of any limit line which is part of the border of the polygon forming the "clean" portion of the graph; a key is printed with the graph indicating the elements represented by each such annotated constraint line. The two lines whose intersection occurs at the transfer limit are assigned the letter codes "A" and "B"; continuing along the border of the polygon, successively encountered constraint lines are assigned letter codes in alphabetical order.

If the user elects to "Place" the graph in the program window, the graph will appear at completion of the calculation. The output, however, is saved in the ******.pol* type file indicated by the user. That file can be processed with a graphic facility launched with the ***Power Flow>Linear networks>Interchange limits calculations (POLY) - previous results…*** option (see Figure 6-12).

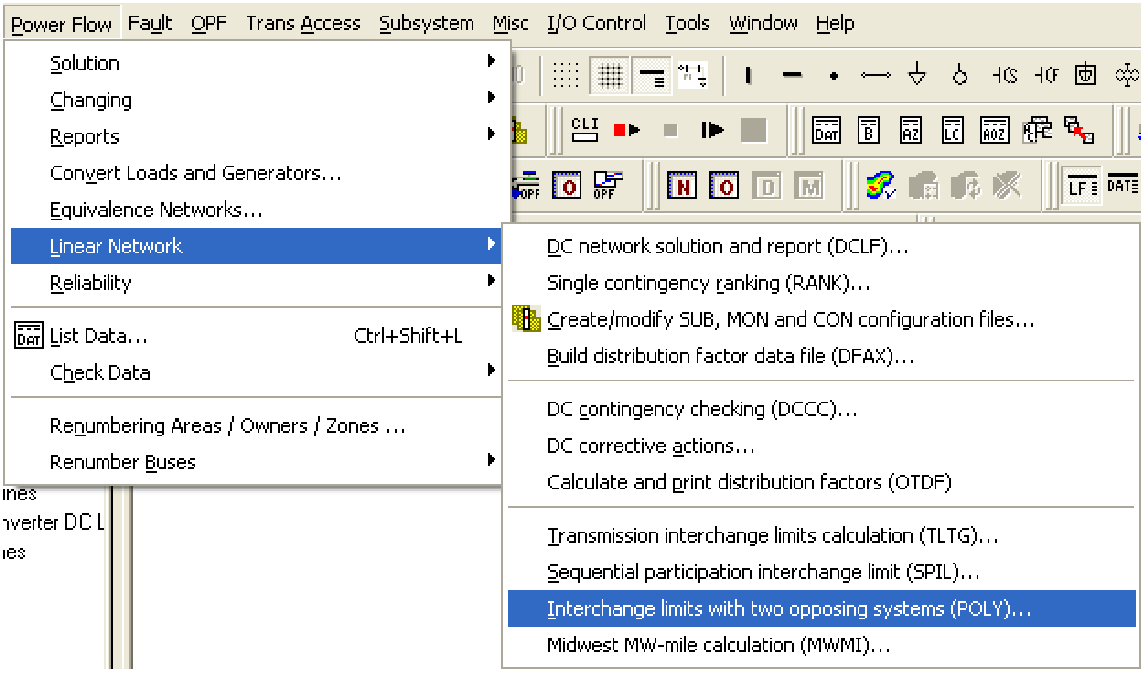


Figure 6-12. Processing the Graphics file for Reporting Interchange Results for Two Opposing Systems

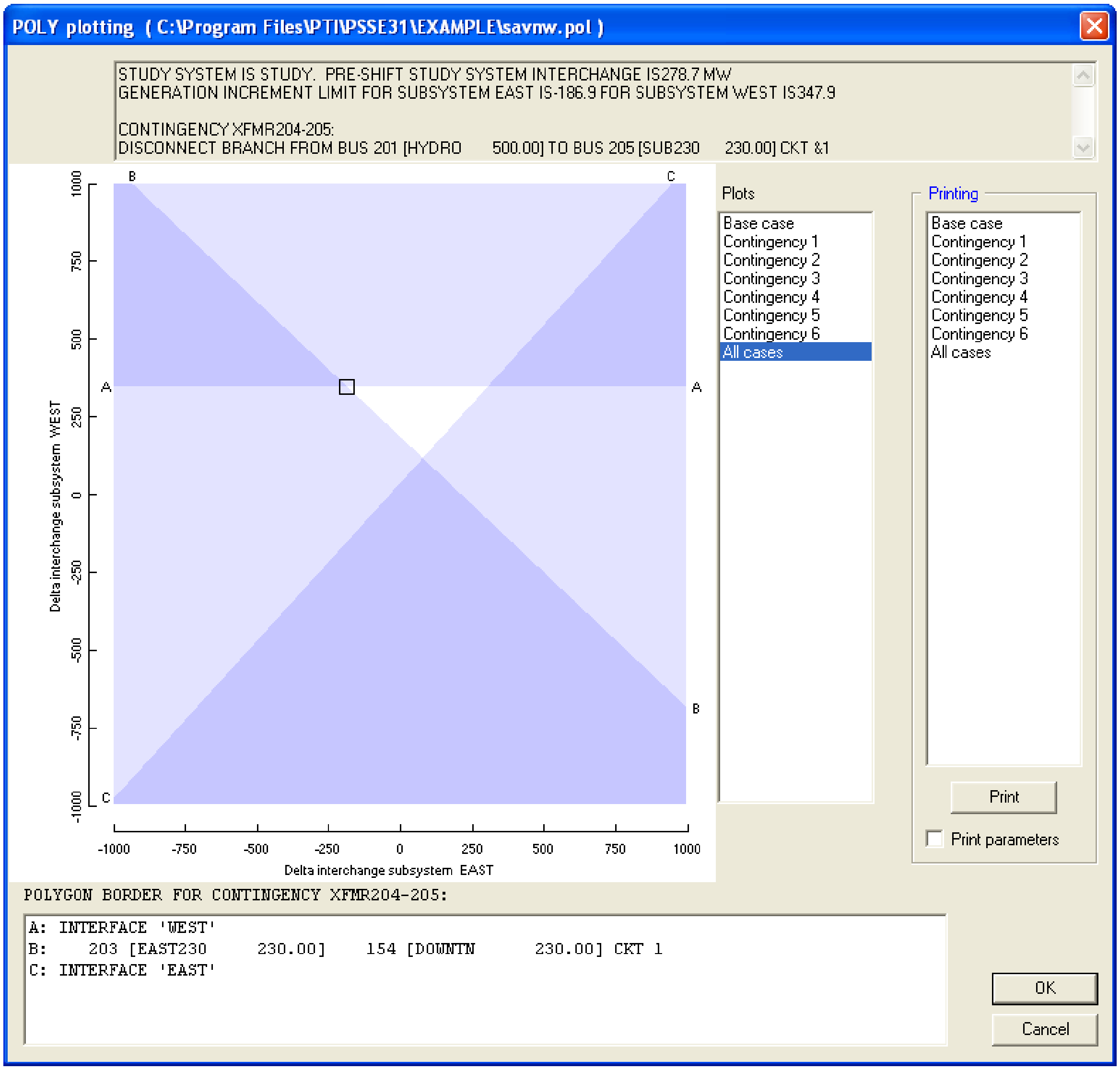


Figure 6-13. Graphical Output from Calculation of Interchange Limit with Two Opposing Systems

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Chapter 7

Short-Circuit Fault Analysis

7.1 Overview: Short-Circuit Fault Analysis

Fault analysis in PSS™E is based on a symmetrical component system representation and treated as a direct extension of the load flow activity group. The positive-sequence system model as established in load flow work is used directly in fault analysis. The negative- and zero-sequence system representations for fault analysis work are established simply by appending negative- and zero-sequence parameter values to the parameter lists describing the system for load flow purposes. The power flow file always includes provision for negative- and zero-sequence parameters of *every* system component. This data may be introduced at any time, and once introduced, it is saved and retrieved as an integral part of a saved case.

PSS™E includes several fault analysis procedures.

- Detailed analysis of complicated multiple unbalanced situations presenting a complete system solution and overall system-oriented output comparable to that of a load flow.
- An automatic sequencing calculations intended for the more routine work of examining simple ground faults at a large number of system locations.
- Circuit breaker duty based on ANSI and/or IEC standards
- Circuit breaker Detailed fault analysis
- Positive sequence pi equivalent for representation of transmission line under single pole operation

Each of these will be discussed in this chapter.

The system under study is modeled by three symmetrical component sequence networks based on the positive-, negative-, and zero-sequence parameters of the three-phase power system elements. The topology of the system, the positive-sequence parameters of all components (except generators in some cases), and the pre disturbance system conditions, are all taken from the load flow saved case. Fault analyses may be made with the same level of system modeling as used in a load flow study. Specifically, fault analyses may do the following:

- Recognize both reactance and resistance and include all actual shunt branches and line charging in the three sequence networks.
- Recognize both the magnitude ratio and phase shift of all transformers, including the inherent shift of delta-wye transformers if it is entered in the load flow data.
- Recognize the actual spread of internal voltage magnitude and phase angle of generators as initialized from a solved load flow case.

- Recognize loads by converting them to equivalent constant shunt admittance.

The level of system modeling detail used in a fault analysis calculation is controlled by manipulating the positive-sequence (or load flow) data in the working file into the required form before commencing fault analysis work. The detailed fault analyses always operate on the assumption that the system is modeled in the highest level of detail. Results corresponding to a simplified modeling basis are obtained if appropriate elements of data have null values, simplified calculating algorithms are not used, and, correspondingly, no computing time advantage is gained by simplifying the system model. The automatic sequencing short circuit analysis operates on the assumption that system modeling will most often be at a low level of detail. The analysis, however, can calculate either on the basis of full detail or a faster algorithm that recognizes only a minimum level of detail.

The overriding principle of fault analysis data management in PSS™E is that the modeling detail and component status information is dictated by the positive-sequence model. Negative- and zero-sequence data values are held in the power flow file only where their values are different from the corresponding positive-sequence values. In setting up the negative and zero-sequence networks, PSS™E assumes the following:

1. All transmission branches (lines and transformers) have the same impedance, charging, and line-connected shunt characteristics in the negative-sequence as in the positive-sequence.

2. All transformers have phase shift in the negative-sequence equal and opposite to that in the positive-sequence.

3. All zero-sequence branches, both transmission branches, line-connected shunts, and bus connected shunts are assumed to have infinite zero-sequence impedance unless a different value is specified.

4. All constant MVA and constant current load specified in the positive-sequence data are converted automatically to constant shunt admittance in the positive-sequence network.

5. All loads are automatically represented by the same shunt admittance in the negative-sequence as in the positive-sequence unless a different negative-sequence shunt admittance is specified.

6. Loads are open circuits in the zero-sequence unless represented specifically by entry of a value of shunt admittance.

7. Lines considered zero-impedance branches in the positive-sequence are considered as zero impedance in the negative- and zero-sequence.

7.2 Preparing Short Circuit Sequence Data

The negative and zero sequence data are appended to the power flow file in preparation for unbalanced network solutions (i.e., fault analysis). The source data records are read from a Sequence Data File (type *.*seq*). This *does not* imply that the data must be executed during any PSS™E work session in which the unbalanced network analyses are to be used. Once a set of sequence data has been appended to a power flow file, it is "carried along" with the network as the case is saved and retrieved.

Sequence data may be listed for examination and modified in a manner similar to that of standard (positive sequence) power flow data. The sequence data appear together with the positive sequence data in the spreadsheet view.

As for positive sequence data, the "raw" sequence data file is read in "free format" with data items separated by a comma or one or more blanks. Each category of data except the change code is terminated by a record specifying an "I" value of zero. Termination of all data is indicated by a value of "Q".

The Sequence Data File contains 10 groups of records (see Figure 7-1) with each group specifying a particular type of sequence data required for fault analysis work. Any piece of equipment for which sequence data is to be entered *must* be represented as power flow data in the powerflow case. If not, the data will not be accepted.

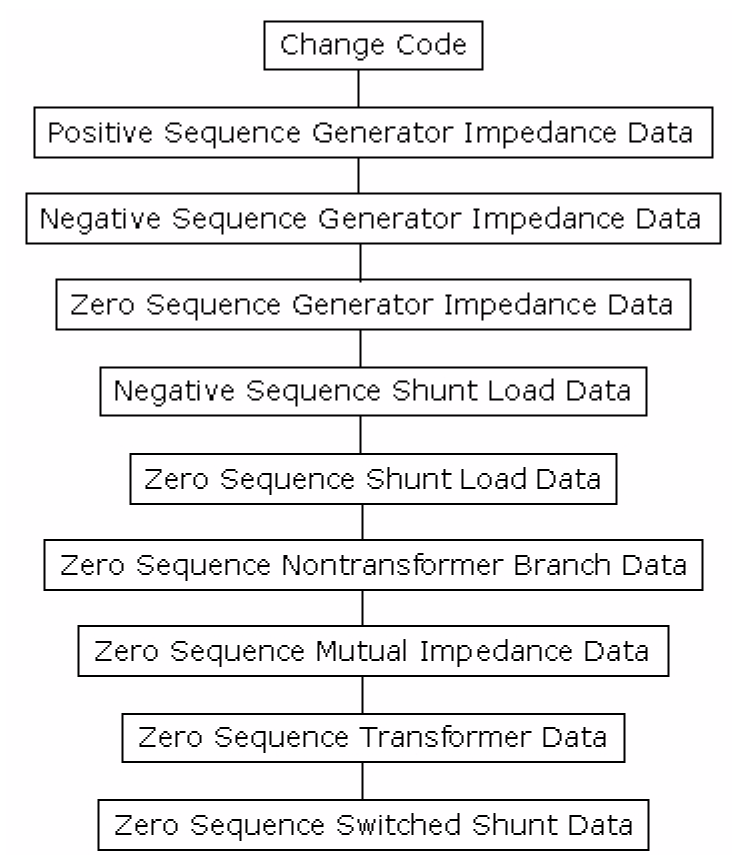


Figure 7-1. Data Stream for Sequence Data Input

7.2.1 Setting the Short Circuit Change Code

The first record in the Sequence Data File contains a single data item, IC, which has the following significance:

IC = 0	Indicates the initial input of sequence data for the network contained in the power flow case. All buses, generators, branches, and switched shunts for which no data record is input in a given category of data have the default values assigned for those data items.
IC = 1	Indicates change case input of sequence data for the network contained in the power flow case. All buses, generators, branches, and switched shunts for which no data record is input in a given category of data have those data items unchanged. (Specifically, they are not set to the default values.)

The use of the change case mode for the appending sequence data is identical to its use in reading the positive sequence power flow data; that is for the addition of equipment to the power flow case (e.g., to add a zero sequence mutual coupling parameters). It is not valid to set IC to one for the initial appending of sequence data. In such a situation, an appropriate message is printed and the process continues its execution as if IC had been specified as zero.

7.2.2 Specifying Positive Sequence Generator Impedance Data

Each network bus to be represented as a generator bus (i.e., as a current source) in the unbalanced analysis activities must have sequence generator impedances appended to the power flow case for all online machines at the bus. The positive sequence values are entered in positive sequence generator impedance data records in the Sequence Data File. Each positive sequence generator impedance data record has the following format:

```
I, ID, ZRPOS, ZXPOS
```

where:

I	Bus number; bus I must be present in the working case as a generator bus.
ID	One- or two-character machine identifier of the machine at bus I whose data is specified by this record. ID = ’1’ by default.
ZRPOS	Generator positive sequence resistance; entered in pu on machine base (i.e., on MBASE base). No default is allowed.
ZXPOS	Generator positive sequence reactance; entered in pu on machine base (i.e., on MBASE base). No default is allowed.

During the initial input of sequence data (i.e., IC = 0 on the first data record), any machine for which no data record of this category is entered has its positive sequence generator impedance, ZPOS (i.e., ZRPOS + j ZXPOS), set equal to ZSORCE. This is the generator impedance which would be entered into the power flow case for use in switching studies and dynamic simulation.

In subsequent appending of sequence data (i.e., IC = 1 on the first data record), any machine for which no data record of this category is entered has its positive sequence generator impedance unchanged. Note that the generator positive sequence impedance appended for fault analysis purposes (ZPOS) is not necessarily the same as the generator impedance (ZSORCE) used in dynamics, and that it *does not* overwrite ZSORCE. That is, the two different positive sequence impedances reside in the power flow file simultaneously at different locations.

Positive sequence generator impedance data input is terminated with a record specifying a bus number of zero.

7.2.3 Specifying Negative Sequence Generator Impedance Data

Each negative sequence generator impedance data record has the following format:

```
I, ID, ZRNEG, ZXNEG
```

where:

I	Bus number; bus I must be present in the working case as a generator bus.
ID	One- or two-character machine identifier of the machine at bus I whose data is specified by this record. ID = ’1’ by default.
ZRNEG	Generator negative sequence resistance; entered in pu on machine base (i.e., on MBASE base). No default is allowed.
ZXNEG	Generator negative sequence reactance; entered in pu on machine base (i.e., on MBASE base). No default is allowed.

During the initial input of sequence data (i.e., IC = 0 on the first data record), any machine for which no data record of this category is entered has its negative sequence generator impedance, ZNEG (i.e., ZRNEG + j ZXNEG), set equal to ZPOS, the positive sequence generator impedance.

In subsequent input of sequence data (i.e., IC = 1 on the first data record), any machine for which no data record of this category is entered has its negative sequence generator impedance unchanged.

Negative sequence generator impedance data input is terminated with a record specifying a bus number of zero.

7.2.4 Specifying Zero Sequence Generator Impedance Data

Each zero sequence generator impedance data record has the following format:

```
I, ID, RZERO, XZERO
```

where:

I	Bus number; bus I must be present in the working case as a generator bus.
ID	One- or two-character machine identifier of the machine at bus I whose data is specified by this record. ID = ’1’ by default.
RZERO	Generator zero sequence resistance; entered in pu on machine base (i.e., on MBASE base). No default is allowed.
XZERO	Generator zero sequence reactance; entered in pu on machine base (i.e., on MBASE base). No default is allowed.

For those machines at which the step-up transformer is represented as part of the generator data (i.e., XTRAN is nonzero), ZZERO (i.e., RZERO + j XZERO) is not used and, in the fault analysis activities, the step-up transformer is assumed to be a delta wye transformer.

Any machine with a zero sequence impedance of zero is treated as an open circuit in the zero sequence.

During the initial input of sequence data (i.e., IC = 0 on the first data record), any machine for which no data record of this category is entered has its zero sequence generator impedance, ZZERO, set equal to ZPOS, the positive sequence generator impedance.

In subsequent input of sequence data RESQ (i.e., IC = 1 on the first data record), any machine for which no data record of this category is entered has its zero sequence generator impedance unchanged.

Zero sequence generator impedance data input is terminated with a record specifying a bus number of zero.

7.2.5 Specifying Negative Sequence Shunt Load Data

Exceptional negative sequence shunt loads (i.e., loads which, in the negative sequence, differ from the positive sequence loads) are appended to the power flow case using the negative sequence shunt load data record with the following format:

```
I, GNEG, BNEG
```

where:

I	Bus number; bus I must be present in the working case.
GNEG	Active component of negative sequence shunt admittance to ground, including *all* load to be represented at the bus; entered in pu.
BNEG	Reactive component of negative sequence shunt admittance to ground, including *all* load to be represented at the bus; entered in pu.

For any bus where no such data record is specified, or GNEG and BNEG are both specified as zero, the load and shunt elements are assumed to be equal in the positive and negative sequence networks.

The user is advised to exercise caution in applying exceptional negative sequence shunt loads. It is the user's responsibility to ensure that the positive sequence loading and shunt data, as contained in the power flow case, is coordinated with the specified negative sequence shunt load.

Negative sequence shunt load data input is terminated with a record specifying a bus number of zero.

7.2.6 Specifying Zero Sequence Shunt Load Data

Zero sequence shunt loads are entered into the working case in zero sequence shunt load data records in the Sequence Data File. Each zero sequence shunt load data record has the following format:

```
I, GZERO, BZERO
```

where:

I	Bus number; bus I must be present in the working case.
GZERO	Active component of zero sequence shunt load admittance to ground to be represented at the bus; entered in pu.
BZERO	Reactive component of zero sequence shunt load admittance to ground to be represented at the bus; entered in pu.

For any bus where no such data record is specified, no shunt load component is represented in the zero sequence. The zero sequence ground tie created by a grounded transformer winding is automatically added to whatever zero sequence shunt load is specified at the bus when the transformer winding connection code data for the transformer is specified (see Section 7.2.9).

Zero sequence shunt load data input is terminated with a record specifying a bus number of zero.

7.2.7 Specifying Zero Sequence Branch Data

Each zero sequence branch data record has the following format:

```
I, J, ICKT, RLINZ, XLINZ, BCHZ, GI, BI, GJ, BJ
```

where:

I	Bus number of one end of the branch.
J	Bus number of the other end of the branch.
ICKT	One- or two-character branch circuit identifier; a non transformer branch with circuit identifier ICKT between buses I and J must be in the working case. ICKT = ’1’ by default.
RLINZ	Zero sequence branch resistance; entered in pu. RLINZ = 0.0 by default.
XLINZ	Zero sequence branch reactance; entered in pu. Any branch for which RLINZ and XLINZ are both 0.0 is treated as open in the zero sequence network. XLINZ = 0.0 by default.
BCHZ	Total zero sequence branch charging susceptance; entered in pu. BCHZ = 0.0 by default.
GI,BI	Complex zero sequence admittance of the line connected shunt at the bus "I" end of the branch; entered in pu. GI + jBI = 0.0 by default.
GJ,BJ	Complex zero sequence admittance of the line connected shunt at the bus "J" end of the branch; entered in pu. GJ + jBJ = 0.0 by default.

The zero sequence network is assumed to be a topological subset of the positive sequence network. That is, it may have a branch in every location where the positive sequence network has a branch, and may not have a branch where the positive sequence network does not have a branch. The zero sequence network does not need to have a branch in every location where the positive sequence network has a branch.

A branch treated as a zero impedance line in the positive sequence is treated in the same manner in the zero sequence, regardless of its specified zero sequence impedance.

During the initial input of sequence data (i.e., IC = 0 on the first data record), any branch for which no data record of this category is entered is treated as open in the zero sequence network (i.e., the zero sequence impedance is set to zero). In subsequent input of sequence data (i.e., IC = 1 on the first data record), any branch for which no data record of this category is entered has its zero sequence branch data unchanged.

Zero sequence branch data input is terminated with a record specifying a "*from bus*" number of zero.

7.2.8 Specifying Zero Sequence Mutual Impedance Data

Each zero sequence mutual impedance data record has the following format:

```
I, J, ICKT1, K, L, ICKT2, RM, XM, BIJ1, BIJ2, BKL1, BKL2
```

where:

I	Bus number of one end of the first branch.
J	Bus number of the other end of the first branch.
ICKT1	One- or two-character branch circuit identifier of the first branch; a branch with circuit identifier ICKT1 between buses I and J must be in the working case. ICKT1 = ’1’ by default.
K	Bus number of one end of the second branch.
L	Bus number of the other end of the second branch.
ICKT2	One- or two-character branch circuit identifier of the second branch; a branch with circuit identifier ICKT2 between buses K and L must be in the working case. ICKT2 = ’1’ by default.
RM,XM	Branch-to-branch mutual impedance coupling circuit ICKT1 from bus I to bus J with circuit ICKT2 from bus K to bus L; entered in pu. No default is allowed.
BIJ1	Starting location of the mutual coupling along circuit ICKT1 from bus I to bus J relative to the bus I end of the branch; entered in per unit of total line length. BIJ1 = 0.0 by default.
BIJ2	Ending location of the mutual coupling along circuit ICKT1 from bus I to bus J relative to the bus I end of the branch; entered in per unit of total line length. BIJ2 = 1.0 by default.
BKL1	Starting location of the mutual coupling along circuit ICKT2 from bus K to bus L relative to the bus K end of the branch; entered in per unit of total line length. BKL1 = 0.0 by default.
BKL2	Ending location of the mutual coupling along circuit ICKT2 from bus K to bus L relative to the bus K end of the branch; entered in per unit of total line length. BKL2 = 1.0 by default.

The following rules must be observed in specifying mutual impedance data:

1. The maximum number of zero sequence mutual couplings that may be entered at the standard size levels of PSS™E is given in Table 1-1 of Chapter 1.
2. The polarity of a mutual coupling is determined by the ordering of the bus numbers (I,J,K,L) in the data record. The "dot" convention applies, with the "*from buses*" (I and K) specifying the two "dot" ends of the coupled branches.
3. RM+jXM specifies the circuit-to-circuit mutual impedance, given the polarity implied by I and K.
4. The geographical "B" factors are required only if one or both of the two mutually coupled lines is to be involved in an unbalance part way down the line, *and* only part of the length of one or both of the lines is involved in the coupling.
5. The values of the "B" factors must be between zero and one inclusive; they define the portion of the line involved in the coupling.

6. BIJ1 must be less than BIJ2, and BKL1 must be less than BKL2.

7. Mutuals involving transformers or zero impedance lines are ignored by the fault analysis solution activities.

Figure 7-2 schematically illustrates a mutual coupling with BIJ1 = 0.0, BIJ2 = 0.4, BKL1 = 0.0 and BKL2 = 1.0 (the first 40% of the first line coupled with the entire second line).

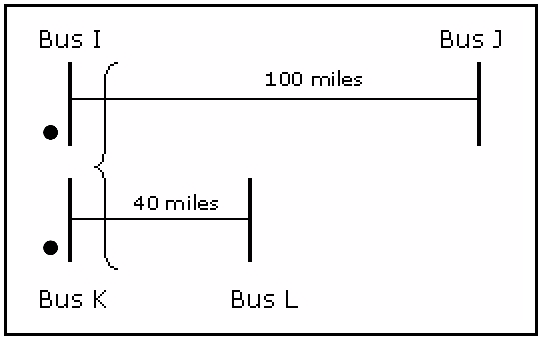


Figure 7-2. Mutual Coupling Example 1

As a second example, BIJ1 = 0.6, BIJ2 = 1.0, BKL1 = 0.0 and BKL2 = 0.6 (last 40% of the first line coupled with the first 60% of the second line) might be depicted as follows in Figure 7-3.

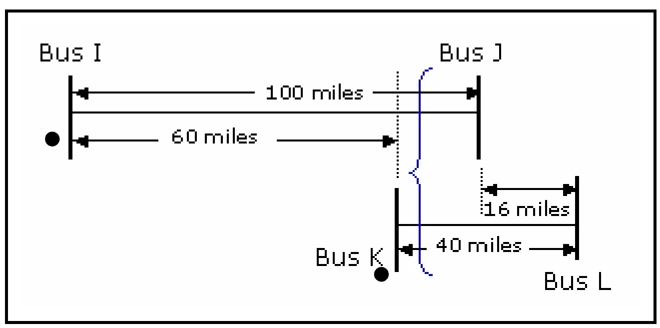


Figure 7-3. Mutual Coupling Example 2

Zero sequence mutual impedance data input is terminated with a record specifying a "*from bus*" number of zero.

7.2.9 Specifying Zero Sequence Transformer Data

Each transformer data record has one of the following formats,

for two-winding transformers:

```
I, J, K, ICKT, CC, RG, XG, R1, X1, RG2, XG2
```

for three-winding transformers:

```
I, J, K, ICKT, CC, RG, XG, R1, X1, R2, X2, R3, X3
```

where:

I	Bus number of the bus to which a winding of the transformer is connected.
J	Bus number of the bus to which another winding of the transformer is connected.
K	Bus number of the bus to which another winding of the transformer is connected. Zero is used to indicate that no third winding is present (i.e., that a two-winding transformer is being specified). K = 0 by default.
ICKT	One- or two-character transformer circuit identifier; a transformer with circuit identifier ICKT between buses I and J (and K if K is nonzero) must be in the working case. ICKT = ’1’ by default.
CC	Winding connection code indicating the connections and ground paths to be used in modeling the transformer in the zero sequence network. For a two-winding transformer, valid values are 1 through 8. They define the following zero sequence connections (see Figure 7-4). I series path (e.g., grounded wye-grounded wye) 2 no series path, ground path on winding one side (e.g., grounded wye-delta) 3 no series path, ground path on winding two side (e.g., delta-grounded wye) 4 no series or ground path (e.g., delta-delta) 5 series path, ground path on winding two side (normally only used as part of a three-winding transformer) 6 no series path, ground path on winding one side, earthing transformer on winding two side (e.g., grounded wye-delta with an earthing transformer) 7 no series path, earthing transformer on winding one side, ground path on winding two side (e.g., delta with an earthing transformer-grounded wye) 8 series path, ground path on each side (e.g., grounded wye-grounded wye core-type autotransformer with a grounding resistance) For a three-winding transformer, values of 1 through 5 define the following transformer types (see also Figure 7-5). The connection codes of the three two-winding transformers comprising the three-winding transformer are shown in parenthesis in winding number order: 1 wye-wye-wye; (5-1-1). 2 wye-wye-delta; (1-1-3). 3 delta-wye-delta (non-autotransformer); (3-1-3). 4 delta-delta-delta; (3-3-3). 5 delta-wye-delta (autotransformer); (1-2-1).

	For a three-winding transformer, CC may also be specified as a three digit number, each digit of which is 1 through 7; the first digit applies to the first winding, the second to the second winding, and the third to the third winding, where the winding connections correspond to the first seven two-winding transformer connections shown in Figure 7-4.
	CC = 4 by default.
RG, XG	Zero sequence grounding impedance for an impedance grounded transformer. For a two-winding transformer, ZG (i.e., RG + jXG) is applied as shown in Figure 7-4 if the connection code is 2, 3, 5, 6, 7 or 8, and is ignored if the connection code is 1 or 4. For a three-winding transformer, ZG is modeled in the lowest numbered winding whose corresponding connection code is 2, 3, 5, 6 or 7; no grounding impedance is modeled in the other two windings regardless of their connection codes. RG and XG are entered in per unit.
	RG + jXG = 0.0 by default.
R1, X1	Zero sequence impedance of a two-winding transformer, or the winding one zero sequence impedance of a three-winding transformer, entered in per unit. R1 + jX1 is equal to the winding’s positive sequence impedance by default.
RG2, XG2	Zero sequence grounding impedance at the winding 2 side of an impedance grounded two-winding transformer whose connection code is 8. ZG2 (i.e., RG2 + jXG2) is applied as shown in Figure 7-4 if the connection code is 8, and is ignored if the connection code is 1 through 7. RG2 and XG2 are entered in per unit. RG2 + jXG2 = 0.0 by default.
R2, X2	Winding two zero sequence impedance of a three-winding transformer, entered in per unit; treated as RG2 and XG2 for a two-winding transformer. R2 + jX2 is equal to the winding’s positive sequence impedance by default.
R3, X3	Winding three zero sequence impedance of a three-winding transformer, entered in per unit; ignored for a two-winding transformer. R3 + jX3 is equal to the winding’s positive sequence impedance by default.

In specifying zero sequence impedances for three-winding transformers, note that *winding* impedances are required, and that the zero sequence impedances default to the positive sequence winding impedances. Recall that, in specifying positive sequence data for three-winding transformers, measured impedances between pairs of buses to which the transformer is connected, not winding impedances, are required. PSS™E converts the measured bus-to-bus impedances to winding impedances which are subsequently used in building the network matrices.

Specification of the transformer connection code along with the impedances entered here enables the fault analysis activities to correctly model the zero sequence transformer connections, including the ground ties and open series branch created by certain grounded transformer windings. If no connection code is entered for a transformer, all windings are assumed to be open. Zero sequence transformer default data is such that the transformer appears as an open circuit in the zero sequence network. Therefore, zero sequence data must be entered for all grounded transformers.

Connection codes *do not* indicate the inherent phase shift due to the relative connection of delta and wye windings. This phase shift is specified in the positive sequence power flow data.

Zero sequence transformer data input is terminated with a record specifying a "*from bus*" number of zero.

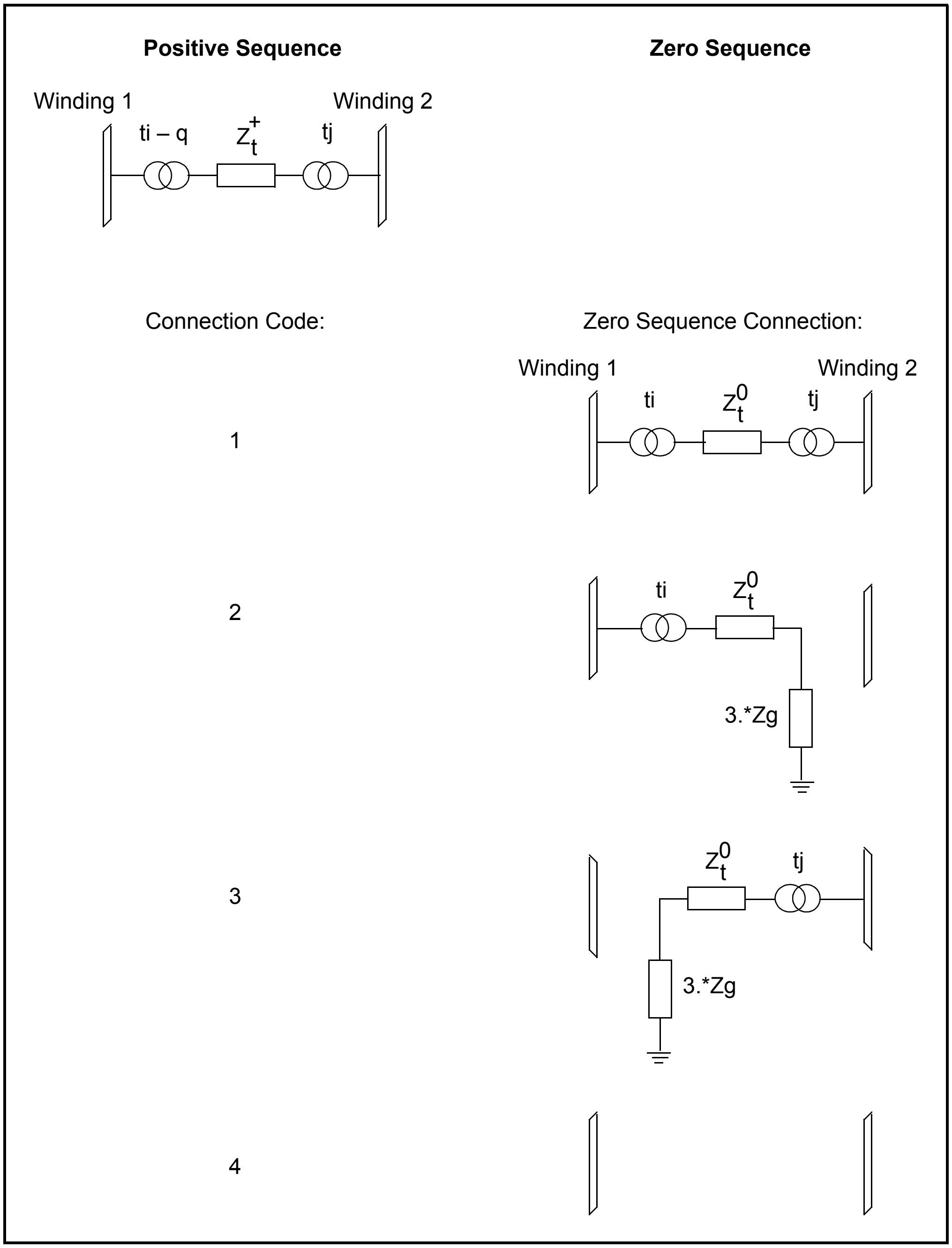


Figure 7-4. Two-Winding Transformer Grounding Codes

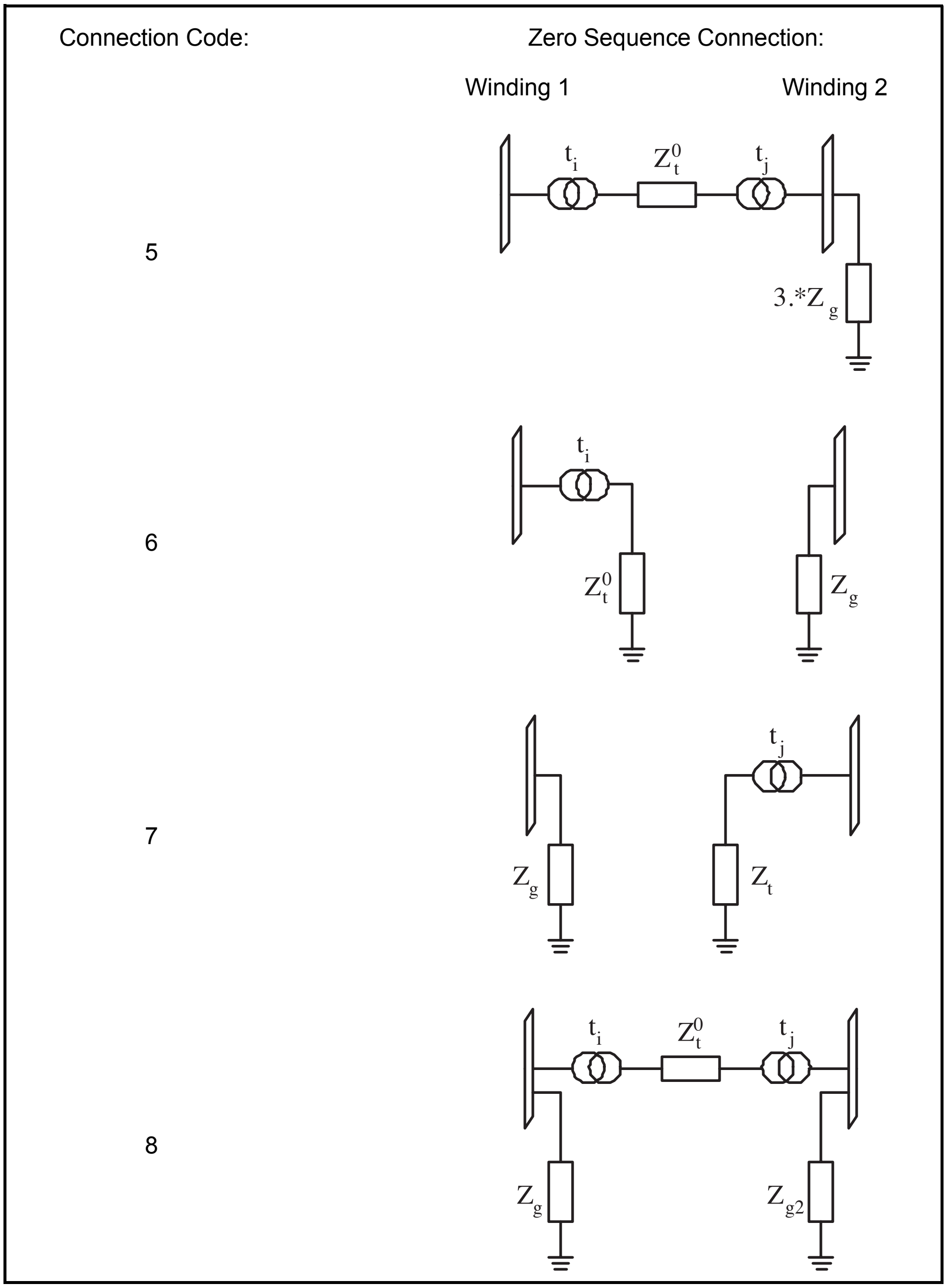
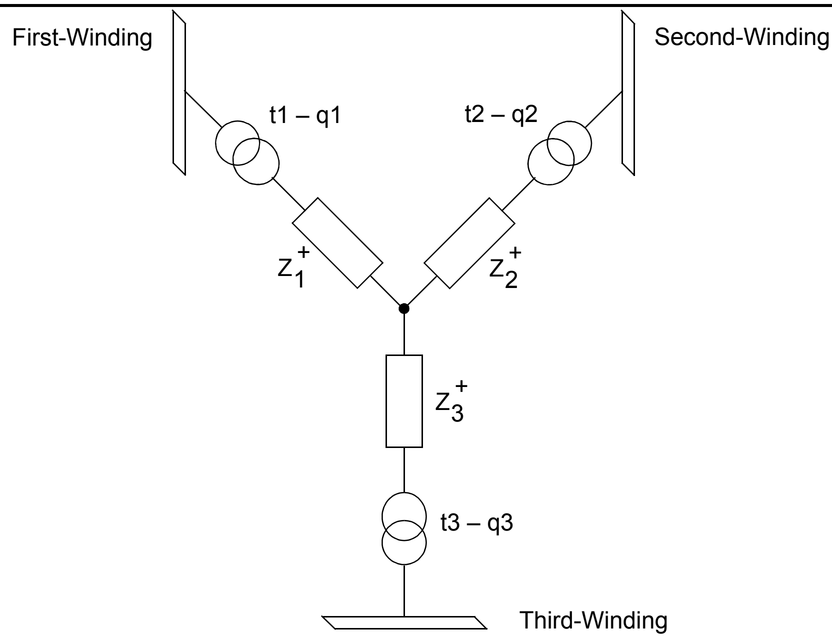
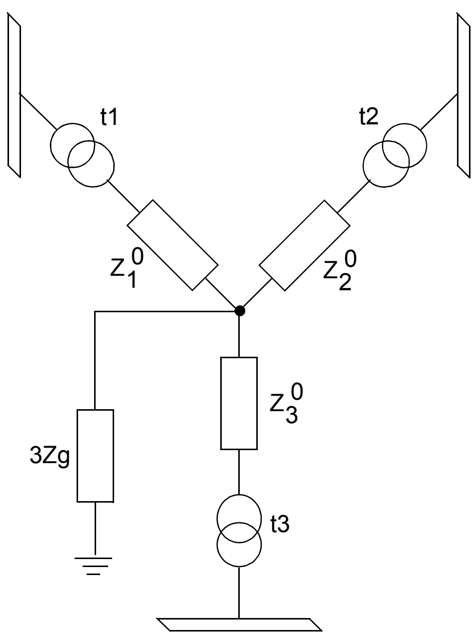


Figure 7-4. (Cont.) Two-Winding Transformer Grounding Codes



a. Positive Sequence



where:

$$Z_1^0 = Z_1^+ + 3Z_{1-G}$$

$$Z_2^0 = Z_2^+ + 3Z_{2-G}$$

$$Z_3^0 = Z_3^+ + 3Z_{3-G}$$

where Z_{n-g} = the impedance from the neutral of a winding to the grounding impedance.

For solidly grounded neutrals:

$$Z_1^0 = Z_1^+$$

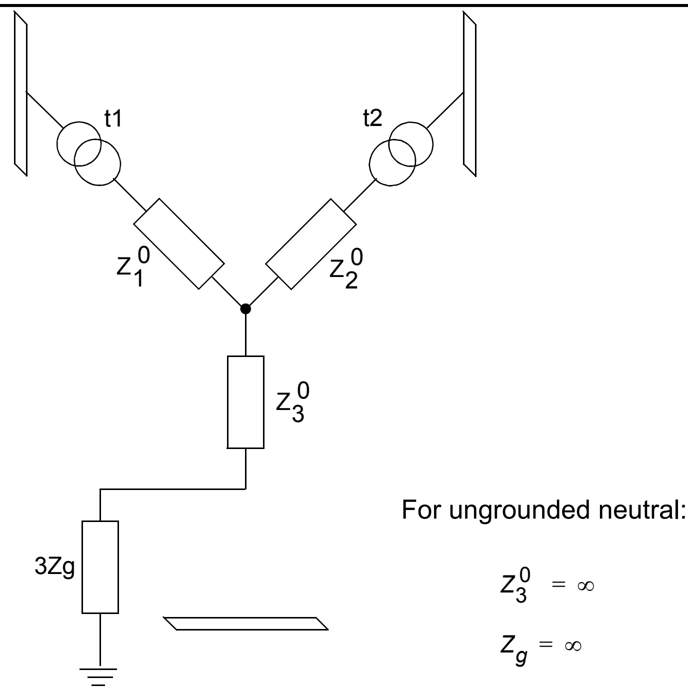
$$Z_2^0 = Z_2^+$$

$$Z_3^0 = Z_3^+$$

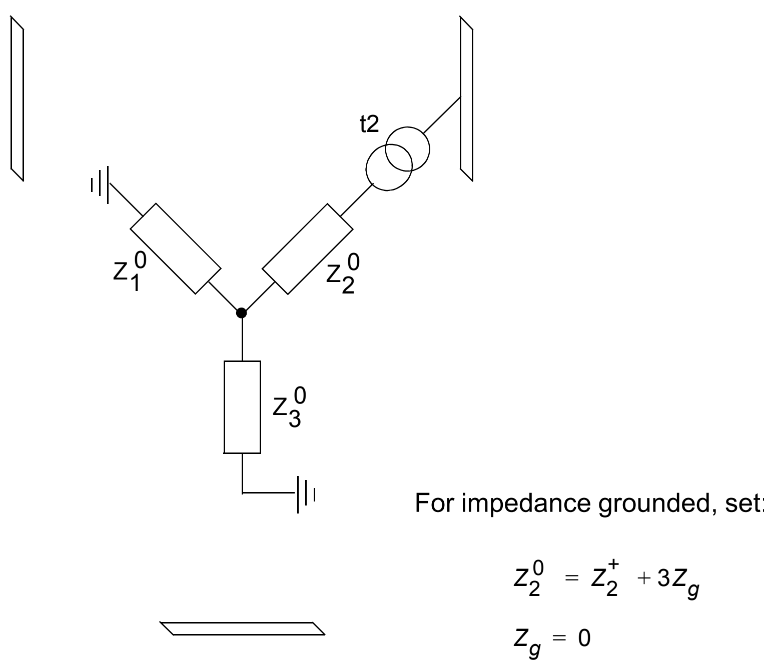
$$Z_g = 0$$

b. Zero Sequence, Connection Code = 1 (wye/wye/wye)

Figure 7-5. Three-Winding Transformer Grounding Codes

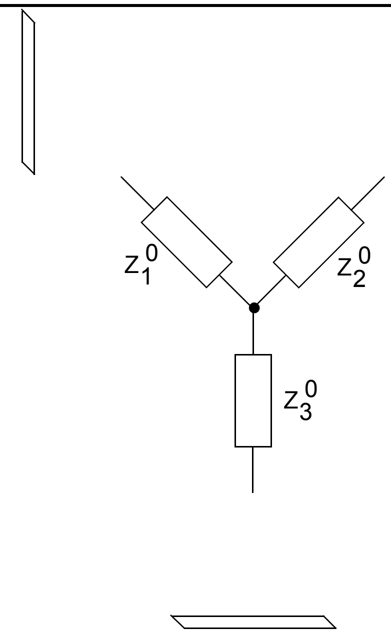


c. Zero Sequence, Connection Code = 2 (wye/wye/delta)

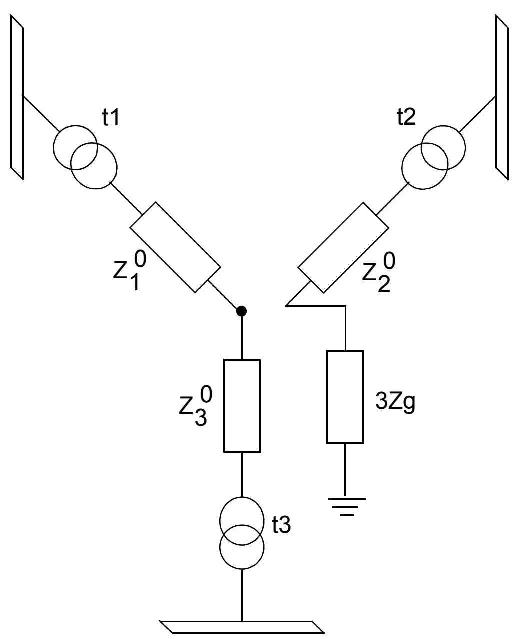


d. Zero Sequence, Connection Code = 3 (non-autotransformer delta/wye/delta)

Figure 7-5. (Cont.) Three-Winding Transformer Grounding Codes



e. Zero Sequence, Connection Code = 4 (delta/delta/delta)



f. Zero Sequence, Connection Code = 5 (autotransformer delta/grounded wye/delta)

Figure 7-5. (Cont.) Three-Winding Transformer Grounding Codes

7.2.9.1 Analyzing the Impact of Transformer Phase Shift

The use of connection codes establishes only the form of the equivalent circuit to be used; it does not complete the representation of the transformer. The details of the transformer must be conveyed to PSS™E by the specification of proper zero-sequence impedance and positive-sequence phase-shift values.

The winding type codes *do not* distinguish between an ungrounded wye-winding and a delta-winding. This distinction is conveyed by the specification of transformer phase shift in the positive-sequence data. A delta-wye transformer, has an inherent 30° phase shift, which must be specified as a positive-sequence phase shift of either +30 or –30° in the load flow data if the behavior of the delta-wye transformer is to be represented completely. If the 30° phase shift is not specified, it is implied that the transformer is either wye-wye or delta-delta connected.

The significance of transformer phase shift, and the effect of ignoring it, is illustrated by Figures 7-6 and 7-7. Consider the radially connected wye-delta transformer as shown in Figure 7-6. It is represented as a two-winding transformer with a connection code of 2. The remaining details are specified via the phase-shift and impedance values. The correct representation is as shown in Figure 7-6, with a 30° phase shift in the turns-ratio of the positive-sequence model. An incorrect, but often used representation, would be to ignore the phase shift, also shown in Figure 7-6.

The fault analysis results, for a single phase-to-ground fault on the wye-connected winding, are shown in Figure 7-7a. The correct result obtained when transformer phase shift is represented properly are shown in Figure 7-7b.

The sequence currents in the wye winding are given by

$$I_0 = I_1 = I_2 = I_f/3$$

The sequence currents flowing in the leads to the delta-winding are given by

$$I_0 = 0$$

$$I_1 = I_f \div 3 \text{ at } 30°$$

$$I_2 = I_f \div 3 \text{ at } -30°$$

The phase currents corresponding to these delta-winding sequence currents are shown in the following figure. One leg of the delta connection carries a current of $I_f \div \sqrt{3}$, which flows in two of the leads on this side of the transformer. This data is correct with respect to magnitude and phase of the sequence currents, and to magnitude and phase of the transformer phase currents.

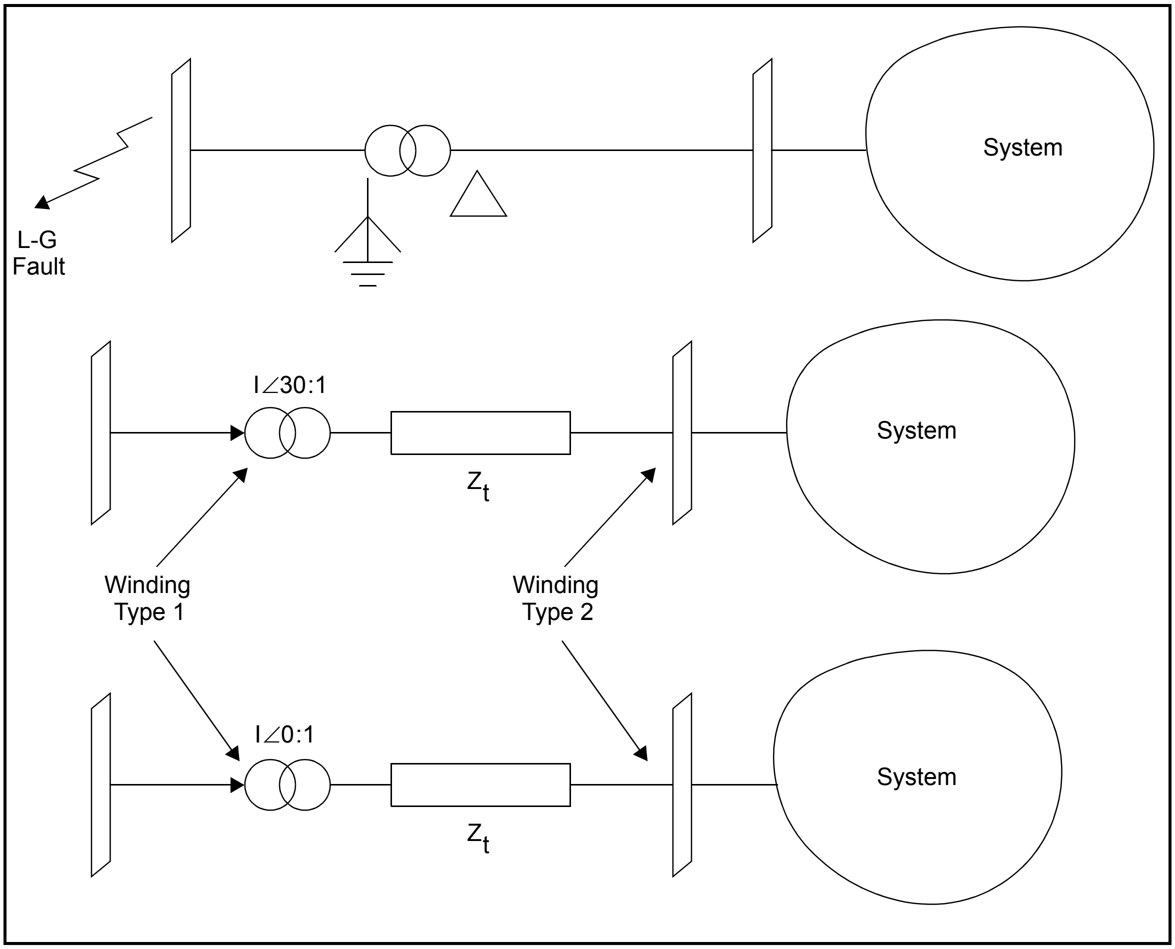


Figure 7-6. Representation of a Wye-Delta Transformer With and Without Its 30° Phase Shift

Figure 7-7b shows the results obtained when the phase shift of the transformer is ignored. The sequence and phase currents on the fault side of the transformer are identical in amplitude to those calculated with phase shift present. (They are all shifted in phase by 30°, however.) The sequence and phase currents calculated for the delta-connected winding in the absence of transformer phase shift are significantly different from those shown in Figure 7-7a.

While Figure 7-7a shows correct results with the positive- and negative-sequence leading and lagging the fault current by 30°, respectively, the results shown in Figure 7-7b have positive- and negative-sequence current in phase with the fault current. The lead currents corresponding to these sequence currents are as shown, with a current $2I_f \div 3$ in one phase and currents of $I_f \div 3$ in the other two. The corresponding currents in the delta-connected transformer windings are inconsistent with the currents in the wye-connected winding.

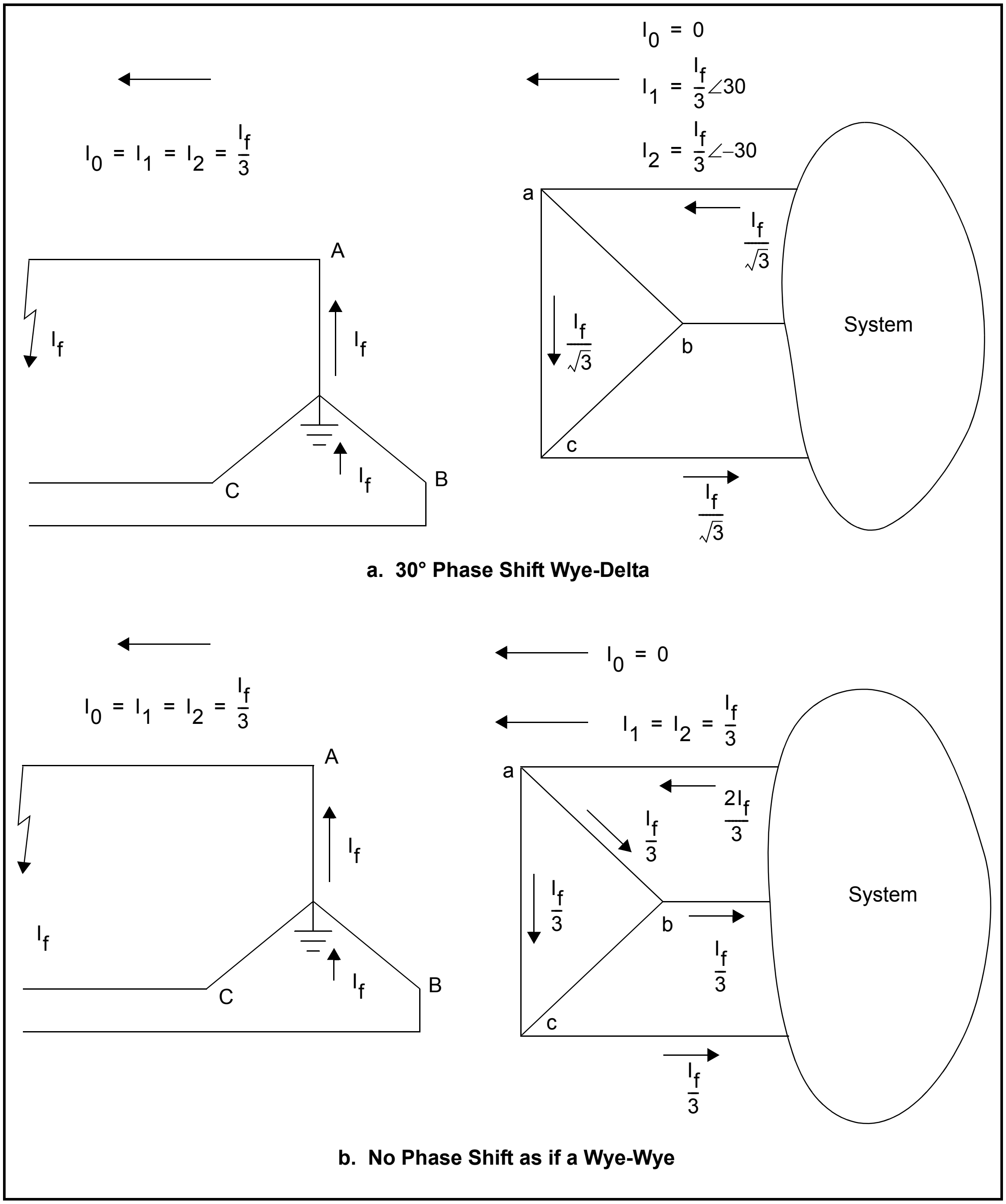


Figure 7-7. Effect of Including and Neglecting 30° Phase Shift in Transformer with One Grounded and One Ungrounded Winding

It is evident, then, that neglect of the inherent 30° phase shift of wye-delta transformers results in the following:

- Calculated sequence and phase currents that are correct in all branches on the fault side of the transformer.
- Calculated sequence currents that are correct in amplitude but erroneous in phase in all branches that are removed from the fault by a transformer.
- Erroneous values of phase current in all branches separated from the fault by a wye-delta transformer.

7.2.9.2 Analyzing Sequence Impedance Adjustment as a Function of Tap Position

When the transformer's positive-sequence leakage impedance is adjusted as a function of tap position in the positive-sequence, the fault calculation process will give the user two options:

- Apply the impedance adjustment factor to the zero-sequence leakage impedance as well as to the positive-sequence impedance.
- Apply the impedance adjustment factor to the positive-sequence leakage impedance alone, and use the zero-sequence impedance value as originally appended to the power flow case.

In both cases the negative-sequence leakage impedance is adjusted by the impedance correction factor in the same way as the positive-sequence impedance. The single option selection applies to all transformers for which impedance adjustment is specified in the load flow data.

7.2.9.3 Analyzing Generators and Step-Up Transformers

Each generator is modeled in the negative and zero-sequences as a simple impedance connected to ground at the generator neutral as shown in Figure 7-8. The negative- and zero-sequence impedances of the generator are specified as the parameters ZNEG and ZZERO. The step-up transformer, if represented as a part of the generator, is assigned the same impedance, ZTRAN, in all three sequences. Figure 7-8a represents the generator model when the transformer is included with the generator, and Figure 7-8b represents it when the transformer is treated as a part of the transmission network. The generators may be characterized in the positive-sequence by either their dynamic impedances, ZSORCE, or a different positive-sequence impedance, ZPOS.

ZSORCE should always be set to the value, normally the subtransient impedance, Z'', required for representation of the generator in dynamic simulations. ZPOS may be set equal to ZSORCE or any other value, such as the transient impedance, Z', which may represent the generator in fault analysis studies. While the ZSORCE values assigned to the generators may be a mixture of subtransient and transient values, depending upon the modeling levels chosen for the individual generators, the ZPOS values should be consistently transient or subtransient values for all generators. The use of subtransient impedances as the values of ZPOS for all generators leads to fault calculations giving the conditions at an instant immediately after the unbalancing event. The use of transient values results in fault calculations giving conditions a short time, say 0.1 seconds, after the event when the subtransient components of the generator flux transients have died out and the generator can be regarded as a voltage source behind transient impedance.

Generators are modeled in the negative-sequence by the impedance, ZNEG, connected in series with the generator transformer reactance, ZTRAN, and thence to ground. The normal value for ZNEG is the *subtransient* impedance of the generator, regardless of the choice of values for ZSORCE and ZPOS. The generator zero-sequence model is the impedance, ZZERO, connected to ground. ZZERO should be assigned the value ($3R_g + jX_o$), where:

R_g = the generator grounding resistance in per unit with respect to generator base voltage and generator base, MVA.

X_o = the generator zero-sequence impedance, per unit, with respect to generator base, MVA.

When the generator step-up transformer is modeled as a part of the generator it is *always* treated as a two-winding unit:

- Delta-connected on the generator side.
- Wye-connected and solidly grounded on the transmission system side.
- Radial to the generator.

Plant arrangements where the step-up transformers cannot be modeled in this manner must have the transformers represented as a part of the transmission system. The plant connections produced in the three sequences by PSS™E are shown in Figure 7-8. The generator zero-sequence impedance need not be specified when the step-up transformer is represented as part of the generator.

The unbalanced solutions of PSS™E calculate and display generator conditions only at the bus to which the generator is connected. Hence, inclusion of the step-up transformer precludes display of generator terminal conditions in the fault analysis results; all generator currents shown in fault analysis reports are as observed at the bus-side of the step-up transformer. Generator unbalanced *terminal* conditions can be observed only when the step-up transformer is represented as a transmission system branch, the generator zero-sequence impedance is specified, and the generator terminals are a bus in the system model.

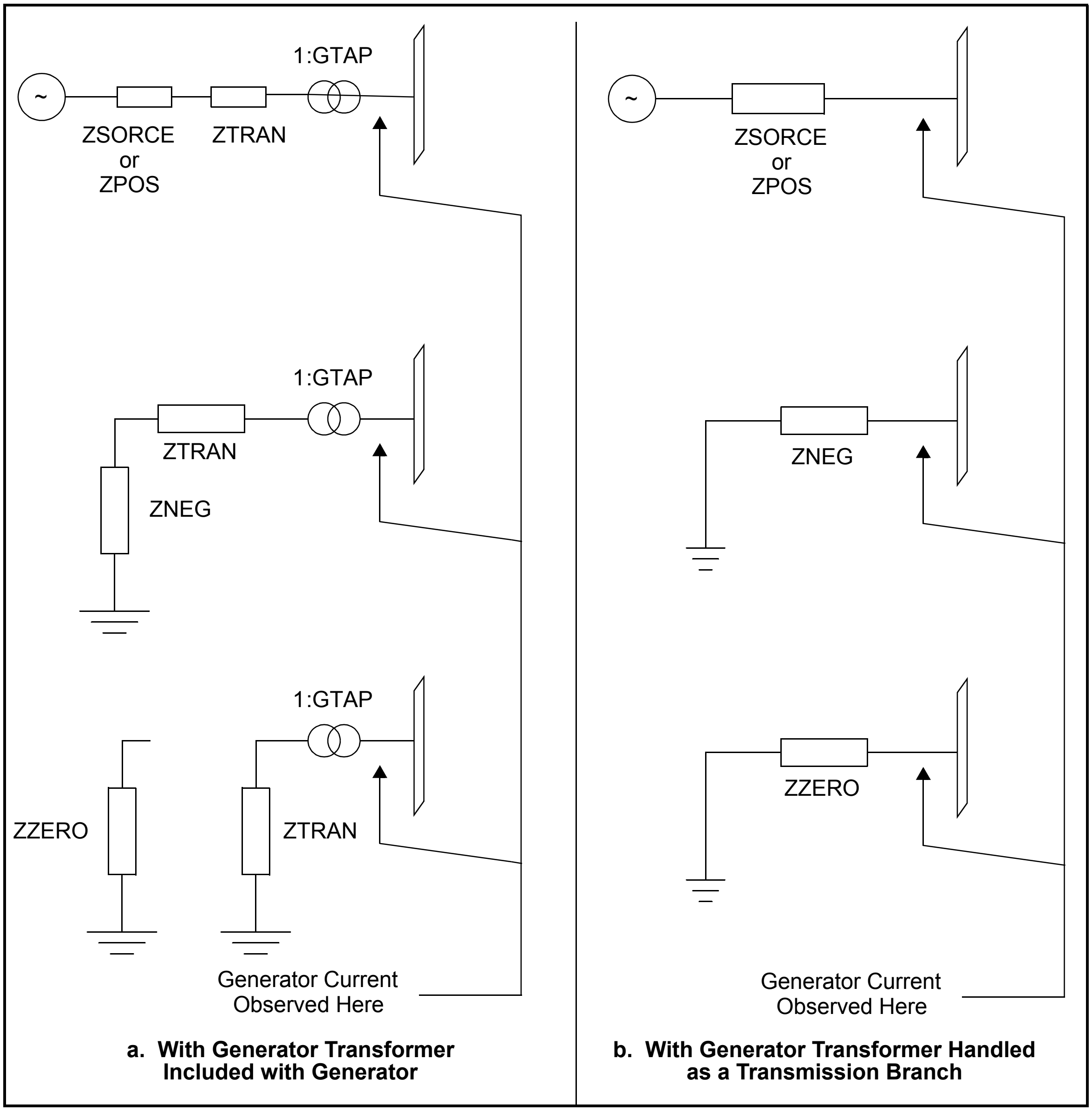


Figure 7-8. Generator Modeling in Fault Analysis Database

7.2.10 Specifying Zero Sequence Switched Shunt Data

Each switched shunt data record has the following format:

```
I, BZ1, BZ2, ... BZ8
```

where:

I	Bus number; bus I must be present in the working case with positive sequence switched shunt data.
BZ_i	Zero sequence admittance increment for each of the steps in block i; entered in pu. BZ_i = 0.0 by default.

Data specified on zero sequence switched shunt data records must be coordinated with the corresponding positive sequence data. The number of blocks and the number of steps in each block are taken from the positive sequence data.

The input process will alarm any block for which any of the following applies:

- The positive sequence admittance is positive and the zero sequence admittance is negative.
- The positive sequence admittance is negative and the zero sequence admittance is positive.
- The positive sequence admittance is zero and the zero sequence admittance is nonzero.

The zero sequence admittance switched on at a bus is determined from the bus' positive sequence value, with the same number of blocks and steps in each block switched on.

Zero sequence switched shunt data input is terminated with a record specifying a bus number of zero.

7.3 Appending Sequence Data to the Power Flow Case

As described in the previous pages in Section 7.2, the user is required to prepare a Sequence Data file (type *.seq) in the data record formats shown and in the required order of data categories. As for positive sequence data, the "raw" sequence data file is read in "free format" with data items separated by a comma or one or more blanks. Once the sequence data has been appended to a power flow case, it is "carried along" with the network as the case is saved and retrieved.

To append the sequence data to the power flow case, the ***File>Open*** option is selected. This, in turn, will open the file dialog where files of the type **.seq* can be accessed (see Figure 7-9).

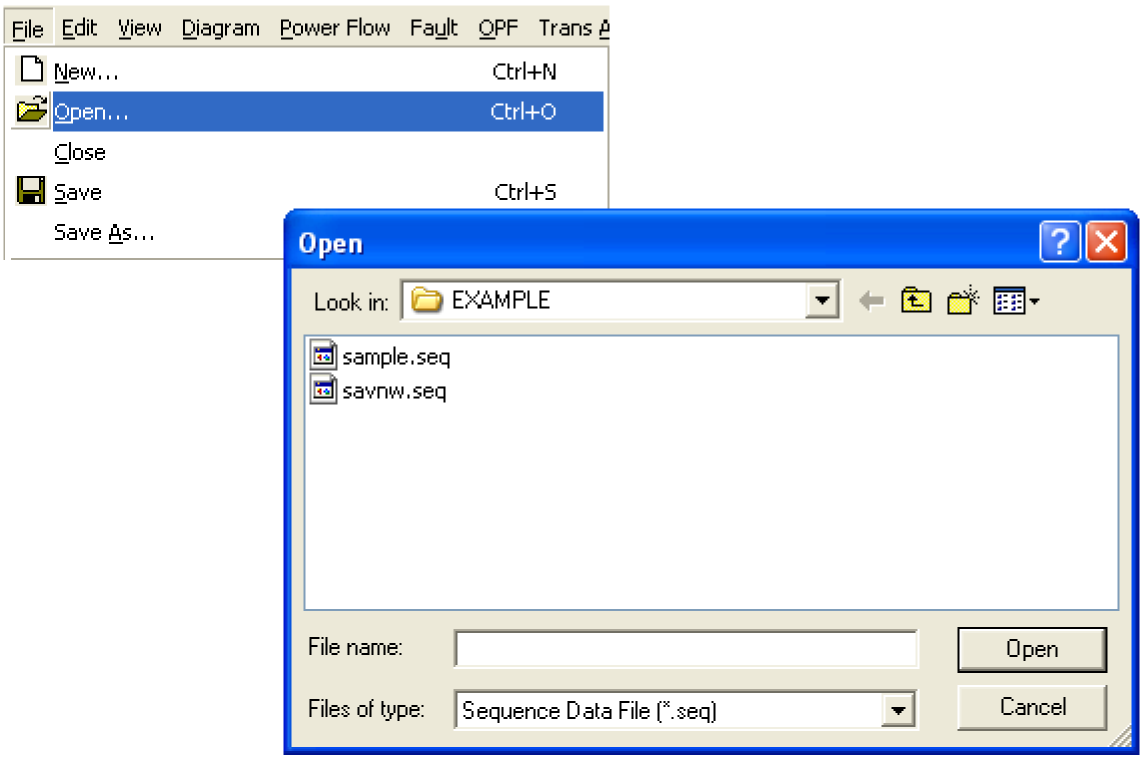


Figure 7-9. Opening the Sequence Data File

Selecting and opening the file will initiate appending the data. Progress in importing of each data category will show in the Output Bar (see Figure 7-10).

```
ENTER IC
ENTER POSITIVE SEQUENCE MACHINE IMPEDANCES
ENTER NEGATIVE SEQUENCE MACHINE IMPEDANCES
ENTER ZERO SEQUENCE MACHINE IMPEDANCES
ENTER NEGATIVE SEQUENCE SHUNTS
ENTER ZERO SEQUENCE SHUNTS
ENTER ZERO SEQUENCE NON-TRANSFORMER BRANCH DATA
ENTER MUTUAL DATA
ENTER ZERO SEQUENCE TRANSFORMER DATA
ENTER SWITCHED SHUNT DATA
```

Figure 7-10. Output when Appending Sequence Data

If the change code parameter IC in the first record of the Sequence Data File is set to one and sequence data had not previously been read for the system in the working case, an alarm is printed and the data is processed as if IC was set to zero. Remember that a code of zero indicates that the data is being appended for the first time.

As for positive sequence data, the "raw" sequence data file is read in "free format" with data items separated by a comma or one or more blanks. Each category of data except the change code is terminated by a record specifying an "I" value of zero. Specifying a data record with a "Q" in column one is used to indicate that no more data records are to be supplied.

In Section 1.6.4 the run-time "Options" were described. One of the options available to the user is to enable warnings to be issued when there are "apparent" problems with the sequence data being appended to the power flow case. When the fault analysis warning option is enabled, the following tabulations are produced:

1. When IC is zero, a listing of all online machines at type two and three buses for which no negative sequence generator impedance is entered. The negative sequence generator impedance, ZNEG, is set to the positive sequence value, ZPOS.

2. When IC is zero, a listing of all online machines at type two and three buses for which no zero sequence generator impedance is entered. The zero sequence generator impedance, ZZERO, is set to the positive sequence value, ZPOS.

Each of these tabulations may be individually suppressed by entering the AB interrupt control code.

7.3.1 Viewing the Sequence Data in the Power Flow Case

As for the positive sequence data, the negative and zero sequence data are shown in the spreadsheet. For the *savnw.sav* power flow case, appended with the *savnw.seq* data file, Figure 7-11 shows the machine sequence data.

RG-Pos (pu)	XG-Pos (pu)	RG-Neg (pu)	XG-Neg (pu)	RG-Zero (pu)	XG-Zero (pu)
0.010000	0.600000	0.010000	0.600000	8000.000000	0.600000
0.010000	0.600000	0.010000	0.600000	8000.000000	0.600000
0.010000	0.500000	0.010000	0.500000	12000.00000	0.500000
0.010000	0.400000	0.010000	0.400000	7000.000000	0.400000
0.010000	0.700000	0.010000	0.700000	14000.00000	0.700000
0.010000	0.700000	0.010000	0.700000	2000.000000	0.700000

Figure 7-11. Machine Sequence Data from Power Flow Case savnw.sav

Section 2.4 describes the means by which the data in the spreadsheet can be edited, filtered, sorted, exported and otherwise manipulated. Those functions apply equally to the sequence data.

Data can be changed or additional data can be imported by using the ***File>Open*** option to open a subsequent Sequence Data file with a change case mode (IC = 1). All buses, generators, branches, and switched shunts for which no data record is input in a given category of data have those data items unchanged. (Specifically, they are not set to the default values.)

Selecting the ***Power Flow>List data*** option will open the List Data dialog (see Figure 7-12). There it can be seen that the user can simply list all data; select by category and select by subsystems. The output listing can be directed to a file or to a Report tab.

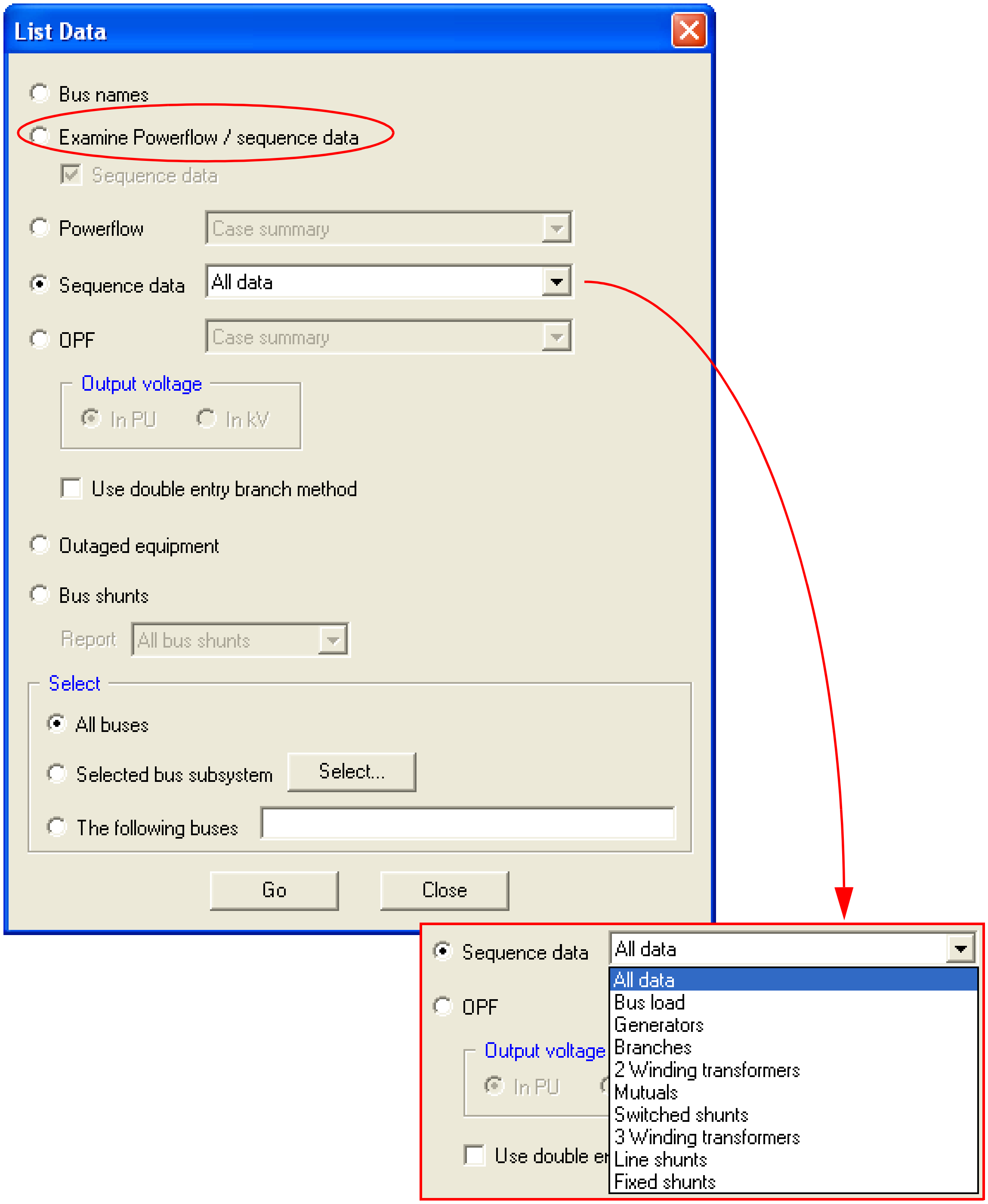


Figure 7-12. Listing Sequence Data

7.4 Fault Calculation Modeling Assumptions

7.4.1 Using a Detailed Fault Calculation Model

The system under study is modeled by three symmetrical component sequence networks based on the positive-, negative-, and zero-sequence parameters of the three-phase power system elements. The topology of the system, the positive-sequence parameters of all components (except generators in some cases), and the pre disturbance system conditions, are all taken from the load flow saved case. Fault analyses may be made with the same level of system modeling as used in a load flow study. Specifically, fault analyses may do the following:

- Recognize both reactance and resistance and include all actual shunt branches and line charging in the three sequence networks.
- Recognize both the magnitude ratio and phase shift of all transformers, including the inherent shift of delta-wye transformers if it is entered in the load flow data.
- Recognize the actual spread of internal voltage magnitude and phase angle of generators as initialized from a solved load flow case.
- Recognize loads by converting them to equivalent constant shunt admittance.

The level of system modeling detail used in a fault analysis calculation is controlled by manipulating the positive-sequence (or load flow) data in the working file into the required form before commencing fault analysis work. The detailed, unbalanced fault analyses activities, described in Section 7.5, usually operate on the assumption that the system is modeled in the highest level of detail. In these activities, although results corresponding to a simplified modeling basis are obtained if appropriate elements of data have null values, simplified calculating algorithms are not used. Therefore, no computing time advantage is gained by simplifying the system model. One advantage to simplifying the model, as described in Section 7.4.3 is to allow comparison of PSS™E results with those obtained from other software packages which usually use a more simple or "classical" model.

7.4.1.1 Detailed Fault Calculation Models for DC Lines and FACTS Devices

If any unblocked DC lines or in-service FACTS devices are present in the working case, the user can specify their treatment in the fault analysis solution. The options are to:

- Block the device: Lines and FACTS devices are treated as open circuits (i.e., fully blocked bridges) in all three sequences, regardless of their actual prefault loadings as given by the initial condition load flow.
- Represent as load: the apparent AC system complex loads are converted to positive sequence constant admittance load at the buses at which these quantities are injected into the AC system during normal power flow work. In the negative and zero sequence networks, DC lines and series FACTS devices are represented as open circuits. The equivalent positive-sequence shunt admittance is derived from the values of PAC and QAC given by the initial condition load flow at each converter AC bus.

Neither of these two representations should be regarded as exact. The first may be regarded as reasonable for the calculation of fault-current duty on circuit breakers since converter controls are usually designed to limit their fault currents to values equal to or less than normal load current.

Only one of these options may be selected in any execution of the unbalanced network solutions. The selected option applies to *all* DC lines and FACTS devices in the working case. The default handling of these devices is to block.

7.4.2 Using a Simplified Fault Calculation Model

A simplified model representation can be used in PSS™E. Generator power outputs are assumed to be zero. Loads and fixed bus shunts are neglected in the positive and negative sequence networks; switched shunts are neglected in all three sequences; zero sequence shunt loads and the zero sequence ground ties created by grounded transformer windings are represented. Line charging capacitances and line connected shunt elements are neglected in all three sequence networks. All transformers, including generator step-ups, are assumed to be at nominal ratio, zero phase shift angle, and a uniform voltage profile of unity magnitude at zero phase angle is assumed; DC lines and FACTS devices are ignored.

Use of the simplified model is more usually applicable in the automatic sequencing calculations described in Section 7.8, where the model is referred to as one using "Flat conditions", although those calculations can use the prefault network condition are as specified in the power flow case when the calculations are initiated.

7.4.3 Using Special Conditions for Fault Calculations

As mentioned in the previous sections, the "detailed" analysis (Section 7.5) can apply simplifying assumptions for the model. Those conditions are required to be established prior to initiating the calculations.

For the automatic sequencing calculations, similar simplifications can be made to the model but the decision for the user can be made during initiation of the calculations.

Other fault calculations can require "special" modelling assumptions.

All of these modelling options are accessible via the ***Fault>Setup for special fault calculations (FLAT)*** option. Figure 7-13 shows the menu, the Setup for Special Fault Calculations dialog and the three special options available.

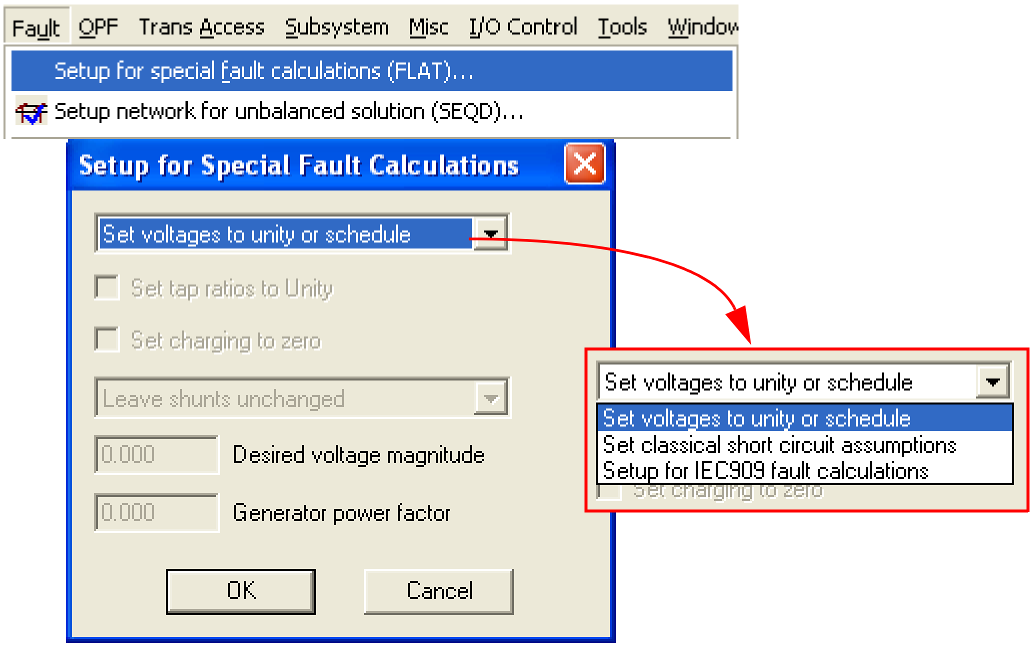


Figure 7-13. Setting Options for Special Fault Calculations

7.4.3.1 Setting the Special Fault Voltage Option

This option leaves network voltages as established in the power flow case or sets *all* bus voltages to one per unit at zero phase angle. This latter alternative *is not* identical in function to the flat start option that may be specified for the network solution activities of PSS™E, which causes swing (type three) bus voltage magnitudes to be set to their scheduled values, and all other bus voltage magnitudes to unity.

7.4.3.2 Setting Classical Short-Circuit Assumptions

The options for this selection are shown in Figure 7-14. The following data changes are implemented in the working case:

1. All bus voltages are set to one per unit at zero phase angle modified as described in Section.
2. Constant power, current, and admittance loads are set to zero.
3. Generator power outputs are set to zero.
4. FACTS devices and DC lines are removed.
5. Transformer phase shift angles are set to zero. Any transformer impedance, which is a function of phase shift angle is set to its nominal value.

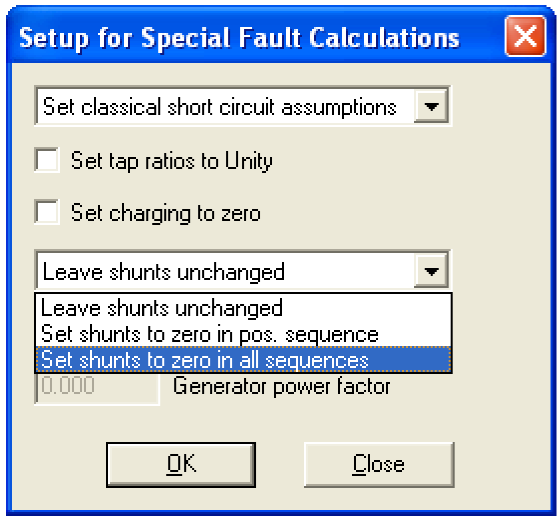


Figure 7-14. Selection of Classical Short-Circuit Calculation Setup

6. Optionally, *all* transformer turns ratios are set to one. This includes generator step-up transformers, which are modeled as part of the machine representation (i.e., the GENTAP). Any transformer impedance, which is a function of turns ratio, is set to its nominal value.

7. Optionally, line charging is set to zero (all three sequences).

8. Optionally, shunt elements, including magnetizing admittances of transformers, are set to zero. The user may elect to have fixed bus shunts and line connected shunts zeroed in only the positive sequence network or in all three sequences; switched shunts are zeroed in all three sequence networks.

7.4.3.3 Setting up for IEC909 Fault Calculations

The following data changes are implemented in the working case:

1. Voltage magnitudes are either left at their present values or are all set to a specified magnitude; phase angles are all set to zero.

2. Constant power, current, and admittance loads are set to zero.

3. Any machine whose active power is zero or negative has its active and reactive power outputs set to zero. All machines whose active power outputs are positive have their reactive power outputs either left unchanged or set such that a specified power factor is maintained.

4. FACTS devices and DC lines are removed.

5. Transformer phase shift angles are set to zero. Any transformer impedance, which is a function of phase shift angle, is set to its nominal value.

6. Optionally, *all* transformer turns ratios are set to one. This includes generator step-up transformers, which are modeled as part of the machine representation (i.e., the GENTAP). Any transformer impedance, which is a function of turns ratio, is set to its nominal value.

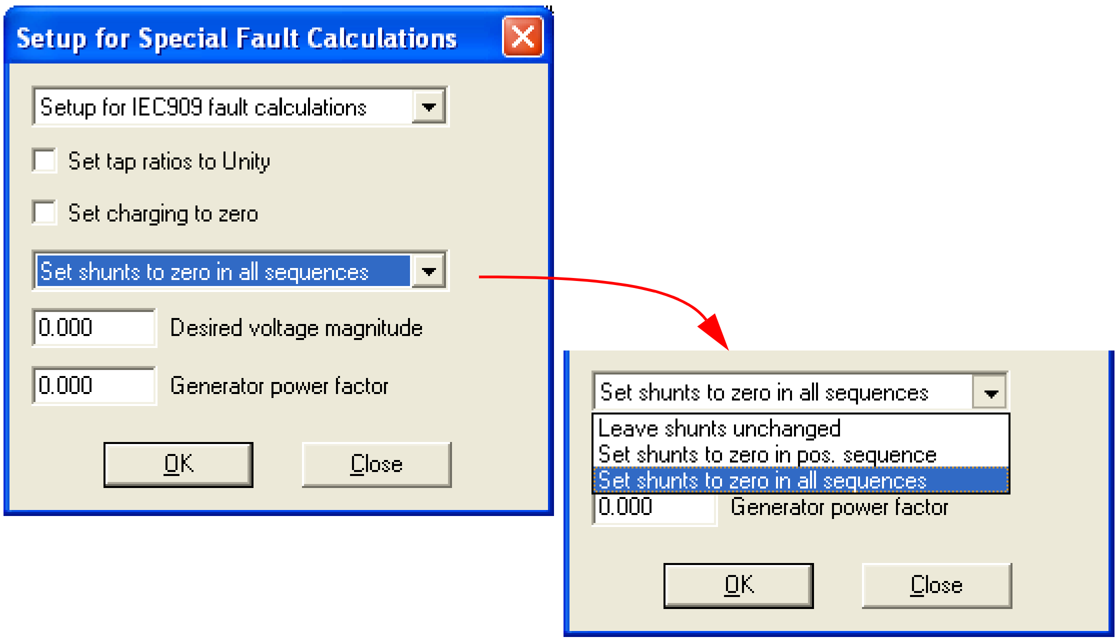


Figure 7-15. Setup for IEC fault Calculations

7. Optionally, line charging is set to zero.

8. Optionally, shunt elements, including magnetizing admittances of transformers, are set to zero. The user may elect to have fixed bus shunts and line connected shunts zeroed in only the positive sequence network or in all three sequences; switched shunts are zeroed in all three sequence networks.

9. Optionally select a voltage magnitude or leave voltages as in the power flow case.

10. Optionally select a generator power factor or leave generator Mvar unchanged.

When this IEC setup is selected activity, short circuit currents in conformance with IEC standard 909 can be calculated for examination of circuit-breaker duties (see Section 7.9).

7.5 About Detailed Unbalanced Fault Types

The multiple, unbalanced network solution allows the user to apply simultaneously, at any bus, on any phase, any or all of the following unbalances or faults:

7.5.1 Bus Faults

- One or two single-line-to-ground faults (L-G) with specified fault impedances, Z_F and Z_G (see Figure 7-16).
- One or two line-to-line (L-L) or double-line-to-ground (L-L-G) faults with specified fault impedances, ZF and ZG

Three-phase bus faults are simulated with a combination of one L-G fault and one L-L-G fault. Consequently, if a three-phase bus fault is simulated, there remain one L-G and one L-L-G fault application available. PSS™E assumes that any three-phase fault is simulated using the "second" single-line-to-ground fault and the "second" double-line-to-ground fault with all fault impedances set to 0.0+j0.0. Figure 7-16 shows the fault combinations together with the impedances available for selection. It shows how a double-line-to-ground fault can be converted to a line-to-line fault by assuming an "infinite" impedance for the impedance to ground Z_G.

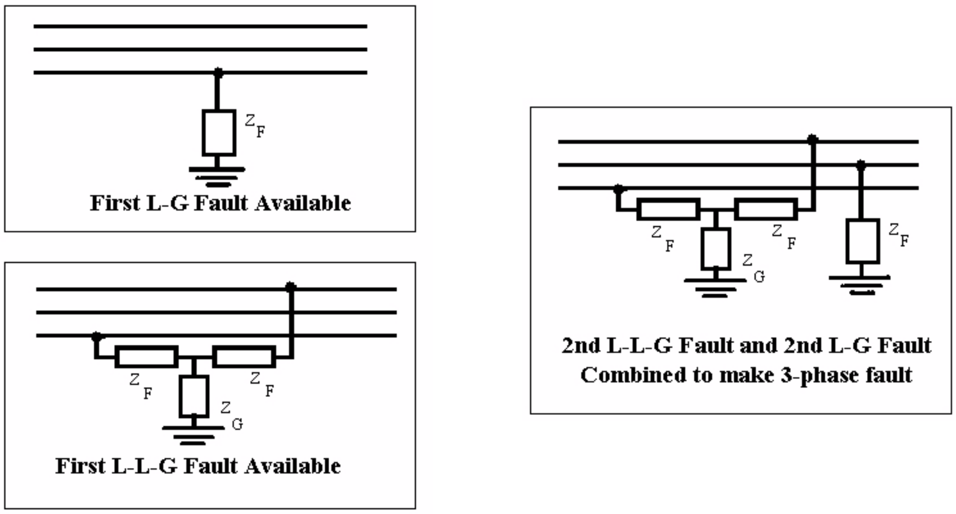


Figure 7-16. Using L-G and L-L-G Fault Combinations

7.5.2 Phase Closed Unbalances

The single and double phase closed unbalances are applicable to represent discrete components such as series capacitors and jumpers, but are not applicable to transmission lines. The unbalance simulation places series elements of the specified *phase* impedance between designated buses in the selected phases (see Figure 7-17). The unbalances available are:

- Single phase, with specified impedance, closed between a pair of buses.
- Two phases, with equal specified impedance, closed between a pair of buses.

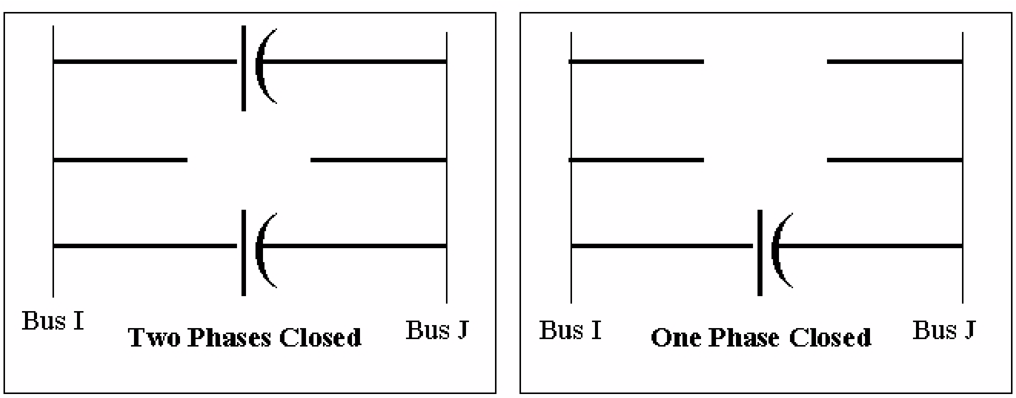


Figure 7-17. Phase Closed Series Unbalances

It should be noted that phase impedances will be placed in parallel with any branch which already exists, in the power flow case, between the selected buses. If the user wishes to use these models to represent an unbalance in an existing branch, then that branch must be switched out of services to avoid duplication (see Section 7.6.1.4).

7.5.3 Line Faults

The inter sequence solution method used in PSS™E for unbalanced fault calculations can apply faults only at buses. The application of a fault at some point along a line, therefore, requires the insertion of a dummy bus in the line at the fault location. The fault will be applied at the dummy bus. The user could introduce a dummy bus and re-organize the line topology to accommodate this type of fault. This is not necessary. PSS™E provides for the temporary addition of the required dummy buses and automates the rerouting of branches to the dummy buses and splitting of the zero sequence mutual couplings on either side of the faulted dummy bus.

The simulation of a fault at any point on a line is designated as the "fault slider". The line may be represented with both ends closed or with one end opened. In either of these two topologies, one of the following may be applied at any point along the line:

1. The *second* L-G fault.
2. The *second* L-L-G fault.
3. A three phase fault utilizing both the *second* L-G fault and the *second* L-L-G fault.

The dummy bus, introduced at the fault point is automatically numbered **999999**. If one end of the faulted line is opened and the fault point is not at the line end position, a second dummy bus, numbered **999998**, is introduced at the opened end (see Figure 7-18).

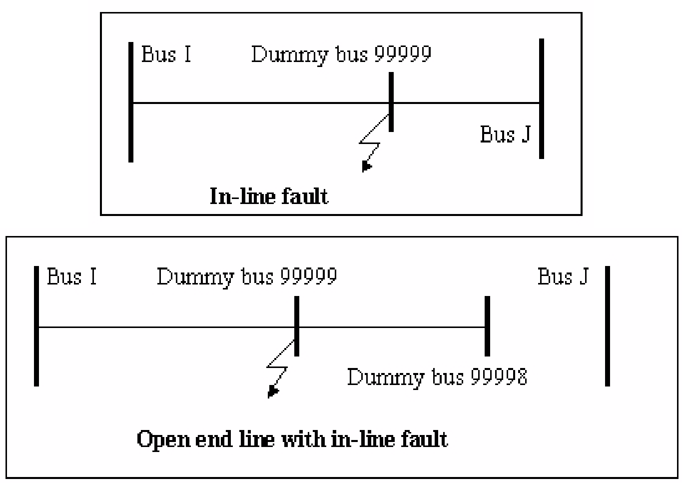


Figure 7-18. Allocation of Dummy Buses for In-Line Slider Faults

7.6 Performing Fault Analysis in PSS™E

7.6.1 Selecting Faults

The user selects the faults to be simulated using the ***Fault>Solve and report network with unbalances (SCMU/SCOP)...*** (see Figure 7-19). This will open the Multiple Simultaneous Unbalances dialog shown in Figure 7-20.

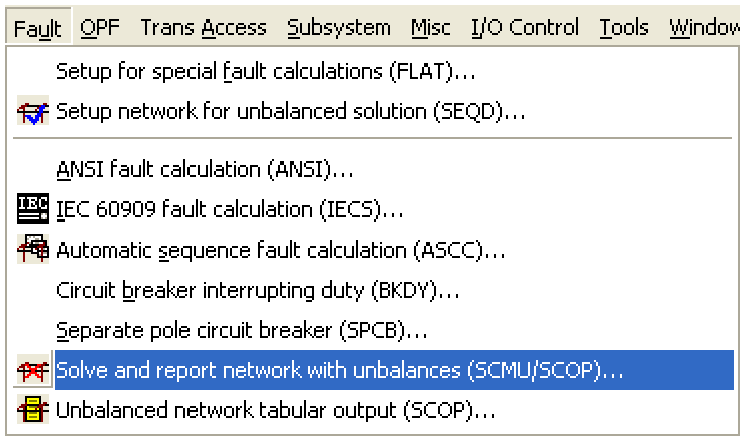


Figure 7-19. Initiation Selection of Unbalanced Faults

The dialog is divided into three main areas. The first is a series of tabs; one for each type of unbalance. Selection of a tab will open the appropriate data selection menus for the type of fault selected and provide a Select check box for the user to confirm selection of the unbalance.

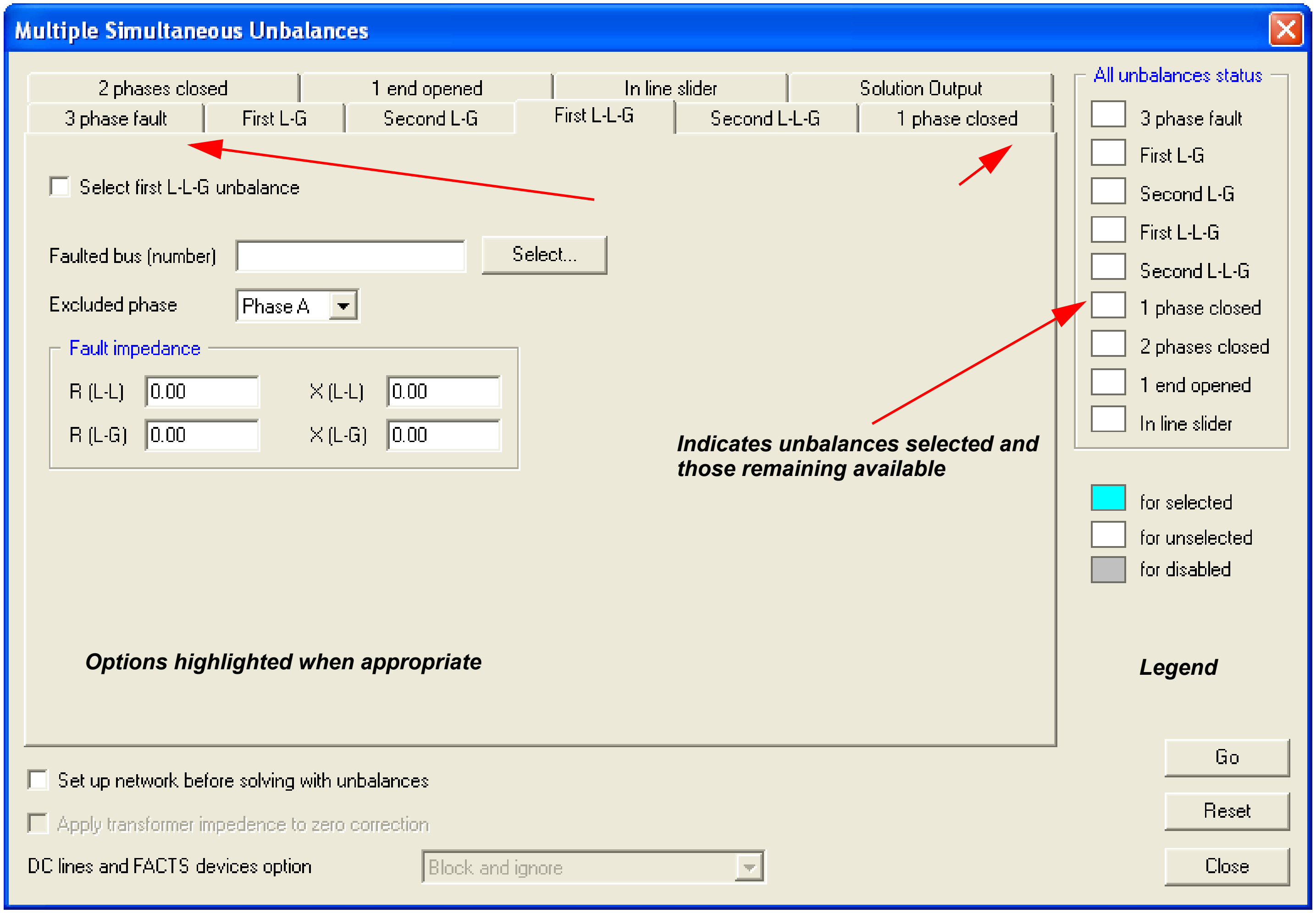


Figure 7-20. Multiple Simultaneous Unbalances Dialog

The second area is at the right hand end of the dialog where the status of selections is shown. This enables the user to see which unbalances have been selected, which have been disabled by previous selections and which selections remain available.

The third area, in the lower let of the dialog (see Figure 7-21), facilitates the selection of treatment for DC lines and FACTS devices and of the transformer impedance correction in the zero sequence (see Section 7.4.1.1).

Figure 7-21. Selection of DC, FACTS and Transformer Impedance Correction Treatment

7.6.1.1 Selecting Bus Faults

Figure 7-22 shows the appearance of the dialog when three alternative bus faults are selected (L-G, L-L-G and 3-phase).

The first selection (a) is a line-to-ground fault on Bus 153. The fault impedance is 0.0 + j0.0 pu of base impedance. The faulted phase has been selected to be the "B" phase.

The second selection (b) is a line-to-line-ground fault on Bus 154. The impedance between phases and to ground are both 0.0 + j0.0. Note that, in this case the phase selected is the one excluded from the fault. Consequently, the fault is between phases "C" and "B".

The third selection shown (c) is for a three phase fault on Bus 205. This is modelled by applying the second line-to-ground and the second line-to-line-to-ground fault on Bus 205. Further, the assumption is that the fault impedance is zero.

7.6.1.2 Selecting In-Line Slider Faults

Figure 7-23 shows the appearance of the dialog when an in-line slider fault is applied. The fault is a single-line-to-ground fault, on Phase A, with zero fault impedance, on the circuit from Bus 203 to Bus 205. The fault is 60% of the line length from Bus 203.

Note that the fault selected could be a line-to-line-to-ground or a three-phase fault type.

To utilize the line faults, the number of buses in the working case must be at least one less (two less for an in-line fault with one end opened) than the maximum number for which PSS™E is dimensioned. In addition, except for the case of a line end fault at the opened end of a line, the following conditions must be met:

- The number of branches in the working case must be less than the maximum number for which PSS™E is dimensioned.
- The geographical "B" factors, BIJ1, BIJ2, BKL1, and BKL2, must have been properly specified for any zero sequence mutual couplings involving the branch (see Section 7.2.8).

Only one line fault may be imposed on the network in any given execution of the unbalanced fault calculation, but other bus faults and the phase closed unbalances may be simultaneously applied.

For this in-line slider fault, with both ends closed, the faulted line may *not* be a transformer, and it may *not* be open in the zero sequence (i.e., its zero sequence impedance *must* be nonzero).

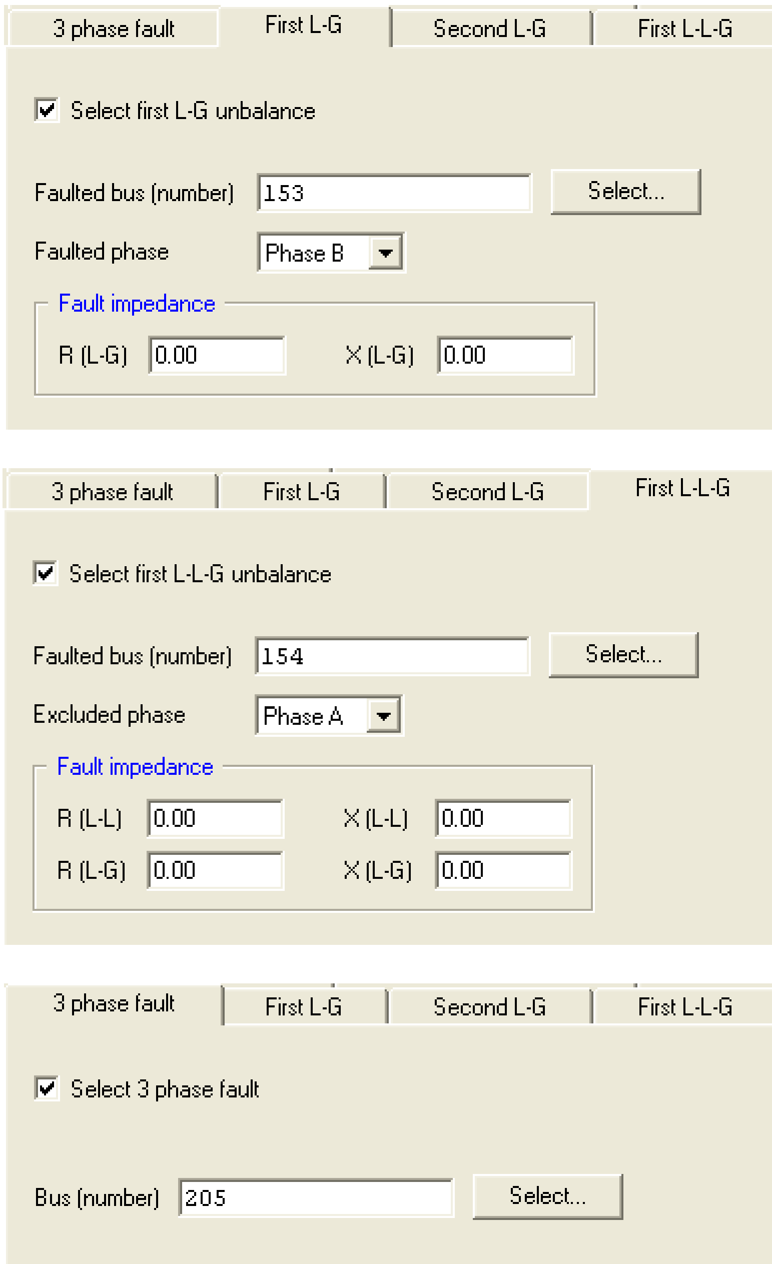


Figure 7-22. Dialog for Bus Faults

In output reports, the faulted dummy bus is listed as bus 999999 with the name "DUMMYBUS". For the one end opened case, the base voltage of the dummy bus is taken to be the same as the opened end bus. For the case of both ends closed, the base voltage of the dummy bus will be that of one of the two buses involved.

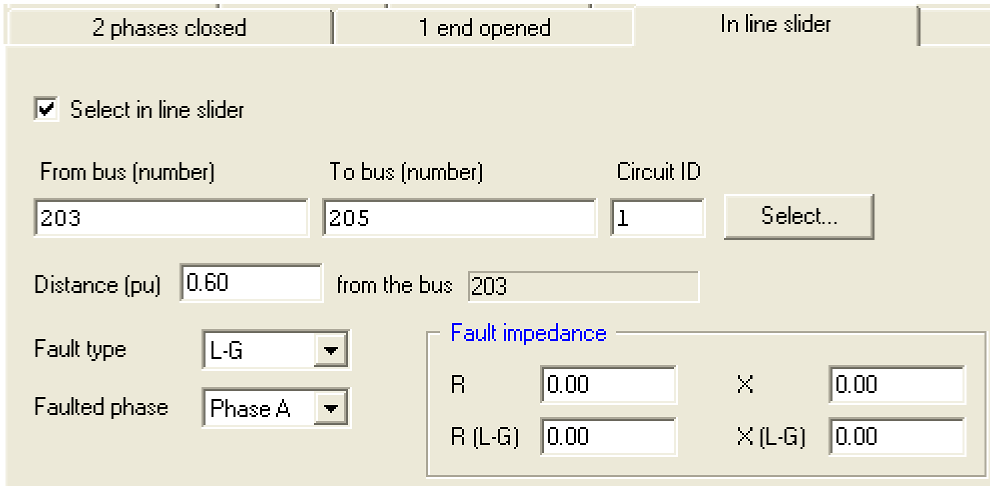


Figure 7-23. Dialog for In Line Slider Fault

7.6.1.3 Selecting a Branch with One Open End

For the case of one end of a branch opened, a non transformer branch, a two-winding transformer, or a three-winding transformer may be designated. A non transformer branch or a two-winding transformer is specified by identifying the two associated buses. A three-winding transformer is designated by specifying the three buses it connects.

With one end of the branch opened, the user designates the opened end and, except for a three-winding transformer, the fault location on the "branch". For a non-transformer branch, the fault location is specified by specifying the fraction of the line between the closed end and the fault point, as for the "slider". The proper designation is a number greater than zero and less than or equal to one (one would indicate a "line end" fault). For a two-winding transformer, the value of **one** *must* be specified. For a three-winding transformer, the user can select the open point at any of the three buses to which the transformer is connected.

In the case of one end opened with the fault location other than at the opened end, the opened end dummy bus is listed as bus 999998 with the name "STUB END" and the base voltage of the original bus at the opened end of the line.

Figure 7-24 shows the appearance of the unbalance dialog for the selection of a single-line-to-ground fault, on Phase A, at the open 500 kV bus of a three-winding transformer. The fault impedance is 0.0 + j0.0 pu.

Note that the fault type can be a line-to-ground, a line-to-line-to ground or a 3-phase fault.

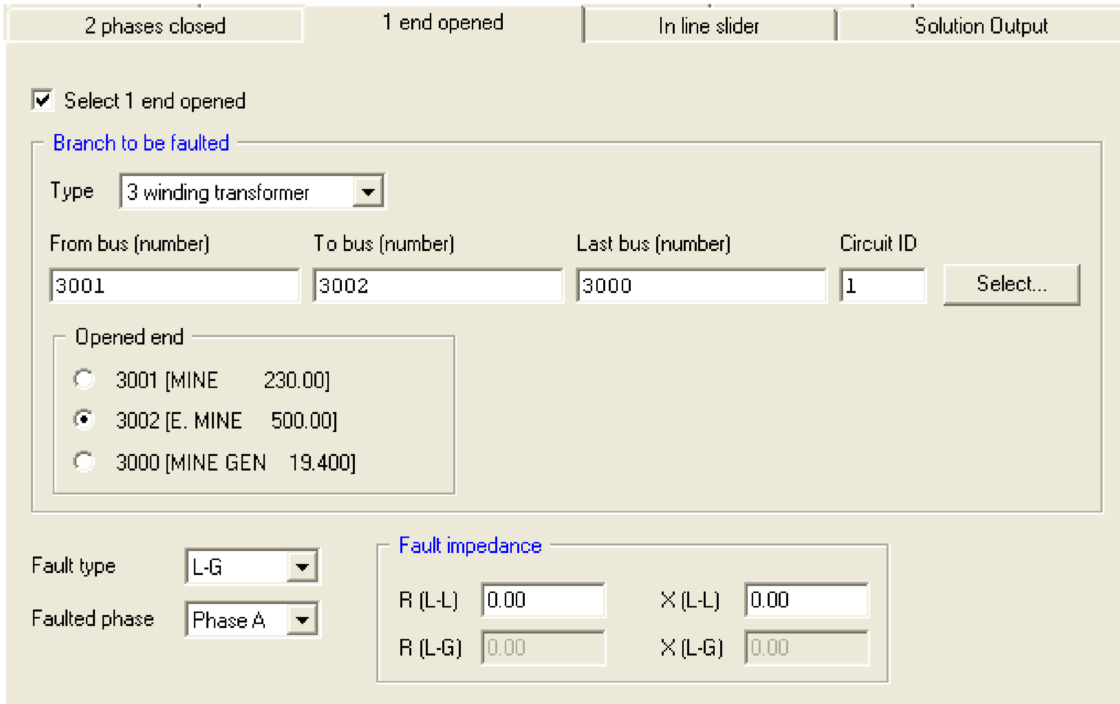


Figure 7-24. Selection of a L-G Fault on the 500 kV Bus Side of a Three-Winding Transformer

7.6.1.4 Selecting One and Two-Phase Closed Unbalance

The user is required to supply the *phase* impedance between designated buses in the selected phases. The user is asked to specify the pair of buses involved, either the phase to be closed (for the single phase closed unbalance) or the opened phase (for the double phase closed unbalance), and the *phase* impedance of the closed phase(s).

Following the unbalance specification process, a warning message is printed if there are already any in-service branches between the designated buses. In this case the new series branch, of which only one or two phases are closed, is placed in parallel with those branches that are already present. It is the user's responsibility to ensure that the working case is in a state such that the application of the phase closed unbalance produces the desired overall condition.

If it is intended to open one or two phases of a branch which already exists, that branch must be taken out of service in order to be replaced by the unbalance model.

Figure 7-25 shows the appearance of the dialog for selection of a two-phases closed branch between Bus 152 and Bus 153. The two phases closed are "B" and "C" and the phase impedance is equal to - 0.02 pu; indicating series capacitance.

Note that the dialog for single-phase closed looks the same. The difference being that the user would identify the closed Phase rather than the open Phase.

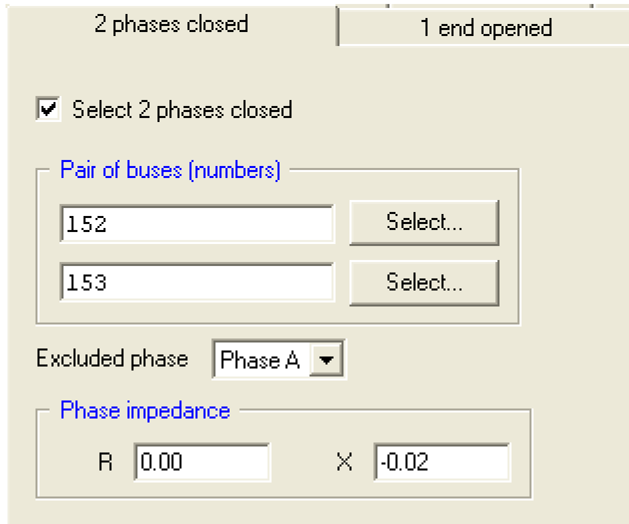


Figure 7-25. Dialog for 2 Phases Closed Unbalance

7.6.2 Setting Up the Pre-Calc Sequence Network

The normal sequencing of activities in preparing for fault analysis work is:

1. Set up the positive sequence network at whatever level of detail is required.
2. Append the required sequence data to the power flow case (Section 7.2).
3. Select the unbalances to be simulated and then click ***Go***.

When the calculation is initiated, the first step in the process is the setting up of the sequence networks. This involves the preparation of the power flow case for the unbalanced network solution (as well as for the Separate Pole Circuit Breaker simulation discussed in Section 7.11.1)

This process involves taking the positive sequence network (i.e., the power flow case) and the various sequence data arrays defining the negative and zero sequence networks, and setting up the factored matrix working file (FMWORK) and the short circuit working file (SCWORK) in the necessary form. The following computations are performed:

- All positive sequence loads are converted to fixed shunt admittances on the basis of the voltage at each load bus in the working case.
- All negative sequence loads, except those for which the user has specified a nonzero negative sequence shunt load are set equal to the positive sequence values calculated in the previous step.
- All generator positive sequence sources are initialized and fixed to correspond to their generator terminal bus conditions in the working case. This is a temporary "conversion" of the power flow generator model to a Norton equivalent for the fault calculations (see Figure 7-26).
- An ordering for the positive and negative sequence networks is determined and summarized in the Output Bar or alternative device selected by the user (see Figure 7-27).

- The positive and negative sequence admittance matrices are constructed and factorized.
- The zero sequence network is ordered and summarized in the Output Bar or alternative device selected by the user (see Figure 7-27).
- The zero sequence network admittance matrix is constructed and factorized.

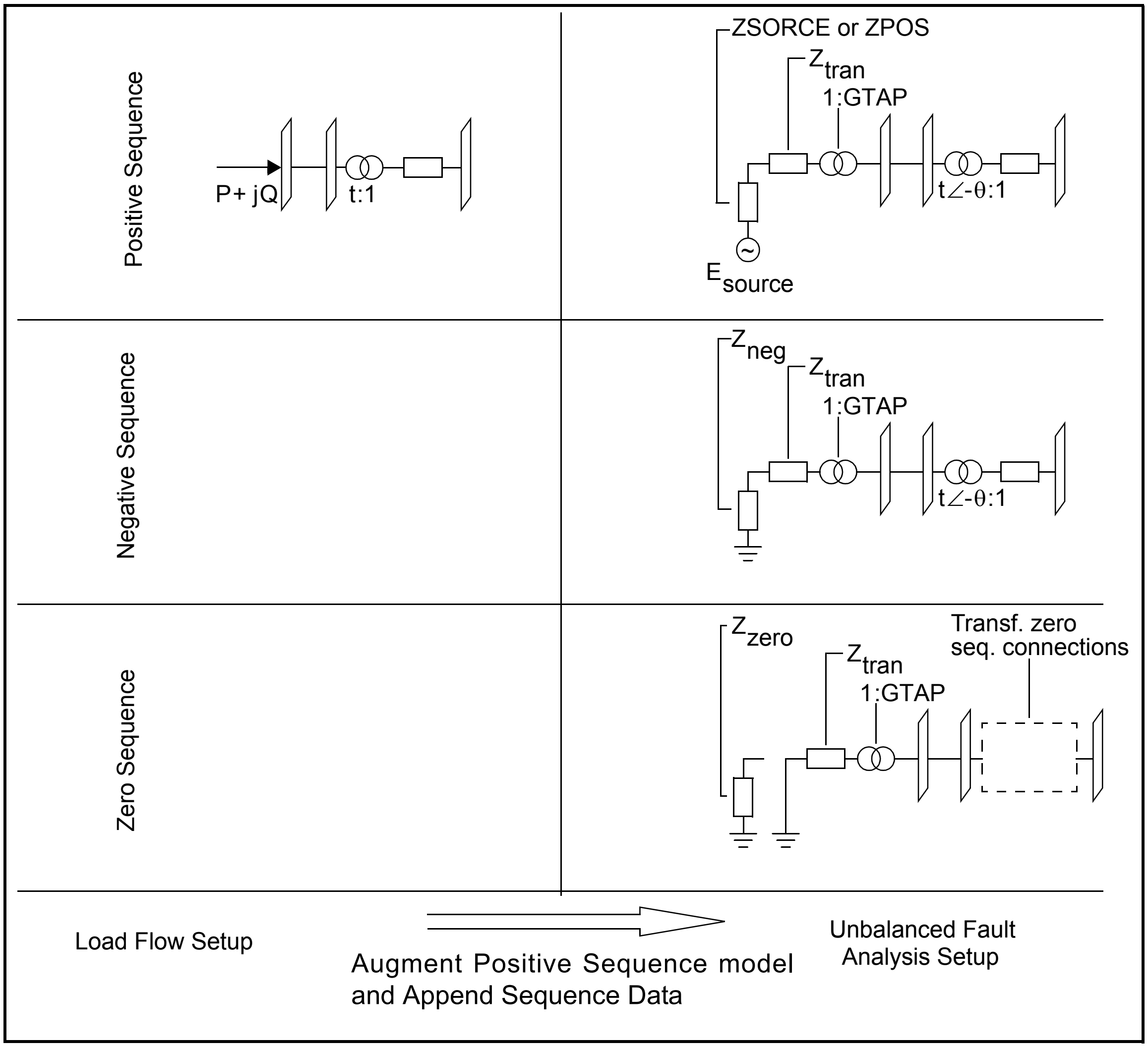


Figure 7-26. Generator Conversion to Norton Equivalent for Fault Calculations

```
DIAGONALS =      23  OFF-DIAGONALS =      41  MAX SIZE =      60
POS. SEQUENCE: DIAGONALS =      23  OFF-DIAGONALS =      41
DIAGONALS =      23  OFF-DIAGONALS =      35  MAX SIZE =      48
BUS    101 [NUC-A       21.600] ISOLATED IN ZERO SEQUENCE
BUS    102 [NUC-B       21.600] ISOLATED IN ZERO SEQUENCE
BUS    206 [URBGEN      18.000] ISOLATED IN ZERO SEQUENCE
BUS    211 [HYDRO_G     20.000] ISOLATED IN ZERO SEQUENCE
BUS   3011 [MINE_G      13.800] ISOLATED IN ZERO SEQUENCE
BUS   3018 [CATDOG_G    13.800] ISOLATED IN ZERO SEQUENCE
     6 BUSES ISOLATED IN ZERO SEQUENCE
ZERO SEQUENCE: DIAGONALS =      23  OFF-DIAGONALS =      35
```

Figure 7-27. Summary from Network Ordering Prior to Fault Calculations

With respect to the summary shown in Figure 7-27, it is quite common, and perfectly valid, to have the generator terminal bus isolated in the zero sequence network. This is, in fact, the usual case since the majority of generator step-up transformers are delta connected on the generator side and wye connected on the high side. This is the assumption inherent in the generator modeling when the step-up transformer is represented as part of the generator data (i.e., XTRAN is nonzero). An alarm message will be printed for any generator with nonzero values of both XTRAN and ZZERO. In this case, the value of only XTRAN is used in setting up the zero sequence ground tie at the type two (high side) bus.

7.6.3 Analyzing the Unbalance Fault Calculation Summary

Following the sequence network set-up, discussed in the previous section, the system Thevenin impedances, as seen at each bus where an unbalance is to be applied, are reported. Each sequence column of this table lists resistive and reactive parts of the Thevenin impedances that would be measured by observations made at each bus in turn without the influence of the prescribed set of unbalances.

An example is shown in Figure 7-28 for a case in which two line-to-ground faults were applied in the savnw.sav power flow case, with a zero fault impedance, on Buses 151 and 3002.

```
UNBALANCES APPLIED:

LINE TO GROUND FAULT AT BUS    151 [NUCPANT     500.00]   PHASE 1
  L-G Z =     0.000         0.000

LINE TO GROUND FAULT AT BUS   3002 [E. MINE     500.00]   PHASE 1
  L-G Z =     0.000         0.000

                    SEQUENCE THEVENIN IMPEDANCES AT FAULTED BUSES

  BUS# X-- NAME --X BASKV          ZERO                 POSITIVE              NEGATIVE
   151 NUCPANT     500.00    0.00019  0.00627     0.00409  0.01765     0.00409  0.01765
  3002 E. MINE     500.00    0.00064  0.02262     0.00673  0.03855     0.00673  0.03855
```

Figure 7-28. Sequence Thevenin Impedance for two Line-to-Ground Faults

The calculation process interconnects the three sequence networks to represent the unbalanced condition and solves for the sequence voltages. Following solution, a summary report is printed for each unbalance applied. The user is then given the opportunity to get complete output for any bus in the working case.

The summary report is printed at the selected output device for each unbalance that is in effect. Each individual unbalance report consists of a tabulation of bus voltages and branch currents in terms of both symmetrical component (sequence) and phase quantities. Voltages and currents are printed in either physical units (kV L-G and amps) or per unit, and in either rectangular or polar coordinates, according to the fault analysis output options currently in effect (refer to Section 1.6.4). If the physical units option is enabled and a bus has no base voltage specified for it, its output is printed in per unit.

The following blocks of output are included:

1. Fault type and bus(es) involved.

2. Bus voltages for the bus at which the unbalance is applied. The first line of each bus voltage block gives the bus zero, positive and negative sequence voltages as well as three times the zero sequence voltage, and the second line gives the bus phase voltages. When the per unit option is enabled, values are in per unit of rated line to ground voltage. The phase voltages are line to neutral values. For the phase closed unbalances, the bus voltage block is printed for both of the buses involved.

3. For the L-G and L-L-G faults, series branch currents flowing in each branch (including any generator contributions) connected to the faulted node. All currents are tabulated as flowing *into* the faulted node and include the effects of line charging capacitance and line connected shunt admittances. When the per unit option is enabled, currents are expressed in per unit of base phase current. The first line gives sequence components of current as well as three times the zero sequence current, and the second line gives the phase currents. For non transformer branches and for two-winding transformers, the number and name of the "*to bus*" is printed, along with the circuit identifier; for three-winding transformers, the output line contains the winding number, the transformer circuit identifier and the transformer name. For the phase closed unbalances, the only branch series currents tabulated are those represented by the unbalance.

4. For the L-G and L-L-G faults, the algebraic "sum of contributions" of all elements tabulated in (3). The format of these currents is the same as for the series branch currents. This is the total current apparently flowing to ground at the bus, and it includes any load connected to the bus, fault current, and the AC side current of any unblocked DC line or FACTS device.

5. For the L-G and L-L-G faults, a value of "contributions equivalent positive sequence admittance" is expressed in per unit, rectangular form, relative to system base values. This quantity is computed from the sum of contributions in (4) and thus *includes* any load and unblocked DC line and FACTS device elements connected to the bus. Furthermore, this equivalent admittance is valid *only* in the case of single ground faults. In the case where there are no DC line or FACTS device effects included in this admittance, and only this single unbalance was applied, this shunt admittance, multiplied by system base MVA, may be entered as a shunt *replacing* the load and shunt elements at the bus, to give the correct positive sequence equivalent representation of this fault in the dynamic simulation activities.

6. For the L-G and L-L-G faults, the current flowing to ground at the bus exclusive of any fault current. The format of these currents is the same as in (3) and (4) above, and they include any load and shunt current at the bus as well as the AC side current of any unblocked DC line or FACTS device. In the zero sequence, only the shunt load is output here; specifically, the zero sequence ground ties created by grounded trans-

former windings are not shown here but are included in the branch contribution output of (3) above. Load and shunt current output is suppressed if the three sequence shunt and load admittances are all zero.

7. For the L-G and L-L-G faults, when no phase closed unbalances are applied and only one bus is involved in the ground faults, "fault current" is calculated and tabulated in a format similar to (4) above, and "positive sequence equivalent fault admittance" is listed in a format similar to (5) above. This admittance, multiplied by system base MVA, would be *added* to any shunt at the bus to represent this fault in the dynamic simulation activities.

Whenever a single ground fault unbalance is solved an entry is appended to a summary file, named "SMRYSC", in the user's directory. This file contains fault descriptive information along with the "sum of contributions" entry described in (4) above. This file is cumulative, and if it does not exist it is created automatically when the unbalanced fault calculations are performed. It is never automatically deleted; results are always appends to it. The user may delete this file at any time when it is no longer of use.

Figure 7-29 shows the summary report for a single-line-to-ground fault at Bus 151 in the savnw.sav power flow case, with zero fault impedance.

Note that the output options are polar coordinates and physical quantities; i.e., the voltages are in kV and the current is in amperes.

Since there is a 600 Mvar shunt connected to bus 151, the "Total Contributions" include the current in this shunt.

The total A Phase current is 8371.6 / -67.76 amps. The zero sequence current is 2756.0 /-67.73 amps, These include contributions from the 600 MVAr shunt.

Since the A Phase current in the 600 Mvar shunt is 103.7 /- 69.48, the actual A Phase fault current at the bus is less and is 8267.9 /-67.73 amps.

```
SEQUENCE                /V0/     AN(V0)     /V+/     AN(V+)     /V-/     AN(V-)     /3V0/    AN(3V0)
PHASE                   /VA/     AN(VA)     /VB/     AN(VB)     /VC/     AN(VC)
   151 (KV L-G)        43.214   -159.48   167.396    12.13    124.805   -170.77   129.643   -159.48
NUCPANT      500.00     0.000      0.00   271.452   -92.73    250.418    115.67

SEQUENCE                /I0/     AN(I0)     /I+/     AN(I+)     /I-/     AN(I-)     /3I0/    AN(3I0)
PHASE                   /IA/     AN(IA)     /IB/     AN(IB)     /IC/     AN(IC)

FROM     101 CKT 1     1270.7    -68.21    1055.3    -25.74     621.9    -79.76    3812.1    -68.21
NUC-A        21.600    2722.6    -55.74    1374.3    -86.91     209.1    156.70

FROM     102 CKT 1     1270.7    -68.21    1055.3    -25.74     621.9    -79.76    3812.1    -68.21
NUC-B        21.600    2722.6    -55.74    1374.3    -86.91     209.1    156.70

FROM     152 CKT 1        7.2     53.87     563.1   -121.62     269.8    -45.02      21.5     53.87
MID500       500.00     672.1    -98.58     786.0    104.25     316.7    -14.60

FROM     152 CKT 2        7.2     53.87     563.1   -121.62     269.8    -45.02      21.5     53.87
MID500       500.00     672.1    -98.58     786.0    104.25     316.7    -14.60

FROM     201 CKT 1      222.4    -65.40    1083.1    -99.68     759.3    -58.76     667.1    -65.40
HYDRO        500.00    1943.1    -80.99    1214.5    108.02     383.0     24.29

SUM OF CONTRIBUTIONS INTO BUS      151 [NUCPANT      500.00]:
   151                 2756.0    -67.73    3152.2    -69.02    2465.1    -66.16    8267.9    -67.73
NUCPANT      500.00    8371.6    -67.76     617.9   -173.86     600.6     15.77

CONTRIBUTIONS EQUIVALENT POSITIVE SEQUENCE ADMITTANCE     7.2462  -46.5166


SHUNT + LOAD CURRENT AT BUS     151 [NUCPANT      500.00]:
   151                    0.0      0.00     401.8    -77.87     299.5     99.23       0.0      0.00
NUCPANT      500.00     103.7    -69.48     617.9   -173.86     600.6     15.77
```

600 Mvar Shunt at bus 151

```
FAULT CURRENT AT BUS     151 [NUCPANT      500.00]:
   151                 2756.0    -67.73    2756.0    -67.73    2756.0    -67.73    8267.9    -67.73
NUCPANT      500.00    8267.9    -67.73       0.0      0.00       0.0      0.00
```

Sum of Contributions without the 600 Mvar Shunt

```
POSITIVE SEQUENCE EQUIVALENT FAULT ADMITTANCE     7.2462  -40.5166
```

Figure 7-29. Summary Output at Bus 151 with L-G Faults at Buses 151 in Power Flow Case savnw.sav

7.6.3.1 Viewing Detailed Output of Unbalanced Fault Analysis

The results summaries, such as those shown in Figure 7-30 are output for each unbalance condition that is in effect. For example, the figure shows conditions at Bus 151 where a single-line-to-ground fault is applied.

For that same fault condition, conditions at other buses in the system can be reported. This is achieved using the Solution Output tab in the unbalance dialog as shown in Figure 7-20. That tab provides access to selection of buses for which reporting is required and, further, allows the selection of output to be in terms of current, apparent impedances or apparent admittances of the branches (see Figure 7-30).

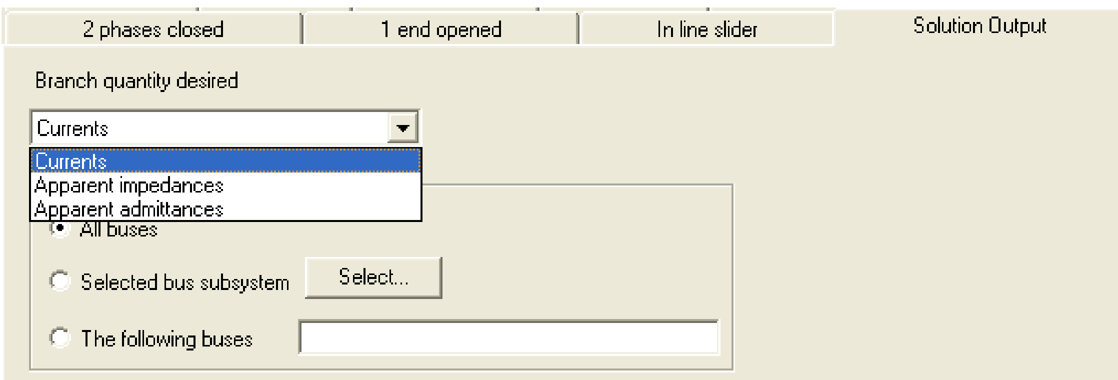


Figure 7-30. Selection of Detailed Output of Unbalance Calculation Results

This reporting facility recognizes the same fault analysis output options, with quantities printed in either physical units or per unit, and in either rectangular or polar coordinates as does the summary report.

The data printed for any selected bus or buses has the same format as for the summary report and consists of:

1. Sequence and phase voltages at the bus.

2. Series branch quantity for each branch and machine connected to the bus, consisting of either:

   a. Branch series currents *leaving* the bus, in either per unit or amps. These are in the reverse direction of the currents shown in the summary report.

   b. Branch apparent impedances looking down each branch from the bus, expressed in either per unit or ohms. These apparent impedances are defined as:

$$Z_{\text{seq ij}} = \frac{V_{\text{seq i}}}{I_{\text{seq ij}}} \qquad\qquad Z_{\text{phase ij}} = \frac{V_{\text{phase i}}}{I_{\text{phase ij}}}$$

   c. where the sequence and phase currents are the total currents flowing into the line at the bus, including line charging capacitance and line connected shunt current. Infinite impedance is printed as 9999 per unit or 999999 ohms.

    d. Branch apparent admittances looking down each branch from the bus, expressed in either per unit or mmhos. Apparent admittances are defined as the reciprocal of apparent impedances. Infinite admittance is printed as 9999 per unit or 99999 mmhos.

3. Sum of branch contributions. When branch currents are being tabulated, the sum of all contributions flowing into the bus is the total current apparently flowing to ground at the bus and will be zero unless there is a load or a shunt connected (see Section 7.6.3).

4. When branch currents are being tabulated, the sum of load and shunt current at the bus. Load and shunt current output is suppressed if the three sequence shunt and load contributions are all zero.

Note that the direction of current flow in the series branch output is the *reverse* of that in the summary output. Rather, it follows the power flow output convention of current leaving the bus.

When output is directed to the user's terminal, a summary description of each active unbalance is printed at the top of the first page of output. Otherwise, the unbalance summary is printed on each page of output.

Production of the detailed report may be terminated by entering the AB interrupt control code.

7.6.3.2 Viewing Graphical Output of Unbalance Conditions

With the diagram view open, it is possible to perform an unbalanced fault calculation on the basis of a three-phase or single-line-to-ground bus fault at a single bus or at a selection of buses. The faults are calculated simultaneously but are not applied simultaneously.

To initiate the calculation process it is necessary to select the ***Diagram>Results>Fault Analysis results…*** option (see Figure 7-31a).

The dialog for launching the calculation is shown in Figure 7-31b. The selections include the option to select either a three-phase or single-phase fault, the option to output Phase A current or three times zero sequence current and the ability to select a single bus to be faulted or all the buses.

The solution options are similar to the detailed unbalance calculation method.

Output options include currents or apparent impedances.

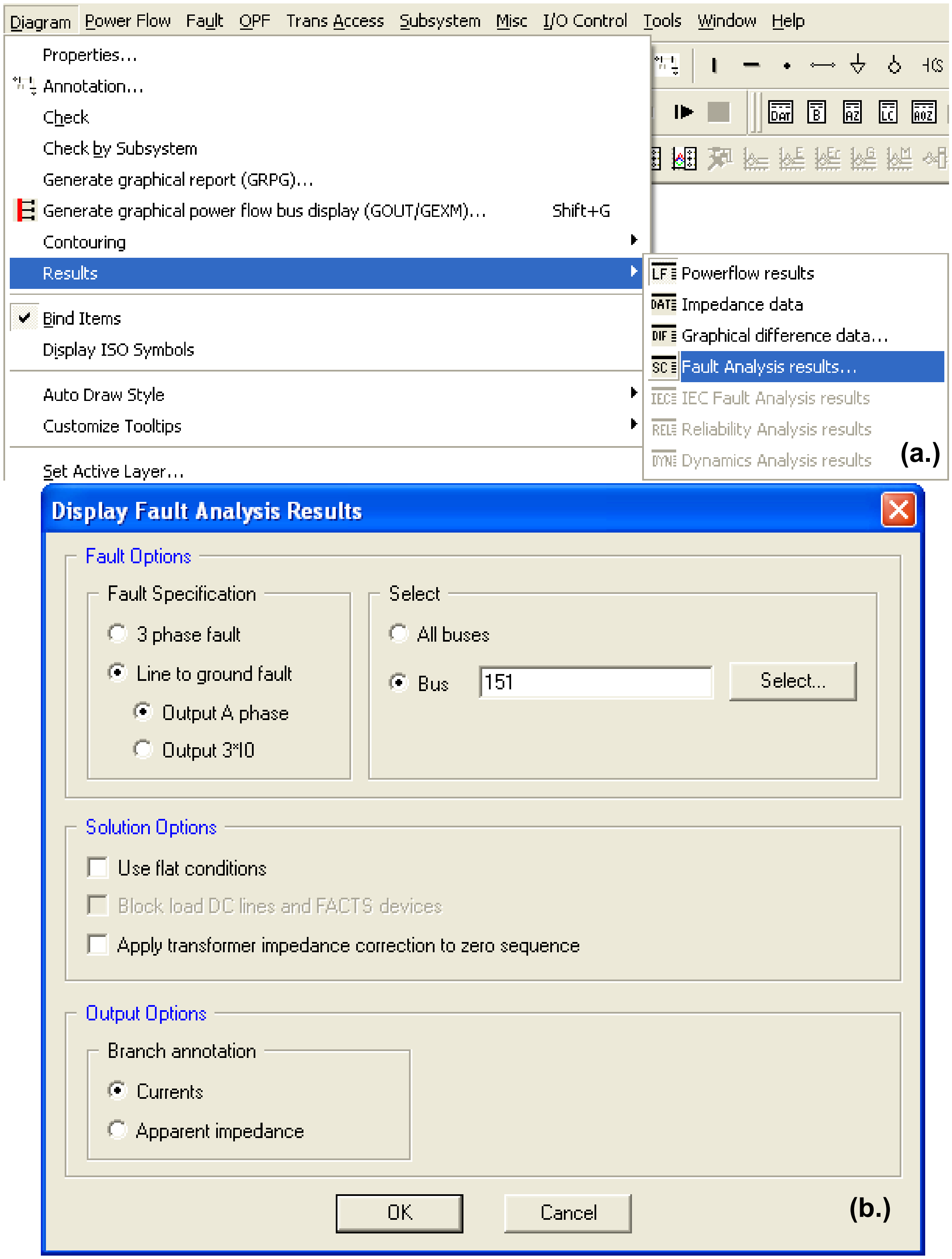


Figure 7-31. Selecting the Graphical Unbalance Calculation

Note that, in this figure, Bus 151 has been selected for calculation of a single-line-to-ground fault with output of Phase A current. The coordinate (rectangular or polar) output will be as selected in the run time options as for the detailed unbalance analysis.

The graphical output shows the results of applying a single-line-to-ground fault on Bus 151 (see Figure 7-32). Output was selected to be in polar coordinates for Phase A.

An examination of the figure will demonstrate that the results are equal to those tabulated in Figure 7-29 where polar coordinates were selected. The diagram shows more clearly, however, the bus connected shunt contribution and the total fault current (at the bottom of the bus) without the shunt contribution, i.e. in the diagram they are recolonized separately.

As an extension of this example, the calculation was run for a fault at all buses. The results for the fault on Bus 152 can be seen. While the results are shown simultaneously, the faults are not simultaneous. The results are independent.

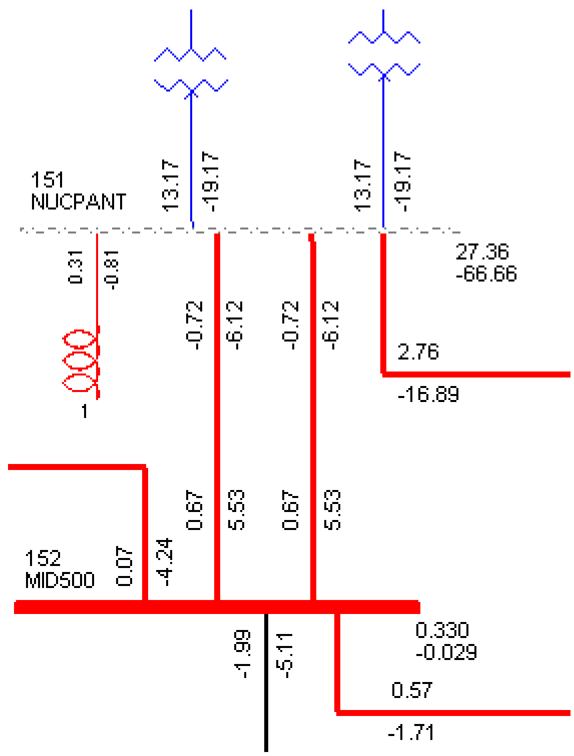


Figure 7-32. Graphical Results of L-G Fault on Bus 151

7.6.4 Application Notes for Fault Analysis

7.6.4.1 General Fault Analysis Application Notes

PSS™E treats unbalanced fault analysis as a direct extension of its power flow activities. All that is needed to perform unbalanced fault calculations on a fully detailed, solved power flow case is to augment the positive sequence power flow data with the corresponding negative and zero sequence data, and to use fault analysis activities in place of power flow activities. The working case always includes provision for negative and zero sequence data values corresponding to the positive sequence parameters of every system component. This data may be introduced into the working case at any time and, once introduced, it is saved and retrieved.

Each fault calculation is a complete solution for the full sequence and phase specification of conditions at every bus. The user may obtain output of voltage at any bus, or current, apparent impedance or apparent admittance at the entry to any branch. Multiple unbalanced conditions may be applied simultaneously.

The principal steps in a fault analysis calculation are:

- Set up the power flow case for the pre switching system condition. When a solved case is to be the initial condition, the working case must be a solved case. Otherwise, the bus boundary conditions must correspond to the prefault condition. This provides the basis for the initialization of all generators and the conversion of all loads to constant admittance.
- Change branch and generator status as required, or adjust loads and shunts, to produce the desired posts witching system conditions excluding unbalances. An example would be the application of a two-phase unbalance between two buses where a branch already exists and the unbalance is to be applied to that branch. It is necessary to remove the branch and to apply the unbalance (see Figure 7-25).
- Apply the unbalances that are to exist in the post switching condition and solve the resulting interconnected sequence networks for the complete set of system voltages. The unbalance fault calculation process will re-establish the network admittance matrices for the posts switching condition prior to performing the calculations.

In applying unbalances, the following points should be noted:

1. Both resistance and reactance must be specified for each impedance shown. Impedances are specified in per unit relative to base impedance.
2. It *is not* necessary to multiply ground fault impedances by three; this is done automatically as part of the fault calculation by.
3. The branch on which an in-line unbalance is to be applied must be in-service in the power flow case before the calculation is initiated. The calculation process will open the branch at one end automatically if the one end opened option is selected and re-establish the network admittance matrices.
4. Only one in-line unbalance may be applied. The location of this unbalance is automatically assigned the bus number 999999.
5. For in-line unbalances, the user is cautioned against the applying faults very close to the sending or receiving end of the branch. Since this can give very low impedances between the dummy bus and the closer real bus.
6. The single and double phase closed unbalances place new phase branches in parallel with those that are already present in the working case.
7. The single and double phase closed unbalances are applicable to discrete components such as series capacitors and jumpers, but are not applicable to transmission lines.

The user may create unbalanced conditions, other than those that are automated by the unbalanced fault calculation process, by judicious use of dummy buses and low impedance branches. The fault analysis is normally able to handle a branch impedance as low as j0.0001 per unit without difficulty. However, when introducing "jumper" branches which are not being treated as zero impedance lines, the user should examine the impedances of other branches connected to these buses to check for an extremely wide range of impedances, which could result in numerical precision problems.

7.6.4.2 Observation of Transformer Currents

Grounded wye-delta transformers pose a difficulty in unbalanced fault analysis because they behave as a shunt path to ground in the zero-sequence, while being series paths in the positive and negative sequences. There is a distinction between the transformer's symmetrical component equivalent circuits and the actual arrangements of its primary, secondary, and neutral leads.

Consider the currents flowing in the leads of a wye-delta transformer as shown in Figure 7-33. The wye-connected winding allows zero-sequence current to flow into the transformer leads and thence to ground via the neutral grounding strap. While the wye-connected winding is certainly a path to ground, observations at the leads that feed this winding see the zero-sequence current just as if it were a series current flowing to the bus at the other side. This zero-sequence current in the transformer leads must be recognized in calculations of the phase values of the lead currents.

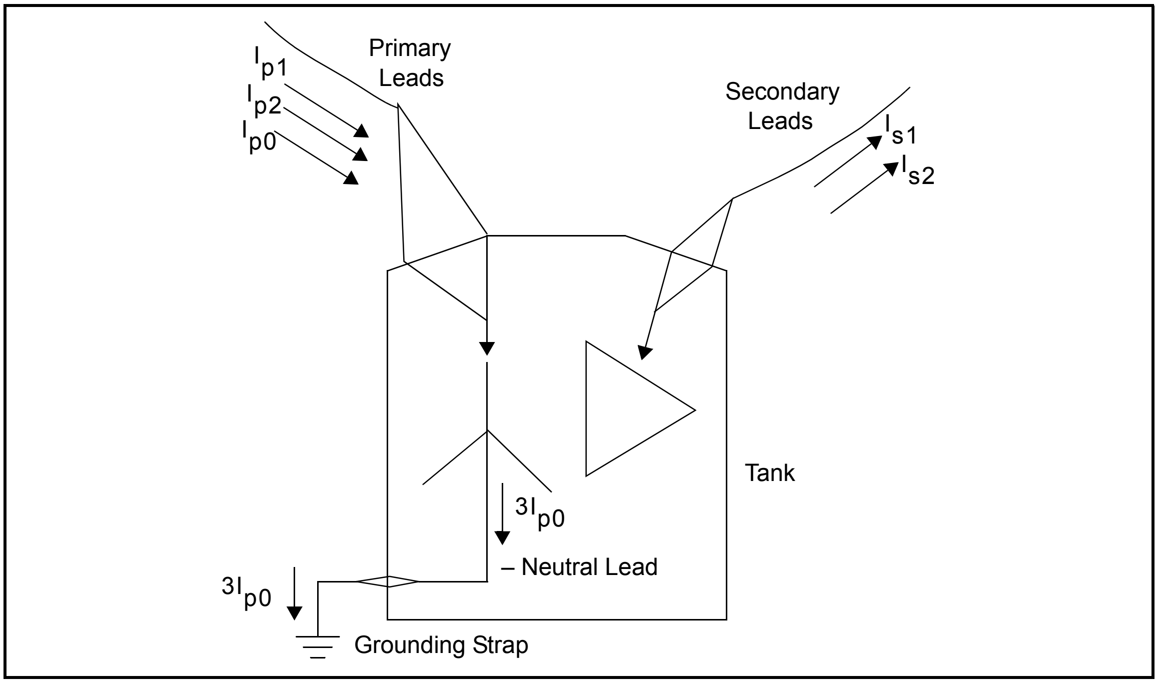


Figure 7-33. Lead Current Flowing Into and Out of a Wye-Delta Transformer

Consider the calculation of conditions at a bus where the following are connected:

- Transmission lines.
- A grounded wye-winding of a wye-delta transformer.
- A grounded wye-connected shunt reactor.
- A phase-to-ground fault somewhere on the bus side of all circuit breakers.

The bus arrangement is shown in Figure 7-34a. There are three components of zero-sequence current flowing from the bus to ground: fault current, reactor zero-sequence current, and transformer zero-sequence current. A conventional way of representing the bus is shown in Figure 7-34b. Here, the transformer is represented as a ground tie at the bus in the zero-sequence. The bus is assigned a shunt admittance equal to the sum of the reactor and transformer admittances. Use of this representation in system network solutions leads to correct results for bus positive-, negative-, and zero-sequence voltages. The subsequent calculation of transformer lead currents is erroneous, though, because the zero-sequence lead current appears to be zero when it should not be.

The alternative and recommended approach is to represent the transformer via the winding type code option of PSS™E. When the winding type code approach is used, the implied bus representation is as shown in Figure 7-34c.

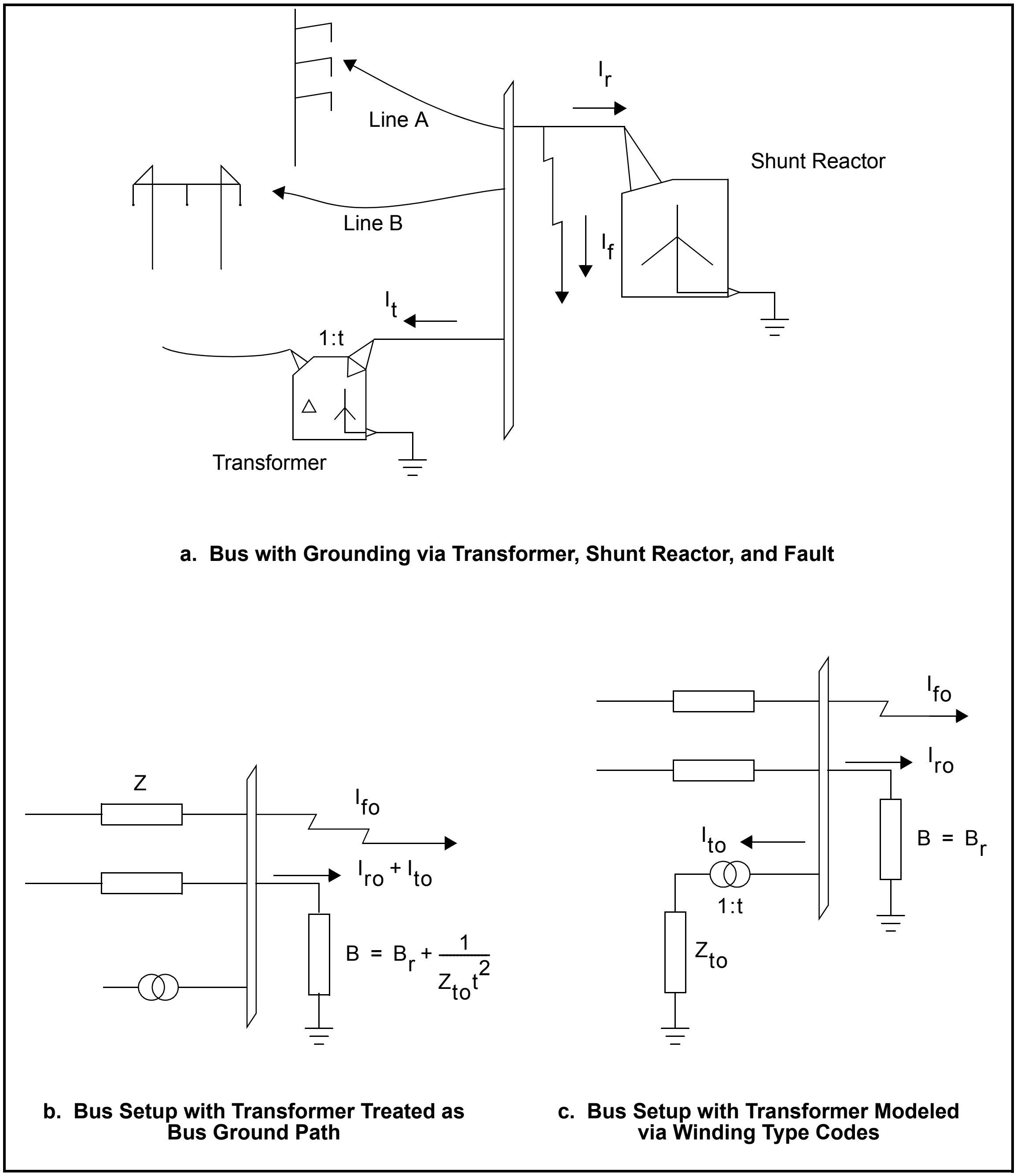


Figure 7-34. Transformer Zero-Sequence Currents Appearing in Alternative Network Representations of the Transformer

This results in the same system solution as obtained with the prior approach, but recognizes the zero-sequence current in the transformer leads. Calculations of transformer lead phase currents are correct, provided that the 30° phase shift of the transformer is handled properly.

While the winding type codes are normally used in the handling of the majority of transformers, use of manually determined shunt paths at buses may still be needed in special situations. When the winding type codes are not used, the following points must be noted:

- If wye windings of wye-delta transformers are to be represented as bus-connected shunt admittances to ground, the shunt admittance should be corrected for off-nominal turns ratio as shown by Figure 7-35.
- When wye-delta transformers are represented by bus-connected shunt admittances, the phase currents calculated by PSS™E for the leads to the delta-connected winding are correct, but the phase currents displayed for the wye winding leads are erroneous.
- Because the bus modeling topology shown in Figure 7-34b is correct for bus arrangements other than that shown in Figure 7-34a, PSS™E must assume that all calculated branch phase currents are valid and leave it for the user to accept or reject the output values.

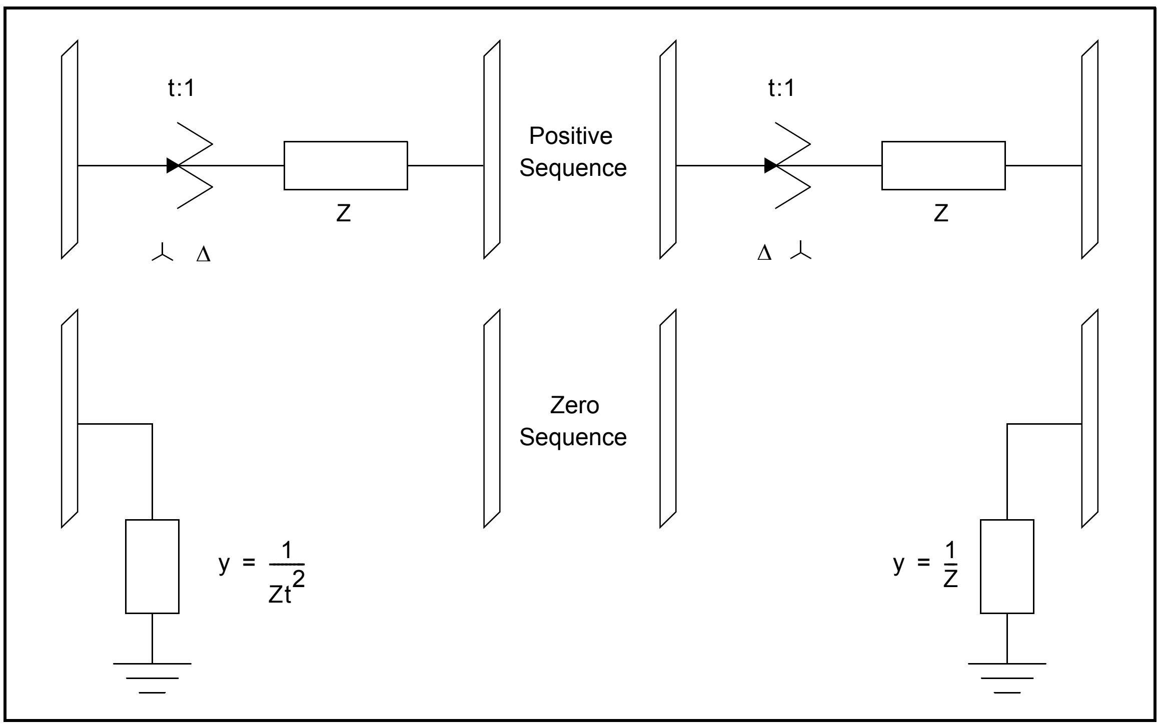


Figure 7-35. Assignment of Zero-Sequence Shunt Branch for Typical Tapped Delta-Wye Transformers, Solidly Grounded

7.7 Working with a Two-Wire System

PSS™E includes an option, in the detailed unbalanced fault analysis and the automatic sequencing fault analysis (Section 7.8), to handle certain two- and one-phase systems. This option was implemented primarily to handle certain European electric traction systems having a primary transmission system of two phases at 180° displacement feeding a single-phase catenary system. The basic system connections in this system are shown in Figure 7-36, but other two- and one-phase systems can be handled by the appropriate setup of the sequence network models.

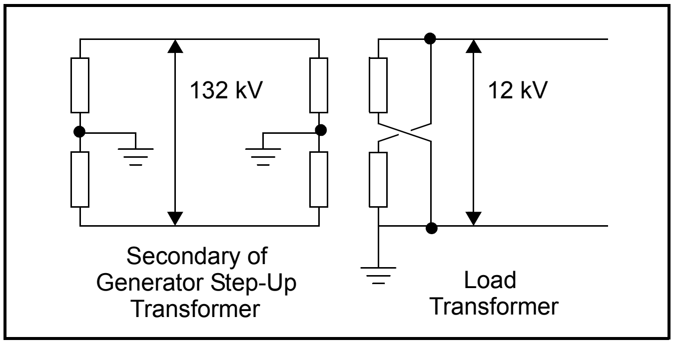


Figure 7-36. Two-Phase System Configuration for Railway Application

The two-phase system modelling assumption is established with the ***Short circuit phase modeling*** run-time option (Section 1.6.4). This option allows the selection of two-phase instead of the conventional three-phase mode. Selecting the two-phase option has the following effects:

- The symmetrical component "a" operator becomes (–1+j0), and the negative sequence is ignored, giving

$$\begin{bmatrix} i_0 \\ i_1 \end{bmatrix} = 1/2 \begin{bmatrix} 1 & 1 \\ 1 & -1 \end{bmatrix} \begin{bmatrix} i_a \\ i_b \end{bmatrix}$$

- The base voltage is taken to be the line-to-line voltage at base conditions, and the base current is taken to be the corresponding line current so that

$$I_{L\ base} = \frac{MVA_{base}}{V_{\mathrm{LL}\ base}}$$

$$Z_{LG\ base} = \frac{V^2_{\mathrm{LL}\ base}}{2MVA_{base}}$$

- Line-to-ground voltages in kV are calculated as

$$V_{LG} = 0.5(V_{\mathrm{LL}\ base} \times v_{pu})$$

  Phase currents in amperes are calculated as

$$I_p = I_{\mathrm{L}\ base} \times I_{pu}$$

  where v_{pu} and I_{pu} are the per-unit bus voltage and branch current, respectively.

Use of PSS™E under the two-phase option is identical to its use in conventional three-phase mode except for the following:

- Negative-sequence data may be entered for generators, branches, and loads but it is ignored in the fault calculations.
- Unbalanced faults may involve only phases 1 and 3. (The excluded phase in an L-L-G fault must be phase 2.) The three-phase fault selection must not be used.
- The two-phases-closed unbalance should not be used.

7.7.1 Transmission Lines

A two-phase two-conductor transmission line is characterized by positive- and zero-sequence impedances:

$$Z_1 = Z_p - Z_m$$

$$Z_0 = Z_p + Z_m$$

where

Z_1	=	Positive-sequence impedance.
Z_0	=	Zero-sequence impedance.
Z_p	=	Self impedance of one phase conductor.
Z_m	=	Mutual impedance between the phase conductors.

Similar expressions hold for the charging capacitances in the positive- and zero-sequences.

7.7.2 Transformers

The positive and zero-sequence characteristics of transformers must be determined from their internal connections. As an example, consider the transformer connection shown in Figure 7-36. The behavior of the transformer when positive and zero-sequence currents, respectively, flow in its primary windings are shown in Figure 7-37. When positive-sequence current flows in the primary side, the two secondary windings are effectively in parallel and a positive-sequence current flows in the secondary leads. When a zero-sequence current flows in the primary leads, the direction of current is reversed in one primary and secondary winding. The two secondary windings now form a short-circuited loop; a current corresponding to the primary zero-sequence current flows around this loop, but no zero-sequence current flows in the secondary leads. The behavior of the primary and secondary currents in this transformer is not affected by the grounding of one secondary lead; no zero-sequence current can flow into the transformer because the ground is external to it.

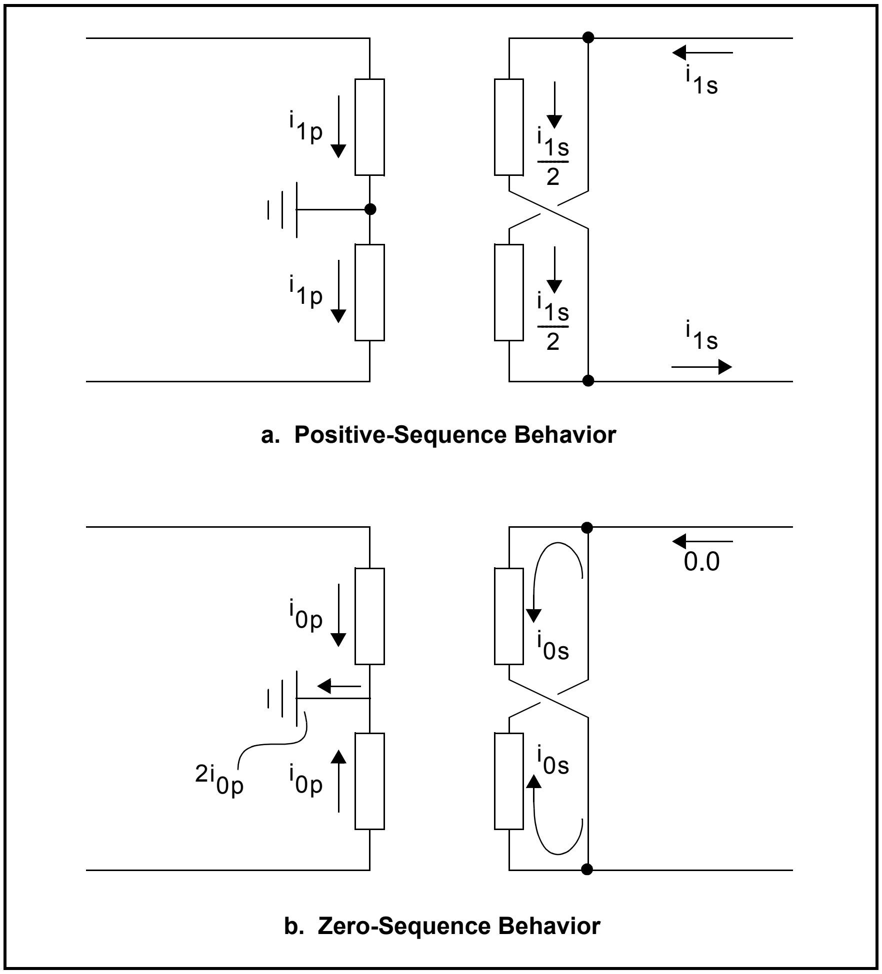


Figure 7-37. Behavior of Transformer with Secondary Windings Parallel to Single-Phase Load

The modeling of the load transformer in PSS™E can be handled in a completely standard manner by the use of grounding codes. The positive- and zero-sequence connections, corresponding to Figures 7-37 and 7-36, are shown in Figure 7-38. They may be specified to PSS™E by grounding codes of 2.

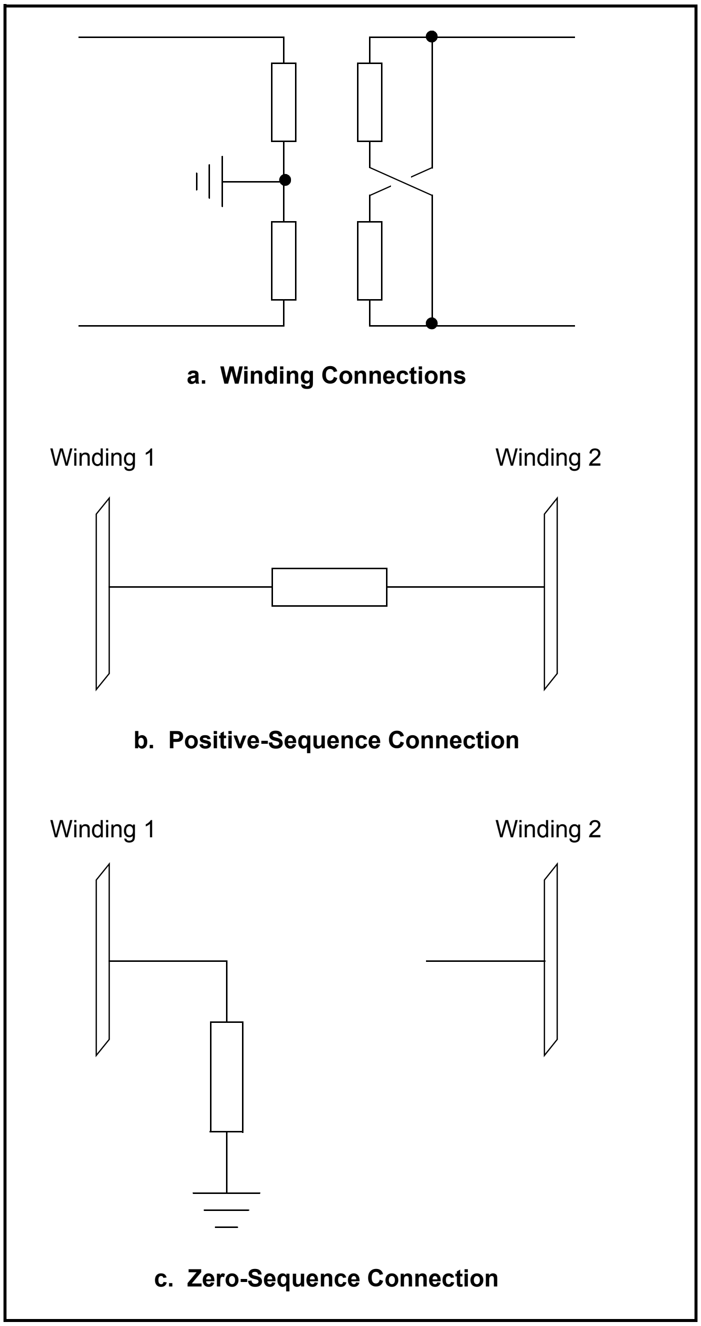
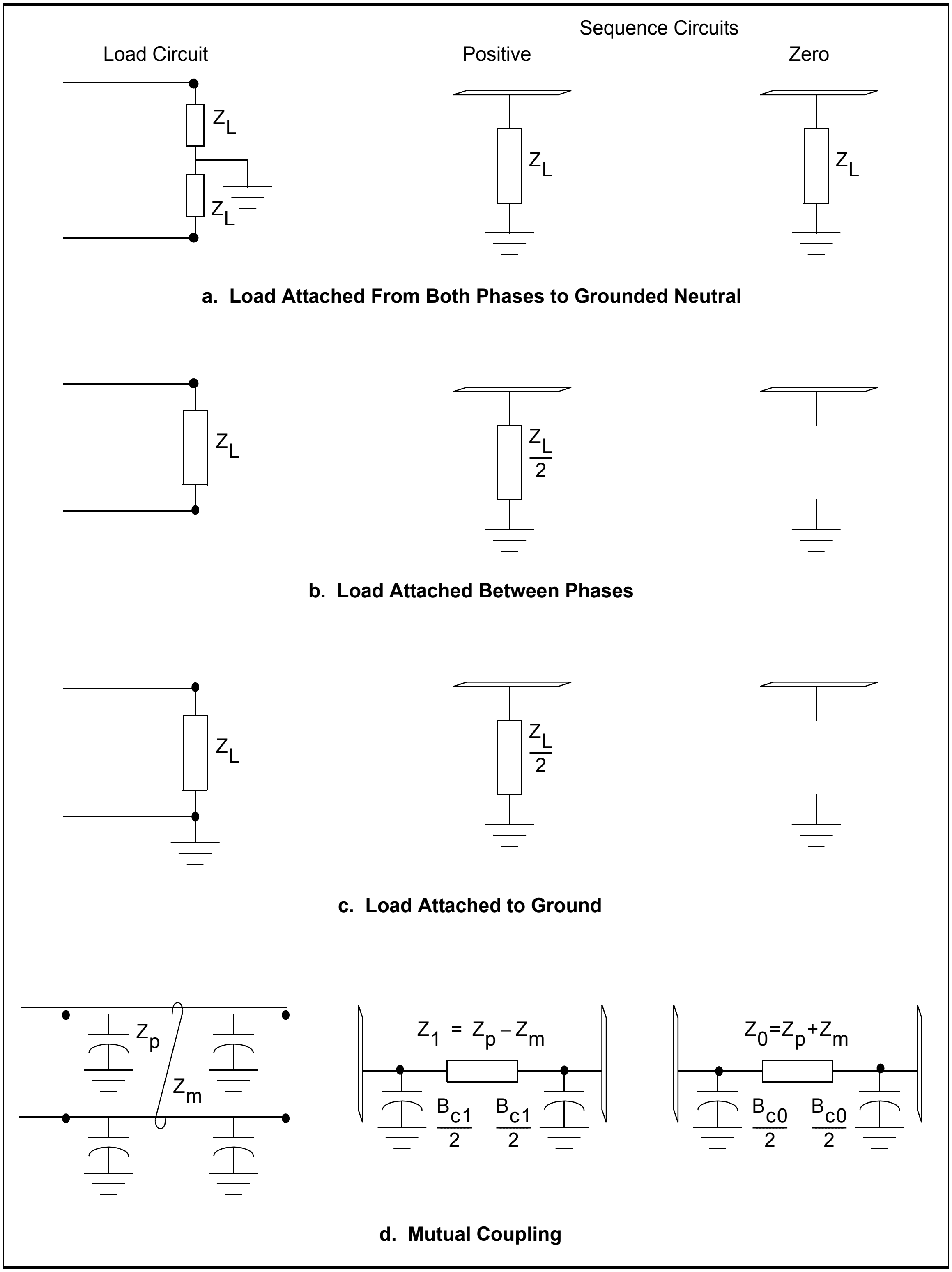


Figure 7-38. Sequence Connections Corresponding to Figure 7-37

7.7.3 Secondary Circuits

The load on the secondary side of the transformer shown in Figure 7-36 must be modeled according to its physical connections. Straightforward possibilities are shown in Figure 7-39. Grounding of one phase of a load does not create a zero-sequence path to ground. A ground must exist inside the load device in order for it to carry a zero-sequence current; such internal ground connections exist in the center-tapped load (Figure 7-39a) and in the transmission line section (Figure 7-39d) as a result of its shunt charging capacitances.



a. Load Attached From Both Phases to Grounded Neutral

b. Load Attached Between Phases

c. Load Attached to Ground

d. Mutual Coupling

Figure 7-39. Sequence Circuits for Loads on Two-Phase System

7.7.4 Faults on a Two-Phase System

Faults on the two phase system may be represented by the standard PSS™E repertoire, except that the three-phase and single-phase-open faults must not be used. The two phase system consists of phases a and c. Hence an L-G fault must be on phase a or c, and an L-L-G fault must exclude phase b.

7.7.5 Examples of Two-Wire Systems

Figure 7-40 shows a small sample system for use in two-phase fault analysis examples. The system data are summarized in Figures 7-41 and 7-42.

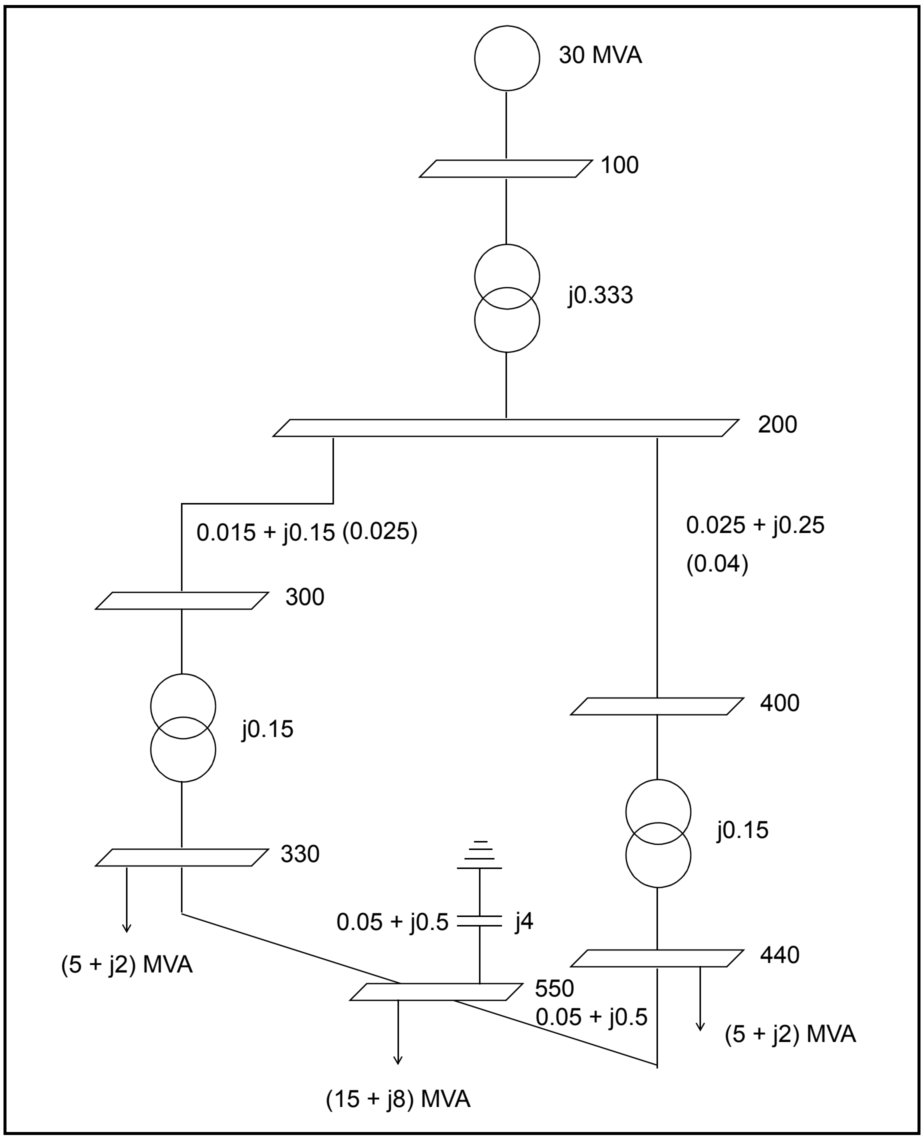


Figure 7-40. Sample System for Two-Phase Example Calculations

```
0,   100.00          / PSS™E-30.0    THU, AUG 05 2004  11:22
SMALL TWO PHASE EXAMPLE

   100,''GEN-1'     ',  10.0000,3,     0.000,     0.000,   1,   1,1.00000,   0.0000,   1
   200,''HYDRO'     ', 132.0000,1,     0.000,     0.000,   1,   1,0.98277,  -4.8404,   1
   300,''WEST'      ', 132.0000,1,     0.000,     0.000,   1,   1,0.97469,  -5.9957,   1
   330,''EAST-LO    ',  12.0000,1,     0.000,     0.000,   1,   1,0.96723,  -7.2034,   1
   400,''EAST'      ', 132.0000,1,     0.000,     0.000,   1,   1,0.97225,  -6.5672,   1
   440,''WEST-LO    ',  12.0000,1,     0.000,     0.000,   1,   1,0.96527,  -7.6463,   1
   550,''MAIN-LO    ',  12.0000,1,     0.000,     4.000,   1,   1,0.95002,  -9.6922,   1
0 / END OF BUS DATA, BEGIN LOAD DATA
   330,'1 ',1,   1,   1,     5.000,     2.000,     0.000,     0.000,     0.000,     0.000,   1
   440,'1 ',1,   1,   1,     5.000,     2.000,     0.000,     0.000,     0.000,     0.000,   1
   550,'1 ',1,   1,   1,    15.000,     8.000,     0.000,     0.000,     0.000,     0.000,   1
0 / END OF LOAD DATA, BEGIN GENERATOR DATA
   100,'3 ',    25.130,     6.283,    20.000,     0.000,1.00000,   200,    30.000,   0.00000,   0.20000,   0.00000,   0.00000,1.00000,1,    1.0,  9999.000, -9999.000,   1,1.0000
0 / END OF GENERATOR DATA, BEGIN BRANCH DATA
   200,    300,'1 ',   0.01500,   0.15000,   0.02500,   40.00,   40.00,   40.00,  0.00000,  0.00000,  0.00000,  0.00000,1,   0.00,   1,1.0000
   200,    400,'1 ',   0.02500,   0.25000,   0.04000,   40.00,   40.00,   40.00,  0.00000,  0.00000,  0.00000,  0.00000,1,   0.00,   1,1.0000
   330,    550,'1 ',   0.05000,   0.50000,   0.00000,   15.00,   15.00,   15.00,  0.00000,  0.00000,  0.00000,  0.00000,1,   0.00,   1,1.0000
   440,    550,'1 ',   0.05000,   0.50000,   0.00000,   15.00,   15.00,   15.00,  0.00000,  0.00000,  0.00000,  0.00000,1,   0.00,   1,1.0000
0 / END OF BRANCH DATA, BEGIN TRANSFORMER DATA
   200,   100,     0,'1 ',1,1,1,   0.00000,   0.00000,2,'            ',1,   1,1.0000
   0.00000,   0.33000,  100.00
1.00000,   0.000,   0.000,   35.00,   35.00,   35.00, 1,    200, 1.15000, 0.85000, 1.03000, 1.01000,  49, 0, 0.00000, 0.00000
1.00000,   0.000
   330,   300,     0,'1 ',1,1,1,   0.00000,   0.00000,2,'            ',1,   1,1.0000
   0.00000,   0.15000,  100.00
1.00000,   0.000,   0.000,   20.00,   20.00,   20.00, 1,    330, 1.15000, 0.85000, 1.00000, 0.98000,  49, 0, 0.00000, 0.00000
1.00000,   0.000
   440,   400,     0,'1 ',1,1,1,   0.00000,   0.00000,2,'            ',1,   1,1.0000
   0.00000,   0.15000,  100.00
1.00000,   0.000,   0.000,   20.00,   20.00,   20.00, 1,    440, 1.15000, 0.85000, 1.00000, 0.98000,  49, 0, 0.00000, 0.00000
1.00000,   0.000
0 / END OF TRANSFORMER DATA, BEGIN AREA DATA
0 / END OF AREA DATA, BEGIN TWO-TERMINAL DC DATA
0 / END OF TWO-TERMINAL DC DATA, BEGIN VSC DC LINE DATA
0 / END OF VSC DC LINE DATA, BEGIN SWITCHED SHUNT DATA
0 / END OF SWITCHED SHUNT DATA, BEGIN IMPEDANCE CORRECTION DATA
0 / END OF IMPEDANCE CORRECTION DATA, BEGIN MULTI-TERMINAL DC DATA
0 / END OF MULTI-TERMINAL DC DATA, BEGIN MULTI-SECTION LINE DATA
0 / END OF MULTI-SECTION LINE DATA, BEGIN ZONE DATA
0 / END OF ZONE DATA, BEGIN INTER-AREA TRANSFER DATA
0 / END OF INTER-AREA TRANSFER DATA, BEGIN OWNER DATA
0 / END OF OWNER DATA, BEGIN FACTS DEVICE DATA
0 / END OF FACTS DEVICE DATA
```

a. Load Flow Raw Data

Figure 7-41. Raw Data Files for Two-Phase System

```
0          / PSS™E-30.0    THU, AUG 05 2004  11:24
   100,'3 ',     0.00000,     0.20000
0  / END OF POSITIVE SEQ. MACHINE IMPEDANCE DATA, BEGIN NEGATIVE SEQ. MACHINE DATA
   100,'3 ',     0.00000,     0.20000
0  / END OF NEGATIVE SEQ. MACHINE IMPEDANCE DATA, BEGIN ZERO SEQ. MACHINE DATA
   100,'3 ',     0.00000,     0.00000
0  / END OF ZERO SEQ. MACHINE IMPEDANCE DATA, BEGIN NEGATIVE SEQ. SHUNT DATA
0  / END OF NEGATIVE SEQ. SHUNT DATA, BEGIN ZERO SEQ. SHUNT DATA
0  / END OF ZERO SEQ. SHUNT DATA, BEGIN ZERO SEQ. NON-TRANSFORMER BRANCH DATA
   200,   300,'1 ',    0.02000,    0.30000,    0.04000,  0.00000,  0.00000,  0.00000,  0.00000
   200,   400,'1 ',    0.04000,    0.45000,    0.06500,  0.00000,  0.00000,  0.00000,  0.00000
   330,   550,'1 ',    0.04000,    0.80000,    0.00000,  0.00000,  0.00000,  0.00000,  0.00000
   440,   550,'1 ',    0.04000,    0.80000,    0.00000,  0.00000,  0.00000,  0.00000,  0.00000
0  / END OF ZERO SEQ. NON-TRANSFORMER BRANCH DATA, BEGIN ZERO SEQ. MUTUAL DATA
0  / END OF ZERO SEQ. MUTUAL DATA, BEGIN ZERO SEQ. TRANSFORMER DATA
   100,   200,     0,'1 ',  2,     0.00000,    0.00000,    0.00000,    0.33000
   300,   330,     0,'1 ',  3,     0.00000,    0.00000,    0.00000,    0.15000
   400,   440,     0,'1 ',  3,     0.00000,    0.00000,    0.00000,    0.15000
0  / END OF ZERO SEQ. TRANSFORMER DATA, BEGIN ZERO SEQ. SWITCHED SHUNT DATA
0  / END OF ZERO SEQ. SWITCHED SHUNT DATA
```

Grounding codes to represent parallel-secondary transformer connections

b. Sequence Raw Data

Figure 7-41. (Cont.) Raw Data Files for Two-Phase System

```
     PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS™E      THU, AUG 05 2004  11:30
SMALL TWO PHASE EXAMPLE                                              BUS DATA

  BUS# X-- NAME --X BASKV CODE LOADS  VOLT  ANGLE       S H U N T  AREA ZONE OWNER
   100 'GEN-1'     10.000   3    0  1.0000    0.0     0.0       0.0    1    1    1
   200 'HYDRO'     132.00   1    0  0.9828   -4.8     0.0       0.0    1    1    1
   300 'WEST'      132.00   1    0  0.9747   -6.0     0.0       0.0    1    1    1
   330 'EAST-LO    12.000   1    1  0.9672   -7.2     0.0       0.0    1    1    1
   400 'EAST'      132.00   1    0  0.9723   -6.6     0.0       0.0    1    1    1
   440 'WEST-LO    12.000   1    1  0.9653   -7.6     0.0       0.0    1    1    1
   550 'MAIN-LO    12.000   1    1  0.9500   -9.7     0.0       4.0    1    1    1

  BUS# X-- NAME --X BASKV ID CD ST   PSI     MVA-LOAD      CUR-LOAD      Y - LOAD  AREA ZONE OWNER
   330 'EAST-LO    12.000 1   1 1  1.000    5.0    2.0    0.0    0.0    0.0    0.0    1    1    1
   440 'WEST-LO    12.000 1   1 1  1.000    5.0    2.0    0.0    0.0    0.0    0.0    1    1    1
   550 'MAIN-LO    12.000 1   1 1  1.000   15.0    8.0    0.0    0.0    0.0    0.0    1    1    1
                                                                                X----- REMOTE BUS ------X
  BUS# X-- NAME --X BASKV COD MCNS PGEN   QGEN   QMAX   QMIN VSCHED  VACT.  PCT Q   BUS# X-- NAME --X BASKV
   100 'GEN-1'     10.000  3   1   25.1    6.3   20.0    0.0 1.0000 0.9828    1.0    200 'HYDRO'     132.00

  BUS# X-- NAME --X BASKV CD ID ST  PGEN   QGEN   QMAX   QMIN   PMAX   PMIN  OWN FRACT  OWN FRACT  MBASE  Z S O R C E    X T R A N    GENTAP
   100 'GEN-1'     10.000  3 3  1   25.1    6.3   20.0    0.0 9999.0-9999.0    1 1.000              30.0 0.0000 0.2000

X------ FROM BUS -------X  X------- TO BUS --------X                              Z S
  BUS# X-- NAME --X BASKV    BUS# X-- NAME --X BASKV CKT   LINE R   LINE X  CHRGING I T  RATEA  RATEB  RATEC LENGTH OWNR FRACT OWNR FRACT
   200 'HYDRO'     132.00*    300 'WEST'      132.00  1   0.01500  0.15000  0.02500   1   40.0   40.0   40.0    0.0    1 1.000
   200 'HYDRO'     132.00*    400 'EAST'      132.00  1   0.02500  0.25000  0.04000   1   40.0   40.0   40.0    0.0    1 1.000
   330 'EAST-LO    12.000*    550 'MAIN-LO    12.000  1   0.05000  0.50000  0.00000   1   15.0   15.0   15.0    0.0    1 1.000
   440 'WEST-LO    12.000*    550 'MAIN-LO    12.000  1   0.05000  0.50000  0.00000   1   15.0   15.0   15.0    0.0    1 1.000

X------ FROM BUS -------X X------- TO BUS --------X        XFRMER    S W M C C     A C T U A L            MAGNETIZING Y        N O M I N A L
  BUS# X-- NAME --X BASKV   BUS# X-- NAME --X BASKV CKT X-- NAME --X T 1 T Z M   R 1-2    X 1-2  W1BASE    MAG1     MAG2  TBL  R 1-2    X 1-2
   100 'GEN-1'     10.000    200 'HYDRO'     132.00  1              1 T T 1 1  0.00000  0.33000  100.0  0.00000  0.00000  0
   300 'WEST'      132.00    330 'EAST-LO    12.000  1              1 T T 1 1  0.00000  0.15000  100.0  0.00000  0.00000  0
   400 'EAST'      132.00    440 'WEST-LO    12.000  1              1 T T 1 1  0.00000  0.15000  100.0  0.00000  0.00000  0

X------ FROM BUS -------X X------- TO BUS --------X     C
  BUS# X-- NAME --X BASKV   BUS# X-- NAME --X BASKV CKT W  WINDV1  NOMV1  ANGLE  WINDV2  NOMV2  RATEA  RATEB  RATEC OWNR FRACT OWNR FRACT
   100 'GEN-1'     10.000    200 'HYDRO'     132.00  1  1 1.00000 0.0000    0.0 1.00000 0.0000   35.0   35.0   35.0    1 1.000
   300 'WEST'      132.00    330 'EAST-LO    12.000  1  1 1.00000 0.0000    0.0 1.00000 0.0000   20.0   20.0   20.0    1 1.000
   400 'EAST'      132.00    440 'WEST-LO    12.000  1  1 1.00000 0.0000    0.0 1.00000 0.0000   20.0   20.0   20.0    1 1.000

X------ FROM BUS -------X X------- TO BUS --------X     W C                                     X---- CONTROLLED BUS ----X
  BUS# X-- NAME --X BASKV   BUS# X-- NAME --X BASKV CKT 1 W CN    RMAX    RMIN    VMAX    VMIN  NTPS    BUS# X-- NAME --X BASKV    CR      CX
   100 'GEN-1'     10.000    200 'HYDRO'     132.00  1  T 1  1 1.15000 0.85000 1.03000 1.01000   49    -200 'HYDRO'     132.00
   300 'WEST'      132.00    330 'EAST-LO    12.000  1  T 1  1 1.15000 0.85000 1.00000 0.98000   49    -330 'EAST-LO    12.000
   400 'EAST'      132.00    440 'WEST-LO    12.000  1  T 1  1 1.15000 0.85000 1.00000 0.98000   49    -440 'WEST-LO    12.000
```

Figure 7-42. Data Listings for Two-Phase System

```
 BUS# X-- NAME --X BASKV CODE   ZERO SEQ SHUNT    NEG SEQ SHUNT     POS SEQ SHUNT        MVA-LOAD        CURRENT-LOAD    ADMITTANCE-LOAD
  100 'GEN-1'     10.000   3   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
  200 'HYDRO'     132.00   1   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
  300 'WEST'      132.00   1   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
  330 'EAST-LO    12.000   1   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0500   0.0200   0.0000   0.0000   0.0000   0.0000
  400 'EAST'      132.00   1   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
  440 'WEST-LO    12.000   1   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000   0.0500   0.0200   0.0000   0.0000   0.0000   0.0000
  550 'MAIN-LO    12.000   1   0.0000   0.0000   0.0000   0.0000   0.0000   0.0400   0.1500   0.0800   0.0000   0.0000   0.0000   0.0000

 BUS# X-- NAME --X BASKV ID CODE ST    ZGEN (ZERO)       ZGEN (POSITIVE)     ZGEN (NEGATIVE)    MBASE      X T R A N     GENTAP
  100 'GEN-1'     10.000 3    3  1  0.00000  0.00000    0.00000  0.20000    0.00000  0.20000    30.0  0.00000  0.00000  1.0000

X------ FROM BUS -------X X------- TO BUS --------X           X- POS AND NEG SEQUENCE -X X---- ZERO SEQUENCE -----X
 BUS# X-- NAME --X BASKV    BUS# X-- NAME --X BASKV CKT ST ZI   LINE R   LINE X CHARGING   LINE R   LINE X CHARGING
  200 'HYDRO'     132.00     300 'WEST'      132.00  1   1      0.01500  0.15000  0.02500  0.02000  0.30000  0.04000
  200 'HYDRO'     132.00     400 'EAST'      132.00  1   1      0.02500  0.25000  0.04000  0.04000  0.45000  0.06500
  330 'EAST-LO    12.000     550 'MAIN-LO    12.000  1   1      0.05000  0.50000  0.00000  0.04000  0.80000  0.00000
  440 'WEST-LO    12.000     550 'MAIN-LO    12.000  1   1      0.05000  0.50000  0.00000  0.04000  0.80000  0.00000

X------ FROM BUS -------X X------- TO BUS --------X    S W C X-- POS & NEG --X X-------- ZERO SEQUENCE --------X X- WINDING1 -X WINDNG2   MAGNETIZING Y
 BUS# X-- NAME --X BASKV    BUS# X-- NAME --X BASKV CK T 1 C     R        X        R        X     RGROUND XGROUND  RATIO   ANGLE  RATIO      G       B
  100 'GEN-1'     10.000     200 'HYDRO'     132.00 1  1 T 2  0.00000  0.33000  0.00000  0.33000  0.0000  0.0000 1.00000    0.0 1.00000  0.0000  0.0000
  300 'WEST'      132.00     330 'EAST-LO    12.000 1  1 T 3  0.00000  0.15000  0.00000  0.15000  0.0000  0.0000 1.00000    0.0 1.00000  0.0000  0.0000
  400 'EAST'      132.00     440 'WEST-LO    12.000 1  1 T 3  0.00000  0.15000  0.00000  0.15000  0.0000  0.0000 1.00000    0.0 1.00000  0.0000  0.0000
```

Capacitor bank not grounded internally

Grounding codes reflect center tapped primary/parallel secondary transformer arrangements

Figure 7-42. (Cont.) Data Listings for Two-Phase System

The initial condition load flow solution is shown in Figure 7-43; this is exactly the same as for a three-phase system solution since it involves only balanced operation and the positive sequence. The bus voltages in kilovolts are line-to-line values. This solution was made with the following PSS™E option settings:

- 50 Hz base frequency.
- Two-phase solution mode.
- Polar output of fault analysis results.

```
     PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS™E      TUE, OCT 08 1991  14:58
SMALL TWO PHASE EXAMPLE                                                 RATING
SYSTEM FOR PROGRAM APPLICATION GUIDE                                     SET A

BUS    100 GEN-1    10.0 AREA CKT     MW      MVAR     MVA  %I 1.0000PU   0.00  100
 GENERATION                1         25.1      5.5R   25.7  86 10.000KV
 TO    200 HYDRO     132   1   1     25.1      5.5    25.7  73 1.0313UN

BUS    200 HYDRO     132 AREA CKT     MW      MVAR     MVA  %I 1.0162PU  -4.83  200
                           1                                   134.13KV
 TO    100 GEN-1    10.0   1   1    -25.1     -3.3    25.3  71 1.0313LK
 TO    300 WEST      132   1   1     13.3      2.5    13.5  33
 TO    400 EAST      132   1   1     11.8      0.8    11.9  29

BUS    300 WEST      132 AREA CKT     MW      MVAR     MVA  %I 1.0087PU  -5.91  300
                           1                                   133.15KV
 TO    200 HYDRO     132   1   1    -13.3     -4.8    14.1  35
 TO    330 EAST-LOD12.0    1   1     13.3      4.8    14.1  70 0.9937UN

BUS    330 EAST-LOD12.0 AREA CKT      MW      MVAR     MVA  %I 0.9955PU  -7.04  330
                           1                                   11.946KV
 TO LOAD-PQ                           5.0      2.0     5.4
 TO    300 WEST      132   1   1    -13.3     -4.5    14.0  70 0.9937LK
 TO    550 MAIN-LOD12.0    1   1      8.3      2.5     8.6  58

BUS    400 EAST      132 AREA CKT     MW      MVAR     MVA  %I 1.0066PU  -6.45  400
                           1                                   132.88KV
 TO    200 HYDRO     132   1   1    -11.8     -4.5    12.6  31
 TO    440 WEST-LOD12.0    1   1     11.8      4.5    12.6  63 0.9937UN

BUS    440 WEST-LOD12.0 AREA CKT      MW      MVAR     MVA  %I 0.9938PU  -7.45  440
                           1                                   11.926KV
 TO LOAD-PQ                           5.0      2.0     5.4
 TO    400 EAST      132   1   1    -11.8     -4.3    12.6  63 0.9937LK
 TO    550 MAIN-LOD12.0    1   1      6.8      2.3     7.2  48

BUS    550 MAIN-LOD12.0 AREA CKT      MW      MVAR     MVA  %I 0.9795PU  -9.39  550
                           1                                   11.754KV
 TO LOAD-PQ                          15.0      8.0    17.0
 TO SHUNT                             0.0     -3.8     3.8
 TO    330 EAST-LOD12.0    1   1     -8.2     -2.1     8.5  58
 TO    440 WEST-LOD12.0    1   1     -6.8     -2.0     7.1  48
```

Figure 7-43. Initial Condition Load Flow Solution for Two-Phase Sample System

Figure 7-43 shows output from activity SCOP corresponding directly to Figure 7-42, with no fault applied. In this report the negative sequence and "b-phase" fields have no significance. The "a" and "c" phase voltage fields show sequence and phase voltages on a line-to-ground basis. The current values are in terms of per unit line current.

```
SEQUENCE             /V0/     AN(V0)     /V+/     AN(V+)     /V-/     AN(V-)
PHASE                /VA/     AN(VA)     /VB/     AN(VB)     /VC/     AN(VC)

  550   (P.U.)      0.0000      0.00    0.9795     -9.39    0.0000      0.00
MAIN-LOD12.0        0.9795     -9.39    0.0000      0.00    0.9795    170.61

SEQUENCE             /I0/     AN(I0)     /I+/     AN(I+)     /I-/     AN(I-)
PHASE                /IA/     AN(IA)     /IB/     AN(IB)     /IC/     AN(IC)

TO    330   1       0.0000      0.00    0.0867    155.97    0.0000      0.00
EAST-LOD12.0        0.0867    155.97    0.0000      0.00    0.0867    -24.03

TO    440   1       0.0000      0.00    0.0722    154.05    0.0000      0.00
WEST-LOD12.0        0.0722    154.05    0.0000      0.00    0.0722    -25.95

SUM OF              0.0000      0.00    0.1589    -24.90    0.0000      0.00
CONTRIBUTIONS       0.1589    -24.90    0.0000      0.00    0.1589    155.10


SEQUENCE             /V0/     AN(V0)     /V+/     AN(V+)     /V-/     AN(V-)
PHASE                /VA/     AN(VA)     /VB/     AN(VB)     /VC/     AN(VC)

  330   (P.U.)      0.0000      0.00    0.9955     -7.04    0.0000      0.00
EAST-LOD12.0        0.9955     -7.04    0.0000      0.00    0.9955    172.96

SEQUENCE             /I0/     AN(I0)     /I+/     AN(I+)     /I-/     AN(I-)
PHASE                /IA/     AN(IA)     /IB/     AN(IB)     /IC/     AN(IC)

TO    300   1       0.0000      0.00    0.1407    154.13    0.0000      0.00
WEST      132       0.1407    154.13    0.0000      0.00    0.1407    -25.87

TO    550   1       0.0000      0.00    0.0867    -24.03    0.0000      0.00
MAIN-LOD12.0        0.0867    -24.03    0.0000      0.00    0.0867    155.97

SUM OF              0.0000      0.00    0.0541    -28.84    0.0000      0.00
CONTRIBUTIONS       0.0541    -28.84    0.0000      0.00    0.0541    151.16
```

Figure 7-44. Output from Short-Circuit Solution Reporting Corresponding to Figure 7-42

Comparison of the flow into bus 550 from bus 330 in Figures 7-42 and 7-43 and shows:

- Received MVA = 8.5
- Receiving voltage = 0.9795 per unit = 11.754 kV (L-L) = 5.877 kV (L-G)
- Phase current, I_p, from Figure 7-42, = $\frac{MVA}{V_{LL}} = \frac{8.5E6}{11.754E3} = 723.2$ A
- Base phase current $= \frac{MVA_{base}}{V_{\text{LL base}}} = \frac{100E6}{12E3} = 8333.3$ A
- Per-unit phase current, from Figure 7-42, $= \frac{723.2}{8333.3} = 0.08605$ per unit
- Per-unit phase current, from Figure 7-43, $=$ 0.0867 per unit

Rerunning the bus based report with the kVA output option in effect shows that bus 550 receives 8496.5 kVA from bus 330. Redoing the above calculations gives the per-unit current as

$$\frac{8.4965E6}{11.754E3 \times 8333.3} = 0.08674 \text{ per unit}$$

All transformers in the system are connected as shown in Figure 7-36 with two low-voltage windings in parallel. This is reflected in the grounding code data in Figures 7-41 and 7-42. The shunt capacitor bank at bus 550 is connected line-to-line and is not grounded internally. Figure 7-45 shows the output from the unbalance fault calculation for a single L-G fault applied at bus 300.

As expected, the a-phase bus voltage at the fault is zero, and a current of 1.6417 per unit flows into the fault, and at the fault $I_0 = I_1 = V_{oc}/(Z_0 + Z_1)$.

$$I_0 = I_1 = \frac{1.009}{0.00127 + j0.11696 + 0.28804 + j1.07742 \text{ (from Figure 7-45)}}$$

$$= 0.1933 - j0.798 = 0.8211\angle{-76.4}$$

Figure 7-46 shows the result for an L-G fault at bus 330. Here, because no zero-sequence ground path exists in the secondary system except for the fault, there is no fault current, and no unbalance appears in the 132 kV primary system.

The ground connection at one point in the system does not affect the balanced load current at bus 330, and the fault current is zero. The a-phase voltage at bus 330 is zero, as expected. The c-phase voltage at bus 330 is listed by SCMU as 1.991 per unit. The phase voltages listed by SCMU are per-unit of phase-to-ground base voltage, and correspond to an a-phase-to-ground voltage of kV.

```
LINE TO GROUND FAULT AT BUS    300 [WEST     132]    PHASE 1
  L-G Z =    0.0000E+00    0.0000E+00

              SEQUENCE THEVENIN IMPEDANCES AT FAULTED BUSES:

  BUS   NAME   BSKV           ZERO              POSITIVE            NEGATIVE
  300 WEST     132     0.00127  0.11696    0.28804  1.07742    0.00000  0.00000



LINE TO GROUND FAULT AT BUS    300 [WEST     132]:

SEQUENCE            /V0/     AN(V0)     /V+/     AN(V+)     /V-/     AN(V-)
PHASE               /VA/     AN(VA)     /VB/     AN(VB)     /VC/     AN(VC)

  300  (P.U.)      0.0960   -172.91    0.0960      7.09    0.0000      0.00
WEST      132      0.0000      0.00    0.0000      0.00    0.1920   -172.91

SEQUENCE            /I0/     AN(I0)     /I+/     AN(I+)     /I-/     AN(I-)
PHASE               /IA/     AN(IA)     /IB/     AN(IB)     /IC/     AN(IC)

FROM    200 1      0.1810    -80.09    0.7558    -80.88    0.0000      0.00
HYDRO     132      0.9368    -80.73    0.0000      0.00    0.5749     98.87

FROM    330 1      0.6400    -82.91    0.0679    -98.25    0.0000      0.00
EAST-LOD12.0       0.7057    -84.37    0.0000      0.00    0.5749    -81.13

SUM OF CONTRIBUTIONS INTO BUS    300 [WEST     132]:

  300              0.8208    -82.29    0.8208    -82.29    0.0000      0.00
WEST      132      1.6417    -82.29    0.0000      0.00    0.0000      0.00

CONTRIBUTIONS EQUIVALENT POSITIVE SEQUENCE ADMITTANCE    0.0927   -8.5492

FAULT CURRENT AT BUS    300 [WEST     132]:

  300              0.8208    -82.29    0.8208    -82.29    0.0000      0.00
WEST      132      1.6417    -82.29    0.0000      0.00    0.0000      0.00

POSITIVE SEQUENCE EQUIVALENT FAULT ADMITTANCE    0.0927   -8.5492
```

Load currents flowing in c-phase

a-phase fault current contributions

I0 = I1 for a-phase fault current

Fault current

Figure 7-45. Simple L-G Fault at Bus 300

```
UNBALANCES APPLIED:

LINE TO GROUND FAULT AT BUS   330 [EAST-LOD12.0]    PHASE 1
  L-G Z =    0.0000E+00    0.0000E+00


              SEQUENCE THEVENIN IMPEDANCES AT FAULTED BUSES:

  BUS   NAME   BSKV            ZERO              POSITIVE            NEGATIVE
  330 EAST-LOD12.0  ******************    0.32217  1.14687    0.00000  0.00000

LINE TO GROUND FAULT AT BUS   330 [EAST-LOD12.0]:

SEQUENCE                 /V0/     AN(V0)     /V+/     AN(V+)     /V-/     AN(V-)
PHASE                    /VA/     AN(VA)     /VB/     AN(VB)     /VC/     AN(VC)

  330   (P.U.)          0.9955    172.96    0.9955     -7.04    0.0000      0.00
EAST-LOD12.0            0.0000      0.00    0.0000      0.00    1.9910    172.96

SEQUENCE                 /I0/     AN(I0)     /I+/     AN(I+)     /I-/     AN(I-)
PHASE                    /IA/     AN(IA)     /IB/     AN(IB)     /IC/     AN(IC)

FROM   300 1            0.0000      0.00    0.1407    -25.87    0.0000      0.00
WEST     132            0.1407    -25.87    0.0000      0.00    0.1407    154.13

FROM   550 1            0.0000      0.00    0.0867    155.97    0.0000      0.00
MAIN-LOD12.0            0.0867    155.97    0.0000      0.00    0.0867    -24.03


SUM OF CONTRIBUTIONS INTO BUS   330 [EAST-LOD12.0]:

  330                   0.0000      0.00    0.0541    -28.84    0.0000      0.00
EAST-LOD12.0            0.0541    -28.84    0.0000      0.00    0.0541    151.16

CONTRIBUTIONS EQUIVALENT POSITIVE SEQUENCE ADMITTANCE     0.0505    -0.0202


FAULT CURRENT AT BUS   330 [EAST-LOD12.0]:

  330                   0.0000      0.00    0.0000      0.00    0.0000      0.00
EAST-LOD12.0            0.0000      0.00    0.0000      0.00    0.0000      0.00

POSITIVE SEQUENCE EQUIVALENT FAULT ADMITTANCE     0.0000     0.0000
```

Zero voltage at point of ground on system

Voltage on ungrounded phase is fully offset

Ground does not affect balanced load current; compare with Figure 7-43

Fault current is zero

Figure 7-46. Simple Ground Connection at Bus 330

Figure 7-47 shows the results when the a-phase of the 12-kV system is grounded (by an L-G fault) at both bus 330 and bus 550. In some cases, the ungrounded zero-sequence network cannot be handled by PSS™E because its admittance matrix is singular. This problem is rectified by connecting a low admittance branch to ground in the zero sequence at an appropriate bus; this small shunt admittance is insignificant in relation to the admittances of the system branches, but is adequate to avoid the numerical problems stemming from the singular matrix.

Figure 7-48 shows the phase currents from Figure 7-47 on the 2-line diagram of the secondary system. Note the following:

- The SUM OF CONTRIBUTIONS shown by the unbalance fault calculation for the *a*-phase includes both load and ground current.

Current does flow on the *a*-phase conductor from bus 330 to 550 even though it is solidly grounded at both ends, as a result of the mutual coupling between the two phases of the line. No current would flow in the *a*-phase conductor if the two phases were of isolated-phase construction and had no phase-to-phase mutual impedance.

```
LINE TO GROUND FAULT AT BUS   330 [EAST-LOD12.0]   PHASE 1
  L-G Z =   0.0000E+00   0.0000E+00

LINE TO GROUND FAULT AT BUS   550 [MAIN-LOD12.0]   PHASE 1
  L-G Z =   0.0000E+00   0.0000E+00

              SEQUENCE THEVENIN IMPEDANCES AT FAULTED BUSES:

  BUS   NAME   BSKV          ZERO               POSITIVE           NEGATIVE
  330 EAST-LOD12.0    0.00007*********    0.32217  1.14687    0.00000  0.00000
  550 MAIN-LOD12.0    0.04007-99.20067    0.42517  1.25624    0.00000  0.00000


SEQUENCE             /V0/     AN(V0)     /V+/     AN(V+)     /V-/     AN(V-)
PHASE                /VA/     AN(VA)     /VB/     AN(VB)     /VC/     AN(VC)

  330  (P.U.)       1.0066    172.51    1.0066     -7.49    0.0000      0.00
EAST-LOD12.0        0.0000      0.00    0.0000      0.00    2.0132    172.51  Zero voltage at
                                                                            grounded point
SEQUENCE             /I0/     AN(I0)     /I+/     AN(I+)     /I-/     AN(I-)
PHASE                /IA/     AN(IA)     /IB/     AN(IB)     /IC/     AN(IC)

FROM   300 1        0.0000      0.00    0.1517    -23.04    0.0000      0.00
WEST      132       0.1517    -23.04    0.0000      0.00    0.1517    156.96

FROM   550 1        0.0386    -26.93    0.0616    155.92    0.0000      0.00
MAIN-LOD12.0        0.0231    160.69    0.0000      0.00    0.1001    -25.18
                                         Note current flow in a-phase conductor even
                                         though it is grounded at both ends

SUM OF CONTRIBUTIONS INTO BUS   330 [EAST-LOD12.0]:

  330               0.0386    -26.93    0.0902    -22.33    0.0000      0.00
EAST-LOD12.0        0.1287    -23.71    0.0000      0.00    0.0518    161.10

CONTRIBUTIONS EQUIVALENT POSITIVE SEQUENCE ADMITTANCE    0.0866   -0.0229
                                                                            Load current

LINE TO GROUND FAULT AT BUS   550 [MAIN-LOD12.0]:

SEQUENCE             /V0/     AN(V0)     /V+/     AN(V+)     /V-/     AN(V-)
PHASE                /VA/     AN(VA)     /VB/     AN(VB)     /VC/     AN(VC)

  550  (P.U.)       0.9953    170.86    0.9953     -9.14    0.0000      0.00
MAIN-LOD12.0        0.0000      0.00    0.0000      0.00    1.9906    170.86  Zero voltage at
                                                                            grounded point
SEQUENCE             /I0/     AN(I0)     /I+/     AN(I+)     /I-/     AN(I-)
PHASE                /IA/     AN(IA)     /IB/     AN(IB)     /IC/     AN(IC)

FROM   330 1        0.0386    153.07    0.0616    -24.08    0.0000      0.00
EAST-LOD12.0        0.0231    -19.31    0.0000      0.00    0.1001    154.82

FROM   440 1        0.0000      0.00    0.0614    -23.79    0.0000      0.00
WEST-LOD12.0        0.0614    -23.79    0.0000      0.00    0.0614    156.21


SUM OF CONTRIBUTIONS INTO BUS   550 [MAIN-LOD12.0]:  Algebraic sum of load and ground current

  550               0.0386    153.07    0.1229    -23.93    0.0000      0.00     Load
MAIN-LOD12.0        0.0844    -22.56    0.0000      0.00    0.1615    155.35     current

CONTRIBUTIONS EQUIVALENT POSITIVE SEQUENCE ADMITTANCE    0.1194   -0.0315
```

Figure 7-47. Secondary System Grounded at Buses 330 and 550

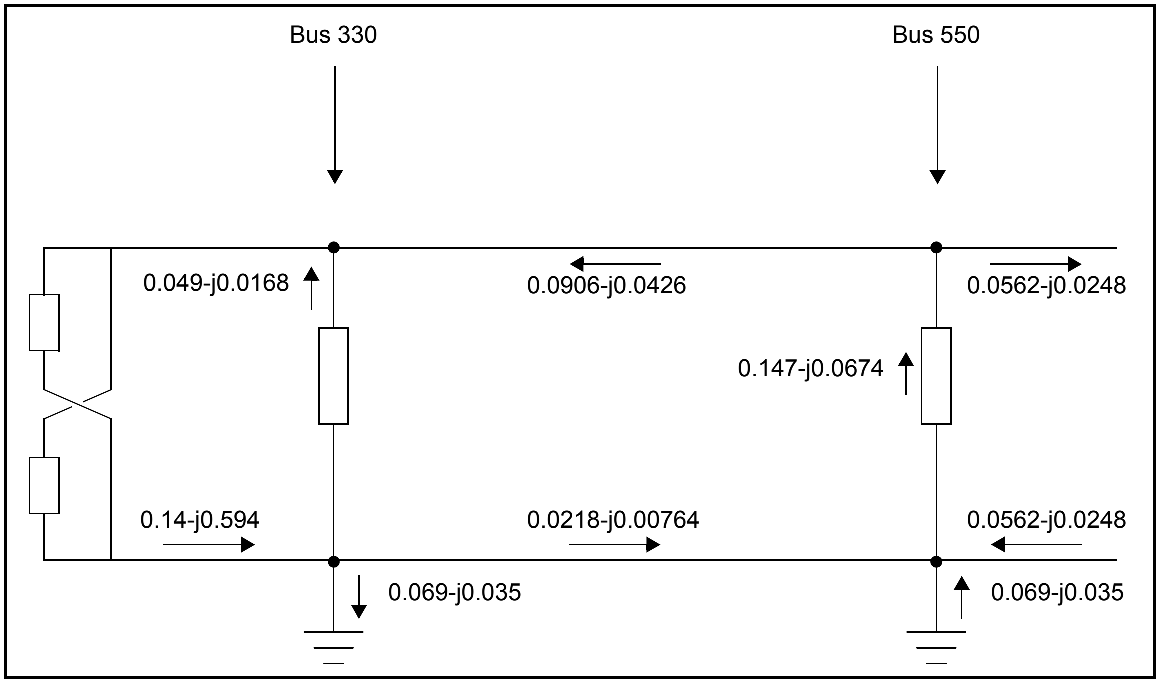


Figure 7-48. Current Flows (per unit) from Figure 7-47

7.8 Performing Automatic Sequencing Fault Analysis

The automatic sequencing short circuit calculation in PSS™E, allows the user to apply a series of single faults at various locations in the working case. The process provides for:

1. A prefault network condition either as specified in the working case or, optionally, corresponding to classical "flat" fault analysis assumptions.
2. The specification of the subsystem to be processed according to the standard selection criteria used throughout PSS™E. Each electrically connected bus in the specified subsystem becomes the "home bus" for one or more fault analysis network solutions.
3. The application of only three phase faults or both three phase and single-line-to-ground faults at each fault location.
4. The application of the faults selected in (3) at each "home bus" selected in (2).
5. Optionally, (4) again with each branch connected to the "home bus" in turn removed from service.
6. Optionally, (4) again with the far end of each branch connected to the "home bus" in turn opened, and the faults applied at the line end position.
7. Optionally, (4) again with specified branches in turn removed from service.
8. A selection of output options for each fault applied, ranging from a tabulation of fault currents through detailed output of conditions at the "home bus" along with detailed output for all buses up to "n" levels away from the "home bus".

7.8.1 Setting the Automatic Sequencing Fault Selection Options

The term "home bus" refers to any bus location selected for application of either three phase faults or both three phase and single-line-to-ground faults. Figure 7-49 shows a three bus system in which Bus I has been selected for fault application L.

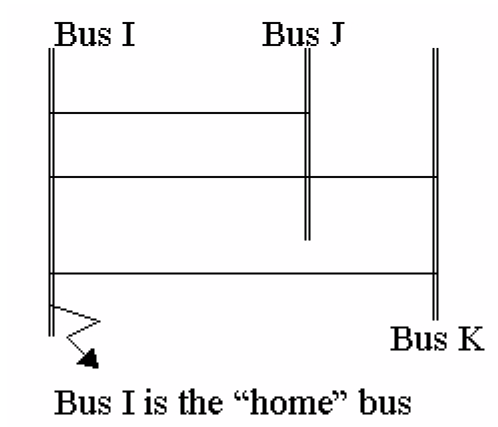


Figure 7-49. Home Bus

Bus I is the "home" bus and if faults are to be selected only at home buses there will be a maximum of 2 faults applied at Bus I, if both a three phase and a single-line-to-ground fault are applied. With only a 3-phase fault applied the number of faults will be limited to one.

Figure 7-50 shows the option where a fault is to be applied at the home bus with all circuits in service and with each outgoing line out of service in turn. In this situation, for this "home" bus, there will be 4 faults if only one fault type is selected. If line outages are performed on a selective basis instead of selecting "all" outgoing branches, the number of faults applied will clearly be reduced.

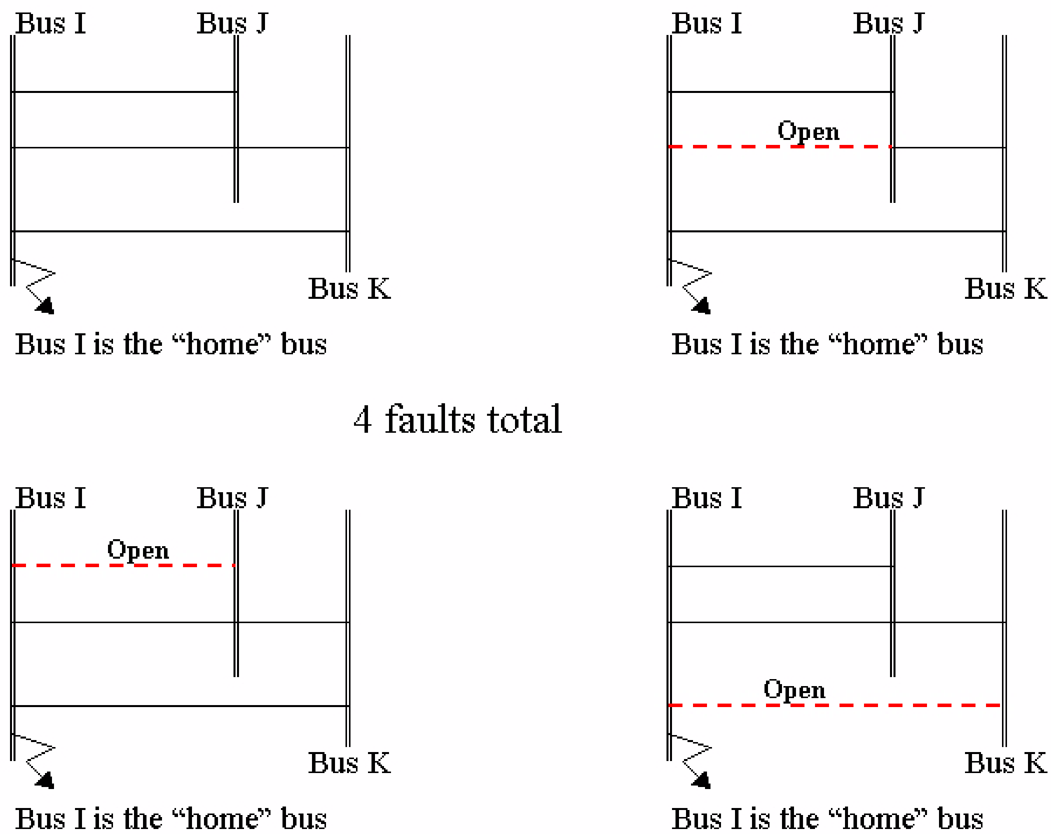


Figure 7-50. Faults at Home Bus for Each Outgoing Line

Figure 7-51 shows the option where a fault is to be applied at the home bus with all circuits in service and faults applied at the open end of each outgoing line. In this situation, for this "home" bus, there will be 4 faults if only one fault type is selected.

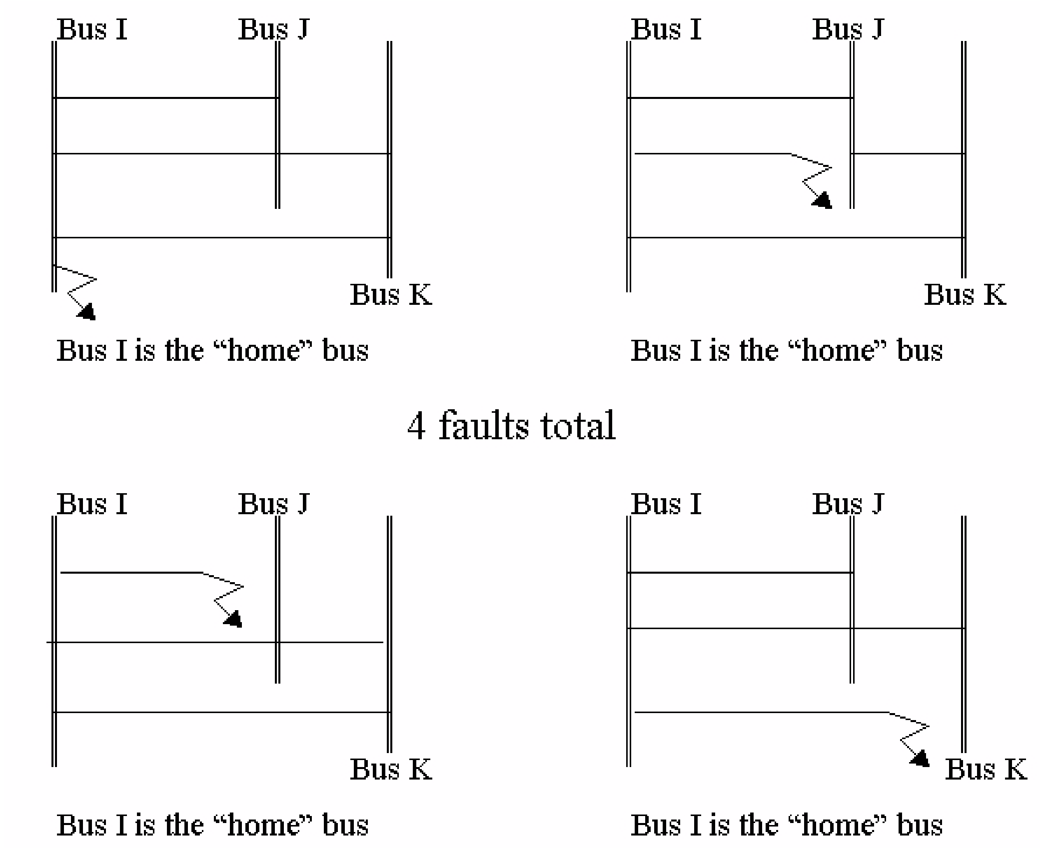


Figure 7-51. Home Bus and Open Line End Faults

7.8.2 Setting Automatic Sequencing Output Options

The user can select output options for each fault applied, ranging from a tabulation of fault currents through detailed output of conditions at the "home bus" along with detailed output for all buses up to "n" levels away from the "home bus".

Figure 7-52 clarifies the concept of "n" levels away. It can be seen that, given the possibility of a large combination of home buses, line out cases and line open end cases, coupled with a value of "n" greater than "1", the possibility arises for a very large output listing or file.

In the diagram, for the home bus shown, there are 3 buses which are 1 level away and 2 buses which are 2 levels away.

The user should take care in selection of the number of fault and output options.

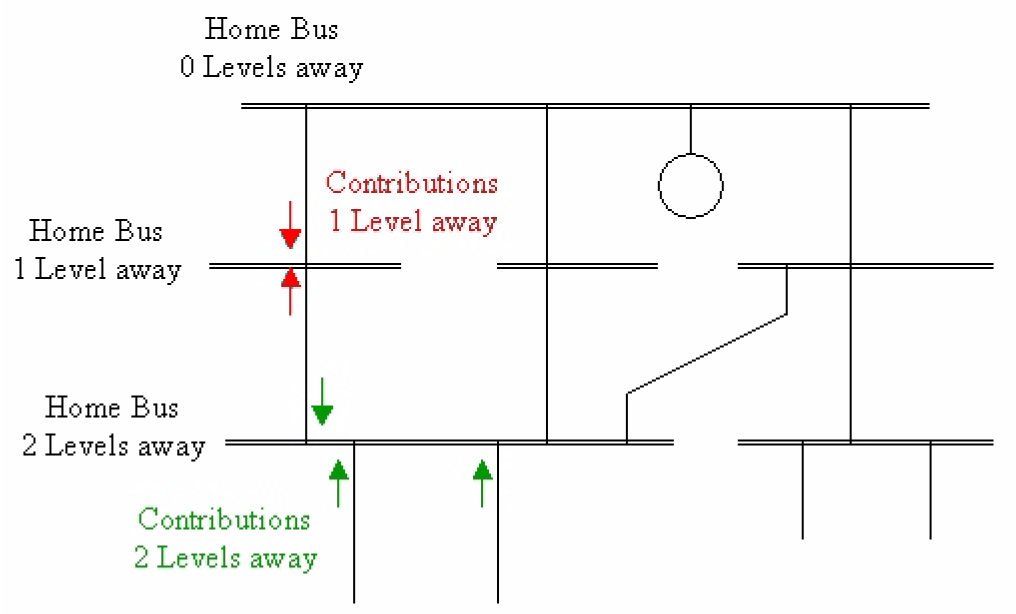


Figure 7-52. Clarification of Home Bus and "n" Levels Away

7.8.3 Preparing for the Automatic Sequence Fault Calculation

The user launches the calculation by selection of the ***Fault>Automatic sequence fault calculation (ASCC)*** option. This will open the dialog shown in Figure 7-54 in which the user selects the required options and identifies associated files: The options include:

Type of faults to be applied: The available faults and topological locations are described in the previous section

Starting power flow conditions: The user selects either the full detailed solution or a Flat or "classical" condition for the network in the power flow case. If the Flat condition is selected, Generator power outputs are assumed to be zero; loads and fixed bus shunts are neglected in the positive and negative sequence networks; switched shunts are neglected in all three sequences; zero sequence shunt loads and the zero sequence ground ties created by grounded transformer windings are represented. Line charging capacitances and line connected shunt elements are neglected in all three sequence networks. All transformers, including generator step-ups, are assumed to be at nominal ratio, zero phase shift angle, and a uniform voltage profile of unity magnitude at zero phase angle is assumed; DC lines and FACTS devices are ignored. The original values of all data items in the power flow case are not modified; i.e. at the termination of the fault calculation, the power flow case is identical in content to what it was prior to initiating the fault calculation process.

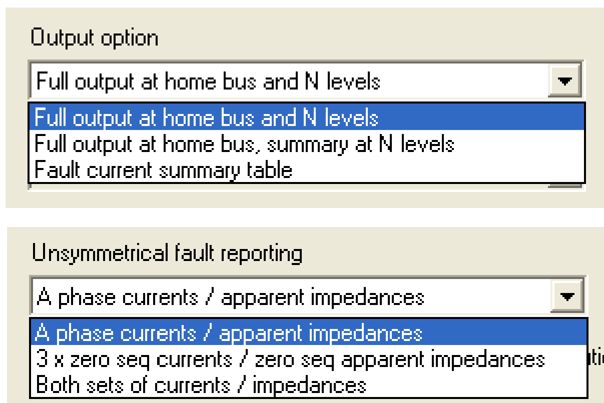
If the flat conditions option is not enabled, the level of network modeling and the bus boundary conditions used as the prefault network condition are as specified in the power flow prior to initiating the fault calculation process.

DC Lines and FACTS Devices: DC lines and FACTS devices can be blocked or be represented as load. If represented as load, the apparent AC system complex loads are converted to positive sequence constant admittance load at the buses at which these quantities are injected into the AC system during normal power flow work. In the negative and zero sequence networks, DC lines and FACTS devices are represented as open circuits. The selected option applies to all DC lines and FACTS devices in the working case.

Transformer impedance: The zero sequence impedance of each such transformer is scaled by the same factor as is its positive sequence impedance. Otherwise, all zero sequence transformer impedances are left at their nominal values

Output options and number of levels "n": These define the level of output required. Output can be at only the home bus or at both the home bus and "n" levels away in full or summary form or as a fault current summary table (see Figure 7-53a).

Line-to-ground reporting: This defines the form of output for cases involving L-G faults. If the L-G faults option is selected the user can select to output the results in the form of A Phase currents and apparent impedances or 3 x zero sequence currents and zero sequence apparent impedances or both (see Figure 7-53b).



(a)

(b)

Figure 7-53. Output and Reporting Options

Subsystem: Identifies the subsystem to be tested including Areas, Owners, Zones, Based and individual buses.

As can be seen in the dialog, the user can identify two file names one of which is the Fault control input file. This file provides the user with more flexibility in selection of faults to be simulated and in the manner in which output is limited or extended (see Section 7.8.3.1).

The Relay file is generated as a user option (see Section 7.8.3.2). This file summarizes the faults performed and the short-circuit current levels in pu. The file is generated as a **.re* type in ASCII format; readily portable to an Excel type.

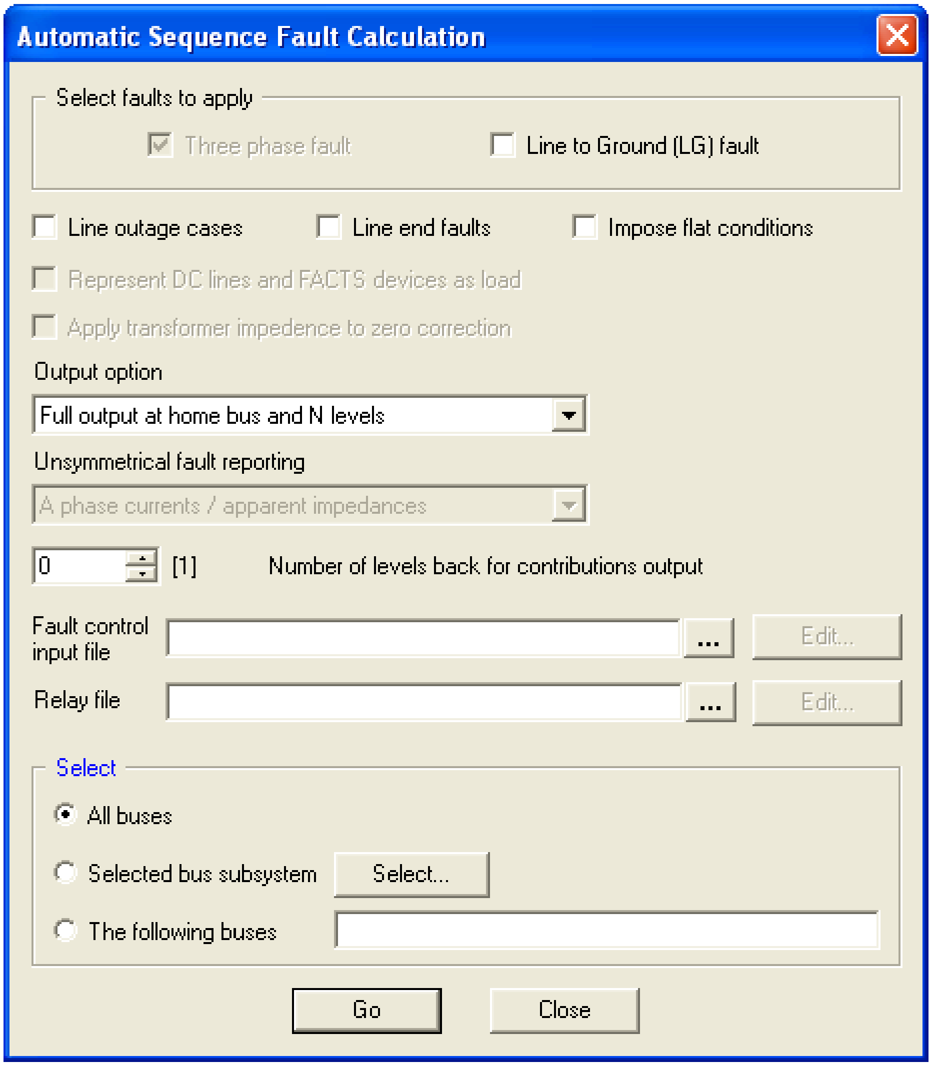


Figure 7-54. Automatic Sequence Fault Calculation Dialog

7.8.3.1 Creating the Fault Control Input File

The Fault Control Data File consists of two groups of records. With the first group of records, buses may be categorized as not to be faulted. This provides, for example, for the suppression of fault calculations at dummy buses. In addition, for the purpose of reporting bus conditions for faults at other buses, each bus may be categorized as being either:

1. Printed and counted in the "levels away" calculation.
2. Not printed but counted.
3. Not printed and not counted.

This group of records is of the form:

```
IBUS, FCODE, PCODE
```

where:

IBUS	Bus number. Bus IBUS must reside in the working case. No default is allowed.
FCODE	Fault code of either zero (suppress faulting of bus IBUS) or one (allow bus IBUS to be faulted). FCODE = 1 by default.
PCODE	Print control code for conditions at bus IBUS when some other bus is faulted. PCODE may be specified as either zero (no reporting, and not counted in the "levels away" calculation), one (no reporting, but counted in the "levels away" calculation), or two (reported and counted). PCODE = 2 by default.

Data records may be input in any order. This group of records is terminated with a record specifying an IBUS value of zero.

The hidden "star point" buses of three-winding transformers are always assumed to have FCODE and PCODE values of zero. Any other bus for which no data record is read is assigned the default values given above.

With the second group of records, for any bus to be faulted, the following may be specified:

1. Up to 20 buses whose conditions are to be tabulated for all fault cases calculated for this home bus. These buses are in addition to those printed as a result of the "levels away" selection.

2. Up to eight additional branches to be outaged in turn with the home bus faulted. These fault cases are calculated only if the line out option was selected, and are in addition to the automatic outaging of the branches connected to the home bus. Only non transformer branches and two-winding transformers may be specified.

Data for each home bus specified here is entered on three consecutive data records as follows:

```
IBUS
JBUS1, JBUS2, ... JBUS20
I1, J1, CKT1, ... I8, J8, CKT8
```

where:

IBUS	Bus number. Bus IBUS must reside in the working case. No default is allowed.
$JBUS_i$	Bus number of a bus to be reported for home bus IBUS fault calculations. The first zero value of $JBUS_i$ is interpreted as the end of JBUS values for bus IBUS. $JBUS_i$ = 0 by default.
I_i, J_i, CKT_i	The "*from bus*" number, "*to bus*" number and branch circuit identifier respectively of a branch to be outaged with bus IBUS faulted. The first zero value of I_i is interpreted as the end of branch specifications for bus IBUS. I_i = 0 and CKT_i = '1' by default; no default is allowed for J_i.

Input is terminated with a record specifying an IBUS value of zero.

If any of the data records in the block for bus IBUS contains an error (e.g., bus not found), an appropriate message is printed and the entire block for bus IBUS is ignored.

All three records must be entered for each bus block specified. If, for example, one or more output buses are to be specified for bus IBUS but no additional branches for outage calculations are required, the third record must still be specified; it may either have a zero as its first bus number or simply be a blank line.

The buses and branches in the block for bus IBUS are used only if bus IBUS is among the buses selected for processing as home buses, and an FCODE value of zero was not specified for bus IBUS.

Bus JBUSi is not reported if it was assigned a PCODE value of zero or one, or if it is not connected back to the home bus via in-service AC branches.

Outage fault cases are calculated only if the Line outage cases option box is checked in the dialog.

7.8.3.2 Creating the Relay File

The relay output file optionally generated by the automatic sequence fault calculations activity contains a single-line summary for each fault calculation performed. Each line commences with a code indicating the type of fault:

Code	Type of Fault
3	Three-phase fault at the home bus
1	Line-to-ground fault at the home bus
30	Three-phase line end fault
10	Line-to-ground line end fault

The following quantities are tabulated in the indicated column positions of each record:

2-3:	Fault code
5-10:	Home bus number
12-17:	"*From bus*" number (0 if the branch is a three-winding transformer) for line out or line end, or blank
19-24:	"*To bus*" number for line out or line end, or blank
26-27:	Circuit identifier for line out or line end, or blank
29-41:	Fault current magnitude in per unit
43-55:	Ratio of imaginary/real components of fault current
58-75:	Extended bus name of home bus
78-95:	Extended bus name of "*from bus*" (" 3WND:" followed by the three-winding transformer name if "*from bus*" field is 0), or blank
98-115:	Extended bus name of "*to bus*", or blank

7.8.4 Performing the Automatic Sequence Fault Calculation

The first step for the user is to identify the location of the output. That can be allowed to be written by default to the Report View on a newly generated Report tab or directed to a file using the ***I/O Control*** option. Note that the fault calculation process does not prompt for an output destination.

Once the output destination has been selected and the user has completed the process of selecting fault, solution and output options and of identifying the required files in the dialog (Figure 7-54) all that is required is to select the ***Go*** button to initiate the calculations. The fault calculation process may be terminated by entering the AB interrupt control code.

If sequence data has not been appended to the power flow case, an appropriate error message is printed and calculation process is terminated.

At initiation of the calculation process, PSS™E builds and factorizes the sequence admittance matrices, reporting its progress to the Output Bar or to an alternative destination selected by the user.

7.8.5 Analyzing Automatic Fault Sequencing Results

In order to better understand the output, several examples will be developed each of which assumes a fault on Bus 151 in the *savnw.sav* power flow case. Different fault and output options will be used. The location of Bus 151 relative to neighboring buses is shown in Figure 7-55 where it can be seen that there are 4 buses at one level away. They are buses 101, 102, 152 and 201.

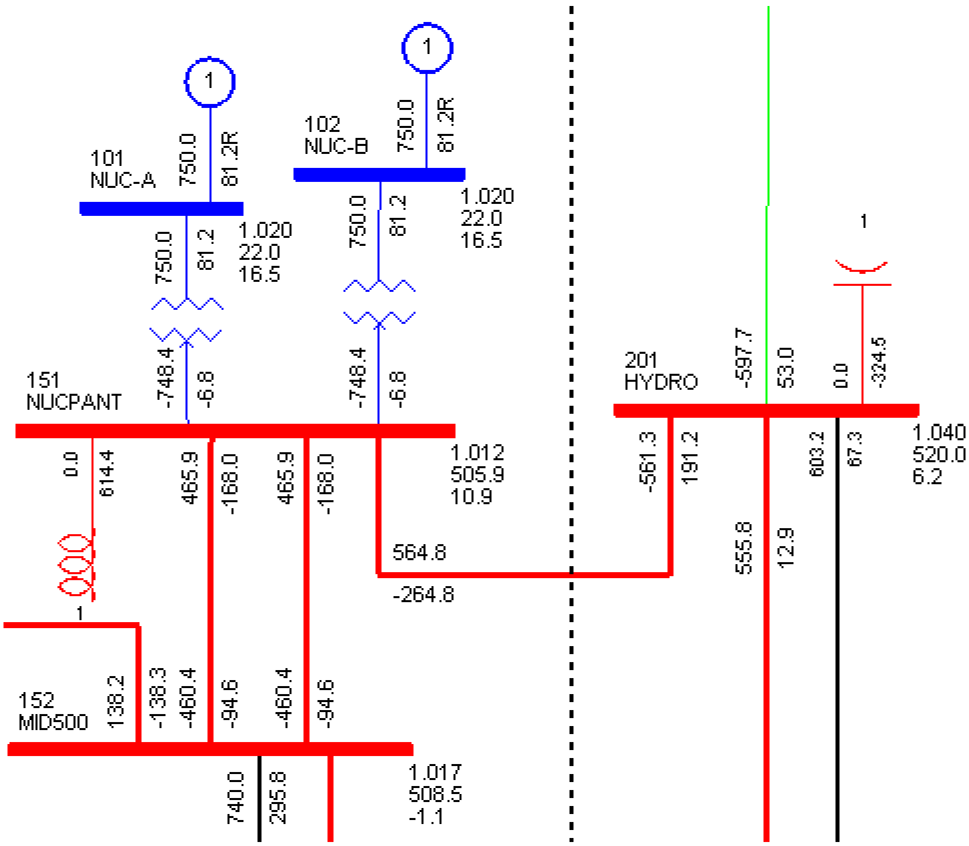


Figure 7-55. Location of Bus 151 and Buses one Level Away in savnw.sav

Each page of the detailed bus output report contains a heading block, which tabulates the current date and time, the two-line case heading, and the home bus number and name. If the flat conditions option was selected, this is noted; if the line outage or line end condition is being reported, this is also flagged. If subsystems are being specified by area, zone, and/or owner, the area, zone, and/or owner, as appropriate, currently being processed are also identified.

The home bus, the level number, relative to the home bus, of buses whose output is printed on the page, and, if appropriate, a line out or line end identifier are printed on the right side of the banner block. If line-to-ground faults are being calculated and subsystem selection by area, zone, and/or owner is enabled, the current area, zone, and/or owner is also printed here.

Voltages, currents and apparent impedances are printed in either physical units (kV L-G, amps and ohms) or per unit, and in either rectangular or polar coordinates, according to the fault analysis output options currently in effect. If the physical units option is enabled and the bus whose base voltage is required for the calculation of a quantity has no base voltage specified for it, the quantity is printed in per unit.

For each bus at which conditions are reported (i.e., for each "*at bus*"), the following quantities are tabulated:

1. The bus number, name, base voltage, and area number in which it resides. This is followed by the positive sequence bus voltage for the three phase fault case. If single line

to ground faults are being calculated, the A phase voltage and the three sequence voltages for the L-G case are printed.

2. If the bus is the home bus, the sequence Thevenin impedances at the fault point in per unit, rectangular coordinates. If only three phase faults are being calculated, only the positive sequence Thevenin impedance is printed.

3. The machine identifier and currents *arriving* at the bus from all online machines at the bus. For the L-G fault, either zero sequence, A phase, or both quantities are printed, according to the user's selection.

4. The "*from bus*" number, name, base voltage, area number, and circuit identifier of each non transformer branch and two-winding transformer connected to the "*at bus*". The branch quantities tabulated include the current *arriving* at the "*at bus*" from the "*from bus*", the apparent impedance as seen at the "*from bus*" looking down the line toward the "*at bus*" (i.e., the V/I ratio at the "*from bus*"), and the ratio of apparent X/R. For the L-G fault, either zero sequence, A phase, or both quantities are printed, according to the user's selection. Branches are printed in ascending "*from bus*" numerical or alphabetical order according to the bus output option in effect.

5. The winding number, transformer name and circuit identifier of each three-winding transformer connected to the "*at bus*". The current *arriving* at the "*at bus*" from the transformer is tabulated. For the L-G fault, either zero sequence, A phase, or both currents are printed, according to the user's selection. Three-winding transformers are printed in ascending transformer name order.

6. The current flowing to ground at the bus exclusive of any fault current. These currents, annotated "TO SHUNT", include any load and shunt current at the bus as well as the AC side current of any unblocked DC line or in-service FACTS device. In the zero sequence, only the shunt load plus switched shunt is output here; specifically, the zero sequence ground ties created by grounded transformer windings are not shown here but are included in the branch contribution output of (4) and (5) above. For the L-G fault, either zero sequence, A phase, or both quantities are printed, according to the user's selection. Load and shunt current output is suppressed if the corresponding sequence load and shunt admittances are all zero.

7. If the bus is the home bus, the fault current.

If the user selected to obtain a full report for home buses and all buses "n" levels away, the reports will be printed as described above for all the buses.

If the user selected to obtain a full report for home buses but only a summary report for "n" levels away, the home bus report will be printed as described above. For the remote buses, however, only machine and branch quantities are tabulated in a form similar to (3), (4) and (5) above. A branch is only reported once: at the end which is "closer to" (i.e., fewer levels away from) the "home bus."

Under both of the output options, the printing of remote contributions at buses for which a PCODE value of zero or one was specified in the Fault Control Data File is suppressed. In addition, upon encountering a remote bus with a PCODE value of zero, those buses connected to the bus that would normally be at the next "level away" are promoted to the current level.

The third output option is the *Fault current summary*. Here, one output line is printed for each fault giving the fault currents. Fault currents are printed in either amps or per unit, and in either rectangular or polar coordinates, according to the fault analysis output options currently in effect. If the physical units option is enabled and the faulted bus has no base voltage specified for it, fault current is printed in per unit. If line out and/or line end faults are being calculated, for a given home bus, the bus fault is reported first. Then the line out and/or line end faults involving each branch connected to the home bus in turn are processed.

7.8.5.1 Automatic Sequencing Example: 3-Phase Faults

This case assumes application of only 3-phase faults at bus 151 with full reporting at the home bus one level away. Faults are applied with all lines in service, with each outgoing line out of service in turn and with an open line-end fault on each outgoing line in turn. Output is in rectangular coordinates.

In Figure 7-56, overleaf, the results for the home bus are listed. It can be seen that although there is a 600 Mvar shunt connected at bus 151, the total shunt current is zero. This is clearly because the voltage at this bus (the faulted home but is zero).

Note that the listing has been compressed slightly from the original output listing for the portrait view.

In Figure 7-57, the results are listed for the "1 Level" away. It can be seen that there is a listing for the four immediate neighbors of bus 151, the home bus. The information on branch flows has the same format as that of the home bus, at the 0 Level since the "full" report options was selected for these buses.

```
-           PSS/E SHORT CIRCUIT OUTPUT   THU, FEB 26 2004  11:35    .HOME BUS IS    151.
-    PSS/E PROGRAM APPLICATION GUIDE EXAMPLE                        .NUCPANT      500.0.
-    BASE CASE INCLUDING SEQUENCE DATA                                               .
-   *** FAULTED BUS IS:    151 [NUCPANT      500.0] ***                   0 LEVELS AWAY

AT BUS    151 [NUCPANT     500.00]  AREA   1  (PU) U+:    0.0000+J 0.0000

THEV. R, X, X/R: POSITIVE  0.00409   0.01765  4.318

                                                   T H R E E  P H A S E  F A U L T
X--------- FROM --------X AREA  CKT  I/Z     RE(I+)    IM(I+)  RE(Z+)   IM(Z+)   APP X/R
   101 [NUC-A     21.600]    1  1   PU/PU    9.8734  -11.0030  0.0003   0.0136   45.333
   102 [NUC-B     21.600]    1  1   PU/PU    9.8734  -11.0030  0.0003   0.0136   45.333
   152 [MID500    500.00]    1  1   PU/PU   -0.2319   -6.2545  0.0031   0.0500   16.264
   152 [MID500    500.00]    1  2   PU/PU   -0.2319   -6.2545  0.0031   0.0500   16.264
   201 [HYDRO     500.00]    2  1   PU/PU    3.3729  -16.5469  0.0010   0.0151   14.864
                          TO SHUNT  (P.U.)   0.0000    0.0000
            TOTAL   FAULT  CURRENT  (P.U.)  22.6560  -51.0619
```

Current flowing from Bus 101 towards Bus 151

Apparent impedance looking from Bus 101 towards Bus 151 and X/R ratio

Total fault current at bus

Figure 7-56. Report Output at the Home Bus (0 level) for a 3-Phase Fault

In Figure 7-57 it can be seen that the immediate neighbors to bus 151 are the buses 101, 102, 152 and 201. Those buses, at 1 level away, are now the "AT" buses. The flows shown in the tabulation are from the "FROM" buses towards the respective "AT" buses.

As an example, it can be seen that the flow shown for bus 101 is the flow from bus 151 to bus 101. The flow is(-9.8734 11.003). This has the opposite sign from that shown in Figure 7-56 where the home bus 151 is the "AT" bus.

Figure 7-58 shows the Fault Current Summary report from the calculation which applies a three phase fault. It shows the fault current for a fault at Bus 151 with all lines in. It can be seen that the result is the same as that shown in Figure 7-56. The report then lists the results for a fault at Bus 151 each outgoing line OUT of service and with the fault at the open END.

```
-            PSS/E SHORT CIRCUIT OUTPUT   THU, FEB 26 2004  11:35    .HOME BUS IS    151.
-     PSS/E PROGRAM APPLICATION GUIDE EXAMPLE                        .NUCPANT      500.0.
-     BASE CASE INCLUDING SEQUENCE DATA                                              .
-    *** FAULTED BUS IS:    151 [NUCPANT      500.0] ***                     1 LEVELS AWAY

AT BUS     101 [NUC-A       21.600]  AREA    1  (PU) U+:     0.1526+J 0.1310

                                                          T H R E E  P H A S E  F A U L T
X--------- FROM --------X AREA  CKT  I/Z      RE(I+)    IM(I+)   RE(Z+)    IM(Z+)   APP X/R
MACHINE 1                            PU/      9.8734   -11.0030
   151 [NUCPANT   500.00]     1   1  PU/PU   -9.8734    11.0030  0.0000    0.0000     0.000

AT BUS     102 [NUC-B       21.600]  AREA    1  (PU) U+:     0.1526+J 0.1310

                                                          T H R E E  P H A S E  F A U L T
X--------- FROM --------X AREA  CKT  I/Z      RE(I+)    IM(I+)   RE(Z+)    IM(Z+)   APP X/R
MACHINE 1                            PU/      9.8734   -11.0030
   151 [NUCPANT   500.00]     1   1  PU/PU   -9.8734    11.0030  0.0000    0.0000     0.000

AT BUS     152 [MID500      500.00]  AREA    1  (PU) U+:     0.2871+J 0.0269

                                                          T H R E E  P H A S E  F A U L T
X--------- FROM --------X AREA  CKT  I/Z      RE(I+)    IM(I+)   RE(Z+)    IM(Z+)   APP X/R
   151 [NUCPANT   500.00]     1   1  PU/PU    0.1847     5.7520  0.0000    0.0000     0.000
   151 [NUCPANT   500.00]     1   2  PU/PU    0.1847     5.7520  0.0000    0.0000     0.000
   153 [MID230    230.00]     1   1  PU/PU   -1.2158    -5.5759 -0.0060    0.0542     9.048
   151 [EAST500   500.00]     2   1  PU/PU    0.5901    -1.5481  0.1073    0.1860     1.733
  3004 [WEST      500.00]     5   1  PU/PU    0.2561    -4.3801  0.0193    0.1146     5.929

AT BUS     201 [HYDRO       500.00]  AREA    2  (PU) U+:     0.2516+J 0.0340

                                                          T H R E E  P H A S E  F A U L T
X--------- FROM --------X AREA  CKT  I/Z      RE(I+)    IM(I+)   RE(Z+)    IM(Z+)   APP X/R
   151 [NUCPANT   500.00]     1   1  PU/PU   -3.3525    16.3960  0.0000    0.0000     0.000
   202 [EAST500   500.00]     2   1  PU/PU   -2.0353    -2.4222 -0.0750    0.0792     1.056
   204 [SUB500    500.00]     2   1  PU/PU   -1.6657    -4.1394 -0.0358    0.0893     2.496
   211 [HYDRO_G   500.00]     2   1  PU/PU    6.9513    -9.0796  0.0117    0.0405     3.461
                          TO SHUNT   (P.U.)  -0.1021     0.7547
```

300 Mvar shunt at Bus 201

Current flow from Bus 211 to Bus 201

Figure 7-57. Current Flows 1 Level Away from Home Bus 151 for Three-Phase Fault

```
    PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E     THU, FEB 26 2004  11:36
PSS/E PROGRAM APPLICATION GUIDE EXAMPLE                        SHORT CIRCUIT
BASE CASE INCLUDING SEQUENCE DATA                              FAULT CURRENTS

                                                        |   THREE PHASE FAULT
X------ BUS ------X   X------ TO BUS ------X CKT                RE(I+)     IM(I+)
151 [NUCPANT  500.0                              P.U.     22.6560   -51.0619
151 [NUCPANT  500.0   101 [NUC-A     21.600] 1  OUT P.U.     12.7826   -40.0589
151 [NUCPANT  500.0   101 [NUC-A     21.600] 1  END P.U.      5.5934   -26.1350
151 [NUCPANT  500.0   102 [NUC-B     21.600] 1  OUT P.U.     12.7826   -40.0589
151 [NUCPANT  500.0   102 [NUC-B     21.600] 1  END P.U.      5.5934   -26.1350
151 [NUCPANT  500.0   152 [MID500    500.00] 1  OUT P.U.     21.9500   -48.2059
151 [NUCPANT  500.0   152 [MID500    500.00] 1  END P.U.      5.0230   -14.4880
151 [NUCPANT  500.0   201 [HYDRO     500.00] 1  OUT P.U.     18.3905   -41.1311
151 [NUCPANT  500.0   201 [HYDRO     500.00] 1  END P.U.     10.0377   -24.6822
```

Total fault current at Bus 151 with the line from Bus 151 to Bus 102 out of service

Total fault current at Bus 151 with a fault at the open end of the line from Bus 151 to Bus 102

Total fault current at Bus 151 with all lines in service. Compare with Figure 7-56.

Figure 7-58. Fault Summary Report with 3-Phase Fault on Bus 151

7.8.5.2 Automatic Sequencing Example: 3-Phase & Single L-G Faults

This case assumes application of 3-phase faults and single-line-to-ground faults at bus 151 with full reporting at the home bus one level away. Faults are applied with all lines in service and output is in polar coordinates. The output will be 3 x zero sequence currents and zero sequence apparent impedances.

In Figure 7-59, it can be seen that with the single-line-to-ground faults included, the report format is the same as for only 3-phase faults. The results now append the zero sequence fault current flows in the branches connected to the home bus. In addition the negative and zero sequence Thevenin impedances are shown, together with the A phase and sequence voltages at the faulted bus.

With polar coordinates used, it can be seen that the total fault current is 55.8625 / -66.07 pu, compared to the rectangular coordinate output which, in Figure 7-56, is 22.656 -51.0619 pu. The listing for "n" levels away will use the same format shown in Figure 7-57 with, in this case, the zero sequence (L-G) results appended in the right hand columns.

7.8.6 Application Notes for Automatic Sequencing Fault Calculations

This fault calculation sequencing process is a totally self-contained fault analysis calculation. All that is required prior to initiation is a valid power flow case with sequence data appended to it. Unless the "flat conditions" option is to be selected the bus voltages and boundary conditions must correspond to the desired prefault network condition.

```
                  PSS/E SHORT CIRCUIT OUTPUT                     MON, MAR 01 2004  14:53                           HOME BUS IS :
         PSS/E PROGRAM APPLICATION GUIDE EXAMPLE                                                          151 [NUCPANT    500.00]
         BASE CASE INCLUDING SEQUENCE DATA
                *** FAULTED BUS IS :          151 [NUCPANT   500.00] ***                                       0 LEVELS AWAY

  RT BUS   151 [NUCPANT   500.00] AREA   1    (PU) V+: / 0.0000/  0.00         (PU) VA: / 0.0000/   0.00    V0: / 0.1497/ -159.48
                                                                                    V+: / 0.5799/  12.13    V-: / 0.4323/ -170.77

  THEV. R, X, X/R: POSITIVE  0.00409  0.01765   4.318      NEGATIVE  0.00409  0.01765   4.138      ZERO  0.00019  0.00627  32.847

                                              T H R E E   P H A S E   F A U L T           O N E   P H A S E   F A U L T
  X--------- FROM -------X AREA CKT I/Z     /I+/      AN(I+)   /Z+/   AN(Z+)  APP X/R      /3I0/    AN(3I0)    /Z0/    AN(Z0)  APP X/R
    101 [NUC-A      21.600    1 1  PU/PU   14.7835  -48.10  0.0136  88.74   45.333     33.0137   -68.21    0.0000    0.00    0.000
    102 [NUC-B      21.600    1 1  PU/PU   14.7835  -48.10  0.0136  88.74   45.333     33.0137   -68.21    0.0000    0.00    0.000
    152 [MID500     500.00    1 1  PU/PU    6.2588  -92.12  0.0501  86.48   16.264      0.1865    53.87    0.1044  -95.14   11.121
    152 [MID500     500.00    1 2  PU/PU    6.2588  -92.12  0.0501  86.48   16.264      0.1865    53.87    0.1044  -95.14   11.121
    201 [HYDRO      500.00    2 1  PU/PU   16.8872  -78.48  0.0512  86.15   14.864      5.7775   -65.40    0.0222  -93.00   19.081
                           TO SHUNT  (P.U.)   0.0000    0.00                            0.0000     0.00
                 TOTAL FAULT CURRENT  (P.U.)  55.8625  -66.07                           71.6023   -68.21
```

from Figure 7-56
rectangular coordinate result
Polar expression equivalent to

Sequence Thevenin Impedances

Zero sequence apparent impedances

Figure 7-59. Results for Three-Phase and Single Phase fault at bus 151

Instead of *imposing flat conditions* for the calculations, it is possible to set up a "converted" power flow case with a classical representation. Having the "converted" case would allow launching the automatic sequencing calculation process without having to select *impose flat conditions* in the selector window (Figure 7-54).

The automatic sequencing process is sensitive to the fault analysis modeling option setting. Under the two phase option, negative sequence Thevenin impedances are shown in the output report as zero.

As with all user specified output files used in PSS™E, the relay output summary file designated when launching these fault calculations does not have data appended to it if the file already exists. If the contents of a relay output file are to be appended to a previously existing file, a new filename should be specified. The two files may be subsequently merged with a text editor following completion of the calculations.

7.9 Calculating Circuit Breaker Interrupting Duty

The sudden application of a short-circuit fault to a power system produces currents whose transient form is shown in Figure 7-60. In the case of a three-phase fault (simultaneously applied in each phase), the total fault current in each phase consists of the following:

1. An alternating component that decays from an initial subtransient value to a final steady-state value.
2. A decaying unidirectional component whose initial amplitude is equal to the difference between the initial instantaneous value of the alternating component of fault current and the instantaneous current in the phase just prior to fault application.

Depending upon the standard (e.g., ANSI Standard C37.5 – 1975 or the International Electrotechnical Commission standards) the determination of circuit breaker duty requires the calculation of either of these values:

- The maximum instantaneous value of current in any phase at the instant, a few milliseconds after fault initiation, when the circuit breaker contacts separate
- The root-mean-square (rms) value of current wave consisting of sinusoidal component of constant amplitude equal to the instantaneous amplitude of the decaying alternating component at an instant, superimposed on a constant unidirectional component of amplitude equal to that of the decaying unidirectional component at the same instant.

Figure 7-61 illustrates the two current values of interest. The maximum instantaneous value, as shown in Figure 7-61a is of interest in connection with the IEC Circuit Breaker standards, while the rms value shown in Figure 7-61b is used by ANSI C37 standards. In this section, we describe the calculations made in PSS™E.

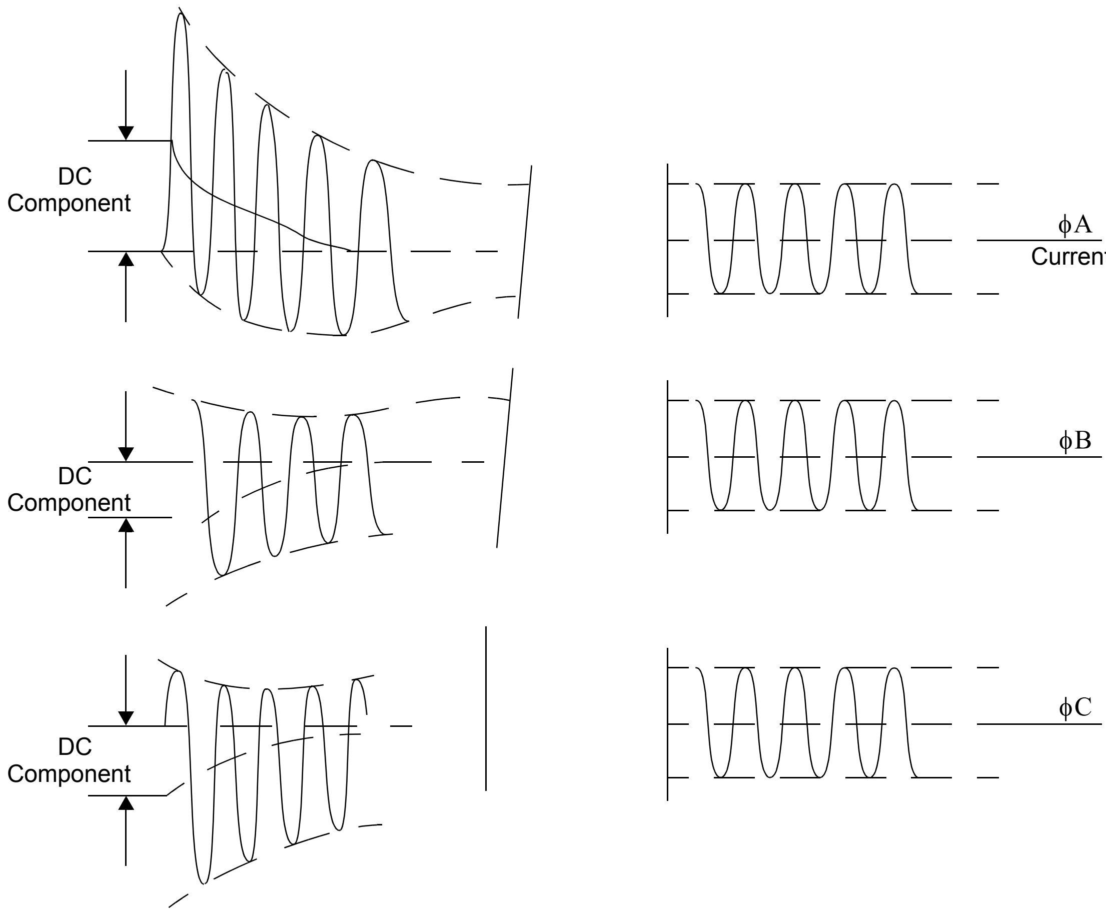


Figure 7-60. Transient Phase Currents in Suddenly Applied Short Circuit

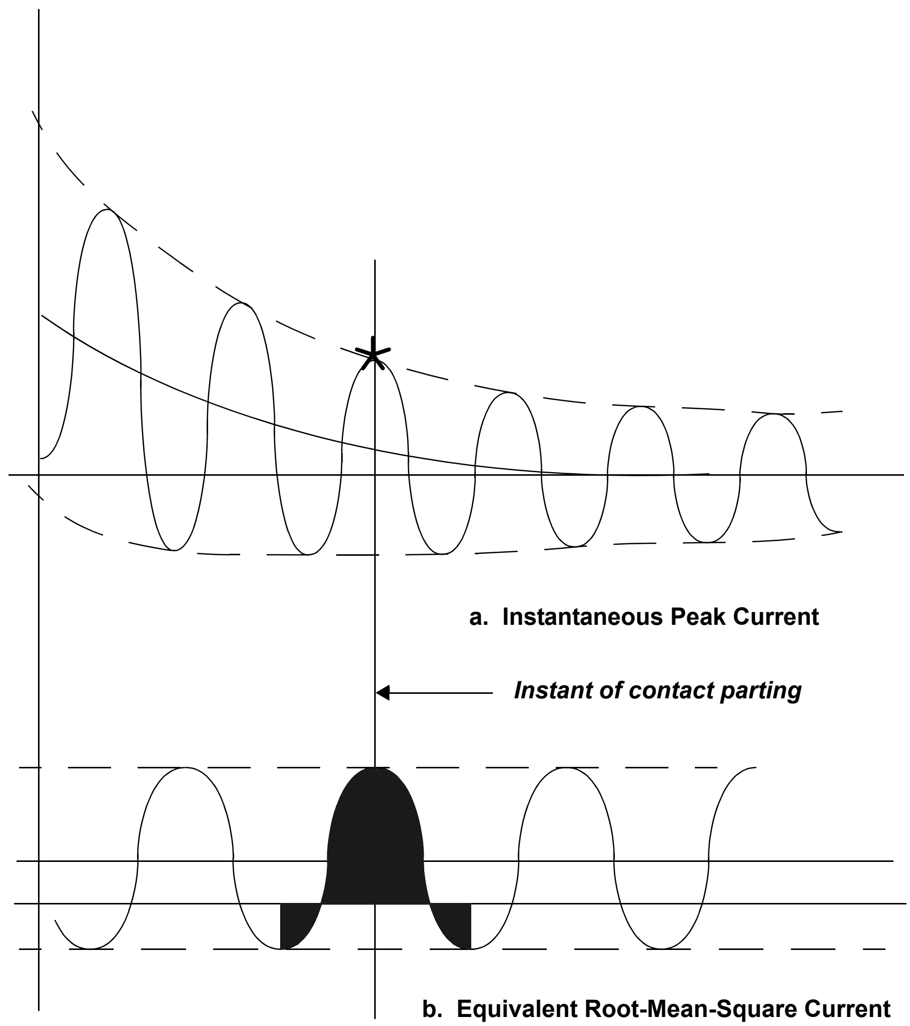


Figure 7-61. Forms of Expression of Fault Current at Instant of Circuit Breaker Opening

To determine these current amplitudes, the following data must be considered:

- The alternating current component results from *decaying* machine internal flux linkages behind *constant* subtransient impedances of the machines.
- The unidirectional component is, at the instant of fault application, determined by the value of the alternating component.

The alternating components can be approximated, with acceptable accuracy for several cycles after fault application, by expressing the generator flux as:

$$\psi''_d = \psi''_{do}(L''_d + L_e)\left[\left(\frac{1}{L_d + L_e}\right) + \left(\frac{1}{L'_d + L_e} - \frac{1}{L_d + L_e}\right)e^{-t/T'_{dz}}\right.$$

$$\left. + \left(\frac{1}{L''_d + L_e} - \frac{1}{L'_d + L_e}\right)e^{-t/T''_{dz}}\right]$$

$$+ i_{do}(L''_d + L_e)\left(\frac{L_d - L''_d}{L_d + L_e}(1 - e^{-t/T'_{dz}})\right.$$

$$\left. + \frac{L'_d - L''_d}{L'_d + L_e}\left(e^{-t/T'_{dz}} + e^{-t/T''_{dz}}\right)\right)$$

and the equivalent for the *q*-axis. For induction motors ($L_d = L_q$ or L'_d or L'_q), the Ld terms are not in the above equations.

The calculations for initial fluxes, ψ''_{do} and ψ''_{qo}, and initial currents, i_{do} and i_{qo}, are based on the initial conditions in the load flow before fault application. The value of L_e at each generator is calculated by dividing the voltage at each terminal by the current flowing at the terminals at fault initiation. Because an initial loading on the machine, L_e, will never be infinity, this approximation will result in flux decaying even for very remote machines. The user is responsible for not including data for machines where flux decay is not wanted.

The initial value of the unidirectional component of fault current is, in the worst case, equal to the initial amplitude of the alternating component; this corresponds to a fully offset current wave as shown for Phase A in Figure 7-60. Using full offset is, of course, conservative. The actual maximum offset depends on the fault point X/R and the point on the wave where the fault occurs. Thus, the peak is reached after some DC decay has occurred. The decay of the unidirectional component of fault current is given by:

$$i_{dc} = I_{ac}(0)\left[a_1 e^{-k_1 t} + a_2 e^{-k_2 t} + a_3 e^{-k_3 t} + \ldots + a_n e^{-k_n t}\right]$$

where $a_1 + a_2 + \ldots + a_n = 1$

and

- The coefficients k_i, characterize the decay of the initial unidirectional components throughout the network.
- The coefficients, a_i, express the contribution of each decaying unidirectional current component to the unidirectional fault current.

In general, an exact expression of the unidirectional fault current would involve a number of k and a coefficients equal to the number of branches in the network. Their determination would require a calculation of the eigenvalues and eigenvectors of the differential equations:

$$[L_{net}][sI_{net}] + [R_{net}][i_{net}] = 0$$

where $[R_{net} + sL_{net}]$ is the operational impedance matrix of the complete network. This calculation is impractical for normal system analysis work, and it is usual to approximate the unidirectional fault current by:

$$i_{dc} = I_{ac}(0)e^{-t/T_s}$$

where

$$T_s = L_{thev}/R_{thev}$$

where L_{thev} and R_{thev} are the Thevenin impedance (inductance, resistance) at the point of the fault.

7.9.1 How PSS™E Calculates Circuit Breaker Duty

PSS™E contains a special short-circuit calculation which reports circuit breaker interrupting duty for three phase faults at all buses in a specified subsystem of the working case. It determines the amplitude of the alternating and unidirectional (DC) components of current flowing in symmetrical faults and in the branches of the network. The alternating and DC components are calculated as indicated in the previous section for the instant of fault application and for a specified time after the fault initiation. These component amplitudes are then used to determine the following:

- The maximum instantaneous current that could flow in any phase at the specified time after fault application, assuming that the fault was initiated at such a time, in relation to the voltage wave that the specified time after application corresponds to a current peak (Figure 7-61).
- The rms value of the current at the specified time after fault application (Figure 7-61).

The maximum instantaneous current, $I_{total\ peak}$, and rms currents, $I_{total\ rms}$, are determined by

$$I_{total\ peak} = I_{dc} + I_{ac}$$

$$I_{total\ rms} = \sqrt{I_{dc}^2 + I_{rms}^2}$$

where:

I_{dc} = Instantaneous amplitude of unidirectional component.

I_{ac} = Peak amplitude of alternating component.

It is convenient to define an instantaneous rms value of the alternating current component, I_{rms}, by

$$I_{rms} = \frac{I_{ac}}{\sqrt{2}}$$

enabling the total rms current to be written as

$$I_{total\ rms} = \sqrt{I_{dc}^2 + I_{rms}^2}$$

The breaker duty calculation starts with a load-flow case corresponding to system conditions just before the application of the fault. The values of the initial internal fluxes, ψ''_{do}, ψ''_{qo}, and initial currents, i_{do} and i_{qo}, are calculated from the prefault machine currents, terminal voltages, and the characteristic machine impedances, ZSORCE.

The calculation recognizes that the time constants T'_{dz}, T''_{dz}, T'_{qz}, T''_{qz} governing the decay of machine internal fluxes and currents are dependent on the relative values of the machine impedances and the impedances of the network between the machines and the fault. The relationships used to calculate these time constants are shown in Figure 7-62. The L_e term is calculated at each machine in the network by dividing terminal voltage by terminal current at the instant the fault is applied.

If the fault location is close to major machines, it will present these machines with conditions approximating a short circuit at their terminals, $L_e = 0$. In this case the short-circuit time constants result. If the fault location is remote from key generators or fault impedances are high, open-circuit time constants result. The calculation process reads the machine reactances, open-circuit time constants, and short-circuit time constants, from a Breaker Duty File. The subtransient reactances specified in this file must correspond to the reactive parts of the impedances, ZSORCE, in the load-flow case.

Total DC offset current is calculated in two different manners.

For method one, the instantaneous DC offset for each branch is set equal to the magnitude of the difference between the prefault current on the branch and the instantaneous AC current after the fault. The total DC offset current is the magnitude of the sum of these differences. Decremented DC currents and hence total rms and total peak currents for each path are calculated by decaying each path's initial DC offset current by the Thevenin impedance at the point of the fault looking out each path.

Again the total DC offset current is the magnitude of the sum of the decayed currents, which have been stored and decayed as complex values. The values are listed in the output report on the line headed with FAULT CURRENT.

For method two, the total instantaneous DC offset current is assumed to be equal to the total instantaneous AC current. This instantaneous DC offset current is decremented by the equivalent Thevenin impedance of all paths from the fault location. The total DC offset, total rms, and total peak current are listed following the Thevenin impedance and initial voltage on the row beginning with the word THEVENIN.

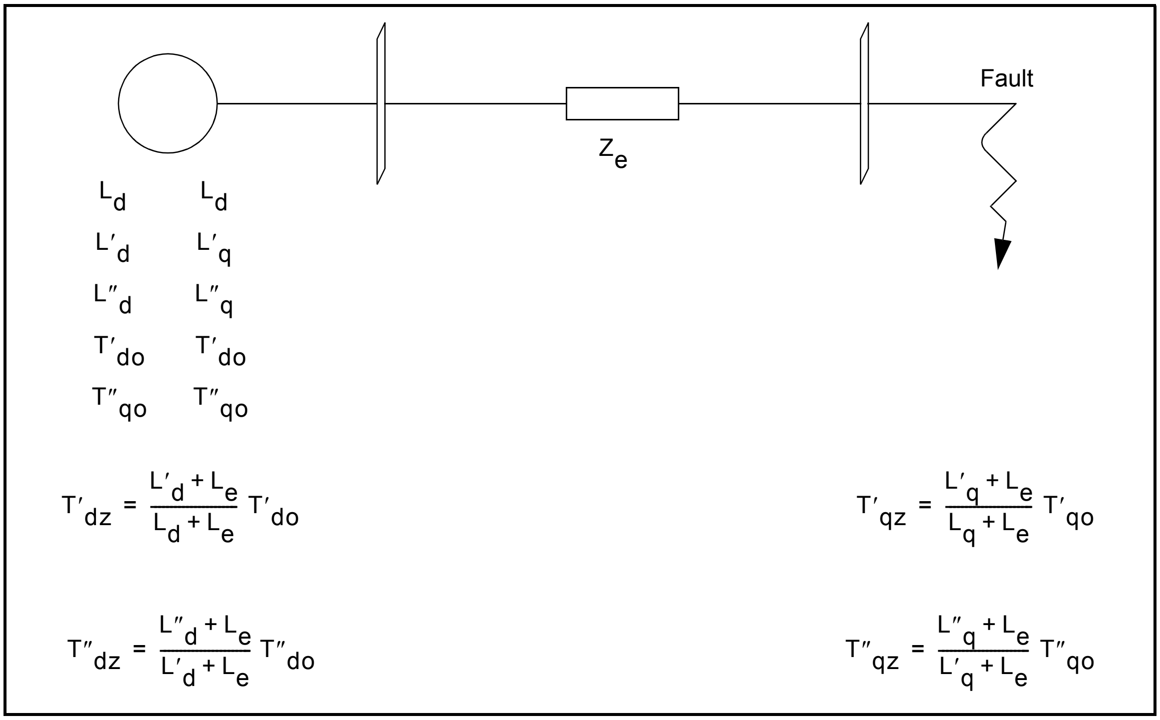


Figure 7-62. Relationships Between Machine Time Constants in Radial System

7.9.2 Creating the Breaker Duty Data File

The input stream to activity BKDY consists of a series of records in the following format:

```
I, ID, T'do, T"do, T'qo, T"qo, Xd, Xq, X'd, X'q, X"
```

where:

I	Bus number. Bus I must reside in the working case with a generator table entry assigned to it. No default is allowed.
ID	One- or two-character machine identifier used to distinguish among multiple machines at a plant (i.e., at a generator bus). ID = ’1’ by default.
T'_{do}	d axis transient open circuit time constant. No default is allowed.
T''_{do}	d axis subtransient open circuit time constant. No default is allowed.
T'_{qo}	q axis transient open circuit time constant. T'_{qo} = 0. by default.
T''_{qo}	q axis subtransient open circuit time constant. No default is allowed.
X_d	d axis synchronous reactance, entered in pu on MBASE base. No default is allowed.
X_q	q axis synchronous reactance, entered in pu on MBASE base. No default is allowed.
X'_d	d axis transient reactance, entered in pu on MBASE base. No default is allowed.
X'_q	q axis transient reactance, entered in pu on MBASE base. X'_q = 0. by default.
X"	Subtransient reactance, entered in pu on MBASE base. No default is allowed.

The reactances listed should be saturated values.

Data records may be input in any order. Input is terminated with a record specifying an "I" value of zero.

7.9.3 Creating the Fault Specification Data Input File

This file consists of a series of records in the following format:

```
IBUS, TIME, JBUS, CKT
```

where:

IBUS	Bus number of the bus to be faulted. No default is allowed.
TIME	Fault duty time. TIME = the value specified during the interactive dialog by default.
JBUS	Branch "*to bus*" number. JBUS = 0 by default.
CKT	Branch circuit or multi section line grouping identifier. CKT = '1' by default.

If a nonzero value is specified for JBUS, the branch designated by IBUS, JBUS and CKT must reside in the working case as an in-service branch or multi section line grouping. The specification of a branch is used solely for output identification purposes if several fault calculations are performed at the same bus, each with a different fault duty time.

Data records may be input in any order; fault cases are calculated and reported in the same order in which data records are read. Input is terminated with a record specifying an "IBUS" value of zero.

7.9.4 Running the Breaker Duty Calculation

The PSS™E circuit breaker duty analysis calculates and reports circuit breaker interrupting duty for three phase faults at all buses in a specified subsystem of the working case. At each bus in the specified subsystem in turn, a three phase fault is applied. Next, two network solutions are calculated, giving the initial alternating fault current and the decremented alternating fault current at the user's specified fault duty time. The decremented DC offset and total fault currents are then derived, and results tabulated.

The calculation is launched with selection of the ***Fault>Circuit Breaker Interrupting Duty (BKDY)*** option which displays the dialog shown in Figure 7-63.

7.9.4.1 Setting Breaker Duty Calculation Options

Fault selections specified via file: As an alternative to the standard subsystem selection accessible in the selector window, the user can identify the name of a file containing information specifically defining fault locations and corresponding breaker operating times to be used. The first check box in the dialog is used to indicate that such a Fault Specification Data file is available (see Section 7.9.3).

Default fault duty time: The user specifies the time after fault application at which the decremented fault current is to be calculated.

Number of levels back for contributions output: The user should specify the number of levels away from the faulted bus for which contributions will be output. A level of zero will output contributions at only the faulted bus.

Breaker duty data file: This file contains the machine parametric data required for the calculation (see Section 7.9.2).

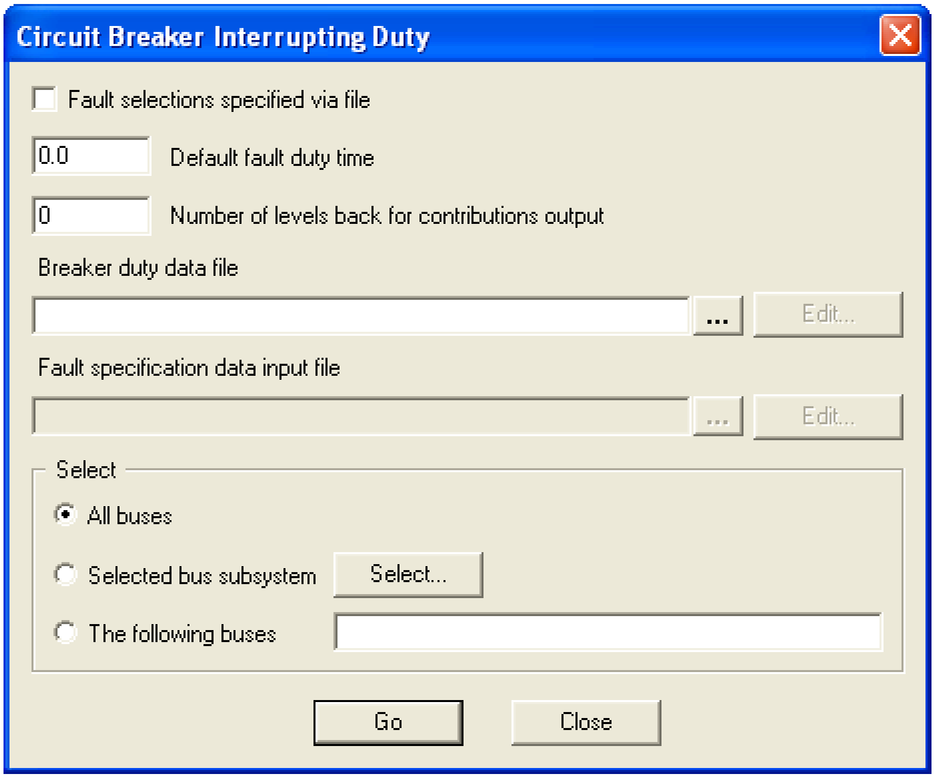


Figure 7-63. Launching the Circuit Breaker Interrupting Duty Calculation

Fault specification data input file: Identifies fault locations and fault duty times required to be investigated (see Section 7.9.3). Without this file, the user can use the usually available Select facility shown in the figure to identify fault locations by Area, Owner, Zone, BasekV or Bus.

Once the selections have been made, the calculations will be initiated by clicking ***Go*** button. Prior to that the user can elect to have the output printed to a Report in the Output Bar or to an identified file selected using the ***I/O Control*** option.

7.9.5 Launching the Breaker Duty Calculation

Prior to initiating the calculation process, the user should ensure that the power flow case to be used is converged to an acceptable mismatch level using one or more of the conventional Gauss-Seidel or Newton-Raphson solution methods.

Additionally, the user should ensure that:

- All generator buses are converted from their power flow representation to a constant Norton current source representation (see Section 7.6.2).
- Load boundary conditions are converted from the conventional constant MVA characteristic used in power flow calculations to a representation suitable for network conditions involving abnormally low voltages.

The user has the option to perform a bus ordering. If not, PSS™E will do a new bus ordering of the admittance matrix such that its sparsity characteristics are preserved. A new ordering is required since the generator conversion process introduces a row and column into the admittance matrix for each former type three (swing) bus.

The short-circuit current calculations employ a triangularized Y matrix network solution which is designed for those situations where the internal flux linkages of generators are assumed to remain unchanged as a load or fault is switched onto the system, as a line is opened or closed, or as a load is removed.This activity is used for balanced short circuit, motor starting, voltage dip, and initial load rejection over voltage studies; this class of studies is termed "switching studies" (see Chapter 8).

The Y matrix solution handles load boundary conditions and the "blowup" check in the same way as the Gauss-Seidel solution method. The solution convergence monitor, the DC transmission line monitors for two-terminal and multi-terminal DC lines, and the mismatch summary also are identical to those of the Gauss-Seidel method.

No automatic adjustments are allowed, and switched shunt devices and DC converter transformer tap settings are locked at their pre switching settings. A two-terminal or multi-terminal DC transmission line is blocked during the remainder of the current execution of this breaker duty calculation if, on any iteration, the AC voltage at a rectifier converter station bus falls below 50% or is insufficient to make margin order. Shunt elements of FACTS devices hold their pre switching reactive currents, and series elements are held at their pre switching series voltages.

For each in-service VSC DC line, the solution starts with each converter holding the active and reactive power at the time the generators were converted to the Norton equivalent. If, on any iteration, the corresponding current exceeds the converter’s IMAX, the injection is reduced using the power weighting factor fraction (PWF) just as in the conventional power flow solution activities. Each converter is treated independently, so that any reduction at one converter does not affect the injection at the other end of the VSC DC line. The DC transmission line monitor for VSC DC lines includes the DC line name, followed by the AC power injection at each converter bus.

The calculation process responds to the following interrupt control codes:

AB	Abandon the calculations following completion of the next iteration.
CM	Print network solution convergence monitor.
DC	Tabulate conditions for each DC line after each iteration.
FD	Tabulate the conditions for each in-service FACTS device after each iteration.

In reading the Breaker Duty Data File, a machine is treated as a salient pole machine if either T'_{qo} or X'_q are specified as zero; a machine is treated as an induction machine if $X_d = X_q$ *and* $X'_d = X'_q$; otherwise, a round rotor machine is assumed. For any online machine in the working case for which no data record is read, the same d and q axis currents are used in the two network solutions performed for each fault case.

Note that the user can convert the generators prior to entering the circuit breaker duty calculation. The power flow case with converted generators can be saved under a different filename for subsequent or frequent calculation of circuit breaker duties. The conversion is initiated using the ***Power Flow>Convert>Generators (CONG)*** option (see Section 8.3.2). When performing the conversion, the user can elect to use the imaginary part of the ZSOURCE (used in stability analyses) or the ZPOS (used in unbalanced fault calculations) machine impedance.

Regardless of the method of designating buses to be faulted, those buses which are "dummy" buses of multi section lines are skipped as the calculation sequences through fault cases when the multi section line reporting option is enabled.

7.9.6 Analyzing the Breaker Duty Results

At each faulted bus, the current contributions from all machines and branches connected to the bus are listed, as well as "fault current." The Thevenin impedance characterizing the faulted bus as well as its prefault voltage are also printed. Five columns of currents are printed:

1. Initial complex alternating current assuming no DC offset.
2. Decremented complex alternating current at the specified fault duty time, again assuming no DC offset.
3. Peak DC offset current magnitude at the fault duty time.
4. Total rms fault current magnitude at the fault duty time.
5. Total peak fault current magnitude at the fault duty time.

The branch decremented peak DC currents in (3) above are calculated assuming that the initial DC offset current follows from the prefault to post fault instantaneous change in current, and that the DC offset current decays at a rate dependent upon the X/R ratio of the Thevenin equivalent of the branch assuming "flat" conditions. Machine currents are similarly calculated, except that the machine (plus step-up transformer if XTRAN is nonzero) impedance is used in setting the X/R ratio. The value printed as "FAULT CURRENT" is the magnitude of the sum of the decayed change in current of each of the above components. For reference, the final line for each faulted bus' output block shows as peak DC current the total instantaneous fault current decayed according to the faulted bus' Thevenin impedance as determined from the "flat" conditions impedance matrix. This line also shows the Thevenin impedance (in per unit, rectangular coordinates) and prefault bus voltage (in per unit, polar coordinates).

All currents are printed in either amps or per unit, and the complex currents in (1) and (2) above in either rectangular or polar coordinates, according to the fault analysis output options currently in effect (refer to Section 1.6.4). If the physical units option is enabled and the bus whose base voltage is required for the calculation of the current has no base voltage specified for it, the current is printed in per unit.

The output report may be extended to provide contributions up to "n" levels away from the faulted bus. Generalizing, the selection of a positive number "n" results in output for the faulted bus, followed by output for all buses connected to it, followed by output for all buses two buses away from it, and so on up to "n" levels removed from the faulted bus. In reporting these remote contributions, only the currents described in (1) and (2) above are tabulated, and a branch is only reported once: at the end which is "closer to" (i.e., fewer levels away from) the faulted bus.

Whenever output is requested for buses more than two levels away from the faulted bus, the program will ask the user to verify the value entered as "n":

```
DO YOU REALLY WANT nn LEVELS? (1=YES):
```

When the multi section line reporting option is enabled, the far end bus (rather than the closest "dummy" bus) of each multi section line connected to the bus being reported (the "*at bus*") is shown as its connected bus (its "*from bus*"). Multi section lines are identified with an ampersand ("&") as the first character of their line identifiers in the branch circuit identifier column. When reporting remote contributions, the "dummy" buses of multi section lines are neither reported nor counted in the "levels away" calculation; i.e., the far end bus is one level removed from the "*at bus*".

Contributions from a three-winding transformer are identified by the winding number, the transformer name and the circuit identifier.

7.9.6.1 Example of Breaker Duty Results Analysis

Figure 7-64 shows a sample output report using polar coordinates and amperes for clarity. The upper block of output shows decremented values of current based on a contact parting delay time of zero; hence it describes the intersection of the envelope of the fully offset current wave with the $t = 0^+$ axis. The AC component of current is stated in rms terms, the ratio of rms value to amplitude is 1.414, and the initial value of the DC (unidirectional) current component is $1.414 \times 18569.7 = 26261.5$ A. Also, with no decay taking place, the total peak current is twice the amplitude of the AC component.

The center block of output specifies the situation at 25 milliseconds after fault initiation. Here the AC component of current has decayed to 16239.1 A, while the DC component has decayed more rapidly to 13996.6 A. The final output block, corresponding to 0.5 seconds with the DC component having decayed to essentially zero, shows the expected 1.414 relationship between rms and peak fault current, when expressed in amperes.

```
     PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS™E      WED, OCT 09 1991  14:57
PSS™E PROGRAM APPLICATION GUIDE EXAMPLE                                 POLAR
BASE CASE INCLUDING SEQUENCE DATA                                    COORDINATES
FAULT DUTY TIME IS  0.000 SECONDS - ALL BREAKERS

AT   154 [DOWNTN   230]   INITIAL RMS      DECREMENTED RMS    /DECREMENTED CURRENTS/
X----- FROM -----X CKT ALTERNATING CURNT  ALTERNATING CURNT PEAK DC   TOT RMS TOT PEAK
  153 MID230    230 1    1921.4    -72.44    1921.4    -72.44    2124.4    2864.4    4841.6
  153 MID230    230 2    1601.1    -72.44    1601.1    -72.44    1759.5    2379.0    4023.9
  203 EAST230   230 1    1623.5    -74.96    1623.5    -74.96    1909.8    2506.7    4205.9
  205 SUB230    230 1   10775.9    -79.68   10775.9    -79.68   13851.1   17549.2   29090.6
 3008 CATDOG    230 1    2685.1    -84.00    2685.1    -84.00    3245.9    4212.5    7043.2
FAULT CURRENT  (AMPS)   18569.7    -78.52   18569.7    -78.52   22878.9   29466.6   49140.4
THEVENIN IMPEDANCE:     0.00078   0.01473 V: 0.9211     -7.68   26261.5   32163.6   52523.0
```

$\sqrt{2}$ ¥ **18569.7 = 26261.5A**

$$\sqrt{(26261.5)^2 + \frac{(26261.5)^2}{2}}$$

Different because of load on bus

18569.7 ¥ $\sqrt{2}$ **+ 26261.5**

$\sqrt{2}$ ¥ **16239.1 = 22965.6**

$$\sqrt{(15918.6)^2 + \frac{(22965.6)^2}{2}}$$

```
FAULT DUTY TIME IS  0.025 SECONDS - ALL BREAKERS

AT   154 [DOWNTN   230]   INITIAL RMS      DECREMENTED RMS    /DECREMENTED CURRENTS/
X----- FROM -----X CKT ALTERNATING CURNT  ALTERNATING CURNT PEAK DC   TOT RMS TOT PEAK
  153 MID230    230 1    1921.4    -72.44    1699.5    -66.24    1144.2    2048.8    3547.7
  153 MID230    230 2    1601.1    -72.44    1416.2    -66.24     947.7    1704.1    2950.6
  203 EAST230   230 1    1623.5    -74.96    1439.0    -68.62    1268.5    1918.3    3303.5
  205 SUB230    230 1   10775.9    -79.68    9382.5    -71.93    9028.0   13020.7   22296.9
 3008 CATDOG    230 1    2685.1    -84.00    2337.7    -79.11    1614.9    2841.2    4920.9
FAULT CURRENT  (AMPS)   18569.7    -78.52   16239.1    -71.58   13996.6   21438.6   36962.2
THEVENIN IMPEDANCE:     0.00078   0.01473 V: 0.9211     -7.68   15918.6   22740.1   38884.2
```

Decaying total

Decaying each path independently

22965.6 + 15918.6 = 38884.2

```
FAULT DUTY TIME IS  0.500 SECONDS - ALL BREAKERS

AT   154 [DOWNTN   230]   INITIAL RMS      DECREMENTED RMS    /DECREMENTED CURRENTS/
X----- FROM -----X CKT ALTERNATING CURNT  ALTERNATING CURNT PEAK DC   TOT RMS TOT PEAK
  153 MID230    230 1    1921.4    -72.44    1405.5    -51.12       0.0    1405.5    1987.7
  153 MID230    230 2    1601.1    -72.44    1171.3    -51.12       0.0    1171.3    1656.4
  203 EAST230   230 1    1623.5    -74.96    1192.7    -53.87       0.5    1192.7    1687.3
  205 SUB230    230 1   10775.9    -79.68    7513.8    -59.33       2.7    7513.8   10628.8
 3008 CATDOG    230 1    2685.1    -84.00    1887.5    -68.18       0.0    1887.5    2669.4
FAULT CURRENT  (AMPS)   18569.7    -78.52   13118.0    -58.49       3.2   13118.0   18554.8
THEVENIN IMPEDANCE:     0.00078   0.01473 V: 0.9211     -7.68       1.2   13118.0   18552.8
```

Figure 7-64. Relationship of Outputs to Offset Fault Current Wave (amps)

7.10 Calculating Fault Currents to ANSI Standards

The ANSI fault current calculation process calculates fault currents according to the ANSI standard C37.5-1979 *Guide for Calculation of Fault Currents for Application of AC High-Voltage Circuit Breakers Rated on a Total Current Basis*.

7.10.1 Creating the Fault Specification Data file

In the ANSI Fault Specification Data File, the data records must be specified in the following format:

```
IBUS, VMAX, TIME
```

where:

IBUS	Is the bus number of the bus to be faulted. No default is allowed.
VMAX	Is the maximum operating voltage of bus IBUS specified in pu. VMAX = 1.0 by default.
TIME	Is the contact parting time in seconds. TIME = one cycle by default.

Data records may be input in any order; fault cases are calculated and reported in the same order in which data records are read. Input is terminated with a record specifying an "IBUS" value of zero.

7.10.2 Setting ANSI Fault Calculation Options

The calculation function is initiated by selecting the ***Fault>ANSI fault calculation (ANSI)*** option which displays the ANSI Fault Current Calculation dialog (see Figure 7-65).

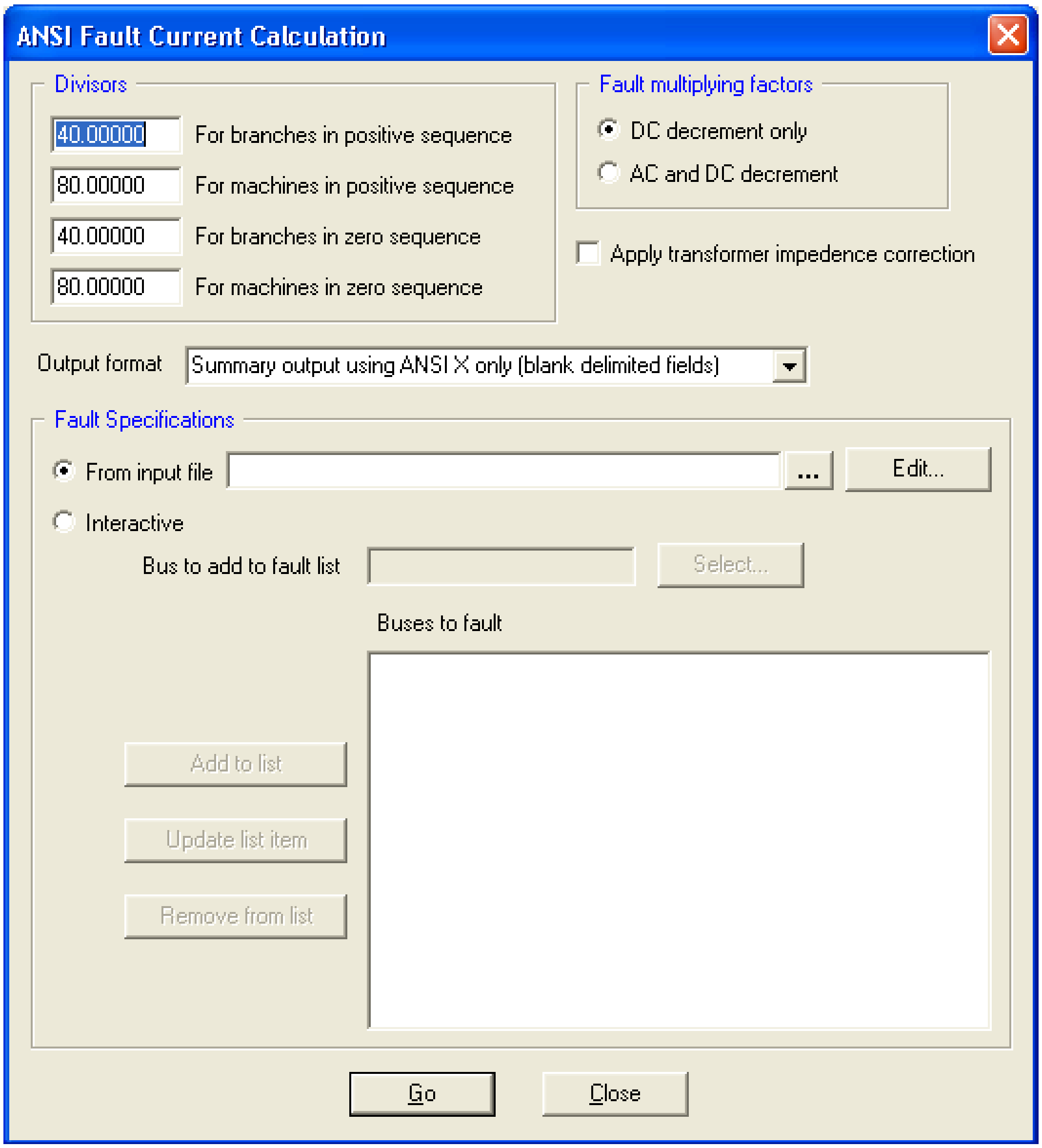


Figure 7-65. ANSI Fault Current Calculation Dialog

In the dialog, the user specifies the following solution and reporting options:

Transformer zero sequence impedance: If this box is checked, the zero sequence impedance of all transformers whose actual positive sequence impedance differs from its nominal value are scaled by the same factor as is its positive sequence impedance. If the box is not checked, all zero sequence transformer impedances are left at their nominal values (i.e., the original values used to establish the sequence network data). The same treatment applies to *all* transformers in the system that are not at nominal impedance.

Decay factors to be applied: The user can select to include the effects of both AC and DC decay, or only the effects of DC decay.

Resistance scaling factors (the Divisors): For branches and machines with a zero value of resistance, activity ANSI assigns a non-zero resistance equal to its reactance divided by a scaling factor. Four such factors (for positive sequence branch impedance, positive sequence machine impedance, zero sequence branch impedance, and zero sequence machine impedance) are specified.

Fault specifications: Faulted buses, along with their highest operating voltages and contact parting times, may be specified either interactively using the selector window or in an ANSI Fault Specification Data file (see Section 7.10.1). When using the interactive approach, buses are added to the "buses to fault" list. During the bus selection process, the Add Bus dialog allow selection of the bus maximum operating voltage and the contact parting time (see Figure 7-66).

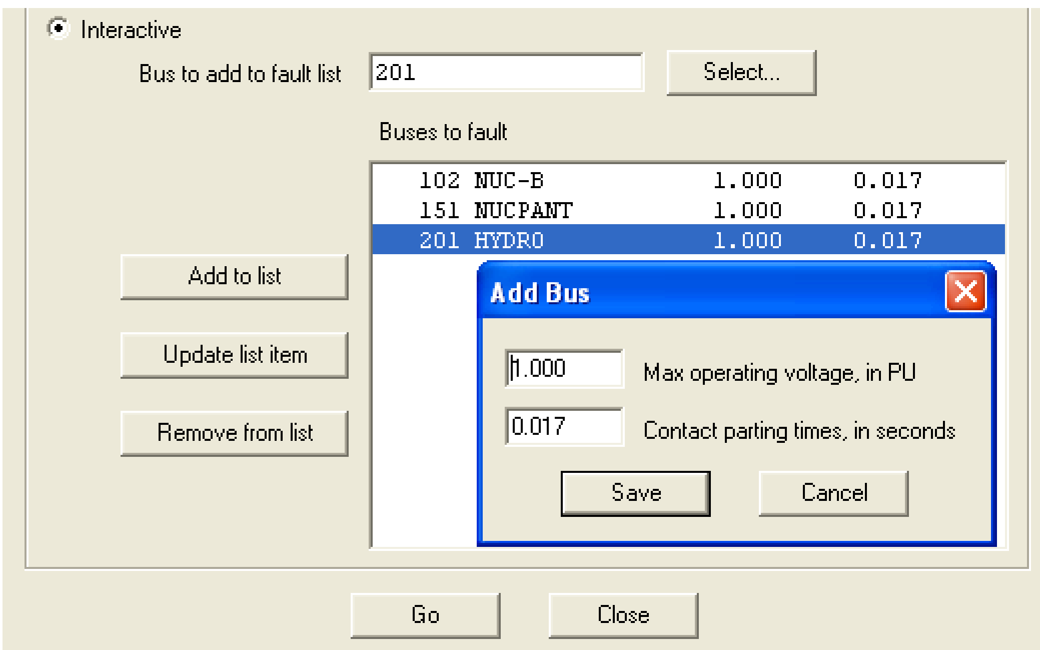


Figure 7-66. Selection of Buses to be Faulted

Output options: There are six output report format options:

- Summary output in report format using only the ANSI X matrices (output fields are separated by blanks).
- Summary output in spreadsheet input format using only the ANSI X matrices (output fields are comma delimited).
- Detailed output in report format using only the ANSI X matrices.
- Detailed output in report format using both the ANSI R and ANSI X matrices.
- Summary output in report format using both the ANSI R and X matrices (output fields are separated by blanks).
- Summary output in spreadsheet input format using both the ANSI R and X matrices (output fields are comma delimited).

7.10.3 Performing ANSI Fault Calculations

Once the user has selected the output device and selected all the solution and reporting options, all that is required is to select the ***GO*** button in the dialog (Figure 7-65).

If sequence data is not contained in the working case, an appropriate error message is printed and the calculation process is terminated.

The following computations are performed on the power flow case:

1. An ordering for the positive sequence network is determined and the standard summary printed at the progress report output device.
2. The positive sequence decoupled admittance matrices are constructed and factorized.
3. The zero sequence network is ordered and the standard summary is printed.
4. The zero sequence decoupled admittance matrices are constructed and factorized.
5. Fault cases are calculated.

If, in the process of building the sequence network admittance matrices, isolated buses are detected, they are alarmed. The presence of isolated buses in the positive sequence network indicates an improperly specified power flow case. Isolated buses in the zero sequence network, though alarmed, are permitted and require no special treatment. The isolated bus summaries may be terminated by entering the AB interrupt control code. When the fault analysis warning option is disabled (see Section 1.6.4), the isolated bus tabulations are suppressed. In either case, the total number of isolated buses in the sequence networks is tabulated.

As each fault case is calculated, its results are tabulated. The processing and reporting of the ANSI fault current calculation process may be terminated by entering the AB interrupt control code.

7.10.4 Viewing ANSI Fault Calculation Output

The summary report for each fault case includes the following:

- The bus number, name and base voltage of the faulted bus, along with the maximum operating voltage and contact parting time input values.
- Three phase fault results, including symmetrical fault MVA, symmetrical fault current in kA, asymmetrical fault current in kA, the ANSI X/R ratio, and the multiplying factor.
- Line-to-ground fault results, including symmetrical fault current in kA, asymmetrical fault current in kA, the ANSI X/R ratio, and the multiplying factor.
- Line-to-line-to-ground fault results, including symmetrical phase current in kA, and three times the zero sequence symmetrical fault current in kA.
- The positive sequence Thevenin impedance as obtained from the decoupled positive sequence admittance matrices.
- The zero sequence Thevenin impedance as obtained from the decoupled zero sequence admittance matrices.

An example of a summary report, obtained using the *savnw.sav* power flow case, with a fault on Bus 151 (see Figure 7-67a).

In the detailed output, an output block for each faulted bus is printed. Voltages, currents and apparent impedances are printed in either physical units (kV L-G, amps and ohms) or per unit, and in either rectangular or polar coordinates, according to the fault analysis output options currently in effect (refer to Section 1.6.4). If the physical units option is enabled and the bus whose base voltage is required for the calculation of a quantity has no base voltage specified for it, the quantity is printed in per unit.

For each faulted bus (i.e., at each "*at bus*"), the following quantities are tabulated:

1. The bus number, name, base voltage, and area number in which it resides, with the specified maximum operating voltage listed below the bus identifiers. This is followed by the positive sequence bus voltage for the three phase fault case, and the A phase voltage and the three sequence voltages for the L-G case.

2. The positive and zero sequence ANSI Thevenin impedances at the fault point in per unit, rectangular coordinates (the positive and negative sequences are identical under the ANSI fault calculation standard).

3. The machine identifier and currents *arriving* at the bus from all online machines at the bus. For the L-G fault, three times the zero sequence current ($3I_0$) is printed.

4. The "*from bus*" number, name, base voltage, area number, and circuit identifier of each non transformer branch and two-winding transformer connected to the "*at bus*". The branch quantities tabulated include the current *arriving* at the "*at bus*" from the "*from bus*", the apparent impedance as seen at the "*from bus*" looking down the line toward the "*at bus*" (i.e., the V/I ratio at the "*from bus*"), and the ratio of apparent X/R. For the L-G fault, zero sequence quantities are printed. Branches are printed in ascending "*from bus*" numerical or alphabetical order according to the bus output option in effect.

5. The winding number, transformer name and circuit identifier of each three-winding transformer connected to the "*at bus*". The current *arriving* at the "*at bus*" from the transformer is tabulated. For the L-G fault, zero sequence quantities are printed. Three-winding transformers are printed in ascending transformer name order.

6. The sum of the currents output in (3), (4) and (5) above. These currents are annotated "SUM OF CONTRIBUTIONS".

7. The fault current as calculated from the maximum operating voltage and the ANSI Thevenin reactance or impedance, as appropriate.

The quantity shown as the sum of contributions will be essentially identical to the quantity shown as fault current for both three phase and line-to-ground faults when fault currents and contributions are calculated using only the ANSI X matrices. However, these quantities will normally differ when the output is calculated using both the ANSI "R" and ANSI "X" matrices. This is due to the error introduced by decoupling the complex sequence admittance matrices into pairs of real matrices, using the real matrices to derive columns of "R" and "X" matrices (i.e., the decoupled impedance matrices), and then coupling the columns back together to get approximations of the complex impedance matrix columns.

Figure 7-67b shows an example of a detailed report obtained for faults on Bus 151 in the *savnw.sav* power flow case.

```
     PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E      TUE, MAR 02 2004  15:48
PSS/E PROGRAM APPLICATION GUIDE EXAMPLE
BASE CASE INCLUDING SEQUENCE DATA
                                BRKER X------- THREE PHASE FAULT --------X X-- LINE TO GROUND FAULT --X X- LLG SYMM I -X
  BUS# X-- NAME --X BASKV MAX V  TIME  FLTMVA  SYMM I ASYMM I   X/R FACTOR  SYMM I ASYMM I   X/R FACTOR   PHASE   3IA0    RPOS    XPOS    RZERO
   151 NUCPANT     500.00 1.000 0.017  5148.2   5.945   9.285  41.02 1.562   7.754  12.113  41.06 1.562   7.588  11.149  0.0005  0.0194  0.0001
```

(a) Summary Report

```
AT BUS    151 [NUCPANT     500.00] AREA    1      (PU) V+:   0.0000+J 0.0000         (PU) VA:   0.0000+J 0.0000    V0:  -0.1304+J 0.0000
MAXIMUM OPERATING VOLTAGE: 1.0000 PU                                                      V+:   0.5652+J 0.0000    V-:  -0.4348+J 0.0000

POSITIVE SEQUENCE THEVENIN R, X, X/R:  0.00047  0.01942   41.022           ZERO SEQUENCE THEVENIN R, X, X/R:  0.00014  0.00582   41.325

                                                   T H R E E   P H A S E   F A U L T              O N E   P H A S E   F A U L T
X--------- FROM ----------X AREA CKT  I/Z     RE(I+)   IM(I+)    RE(Z+)   IM(Z+)  APP X/R     RE(3I0)  IM(3I0)   RE(Z0)   IM(Z0)  APP X/R
   101 [NUC-A       21.600]    1 1   PU/PU   0.1974 -12.4560   0.0003   0.0136   45.333      0.6385 -28.7427   0.0000   0.0000    0.000
   102 [NUC-B       21.600]    1 1   PU/PU   0.1974 -12.4560   0.0003   0.0136   45.333      0.6385 -28.7427   0.0000   0.0000    0.000
   152 [MID500      500.00]    1 1   PU/PU   0.2483  -5.5877   0.0026   0.0460   17.692      0.1166  -1.7436  -0.0059  -0.0833   14.108
   152 [MID500      500.00]    1 2   PU/PU   0.2483  -5.5877   0.0026   0.0460   17.692      0.1166  -1.7436  -0.0059  -0.0833   14.108
   201 [HYDRO       500.00]    2 1   PU/PU   0.7493 -15.3368   0.0010   0.0150   15.000      0.3883  -6.1349  -0.0010  -0.0185   18.332
              SUM OF CONTRIBUTIONS  (P.U.)   1.6407 -51.4243                                  1.8986 -67.1074
             TOTAL  FAULT  CURRENT  (P.U.)   1.2546 -51.4667                                  1.6350 -67.1360
```

(b) Detailed report

Figure 7-67. Summary and Detailed Report of ANSI Fault Calculation

7.11 Calculating PI Equivalent for Unbalanced Switching

The short-circuit fault current calculations described in previous sections are based on the assumption that the phase self- and mutual-impedances of each branch are balanced. Several situations exist, especially in dynamics, where the user will want to simulate a situation in which unbalance of the phase impedances and phase-to-phase coupling is a key effect. PSS™E contains an analytical process which is designed to calculate positive-sequence PI equivalents for these cases. The process constructs positive-sequence equivalents for the following situations:

1. One open phase either grounded or not.
2. Two open phases.
3. Mid-line, line-ground, line-line-ground, or three-phase fault.
4. One breaker open.

A series of situations where this activity would be used is shown in Figure 7-68. In this series, a line-ground fault occurs 40% of the way down the line from bus 151 to bus 152. This is the first unbalance condition. Next, the single-pole breaker at one end of the line opens the faulted phase while the breaker at the other end of the line remains closed (stuck) for a period of time. This is the second unbalanced condition. Finally, the second breaker opens to leave an unbalanced condition which is with two phases closed on the line section. The user, in a stability study, may then want to simulate the results of such a sequence of events.

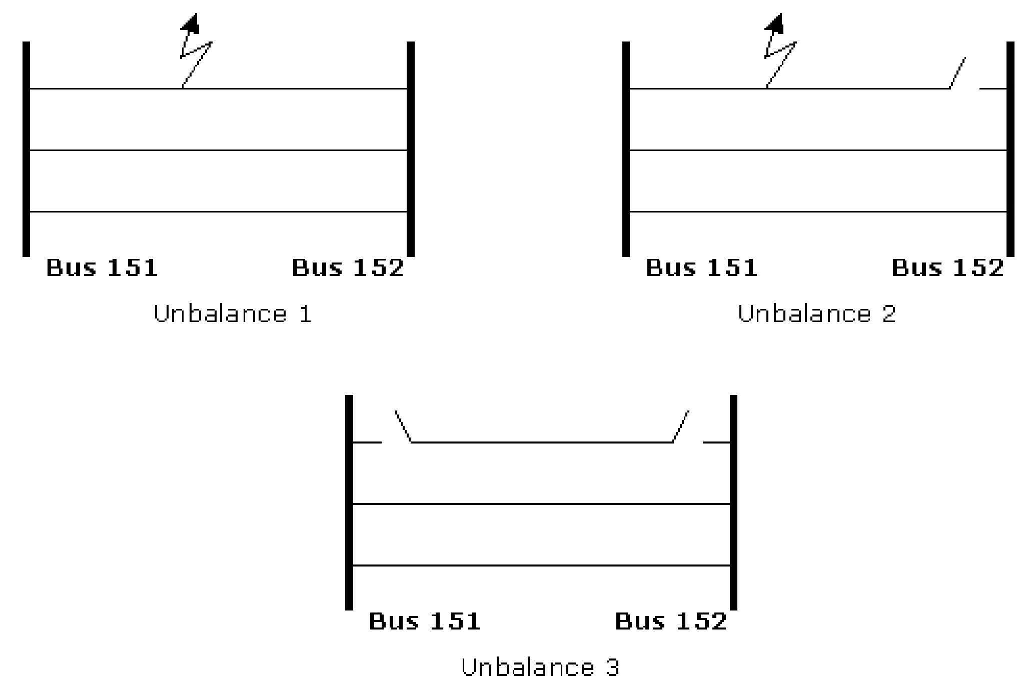


Figure 7-68. Examples of Unbalanced Network Conditions Requiring a PI Equivalent

In order to be able to simulate the three unbalanced conditions, in a stability case, the user would have to replace the positive sequence branch, in the power flow case, with a positive sequence PI equivalent for each of the three conditions, in sequence.

7.11.1 Setting Up for the Calculation of PI Equivalents

The calculation process is launched by selection of the ***Fault>Separate pole circuit breaker (SPCB)*** option which will display the Separate Pole Circuit Breaker dialog (see Figure 7-69).

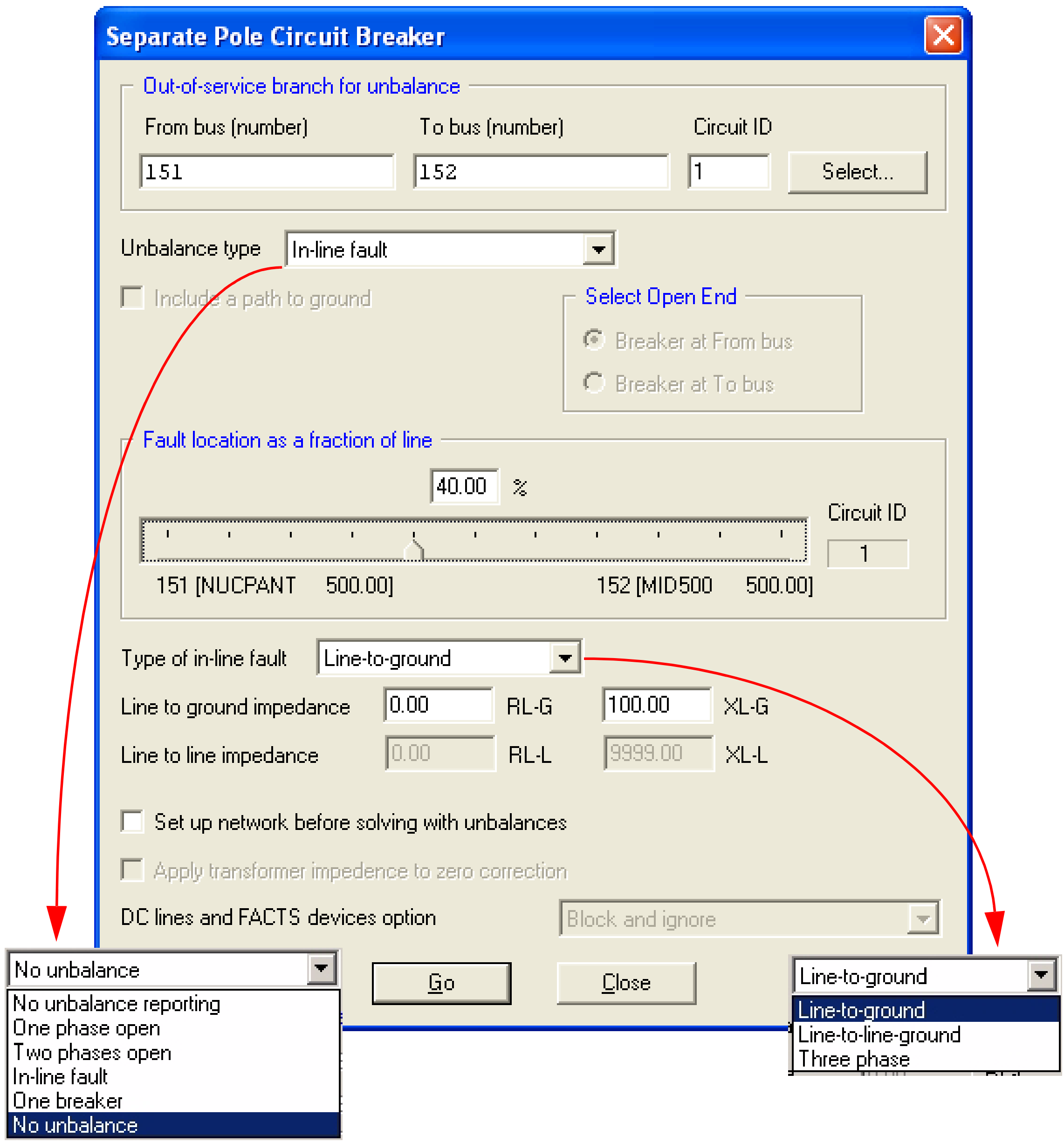


Figure 7-69. Separate Pole Circuit Breaker Calculation Dialog

Using the facility of the dialog the user can identify the topologies, fault locations and type and grounding impedances to be simulated.

First the user selects the circuit on which the unbalance will be placed. In Figure 7-69 circuit #1 of the branch from bus 151 to bus 152 has been selected.

Next the user selects the type of unbalance of which there are four options:

- One phase open at both ends of the branch. With this option a "path to ground" can be selected to be placed at any point on the line with a specified impedance.
- Two phases open. this option has no fault applications.
- In-line fault. This assumes both circuit breakers are closed. The fault can be located at any point on the line and can be a single-line-to-ground fault, a line-to-line fault or a 3-phase fault; with selectable fault impedance where appropriate.
- One breaker. This allows opening the branch at one end (selected by the user) and further facilitates the application of an in-line line-to-ground fault at any point on the branch with a selectable fault impedance.

Having made the selections, the user selects the ***Go*** button to initiate the calculation.

7.11.2 Running Calculations Prior to PI Equivalents

Prior to calculating the PI equivalents, the PSS™E power flow case and working files must be set up in the form required. The user *must*:

1. Solve the working case in the pre-unbalance condition.
2. Take the transmission line which is to be subjected to the unbalance out-of-service.
3. Ensure that the fault analysis modeling option setting is placed in the normal three phase mode.

Having selected the output device and made the fault and unbalance type selections, the user selects the ***Go*** button to initiate the calculation.

PSS™E will then prepare the power flow case for the unbalanced network solution in a manner similar to that used at the initiation of the detailed unbalanced fault analysis described in Section 7.6.2.

Next calculates the columns of the three sequence impedance matrices corresponding to the specified buses are calculated in submatrix form.

Finally the positive sequence pi-equivalent of the branch unbalance is calculated and the results printed in the Report window or to a file designated by the user.

The calculation is not sensitive to any interrupt control code options.

7.11.3 Analyzing PI-Equivalent Results

For each transmission line unbalance calculated, the following data is tabulated:

1. The admittance matrix terms corresponding to the branch with the selected unbalance present.
2. A summary description of the branch unbalance.
3. The positive sequence pi-equivalent. This is presented in the form of a branch impedance (R + jX) and the equivalent line connected shunts at each end of the branch.

The pi-equivalent calculated may be used in dynamic simulations to model the branch unbalance. It should *replace* the branch parameters used in modeling the branch without the presence of the unbalance.

Figure 7-70 shows the output for a single-line-to-ground fault applied on the branch from bus 151 to bus 152 at a point 40% along the line from bus 151. The fault impedance is zero. Figures 7-71a and 7-71b show diagrammatic view of the equivalent PI.

```
ZERO SEQUENCE THEVENIN IMPEDANCE SUBMATRIX:
  BUS      151 [NUCPANT  500]       152 [MID500   500]
  151  (   0.00017,    0.00617)  (   0.00014,    0.00235)
  152  (   0.00014,    0.00235)  (   0.00346,    0.03491)

POS. SEQUENCE THEVENIN IMPEDANCE SUBMATRIX:
  BUS      151 [NUCPANT  500]       152 [MID500   500]
  151  (   0.00328,    0.01784)  (   0.00452,    0.01015)
  152  (   0.00452,    0.01015)  (   0.00775,    0.01943)

NEG. SEQUENCE THEVENIN IMPEDANCE SUBMATRIX:
  BUS      151 [NUCPANT  500]       152 [MID500   500]
  151  (   0.00328,    0.01784)  (   0.00452,    0.01015)
  152  (   0.00452,    0.01015)  (   0.00775,    0.01943)

PI EQUIVALENT Y MATRIX IS:
(     1.7790,   -24.6553)   (    -0.8554,     18.5130)
(    -0.8554,    18.5130)   (     1.4711,    -22.0245)

TO SIMULATE:

ONE PHASE GROUNDED WITH IMPEDANCE=    0.0000 +J      0.0000
  40.0 PERCENT OF WAY DOWN LINE FROM    151 [NUCPANT  500]

FOR BRANCH FROM BUS 151 [NUCPANT500] TO BUS 152 [MID500 500] CIRCUIT 1
 USE EQUIVALENT R+JX= (     0.00249,     0.05390)  B= 0.0

AT BUS 151 [NUCPANT500] USE LINE CONNECTED SHUNT= ( 0.92358, -6.14228)

AT BUS 152 [MID500 500] USE LINE CONNECTED SHUNT= ( 0.61572, -3.51151)
```

Figure 7-70. Output Report for Equivalent PI shown in Figure 7-71

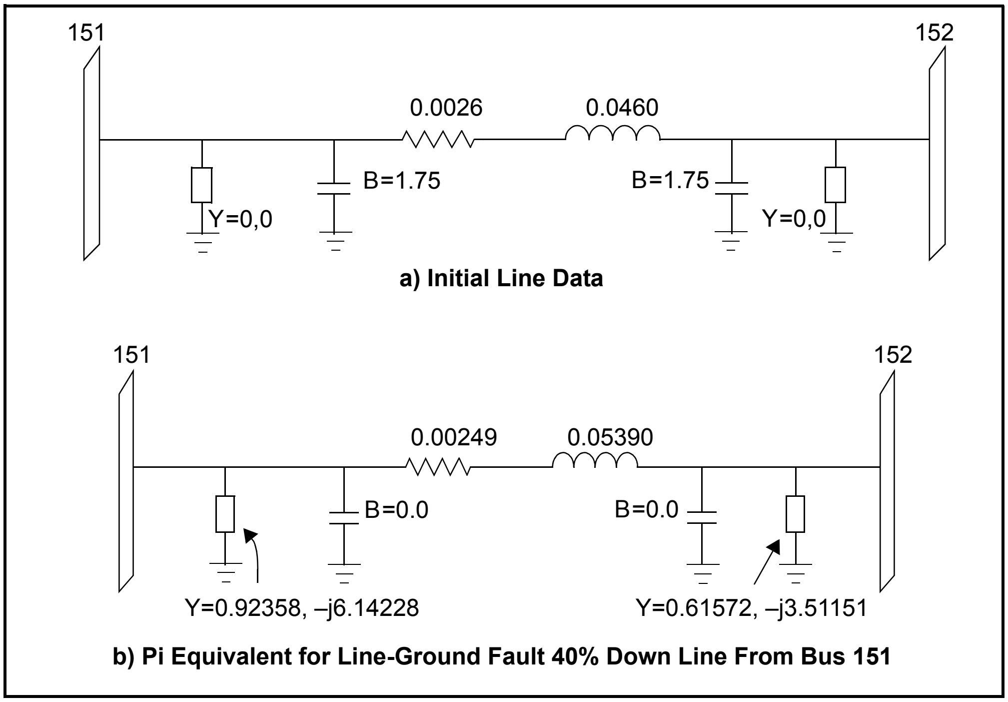


Figure 7-71. Diagram View of Equivalent Pi and the Branch Power Flow Data

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Chapter 8

Balanced Switching

8.1 Overview: Balanced Switching

The voltage versus current characteristics of synchronous generators are different in different time regimes. Power system network solutions must, therefore, be categorized according to the conditions just before and at the instant for which the solution is to apply. The time regimes of significance in network solutions are illustrated in Figure 8-1.

All power system simulations assume that the system is in the steady state for an extended period prior to the time, t. It is assumed that the first incident of interest, such as a switching operation, fault, load change, or control setpoint change, occurs at, t. Power flow calculations apply to the instant, t^{-} (t minus). The power flow generator boundary conditions, therefore, assume that the system is in the steady state, or more practically, experiencing the gentle motions of normal undisturbed operation. Every power flow calculation establishes the condition of the entire transmission network, outward from generator terminals to load terminals, for an instant, t^{-}.

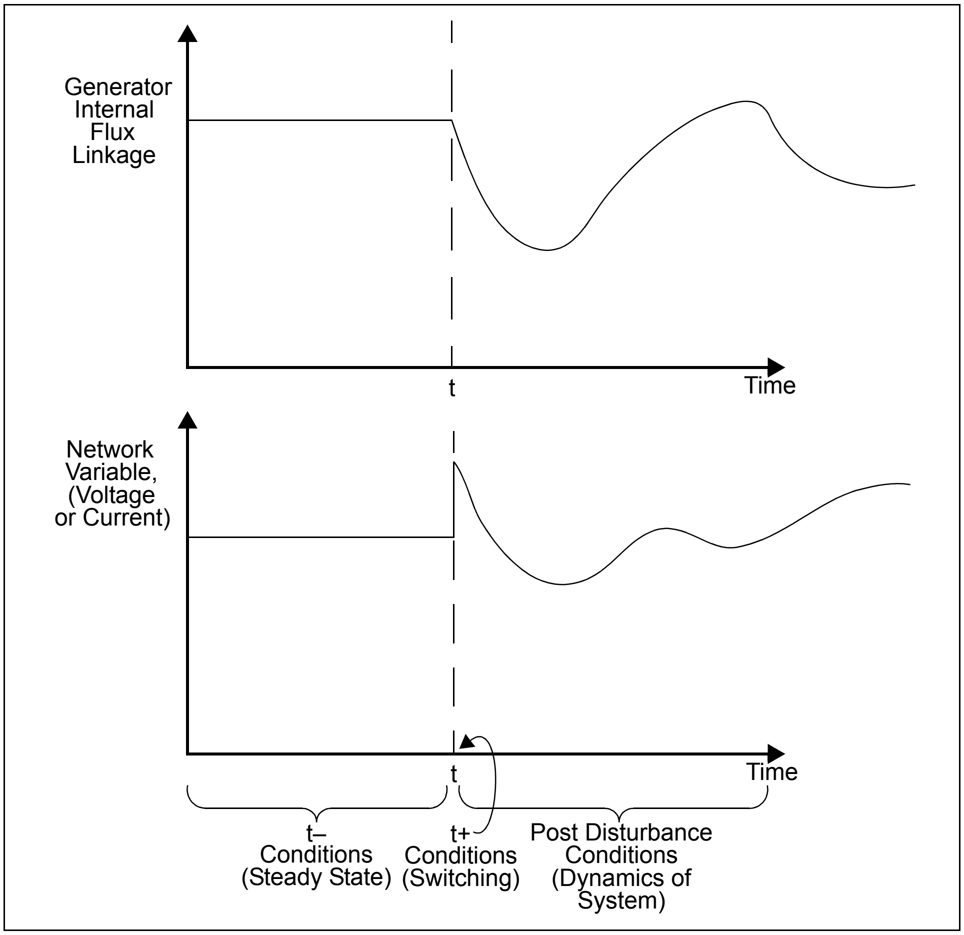


Figure 8-1. Time Regimes Considered in Power System Simulations

Any switching operation, fault, significant load change or change of control inputs (governor or excitation system reference) starts the system moving. PSS™E simulations assume that high frequency switching transients in the electric network die away very rapidly in relation to the time durations of the transients that are of interest. The power frequency phasors representing currents and voltages throughout the network are assumed to change instantaneously at time t.

The transients of the flux linkages in the rotors of electrical machines are of prime interest and must be accurately accounted for. Simulations of conditions at, t^+ (t plus), and later must, therefore, use boundary conditions that recognize dynamic, rather than steady state, behavior of equipment. Both generator and load characteristics applicable to t^+ are different from those applying at t^-. Loads are commonly assumed to have a constant MVA steady-state characteristic in steady-state power flow solutions applying to t^-, but to be better modeled by a mixture of constant current and constant impedance characteristics at t^+ and later.

The instantaneous change caused by a switching is followed by a period when all generator flux linkages, rotor angular positions, and other power plant quantities vary, as dictated by the differential equations governing their dynamic behavior.

The power flow database of PSS™E allows the entry of generator and load data pertaining to predisturbance conditions at t^-, to switching conditions at t^+, and to system dynamic behavior over an arbitrarily long period after the initiation of the disturbance. The user of PSS™E may then obtain a solution for any of the three time regimes, *steady state*, *switching*, or *dynamic behavior*, by executing appropriately selected sequences of PSS™E analytical processes.

Switching, or t^+, solutions and dynamic simulations require the generator boundary conditions to be set in accordance with the electromagnetic laws governing rotor flux linkages. Therefore, the power flow boundary condition in which power output and bus voltage are specified, must be replaced by a specification of a Thevenin or Norton source whose instantaneous value is determined by instantaneous values of flux linkages. The generator boundary conditions applying at instants, t^- and t^+, are illustrated by Figure 8-2. The t^+ boundary condition recognizes that generator rotor flux linkages must obey Lenz's and Maxwell's laws.

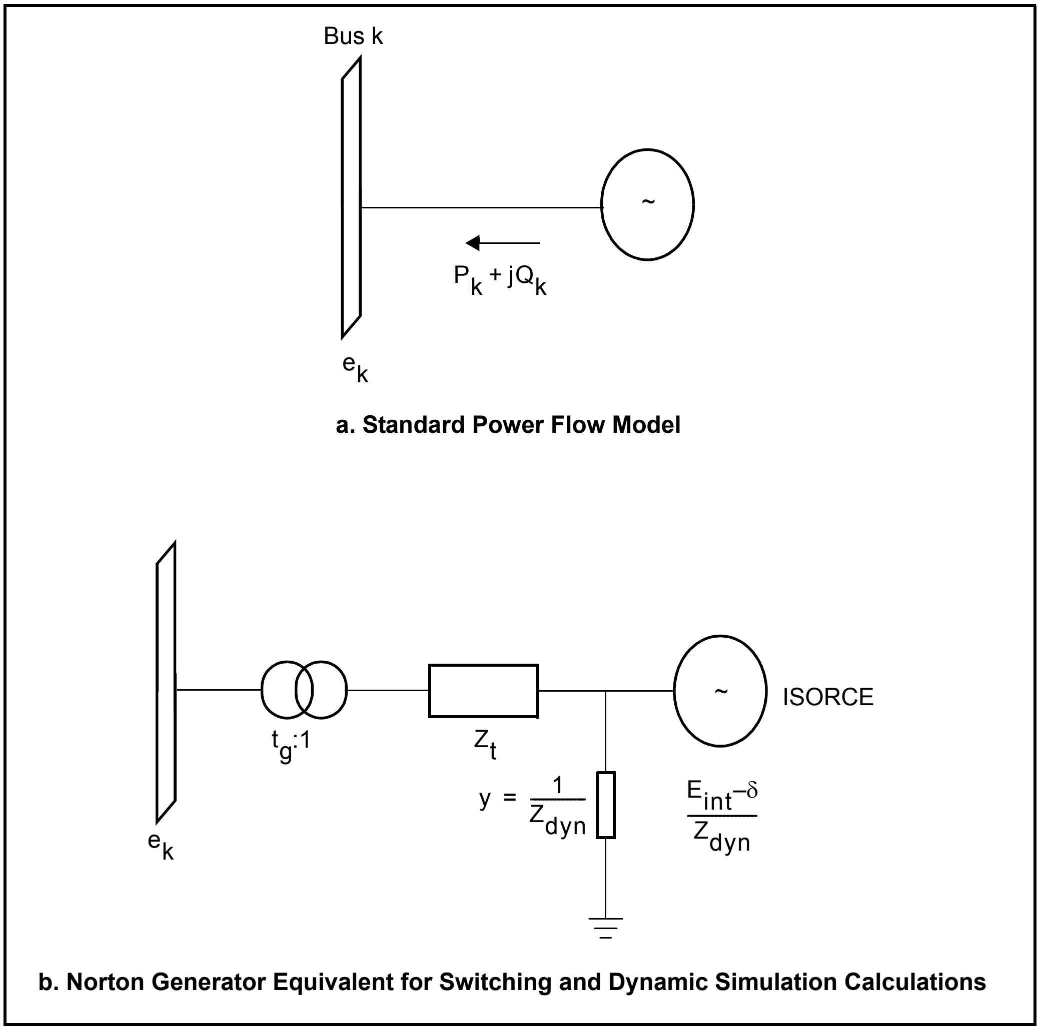


Figure 8-2. Standard Load-Flow Model and Norton Equivalent Used for Switching and Dynamic Studies

8.2 Objectives of a Balanced Switching Study

The objective of a switching study is to calculate the conditions that will exist in the power system just after a sudden change such as the opening of a transmission line, switching on of a large load, application of a fault, or tripping of a generator. These calculations are useful, for example:

1. To show the immediate voltage dip caused by switching on of a large motor.
2. To give symmetrical fault duty at a bus.
3. To show the immediate change of flow that will be seen on each tie-line into an area (before the inertial swing of rotor angles) when one such tie or a generator within the area is tripped.
4. To show the voltage rise which occurs when a line is opened at one end. This could separate a generation plant from the network and result in what is commonly known as "load rejection".

A switching study is a calculation of conditions at time, t^+. A switching study is, in effect, the calculation of the transmission system conditions at the first instant, $t = t^+$, of a dynamic simulation, separated from the subsequent calculation of conditions at later instants, $t > t^+$. Switching study results are presented and examined with the same output and limit checking activities as are used in power flow work studies.

8.3 Preparing a Powerflow Case for Balanced Switching

Prior to performing the switching operations, the user must prepare the Powerflow case. The three steps are to:

- Ensure the power flow case is solved and contains the required generator dynamic data
- Convert the generators to a Norton Equivalent (generator boundary condition)
- Convert the loads to a voltage dependent model (load boundary condition)

These operations result in a converted power flow case which can be saved in its converted form for subsequent switching analyses. Note that this converted case should be saved under a different name because the conversion process is not reversible.

8.3.1 Establishing the Powerflow Base Case for Balanced Switching

The starting point for a switching study is a conventional solved load flow case giving data and solution corresponding to the pre switching (t^-) condition. Conventional procedures are used with the provision that the dynamic impedance, ZSORCE, must be included in the database for *every* generator, and step-up transformer data, XTRAN and GENTAP, must be present for all generators where the implicit step-up transformer treatment is used.

The generator dynamic impedance and step-up transformer parameters are not needed during load flow solutions; they may be added to the power flow but a solved load flow case need not be resolved after any item of generator dynamic impedance or step-up transformer is added or changed since the dynamic impedance and step-up transformer parameters affect only the Norton equivalent current sources, ISORCE, that will represent the generators in the post switching calculation.

8.3.2 Converting the Generators for Balanced Switching

The Norton source current is determined from the results of a load flow (t^-) solution. The generator dynamic impedance may be taken to be either the generator load flow attribute, ZSORCE, or the fault analysis generator attribute, ZPOS. Normal practice is to set ZSORCE equal to subtransient impedance and ZPOS equal to either transient or subtransient impedance depending upon the requirements of fault analysis. While those switching studies taking the dynamic impedance to be subtransient reactance, Z'', give an *accurate* calculation of conditions immediately after a switching, while those switching studies taking the dynamic impedance to be transient reactance, Z', give an *approximate* calculation of conditions roughly three to five cycles after a switching.

The initialization of the Norton sources and changeover of boundary conditions is illustrated in Figure 8-4. The conversion process, which initializes all source currents to correspond to the flux linkages behind the dynamic impedance (ZSORCE or ZPOS), sets flags to cause ISORCE to be held constant in all subsequent solutions, and changes all Type 3 buses to Type 2. The choice of dynamic impedance is controlled during the conversion process and selected by the user.

To initiate the conversion process, the user selects the ***Powerflow>Convert>Generators (CONG)***. This will open a dialog for electing to use ZSORCE or ZPOS (see Figure 8-3).

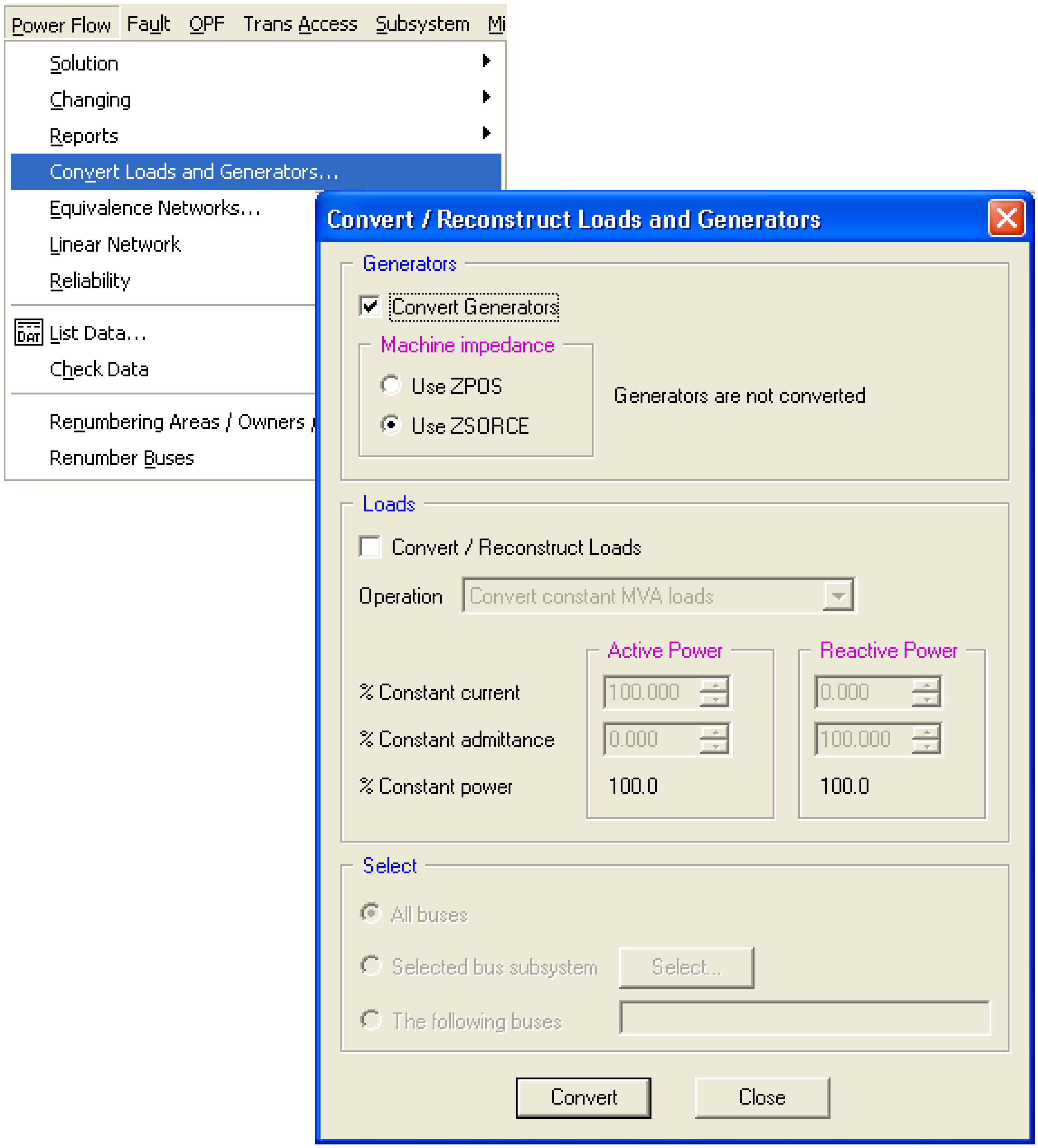


Figure 8-3. Performing the Generator Conversion

When the conversion process is complete, it will print a notification in the Output Bar so indicating.

8.3.2.1 Ordering the Network Buses

Because it changes at least one bus type code, the generator conversion process must be followed by an ordering of the network buses such that sparsity is maintained as the Jacobian matrix is triangularized in a variety of PSS™E analytical processes. The network bus ordering generally takes place in the background. In this case, however, where the user is specifically setting up conditions for the switching analysis, it is necessary to convert generators and order the network as a separate task.

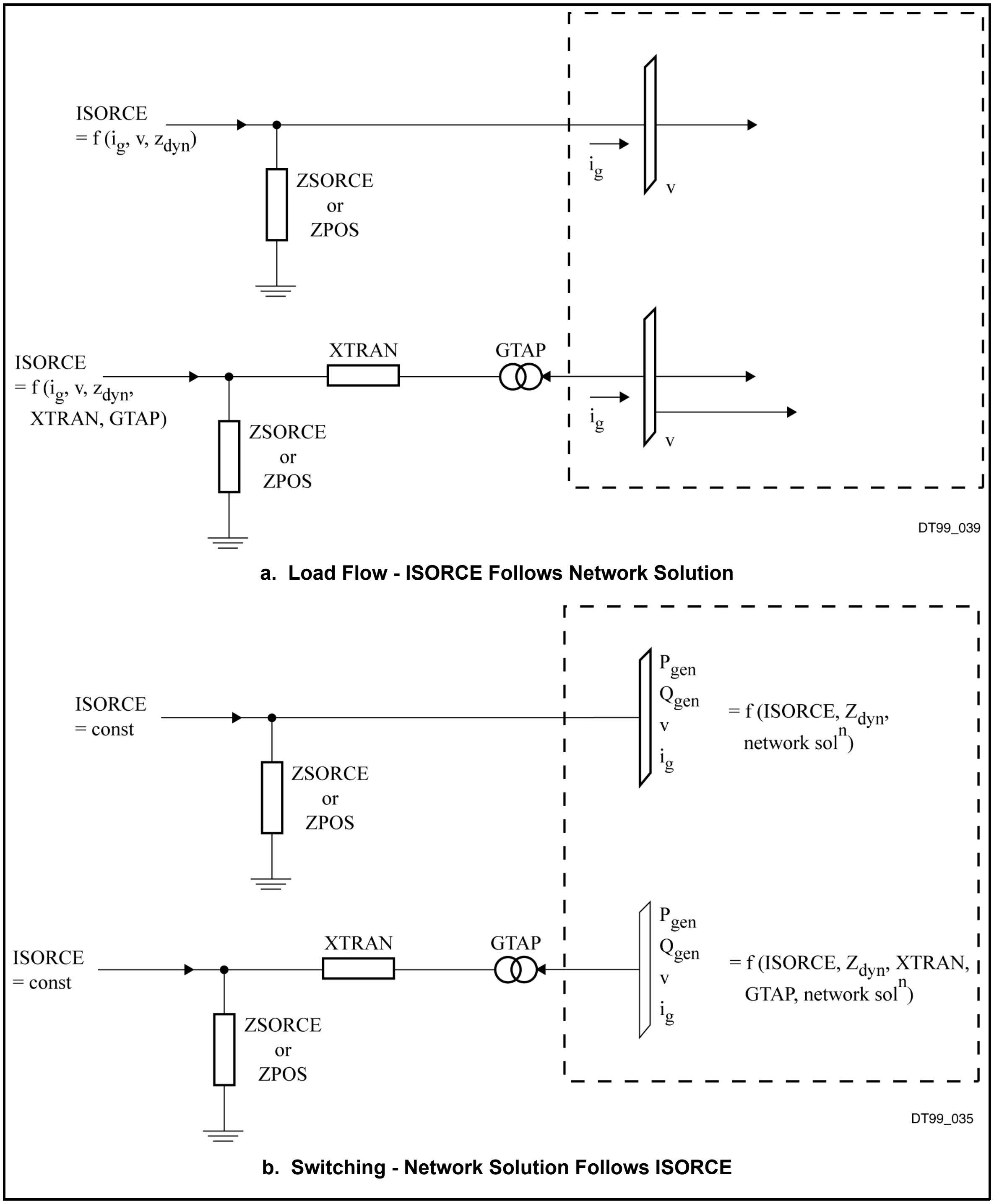


Figure 8-4. Change of Generator Boundary Condition for Switching

To launch the ordering process, the user should select the ***Powerflow>Solution>Order network for matrix operations (ORDR)***. This, in turn will display the dialog where the user can elect to Ignore out of service branches, (recognizes the status of network branches and ignores out-of-service branches in determining the bus ordering), or to Assume all branches are in-service, (ignores the service status of all branches and assumes all branches connected to type one, two, or three buses are in-service) (see Figure 8-5).

If the user elects to ignore out of service branches, when a branch previously out-of-service is returned to service, the network has to be ordered again. Consequently, the advantage of assuming that all branches are in service is to avoid having to re-order. However, when a large number of branches are out-of-service, the "ignore" option *might* result in a more efficient matrix storage, thereby decreasing both the time and memory required to perform calculations using the network matrices.

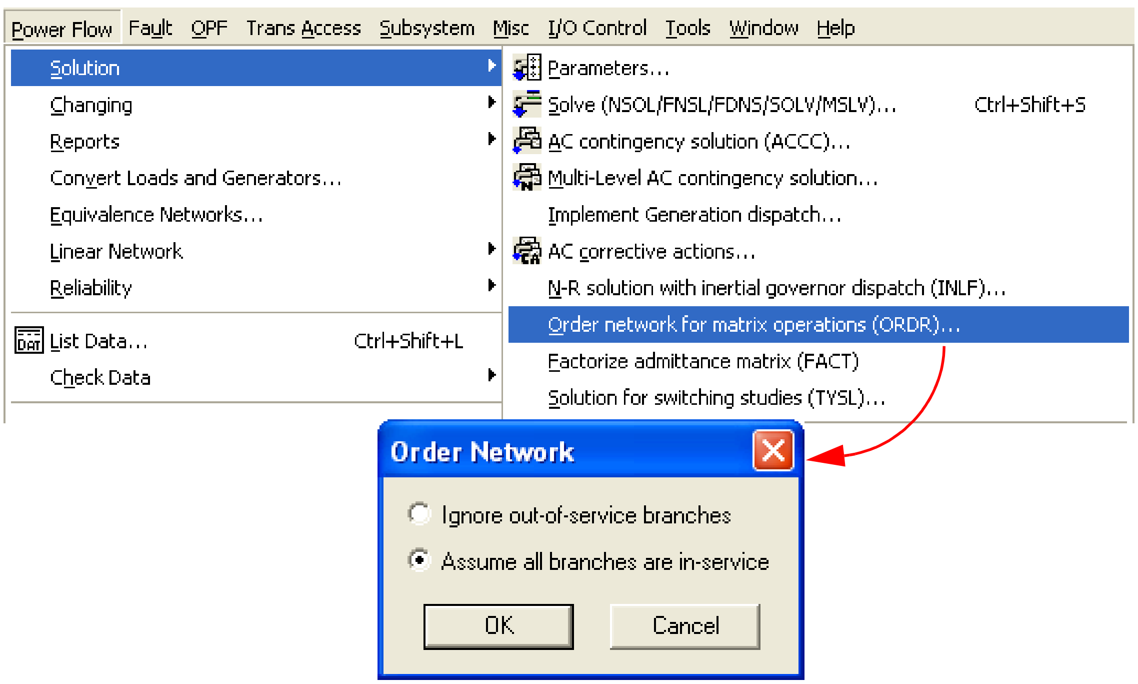


Figure 8-5. Ordering the Network Buses

8.3.3 Converting Loads for Balanced Switching

The load boundary condition for switching studies should reflect the relationship between load voltage and current during sudden changes of voltage. The constant (P,Q) characteristic used in load flow studies is generally regarded as unsuitable for switching studies. A mixture of constant current and constant impedance is usually regarded as a more accurate treatment of loads when the supply voltage is changing rapidly. Load characteristics should be adapted for switching studies as described in Section 4.5.

8.3.4 Performing a Balanced Switching Study

The sequence of steps required to perform a balanced switching study is shown in Figure 8-6. It can be seen that the basic preparation is as described as discussed in the previous sections. Once that preparation is complete, the user can perform a variety of switching studies on the converted power flow case. The method involves:

- Performing the switching action by changing the network as required
- Obtaining a solution and outputting the results

The switching of network elements is performed using the processes used by the conventional power flow facilities. Further, the output of results and network conditions can be performed using the same output and reporting facilities used for the conventional power flow and getting a solution.

There are, however, two functions highlighted in Figure 8-6 which have not yet been discussed. These are the Factorization (FACT) process and the triangularized Y matrix network solution. These are discussed in Sections 8.3.4.1 and 8.3.4.2.

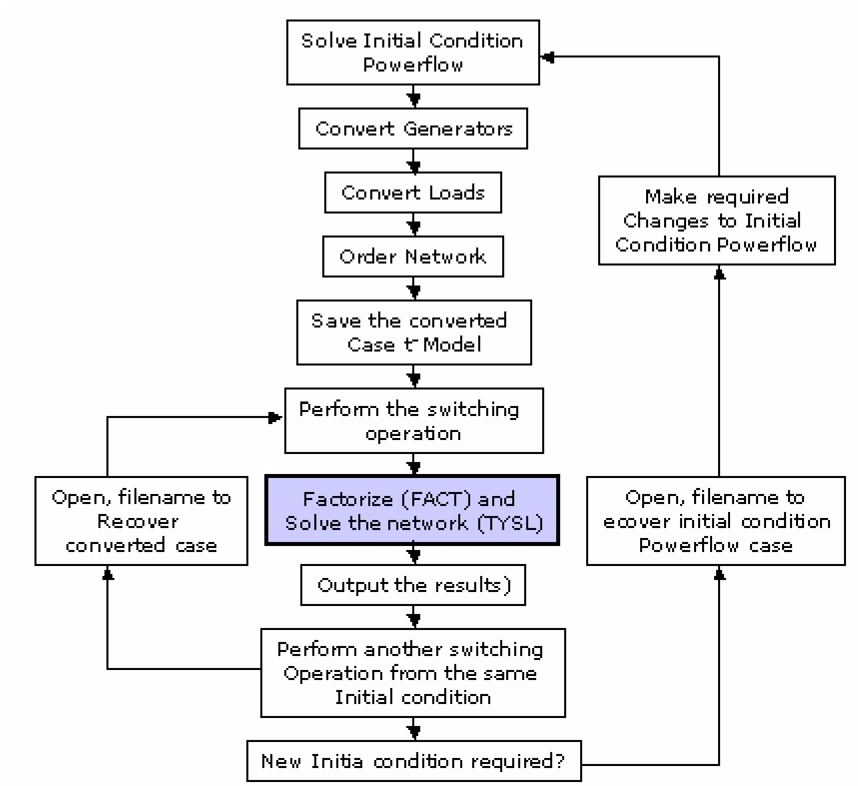


Figure 8-6. Switching Analysis – Sequence of Processes

8.3.4.1 Factorizing the Network Admittance Matrix

The triangular factorization process decomposes the network admittance matrix ("Y" matrix) into its upper and lower triangular factors for use in the triangularized Y matrix network solution or in the network balance of dynamic simulations. This computation also takes place, without being specifically invoked, during a variety of PSS™E analytical processes.

Since the process performs a computation involving the admittance matrix, it follows that it must be re-executed any time this matrix changes and switching studies or dynamic simulations are to be run. Thus, in these applications, the factorization process must be rerun any time one or more of the following occurs:

- Change of load characteristic
- Change of bus type code.
- Change of machine, branch or load status.
- Change of machine impedance parameters.
- Change of branch impedance or charging.
- Change of which branches are modeled as zero impedance lines.
- Change of transformer ratio or phase shift angle.
- Change of bus or line connected shunt.
- Change of constant admittance load.

To launch the Factorization process, the user should select the ***Powerflow>Solution>Factorize admittance matrix (FACT)*** option (see Figure 8-7). Factorization, however, must be preceded by conversion of generators. An appropriate error message is printed if generators have not been converted and the factorization process terminated.

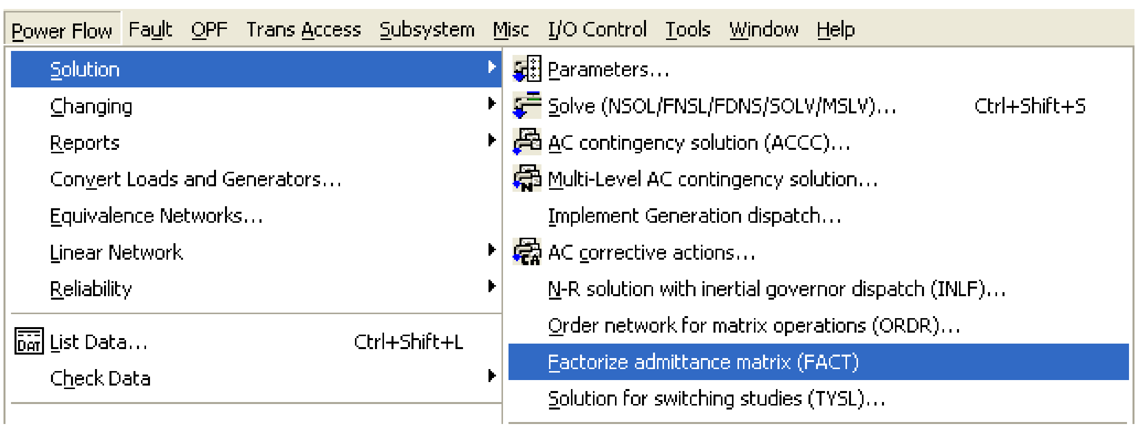


Figure 8-7. Launching the Factorization Process

Following factorization, the number of nonzero diagonal and off-diagonal terms in each factor of the matrix are tabulated in the Output Bar.

Finally, if the factorization process detects that the network requires to be re-ordered, this is automatically executed prior to the factorization.

The process is not sensitive to any interrupt control code options.

8.3.4.2 Executing a Triangularized Y Matrix Solution

The triangularized Y matrix network solution is designed for those situations where the internal flux linkages of generators are assumed to remain unchanged as a load or fault is switched onto the system, as a line is opened or closed, or as a load is removed. It determines the instantaneous change in network variables as the switching operation takes place.

This network solution is launched by selection of the ***Powerflow>Solution>Solution for switching studies (TYSL)*** (see Figure 8-8). This in turn displays the dialog where the user can elect to perform the solution on the basis of a FLAT start or to use the existing voltage vector in the converted power flow case as the initial voltage estimate.

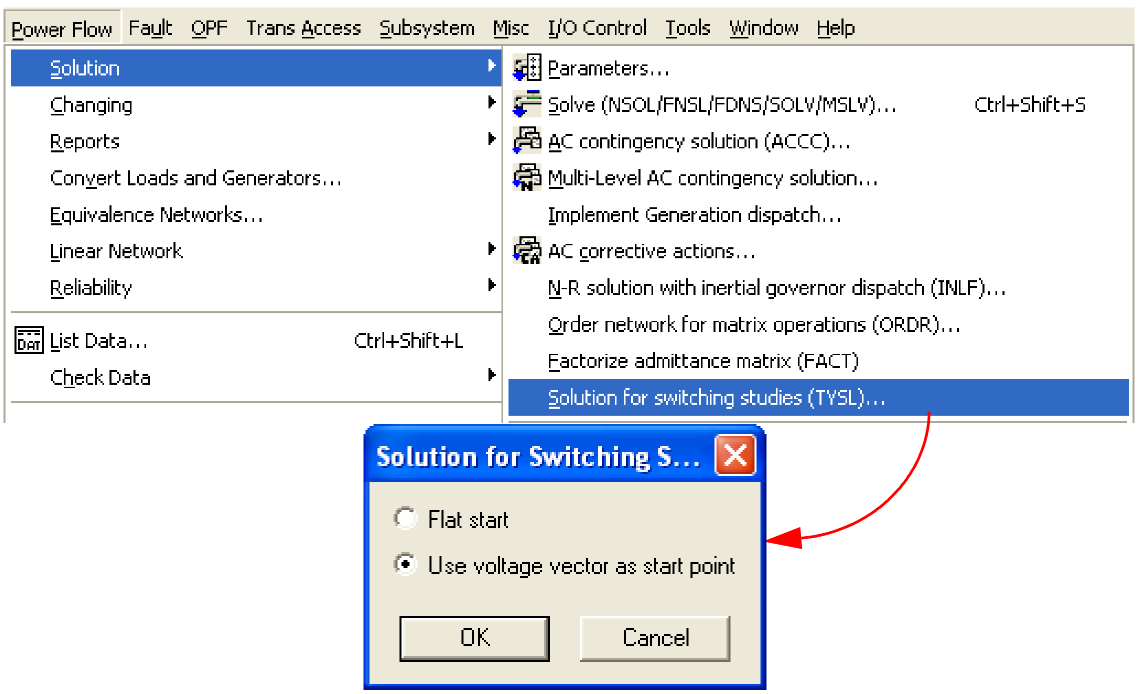


Figure 8-8. Launching the Triangularized Y Matrix Solution

During the solution, generator buses are not treated as they are in the other PSS™E network solution methods. Rather, the type two bus voltages become "free variables" just as the voltages at type one buses, and a fixed source current is injected into the network at each generator bus.

The load boundary conditions and the "blowup" check are handled in the same way as in the Gauss-Seidel solution method. Further, the solution convergence monitor, the DC transmission line monitors for two-terminal and multi-terminal DC lines, and the mismatch summary are identical too.

No automatic adjustments are allowed, and switched shunt devices and DC converter transformer tap settings are locked at their pre switching settings. A two-terminal or multi-terminal DC transmission line is blocked for the remainder of the current execution of the network solution if, on any iteration, the AC voltage at a rectifier converter station bus falls below 50% or is insufficient to make margin order. Shunt elements of FACTS devices hold their pre switching reactive currents, and series elements are held at their pre switching series voltages.

For each in-service VSC DC line, the solution starts with each converter holding the active and reactive power at their values at the time the generators are converted. If, on any iteration, the corresponding current exceeds the converter's IMAX, the injection is reduced using the power weighting factor fraction (PWF) just as in the conventional power flow solution activities. Each converter is treated independently, so that any reduction at one converter does not affect the injection at the other end of the VSC DC line. The DC transmission line monitor for VSC DC lines includes the DC line name, followed by the AC power injection at each converter bus.

By default, this Y matrix solution has a convergence tolerance of 0.00001 on voltage change and a limit of 20 iterations. A deceleration factor, which has a default value of unity, is applied to the voltage change at each bus. For optimum convergence characteristics, it may be advantageous to reduce the deceleration factor, especially when a large fraction of the reactive load is represented by the constant MVA and/or current characteristics. The presence of DC lines may also require some deceleration of the solution. The user may modify any of these solution parameters with the data in the solution parameters data editor window.

The user should remember, as described in Figure 8-6, the Y matrix solution requires that the factors of the network admittance matrix reside in the factored matrix working file (i.e., it requires prior factorization.

The solution will respond to the following interrupt control codes:

AB	Abandon activity TYSL following completion of the next iteration.
NC	Suppress the convergence monitor.
DC	Tabulate conditions for each DC line after each iteration.
FD	Tabulate the conditions for each in-service FACTS device after each iteration.

Note that the Y admittance solution method *is not* a power flow solution; it is unable to handle the power flow style representation of generator buses (i.e., fixed power and voltage). But, for networks in which generators are represented by constant internal flux linkages (i.e., following conversion), it is capable of producing very small mismatches in only a few iterations. (Note that its default convergence tolerance is an order of magnitude smaller than that used by the Gauss-Seidel and Newton-Raphson solutions). It is much less sensitive to the values of branch impedances than the other network solution activities.

8.4 Examples of Balanced Switching Studies

For the purposes of further explaining the process the following examples show switching cases for:

- Voltage rise on a line end
- Motor starting
- Fault application

8.4.1 Voltage Rise on Open Line End

The calculation of voltage on the open end of a line is often required to examine the conditions which could be encountered by line connected reactors; by surge arresters and by breakers. The latter have limits of voltage across the open break within the equipment. Voltage on the line side could be high while voltage on the system side could have fallen due to loss of the line's incoming power.

This example will open the line from bus 151 to bus 152, circuit 1, at the end terminating on bus 152, in the *savnw.sav* power flow case. Figure 8-9 shows the power flow diagram for these buses.

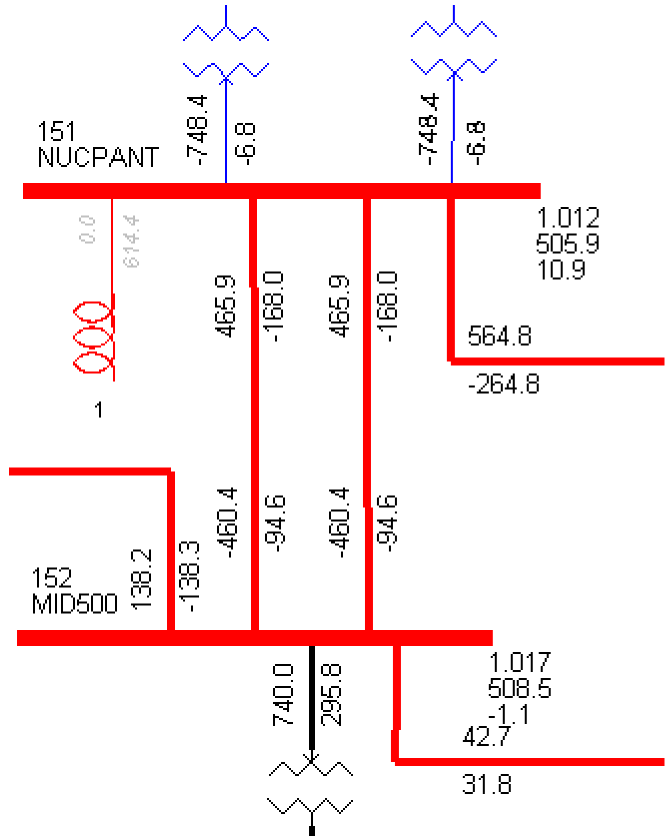


Figure 8-9. Example – Circuits from Bus 151 to Bus 152

One way of performing the breaker operation, is to establish a dummy bus on the circuit from bus 151 to bus 152 which is connected to Bus 152 via a zero impedance line. To "open the breaker" it would require taking the zero impedance line out of service (see Figure 8-10). The circuit from bus 151 to the dummy bus 999 will have the same line parameters as the actual circuit from bus 151 to bus 152 circuit 1. When the zero impedance line between bus 999 and bus 152 is opened, circuit 1 from bus 151 will be connected at bus 151 and "hanging" open. The post-switching voltage at bus 999 is the line-end voltage of interest together with the voltage at bus 152.

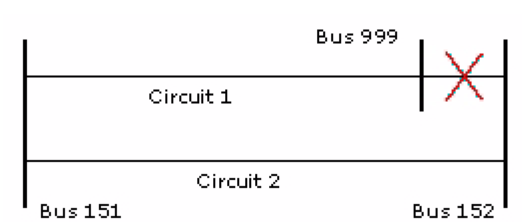


Figure 8-10. Opening a Line at One End

To avoid having to pre-view the need for dummy buses, the "split bus" tool can be used. Here the user would split bus 152 and move circuit 1 to bus 151 to a new bus automatically created by the program and provided with its own new number by the user. The process is shown below in Figure 8-11.

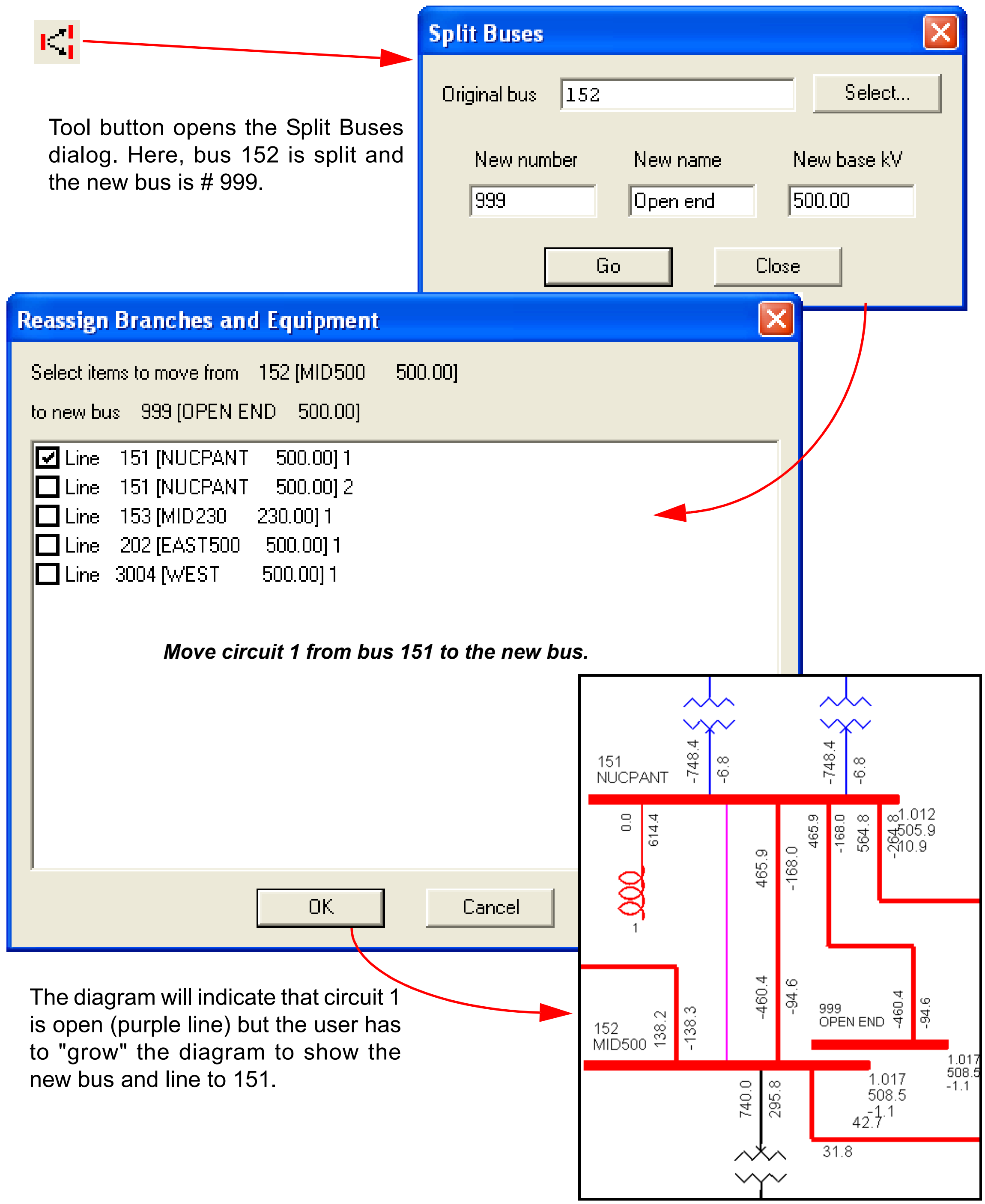


Figure 8-11. Using the Split Bus Tool to Produce an Open Line End

The bus split will introduce a new zero impedance branch between bus 999 and bus 152. The user will open this zero impedance line to perform the line opening. Further, the new bus; the new line to bus 151 and the zero impedance branch will be seen in the Tree View and the Spreadsheet View.

The user should remember the sequence of events:

- First convert the power flow case and order the network buses
- Do the bus split and open the new zero impedance line to create an open ended line
- Factorize the matrix and perform the Y matrix solution

Now the voltages can be examined with a bus based report or by examining the solution shown in the diagram.

8.4.1.1 Viewing Open End Line Results

It is interesting to look at the bus voltages, in this example, on buses 151, 152 and 9999 for the power flow condition, for the post switching condition and for a condition obtained by opening the line in the unconverted power flow case and solving with a conventional solution (e.g., Gauss-Seidel). This latter case will show conditions after all the voltage regulation devices have had time to operate to adjust back to set-point voltages (V long-term).

Table 8-1. Results of Line Open End Balanced Switching Calculation

Results of Line Open Operation			
Bus Number	**V pre-switch**	**V post-switch**	**V long-term**
151	1.012	1.023	1.015
152	1.017	0.996	0.981
9999	--	1.112	1.104

It can be seen that immediately after switching the voltage at bus 152 drops because of the sudden loss of incoming power and the need for greater voltage support. The voltage at bus 151 rises slightly because, in part, of unconsumed reactive power from the open line. The line end voltage has increased from its original level of 1.017 pu to 1.112 pu (see Table 8-1).

Following voltage regulator action, the voltage at all buses has been reduced to a new steady-state level. The voltage at the open end is elevated but reasonable for sustained operation.

8.4.2 Motor Starting

A fairly common switching study requirement is illustrated by Figure 8-12. One of a pair of large motors is running under load, and the second one is to be started by switching it directly onto the bus. The extent of the voltage dip produced by switching on the second motor is needed for the coordination of overcurrent and undervoltage protection.

The example will assume a load at bus 3006, in the *savnw.sav* power flow case, to consist of two large motors which, at full load and unity voltage, draw (7.5 + j3.95) MVA each. The starting current for one motor is given in specification data as 2.72 times rated current at 0.275 power factor. The calculation in Figure 8-12 shows that this starting duty corresponds to an initial shunt admittance of (0.0625 j0.218) per unit, relative to a 100-MVA base (I = YV), and nominal voltage.

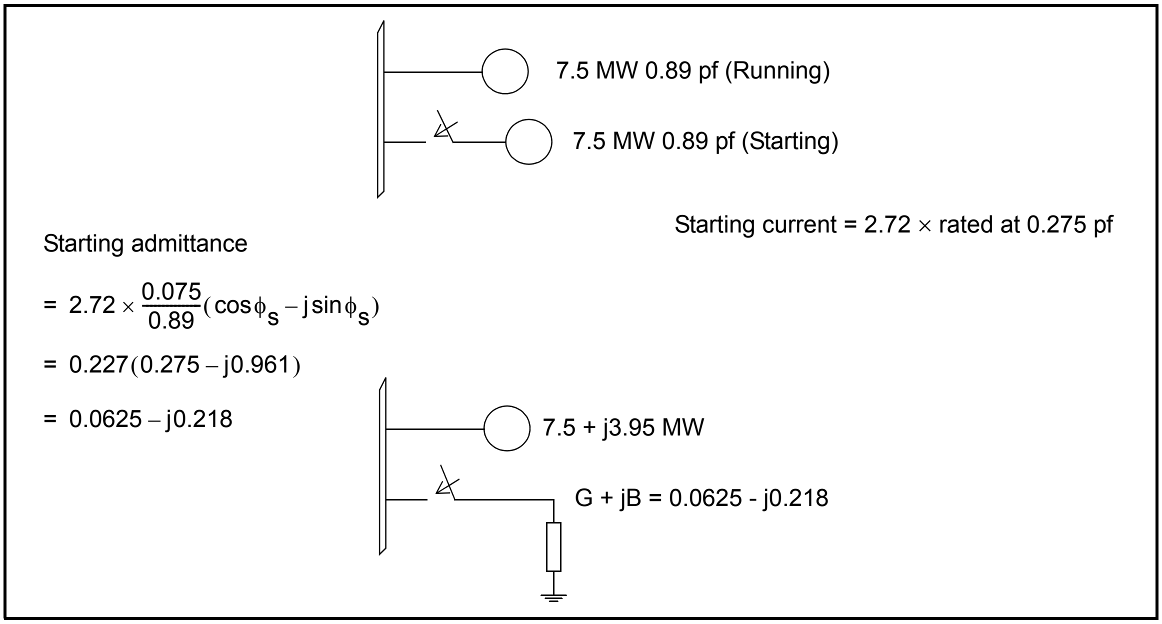


Figure 8-12. Motor Starting Example

The switching operation comprises the connection of the starting admittance to the case. As previously discussed, the user will convert and order the power flow case; then connect the admittance to bus 3006 then factorize and perform the Y matrix solution. Note that the starting admittance is on a 100 MVA base. This means that the user should add a shunt of 6.25 -j21.8 MVA which is the MVA at 1.0 pu voltage. Figure 8-13 shows the bus based report for bus 3006.

```
BUS   3006 UPTOWN       230.00 CKT      MW      MVAR      MVA  %I 0.9871PU
                                                                 227.04KV
 TO LOAD-I                             7.5       0.0      7.5
 TO LOAD-Y                             0.0       3.9      3.9
 TO SHUNT                              6.1      21.2     22.1
 TO    153 MID230       230.00  1    -85.5      -3.2     85.6
 TO   3005 WEST         230.00  1     72.0     -21.9     75.3
```

Figure 8-13. Bus Based Report Following Motor Starting

It can be seen that the inrush is 85.6 MVA at 0.987 pu voltage. The initial voltage was 0.993 pu, indicating a voltage dip of only less than 1.0%.

It can be seen too that the load on the bus (the other motor) was converted to 100% constant current for real power and 100% constant admittance for reactive power.

8.4.3 Fault Current

Since these examples lie within the realm of "balanced" switching, the only faults which can be analyzed are three-phase faults.

In the case of a three-phase fault, the switching operation which is performed before factorization and solution is the connection of a very large reactive admittance to ground at the fault point. A value of -j1E9 is adequate. Once a solution has been obtained for the instant, t^+ output of results is handled by the standard load flow output formats such as the bus based reports. Such a bus based report will provide the fault point and branch information (see Figure 8-14).

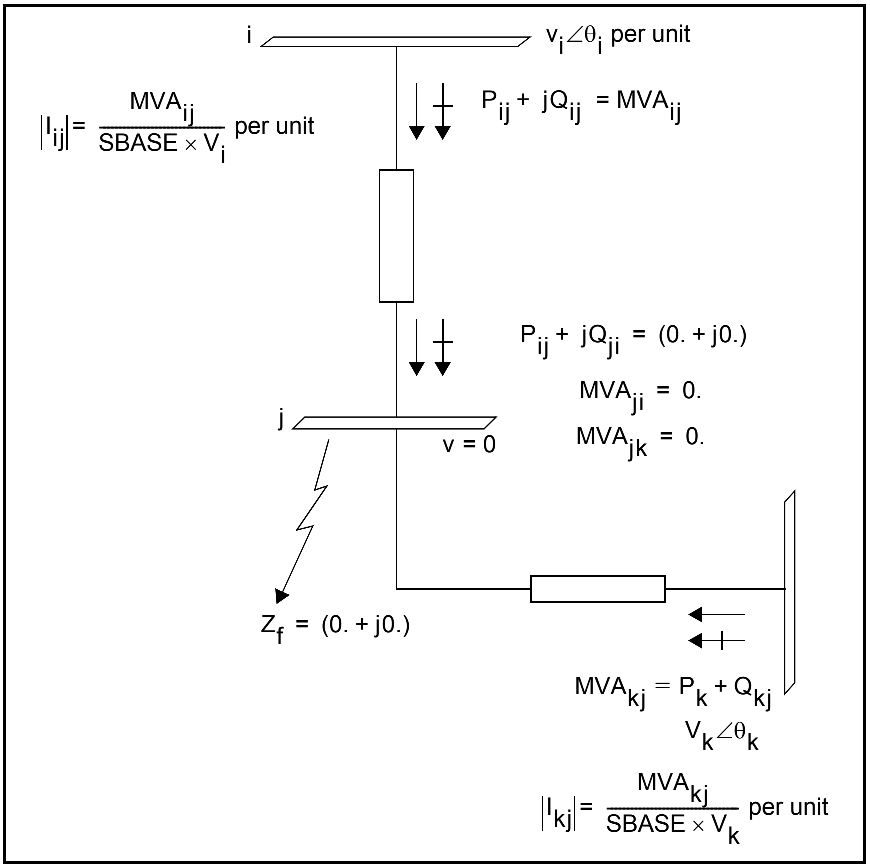


Figure 8-14. Calculation of Branch Currents Flowing into a Bus Faulted through Zero-Impedance

The format of the bus based report will be unchanged except that it will display the net current flowing to ground at any bus whose voltage is below 0.1 per unit. This current value is expressed in terms of fault MVA where

$$\text{FAULT MVA} = \sqrt{3} \times (\text{Base Voltage, kV}) \times (\text{Current, A}) \times 10^{-3}$$

Because the output reports display load flow results, the current flowing in faults and branches must be calculated from the displays of voltage and complex power or MVA flow. Current in amperes is obtained from

$$|\text{Current}| = \frac{\text{MVA flow}}{\sqrt{3} \times (\text{Voltage, kV}) \times (1 \times 10^{-3})} \text{A}$$

Per-unit current is obtained from

$$|\text{Current}| = \frac{\text{MVA flow}}{(\text{System Base MVA}) \times (\text{Voltage, per unit})} \text{ per unit}$$

The calculation of currents flowing into a bus faulted through a zero impedance is illustrated by Figure 8-14. Because the voltage at the faulted bus is zero, the MVA flows into it are zero even though the currents are nonzero. The currents in the branches feeding the fault must be determined from the MVA flows and voltages at the ends that are away from the fault.

Figure 8-15 shows the output report for a fault on bus 3006, in the *savnw.sav* power flow case. Output is for the faulted and two adjacent buses.

```
BUS     153 MID230       230.00 CKT      MW      MVAR      MVA  %I 0.2562PU
                                                                   58.937KV
 TO LOAD-PQ                             34.7     17.3     38.8
 TO LOAD-I                              21.0      0.0     21.0
 TO LOAD-Y                               0.0      3.3      3.3
 TO     152 MID500       500.00  1    -211.4   -466.2    511.8  80 1.0000UN
 TO     154 DOWNTN       230.00  1      60.2    -53.2     80.4 105
 TO     154 DOWNTN       230.00  2      50.2    -44.6     67.1  87
 TO    3006 UPTOWN       230.00  1      45.3    543.3    545.2

BUS    3005 WEST         230.00 CKT      MW      MVAR      MVA  %I 0.3144PU
                                                                   72.309KV
 TO LOAD-PQ                             23.2     11.6     25.9
 TO LOAD-I                              14.1      0.0     14.1
 TO LOAD-Y                               0.0      2.5      2.5
 TO    3003 S. MINE      230.00  1     -54.3   -113.9    126.1
 TO    3003 S. MINE      230.00  2     -54.3   -113.9    126.1
 TO    3004 WEST         500.00  1     -79.4    -87.7    118.4  47 1.0000UN
 TO    3006 UPTOWN       230.00  1      37.9    324.7    326.9
 TO    3008 CATDOG       230.00 &1      74.0     -2.9     74.0
 TO    3008 CATDOG       230.00  1      38.8    -20.5     43.9

BUS    3006 UPTOWN       230.00 CKT      MW      MVAR      MVA  %I 0.0000PU
                                                                    0.0004KV
 TO SHUNT                                0.0      0.0      0.0
 TO     153 MID230       230.00  1       0.0      0.0      0.0
 TO    3005 WEST         230.00  1       0.0      0.0      0.0
 FAULT MVA                              70.9   3165.7   3166.4
```

PU current contribution = MVA / (SBASE x V)

= 326.9 / (100 x 0.3144) = 10.397 pu

Fault MVA = 3166.4 i.e.

fault current = 31.66 pu

Figure 8-15. Bus Based Output for Three-phase Balanced Fault on Bus 3006

Chapter 9

Equivalent (Reduced) Networks

9.1 Overview: Equivalent (Reduced) Networks

An equivalent represents a network, which contains many buses but only a few boundary buses, by a reduced network that contains only the boundary buses and a few of the original buses. Equivalents are used in two circumstances: both to allow larger areas of major interconnected systems to be represented in studies and also to achieve improved computational speed in simulations by removing buses and branches that influence system behavior, but are not of specific interest.

9.1.1 Nomenclature of Equivalents

In discussing the application of equivalents, it is useful to adopt the terminology shown in Table 9-1.

Table 9-1. Terminology for Equivalencing

Study System	A group of buses under detailed study; all components are represented explicitly.
External System	A group of buses and branches that connect to and influence a study system, but do not need to be represented in detail.
Boundary Buses	Buses from which branches run into either a study system and one or more external systems, or into more than one external system.
Source System	A power system representation which contains all components of an external system as a subset of its own components. It is used to solve for the base conditions within the external system. The source system does not need to include the study system, but must recognize flows between the external and study system.
Electrical Equivalent	An artificial group of branches and buses which represents the behavior of the external system as seen from its boundary buses.
Retained Bus	A bus of the external system which is also a bus of the electrical equivalent. A retained bus is not necessarily a boundary bus, but all boundary buses are retained buses.
Deleted Bus	A bus of the external system which is not a bus of the electrical equivalent, but whose effect is represented by the equivalent.
Tie Branch	A branch with one end in one system (study or external) and the other end in a different system.
Area	A group of buses designated in load flow input data for interchange control purposes. An area may, but does not necessarily, coincide with a study or external system.

9.2 Methodology of the Electrical Equivalent

An electrical equivalent is constructed by performing a reduction operation on the admittance matrix of the external system that is to be represented by the equivalent. The admittance matrix equation of the external system may be written in the partitioned form

$$\begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} Y_1 & Y_2 \\ Y_3 & Y_4 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} \tag{9.1}$$

where I_1 and V_1 are node current and voltage at the nodes to be retained and I_2 and V_2 are node current and voltage at the nodes to be deleted.

The desired form of an equivalent is an equation involving only I_1 and V_1 explicitly, with the I_2 and V_2 variables assumed to be linearly dependent upon I_1 and V_1, and recognized implicitly. The equivalent is obtained by rearranging the second row of (9.1) as

$$V_2 = Y_4^{-1}(I_2 - Y_3 V_1) \tag{9.2}$$

and substituting this into the first row of (9.1) to give

$$I_1 = (Y_1 - Y_2 Y_4^{-1} Y_3) V_1 + Y_2 Y_4^{-1} I_2 \tag{9.3}$$

The first term of (9.3) specifies a set of equivalent branches and static shunt elements connecting the retained nodes, while the second term specifies a set of equivalent currents which must be impressed on the retained nodes to reproduce the effect of load currents at the deleted nodes. These equivalent currents may be translated into equivalent constant real and reactive power loads at the retained buses. The equivalent obtained by translating the two terms of (9.3) into equivalent branches, shunts, and loads is exact in the base case for which the current vector, I_2, was calculated. When voltage conditions at the boundary buses are changed, the equivalent gives an approximation to the change in power flow into the external system. This approximation is good as long as the changes are small, but may become unreliable when boundary bus voltages and power flows into the external system (or its equivalent) deviate from the base values by large amounts.

An electrical equivalent is, therefore, correctly applied when it represents an external system in which the disturbances or switching operations under study produce only minor effects; but equivalents should not be applied to network segments in the close vicinity of the disturbances or switchings.

9.3 Defining Boundaries and Boundary Buses

A boundary cuts a set of tie-lines between areas or otherwise identifiable sections of a network but passes through no buses. A boundary bus is part of only one area (see Figure 9-1).

An equivalent makes more efficient use of storage when the ratio of branches to buses in the equivalent is reduced. The relative efficiency of different equivalents of a given system is best determined by trial and error. As a general rule, however, reducing a system into a number of small equivalents is more efficient than reducing of a large system in one step to produce a single equivalent.

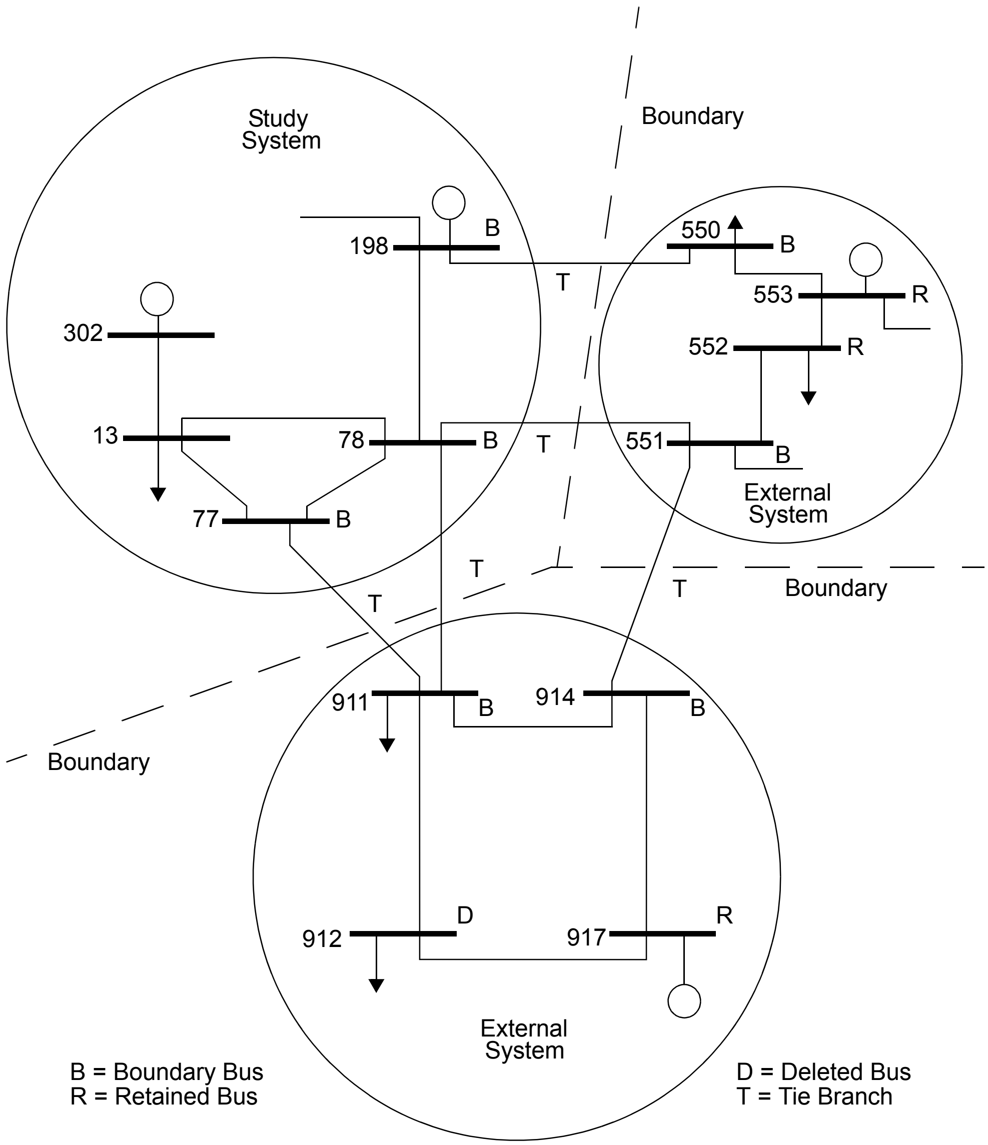


Figure 9-1. Separation of Complete Network into Study System and External Systems by Boundaries

Three special bus type codes are used to designate boundary buses at various stages of the equivalent construction processes:

Type 5	As for Type 1 (load bus); boundary bus or a bus that is not to be deleted by equivalencing, retained bus.
Type 6	As for Type 2 (generator bus); boundary bus.
Type 7	As for Type 3 (swing bus); boundary bus.

It can be seen in Figure 9-1 that the area designated as the "Study System" there are three buses (buses 198,78 and 77) which are the terminals of lines incoming from the other two areas and there are four boundary buses in the external systems. If the external systems bus were to be reduced to an equivalent network, it is possible that boundary 914 could be eliminated. But it would probably be important for the user to retain this bus because of its strategic position in the network. Consequently, it would be important to change the code of this bus, or to retain area boundary buses in the dialog (see Figure 9-2), to represent it as a "boundary" bus to avoid having it deleted.

Several analytical processes of PSS™E change the type codes of boundary buses back and forth between 1, 2, 3 and 5, 6, 7, respectively. The user may also change type codes manually by editing the data in the spreadsheet view.

It is important to note that type codes 5, 6, 7 are valid only during equivalent construction and system data processing operations. Type codes 5, 6, or 7 must be returned to 1, 2, or 3, respectively, before invoking any optimal ordering, factorization, generator or load conversion, or solution processing.

9.4 Handling DC Lines

In PSS™E, the equivalencing process automatically retains converter buses of unblocked DC transmission lines. Hence, all buses that are affected by DC transmission must become part of a study system before commencing the construction of an equivalent.

9.5 Approaching the Network Equivalent Process

The equivalencing process in PSS™E is designed to develop an electrical equivalent of a power flow case or a subsystem of it, as described in Section 9.2, while allowing the user to control which buses, lines, generators and phase-shifters are retained. This global approach is supported with other reduction process which can be useful in making selected "equivalents" of generators, prior to making the global network equivalent, or radial lines.

Additionally, PSS™E provides a process for the construction of network equivalents of the positive and zero sequence networks, and calculates source impedances at equivalent source nodes for all three sequences in preparation for the unbalanced fault analysis activities of PSS™E.

Further, PSS™E provides a boundary bus balance process which converts the mismatch at boundary buses to equivalent load and/or generation. It is intended to be used following the removal of a subsystem from a solved power flow case, with the flows to the deleted subsystem replaced by load and/or generation at those retained buses which were directly connected to the removed subsystem.

All these related processes are accessed by selection of the ***Powerflow>Equivalence networks*** option which will display the Equivalence Networks dialog (see Figure 9-2).

As seen in the figure, there are several tabs each of which is used to initiate the various processes cited above. The following sections will discuss these in turn.

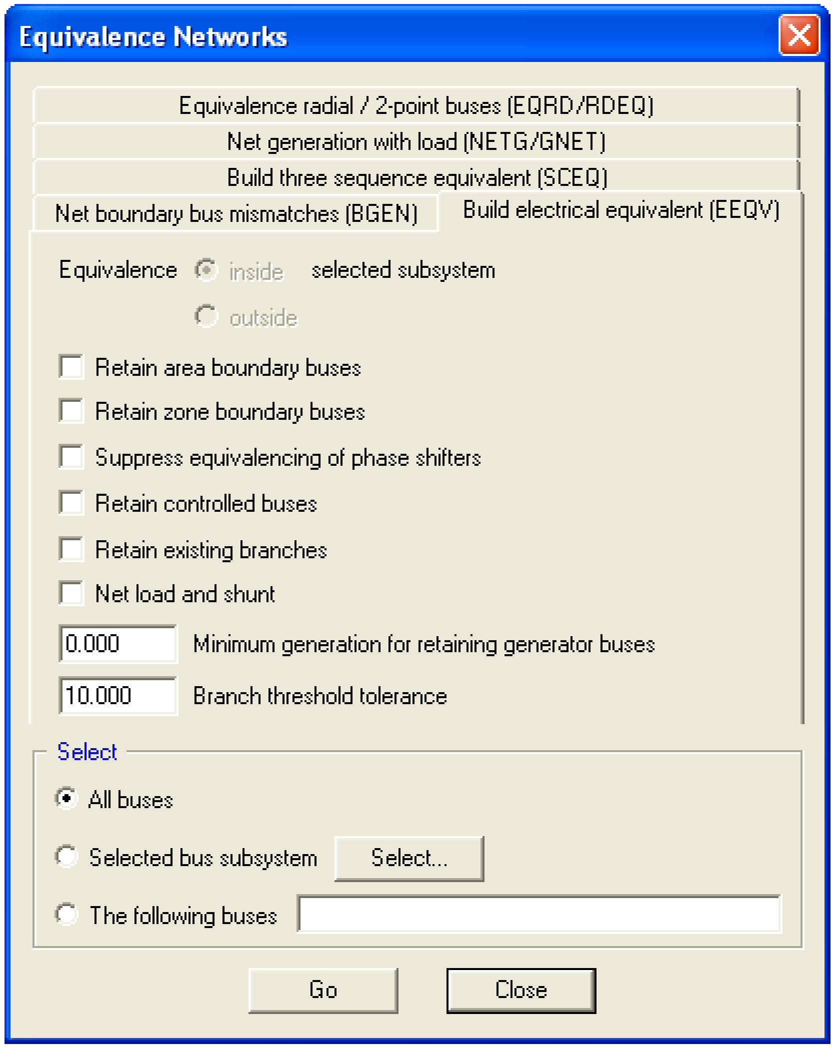


Figure 9-2. Dialog for Equivalencing and Related Processes

9.5.1 Netting Generation with Load

Prior to performing a global network equivalence or when it is required merely to reduce the number of generators modelled in a power flow case, generators can be removed by netting their output with the load at a bus. Generators at all type 2 and 3 buses will be replaced with equivalent negative load with these exceptions:

- Buses that are designated by the user at the start of the activity.
- Buses which are indicated by type codes 6 or 7 to be boundary or retained buses.

When replacing generation with an equivalent load, the power flow solution will remain the same, i.e. re-solving the case after the netting process will not produce a different solution.

The user specifies the manner of selecting buses using the dialog shown in Figure 9-2 with the ***Net generation with load*** tab selected (see Figure 9-3).

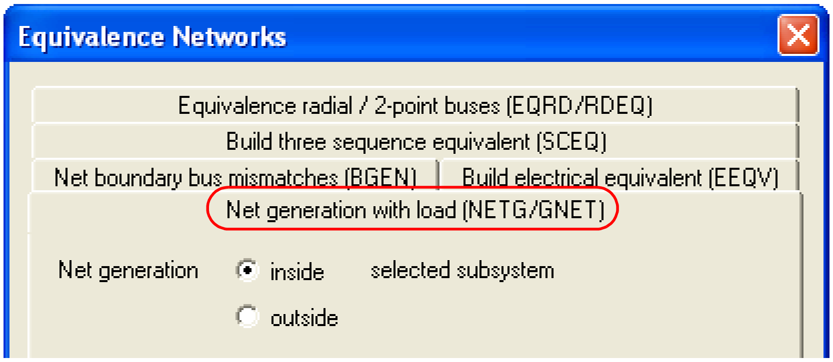


Figure 9-3. Selection for Netting Generation with Load

Not shown in Figure 9-3 is the usual subsystem selector where the user can select generators by Area, Owner, Zone, BasekV or individually. What is different from most of the other subsystem selections is that, for netting generation, the user can choose to identify those generators which **will** be netted (see the "*inside the selected subsystem*" in the figure) or choose to identify those generators which **will not** be netted (see the "*outside*" option).

Following the specification of those buses to be netted, the program processes all type two and three buses specified as follows:

1. The type code is set to one.
2. A new load entry is introduced at the bus.
3. PL of the new load is set to -PG.
4. QL of the new load is set to -QG.

In the *savnw.sav* power flow case there are three areas each of which has two generation buses. Figure 9-4 shows the machine and load data from the spreadsheet. Note that the Load tab data has been compressed to show the Load P and Q.

If the LIGHTCO Area is selected as the subsystem inside of which all generators will be netted, the two generators there, on bus 206 and bus 211 will be netted. In the listing of loads, there will be two new loads each assigned the identifier "99". If a load with the identifier "99" already exists at the bus, an unused two-digit identifier is assigned. The two new loads are shown in the spreadsheet view in Figure 9-5.

Prior to terminating the netting process, PSS™E prints a message in the Output Bar, or destination of the user's choice, stating:

```
GENERATION AT nnnnn BUSES NETTED WITH THEIR LOAD
```

Since only type two and three buses, those generator buses are netted, those which have been designated as "boundary buses," and hence have type codes of six or seven, do not have their generation netted. Further, the netting process is not sensitive to any interrupt control code options.

Generation

Bus Number	Bus Name	Id	In-Service	Pgen (MW)	Pmax (MW)
101	NUC-A 21.600	1	☑	750.0000	810.0001
102	NUC-B 21.600	1	☑	750.0000	810.0001
206	URBGEN 18.000	1	☑	800.0000	900.0000
211	HYDRO_G 20.000	1	☑	600.0000	616.2500
3011	MINE_G 13.800	1	☑	258.6573	900.0000
3018	CATDOG_G 13.80	1	☑	100.0000	117.0000

mpedanc... Inter-area... Loads **Machines** Multi-sect... Mutual C... Ow

Loads

Bus Number	Bus Name	Id	Area Number/Name	Pload (MW)	Qload (Mvar)
153	MID230 230.00	1	1 FLAPCO	200.0000	100.0000
154	DOWNTN 230.00	1	2 LIGHTCO	600.0000	450.0000
154	DOWNTN 230.00	2	2 LIGHTCO	400.0000	350.0000
203	EAST230 230.00	1	2 LIGHTCO	300.0000	150.0000
205	SUB230 230.00	1	2 LIGHTCO	1200.0000	700.0000
3005	WEST 230.00	1	5 WORLD	100.0000	50.0000
3007	RURAL 230.00	1	5 WORLD	200.0000	75.0000
3008	CATDOG 230.00	1	5 WORLD	200.0000	75.0000

... Fixed Sh... Impedanc... Inter-area... **Loads** Machines Multi-sect... Mut

Figure 9-4. Generation and Load in Powerflow Case savnw.sav

Bus Number	Bus Name	Id	Area Number/Name	Pload (MW)	Qload (Mvar)
153	MID230 230.00	1	1 FLAPCO	200.0000	100.0000
154	DOWNTN 230.00	1	2 LIGHTCO	600.0000	450.0000
154	DOWNTN 230.00	2	2 LIGHTCO	400.0000	350.0000
203	EAST230 230.00	1	2 LIGHTCO	300.0000	150.0000
205	SUB230 230.00	1	2 LIGHTCO	1200.0000	700.0000
206	URBGEN 18.000	99	2 LIGHTCO	-800.0000	-600.0000
211	HYDRO_G 20.000	99	2 LIGHTCO	-600.0000	-17.7473
3005	WEST 230.00	1	5 WORLD	100.0000	50.0000
3007	RURAL 230.00	1	5 WORLD	200.0000	75.0000
3008	CATDOG 230.00	1	5 WORLD	200.0000	75.0000

... Fixed Sh... Impedanc... Inter-area... **Loads** Machines Multi-sect... Mut

New loads representing Generation at Bus 206
and Bus 211

Figure 9-5. Result of Netting Generation in the LIGHTCO Area

9.5.2 Equivalencing Radial and Two-Point Type Buses

PSS™E has the facility to equivalence radial buses and, optionally, "two point" type one buses in all but specified subsystems of the power flow case. Two-point buses are those connected to only two other buses.

If sequence data is contained in the working case, the zero sequence network is equivalenced along with the positive sequence.

The radial equivalent process determines the buses to be equivalenced based upon their current electrical connections. Suppose, for example, that bus "I" is a type one bus connected to two other buses by in-service branches and that there is an out-of-service branch from bus "I" to a third bus. Assuming that bus "I" is not in the subsystem to be exempted from equivalencing and that the "two point" bus equivalencing option was enabled, bus "I" will be equivalenced.

It is neither necessary nor helpful to perform equivalencing of radial or "two-point" buses prior to performing a global equivalence of a network or subsystem.

Buses which are always retained by this radial/two-point option are those:

- Connected by three-winding transformers
- Converter station buses of DC lines
- With FACTS devices connected to them are always retained.

Whenever a two point bus and its connected branches are equivalenced, the resulting equivalent branch is assigned the smaller RATEA, RATEB, and RATEC of the connected branches. If load existed at the two-point bus, the ratings of the equivalent branch should be checked.

Whenever a two-point bus and its connected branches are equivalenced, the length assigned to the equivalent branch is the sum of the lengths of the equivalent paths. If parallel branches existed between a retained bus and the equivalenced bus, the length of that path is assumed to be the length of the longest of the parallel branches.

Equivalent branches, introduced by the radial equivalencing process, are assigned the circuit identifier "99". Equivalent branches between the same pair of buses have descending circuit identifiers assigned starting at "99".

Equivalent loads introduced by the radial equivalencing process, are assigned the load identifier "99". If a load with the identifier "99" already exists at a retained bus, the process adds any equivalent load to the load already modeled as load "99". If such a load is associated with an adjustable bus load table for which the load multiplier is zero, a mismatch is introduced at the corresponding retained bus.

The user specifies the requirements for performing the radial equivalent using the dialog shown in Figure 9-2 with the ***Equivalence radial / 2-point buses*** tab selected (see Figure 9-6).

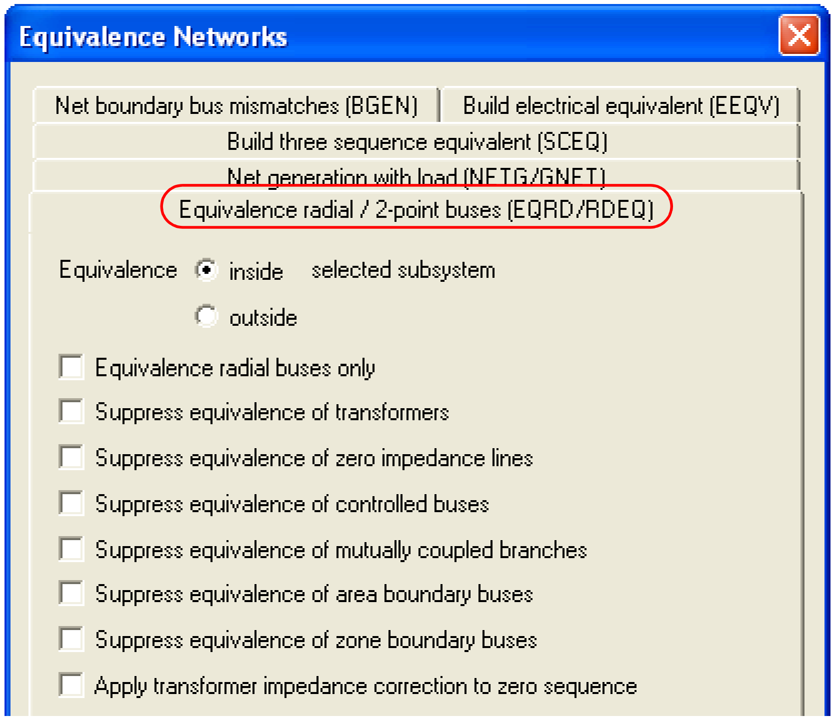


Figure 9-6. Dialog for Radial and 2-Point Bus Equivalencing

Not shown in Figure 9-6 is the usual subsystem selector where the user can select buses by Area, Owner, Zone, BasekV or individually. As in netting generation, the user can choose to identify those buses which **will** be equivalenced (*see the "inside the selected subsystem*" in the figure) or choose to identify those buses which **will not** be equivalenced (see the "*outside"* option).

Following the selection of equivalencing "inside" or "outside" the selected subsystem, the user has other options.

Equivalence radial buses only: The user will check this to limit equivalencing to only radial buses, otherwise both radial buses and those buses connected to only two other buses are to be eliminated.

Suppress equivalence of transformers: The user will check this to exclude transformer branches from the equivalencing process.

Suppress equivalence of zero impedance lines: If the working case contains any branches that are treated as zero impedance lines, this can be checked to exempt from equivalencing buses connected by such lines.

Suppress equivalence of controlled buses: This would be checked to suppress the equivalencing of buses whose voltage or reactive power output is controlled by remote generation, switched shunts, and/or VSC DC line converters.

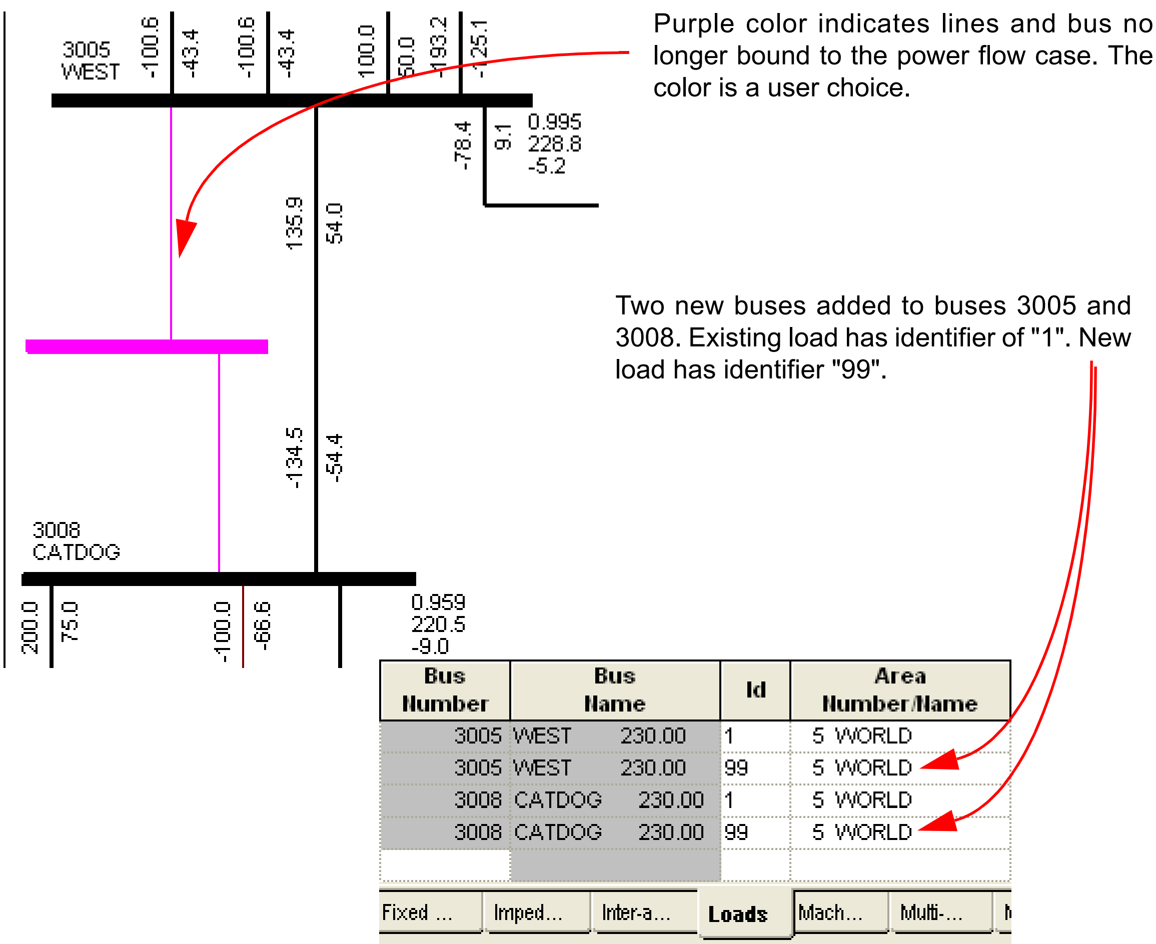
Suppress equivalence of mutually coupled branches: If sequence data is contained in the working case and zero sequence mutual couplings have been specified, the user can check this to exempt from equivalencing any branch (and the buses it connects) involved in such a coupling.

Suppress equivalence of area or zone boundary buses: Checking these will keep area and zone boundaries intact.

Apply transformer impedance correction to zero sequence: If the actual positive sequence impedance of any transformer being equivalenced differs from its nominal value, the user can elect to specify the treatment of the zero sequence impedance of all such transformers: If this option is checked, all zero sequence transformer impedances are left at their nominal values (i.e., the values input to the power flow case). Alternatively, the zero sequence impedance of each such transformer is scaled by the same factor as is its positive sequence impedance. The same treatment applies to *all* transformers to be equivalenced.

Once the user has selected the output device, and completed the selections, all that is required is to click the ***Go*** button in the dialog to initiate the equivalencing process.

Using the *savnw.sav* power flow case, and selecting to equivalence only radial buses, with all other options suppressed, will result in the removal of one radial bus (bus 3007). The load on that bus is moved to the neighboring buses 3005 and 3008 (see Figure 9-7).



Bus Number	Bus Name	Id	Area Number/Name
3005	WEST 230.00	1	5 WORLD
3005	WEST 230.00	99	5 WORLD
3008	CATDOG 230.00	1	5 WORLD
3008	CATDOG 230.00	99	5 WORLD

Figure 9-7. Result of Radial Equivalencing

9.6 Creating a Network Equivalent

PSS™E provides the user with the capability to construct an electrical equivalent of all or a subsystem of the network in the currently open power flow case. The case must be solved to an acceptable mismatch level. The output of the construction process is a case with part or all of the original network model replaced by an equivalent representation.

The primary purpose in constructing equivalents is to represent a portion of a network containing many buses but having only a few "boundary buses" by a reduced network containing only the boundary buses and, perhaps, a few selected buses from within the original subnetwork. Historically, equivalents have often been used to allow the representation of larger areas of major interconnected systems in studies using computer programs which, due to restrictions imposed by the computing hardware, were of limited dimensional capacity. Advances in computer technology, particularly in the area of memory address capability, have lifted these restrictions to the extent that network modeling capacity is usually no longer an issue. The primary application of equivalents in modern engineering computers is to achieve improved computational speed in simulations by removing buses and branches that are not of specific interest but which do influence system behavior.

The equivalent constructed by PSS™E is exact in the base case from which it was calculated. It gives an exact reproduction of the self and transfer impedances of the external system as seen from its boundary buses. The net total of load, generation, and losses in the equivalent matches this total in the complete external system if the bus voltages in the working case were a valid power flow solution. However, the load, generation, and loss totals in the equivalent may not individually match those of the complete external system.

When voltage conditions at the boundary buses of the study system are changed, the equivalent gives an approximation to the change in power flow into the external system. This approximation is good as long as the changes are small, but may become unreliable when boundary bus voltages and power flows into the external system (or its equivalent) deviate from the base values by large amounts.

An electrical equivalent is, therefore, correctly applied when it represents an external system in which disturbances or switching operations under study produce only minor effects. Equivalents should not be applied to network segments in the close vicinity of the disturbances or switchings.

9.6.1 Selecting Network Equivalent Options

The user specifies the requirements for performing the radial equivalent using the dialog shown in Figure 9-2 with the ***Build electrical equivalent*** tab selected (see Figure 9-8). Note that the subsystem selector is not shown in the figure. There the user starts by identifying the buses to be equivalenced by Area, Owner, Zone, BasekV or individually.

Following the selection of equivalencing "inside" or "outside" the selected subsystem, the user specifies the following options and parameters:

> **Retain area boundary buses:** Checking this box will keep area boundaries intact.
>
> **Retain zone boundary buses:** Checking this box will keep zone boundaries intact.
>
> **Suppress equivalencing of phase shifters:** Checking this box will suppress the equivalencing of any two-winding transformers with a nonzero phase shift angle which are present in the subsystem to be equivalenced.

If the user elects to retain two-winding transformer phase shifters, the retention of the buses involved is forced by changing their type codes from one, two, or three to five, six, or seven, respectively. Thus, the phase shifter and the buses it connects are all explicitly retained in the equivalent.

If the user chooses to equivalence two-winding transformer phase shifters, the phase shift angle is reset to zero degrees. Additionally, an equivalent MVA load at the buses connected by the phase shifter is introduced such that an electrical balance is retained. The phase shifter is then treated like any other transformer.

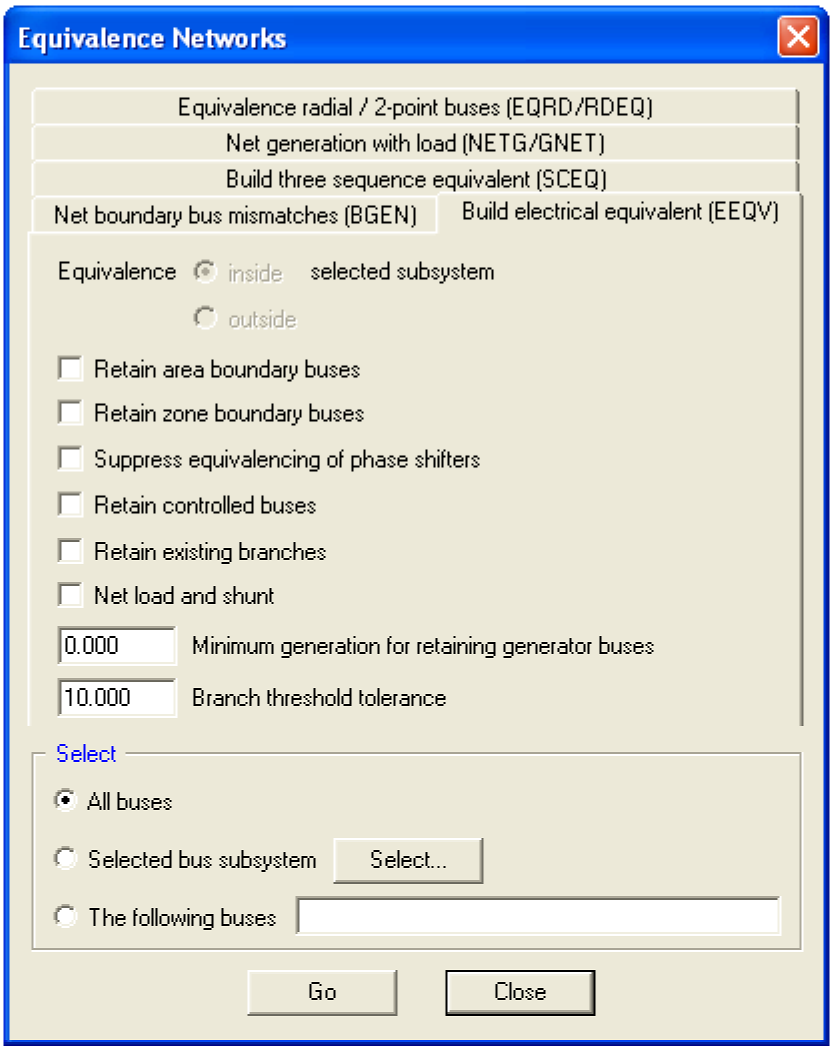


Figure 9-8. Dialog for Building Electrical Equivalent

Retain controlled buses: Checking this box will suppress the equivalencing of buses whose voltage or reactive power output is controlled by remote generation, switched shunts, and/or VSC DC line converters.

Retain existing branches: Checking this box will force the retention of the identity of all non transformer branches and two-winding transformers in the power flow case connecting buses to be retained in the equivalent. If this option is selected, the equivalent may contain an additional equivalent branch in parallel with any real branches between any such pair of buses; if this option is not selected, the equivalent branch between any such pair of buses represents the single circuit equivalent of all real branches between the buses and (possibly) an equivalent branch.

Net load and shunt: Checking this box will result in netting the total equivalent load and shunt at retained buses such that occurrences of load and shunt which "cancel out" at a bus (e.g., positive load and negative shunts) are eliminated. The component of smaller magnitude is set to zero with the other component set to the netted quantity. Active and reactive components at each retained bus are processed independently. If this option is not selected, the equivalent load and shunt components at retained buses remain as calculated by the equivalent construction matrix reduction process

Minimum generation for retaining generator buses: The user sets the positive threshold below which type two buses will have their generation netted with the bus load and its type code changed to one. This does not apply to boundary type two buses or area swing buses. Both active and reactive power generation magnitudes must be below the threshold. If the threshold specified is zero, all type two generator buses in the subsystem being equivalenced are retained.

Branch threshold tolerance: The user selects this impedance tolerance above which any equivalent branch, which is created by the equivalencing process, whose magnitude of impedance is greater than this tolerance is not retained in the equivalent. The default value is 10 per unit.

Once the selections are made, the user clicks the ***Go*** button and the equivalent is constructed. This process is not sensitive to any interrupt control code options.

9.6.2 Constructing the Network Equivalent

The task of constructing and using an electrical equivalent can be separated into three steps:

1. Isolating an external system in the working case. The process temporarily discards from the open power flow case all other subsystems (study and external) contained in the source system except the one to be equivalenced. Boundary and retained buses are identified and, if desired, selected generators are replaced by negative load.

2. Constructing the electrical equivalent by performing the required matrix reduction operation on the external system remaining in the working case.

3. Combining system sections together to form a valid system model in the working case. In this step, detailed representations of selected external systems are replaced with their electrical equivalents.

Electrical equivalents are constructed on the following basis:

Bus Type Code	Treatment By Activity EEQV
1	Bus eliminated.
2 and 3	Bus retained.
4	Bus ignored in the computation and not included in the equivalent.
5, 6, and 7	Bus retained in the equivalent with four subtracted from its bus type code.

That is, it constructs an equivalent of a subsystem of the working case with its interior type one buses eliminated. The equivalent construction process automates many of the data handling tasks required in preparation for, and following the execution of, the equivalent construction calculation. It may be used whenever the entire solved source system is able to be opened in PSS™E.

The equivalent constructed resides along with the unequivalenced portions of the system in the same form as an unequivalenced power flow case. There are normally no operations required to combine system sections.

Only the positive sequence network is processed. If sequence data is included in the working case, the following message is printed when initiating the process and processing continues:

```
WARNING: SEQUENCE DATA WILL NOT BE EQUIVALENCED
```

The pre-equivalenced power flow case must represent a solved system condition.

In constructing the equivalent, all nonboundary type one buses in the designated external system are eliminated, and all type five, six, and seven buses are retained as type one, two, and three buses, respectively. Normally, the boundary buses from within the subsystem being equivalenced are those connected to buses outside of the specified subsystem. However, when the subsystem to be equivalenced is specified by bus only, type one and netted type two buses specified are equivalenced, with the boundary buses being those buses to which they are connected and that are not among those specified.

When three or more buses are all connected together by zero impedance lines, either all may be equivalenced, all may be retained, or one may be retained. If the bus type codes are such that more than one but not all the buses in such a group of buses are to be retained, an appropriate message is printed and all buses in the group are retained.

Three-winding transformers are handled as follows:

- If all three buses connected by an in-service three-winding transformer are to be retained, the transformer is explicitly retained.
- If at least one of the three buses connected by an in-service three-winding transformer is to be equivalenced, the transformer is equivalenced.
- Out-of-service three-winding transformers are ignored in constructing the equivalent and are omitted from the equivalent.

The converter buses of unblocked DC lines, the sending and terminal end buses of in-service FACTS devices, and buses connected to terminal end buses of in-service FACTS devices are automatically retained.

For any bus whose voltage is being controlled by a remote generator, switched shunt, or VSC DC line converter, an alarm is printed if the controlled bus is equivalenced while the voltage controlling equipment is retained. The controlling equipment is then set to control local bus voltage and the scheduled voltage setpoint or band is not changed.

For any bus with voltage controlling equipment which is being controlled by a remote switched shunt, an alarm is printed if the controlled bus is equivalenced while the controlling switched shunt bus is retained. The switched shunt's control mode is *not* changed.

Equivalent branches created by the equivalencing process are assigned the circuit identifier "99". Equivalent loads are assigned the load identifier "99". If a load with the identifier "99" already exists at a retained bus, the process adds any equivalent load to the load already modeled as load "99".

If such a load is associated with an adjustable bus load table for which the load multiplier is zero, a mismatch is introduced at the corresponding retained bus.

9.6.3 Equivalencing a Power Flow Case

In the *savnw.sav* power flow case there are three areas; FLAPCO, LIGHTCO and WORLD. The WORLD area, which will be replaced by its equivalence network has 10 buses, three of which are load buses and three ties to neighboring areas. As seen in Figure 9-9, the eleven buses are from bus 3001 to bus 3018. The load buses are 3005, 3007 and 3008. The ties are between buses 3004, 3006 and 3008 to buses 152, 153 and 154 in adjacent areas respectively.

```
3001,'MINE    ', 230.0000,1
3002,'E. MINE ', 500.0000,1
3003,'S. MINE ', 230.0000,1
3004,'WEST    ', 500.0000,1
3005,'WEST    ', 230.0000,1
3006,'UPTOWN  ', 230.0000,1
3007,'RURAL   ', 230.0000,1
3008,'CATDOG  ', 230.0000,1
3011,'MINE_G  ',  13.8000,3
3018,'CATDOG_G',  13.8000,2
```

(a) WORLD Buses

```
3005,'1 ',1,   5,   5,   100.000,    50.000
3007,'1 ',1,   5,   5,   200.000,    75.000
3008,'1 ',1,   5,   5,   200.000,    75.000
```

(b) WORLD Load Buses

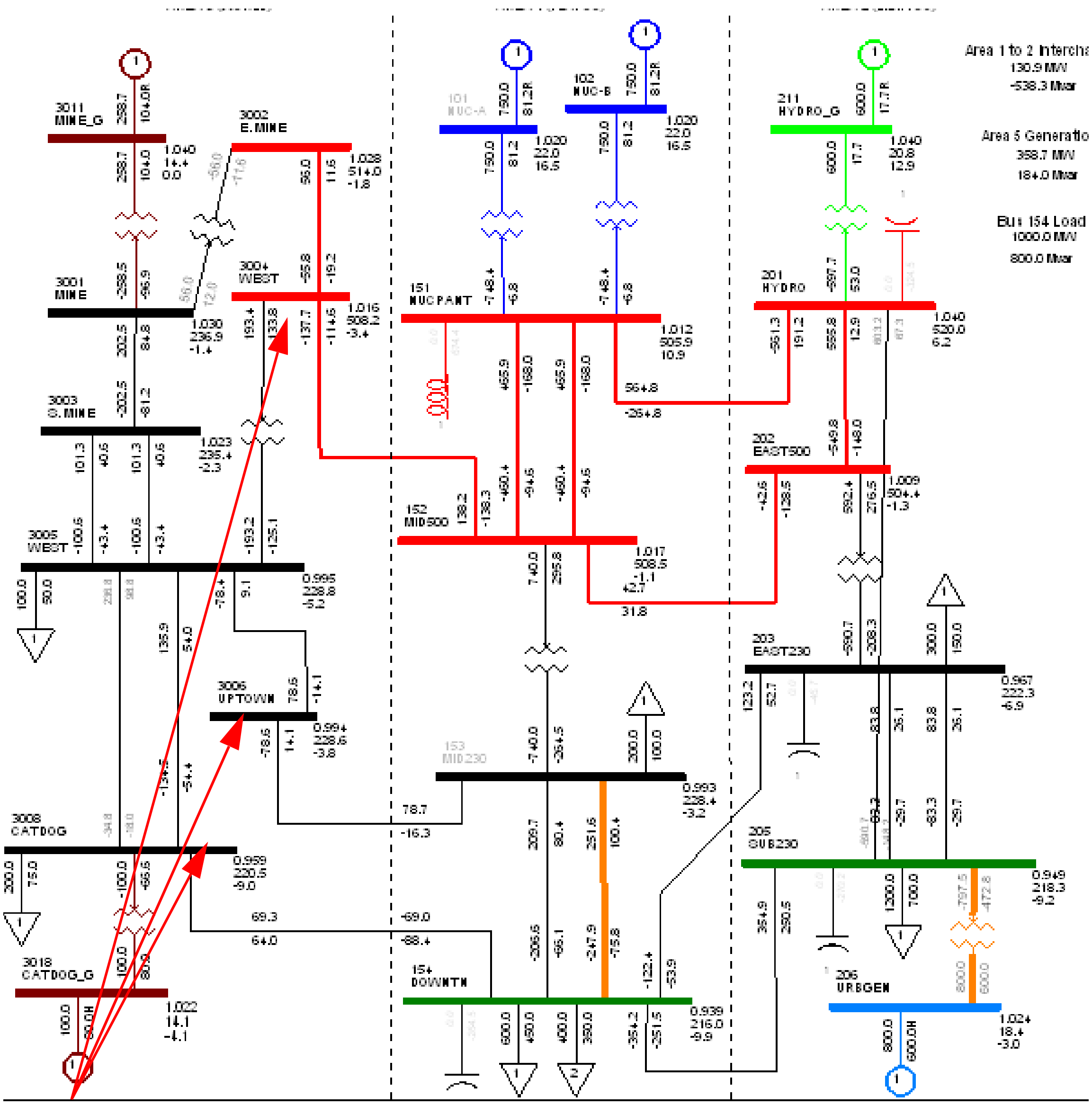
```
 152,   3004,'1
 153,    154,'1
 153,    154,'2
 153,   3006,'1
 154,    203,'1
 154,    205,'1
 154,   3008,'1
 201,    202,'1
 201,    204,'1
 203,   -205,'1
 203,   -205,'2
3001,   3003,'1
3002,   3004,'1
3003,   3005,'1
3003,   3005,'2
3005,   3006,'1
3005,   3007,'1
3005,   3008,'1
3007,   3008,'1
```

(c) Ties and WORLD Area Lines

Figure 9-9. Components of the WORLD Area in the savnw.sav Powerflow Case

There are also several two-winding transformers in the WORLD area along with generators at buses 3011 and 3018. A plot of the area is shown in Figure 9-10.

It is to be expected that the result of creating an equivalent of the WORLD area would be to leave the two generator buses intact, (unless the threshold for retaining generation is chosen to be greater that their generation) and leave the boundary buses 3004, 3006 and 3008 intact. This will result in the removal of 5 of the 10 buses. In this example, area boundary buses are retained and the generation threshold is 0.00.



WORLD Area Boundary Buses

Figure 9-10. Pre-Equivalence Powerflow Diagram for the WORLD Area

Following the equivalencing of the WORLD area, the raw data will now appear as shown in Figure 9-11.

It can be seen that the total load of 500 MW in the WORLD area has been retained but allocated to the retained buses 3004, 3006, 3008 and 3011 with an identifier of "99". Note that bus 3008 already had a load of 200 MW with an identifier of "1".

The buses at the boundaries have been maintained but now the number of buses is reduced to five.

There are now 6 new branches with in the WORLD area each with a circuit identifier of "99".

```
3004,'WEST        ', 500.0000,1
3006,'UPTOWN      ', 230.0000,1
3008,'CATDOG      ', 230.0000,1
3011,'MINE_G      ',  13.8000,3
3018,'CATDOG_G    ',  13.8000,2
```

(a) Remaining World Area buses

```
3004,'99',1,   5,   5,    82.803,     25.971
3006,'99',1,   5,   5,    43.244,      9.177
3008,'1 ',1,   5,   5,   200.000,     75.000
3008,'99',1,   5,   5,   148.157,     39.146
3011,'99',1,   5,   5,    25.901,      2.971
```

(b) Original and New WORLD Area Load buses

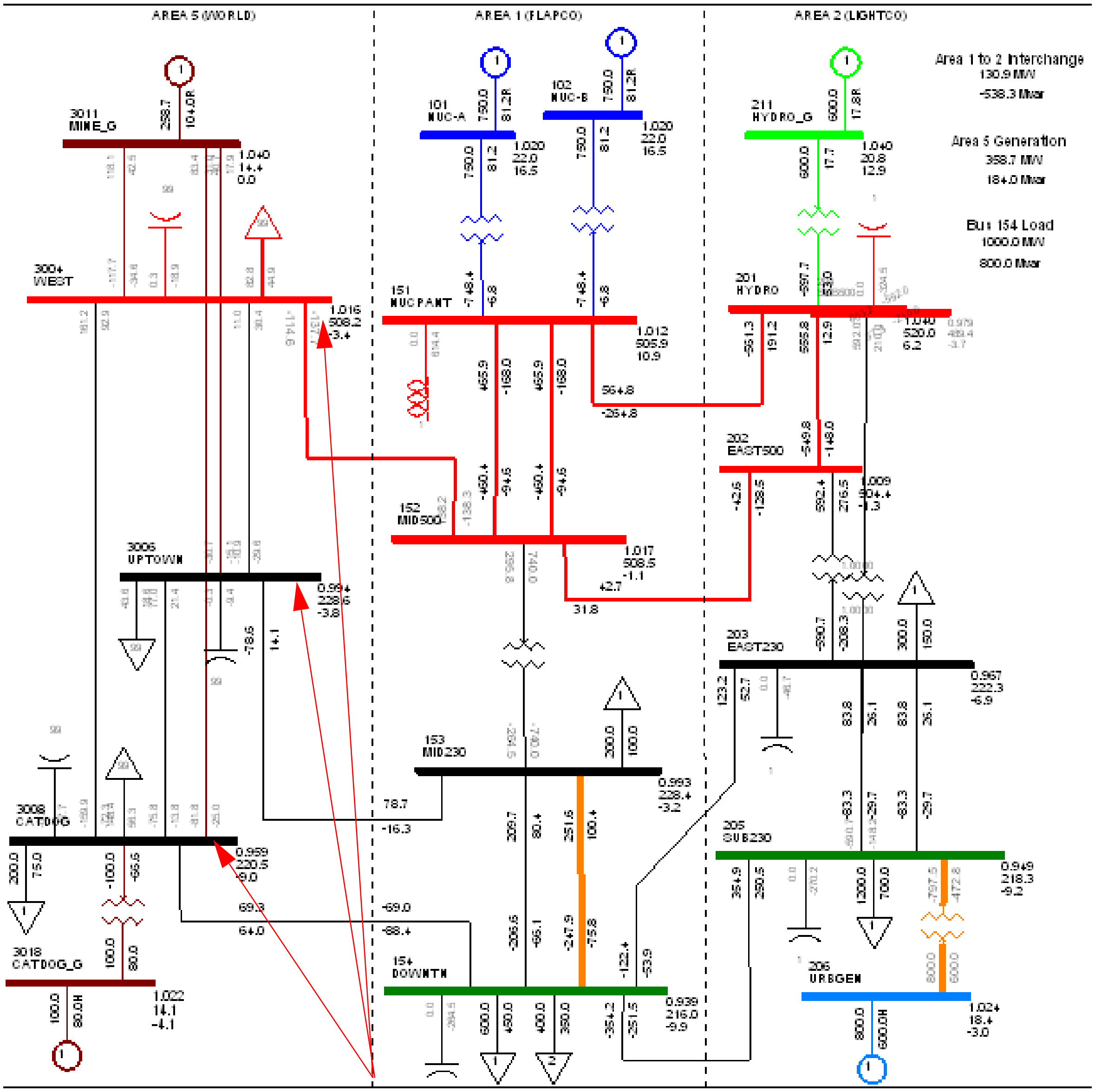
```
 152,    3004,'1
 153,     154,'1
 153,     154,'2
 153,    3006,'1
 154,     203,'1
 154,     205,'1
 154,    3008,'1
 201,     202,'1
 201,     204,'1
 203,    -205,'1
 203,    -205,'2
3004,    3006,'99
3004,    3008,'99
3004,    3011,'99
3006,    3008,'99
3006,    3011,'99
3008,    3011,'99
```

(c) Retained Ties and Reduced Area Lines in WORLD Area

Figure 9-11. Reduced Components of the WORLD Area after Equivalencing

It should be noted that the slider file (*savnw.sld*) which was used to create the plotted results in Figure 9-10 will not suffice for the new power flow with the WORLD area equivalenced. Five of the buses have been removed and new branches have been created. The user's selected color coding for the diagram properties will indicate that the buses and branches are "unbound", i.e., do not exist in the power flow case. This is because the slider file no longer matches the network. A new or modified slider file will have to be produced.

Figure 9-12 shows the redrawn slider file presentation with the new branches and loads indicated. Comparing this diagram with that of Figure 9-10 will clarify the changes in topology due to the changes brought about by the equivalencing process.



Boundary buses

Figure 9-12. Redrawn One-Line Diagram to Match Topology after Equivalencing

9.6.4 Application Notes for Network Equivalents

This section summarizes some general points regarding equivalencing and some potential pitfalls to watch for.

The goal in equivalent construction is to generate efficient equivalents. An equivalent may be regarded as making more efficient use of storage, and therefore improving computational speed of solution of the network containing the equivalent, when the ratio of branches to buses in the equivalent approaches that of real system (about 1.5). The relative efficiency of different equivalents of a given system is best determined by trial and error. As a general rule, however, the reduction of a group of external systems into a number of small equivalents is more efficient than their reduction in one step to produce a single equivalent.

It is not advisable to net all generation in an external system when constructing an equivalent in which more than a very few buses are to be retained. Type two buses have a generally beneficial effect on the convergence of power flow iterations and excessive netting of generation removes this effect from the composite power flow case when the equivalent is finally put to use. It is generally advisable to retain some major generator and synchronous condenser buses and to net the small generators that do not contribute strongly to the regulation of system voltage.

When generator netting has taken place in constructing equivalents, it is advisable to check for the existence of a swing (type three) bus in the working case at the completion of the equivalencing calculation. Use the ***Powerflow>Check data>Buses not in swing bus tree (TREE)*** option.

Bus type codes of five, six, and seven are valid only during equivalent construction. All such type codes are returned to one, two, and three, respectively, when the equivalencing process is complete.

The values of load and shunt admittance at each retained bus in the equivalent represent both actual and equivalent quantities at these buses. Changing these values invalidates the equivalent. Similarly, changing the status of any branches in the equivalent invalidates it.

A power flow case containing elements introduced via an equivalent is identical in form to a power flow case containing only real system elements and may be operated on by all PSS™E analytical processes. It is permissible to construct an equivalent of an external system which contains an equivalent.

9.7 Working with Boundary Bus Mismatches

Whenever a subsystem is removed from a solved power flow case, there will be mismatches at those buses which are boundary buses. PSS™E facilitates the establishment of a boundary bus balance by converting the mismatches at boundary buses to equivalent load and/or generation. The original flows to and from the deleted subsystem are replaced by load and/or generation at those retained buses which were directly connected to the removed subsystem.

The user specifies the requirements for performing the mismatch netting using the dialog shown in Figure 9-2 with the ***Net boundary bus mismatches*** tab selected (see Figure 9-13). Note that the subsystem selector is not shown in the figure. There, the user starts by identifying the buses to have their mismatch netted by Area, Owner, Zone, BasekV or individually.

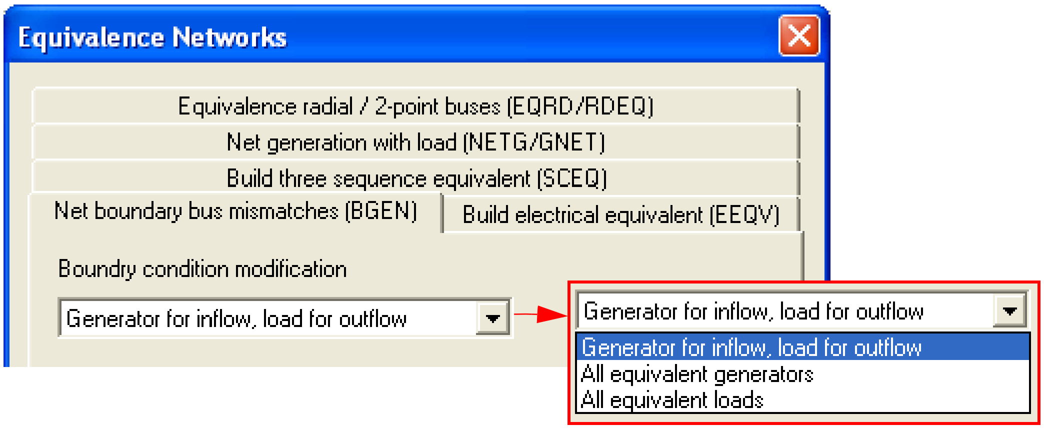


Figure 9-13. Net Boundary Bus Mismatches Dialog and Modification Options

All load and generator additions, implemented by the netting process, are tabulated at the selected output device. The user should first select the destination; preferably a file.

In Figure 9-13, there are three options for the type of boundary condition modifications to be used:

- Model the inflow of power to the retained area as a generator and the outflow of power as a load. A a new machine is introduced at any boundary bus at which there was a net inflow of active power from the removed subsystem into the retained subsystem; at boundary buses where there was a net outflow of active power, a new load is introduced.
- Independent of the power flow at the boundary a new machine is introduced at each boundary bus.
- Independent of the power flow at the boundary a new load is introduced at each boundary bus.

When the user has selected the modification method and the subsystem to be treated, all that is necessary is to click the ***Go*** button.

The selected buses are checked in ascending order of Area, Owner or Zone and in ascending order of buses (numeric or alphabetical, depending on the current option) specified by user input. When a bus has a mismatch in excess of 0.5 MVA, it is assumed to be a boundary bus and a new load or machine, as selected above, is introduced.

Boundary buses are reported in ascending bus number order (under the "numbers" output option) or alphabetical order (under the "names" output option).

When the netting process is complete, the user has given the opportunity to specify an additional group of buses.

When a new machine is introduced at a bus, it is assigned the machine identifier "99". If a machine "99" already exists at the bus, an unused two-digit identifier is used.

When a new load is introduced at a bus, the load is assigned the identifier "99". If a load with the identifier "99" already exists at the bus, an unused two-digit identifier is assigned.

The processing may be terminated by entering the AB interrupt control code.

9.8 Creating Short Circuit Equivalents

While network reduction for fault analysis work could be handled with the standard equivalent handling activities covered in the previous sections, PSS™E provides the user with a superior process for creating short-circuit equivalents which is designed specifically for fault analysis applications.

This process applies all of its operations to all three sequences in parallel, using the same topological boundary definitions for each, as shown in Figure 9-14. This process handles all steps of the equivalencing process automatically so that its single execution, in effect, accomplishes the following tasks:

- Separates the external system in the power flow case.
- Builds an equivalent.
- Replaces the detailed external system model with the equivalent.
- Rejoins the study system onto the equivalent.

A single step in the process replaces the full system model in the power flow case with a reduced model consisting of detailed study system and equivalenced external system. The boundary buses of the external system are retained so that tie branches appear as real system elements in the reduced system model.

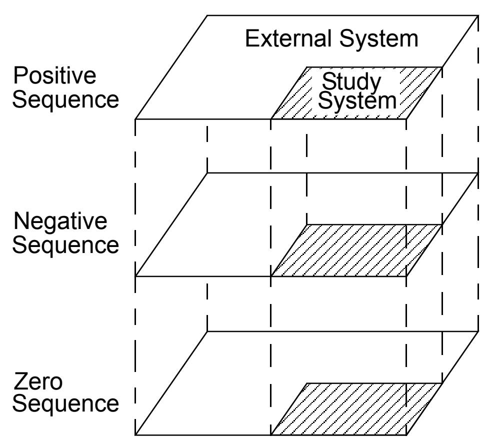


Figure 9-14. Pictorial Image of Powerflow Case with Equivalenced Sequence Networks

The short-circuit equivalencing process performs a simple network reduction without regard to loads, transformer phase shift, or pre-event voltages. All generators in the external system are represented by simple Norton equivalents so that their effective impedances (i.e., Norton shunt admittances) and positive-sequence source currents can be transferred to the boundary buses by standard network mathematics. The process operates on a standard fault analysis model set up in accordance with Section 7.2, but with FLAT pre-event voltages.

The network reduction is performed by setting up the partitioned admittance matrix of the external system:

$$\begin{bmatrix} I_b \\ I_n \end{bmatrix} = \begin{bmatrix} Y_{bb} & Y_{bn} \\ Y_{nb} & Y_{nn} \end{bmatrix} \begin{bmatrix} V_b \\ V_n \end{bmatrix} \tag{9.4}$$

where:

b	Denotes boundary buses.
n	Denotes buses to be deleted.
I_b, I_n	Contains either zero or generator Norton source current as calculated the generator conversion process.

The generator internal impedances, Z_{pos}, Z_{neg}, Z_{zero}, where appropriate, are included in the network as shunt elements and are accounted for by the diagonal terms of the admittance matrix. The positive-sequence source currents are taken as ISORCE = (1./Z_{pos}). The admittance matrix and equivalent source currents of reduced network are then obtained from the elimination formula:

$$(I_b - Y_{bn}Y_{nn}^{-1}I_n) = (Y_{bb} - Y_{bn}Y_{nn}^{-1}Y_{nb})V_b \tag{9.5}$$

After calculating these matrix equivalent of the reduced network, the short-circuit equivalencing process automatically deletes the true data for the external system from the working case and replaces it with data for the equivalent network. This equivalent network comprises:

- Branches with series impedance but no charging capacitance or shunts, and with circuit number 99.
- Equivalent generators with rating equal to system MVA base and a nonzero positive-sequence source impedance.
- Negative- and zero-sequence source impedance for each equivalent generator.
- Positive-, negative-, and zero-sequence equivalent shunts.

This equivalent can have an equivalent generator at every boundary bus. As indicated by the left-hand side of (9.5) the source currents of these generators are the compendium of source current of any real generators at the boundary bus plus equivalent source currents representing the effect of generators at deleted buses. The short-circuit equivalencing process replaces all real generators at each boundary bus with a single equivalent generator and identifies it as such by assigning it machine number 9. It also assigns the circuit number 99 to all equivalent branches.

All shunt admittances (charging, reactors, capacitors, etc.) arising in the equivalent, except the generator Norton admittances, are collected together and included in the equivalent as a single shunt admittance at each boundary bus. These shunts and the generator Norton admittances are always connected as shunts to ground when the equivalent is used within PSS™E.

The form of the equivalent is illustrated in Figure 9-15. Each sequence equivalent is contained in the working case as fault analysis data for equivalent branches and generators. Each equivalent is joined by real tie branches to the study system, which remains in the working case, completely unaltered.

The generator positive- and negative-sequence source impedances in the power flow case need not be identical. If they are different, the positive-sequence and negative-sequence reduced admittance matrices will be different. The standard PSS™E negative-sequence model format recognizes differences between positive and negative sequence only in the generator source impedances, Z_{pos} and Z_{neg}.

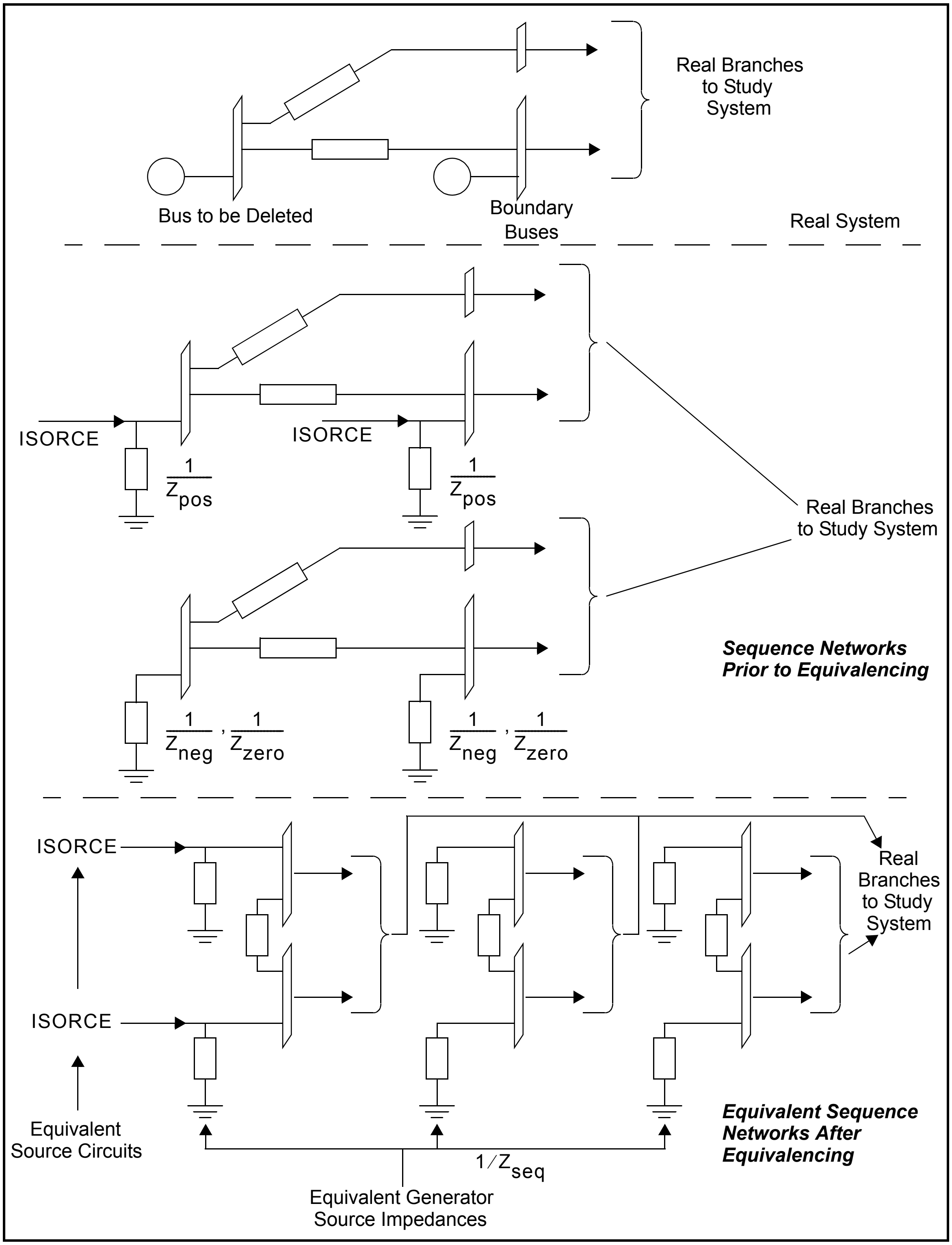


Figure 9-15. Form of Sequence Equivalents Built the Short-Circuit Equivalencing Process

Hence when the short-circuit equivalencing process encounters a negative-sequence equivalent branch impedance different from the corresponding positive-sequence value, it ignores it and uses the positive-sequence value in both sequences. An alarm messages is given whenever the positive and negative-sequence branch impedances differ by more than 5%. This approximation in the reduction and equivalencing of the negative sequence occurs only when generator Z_{pos} and Z_{neg} values are different and is rarely a significant influence on the accuracy of the equivalent.

9.8.1 Preparing for the Short Circuit Equivalent

The user specifies the requirements for making a short-circuit equivalent using the dialog shown in Figure 9-2 with the ***Build three sequence equivalent*** tab selected (see Figure 9-16). Note that the subsystem selector is not shown in the figure. There the user starts by identifying the buses or subsystem to be equivalenced by Area, Owner, Zone, BasekV or by individual bus.

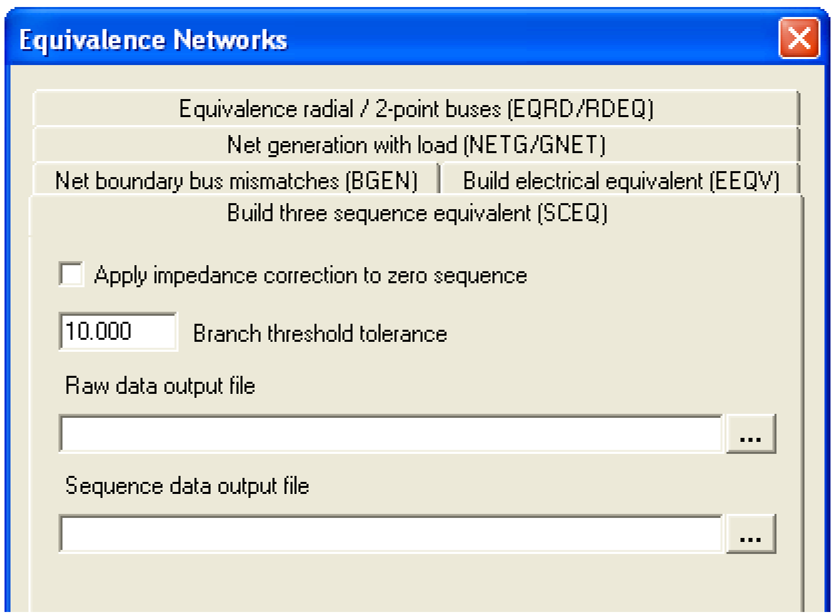


Figure 9-16. Dialog for Short-Circuit Equivalent Construction

The user's first task is to select the subsystem of buses to be equivalenced. This can be done by Area, Owner, Zone, BasekV or by individual buses using the normal Select facility. Following the specification of the subsystem to be equivalenced, the equivalencing process alarms and terminates if either none or all buses are to be retained.

In Figure 9-16, it can be seen that the user is required to complete some selections:

> **Apply impedance correction to zero sequence:** If the actual positive sequence impedance of any transformer in the subsystem to be equivalenced differs from its nominal value, the user is free to specify the treatment of the zero sequence impedance of all such transformers. If this box is checked, the zero sequence impedance of each such transformer is scaled by the same factor as is its positive sequence impedance. Otherwise, all zero sequence transformers are left at their nominal values (i.e., the raw data values entered to populate the power flow case). The same treatment applies to *all* transformers in the subsystem to be equivalenced which are not at nominal impedance.

Branch threshold tolerance: The user can select this tolerance. Any equivalent branch whose magnitude of impedance is greater than this tolerance is not retained in the equivalent. The default value is 10 per unit.

Raw data output file: The user is given the option of saving the equivalents in the form of a Power Flow Raw Data File.

Sequence data output file: The user is given the option of saving the equivalents in the form of a Sequence Data File.

9.8.2 Constructing a Short Circuit Equivalent

The process requires several steps:

- Create FLAT power flow conditions.
- Convert generators.
- Identify the subsystem to be equivalenced.
- Select the solution options and identify the output files (see Section 9.8.1).

At completion of this process the user clicks the ***Go*** button in the dialog to initiate the calculation process.

Create FLAT condition: The network must reflect classical fault analysis assumptions. That is, a uniform voltage profile must be specified, loads must be zero, and all transformers must be at zero phase shift angle. The set up of these conditions is discussed in Section 7.4.3. The FLAT profile setup is accessible via the ***Fault>Setup for special fault calculations (FLAT)*** option.

Convert generators: The generator source currents must be determined on the basis of the positive sequence generator impedances and the flat generator conditions described in (1) above. The conversion of generators is discussed in Section 8.3.2. To initiate the conversion process, the user selects the ***Powerflow>Convert>Generators (CONG)*** option.

If these conditions are not satisfied when initiating the equivalencing process, an appropriate alarm message is printed and the process terminated.

Identify the subsystem: The short-circuit equivalencing process works on the basis of classical fault analysis assumptions. External systems, following the terminology of Table 9-1, are defined when identifying the subsystem to be equivalenced. Subsequently the process handles the data processing tasks automatically.

If sequence data is not contained in the working case, an appropriate message is printed, the equivalent is constructed in the normal manner, but only the positive sequence equivalent is valid.

The equivalencing process begins by temporarily removing the portion of the power flow network which is exempted from equivalencing. All radial and two point type one buses are equivalenced. Next, the processing of the positive and negative sequence networks is then completed and the zero sequence calculation commenced. A summary output of the optimal ordering function is printed and the zero sequence network equivalent is constructed. Finally, the process is completed by combining the equivalent and detailed system sections.

When three or more buses are all connected together by zero impedance lines, either all may be equivalenced, all may be retained, or one may be retained. If the bus type codes are such that more than one but not all the buses in such a group of buses are to be retained, an appropriate message is printed and all buses in the group are retained.

The process is not sensitive to any interrupt control code options.

9.9 Analyzing the Results of a Short Circuit Equivalent

The constructed equivalent resides in the power flow case file along with the unequivalenced portions of the system in the form required for fault analysis work under classical assumptions. There are no operations required to combine system sections.

In constructing the equivalent, all nonboundary type one and two buses in the designated external system are eliminated, and all type five and six buses are retained as type one or two buses, respectively. Normally, the boundary buses from within the subsystem being equivalenced are those which are connected to buses outside of the specified subsystem. However, when the subsystem to be equivalenced is specified by bus only, type one and two buses specified are equivalenced, with the boundary buses being those buses to which they are connected and which are not among those specified.

All boundary buses that represent equivalent sources are set to type two buses with appropriate Norton source currents and source impedances. Boundary buses with no equivalent source are set to type one. Ground paths other than those resulting from equivalent generator impedances are included as positive (and hence, negative) sequence shunts and zero sequence shunts.

The topology of the equivalent network is determined from the positive sequence network. As is the case with "real system," there may be branches in the positive (and negative) sequence network for which the zero sequence path is open.

If, in the original data, positive and negative sequence generator impedances are equal, the corresponding sequence source and branch impedances in the equivalent will be identical. For generators initially characterized by different positive and negative sequence impedances, the corresponding sequence source and branch impedances will differ in the equivalent. Since the fault analysis activities of PSS™E assume that the branch impedances are identical in the positive and negative sequence networks, the equivalent construction process gives an approximation of the negative sequence branch impedances by using those of the equivalent positive sequence network.

A warning message is printed any time the calculated negative sequence branch impedance differs from the positive sequence impedance by more than 5% of the positive sequence value.

This equivalencing process is not capable of handling the case in which zero sequence mutual couplings span the boundary of the external system to be equivalenced and the portion of the system to be retained in detail. Any such mutual is alarmed, the mutual is ignored, and processing continues.

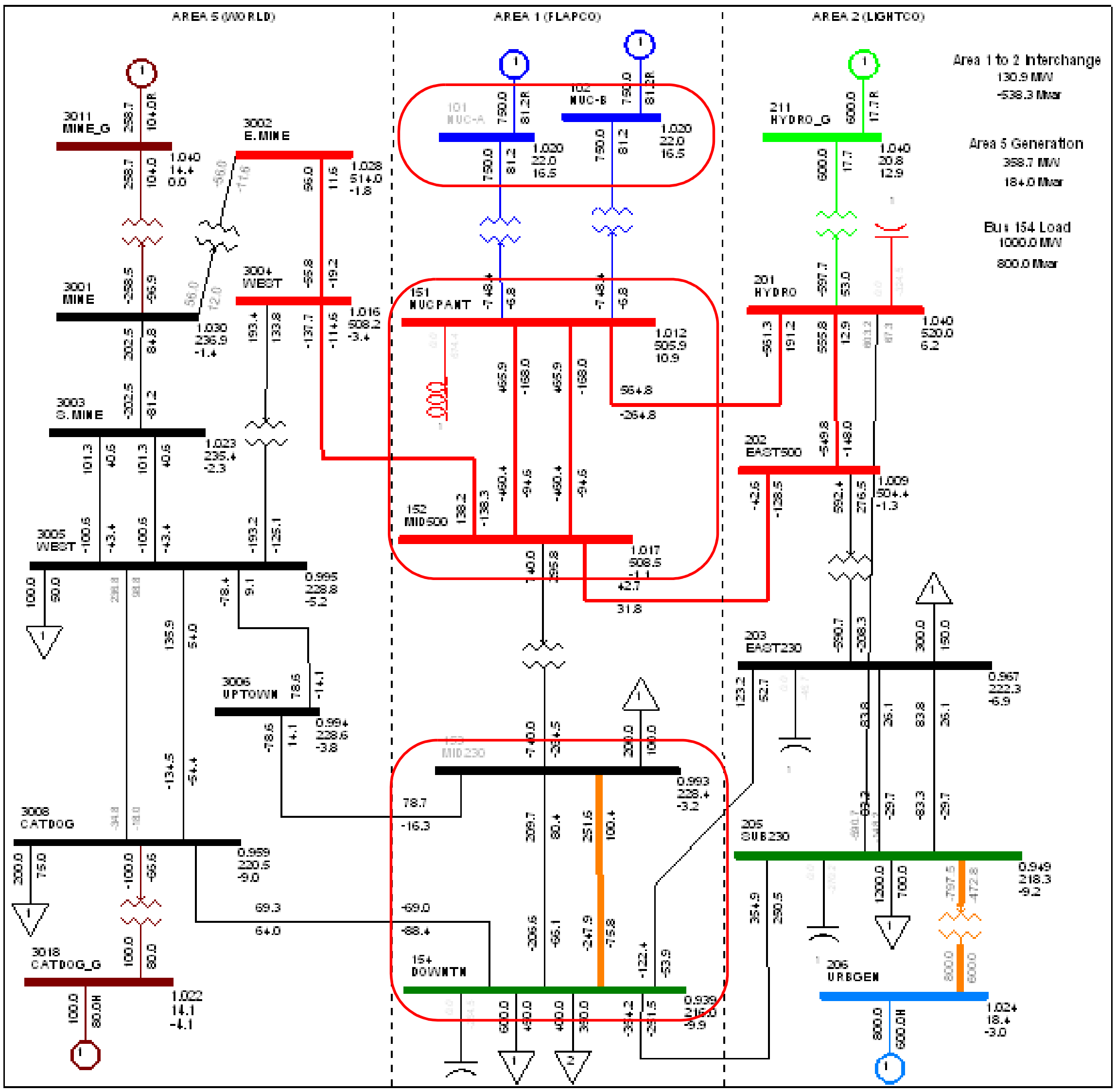
Further, the process is not able to build an equivalent of a subsystem in which a DC line or FACTS device is present. If any DC lines or FACTS devices are encountered, an alarm message is printed but the process continues. Upon completion of the equivalencing process, the user should ensure that any such DC lines and FACTS devices are blocked before using the case in any fault analysis calculation.

An appropriate error message is printed if the number of equivalent source nodes (i.e., generators) or branches exceeds the capacity limits of PSS™E.

9.10 Short Circuit Equivalencing of a Power Flow Case

In the *savnw.sav* power flow case, one of the three Areas (FLAPCO) is subject to a short-circuit equivalencing. Figure 9-17 shows the 6 buses in the Area. It can be seen that there are two generators (at buses 101 and 102); one bus (151) with a shunt reactor and one bus (154) with a shunt capacitor. While there are two loads shown on bus 154, the loads themselves belong in Area LIGHTCO.

The short-circuit equivalencing removes the two generator buses and original area branches. An equivalent generator is attached to bus 151. Three new equivalent branches are created linking buses 151, 152 and 153 (see Figure 9-18). Branch impedances are shown.



FLAPCO Area Buses

Figure 9-17. Pre-Equivalence Power Flow One-Line Diagram Showing the FLAPCO Area Buses

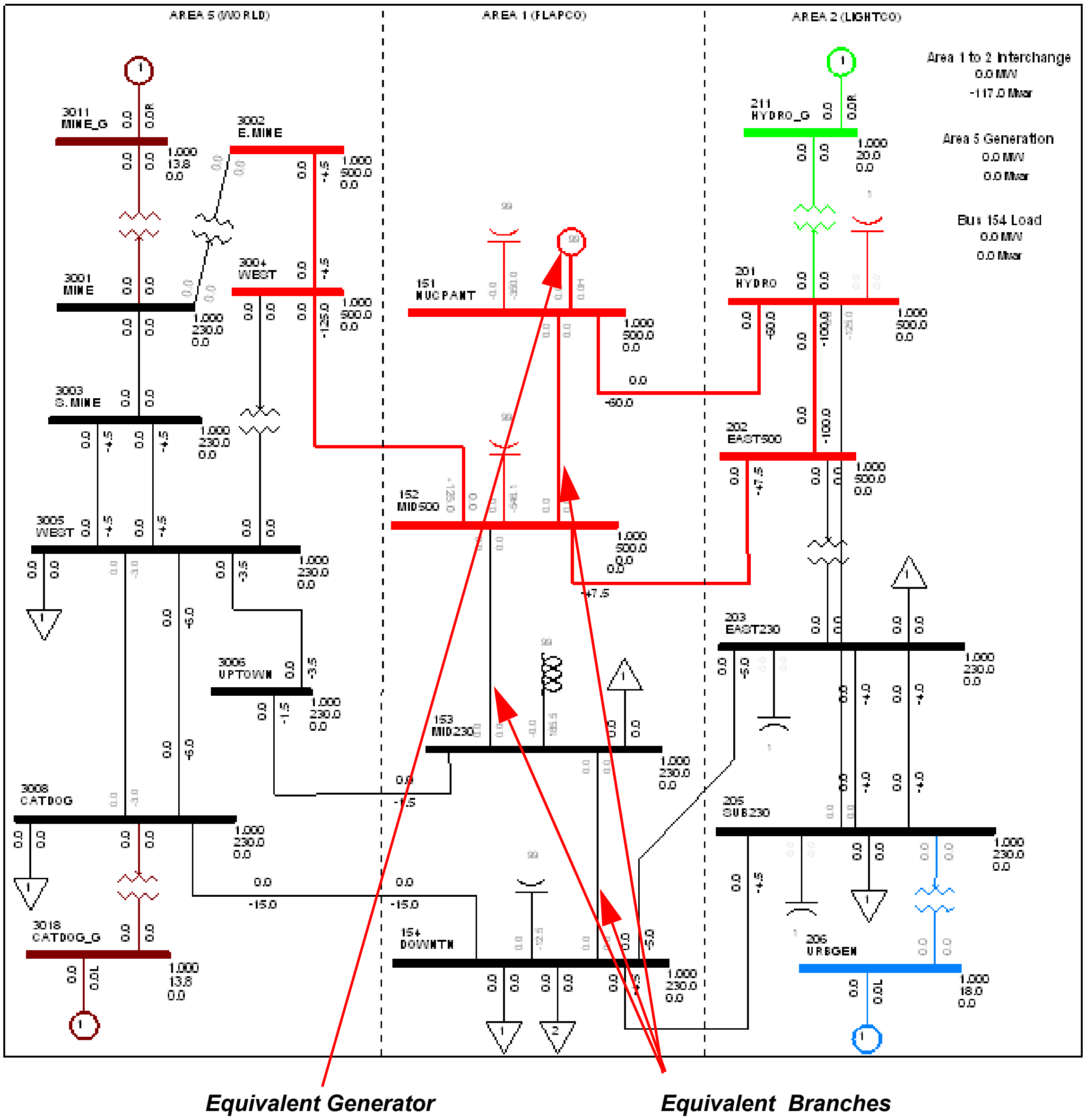


Figure 9-18. Equivalent FLAPCO Area

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Chapter 10

Open Access and Pricing

10.1 Overview: Open Access and Pricing

The electric utility industry restructuring, prevalent in the United States and many other countries in the close of the 20th century has generated interest in analytic tools for transaction processing. Open Access and Pricing Activities (OPA) have been introduced to the load flow processor to aid in assessing transaction feasibility, and cost allocation. In PSS™E, the transaction feasibility assessment is supported by a transaction impact calculator and a line loading relief calculator. The transmission cost allocation technique mandated by the Public Utility Commission of Texas for computing the "impact fee" component of transmission usage fee is provided in PSS™E's allocation function. Transmission loss allocation techniques also are provided.

OPA requires a load flow model, which can be employed to produce a valid DC load-flow solution, be imported into PSS™E. This model is then augmented with transaction data. Transaction data includes transaction event definitions.

A transaction event consists of the following attributes:

- A unique number used for reporting, for defining sequence order, and for referring to transactions in program dialog.
- An alpha numeric label.
- Service status.
- Priority for grouping and ranking.
- A magnitude value in MW.
- A curtailment value in MW.
- A list of participating network buses.

Buses participate in a transaction as points of power injection into or demand from the power system network. An in-service transaction of nonzero magnitude will result in power flows on transmission branch elements. Load and generation input values are associated with each participating bus. A bus participates as a power injection point when its generation value is greater than zero or its load value is less than zero. A bus participates as a power demand point when its load value is greater than zero or its generation value is less than zero. The injection or demand magnitude is a function of the transaction magnitude, the load and generation values, and for some functions, the transaction curtailment value.

Transmission cost and loss allocation methods are concerned with branch ownership and control area, respectively. The flow or loss impact of a branch is computed and accumulated by owner or control area.

10.2 Managing Transaction Data

Each transaction event the user first assigns a set of transaction attributes and then identifies which buses will be participating in the transaction event. The transaction attributes are the following:

ID	A Transaction event number. ID = 0 by default.
DESCRIPTION	Alphanumeric label assigned to the transaction event. The label may be up to twenty four characters and may contain any combination of blanks, uppercase letters, numbers and special characters. LABEL is twenty four blanks by default.
STATUS	Transaction event status: 0 for out-of-service, 1 for in-service. STATUS = 0 by default.
PRIORITY	Transaction event priority. This integer value priority number is used to group transactions into sets. IPR = 0 by default.
MAGNITUDE	Transaction event magnitude in MW. MAG = 0.0 by default.
CURTAILMENT	Transaction event curtailment magnitude in MW. CURT = 0.0 by default.

For each transaction event the user identifies which will be the participating buses. For each participating bus, the following information is required:

I	Bus number. I = 0 by default.
LOAD	Participating bus load value. LV = 0.0 by default.Can be negative.
GENERATION	Participating bus generation value. GV = 0.0 by default.Can be negative.

Table 10-1 shows an example transaction data consisting of two transaction events.

Table 10-1. Example of Transaction Data for Two Transactions

Typical Transaction Data	
First Transaction	
`6 UPSTART 1 1 200.0 0.0`	Transaction Attributes
`3008  1.0000   .0000`	Participating Buses
`102    .0000   .2667`	
Second Transaction	
`5 WORLD 1 1  354.0  0.0`	Transaction Attributes

Table 10-1. Example of Transaction Data for Two Transactions (Cont.)

Typical Transaction Data	
3008 .0000 1.0000	Participating Buses
3007 1.0000 1.0000	
3006 1.0000 1.0000	
3005 1.0000 1.0000	
3004 .0000 1.0000	
3003 .0000 1.0000	
3002 .0000 1.0000	

Data is facilitated by selection of the ***Trans Access>Data…*** option (see Figure 10-1). This in turn opens the Transaction Data dialog (see Figure 10-2). Note that the data is neither saved nor retrieved with the power flow case. It is only temporarily available for the Access analyses.

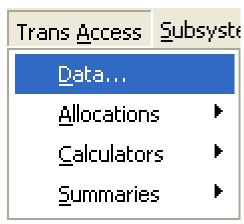

Figure 10-1. Opening the Transaction Data Dialog

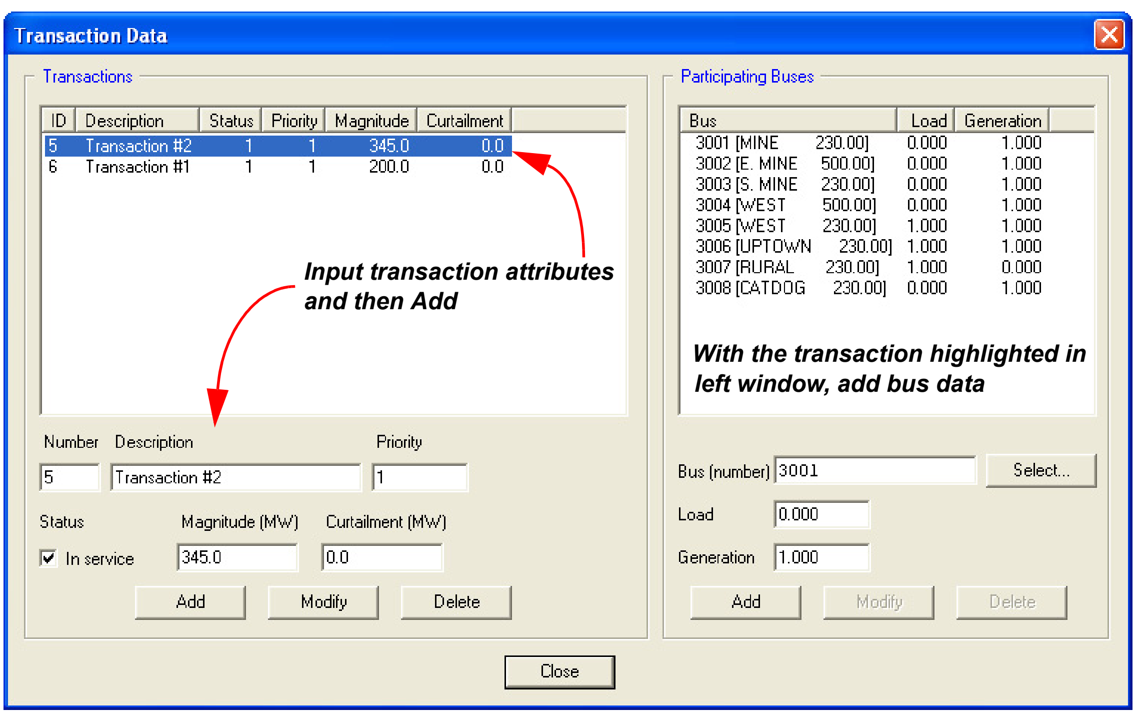

Figure 10-2. Transaction Data Input Dialog

In Figure 10-2 the data from Table 10-1 has been entered. To enter, the user first "Adds" the attribute data which is entered in the lower left dialogue area and then, with the transaction highlighted, enters the information on participating buses. Both attribute and bus data can be modified.

The user should remember that this data is not saved and retrieved with the power flow case.

10.3 Overview of Transmission Allocation Reports

Transmission allocation reports and related transaction event worksheets are generated to provide an accounting basis which illustrates the impact on the transmission system due to transaction events. The accounting basis may be used to allocate embedded transmission costs or controls area losses among the various transaction events making use of the transmission networks.

A Vector Absolute MW-Mile (VAMM) method is used to produce the transmission embedded cost allocation. MW-mile methods are techniques for ascribing the use of the electric power transmission system among the various beneficiaries. These are accounting practices which rely on engineering analysis to determine the basis. This basic accounting unit is the product of branch MW flow with branch length.

The VAMM method determines the impact for each individual transaction event by perturbing each bus generation associated with the event against the associated event load. For each perturbation, the absolute value of change in branch flow (i.e., change from the initial condition power flow model) is multiplied by the branch length in miles, and this result is accumulated in the event's MW-Mile vector, one entry for each branch owner of the load flow model (i.e., each facility owner) as illustrated in equation (10.1).

$$MWM_{ij} = \sum_{k}^{NAG_j} \sum_{l}^{NAL_i} |\Delta P_l| L_l \qquad (10.1)$$

where:

MWM_{ij}	=	MW-Mile impact for the i^{th} owner and j^{th} transaction event.
NAG_j	=	Number of j^{th} transaction event associated generators.
NAL_i	=	Number of branches owned by the i^{th} owner (transmission facility owner).
ΔP	=	Incremental MW branch flow due to perturbing MW generation.
L	=	Branch length in miles.

The union of these vectors for each transaction event forms an aggregate MW-Mile allocation matrix. This matrix is then employed in a spreadsheet program to allocate each facilities owner's cost of service among the transaction events, each transaction event being responsible for costs in proportion to the ratio of its impact to the total impact on that facilities owner.

The aggregate MW-Mile allocation matrix may be constructed directly by using a procedure which repeatedly perturbs the participating generation buses for each of the various transaction events, computing the flow impact and accumulating the impacts into the appropriate matrix positions. The aggregate matrix may also be constructed as the union of impact vectors, one for each transaction, where these impact vectors are computed by a transaction event worksheet.

Transaction event worksheets compute an impact vector as a product of generation vector with a coefficient matrix; a generation on MW-Mile shift factor matrix. An element of this coefficient matrix is the sensitivity of the MW-mile impact on a facility owner to the generation output of a participating bus. The matrix elements have units of MW-Mile per MW. The inner summation of equation (10.1) is used to compute the elements of the generation on MW-Mile shift factor matrix, where the generation perturbation magnitude is 1.0 MW. Computing the aggregate MW-Mile allocation matrix in this manner while more involved, provides for analyzing the impact of various generation dispatch scenarios with the spreadsheet program. A generation vector can be selected which satisfies the demand and minimizes the transmission cost.

The reports generated can produce information for allocating control area transmission losses among the various transaction events. Two loss allocation methods are available, the Vector Absolute MW-Ohm (VAMO) and the Vector Sum MW-Ohm (VSMO). As with the MW-Mile methods, these MW-Ohm methods are accounting practices which rely on engineering analysis to determine the basis. This basic accounting unit is the product of branch MW flow with branch per unit resistance.

The computation required to produce both the VAMO and the VSMO aggregate allocation matrices is that described in equation (10.1) modified as follows:

- Branch length is replaced by branch per unit resistance.
- The inner summation is over branches belonging to control area as opposed to branch owners.
- For VSMO, only the signed value as opposed to the absolute value of incremental branch flow is employed.

The generated reports may be directed to produce the aggregate allocation matrix for any of the VAMM, VAMO, or VSMO methods. It may also be directed to report the generation vector and the shift factor matrix for both the VAMM and VAMO methods. Further the generated reports can include the summation of branch mileage for each facility owning area. This mileage report is useful for checking the integrity of the mileage and joint branch ownership data.

10.4 Available Calculators

Figure 10-3 shows the menu track for accessing the two calculators. They are:

- Calculation of incremental monitored element MW flow impacts due to transaction events
- Calculation of the active power flow on monitored elements as a function of transaction events. This Line Loading Relief calculation (LLRF) is used to: determine the transfer distribution factors on all monitored elements due to all transaction events; determine the incremental curtailment of transaction events required to achieve an incremental flow change on a target monitored element; and determine the incremental restoration of previously curtailed transaction events needed to achieve an incremental flow change on a target monitored element.

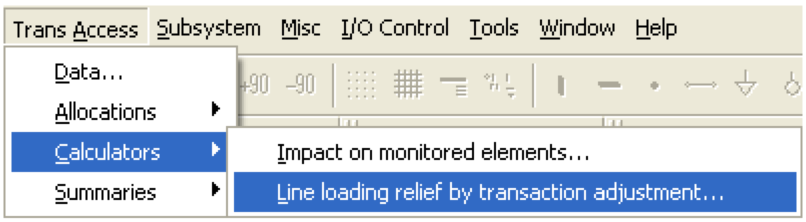

Figure 10-3. Menu Selection for Transmission Access Calculations

10.4.1 Transaction Impact Calculator

The transaction impact calculator computes the incremental MW flow impact on a set of monitored elements due to a single transaction event. It uses a distribution factor data file to define the monitored element set. It employs the transaction magnitude, without regard to the curtailment value, to determine the power injections and demands at participating buses. It employs the linearized solution technique to compute the incremental element flows. Regulating in-service phase shifting transformers have zero incremental MW flow.

The impact calculator produces a report which illustrates the incremental MW flow impacts on each of the monitored elements, along with the initial available transfer capability (ATC) for the element and a final ATC which is adjusted for the flow impact due to the transaction. For monitored interfaces, a value is provided which illustrates the maximum transaction magnitude that can be supported by the element's ATC.

10.4.1.1 Selecting the Transaction Impact Calculator

Selecting the ***Impact on monitored elements*** option will open the dialog shown in Figure 10-4. The user is required to:

1. Select an output destination using the ***I/O Control*** menu.

2. Enter the number of the transaction event to be analyzed.

3. Identify the name of a Distribution Factor Data file constructed as described in Section 5.2.2.1 or to initiate the construction of such a file. The file should correspond to the network condition contained in the power flow case and to the desired Linear Network Analysis Data Files. The bus input option must have the same setting that was in effect when the data file was constructed.

The user may provide the name of the Available Transmission Capacity (ATC) update file. Providing a filename is optional. When provided, this file may modify the monitored interface ratings employed in the report as available transfer capability (ATC). The ATC update file consists of one or more records. Each record consists of two fields, a text field which identifies an interface by twelve character label and a numeric value field which identifies the interface ATC in MW.

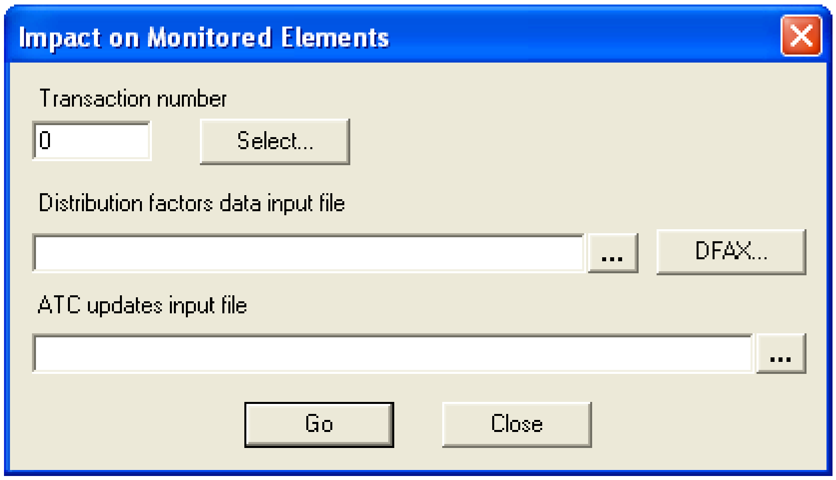

Figure 10-4. Input Dialog for Transaction Impacts Calculation

Having provided the required information, the user selects ***Go***. This will initiate the calculation the result of which is a report of results.

The calculation uses the same linearized network model as is used in DC power flow analyses (see Section 5.5). Thus, the comments given in that section apply here as well. Regulating in-service phase shifting transformers hold constant MW flow.

10.4.1.2 Viewing the Transaction Impact Calculator Results

The report begins with an initial page header followed by four records which identify the source of Distribution Factor and Linear Network Analysis Data Files.

The remainder of the report is divided into two sections. The first section reports impacts for all monitored branches contained in the Distribution Factor Data File. The second section reports impacts for all monitored interfaces. The selected transaction event is identified and followed by a table of monitored elements. The transaction event identification includes: transaction event number, transaction event label and transaction magnitude. Each record of the monitored element table includes: a monitored element description, an initial ATC value in MW, the incremental MW flow impact on the monitored element due to the transaction event, and a final (adjusted for incremental flow) ATC value in MW. Branch RATEA values are employed as ATC values for monitored branches. Monitored interface ATC values default to the interface RATEA and may be adjusted by entries in the "ATC update file" if such a file was requested by the user.

For monitored branches the monitored element description consists of: "*from bus*" number and name, "*to bus*" number and name, and circuit id. For monitored interfaces the twelve character monitored element label is employed as the monitored element description.

The monitored interface table includes an additional column of numeric values. These values illustrate the transaction magnitude, in MW, which would result in a final ATC value of zero for that element. This maximum transaction field will take a value only when the initial ATC and incremental flow values are of the same sign and when the incremental flow value magnitude significantly exceeds zero.

Using the *savnw.sav* power flow case and the associated data files (*savnw.sub/.mon/.con*), all of which are available in the PSSE/EXAMPLE directory in the user's installation, an example case is run using Transaction #6 described in Figure 10-2. The report generated by the impact calculation is shown in Figure 10-5.

```
     PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E   THU, MAR 11 2004  11:35
PSS/E PROGRAM APPLICATION GUIDE EXAMPLE                              PAGE 1
BASE CASE INCLUDING SEQUENCE DATA
                       ** TRANSACTION IMPACT SUMMARY **

DISTRIBUTION FACTOR FILE:     C:\Program Files\PTI\PSSE30\EXAMPLE\dc-contingency.dfx
SUBSYSTEM DESCRIPTION FILE:   C:\Program Files\PTI\PSSE30\EXAMPLE\savnw.sub
MONITORED ELEMENT FILE:       C:\Program Files\PTI\PSSE30\EXAMPLE\savnw.mon
CONTINGENCY DESCRIPTION FILE: C:\Program Files\PTI\PSSE30\EXAMPLE\savnw.con

TRANSACTION:             6 Transaction #1
<------- F R O M -------> <--------- T O --------->CKT  <INT ATC MW> <IMPACT MW-> <FIN ATC MW>
   201 HYDRO        500.00    151 NUCPANT     500.00 1      1200.00       -91.75      1291.75
   202 EAST500      500.00    152 MID500      500.00 1      1200.00        31.82      1168.18
   203 EAST230      230.00    154 DOWNTN      230.00 1       200.00         3.03       196.97
   205 SUB230       230.00    154 DOWNTN      230.00 1       600.00        56.90       543.10
  3004 WEST         500.00    152 MID500      500.00 1         0.00       -47.66        47.66
  3006 UPTOWN       230.00    153 MID230      230.00 1         0.00       -39.00        39.00
  3008 CATDOG       230.00    154 DOWNTN      230.00 1       400.00      -113.34       513.34

TRANSACTION:             6 Transaction #1
<-INTERFACE-> <INT ATC MW> <IMPACT  MW> <FIN ATC MW> <MAX TRN MW>
WEST                200.00      -200.00      400.00
EAST                350.00         0.00      350.00
```

Figure 10-5. Results of Impact Calculation

10.4.2 Line Loading Relief Calculator

The line loading relief calculator provides a menu of functions related to computing transaction magnitude adjustments which result in feasible monitored element branch MW flows. It uses a distribution factor data file to define the monitored element set. It employs the transaction magnitude an the curtailment value to determine the power injections and demands at participating buses. It employs the linearized solution technique to compute monitored element distribution factors and the incremental element flows. Regulating in-service phase shifting transformers have zero incremental MW flow. It reflects adjustments in the transaction curtailment value.

The user may specify the desired MW flow increment on a monitored element. This incremental flow value may, for example, represent the amount by which the element is overloaded. The line loading relief calculator will report adjustments to transaction magnitudes required to satisfy this incremental flow. These transaction adjustments may be limited to transaction curtailment (i.e., increases in transaction curtailment value magnitude not to exceed the transaction magnitude value) or transaction restoration (i.e., decreases in transaction curtailment value magnitude).

Transactions participate in adjustment as a function of their transaction priority and the applied adjustment method. Four adjustment methods are available: first in last out, decreasing order by distribution factor magnitude, pro rata by distribution factor magnitude, and pro rata by the product of distribution factor with transaction schedule (transaction magnitude less curtailment). Transactions are excluded from adjustment when their distribution factor magnitude is less than a user-specified tolerance. Individual events are grouped by priority. The curtail transactions function proceeds to investigate the priorities from lowest to highest priority number until the incremental flow target is satisfied or all transaction priority groups are exhausted. The restore transactions function proceeds to investigate the priorities from highest to lowest priority number until the incremental flow target is satisfied or all transaction priority groups are exhausted.

The line loading relief calculator produces reports which illustrate:

- Transaction adjustments which result in a specified incremental flow on a selected monitored element.
- Distribution factors (i.e., sensitivity of monitored element MW flow to transaction magnitude) for all monitored elements and transaction events).

10.4.2.1 Selecting the Line Loading Relief Calculator

Selecting the ***Line loading relief by transaction adjustment*** option will open the dialog shown in Figure 10-6.

The user's first requirement is to Identify the name of a Distribution Factor Data file constructed as described in Section 5.2.2.1 or to initiate the construction of such a file. The file should correspond to the network condition contained in the power flow case and to the desired Linear Network Analysis Data Files. The bus input option **must** have the same setting that was in effect when the data file was constructed.

When the distribution factor file is identified, the monitored element list (from the *savnw.mon* file) is tabulated in the window.

The user is next presented with a menu prompting for a selection among three functions: curtail transactions, report distribution factor matrix and restore transactions.

10.4.2.2 Curtailing and Restoring Transactions

To either curtail transactions or restore transactions, the user must select the target element from the monitored element list and must define the target adjustment value in MW. The conventions for positive and negative element flow are defined when presenting the monitored element list for construction of the distribution factor data file.

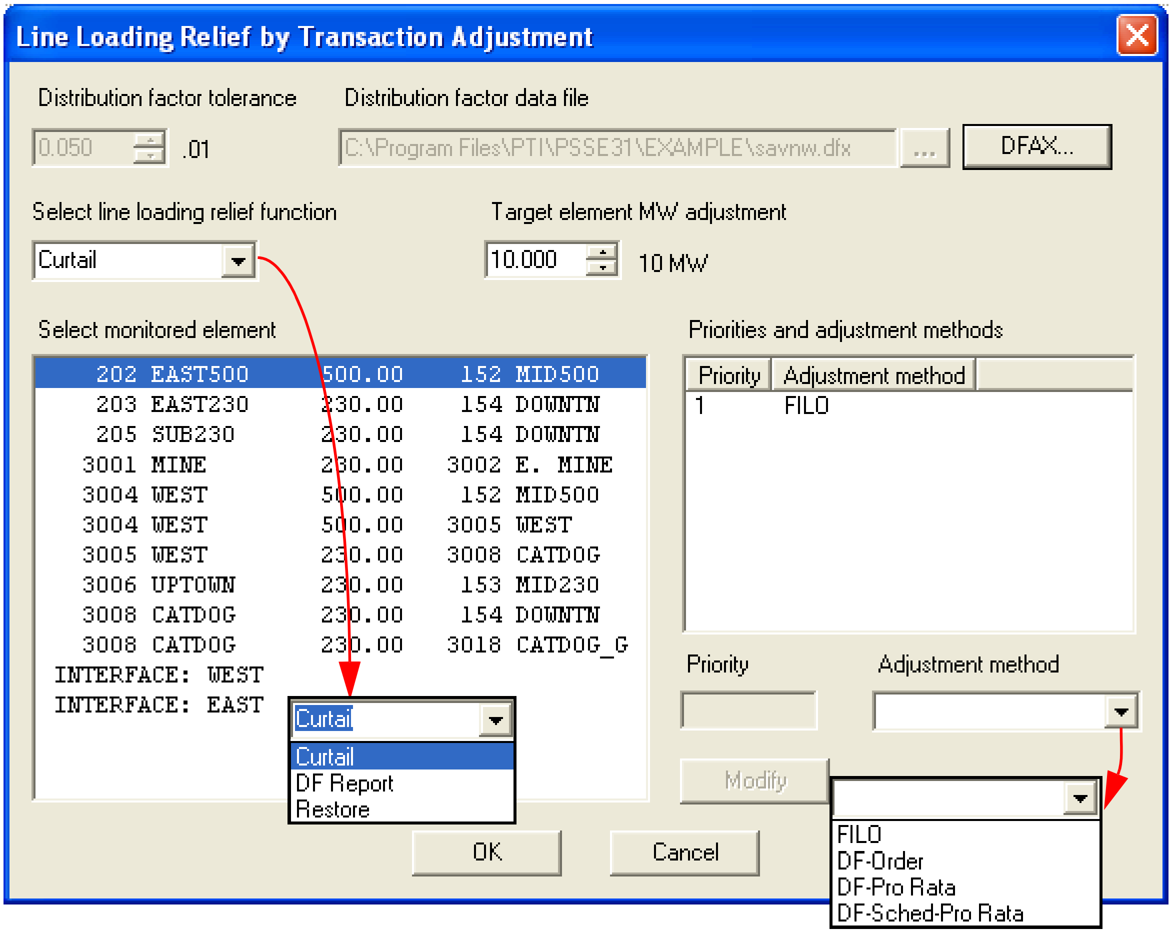

Figure 10-6. Line Loading Relief Calculation Dialog

After selecting a target element and defining the incremental flow target the user needs to select an adjustment method association. Four transaction event adjustment methods are available:

- First in last out (`FILO`).
- Decreasing order of distribution factor magnitude (`DF-ORDER`).
- Distribution factor pro rata (`DF-PRO RATA`).
- Pro rata base on the product of distribution factor with transaction schedule (`DF-SCHED-PRO RATA`).

A transaction's schedule is the transaction magnitude less curtailment. The window shows the list of transaction event priorities and associated adjustment method. The user may alter the adjustment method associated with each priority.

Individual events, whose distribution factors exceed a tolerance, are grouped by priority. The curtail transactions function investigates the priorities from lowest to highest priority number until the incremental flow target is satisfied or all transaction priority groups are exhausted. The restore transactions function investigates the priorities from highest to lowest priority number until the incremental flow target is satisfied or all transaction priority groups are exhausted.

The calculation produces a report of transaction adjustments and the effect of each on the target monitored element. The transaction event curtailment values are updated by the reported adjustments.

The line loading relief calculation uses the same linearized network model as is used in DC power flow analyses (see Section 5.5). Thus, the comments given in that section apply here as well. Regulating in-service phase shifting transformers hold constant MW flow.

Transaction events may be adjusted by the curtailment or restoration functions when their distribution factor magnitudes exceed the distribution factor tolerance and are of the correct sign with respect to the sign of the adjustment MW value (e.g., having opposite sign for curtailment and the same sign for restoration).

When performing curtailment, the adjustment magnitude limit for each transaction event is equal to the transaction event magnitude less the initial curtailment magnitude. When performing restoration the adjustment magnitude limit for each transaction event is equal to the initial transaction event curtailment magnitude. Adjustments resulting from the curtailment and restoration functions update the transaction event curtailment magnitude.

10.4.2.3 Working with Distribution Factor Matrix

When continuing with a "report distribution factor matrix" selection the activity proceeds to produce a report of transfer distribution factors for all monitored elements due to all transactions events. Out-of-service transaction events will have distribution factors of zero.

10.4.2.4 Viewing Line Loading Relief Calculator Results

All reports begin with an initial page header followed by four records which identify the source of the Distribution Factor Data File and the Linear Network Analysis Data Files.

Curtail and Restore Transactions

Following the Distribution Factor Data File and the Linear Network Analysis Data Files summary, the target element and target adjustment MW value are reported. This is followed by a table which illustrates for each affected transaction event: the transaction event number, the transaction event priority, the transaction event label, the initial transaction schedule (transaction event magnitude less curtailment) in MW, the schedule adjustment in MW (increment used to update the transaction event curtailment), the final transaction schedule in MW, and the impact of this adjustment on the target element in MW. A statement which indicates if the adjustment target MW value is satisfied follows the table.

Distribution Factor Matrix

The distribution factor matrix is reported after the Distribution Factor Data File and the Linear Network Analysis Data Files summary. Rows of this matrix are the transaction events. These are identified by transaction event number, transaction priority, and transaction label. Columns of the matrix are monitored elements. The column headers are limited to twelve characters. For monitored branches these headers are references to a monitored branch legend. For monitored interfaces the headers are the interface labels. The matrix presentation is "wrapped" across multiple records when the number of columns to be presented exceeds the presentation width.

The distribution factor values of the matrix represent the sensitivity of monitored element MW flow to transaction event magnitude. A positive value indicates that the monitored element flow will increase with increasing transaction event magnitude.

10.5 Making Allocations

The allocations process performs various analyses related to identifying the MW-mile impact of transaction events on transmission facility owners. It is used to:

- Determine the MW-mile impacts of all transaction events on all transmission facility owners.
- Determine the active power generation on MW-mile shift factors of an individual event on all transmission facility owners.
- Determine the MW-ohm impacts of all transaction events on all control areas.
- Determine the active power generation on MW-ohm shift factors of a individual event on all control areas.
- Report the total branch mileage of each transmission facility owner.

The Vector Absolute MW-Mile method is employed as required by the Public Utility Commission of Texas for computing the "impact fee" (see PUCT Substantive Rule 23.67, *Open-Access Comparable Transmission Service*, and PUCT Substantive Rule 23.70, *Terms and Conditions of Open-Access Comparable Transmission Service*).

10.5.1 Selecting Allocations

Selecting the ***Trans Access>Allocations>Megawatt shift factors…*** option will open the dialog shown in Figure 10-7.

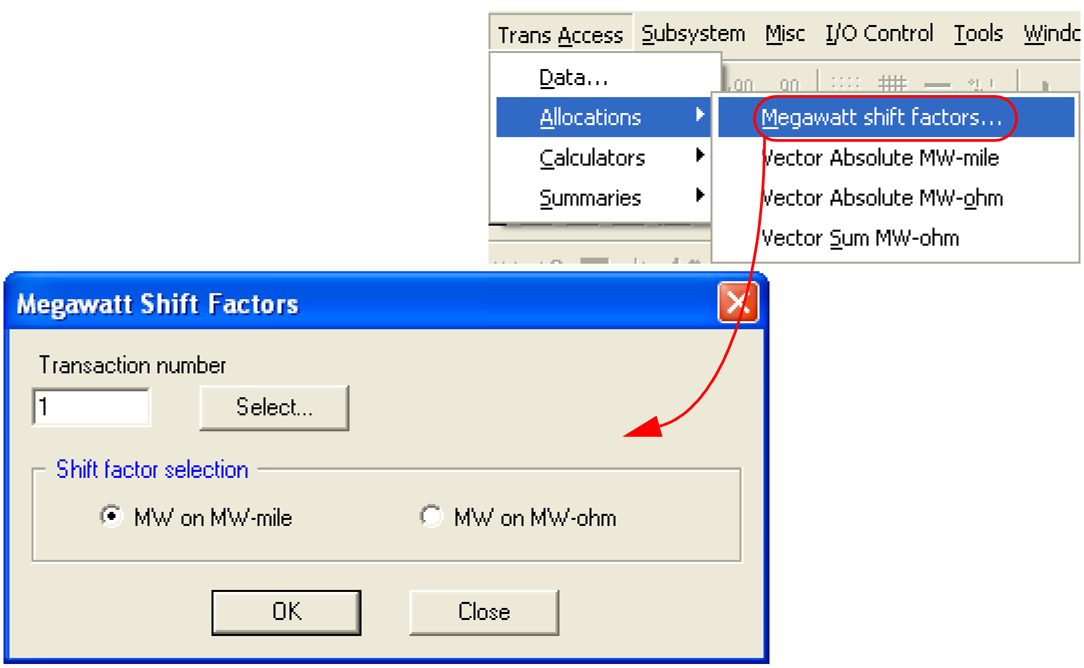

Figure 10-7. Selecting Allocations

The user is presented with a menu prompting for a selection among five reports, including:

- Vector Absolute MW-mile,
- Generation on MW-mile shift factors,
- Vector Absolute MW-ohm,
- Generation on MW-ohm shift factors (employing the Vector Absolute method),
- Vector MW-ohm.

When making the selection of Generation on MW-mile shift factors or Generation on MW-ohm shift factors the user selects one of them, as shown in Figure 10-7 and an item from the list of transaction events. The report is delivered either to the Output Bar or to a file of the user's choice.

When selecting Vector Absolute MW-mile, Vector Absolute MW-ohm or Vector MW-ohm, the user has only to select the output device.

10.5.2 Analyzing Allocation Results

Reports are formatted for import to a spreadsheet program; records with data fields delimited by semicolons. Alternatively the can be printed on a Report tab in a tabular display format. Selections from the ***File*** menu allow for formatting the spreadsheet reports (see Section 2.6).

For import to a spreadsheet program, the reports include an initial record of text fields for use as column headings in a spreadsheet table. The first field of each subsequent record provides a row label. All other fields are numeric data.

10.5.3 Viewing Branch Mileage by Owner

This summary report is initiated by selection of the ***Trans Access>Summaries*** option (see Figure 10-8).

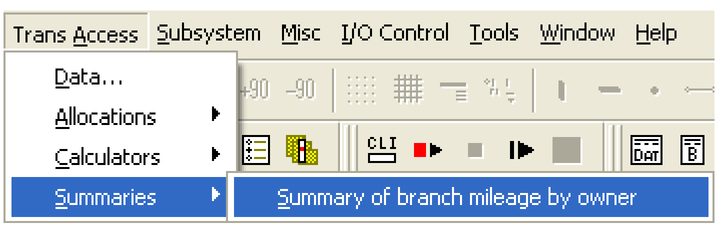

Figure 10-8. Selecting the Branch Mileage Report

The report can be printed on a Report tab on the interface or to a file of the user's choice. The report contains only the branch mileage summary by owner.

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Chapter 11

Performing PV/QV Analyses

11.1 Overview

The PV/QV analyses that are described in this chapter are designed for studies of slow voltage stability, which could be analyzed as a steady-state problem. They are load flow based analyses used to assess voltage variations with active and reactive power change. Two methods are used to determine the loading limits imposed by voltage stability under the steady-state conditions.

The PV/QV analyses do not provide solutions to specific problem but function as tools that can be directed by the user to perform analyses in the solution of problems associated with the steady-state voltage stability of power systems.

11.2 How to Perform PV and QV Analysis in PSS™E

11.2.1 Performing PV Analysis

To access the PV analysis module:

1. Open an existing data file containing network data (*.*raw*, *.*sav*) by selecting ***File>Open*** from the Main Menu.

2. Select ***PowerFlow>Solution>PV analysis…***. The PV Analysis dialog containing default settings will be displayed (see Figure 11-1).

3. Enter and select the PV analysis options you want for your calculation:

   Solution options: Select solution options for the series of load flow calculations performed to obtain the PV curves. The contingency-case solution options allow for a different set of automatic adjustments of the contingency cases than those used in the base case solutions. For more information, please refer to Chapter 4 of the *Program Operation Manual, Volume I*.

   Solution Engine: Select the solution engines for the series of load flow calculations and contingency studies to obtain the PV curves please refer to Chapter 4 of the *Program Operation Manual, Volume I*.

   Var Limit Code: Select the var control options limit code for contingency case initial power flow solution and subsequent transfer increment cases. The var limit control can be set to apply immediately to limit the var output of all generators, or to ignore var limit at initial iterations and then apply automatically afterwards.

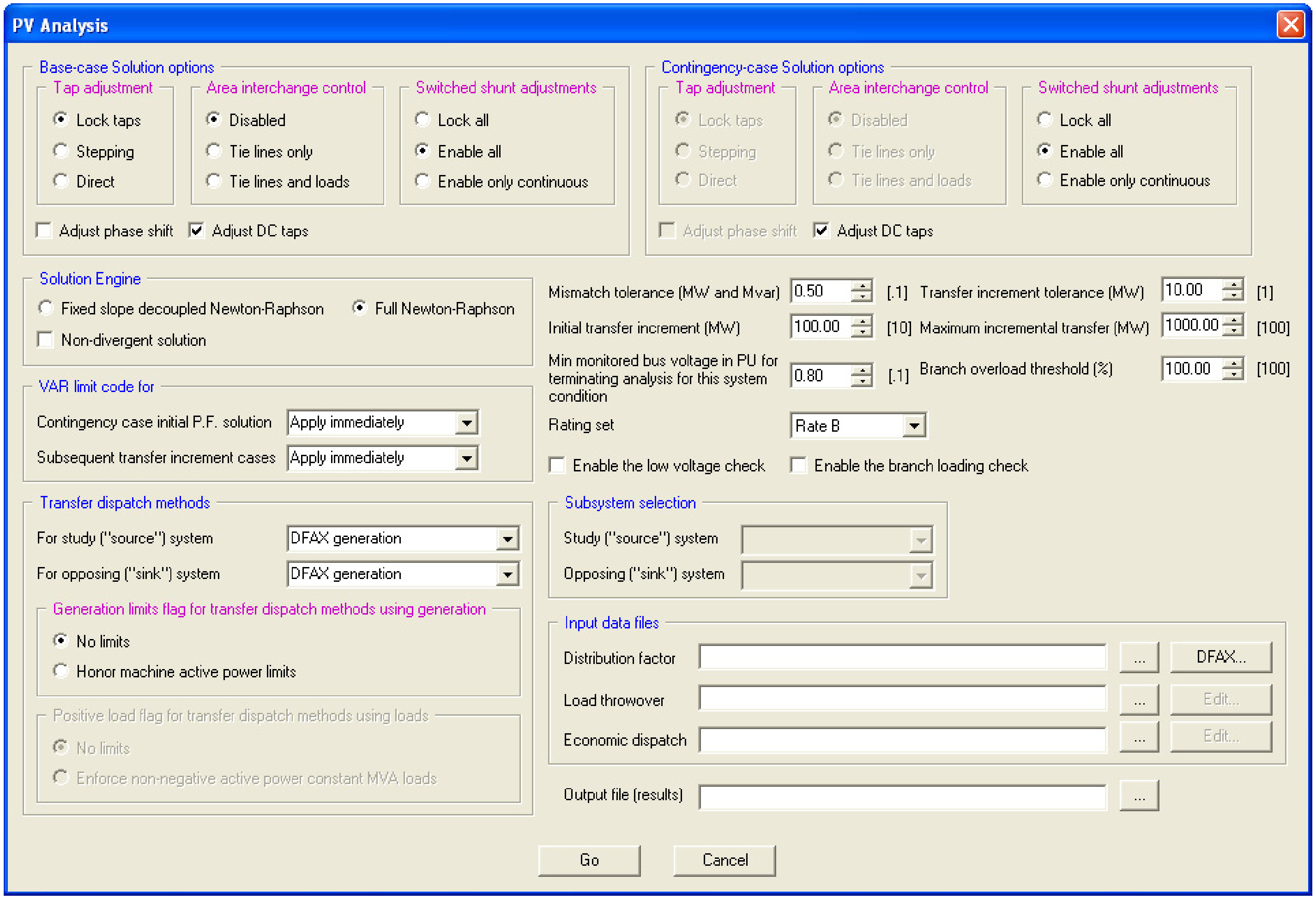


Figure 11-1. PV Analysis Dialog

4. **Transfer Dispatch Methods:** Dispatch codes for study and opposing dispatch calculations in PV analysis.

    - **Dfax generation:** Participating buses and their participation factors are taken from the DFAX file for buses in the subsystem with one or more in-service machines whose active power generation is positive.
    - **Dfax load:** Participating buses and their participation factors are taken from the DFAX file for buses in the subsystem with one or more in-service loads whose constant MVA load active power is positive.
    - **Dfax generation or load:** Participating buses and their participation factors are taken from the DFAX file for buses in the subsystem with either one or more in-service machines whose active power generation is positive, or one or more in-service loads whose constant MVA load active power is positive. If both generation and load meeting the above criteria are present at a bus, the generation is dispatched if the bus is in the study subsystem, and the load is dispatched, if the bus is in the opposing subsystem.
    - **Subsystem load:** Participating buses are subsystem buses with one or more in-service loads whose constant MVA load active power is positive; each bus' participation factor is the total of its positive active power constant MVA load.
    - **Subsystem machines (MW):** Participating buses are subsystem buses with one or more in-service machines whose active power generation is positive; each bus' participation factor is the total of the active power generation of its machines with positive active power generation.
    - **Subsystem machines (MBASE):** Participating buses are subsystem buses with one or more in-service machines whose active power generation is positive; each bus' participation factor is the total of the MBASEs of its machines with positive active power generation.
    - **Subsystem machines (Reserve):** Participating buses are subsystem buses with one or more in-service machines whose active power generation is positive; each bus' participation factor is the total of the reserve (PT-PG) of its machines with positive values of both active power generation and reserve.
    - **Subsystem machines (ECDI):** Participating buses are subsystem buses with one or more in-service machines specified in the Economic Dispatch Data File; machines participate in the transfer based on an equal incremental cost dispatch as implemented by activity ECDI.

    Mismatch tolerance (MW and Mvar): Specify mismatch tolerance. This tolerance will be used to check for largest initial active or reactive power mismatch. If exceeded the process is terminated. This value is also used as the convergence tolerance in the power flow solution of each contingency and transfer increment case; please refer to Chapter 4 of the *Program Operation Manual, Volume I.*

    Initial transfer increment (MW): Specify the starting transfer increment value. This value will be the initial transfer increment step size in MW between the two defined subsystems.

    Transfer increment tolerance (MW): Specify the largest acceptable difference in transfer level between a transfer level for which a solution is found and a higher transfer level which fails to achieve convergence.

Maximum incremental transfer (MW): Specify the maximum transfer value in MW between the two defined subsystems.

Min monitored bus voltage in PU for terminating analysis for this system condition: Specify the minimum voltage value for termination of calculation. If the low voltage check is enabled, calculations will stop if any monitored voltage is less than this value.

Branch overload threshold (%): Specify branch overload threshold. This value will be the threshold in determining branch overloads.

Rating set: Select branch rating set. This value will be the line loading limit used in determining overloads. If the branch loading check is enabled, calculations will stop if any monitored branches are overloaded beyond this limit.

Enable the low voltage check: If enabled the calculations will stop if any monitored voltage is less than the minimum monitored voltage specified.

Enable the branch loading check: If enabled the calculations will stop if any monitored branches are overloaded beyond the limit specified by overload threshold and rating set.

Subsystem selection: Select the subsystems for the power transfer. Power transfers from the study system to the opposing system.

In order to begin calculations, two data files are required:

1. The distribution factor input data file (**.dfx*). For more information on the distribution factor input data file, please refer to Chapter 4 of the *Program Operation Manual, Volume I.*

2. The output file (results)(**.pv*). The results of the PV calculation will be stored in the file specified in this field. The results file is provided so that you may view the PV calculation results at a later time by simply selecting the output results file rather than re-running the PV calculations.

Enter and select the parameters that apply and click the ***Go*** button to start the PV calculations. Select ***Cancel*** to close the window and return. The results window for PV analysis will be displayed (see Figure 11-2).

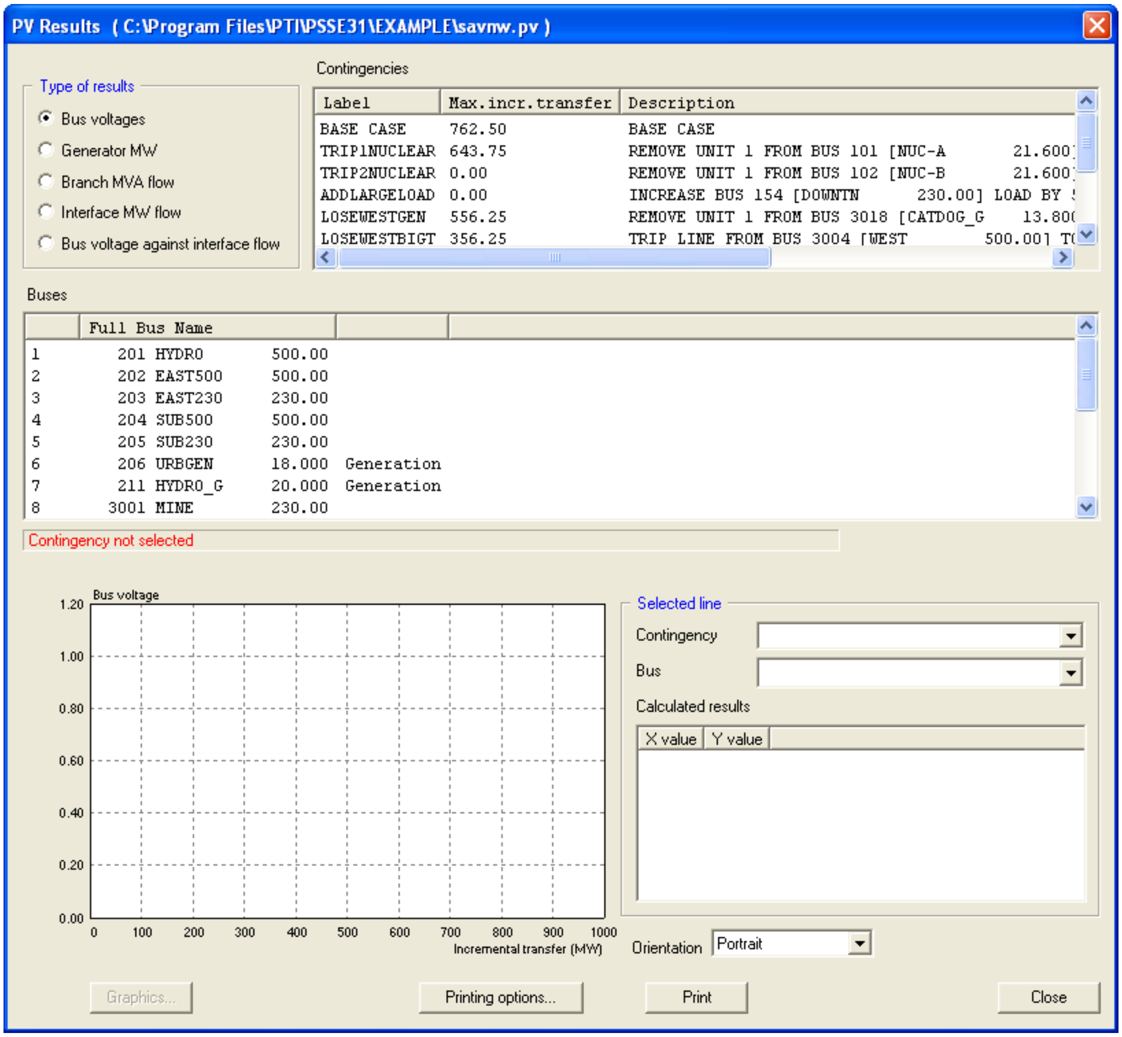


Figure 11-2. PV Analysis Results Window: Calculations Results

Select the type of graph you wish to plot and select the items of interest in the list provided:

Bus voltages: Plots bus voltages against incremental power transfer of selected base case or contingencies.

Generator MW: Plots generator MW output against incremental power transfer of selected base case or contingencies.

Branch MVA Flow: Plots branch MVA against incremental power transfer of selected base case or contingencies.

Interface MW Flow: Plots interface MW against incremental power transfer of selected base case or contingencies.

Bus voltage against interface flow: Plots the selected bus voltage against interface flow.

Items in the list may be selected individually or as a continuous set. To select individual items, left-click on the item you want to select. Hold the **[Ctrl]** key down while clicking the left mouse button to select the additional items. To select continuous items, hold the **[Shift]** key down while clicking the left mouse button.

Select the ***Graph*** button to plot the graphs. The graphs will be displayed as shown in Figure 11-3.

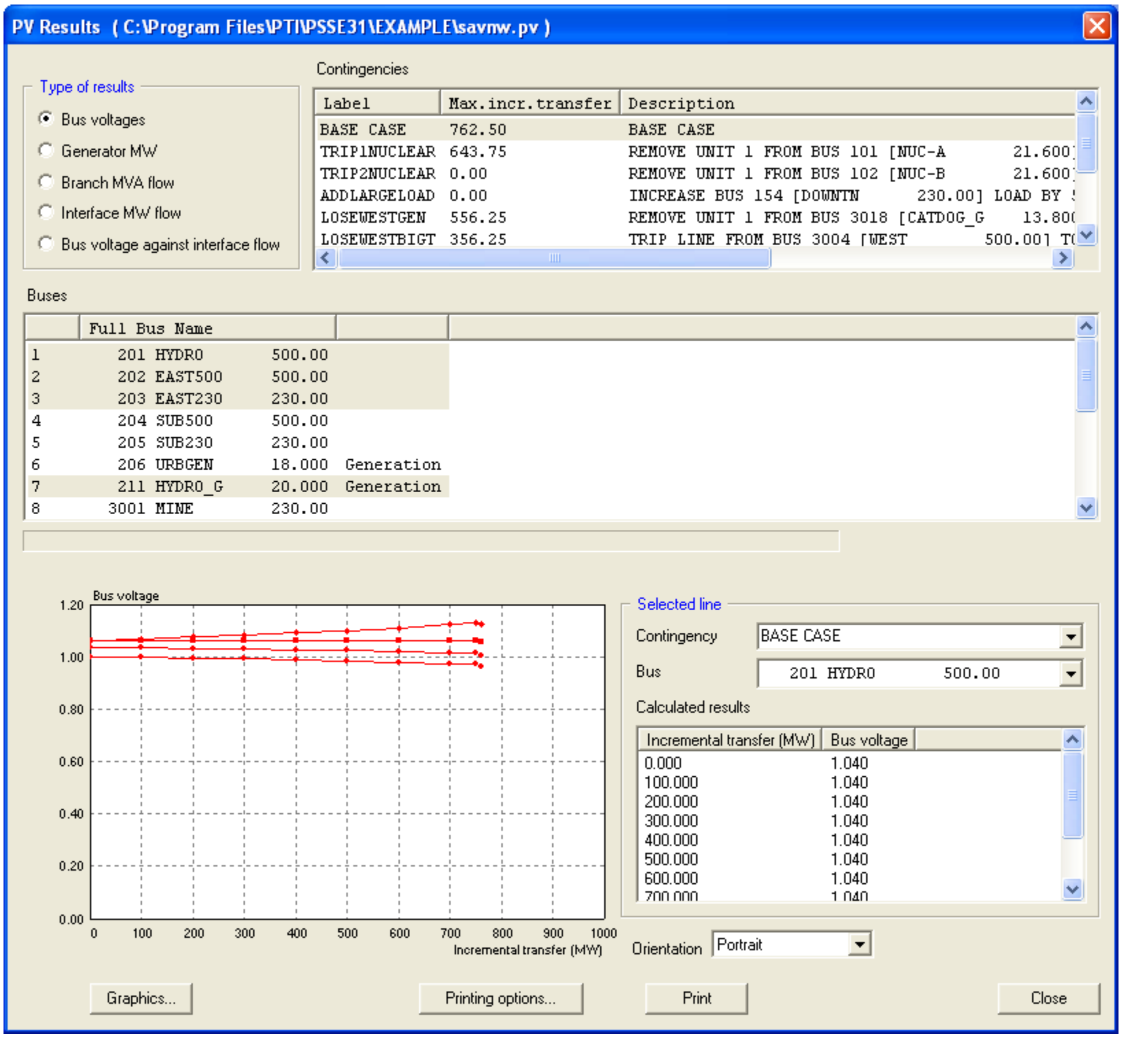


Figure 11-3. PV Analysis Results Window: Graph Results

Graph axis's parameters are fully adjustable. To adjust parameters such as decimal places and axis labels, left-click on the axis of interest. The Scale Values dialog is displayed in Figure 11-4 and Figure 11-5 for both vertical and horizontal axes:

> **Values:** Specify a top value and bottom values of the axes. These values can be adjusted based in grid step size if ***Adjust to grid step*** is checked. Select the start point of the grid step. If undefined then grid step will start from bottom. Select grid step method either by step value or defined the number of values required on the axes.

View (not real values): Select the graphs display options in this section. The changes will be reflected on the sample display on the left.

The Scale Values dialogs are displayed in Figure 11-4 and Figure 11-5 for both vertical and horizontal axes.

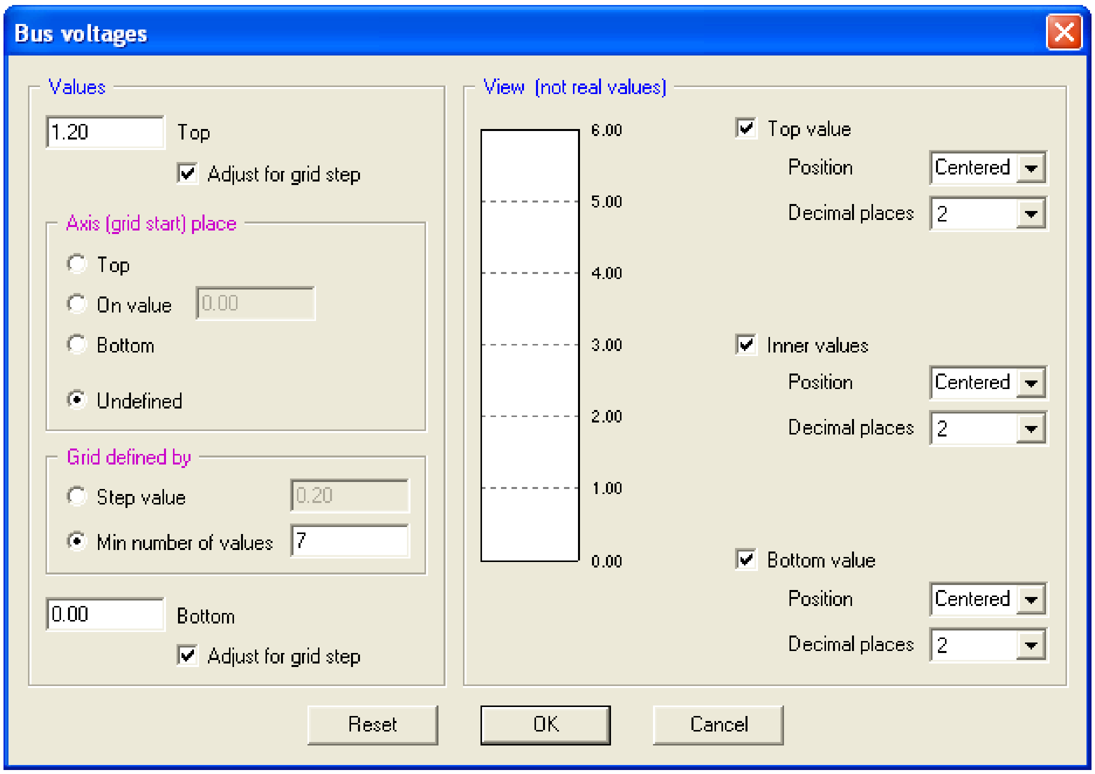


Figure 11-4. Scale Values Dialog for Vertical Axis

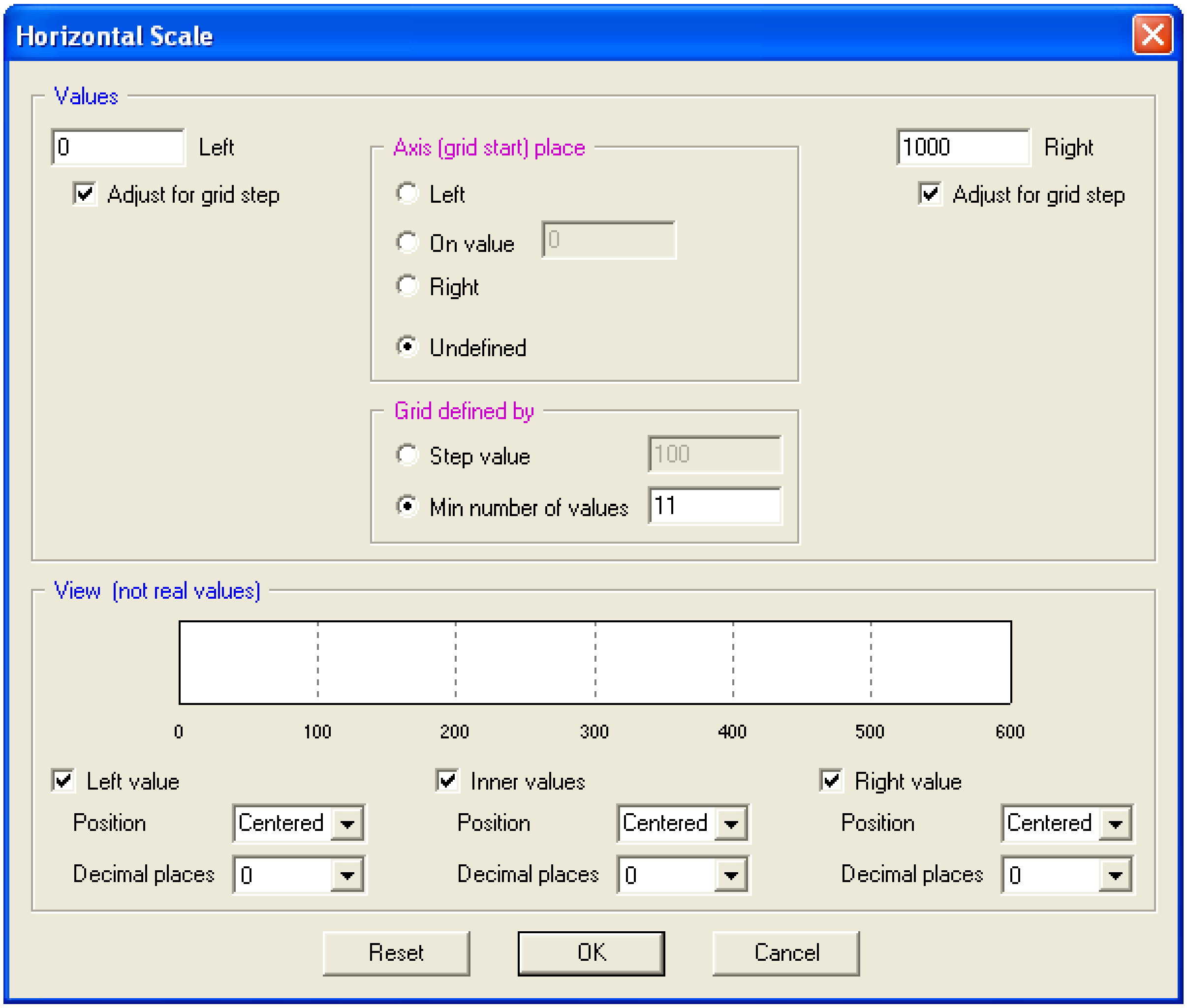


Figure 11-5. Scale Values Dialog for Horizontal Axis

To change the visual parameters of the graph area, left-click on the graph area. The Graph Area Visual Parameters dialog will be displayed (see Figure 11-6).

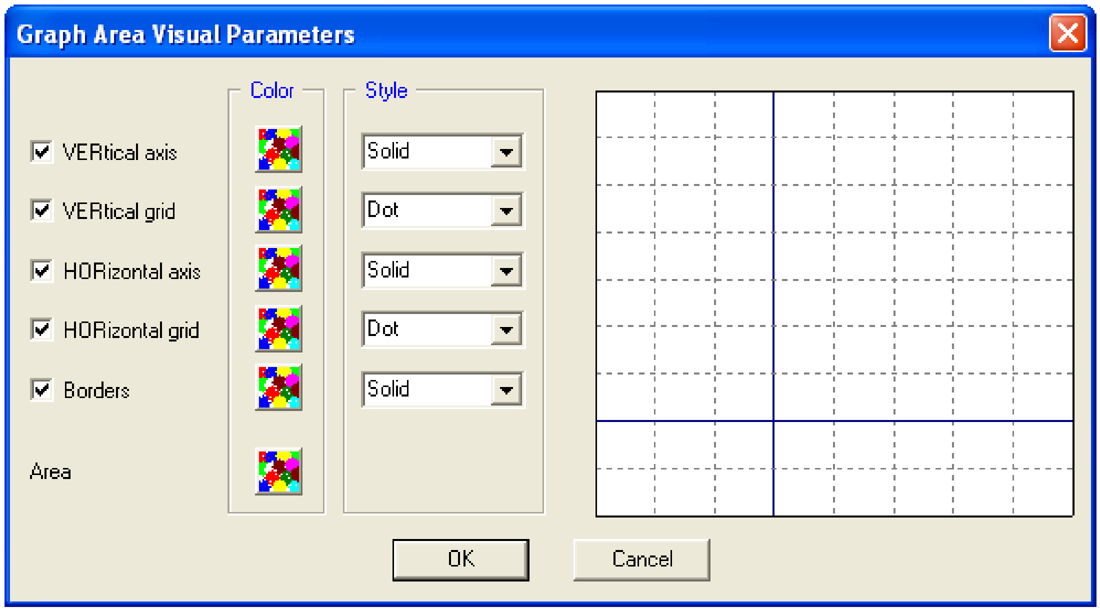


Figure 11-6. Scale Values Dialog

Select the color and line style for the axes, the grid lines, the border and background area. When finished, select the ***OK*** button. The graph view will be displayed with your updated selections.

For printing result clarity, there are additional options:

- Place a check mark in the box labeled ***Use different line styles*** to print each selected item plot in a different line style. This will ensure line clarity on non-color printers.
- Place a check mark in the box labeled ***Numbers on the lines*** to label each selected item plot for identification.
- Select the ***Print*** button to send the graph to a standard Windows® default printer. The Printer Selection dialog will be displayed to allow selection of an appropriate printer.

To retrieve results from a previous PV analysis, select ***Solution>PV previous results***. The PV Analysis – Parameters window is displayed. Select a PV analysis output file by clicking the ***Select…*** button. Choose the output file of interest and select ***Open***. Parameters used for the select PV analysis will be shown. These values are for reference only and are not editable. Select ***Show Results…*** to display the results window (see Figure 11-2).

11.2.2 Performing QV Analysis

To access the QV analysis module:

1. Open an existing data file containing network data (*.*raw*, *.*sav*) by selecting ***File>Open*** from the Main Menu.
2. Select ***PowerFlow>Solution>QV analysis…*** The QV Analysis dialog containing default settings will be displayed as in Figure 11-7.

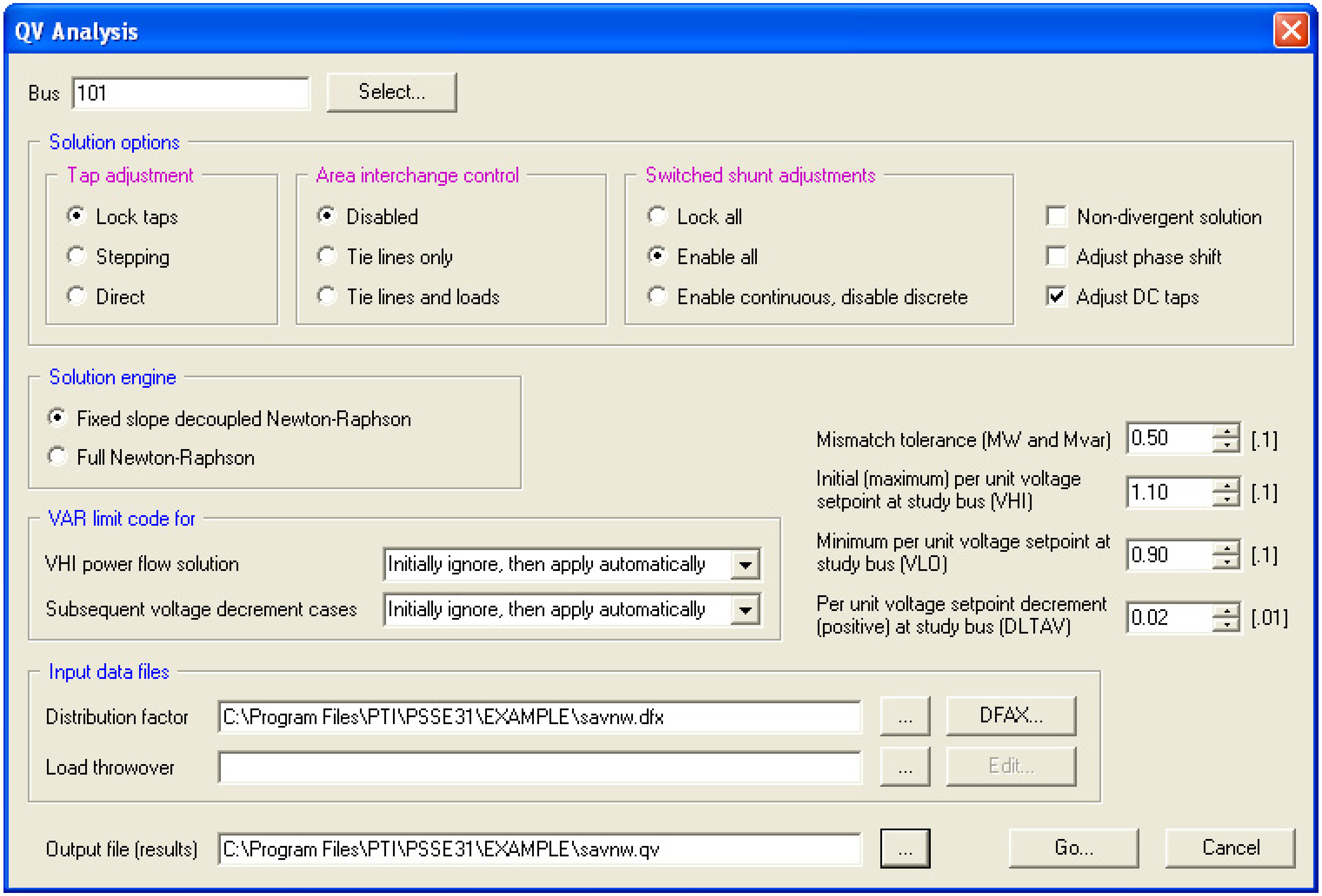


Figure 11-7. QV Analysis Dialog

3. Enter and select the QV analysis options you want for your calculation:

   Tap adjustment: Select transformer tap adjustment options for the series of load flow calculations performed to obtain the QV curves, please refer to Chapter 4 of the *Program Operation Manual, Volume I*.

   Area Interchange control: Select area interchange control options for the series of load flow calculations performed to obtain the QV curves, please refer to Chapter 4 of the *Program Operation Manual, Volume I*.

   Solution options: Select solution options for the series of load flow calculations performed to obtain the QV curves, please refer to Chapter 4 of the *Program Operation Manual, Volume I*.

   Solution engine: Select the solution engines for the series of load flow calculations and contingency studies to obtain the QV curves, please refer to Chapter 4 of the *Program Operation Manual, Volume I*.

   VAR Limit Code: Select the var control options limit code for contingency case initial power flow solution and subsequent transfer increment cases. The var limit control can be set to apply immediately to limit the var output of all generators, or to ignore var limit at initial iterations and then apply automatically afterwards.

   Mismatch tolerance (MW and Mvar): Specify mismatch tolerance. This tolerance will be used to check for largest initial active or reactive power mismatch. If exceeded the process is terminated. This value is also used as the convergence tolerance in the power flow solution of each contingency case; please refer to Chapter 4 of the *Program Operation Manual, Volume I*.

   Initial (maximum) per unit voltage setpoint at study bus (VHI): Specify the maximum voltage of study bus.

   Minimum per unit voltage setpoint at study bus (VLO): Specify the minimum voltage of the study bus.

   Per unit voltage setpoint decrement (positive) at study bus (DLTAV): Specify the voltage increment size from VLO to VHI.

In order to begin calculations, the bus number and two data files are required:

1. The distribution factor input data file (*.dfx*). For more information on the distribution factor input data file, please refer to Chapter 4 of the *Program Operation Manual, Volume I*.

2. The output file (results)(*.qv*). The results of the QV calculation will be stored in the file specified in this field. The results file is provided so that you may view the QV calculation results at a later time by simply selecting the output results file rather than re-running the QV calculations.

Enter and select the parameters that apply and click the ***Go*** button to start the QV calculations. Select ***Cancel*** to close the window and return. The results window for QV analysis will be displayed (see Figure 11-8).

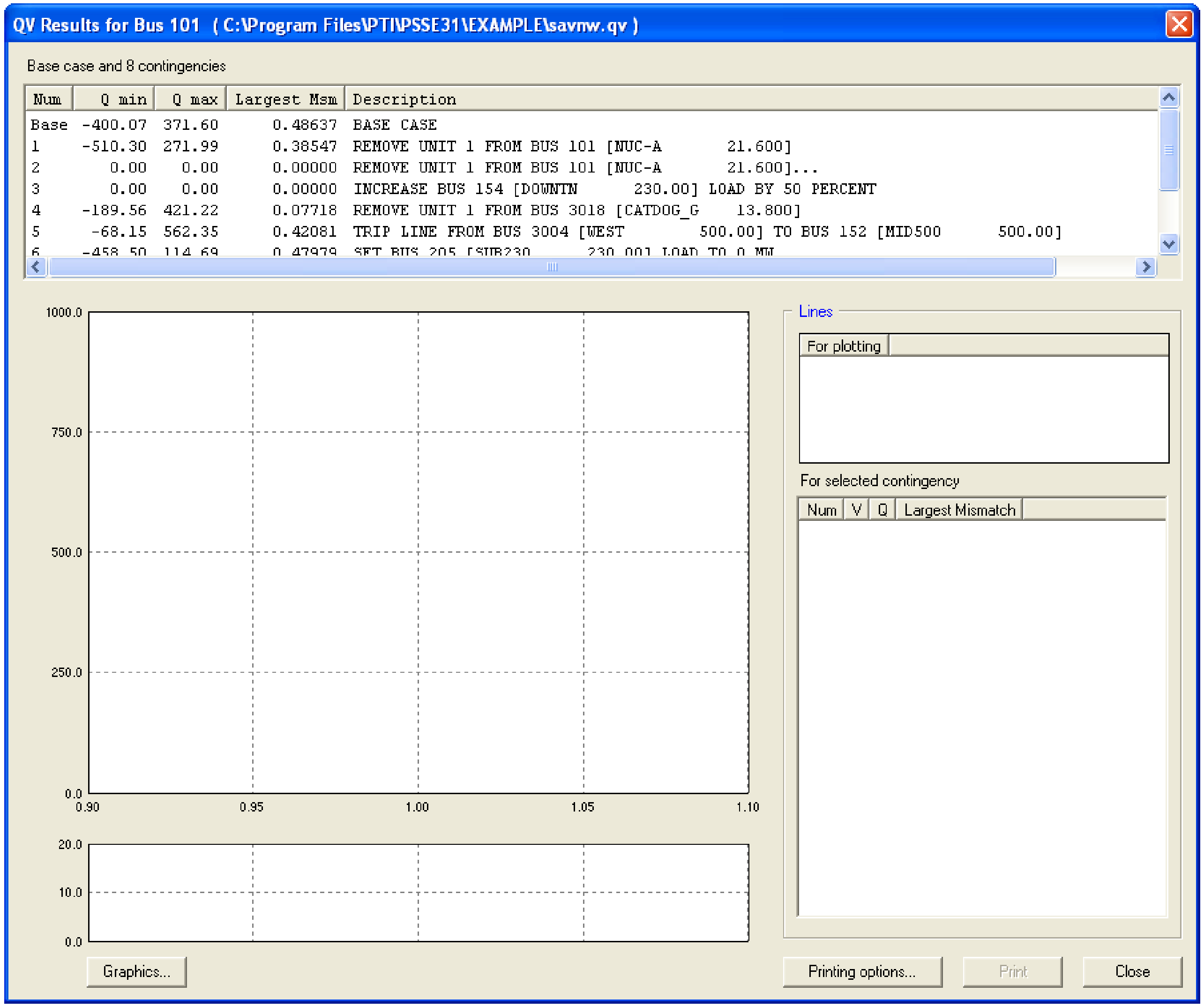


Figure 11-8. QV Analysis Results Window: Calculation Results

Select the base case and/or contingencies. Items in the list may be selected individually or as a continuous set. To select individual items, left-click on the item you want to select. Hold the **[Ctrl]** key down while clicking the left mouse button to select the additional items. To select continuous items, hold the **[Shift]** key down while clicking the left mouse button.

Select the ***Show Graphs*** button to plot the graphs. The graphs will be displayed as shown in Figure 11-9.

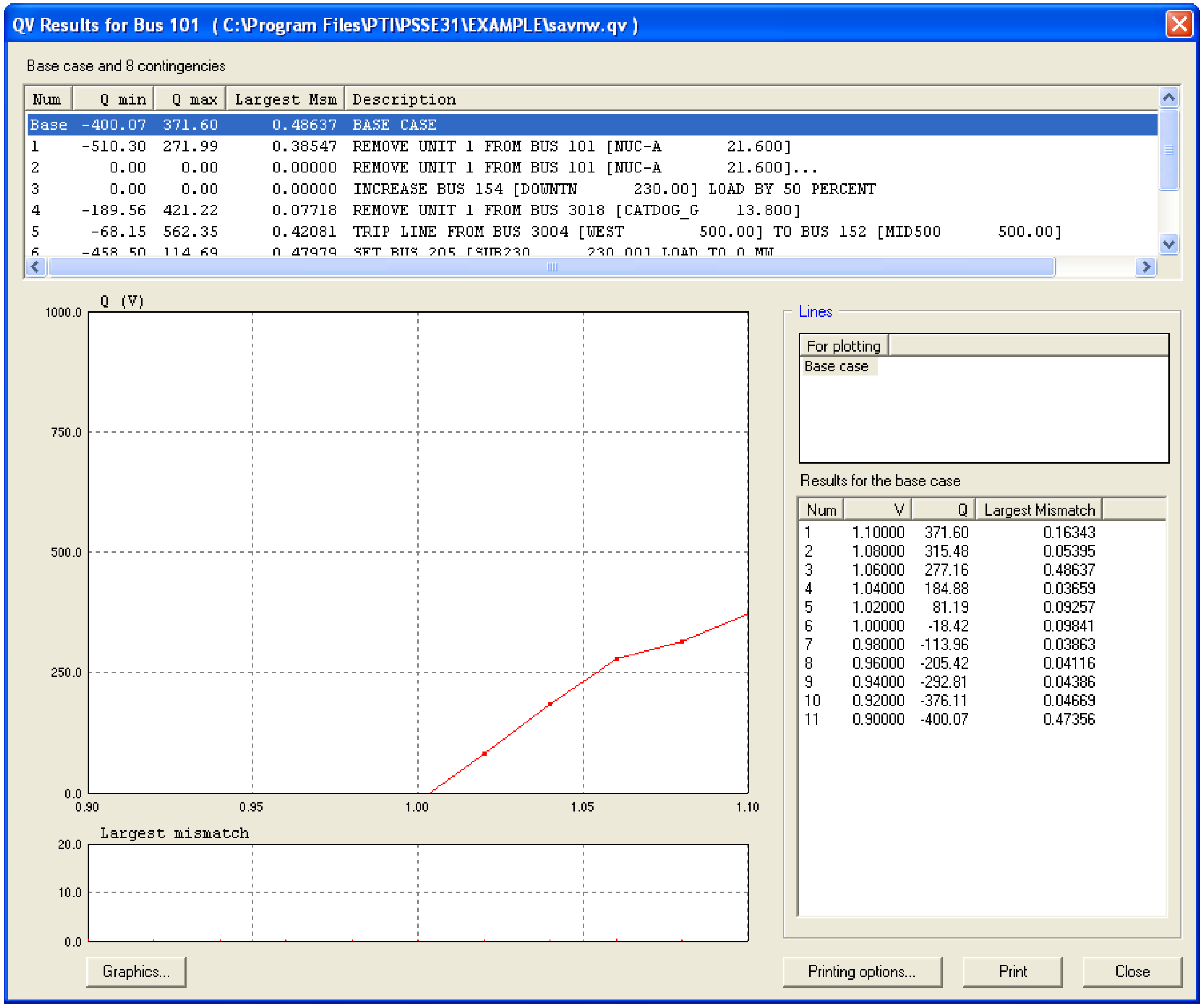


Figure 11-9. QV Analysis Results Window: Graph Results

Graph axes parameters are fully adjustable. To adjust parameters such as decimal places and axis labels, left-click on the axis of interest. The Scale Values dialog is displayed as in Figure 11-10.

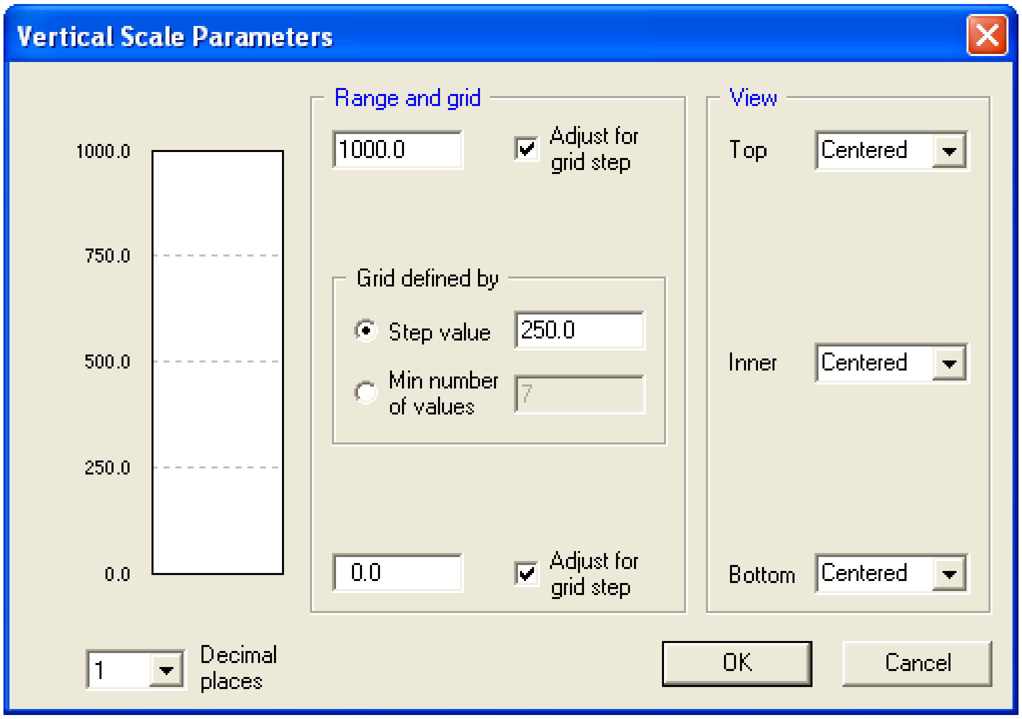


Figure 11-10. Scale Values Dialog

To change the visual parameters of the graph area, left-click on the graph area. The Graph Area Visual Parameters dialog will be displayed (see Figure 11-11).

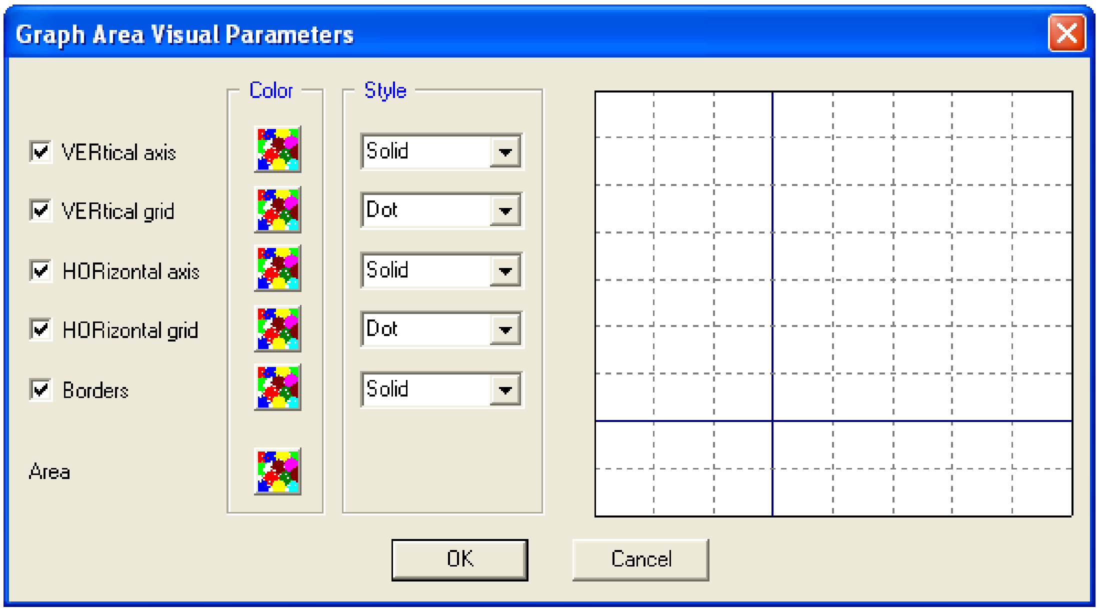


Figure 11-11. Graph Area Visual Parameters Dialog

Select the color and line style for the axes, the grid lines, the border and background area. When finished, select the ***OK*** button. The graph view will be displayed with your updated selections.

For printing result clarity, there are additional options:

- Place a check mark in the box labeled ***Use different line styles*** to print each selected item plot in a different line style. This will ensure line clarity on non-color printers.
- Place a check mark in the box labeled ***Numbers on the lines*** to label each selected item plot for identification.
- Select the ***Print*** button to send the graph to a standard Windows® default printer. The Printer Selection dialog will be displayed to allow selection of an appropriate printer.

To retrieve results from a previous QV analysis, select ***Solution>QV previous results***. The QV Analysis – Parameters window is displayed. Select a QV analysis output file by clicking the ***Select…*** button. Choose the output file of interest and select ***Open***. Parameters used for the select QV analysis will be shown. These values are for reference only and are not editable. Select ***Show Results…*** to display the results window (see Figure 11-8).

11.3 Basic Engineering Guide to PV and QV Curves Applications

11.3.1 Objective

The objective of a PV and QV curves is to determine the ability of a power system to maintain voltage stability at all the buses in the system under normal and abnormal steady state operating conditions. They are useful, for example:

- To show the voltage collapse point of the buses in the power system network.
- To study the maximum transfer of power between buses before voltage collapse point.
- To size the reactive power compensation devices required at relevant buses to prevent voltage collapse.
- To study the influence of generator, loads and reactive power compensation devices on the network.

The PV and QV curves are obtained through a series of AC load flow solutions. The PV curve is a representation of voltage change as a result of increased power transfer between two systems, and the QV curve is a representation of reactive power demand by a bus or buses as voltage level changes.

11.3.2 PV Analysis (PV Curves) Applications

PV curves are parametric study involving a series of AC load flows that monitor the changes in one set of load flow variables with respect to another in a systematic fashion. This approach is a powerful method for determining transfer limits which account for voltage and reactive flow effects. As power transfer is increased, voltage decreases at some buses on or near the transfer path. The transfer capacity where voltage reaches the low voltage criterion is the low voltage transfer limit. Transfer can continue to increase until the solution identifies a condition of voltage collapse; this is the voltage collapse transfer limit.

This can be demonstrated using a simple two terminals network as in Figure 11-12. From reference P. Kundur, Power System Stability and Control, McGraw-Hill 1994, the power flow relationship between the source and the load can be summarized by equations (11.1) and 11.2).

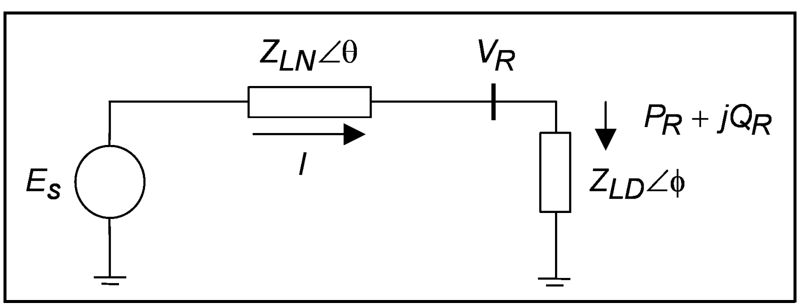


Figure 11-12. Two Terminals Simple Network

$$P_R = V_R I\cos\phi = \frac{Z_{LD}}{F}\left(\frac{E_s}{Z_{LN}}\right)^2\cos\phi \tag{11.1}$$

$$V_R = \frac{1}{\sqrt{F}} \frac{Z_{LD}}{Z_{LN}} E_S \tag{11.2}$$

where:

$$F = 1 + \left(\frac{Z_{LD}}{Z_{LN}}\right)^2 + 2\left(\frac{Z_{LD}}{Z_{LN}}\right)\cos(\theta - \phi)$$

The loading of the network can be increased by decreasing the value if Z_{LD}. This is done with E_S, load power factor and line parameters fixed. From equation (11.1), as ZLD is decreased gradually the load power, P_R, increases, hence the power transmitted will increase. As the value of Z_{LD} approaches Z_{LN} the value of P_R starts to decrease gradually due to F. However, from equation (11.2) as Z_{LD} decreases the receiving voltage V_R decreases gradually.

The plot of the relationship between voltage at the receiving end, V_R, and the load power, P_R, as the power transfer is increased due to increase loading, gives the PV curves similar in characteristic to the curve shown in Figure 11-13.

PV curves are typically used for the "knee curve analysis". It is as named because of its distinctive shape at the point of voltage collapse as the power transfer increases, as shown in Figure 11-13. Depending on the transfer path, different buses have different knee point. The buses closer to the transfer path will normally exhibit a more discernible knee point.

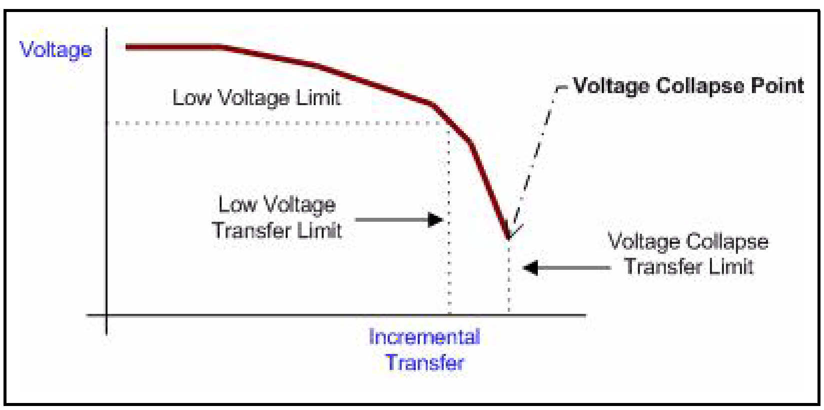


Figure 11-13. PV Curves Voltage and Incremental Power Transfer Characteristics

Voltage instability occurs at the "knee point" of the PV curve where the voltage drops rapidly with an increase in the transfer power flow. Load flow solution will not converge beyond this limit, indicating voltage instability. Operation at or near the stability limit is impractical and a satisfactory operating condition must be ensured to prevent voltage collapse.

In PSS™E, the PV curves are generated by selecting two subsystems where the power transfer between the subsystems is incremented in a defined step size for a series of AC load flow calculations while the bus voltages, generator outputs and the branch flows of the system are monitored. When the bus voltages are plotted as a function of the incremental power transfer the PV curves are obtained. One of the subsystems in the study must be defined as the study (source) system and another as the opposing (sink) system. The power flows from the study subsystem to the opposing subsystem.

Figure 11-14 shows the PV curves of a bus 203 in an example network under normal and various contingency conditions. The maximum transfer limit for this bus in base case is approximately 750 MW. The maximum transfer limit decreases under contingency conditions. The response shown is expected since under network contingencies the loading of the line will increase. These curves can be used to set transfers or local generation dispatch so that the system will not fall below the knee point following a disturbance (i.e., loss of lines).

The PV curves for different buses under the same network conditions (base case or contingency) can also be plotted in the results window as shown in Figure 11-15. The plots of three different buses in base case indicate that the "knee point" is below the 90% of the nominal voltage and the transfer limit is approximately 750 MW. However, this transfer limit is not reasonable as voltages below 90% will cause motors in the system to stall. The transfer limit should be set for voltages in the vicinity of 95% of the nominal voltage.

The distribution of generations between the generators in the system as a result of the power transfer can be observed by analyzing their relationship as shown in Figure 11-16.

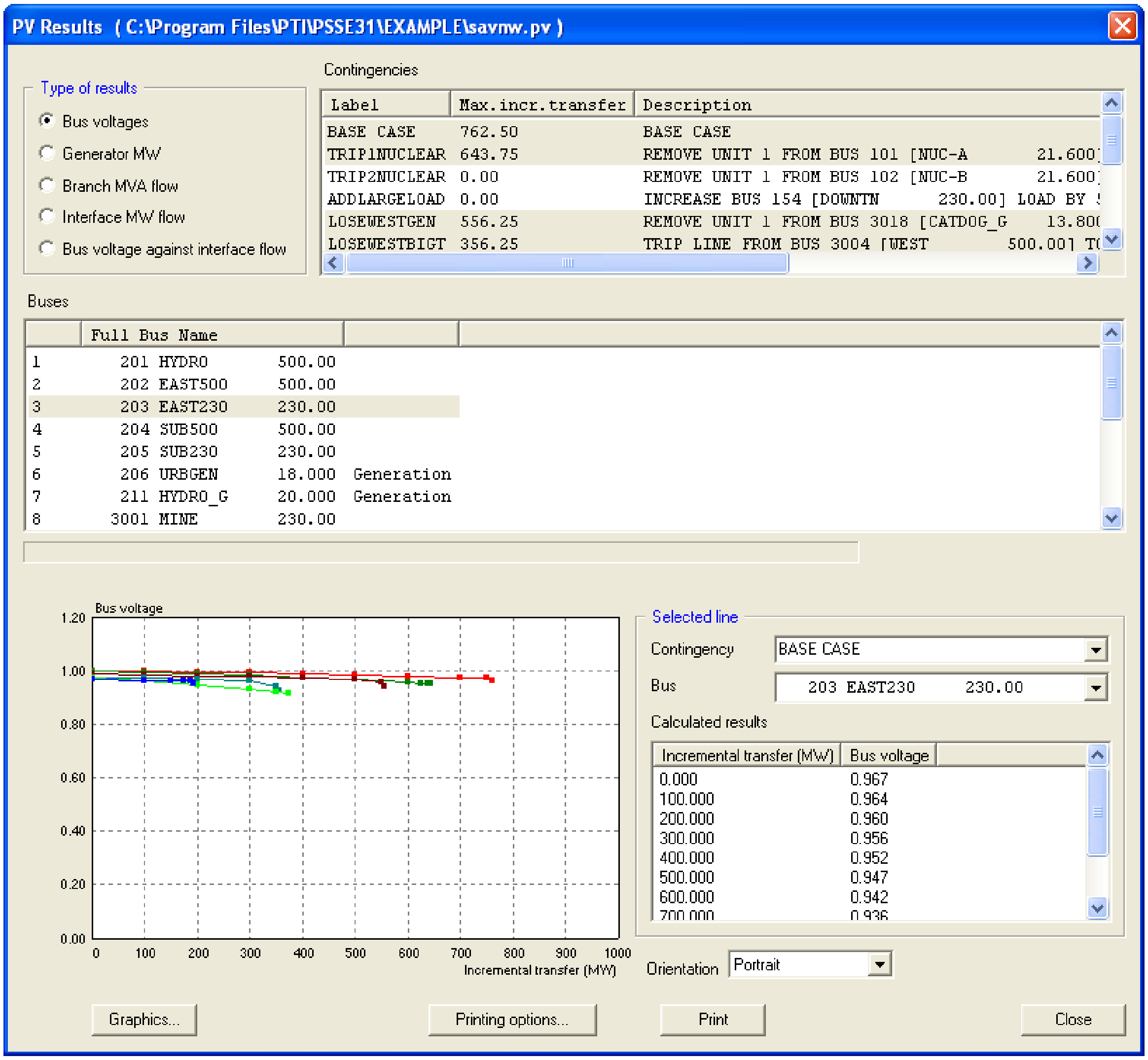


Figure 11-14. PV Curves Voltage and Incremental Power Transfer Characteristics for Bus 203 under Different Network Conditions

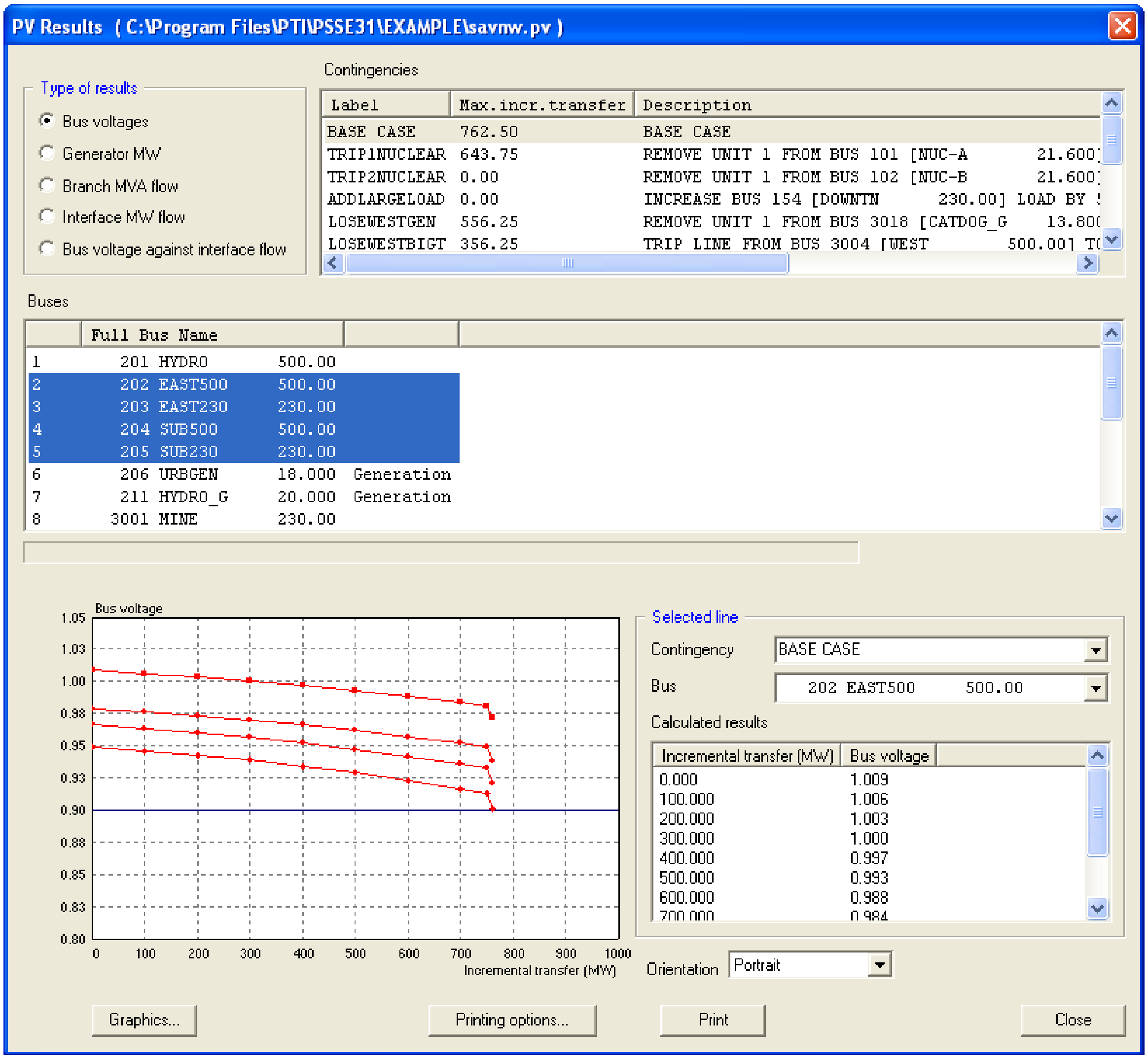


Figure 11-15. PV Curves Voltage and Incremental Power Transfer Characteristics for Different Buses in Base Case

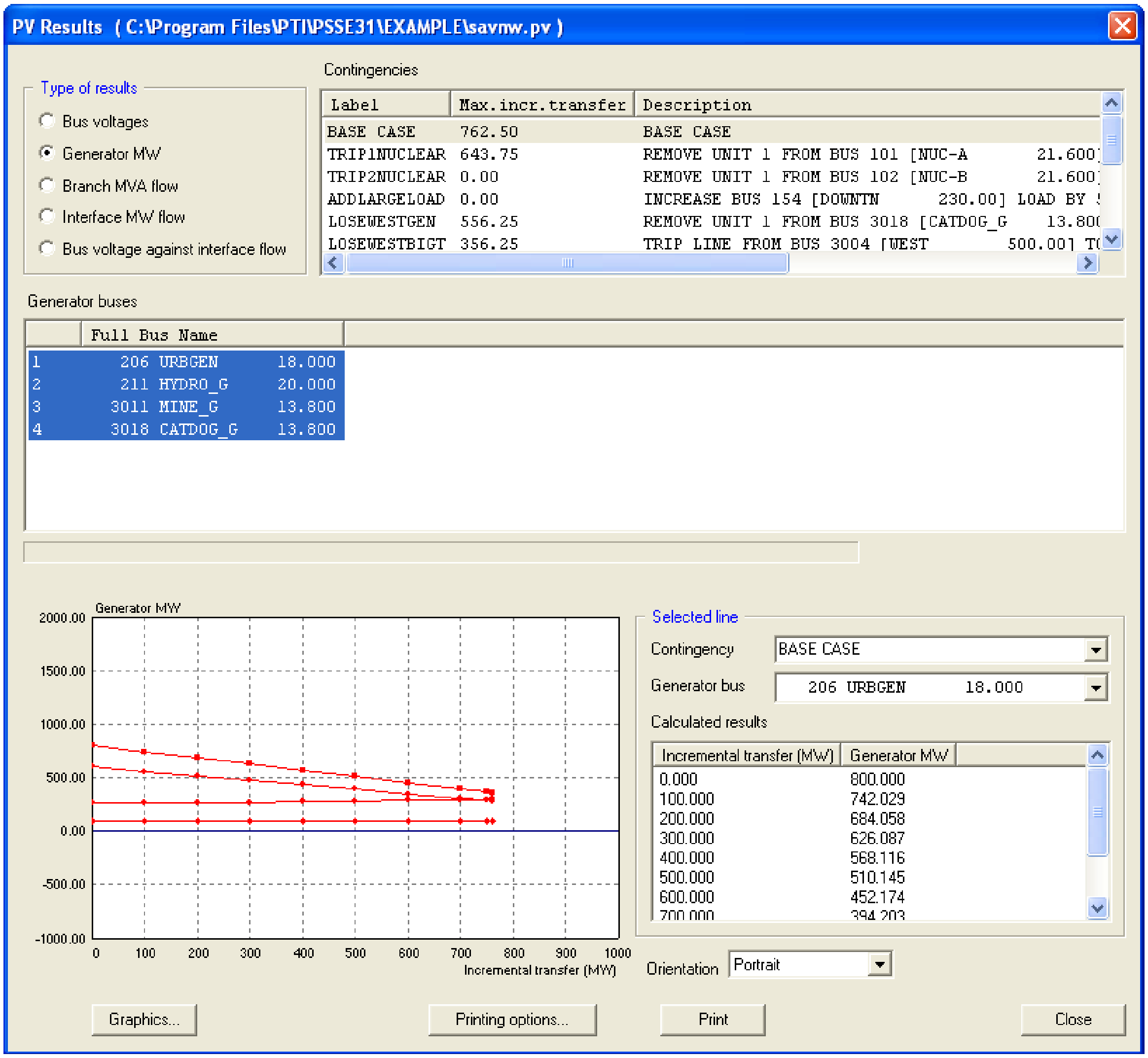


Figure 11-16. Generator Output Versus Power Transfer Curves

11.3.3 QV Analysis (QV Curves) Applications

In the PV curve analysis we have demonstrated the effect of active power flow on voltage instability. However, if we revisit equations (11.1) and (11.2), we see that the power factor of the load has a significant impact on the overall equations. This is to be expected since the voltage drop in the line is a function of both active and reactive power transfer. Hence, the QV curves may also be used to assess voltage stability of the system.

QV curves are used to determine the reactive power injection required at a bus in order to vary the bus voltage to the required value. The curve is obtained through a series of AC load flow calculations. Starting with the existing reactive loading at a bus, the voltage at the bus can be computed for a series of power flows as the reactive load is increased in steps, until the power flow experiences convergence difficulties as the system approaches the voltage collapse point.

Figure 11-17 is a typical of the QV curves that will be generated for a system that is stable at moderate loading and unstable at higher loadings.

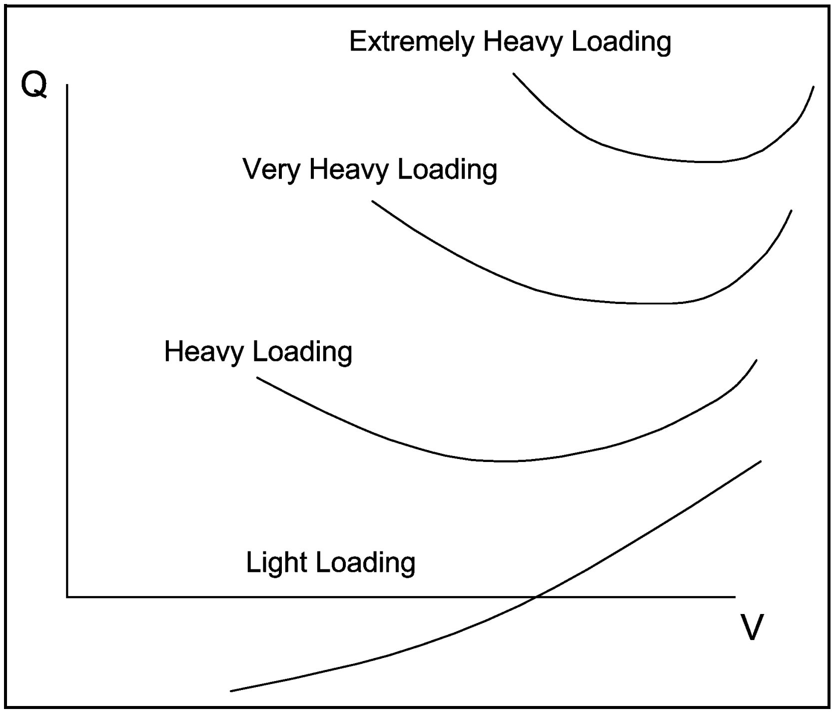


Figure 11-17. QV Curves for a Range of System Loading

The bottom of the QV curve, where the change of reactive power, Q, with respect to voltage, V (or derivative dQ/dV) is equal to zero, represents the voltage stability limit. Since all reactive power compensator devices are designed to operate satisfactorily when an increase in Q is accompanied by an increase in V, the operation on the right side of the QV curve is stable, whereas the operation on the left side is unstable. Also, voltage on the left side may be so low that the protective devices may be activated.

The bottom of the QV curves, in addition to identifying the stability limit, defines the minimum reactive power requirement for the stable operation. Hence, the QV curve can be used to examine the type and size of compensation needed to provide voltage stability. This can be performed by superimposing the QV characteristic curves of the compensator devices on that of the system. For instance the capacitor characteristic can be drawn over the system's QV curves as shown in Figure 11-18.

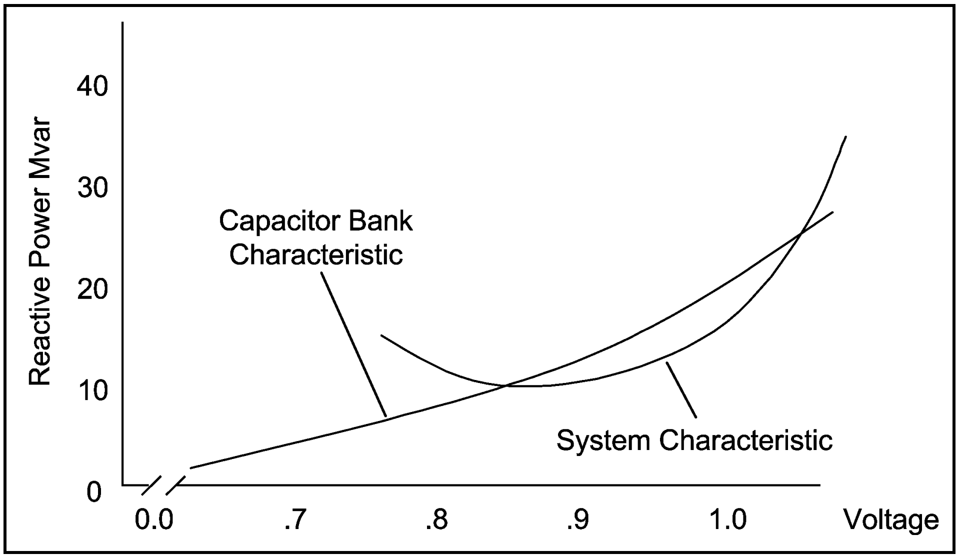


Figure 11-18. QV Curves and Characteristics of a Capacitor Bank Required at Stable Operating Point

Figure 11-19 shows the QV curves for a range of capacitor banks with different rating superimposed on the system's QV curves under different loading conditions. From the plot we can determine that capacitor rating of 300 Mvar is required to maintain 1 pu voltage at loading of 1300 MW, 450 Mvar at 1500 MW and so on.

For the case of very high loading at 1900 MW, even though the capacitor bank rating of 950 Mvar can maintain a voltage of 1 pu, point B is not a stable operating point. If there is a drop in voltage from point B to B', the ability of the capacitor to supply reactive power is decreased more than the drop in requirement of the system. This will result in continuous drop in voltage. Alternatively, if the voltage is increased above point B, the capacitor will supply more reactive power than the increase in requirement of the system. This will result in continuous rise in voltage.

Hence, the criterion for stable operating point when using a reactive power compensator is as follow:

System dQ/dV > Compensator dQcomp/dV

where:

dQ/dV	is the change of the system's reactive power, Q, with respect to voltage, V.
dQcomp/dV	is the change of the compensator's reactive power output, Qcomp, with respect to voltage, V.

For the case of light loading at 1300 MW with capacitor rating of 300 Mvar, point A is a stable operating point. If the voltage is increased from point A to A', the capacitor will supply less reactive power than the increase in system's demand, hence reducing the voltage to 1 pu. Alternatively, if the voltage is decreased from point A towards the bottom of the QV curve, the capacitor will supply more reactive power than the system's demand, hence returning the voltage to 1 pu.

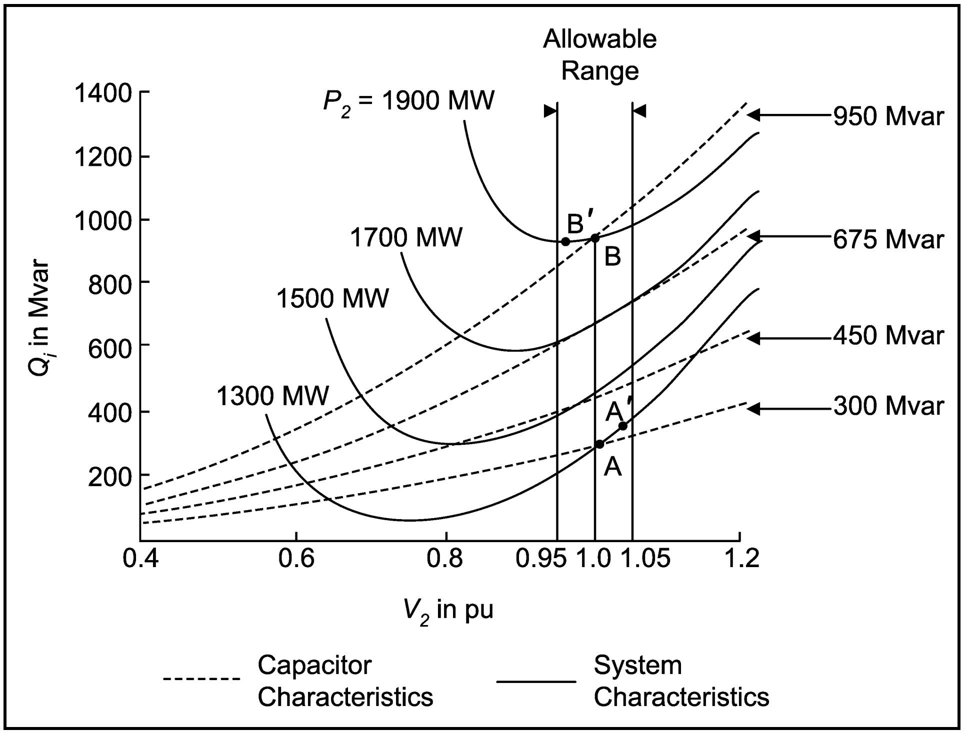


Figure 11-19. Compensator Operations and Size on Voltage Stability using QV Curves

In PSS™E, the QV curves are generated by artificially introducing a synchronous condenser, with high reactive power limits, at a bus to make this a PV bus. As the scheduled voltage set point (bus voltage) of the PV bus is varied in steps for a series of AC load flow calculations, the reactive power output from the condenser is monitored. When the reactive power is plotted as a function of the bus voltage a QV curves are obtained.

QV curves are commonly used to identify voltage stability issues and reactive power margin for specific locations in the power system under various loading and contingency conditions. The QV curves are also used as a method to size shunt reactive compensation at any particular bus to maintain the required scheduled voltage.

Figure 11-20 shows QV curves for bus 203 in an example network. From the curves we can determine the reactive power required to hold the desired scheduled voltage in the base case and under various contingencies. In this example, the reactive power required is approximately 110 Mvar to hold the scheduled voltage at bus 203 at 1.0 pu in the base case.

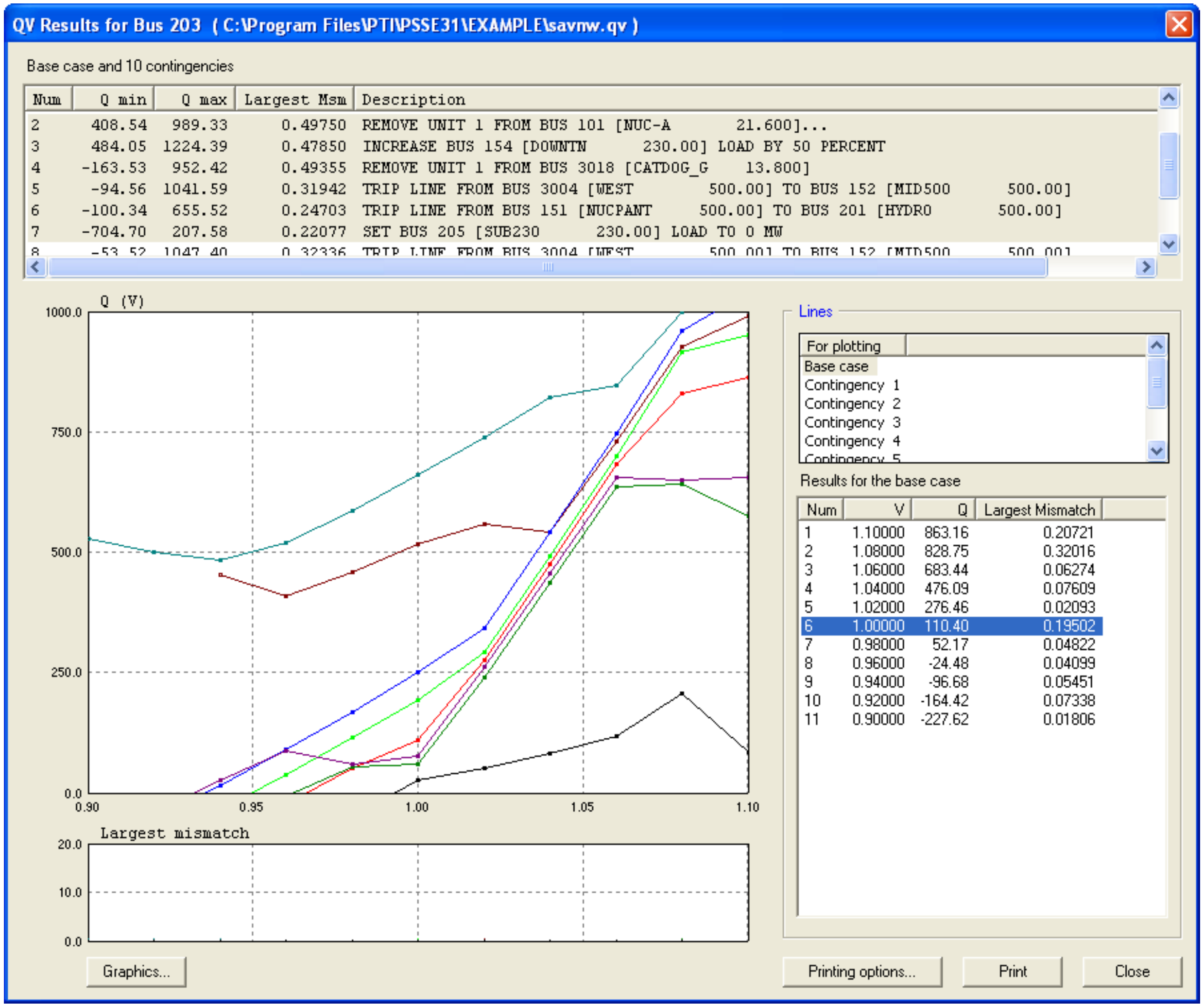


Figure 11-20. QV Curves under Various Contingencies for Bus 103

Figure 11-21 show the QV curves of bus 103 in base case under higher loading conditions. It is observed that the demand for reactive power to hold the scheduled voltage at 1.0 pu increases with loading.

There are no functions in PSS™E QV Analysis that allow super-imposing of compensator QV characteristics over that of the system. However, this can be performed using IPLAN or Python programming tools.

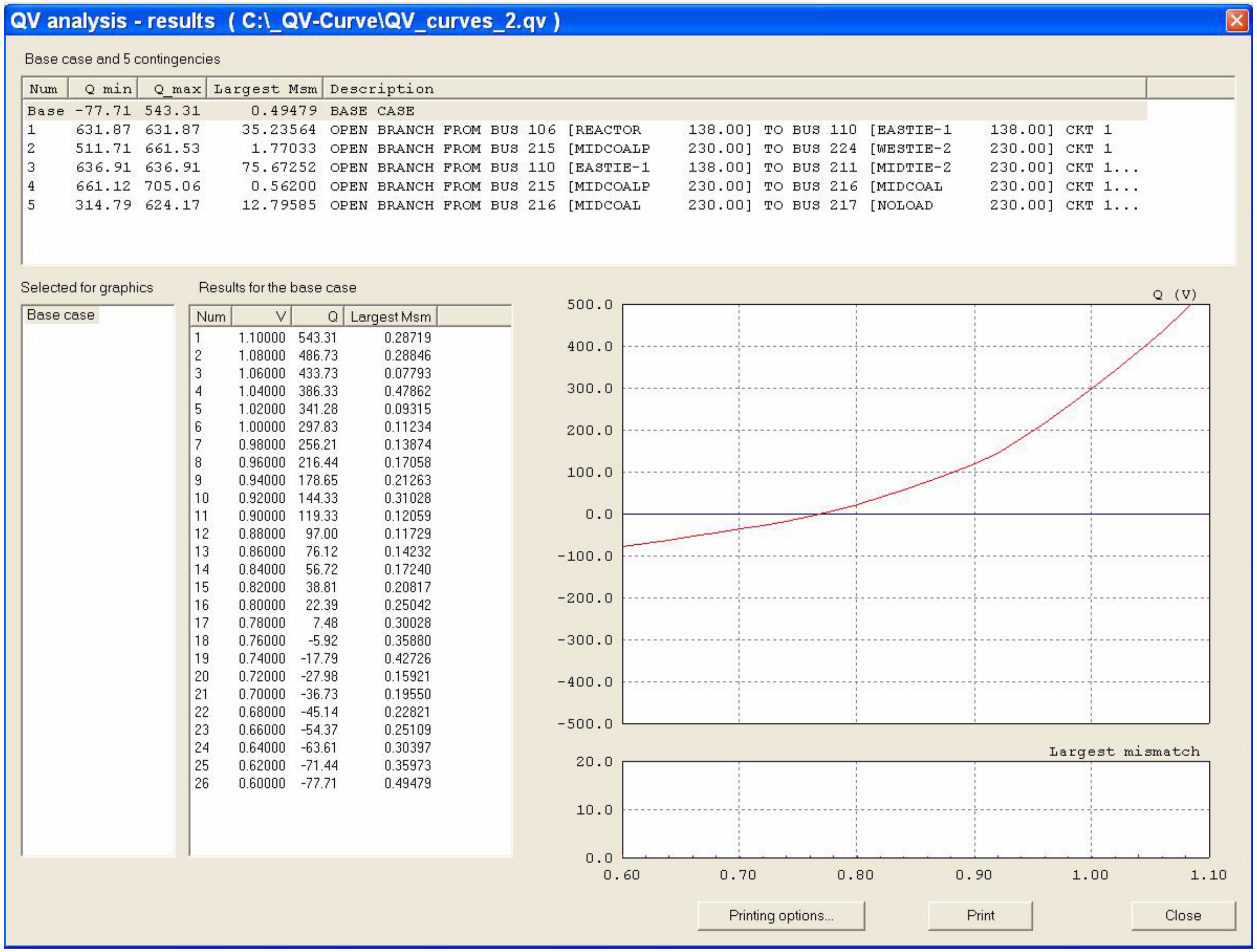
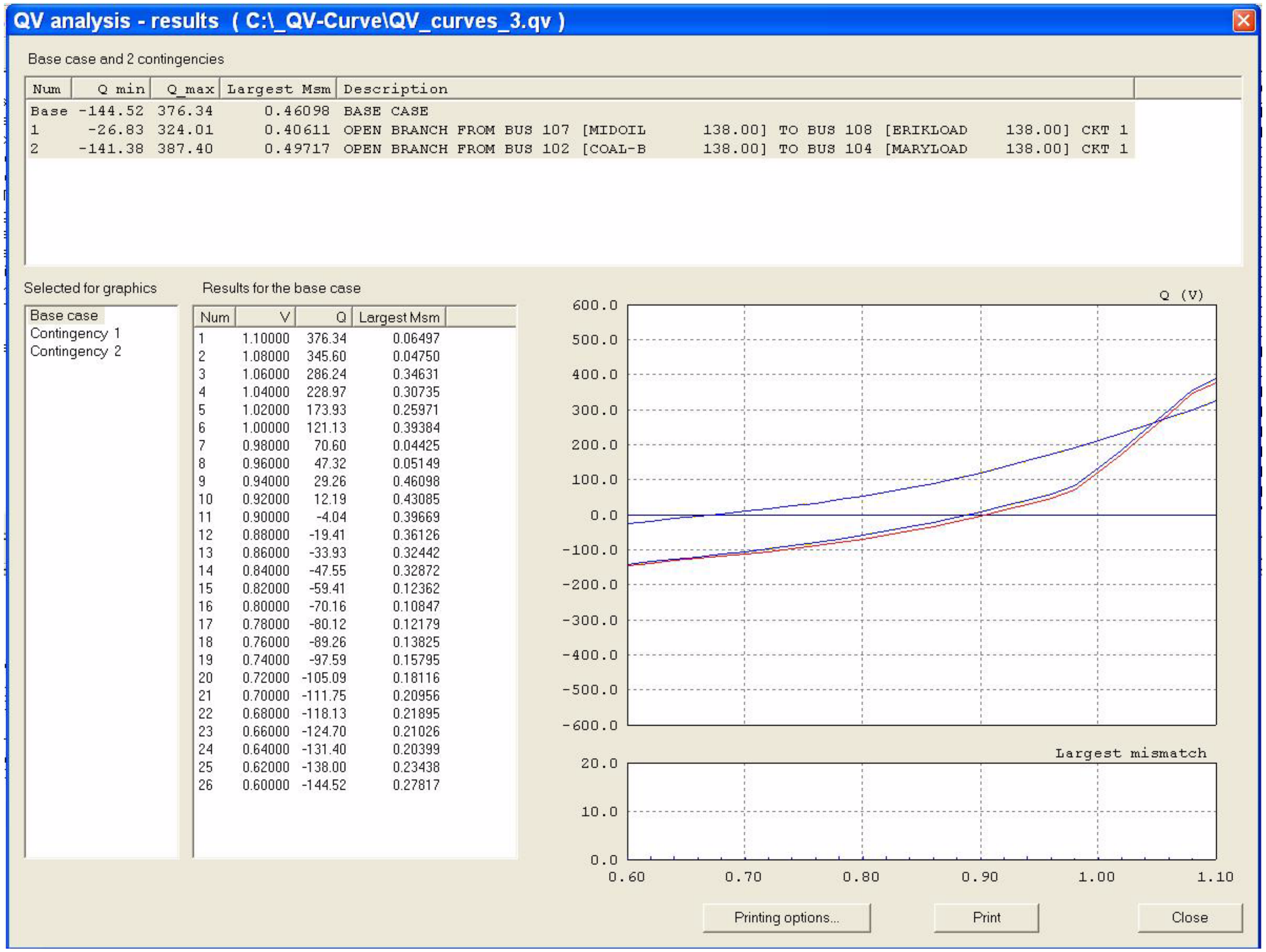


Figure 11-21. QV Curve in Base Case with Increase in Load on Bus 103

The shape of the QV curves can also be used to determine the load characteristic, and study the effect of load tap changer (LTC) transformer on the system. Figure 11-22 shows the QV curve on bus 108 of the example system. The load on the bus 108 is of constant current type controlled by a LTC transformer. It is observed that the QV curves are slightly shaped like an 'S'. The S-shape characteristics are due to the load type in the system and the action of the LTC transformer as illustrated in Figure 11-23.


QV analysis - results (C:_QV-Curve\QV_curves_3.qv)

Base case and 2 contingencies

Num	Q min	Q_max	Largest Msm	Description
Base	-144.52	376.34	0.46098	BASE CASE
1	-26.83	324.01	0.40611	OPEN BRANCH FROM BUS 107 [MIDOIL 138.00] TO BUS 108 [ERIKLOAD 138.00] CKT 1
2	-141.38	387.40	0.49717	OPEN BRANCH FROM BUS 102 [COAL-B 138.00] TO BUS 104 [MARYLOAD 138.00] CKT 1

Selected for graphics

Base case
Contingency 1
Contingency 2

Results for the base case

Num	V	Q	Largest Msm
1	1.10000	376.34	0.06497
2	1.08000	345.60	0.04750
3	1.06000	286.24	0.34631
4	1.04000	228.97	0.30735
5	1.02000	173.93	0.25971
6	1.00000	121.13	0.39384
7	0.98000	70.60	0.04425
8	0.96000	47.32	0.05149
9	0.94000	29.26	0.46098
10	0.92000	12.19	0.43085
11	0.90000	-4.04	0.39669
12	0.88000	-19.41	0.36126
13	0.86000	-33.93	0.32442
14	0.84000	-47.55	0.32872
15	0.82000	-59.41	0.12362
16	0.80000	-70.16	0.10847
17	0.78000	-80.12	0.12179
18	0.76000	-89.26	0.13825
19	0.74000	-97.59	0.15795
20	0.72000	-105.09	0.18116
21	0.70000	-111.75	0.20956
22	0.68000	-118.13	0.21895
23	0.66000	-124.70	0.21026
24	0.64000	-131.40	0.20399
25	0.62000	-138.00	0.23438
26	0.60000	-144.52	0.27817

Figure 11-22. S-Shaped QV Curve on Bus 108

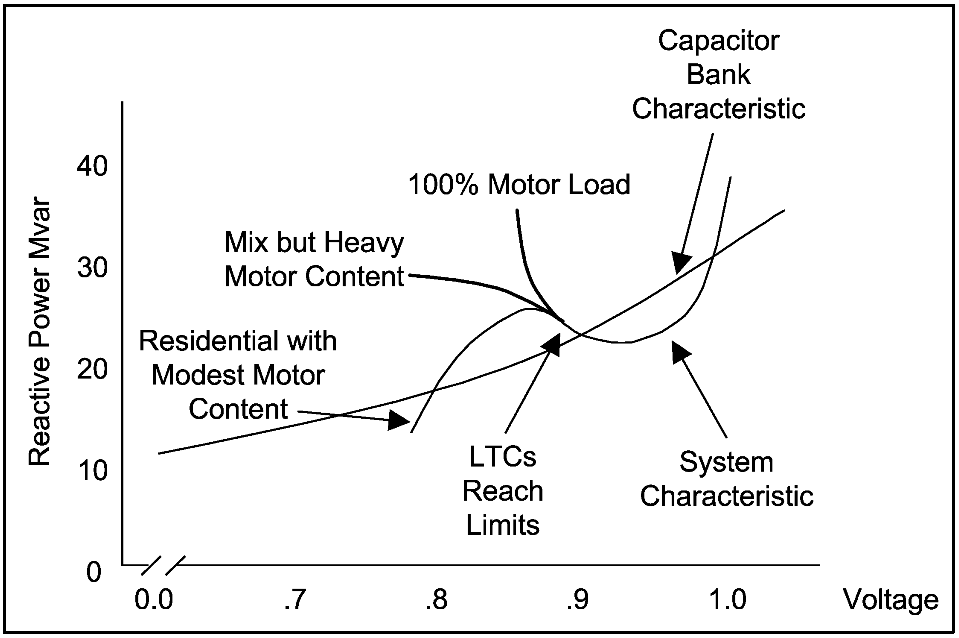


Figure 11-23. QV Curves for Different Load Type with Consideration of LTC

11.4 How to Implement a Specific PV Transfer

Often, it is important to study the performance of the power system at or near the transfer limit which had been determined by a PV analysis study. The implement PV transfer function may be used to implement a transfer between designated "source" and "sink" systems using the same transfer dispatch methods that are available in the PV analysis function.

To impose a designated transfer:

1. Open the Saved Case File containing the power flow case on which the transfer is to be imposed by selecting the ***File>Open*** menu entry. Normally, the same Saved Case File on which an earlier PV analysis calculation had been performed is specified.

2. Select the ***Power Flow>Solution>Implement PV transfer…*** menu entry. The Implement PV Transfer dialog containing default settings will be displayed (see Figure 11-24).

3. Specify the same Distribution Factor Data File, "source" and "sink" systems, and transfer dispatch method data as was specified in the earlier PV analysis calculation.

4. Specify the desired transfer increment.

5. Press the ***OK*** button.

The implement PV transfer function then changes the generation or load, as appropriate, at those subsystem buses participating in the transfer.

Details on the transfer may be examined using the Powerflow Cases tab of the ***File>Compare…*** menu entry.

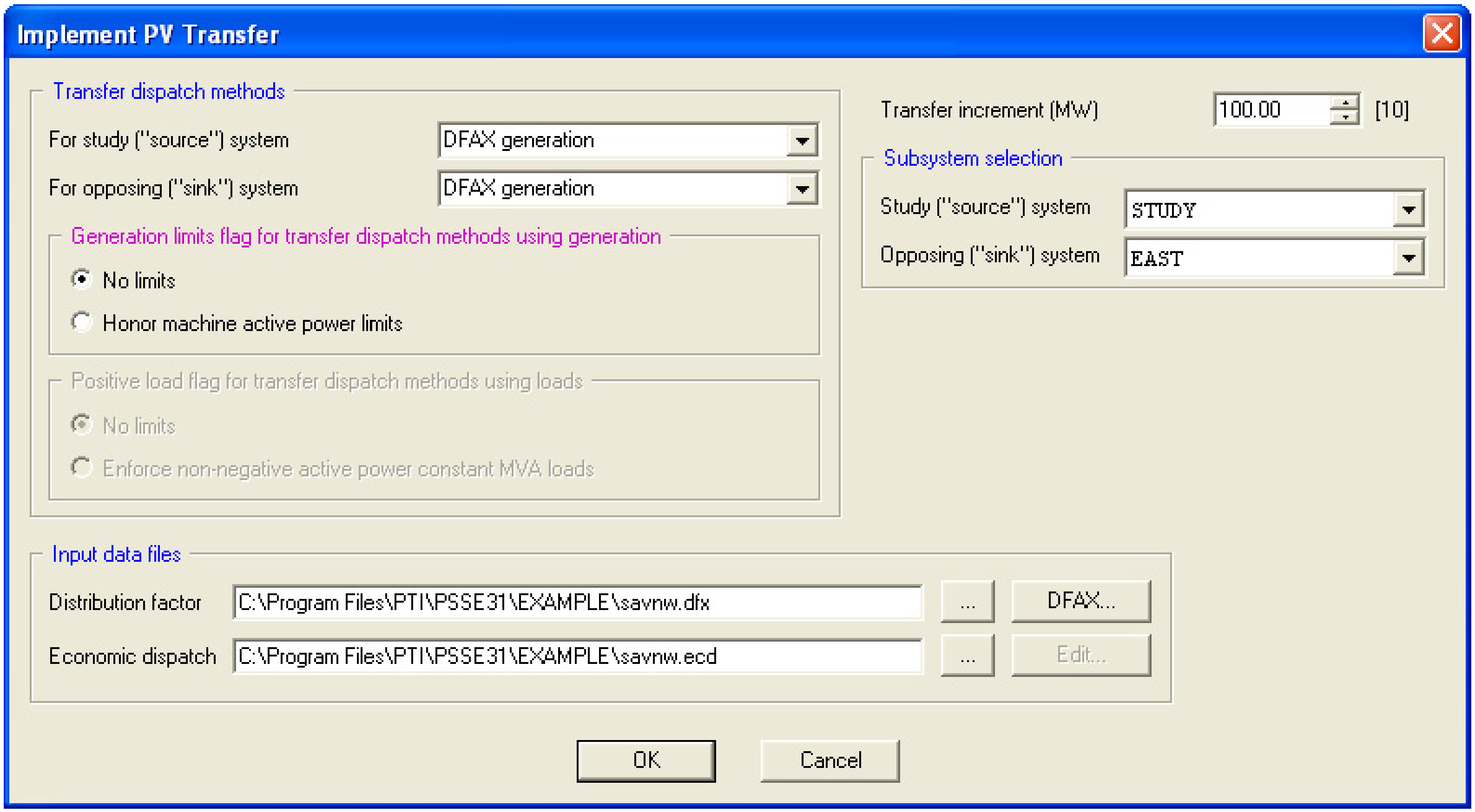


Figure 11-24. Implement PV Transfer Dialog

Chapter 12

Program Automation

12.1 What is Program Automation?

Program automation in PSS™E provides the mechanism to control PSS™E execution other than by direct user interaction. This is the ability to define a set of operations for PSS™E to perform in a file of some kind (explained in the following sections) and to tell PSS™E to use the instructions in that file as a single command. We will call these files Automation Files. There are two primary ways to use Automation Files:

- As a program extension. In this case the user, in the course of using the program interactively, can decide to select an existing Automation File as the next instruction to the program.
- For un-attended execution. This is commonly called batch execution. In this case the entirety of the user's interaction would be the specification of the source of the instructions for it to execute (although there may be other options specified at the same time).

Although there are a few minor exceptions, for the most part the specification of the instructions, i.e. the contents of the Automation File, is the same in both cases.

The following sections will concentrate on the first alternative. Near the end of the chapter is a section on batch execution. There is also a section on entering single commands; while not a program automation method it uses the commands defined here and is best understood in this context.

12.2 Controlling PSS™E Execution Using the API

An Application Program Interface (API) is a set of callable routines for building software applications. PSS™E has a supported, documented API available for use with PSS™E. The API is the primary and recommended method for accessing PSS™E functionality for automation. The PSS™E API is described in *PSS™E Application Program Interface (API)*. That manual includes descriptions of the syntax for using each API routine in each automation method in which it is supported. Not every API routine is supported in every automation method.

In most cases the API manual will also describe the syntax for calling an equivalent Fortran subroutine.

Siemens PTI will support users who make use of the API through the automation methods described here, such as batch commands and Python programs, only. No support is provided for Fortran or, say, C applications developed by users of PSS™E.

12.3 Automation Methods in PSS™E

There are six automation processors PSS™E:

- An embedded Python interpreter
- The Batch (or BAT_) Command interpreter
- The Line Mode Interpreter (LMI)
- The IPLAN simulator
- The PSS™E Simulation Run Assembler (PSAS) macro processor
- The PSS™E Engineering Basic (PSEB) macro processor

Automation files can be run from within the PSS™E user interface using the ***I/O Control>Run Program Automation File…*** option. Figure 12-1 shows the dialog for selecting an Automation File:

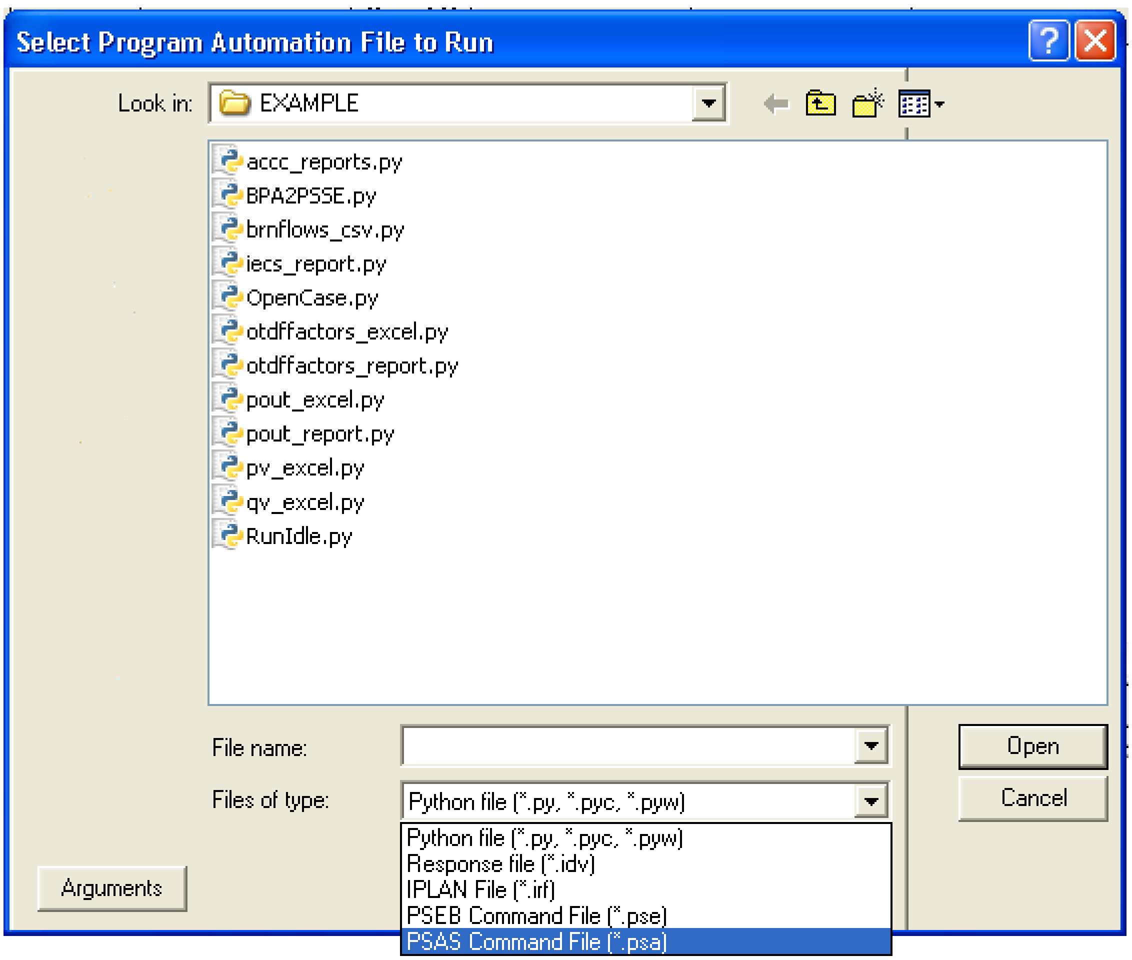


Figure 12-1. Select Automation File

Only five file types are shown. This is because Line Mode commands and Batch commands can be intermingled in the same file, so the **Response File** file type (*.idv) is used for either (or both).

Some general observations are appropriate at this point:

- Python and IPLAN are both programming languages, i.e. they can be used to write any kind of a program, not just control PSS™E (although IPLAN's features are fairly limited, relatively speaking).
- IPLAN programs must be compiled (they do not need to be linked). The compiler (called IPLAN) is a Siemens PTI product and supplied with PSS™E. The source files are of file type *.ipl. The result (*.irf) are not object code files in the normal sense, but a unique format.
- Python programs are interpreted (one command at a time is executed - no compilation is necessary); although Python does support optional byte-compilation.
- PSEB and PSAS commands can also be embedded in Response Files, albeit in a particular context.
- Python programs can use existing IPLAN programs and Response Files. The other automation methods can all interact with each other.
- Response Files, PSAS, and PSEB Command Files are free-format data files.

12.4 Python Programs

Python is an OSI certified, freely available, object-oriented, interpreted programming language. It's syntax and usage are well-documented on the web and in numerous publications, so we will concentrate here solely on its interaction with PSS™E.

A Python installer is included in the PSS™E program installation package for your convenience. The language can also be downloaded from the official Python site at http://www.wxpython.org/. Python language documentation, extension modules, book recommendations, and user forums are also available directly from this site. Siemens PTI recommends the following textbooks for reference:

- *Learning Python* - Lutz and Ascher
- *Python Essential Reference* - Beazley
- *Programming Python* - Lutz
- *Python in a Nutshell* - Martelli
- *Python Cookbook* - Martelli and Ascher
- *Python Programming on Win32* - Hammond and Robinson

Siemens PTI supports the use of Python programs within PSS™E, however, the language itself is not supported nor maintained by Siemens PTI staff.

The PSS™E installation package will also install the following freely available third-party extension modules:

- wxPython (http://www.wxpython.org//)
- win32all (Python Extensions for Windows) (http://sourceforge.net/projects/pywin32/)

Python files can be in source form (*.py, *.pyw) or byte-compiled (*.pyc). Python Files can be used in PSS™E in any of the following ways:

- from the ***Run Program Automation File…*** (see Section 12.3)
- At program startup by using the ***-pyfile*** option (see Section 12.13)

12.4.1 PSS™E Extension Modules For Python

One of Python's greatest strengths is its ability to be easily extended. These extensions can be written in Python or in "system" languages (C/C++, Fortran, etc.). Libraries and legacy code can be therefore be made accessible in Python. It is also an excellent "glue" language in that it can "talk" to other programs and processes (e.g. Microsoft® Excel). Extensions are accomplished through the creation and use of packages that Python calls **modules**.

Many extension modules are currently available on the Internet for download including: numeric processing and optimization, graphic and data visualization (plotting), database connectivity, graphical user interface programming, XML and text processing, network programming and connections to Microsoft® Excel and Microsoft® Access.

Your PSS™E installation will include the following Python extension modules, which are documented in the PSS™E Application Program Interface Manual, and which can be imported into user programs inside or outside of the PSS™E GUI:

- **excelpy** - provides Python functions to interface with Excel; these functions can be used to create, populate and format Excel workbooks from Python.
- **pssarrays** - provides Python functions to retrieve PSS™E solution results
- **pssexcel** - provides Python functions to export PSS™E data or solution results to Microsoft® Excel spreadsheets.
- **pssplot** - provides access to the PSS™Plot API
- **psspy** - provides access to the PSS™E API

Your PSS™E installation will also include the following Python extension modules which can also be imported into user programs inside or outside of the PSS™E GUI:

- **bsntools** - a set of simple bus name manipulation tools
- **caspy** - provides access to the Saved Case Data Extraction routines (USRCAS)
- **redirect** - some tools to connect I/O streams between PSS™E and Python

These modules are fully supported as part of the PSS™E program product. There are other Python modules and programs that are supplied with PSS™E that either support the above modules or are used by other program features. In addition you will find several *.py files supplied in the Example directory for you to use and modify as you see fit.

Each of the modules above provides built-in documentation which can be accessed via the Python help command. In the case of psspy, however, the result will be too voluminous to be useful. A summary is available by entering:

```
help(psspy.psspyc)
```

Help is also available for individual API routines, e.g:

```
help(psspy.pout)
```

Some features of the psspy module that are not part of the API itself are documented in the doc string for psspy. Enter:

```
print psspy.__doc__
```

12.4.2 The Embedded Interpreter Environment

PSS™E contains an embedded Python interpreter. This is what allows PSS™E to execute Python files and commands. When the PSS™E GUI is started, it initializes the Python interpreter and executes a few initial commands. Those commands are:

```
import os,sys
sys.path.append(pathname)
import psspy
_i,_f=psspy.getbatdefaults()
import pssplot,redirect
redirect.py2psse()
```

(where pathname is a variable containing a value retrieved from the registry; you will generally not need to be concerned with this)

The os and sys modules are supplied with Python and contain commonly used functions for accessing operating system features. The psspy, pssplot, and redirect modules are defined above. The use of the _i and _f variables is explained in the section about Default Values in Python Files, below, and in the *PSS™E Application Program Interface (API)*. The redirect.py2psse() function causes Python's *stdin* (standard input) to use the function *userin* from the *psspy* module (*psspy.userin*) and Python's *stdout* (standard output) and *stderr* (standard error) to be redirected to PSS™E's progress device.

Note in particular that none of the modules are imported into the local name space. That means, for example, that to use a PSS™E API routine defined in the API manual as, say:

```
ierr = abc()
```

You would need to reference it as:

```
ierr = psspy.abc()
```

This is in keeping with standard practice for the Python community.

A Python program is shown below that performs the following:

- Read in a PSS™E Saved Case "savnw.sav".
- Solve the power flow.
- Loop through the buses and print the bus number and area to the Report View.

```
psspy.case('savnw.sav')
psspy.fnsl((0,0,0,1,1,0,99,0))
psspy.inibus(0)

while 1:

    ierr,busnum,busname = psspy.nxtbus()
    if ierr!=0: break
    ierr,busarea = psspy.busint(busnum,'AREA')
    psspy.report('%s %s' % (busnum,busarea))
```

One current idiosyncrasy of the embedded interpreter is that results are not automatically echoed to the terminal as they are in the stand-alone Python interpreter. To see the values of expressions you must use the print command.

12.4.3 The External Interpreter Environment

Python programs that access PSS™E functions can be used without starting the PSS™E GUI. Python is installed with its own command line interpreter, its own integrated Development Environment (IDE) - called IDLE -, and programs can be written to create their own GUI's. Any of these can use the PSS™E supplied extension modules shown above.

In order to use the PSS™E supplied extension modules in this way, you must first make sure that the Python import path can find all the modules by name, and that the windows load path can find any required DLL's. The following example replicates the environment in the embedded interpreter explained in the preceding section:

```
>>> import os,sys
>>> sys.path.append("C:\\program files\\pti\\psse31\\pssbin")
>>> os.environ['PATH'] += ";C:\\program files\\pti\\psse31\\pssbin"
>>> os.chdir("C:\\work_dir")
>>> import psspy
>>> import redirect
>>> _i,_f=psspy.getbatdefaults()
>>> redirect.psse2py()
>>> psspy.psseinit(80000)
```

This example assumes the standard PSS™E installation location, and a starting bus size of 80000. Other values could have been chosen. Other techniques could be used as well. For example, if the PYTHONPATH and PATH variables already contained the PSSBIN directory, then they would not need to be set here. If the current directory was to be the working directory then that statement would not be necessary, either. The only absolutely critical statements are the **import psspy** and the call to **psseinit**.

The import of pssplot is omitted in the example above because its functions depend on the PSS™E GUI and cannot be used in this mode. There are some graphics functions in psspy for which this is true as well.

12.5 Batch Commands

Batch commands are free-format forms of inputs to the PSS™E API. What this means is best illustrated by an example.

Let's say there is a PSS™E API routine called abcd. It takes an integer argument (IVAL), a two-element integer array (IDATA) and returns a floating-point value and an integer return code. The batch command syntax for this hypothetical API routine would be:

```
BAT_ABCD IVAL IDATA(1) IDATA(2)
```

In other words, three integers after the command name that correspond to the arguments IVAL, the first element of IDATA and the second element of IDATA, respectively. The returned values are not represented. Furthermore, if the function of the API routine was only to return those values, then there will not be a Batch Command syntax defined for it. The reason for this is that the Batch Commands are not a language; there are no variables or logic controls. A Batch Command is really data to the Batch Command interpreter, which then calls the indicated API routine with the input values defined after the command name.

The format of the Batch Commands is the same as the standard free-format rules used for all PSS™E data files. The following additional rules apply to Batch Commands, though:

- The command name itself is case insensitive, i.e. it doesn't matter whether you use upper case or lower case letters, or mix them (the documentation will always define them as all upper case).
- The commands may be continued on multiple lines. The interpreter keeps reading data until all the arguments that it needs for a given API routine are satisfied.
- There is a special token, a semi-colon, that can be used to tell the interpreter that it should default all remaining inputs for that particular API routine. It must be a separate token, not part of the previous value. In our example above,

  ```
  BAT_ABCD 1 34 ;
  ```

  will default the third value, but

  ```
  BAT_ABCD 1 34;
  ```

  will return a syntax error because "34;" is not a valid integer.

12.5.1 Response Files

Files containing Batch Commands are called Response Files (*.idv) because they can be mixed with the older PSS™E Line Mode which uses files of that type. Response Files can be used in PSS™E in any of the following ways:

- from the ***Run Program Automation File…*** (see Section 12.3)
- At program startup by using the ***-rspfile*** option (see Section 12.13)
- via the Line Mode activity IDEV (see Section 12.6)
- via the Immediate Commands @input or @chain (see Section 12.6.2)
- via the USE/COPY/IDEV command in PSAS and PSEB (see Sections 12.8 and 12.9)
- via the runrspnsfile function in the Python extension module psspy (see Section 12.4.1)

12.6 Line Mode

The Line Mode was the primary method of controlling PSS™E through rev 29 (and the only method through rev 18). It was highly efficient, very thorough, but completely procedural. It was essentially a question-and-answer session with the program that began with the question:

```
Activity?
```

The appropriate response to this question was any of about 170-180 (in the last few releases) "activities" which comprised the primary functions that PSS™E could perform. Each activity name was four characters long; most could be abbreviated. Some activities could accept optional "suffixes" which modified their behavior somewhat. Almost all would then ask a series of questions, unique to each activity, to which the user would respond to operate the program. Many of those activity names are preserved today in API routines that perform similar functions.

Line Mode commands can be used to automate PSS™E through Response Files (*.idv), so called because they contain responses to the questions that the Line Mode of PSS™E asks.

The modern GUI has replaced this previously common method of operation, but there is a wealth of existing Response Files containing Line Mode commands used to automate PSS™E. Therefore PSS™E currently contains a feature called the Line Mode Interpreter (LMI) - a new program written to imitate the traditional line mode of PSS™E, but that actually uses the PSS™E API. In a way it is a translator from Line Mode to Batch Commands. It is not a perfect imitation, and those differences are captured in Appendix D. The Line Mode itself is documented in the *PSS™E Program Operation Manual (POM)*.

It is worth noting that, although the Line Mode now comprises a subset of the full functionality of PSS™E, for those functions it can perform, and for those users who are thoroughly familiar with the Line Mode (and are good typists), that the program can still be operated more quickly from the keyboard than is physically possible with a point-and-click interface (i.e. a mouse). So while Line Mode capabilities are not likely to be enhanced in the future, it’s current operation is considered to be an important feature of the program.

12.6.1 Mixing Line Mode and Batch Commands

Response files can contain both Line Mode and Batch Commands. The Batch Commands can be thought of as additional "activities" of the Line Mode; they are not, and they are handled very differently, but for purposes of understanding how they may be combined in the same file, that image provides the guidelines that need to be followed.

The format of the Line Mode also conforms to the PSS™E standard free-format rules

12.6.2 Immediate Commands

The Line Mode has been augmented over the years with a set of Immediate (@) Commands, so called because their actions occur without the involvement of any of the API routines in PSS™E. They are functions of a utility library (a Siemens PTI product) that is used by PSS™E but separately maintained. Immediate Commands can also be mixed with Line Mode and Batch Commands. Unlike Batch Commands, however, they can be used anywhere, even in the middle of a series of responses to a particular activity in Line Mode. Their use is documented in other manuals (in particular (see Section 3.7 in the *POM*). The following list is provided for convenience:

@CHAIN filename - Open the specified file as a chained response file.

@INPUT filename - Open the specified file as a nested response file.

@PAUSE - Temporarily suspend response file operation.

@CONTINUE - Resume "PAUSEd" response file operation.

@END - Close the current response file.

@SYSTEM command - Issue a designated operating system specific command

@RELEASE - display the PSS™E release number and date, along with similar information about selected subsystems.

@DONGLE - display time used statistics for time lock users

@! - Ignore the entire line.

The last one, @!, will work from any input file. The others are only recognized from "terminal input", such as a Response File.

12.6.3 Version

The LMI provides one additional feature that the Line Mode does not - the ability to change versions. As releases of PSS™E come out sometimes changes are necessary in the sequence of Line Mode commands. The creates maintenance work for existing Response Files. The LMI provides a command, "VERSION", which displays or sets the version of the Line Mode "language" being processed. Introduced at rev 31 of PSS™E, it recognizes versions from rev 30 and afterwards, e.g.:

```
VERSION 30 - sets the version to rev 30

VERSION 31 - sets the version to rev 31

VERSION - displays the current version
```

12.7 IPLAN Programs

IPLAN is high-level programming language designed to be utilized as an enhancement to existing application programs such as PSS™E, but which can also be used as a stand-alone product. IPLAN is a Siemens PTI proprietary programming language that requires compilation in order to be executed in PSS™E. The compiled IPLAN program in binary format is used as input to the IPLAN simulator which is built into PSS™E. Programs written in IPLAN are created by the user with a standard text editor and "compiled" using the IPLAN compiler program supplied with PSS™E.

Compiled IPLAN Files can be used in PSS™E in any of the following ways:

- from the ***Run Program Automation File…*** (see Section 12.3)
- via the Line Mode activity EXEC (see Section 12.6)
- via the EXECUTE command in PSAS and PSEB (see Sections 12.8 and 12.9)
- via the runiplanfile function in the Python extension module psspy (see Section 12.4.1)

For specific detailed information and instructions on how to use the IPLAN language, please refer to the *IPLAN Program Manual*.

12.7.1 Interaction With PSS™E

The IPLAN compiler and simulator recognize the Single Element Data Retrieval routines from the PSS™E API. They are used in IPLAN CALL statements. This means that IPLAN programs can assign various values from the PSS™E network case to variables and act on them.

IPLAN cannot modify PSS™E directly, or call other routines in the PSS™E API directly. However, via the PUSH (and PUSHX, QPUSH, QPUSHX) command(s) it can do anything that can be done in a Response File. That includes, say, @input, which will open a Response File; in that case, the commands in that response file will not take effect immediately unless other steps are taken. This is explained in detail in the *IPLAN Program Manual*.

One of the commands in the Line Mode is EXEC, which is used to load an IPLAN program. If an IPLAN program invokes EXEC through a PUSH statement or by causing a Response File containing EXEC to run, that program will replace the current one in the IPLAN simulator. IPLAN programs do not nest.

12.7.2 The IPLAN Stand-Alone Simulator

The IPLAN compiler can call the IPLAN simulator directly. When used in this mode PUSH commands are just displayed at the terminal, and fetch routines return default values (non-zero return codes where appropriate, else zeros and blanks).

12.8 PSS™E PSEB Macro Language

PSEB (PSS™E Engineering Basic) is a built-in macro language that supports PSS™E Power Flow operations through the use of "English like" command macros. PSEB commands are created within a text file using a text editor. Each record is in the form of a command starting with a verb from a previously defined vocabulary. The PSEB commands are documented in Section 4.83 of the *PSS™E Program Operation Manual (POM)* and in the *PSEB User's Ready Reference*.

PSEB Files can be used in PSS™E in any of the following ways:

- from the ***Run Program Automation File…*** (see Section 12.3)
- via the Line Mode activity PSEB (see Section 12.6)

PSEB commands do not interact with PSS™E directly. The PSEB macro processor is really a translator from the PSEB language to a Response File, which may contain a mixture of Line Mode and Batch Commands. The PSEB Line Mode command normally automatically performs the commands in the Response File after the translation. When used with the suffix "CHECK" (i.e. PSEB, CHECK) only the translation is performed. When PSEB is used from the CLI (see Section 12.14) only the translation is performed, even if the CHECK option is not specified. When using the PSEB API routine only the translation is performed.

12.9 PSS™E PSAS Macro Language

PSAS (Simulation Run Assembler) is a built-in macro language that supports PSS™E Dynamics simulations through the use of "English like" command macros. PSAS commands are created within a text file using a text editor. Each record is in the form of a command starting with a verb from a previously defined vocabulary. The PSAS commands are documented in Section 5.20 of the *PSS™E Program Operation Manual (POM)* and in the *PSAS User's Ready Reference*.

PSAS Files can be used in PSS™E in any of the following ways:

- from the ***Run Program Automation File…*** (see Section 12.3)
- via the Line Mode activity PSAS (see Section 12.6)

PSAS commands do not interact with PSS™E directly. The PSAS macro processor is really a translator from the PSAS language to a Response File, which may contain a mixture of Line Mode and Batch Commands. The PSAS Line Mode command normally automatically performs the commands in the Response File after the translation. When used with the suffix "CHECK" (i.e. PSAS, CHECK) only the translation is performed. When PSAS is used from the CLI (see Section 12.14) only the translation is performed, even if the CHECK option is not specified. When using the PSAS API routine only the translation is performed.

12.10 Recording

The PSS™E interface is capable of recording PSS™E API commands. Recorded API commands can be in the form of either Python statements or Batch Commands (Response File) depending on a specified user option. The easiest way to record a Python script (*.py, for Python statements) or a Response File (*.idv, for Batch Commands) for later execution is to use the ***I/O Control>Start Recording…*** option. Selecting this option will start the recorder. The entry of subsequent selections of PSS™E commands will record the API routines used to an automation file for later use until the ***I/O Control>Stop Recording*** option is selected.

As an example, suppose you wanted to print power flow results to the Report View for buses 101, 201, 205, 154, and 3001. To record these interactions:

1. Select ***I/O Control>Start Recording…*** and select the type of file you wish to record: Python File (**.py*) or Response File (**.idv*).
2. Specify, say, *busout.idv* or *busout.py* as the file name depending on your selection of file type in Step 1, and select ***Open***.
3. Select ***File>Open*** and select ***savnw.sav***, select ***Open***.
4. Select ***Power Flow>Solution>Solve***. The loadflow solutions dialog is displayed. Select ***Solve***. Select ***Close***.
5. Select ***Power Flow>Reports>Bus based reports…***. The bus based reports dialog is displayed. Select the radio button for ***The following buses*** and enter 101, 201, 205, 143, 3001 in the text box provided. Select ***Go***. Select ***Close***.
6. Select ***I/O Control>Stop Recording***.

Using a text editor, open the file ***busout.idv*** (Figure 12-2) or ***busout.py*** (Figure 12-3) and you will see the following

```
@! File:"C:\Program Files\PTI\PSSE31\EXAMPLE\busout.idv", generated on TUE, AUG 17 2004 15:41
BAT_CASE,'C:\Program Files\PTI\PSSE31\EXAMPLE\savnw.sav'
BAT_FDNS,0,0,0,1,1,0,99,0
BAT_BSYS,1,0,0.0,0.0,0,5,101,201,205,154,3001,0,0
BAT_POUT,1,0
```

Figure 12-2. Response File Recorded by PSS™E

```
# File:"C:\Program Files\PTI\PSSE31\EXAMPLE\busout.py", generated on WED, AUG 18 2004  15:13
psspy.case(r"""C:\Program Files\PTI\PSSE31\EXAMPLE\savnw.sav""")
psspy.fdns([0,0,0,1,1,0,99,0])
psspy.bsys(1,0,[0.0,0.0],0,[],5,[101,201,205,154,3001],0,[],0,[])
psspy.pout(1,0)
```

Figure 12-3. Python File Recorded by PSS™E

12.10.1 ECHO

Users of PSS™E's traditional Line Mode will be familiar with the activity ECHO. It performs a function similar in effect to the recording function in the current program. It is a very different thing, however, and a remnant of it remains.

ECHO copied all terminal input to a file. Since all PSS™E input at that time either came from a terminal or a device that imitated the terminal, that meant all (interactive) input.

The current recording function is a feature of the API routines. When they are called, if recording is enabled, they record a copy of their input in the designated format in the designated file; it doesn't matter how the call occurred - by menu selection, through the CLI, from an automation file, etc.

The ECHO function still exists, and it still does the same thing, i.e. copies all terminal input to a file. The difference is that there is very little terminal input. The API routine userin, the IPLAN function INPUT (and INPUTLN), and the @pause immediate command all attempt to read from the terminal, which is handled in via a pop-up window. So data entered there will show up in an ECHO file.

Related to this is the traditional Line Mode activity IDEV, meaning Input DEVice. IDEV was used to replace the terminal with a file so that subsequent READ's from the terminal would find the responses in the file (hence the name "Response File"). IDEV never "executed" the commands in a Response File, but it appeared that way to most people. The implementation of IDEV in the LMI does what most people would expect, therefore; it causes the commands in the Response File to be interpreted by the LMI. This means, however, that IDEV no longer does what it used to do, i.e. replace terminal input with a file. This function is now performed by the API routine SET_INPUT_DEV. The effect of that API is open a file to respond to input requests from the terminal (except @pause which will still force an actual terminal read, handled via a pop-up window).

12.11 Argument Passing

Arguments can be passed to a response file by using the ***Arguments*** button located on the Select Program Automation File dialog. A text box allowing a single line of input will be displayed, e.g.:

1. Select ***I/O Control Run Program Automation File…***. The Select Program Automation File dialog displays (Figure 12-4).

2. Select the type of file you wish to execute from the Files of Type drop-down list.

3. Enter the filename in the text box provided.

4. Select the ***Arguments*** button, enter the argument string in the box provided, and select ***OK*** (Figure 12-5).

5. Select ***Open***. The file will be executed within the PSS™E user interface with results being displayed appropriately to the spreadsheet, report, and progress views.

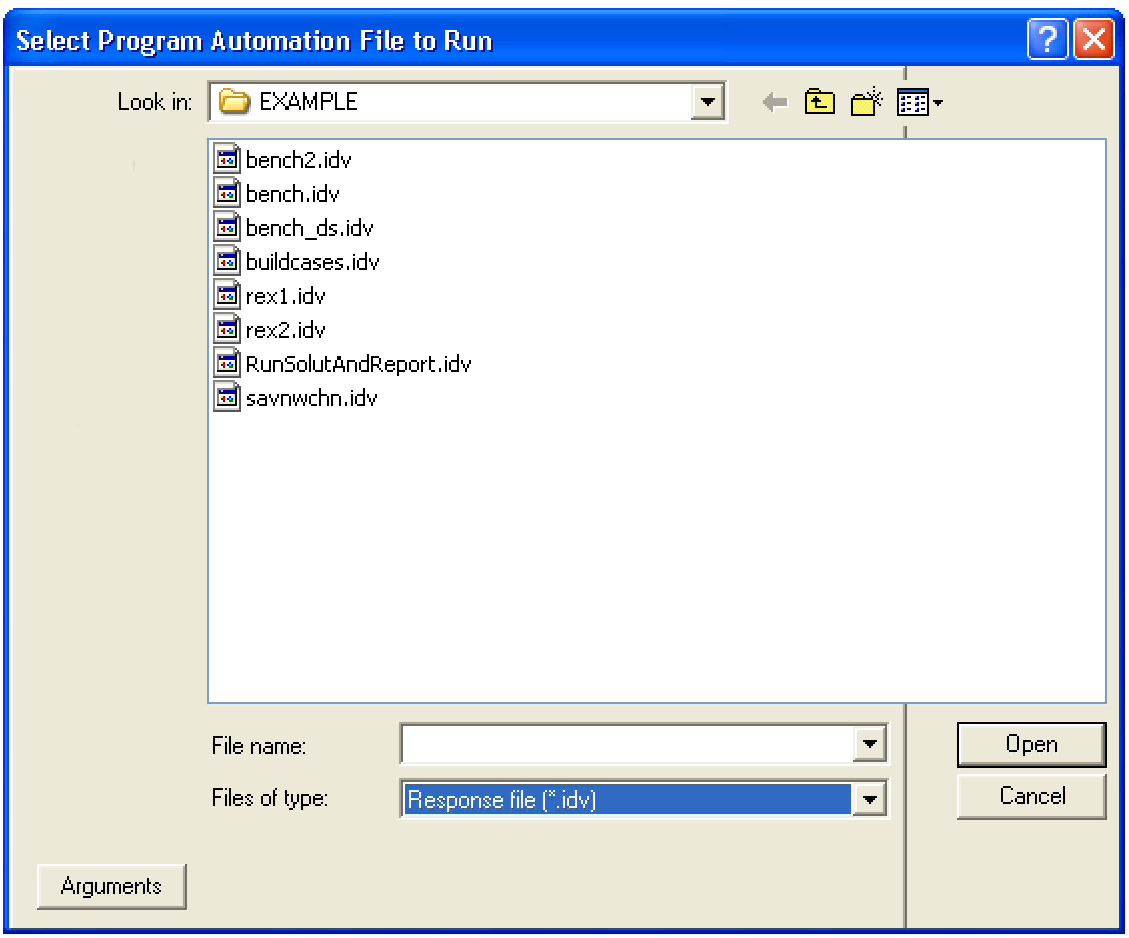


Figure 12-4. Select Program Automation File Dialog

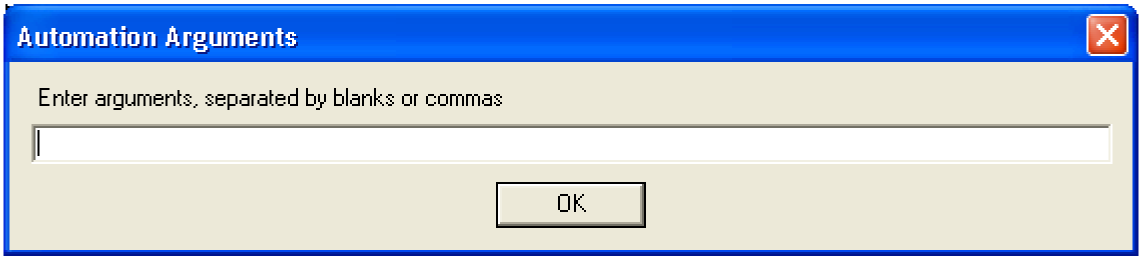


Figure 12-5. Enter Automation File Arguments

Arguments can be passed to the following types of automation files:

- Python files
- Response files
- IPLAN files

but how they are handled by each varies. Note that the dialog permits specifying arguments for PSAS and PSEB files, but those languages have no facility for retrieving the argument values.

12.11.1 Arguments in Python Files

The list argv in the module sys can be used to access the program arguments. Consider the following Python program named arg0.py:

```
import sys
print sys.argv
```

When run using the Python interpreter from a Command Prompt the input is assumed to be space delimited and is parsed into separate values, e.g.:

Enter:

```
python arg0.py a list of words
```

and the following is displayed:

```
['arg0.py', 'a', 'list', 'of', 'words']
```

From within PSS™E the input string is entered as a single argument. If the file arg0.py is selected (say, in the root directory of the C drive) and the string "a list of words" is entered in the argument string dialog box, the following will be displayed in the progress view:

```
Executing Python file:C:\LocalDocs\dev\testing\arg0.py
['C:\\arg0.py', 'a list of words']
```

12.11.2 Arguments in Response Files

The argument string is parsed according to the standard PSS™E free-format input rules for strings. Arguments in the Response File are then replaced by simple string substitution.

Response File arguments are documented in Section 3.7.3 of the *PSS™E Program Operation Manual (POM)*. An example of an argument would be %1%, which could appear anywhere in the file. In this case %1% would be replaced by the first value parsed from the argument string. Likewise %5% would be replaced by the fifth value parsed from the argument string.

Response Files require that all arguments receive values. A useful technique is to document all arguments referenced in a Response File using the TEXT command at the beginning of the Response File. This approach will help detect missing argument errors before any lengthy computations specified in the Response File are performed.

12.11.3 Arguments in IPLAN Files

The entire argument string is placed in a buffer. The IPLAN command ARGUMENT can then be used to parse the string in any way - and repeatedly - using the standard PSS™E free-format input rules. See Section 3.26 of the *IPLAN Program Manual*.

12.12 Default Values

Many of the statements in automation files specify data for which defaults exist. The idea of a default value is one that is simply not specified. Typically this means that either some function or action associated with that value is ignored, or a specific documented value is used; that specific value might be a fixed value - say, zero - or the current value of some quantity in the network case or a program setting.

While it is possible in some programming languages for a value to be "not there", the general case is that in order to indicate this situation a special value is used. When input values are omitted in automation files such special values are substituted for them. The various API routines check for the special values and take appropriate default actions when they are encountered.

Currently spaces and false are used for string and logical values when they are omitted. The special values for integers and reals (floats) are returned from the API routine GETBATDEFAULTS. No assumptions should be made that these precise values will be identical from one release of the PSS™E to another. If it is necessary to acquire these values, always run the API routine to get the current values.

Default values can be specified in references to API routines in Python Files. Data items can be omitted in Response Files. The concept of default values does not apply to IPLAN programs in general, but there are some functions that take optional arguments, and since PUSH statements can contain anything that could be in a Response File, any comments about Response Files will apply there. All data values are required in PSEB and PSAS files

12.12.1 Defaults in Python Functions

The Python language provides an easy mechanism for permitting optional arguments to functions. However it requires that each function be coded in such a way as to permit this. Not every one is. All the functions in the psspy module are coded in this way. For other modules delivered with PSS™E please check the help facility.

12.12.2 Defaults and Keywords in Module psspy

All arguments to functions defined in module psspy may be omitted and default values will be supplied. All arguments to functions defined in module psspy may be specified by keyword.

In addition psspy contains a unique feature for specifying values for specific elements in an input list. This is best illustrated by example. Let’s say a function mysub takes a single argument, opt, which is a 2-element list of integers, then the following are equivalent:

```
mysub([_i,1])
mysub(opt=[_i,1])
mysub(opt2=1)
mysub(opt=None,opt2=1)
mysub(opt=[_i,42],opt2=1)
mysub(opt2=1,opt=[_i,352])
mysub(opt1=_i,opt2=1)
```

where _i is a variable equal to the default integer value.

What this means is that all the functions in psspy recognize special keywords formed by concatenating any input list name and the string representation all the possible index values (starting at 1) and will use them to override just that specific element of the list.

12.12.3 Defaults in Recorded Python Files

When recording is enabled and the Python format is chosen, values for all arguments are specified. Where default values are recorded, actual values are used except for the following:

- in place of default integer values, the variable _i is used.
- in place of default float values, the variable _f is used.

This will work directly inside of the PSS™E GUI because those variable are automatically assigned the appropriate values at program startup. This is why the statement

```
_i,_f=psspy.getbatdefaults()
```

is recommended in Section 12.4.3.

12.12.4 Defaults in Response Files

Since Response Files are simply free-format data files, an input value can be omitted by two commas either together or separated by only spaces.

For Batch Commands there is a special token, a semi-colon, that can be used to tell the interpreter that it should default all remaining inputs (see Section 12.5).

Files containing recorded Batch Commands will use consecutive commas for default values specified to the API routine.

12.13 Unattended Execution of PSS™E

In some cases, it may be desirable to run PSS™E in batch mode, that is, without any user interface. PSS™E provides command line options that can be used for this purpose. In Appendix C you will find a list of all the available command line options; these four specifically pertain to this purpose:

-rspfile -pyfile -argstr -embed

- note that the initial "-" is part of the command
- -rspfile, -pyfile, and -argstr all expect to be followed by a string
- -pyfile will be ignored if -rspfile is specified
- -argstr and -embed will be ignored if neither -rspfile not -pyfile are specified
- the command line is blank delimited; if the string specified to -rspfile, -pyfile, or -argstr contains a blank then the string must be quoted
- if the same option is specified more than once, only the last one will be used
- notwithstanding the previous point, the order of the options is unimportant
- the string value for the -argstr option is the argument string (see Section 12.11)

Provision is made for specifying only Response Files or Python Files. Both of those file types can use other types of Automation Files so, indirectly at least, any type can be used.

The -embed option has the effect of suppressing the display of the PSS™E GUI. If the Automation File terminates without stopping the execution of PSS™E the GUI will be displayed at that time.

The following are a few points to be aware of when preparing to run PSS™E in an unattended mode:

- PSS™E does not read input from stdin or write to stdout, so pipes cannot be used for batch execution of PSS™E.
- Be aware of the nature of the operating system tool you are using to start PSS™E. In Microsoft® Windows, for example, non-console application programs, such as PSS™E, are executed asynchronously. This means that should you have a batch file that starts PSS™E it will not wait for the program to stop before continuing on the next statement in the batch file.
- PSS™E needs exclusive access to a set of working files that it will find or create in its initial working directory. This means that an attempt to start a second execution of PSS™E in the same working directory will fail.
- When running in batch mode (i.e. with a startup automation file specified that stops the program) the progress view and report view output should be re-directed to a printer or file, otherwise output will be sent to the windows that will be closed when the program stops.

Here are some examples of starting PSS™E from a Command Prompt:

```
psse31 -rspfile busout.idv

psse31 -pyfile busout.py

psse31 -pyfile busout.py -embed

psse31 -embed -pyfile "study number 2.py" -argstr 101
```

12.14 Using the Command Line Interface

A facility is provided to enter the same commands as would appear in a Response File or a Python File interactively. That facility is called the Command Line Interface (CLI). To use the CLI, do the following:

1. Select ***I/O Control>Begin command line input session…***. The command line input dialog displays (Figure 12-6, Figure 12-7, Figure 12-8). The command line input dialog has a tabbed format, presenting an Input tab and Report tabs. The Input tab is where commands are typed and prompts and Progress view information are displayed. The Report tab(s) function(s) similarly to the main GUI.

2. Select the Command Language you wish to use from the available list containing Python and PSS™E Response. If the Python language is chosen (default), the interface will expect entry of Python commands in the Input tab. If PSS™E Response is chosen, you can enter Line Mode or Batch Commands. Place your mouse cursor in the Input tab and begin typing commands. Press the **[Return]** key to allow PSS™E to interpret and process your command. Once the command is processing, output messages and prompts will be directed to the Input tab.

3. Previously executed commands may be recalled by either selecting the command from the drop-down list labeled Command History or hitting the **[Scroll Up]** and **[Scroll Down]** keys.

4. If you wish to execute an automation file, select the ***Run Auto…*** button and select the desired file name using the file selector. Once the automation file has completed its execution, the ***Run Again…*** button will be activated. Select ***Run Again…*** to repeat the execution of the automation file, eliminating the need to re-specify the automation file name and associated path.

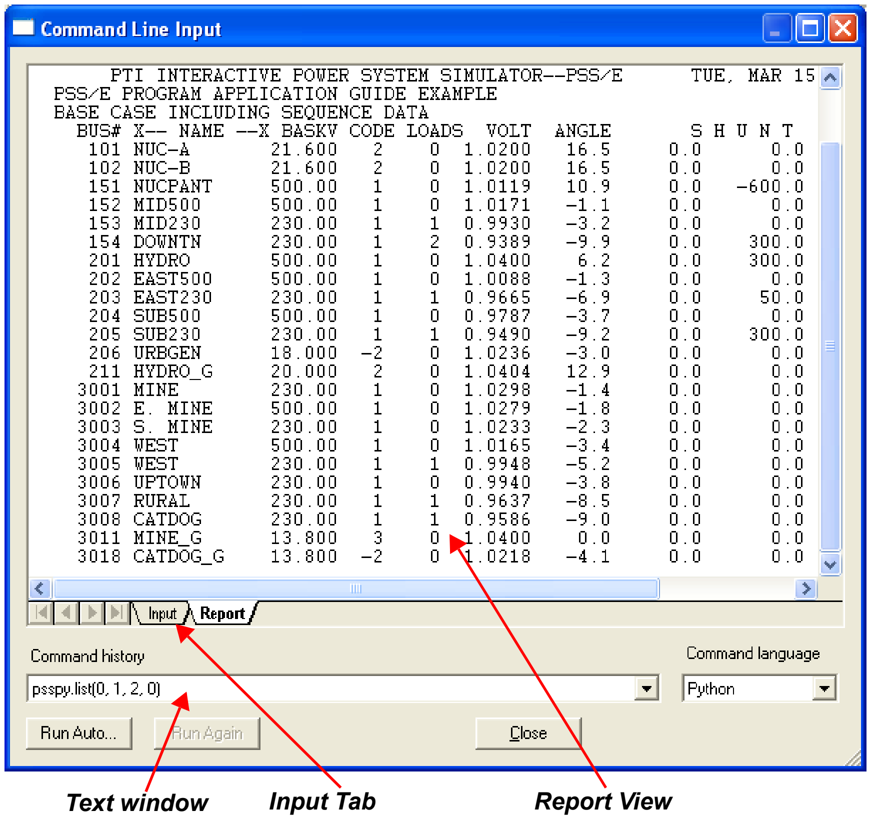


Figure 12-6. Command Line Input Dialog showing Report View

Line Mode commands entered in the CLI are handled by the LMI; Batch Commands are handled by the Batch Command interpreter, and Python Commands are passed to the embedded Python interpreter. When using the Line Mode, prompts are provided that resemble the traditional Line Mode prompts; when an activity is completed the "Activity?" prompt is presented. When an incomplete Batch Command is entered, a prompt of the form "API-name:" is presented.

Every time the CLI is started, the various processors are set to receive new commands. If the CLI is closed without completing a command, the uncompleted information is discarded. However, there are some API routines that are designed to be called in a series with different options. If a Line Mode activity is interrupted that used such an API routine, and some of the API calls in the series have taken place, it will be difficult to return that API routine to a state where is can be used again (this same situation can be created by a Batch Command or Python statement invoking the API, but it is more apparent there).

The CLI is a modal dialog; i.e. while it is running the remainder of the PSS™E GUI is unavailable.

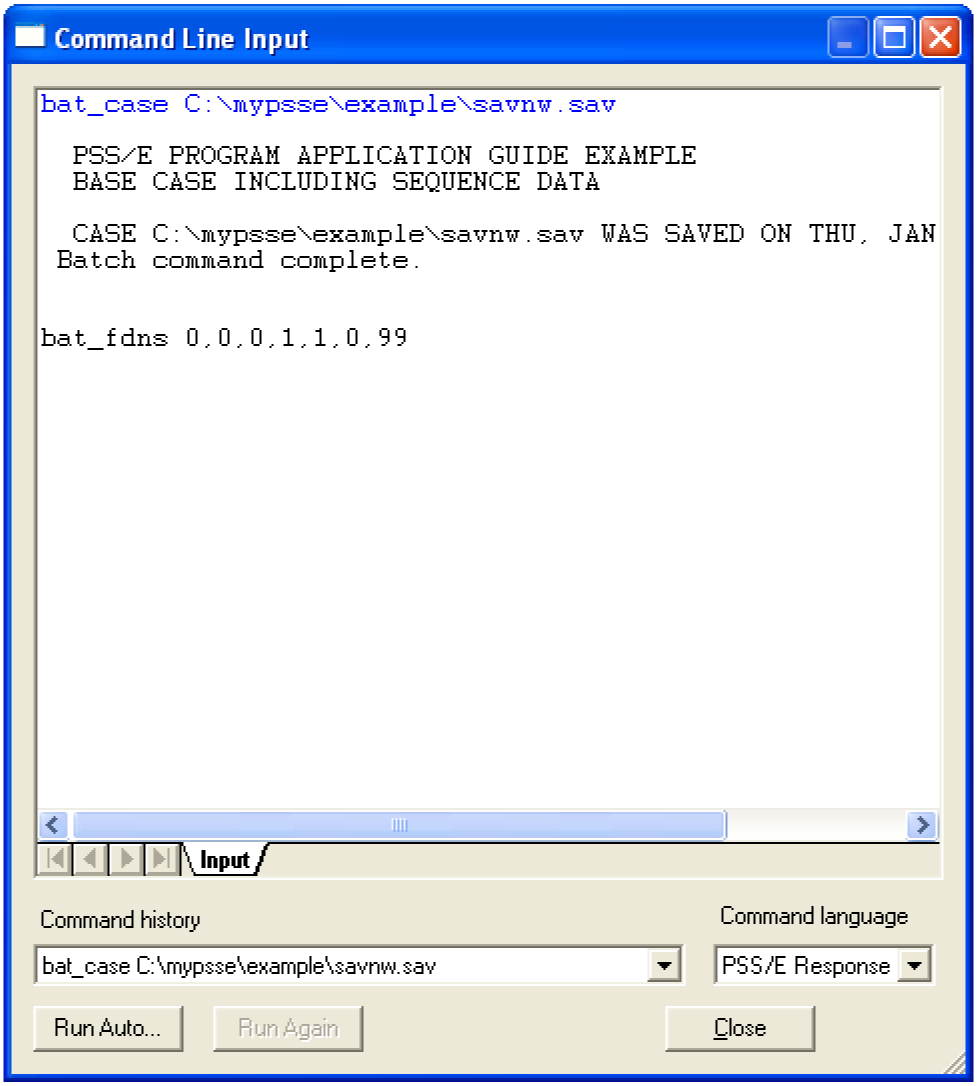


Figure 12-7. Command Line Interface using Batch Commands

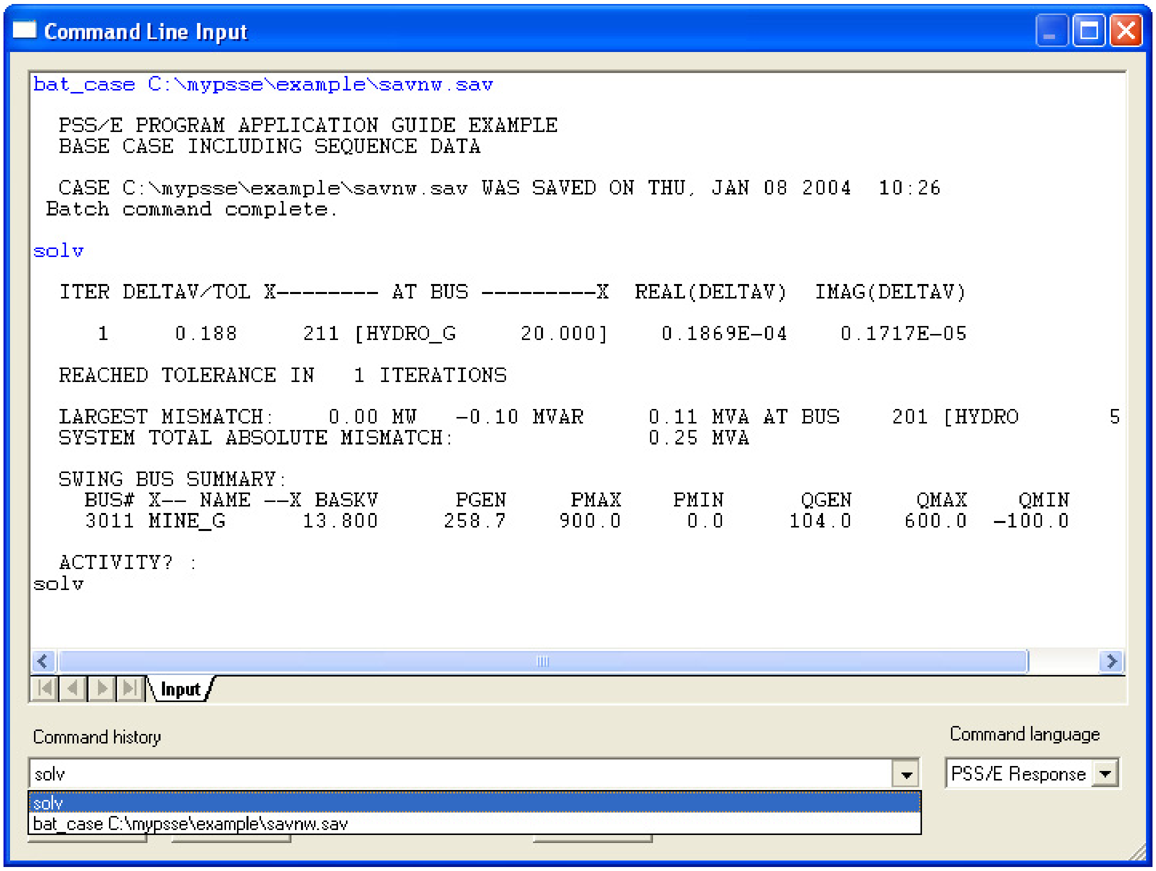


Figure 12-8. Command Line Interface using the LMI

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Chapter 13

Result Retrieval APIs

13.1 Exporting PSS™E results to Excel using Excel Export GUI

To launch Excel export GUI select:

- PSS™E menu ***Power Flow>Reports>Export to Excel***

  or

- ***Start>Programs>PSSExx>Export Results to Excel***

This will open the Excel Export dialog where PSS™E solution/analysis results file, excel output file and the quantities to export can be identified (see Figure 13.1).

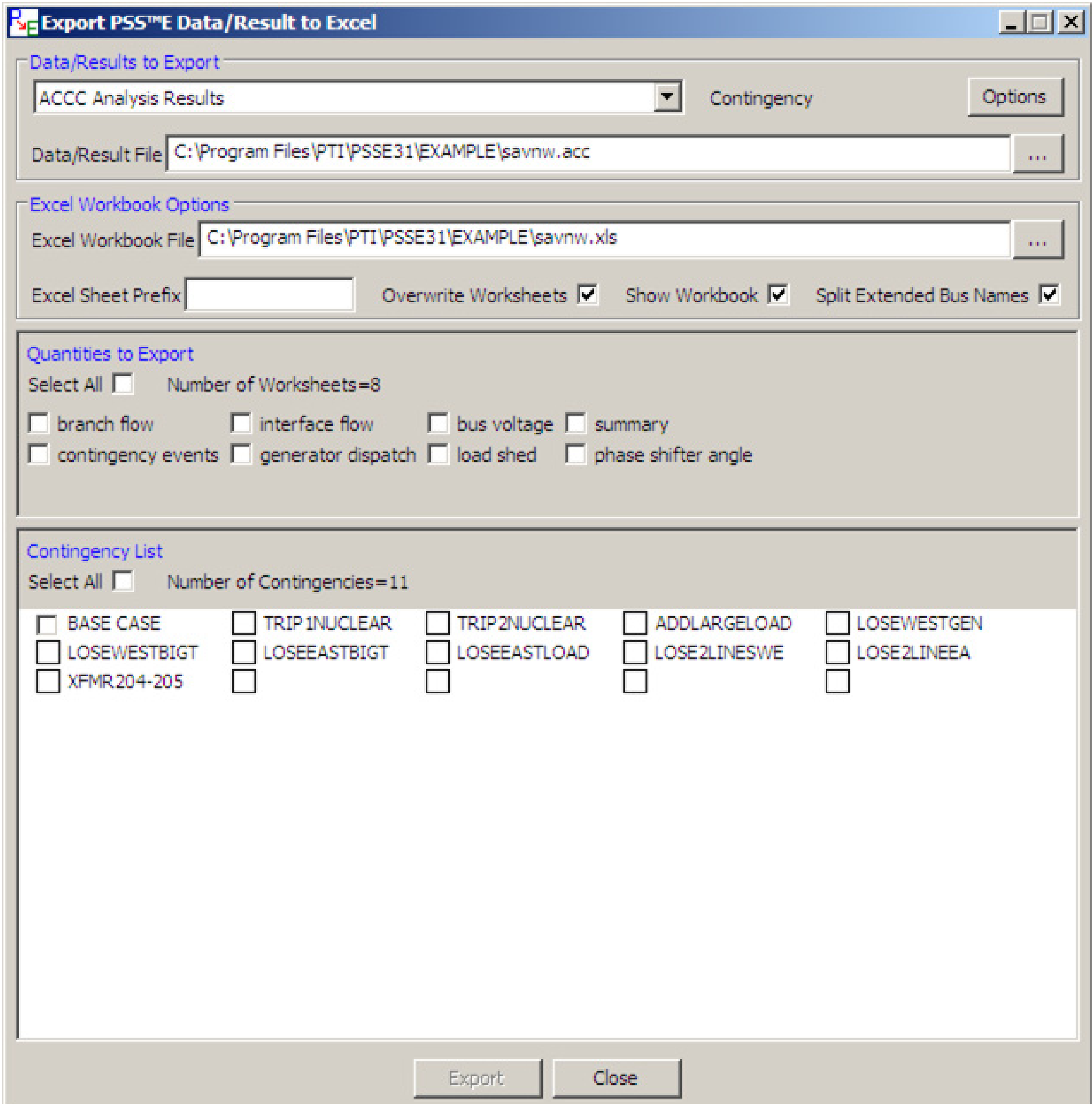


Figure 13-1. Export PSS™E Data/Result to Excel Dialog

Data/Results to Export - Options button: The solution type to export (contingency, tripping or corrective action) can be specified as part of options data, in this example, ACCC.

Data/Result File: The default excel file name is the name of the results file with an xls extension, if no name is specified for *Excel Workbook File*.

Excel Workbook File: One worksheet for each selected item from *Quantities to Export* is created in a specified workbook. The name of the worksheet is the name of the quantity to export. This worksheet name will be prefixed by the text specified in *Excel Sheet Prefix*.

- *Overwrite Worksheets* flag: Select to overwrite existing worksheets. Deselect to copy existing worksheets; filenames are automatically appended with (#), where # is the next sequence number.

- *Show Workbook* flag: Select to open and display workbook as it is being written to. Deselect to populate workbook without displaying it.
- *Split Extended Bus Names* flag: Select to split extended bus names into three columns - Bus Number, Bus Name and Bus Voltage.

13.2 Python Lists

PSS™E result retrieval APIs (*PSS™E Application Program Interface manual Chapter 9*) are used to retrieve PSS™E activity results into Python lists. Such lists then can be used to make customized reports or for further processing using Python scripts. This chapter describes how to invoke these APIs from PSS™E Python automation files or the PSS™E CLI (command line input), and write simple Python scripts using these APIs to further process the results. The Python modules available for such a use are:

- PSSARRAYS module returns data and results from PSS™E activities to Python lists.
- PSSEXCEL module creates and populates Excel spreadsheets with data and results from PSS™E activities. This module is an example of how to use Python lists returned by PSSARRAYS for further processing. This modules uses the PSSARRAYS module to retrieve PSS™E activity data and results and the EXCELPY module to write the data and results to Excel spreadsheets.
- EXCELPY is an auxiliary module that provides Python functions to create and populate Excel spreadsheets.

Following sections describe just few functions and give sample Python commands/code to illustrate how to use Python functions available in these modules. These Python commands can be executed from either PSS™E program automation files or the PSS™E CLI.

13.3 pssarrays.accc_summary

13.3.1 CLI

```
import pssarrays (1)

smry = pssarrays.accc_summary(r"savnw.acc") (2)
or
smry = pssarrays.accc_summary(accfile=r"savnw.acc")
or
smry = pssarrays.accc_summary(accfile=r"c:\filepath\savnw.acc")

print smry.ierr (3)
0

print smry.acccsize.nmline
11

print smry.file.acc
C:\Program Files\PTI\PSSE31 Alpha 2\EXAMPLE\savnw.acc

print smry.melement
('   201 HYDRO       500.00    151 NUCPANT     500.00 1', '   202
EAST500     500.00    152 MID500      500.00 1', '   203 EAST230
230.00    154 DOWNTN      230.00 1', '   205 SUB230      230.00    15
DOWNTN      230.00 1', '  3001 MINE        230.00   3002 E. MINE
500.00 1', '  3004 WEST        500.00    152 MID500      500.00 1', '
3004 WEST        500.00   3005 WEST        230.00 1', '  3005 WEST
230.00   3008 CATDOG      230.00 1', '  3006 UPTOWN      230.00    15
MID230      230.00 1', '  3008 CATDOG      230.00    154 DOWNTN
230.00 1', '  3008 CATDOG      230.00   3018 CATDOG_G    13.800 1', '
INTERFACE WEST', '        INTERFACE EAST')

print smry.mvbuslabel
('  3001 MINE        230.00', '   201 HYDRO       500.00', '   202
EAST500     500.00', '   203 EAST230     230.00', '   204 SUB500
500.00', '   205 SUB230      230.00', '   206 URBGEN      18.000', '
211 HYDRO_G     20.000', '  3001 MINE        230.00', '  3002 E. MINE
500.00', '  3003 S. MINE     230.00', '  3004 WEST        500.00', '
3005 WEST        230.00', '  3006 UPTOWN      230.00', '  3007 RURAL
230.00', '  3008 CATDOG      230.00', '  3011 MINE_G      13.800', '
3018 CATDOG_G    13.800')
```

1. By importing the pssarrays module, the functions defined inside this module are made available outside of the module.

2. The “accc_summary” function can be called in any of the following ways:

   - ACCC solution output file is available in the working folder.

     ```
     smry = pssarrays.accc_summary(r"savnw.acc")
     ```

- ACCC solution output file is available in the working folder, accc_summary function called with keyword argument 'accfile'.

  ```
  smry = pssarrays.accc_summary(accfile=r"savnw.acc")
  ```

- ACCC solution output file is not available in the working folder, then its location needs to be specified.

  ```
  smry = pssarrays.accc_summary(accfile=r"c:\filepath\savnw.acc")
  ```

Note: The accfile name is specified in r"..." format, to make the file name a Python raw string. It suppresses escapes sequences, viz., \n for newline character, \t for tab etc.

3 ACCC summary results are returned in the Python list "smry". The various values available in this list are accessed by their names as an attribute of the returned list. The API documentation provide the list of values available in the returned list.

The following Python commands print some of these values.

- Value "`ierr`" gives the error condition.

  ```
  print smry.ierr
  ```

- Value "`acccsize.nmline`" gives the number of monitored elements (branches + interfaces).

  ```
  print smry.acccsize.nmline
  ```

- Value "`file.acc`" gives the ".acc" input file name.

  ```
  print smry.file.acc
  ```

- Value "`smry.melement`" gives the monitored element labels.

  ```
  print smry.melement
  ```

- Value "`smry.mvbuslabel`" gives the monitored bus labels.

  ```
  print smry.mvbuslabel
  ```

13.3.2 Automation File

The examples above can be combined into one Python file, as shown below, and run as a PSS™E automation file to report on the basic data contained within an ACCC output file. Any Python code can be added to this code to further process the returned values.

```
import pssarrays

smry = pssarrays.accc_summary(r"savnw.acc")

print smry.ierr

print smry.acccsize.nmline

print smry.file.acc

print smry.melement

print smry.mvbuslabel
```

13.4 pssarrays.accc_solution

The following Python code example shows how to get ACCC analysis results and write them to a report.

```
import pssarrays

reptfile = 'accc_output.txt'

reptnam = open(reptfile,'w')


smry = pssarrays.accc_summary(accfile=r'savnw.acc')

rate = smry.rating.a

stype = 'con'


for lbl in smry.colabel:

    soln  = pssarrays.accc_solution(accfile=r'savnw.acc',

            colabel=lbl,stype=stype,busmsm=0.5,sysmsm=5.0)

    if  soln == None: continue # contingency solution not found,

                               # move to next

    if soln.ierr !=0: continue # return any non-zero ierr

    reptnam.write("CONTINGENCY EVENTS\n")


    # (1) contingency events summary

    cnvflag  =  soln.cnvflag

    cnvcond  =  soln.cnvcond

    island   = ("%d" %  soln.island).center(7)

    mvaworst =  soln.mvaworst

    mvatotal =  soln.mvatotal

    for jj in range(len( soln.codesc)):

        desc =  soln.codesc[jj]

        if jj == 0:

            reptnam.write("%(lbl)s %(desc)s %(cnvflag)s \

    %(cnvcond)s %(island)s %(mvaworst)11.4f \

    %(mvatotal)11.4f\n" % vars())

        else:

            tmp = 12*' '

            reptnam.write("%(tmp)s %(desc)s\n" % vars())
```

```
    if not cnvflag:
        reptnam.write("\n================================\n")
        continue    # consider solution for converged cases only

    # (2) flows
    txtstr = ''
    for jj in range(smry.acccsize.nmline+smry.acccsize.ninter):
        mvaflow = "%9.2f" %  soln.mvaflow[jj]
        if jj < smry.acccsize.nmline:
            ampflow = "%9.2f" %  soln.ampflow[jj]
            pctflow = abs( soln.ampflow[jj])
        else:
            ampflow = 9*' '
            pctflow = abs( soln.mvaflow[jj])
        if rate[jj]:
            pctflow = "%6.2f" % (pctflow*100.0/rate[jj])
        else:
            pctflow = 6*' '

    txtstr += " %(mvaflow)s %(ampflow)s %(pctflow)s " %vars()
    if txtstr:
        reptnam.write("\nMONITORED ELEMENT FLOWS\n")
        reptnam.write("%(lbl)-12s%(txtstr)s\n" % vars())

    # (3) voltages
   if smry.acccsize.nmvbus:
        reptnam.write("\nMONITORED BUS VOLTAGES\n")
        txtstr = ''
        for eachv in  soln.volts:
            txtstr += " %8.5f" % eachv
        if txtstr:
            reptnam.write("%(lbl)-12s%(txtstr)s\n" % vars())
```

```
    # (4) loads shed
    if len( soln.lshedbus):
        reptnam.write("\nLOADS SHED\n")
        for jj in range(len(soln.lshedbus)):
            if stype in ['caction','corrective action','cor']:
                reptnam.write("%25s %10.2f %10.2f %12s\n" % \
                    (soln.lshedbus[jj], soln.loadshed[0][jj],
                     soln.loadshed[1][jj], lbl))
            else:
                reptnam.write("%25s %10.2f %12s\n" % \
                    (soln.lshedbus[jj], soln.loadshed[jj], lbl))

    # (5) generator dispatch
    if stype in ['caction','corrective action','cor'] and \
       len( soln.gdispbus):
        reptnam.write("\nGENERATOR DISPATCH\n")
        for jj in range(len( soln.gdispbus)):
            reptnam.write("%25s %11.2f %11.2f %12s\n" % \
                    (soln.gdispbus[jj], soln.gendisp[0][jj],
                     soln.gendisp[1][jj], lbl))

    # (6) phase shifter
    if stype in ['caction','corrective action','cor'] and \
       len( soln.phsftr):
        reptnam.write("\nPHASE SHIFTER ANGLE\n")
        for jj in range(len( soln.phsftr)):
            reptnam.write("%54s %12.2f %11.2f %12s\n" % \
                    (soln.phsftr[jj], soln.phsftrang[0][jj],
                     soln.phsftrang[1][jj],lbl))

    reptnam.write("\n================================\n")

reptnam.close()
print "ACCC Solution saved in file %s." % reptfile
```

13.5 pssarrays.accc_violations_report

This function creates the following reports:

- monitored element flow violations (percent flow greater than flow limit). The flow limit is specified as an argument of this function.
- monitored bus voltage violations (bus voltage <minimum voltage bound or >maximum voltage bound). The voltage bound values are taken from monitored element data file (.mon).
- loads shed
- generator dispatch
- phase shifter angle adjustments

The following command, executed from either the CLI or a Python automation file, produces ACCC violations reports for corrective action solution and reports on monitored branches whose loading is above 95%.

```
ierr = pssarrays.accc_violations_report( accfile=r"savnw.acc",
            stype="cor", busmsm=0.5,sysmsm=5,rating=’a’,
            flowlimit=95,rptfile=r"savnw_violations.txt")
```

13.6 pssexcel.accc

Using the “pssarrays” module, ACCC analysis results are retrieved from an *.acc input file and then, using the “excelpy” module, these results are written to Excel Spreadsheets.

The Python commands below create a ’savnw_acc.xls’ file and the following worksheets populated with “ACCC Corrective Action” solution data from the ’savnw.acc’ file for contingencies ’base case’ and ’trip1nuclear’. If a ’colabel’ value is not provided, all contingencies are considered. Also the extended bus names of monitored branches and buses are split into three Excel spread columns (namesplit=True). The argument show=True displays the workbook when it is being populated.

- test Summary
- test Contingency Events
- test Branch Flow
- test Interface Flow
- test Bus Voltage
- Test Load Shed
- test Generator Dispatch
- test Phase Shifter Angle

```
import pssexcel
pssexcel.accc(accfile   = r"savnw.acc",
              string    = ['b','e','g','i','l','p','s','v'],
              colabel   = ['base case', 'trip1nuclear'],
```

```
stype     = 'cor',
busmsm    = 0.5,
sysmsm    = 5.0,
rating    = 'a',
namesplit = True,
xlsfile   = r'savnw_acc.xls',
sheet     = 'test',
overwritesheet = True,
show      = True
)
```

In the command above, ’accfile’ and ’string’ are the only mandatory arguments. The worksheets to create are defined by the ’string’ argument.

13.7 pssexcel.pv

Using the “pssarrays” module, PV solution results are retrieved from a *.pv input file and then, using the “excelpy” module, these results are written to Excel Spreadsheets.

The Python commands below create a ’savnw_pv.xls’ file and the following worksheets populated with PV solution results from the ’savnw.pv’ file for contingencies ’base case’ and ’trip1nuclear’. If a ’colabel’ value is not provided, all contingencies are considered. Also the extended bus names of monitored branches and buses are split into three Excel spread columns (namesplit=True). The argument show=True displays the workbook when it is being populated.

- testpv Summary
- testpv Bus Voltage
- testpv Mismatch
- testpv Generator Dispatch
- testpv Bus Load
- testpv Branch Flow
- testpv Interface Flow

```
import pssexcel

pssexcel.pv(pvfile    = r"savnw.pv",
            string    = ['s','m','v','g','l','b','i'],
            colabel   = ['base case', 'trip1nuclear'],
            namesplit = True,
            xlsfile   = r'savnw_pv.xls',
            sheet     = 'testpv',
            overwritesheet = True,
            show      = True
            )
```

In the command above, ’pvfile’ and ’string’ are the only mandatory arguments. The worksheets to create are defined by the ’string’ argument.

13.8 excelpy Examples

13.8.1 Export QV Solution to Excel Spreadsheet

The following Python code writes QV solution “summary” and “bus voltage” results from ’savnw.qv’ file to the Excel spreadsheet ’testqv.xls’.

- Using the pssexcel.qv function

```
import pssexcel

pssexcel.qv(qvfile    = r"savnw.qv",
            string    = ['s','v'],
            colabel   = ['base case', 'trip1nuclear'],
            namesplit = False,
            xlsfile   = r'testqv.xls',
            sheet     = '',
            overwritesheet = True,
            show      = True
            )
```

- Using the pssarrays and excelpy modules

The following example illustrates how the ’pssarrays’ and ’excelpy’ modules can be used to export PSS™E activity data and results to Excel spreadsheets.

```
import excelpy
import pssarrays

qvfile  = r"savnw.qv"
colabel = ['base case', 'trip1nuclear']
xlsfile = 'testqv.xls'

# create Excel workbook, with sheet 'qvsummary'
qvxls = excelpy.workbook(xlsfile=xlsfile, sheet='qvsummary',
                         overwritesheet=True)
qvxls.show()        # show workbook
qvxls.font_sheet()  # set default font for 'qvsummary' worksheet

# add other sheets as required
qvxls.worksheet_add_end(sheet='qvvolts',overwritesheet=True)
```

```
qvxls.font_sheet()  # set default font for ''qvvolts' worksheet

# Get Summary and validate contingency labels provided
smry = pssarrays.qv_summary(qvfile)

# populate qvsummary worksheet
qvxls.set_active_sheet('qvsummary')
row, col = 1, 1
qvxls.set_cell((row,col),"QV SOLUTION RESULTS",fontStyle="bold",
                fontSize=14, fontColor="blue")

tmplst=[
    smry.casetitle.line1,
    smry.casetitle.line2,
    'QV output file   = %s' % smry.file.qv,
    'Saved Case file = %s' % smry.file.sav,
    'DFAX file        = %s' % smry.file.dfx,
    'Subsystem file   = %s' % smry.file.sub,
    'Monitored Element file  = %s' % smry.file.mon,
    'Contingency Description file = %s' % smry.file.con,
    ' ',                                             # blank row
    'Number of Contingencies+Base Case = %d' % smry.qvsize.ncase,
   'Number of Monitored Generators(Plants)= %d' % smry.qvsize.nmgn-
bus,
    'Number of Voltage Monitored Buses = %d' % smry.qvsize.nmvbus,
   'Number of Voltage Monitored Records = %d' % smry.qvsize.nmvrec,
    'Number of max.volt. setpoint changes = %d' % smry.qvsize.nmx-
vstp,
    ]

if smry.file.thr:
    tmplst.insert(4,'Load throwover file = %s' % smry.file.thr)

row += 2
```

```
bottomRow,rightCol = qvxls.set_range(row,col,tmplst,trans-
pose=True)
qvxls.font_color((row,col,row+1,col),'brown')

row = bottomRow+2
qvxls.set_cell((row,col),"QV Contingencies",fontStyle="Bold",
                fontSize=12, fontColor="red")

conlst = [['CON#', 'LABEL', 'Min Vstp', 'Max Vstp', 'Min MVAR',
           'Max MVAR', 'Max Mismatch', 'DESCRIPTION']]
for i in range(smry.qvsize.ncase):
    if i==0:
        srnum = ' '
    else:
        srnum = str(i)
    nam  = smry.colabel[i]
    minvstp = smry.minvstp[i]
    maxvstp = smry.maxvstp[i]
    minmvar = smry.minmvar[i]
    maxmvar = smry.maxmvar[i]
    maxmsm  = smry.maxmsm[i]
    for j in range(len(smry.codesc[i])):
        dsc = smry.codesc[i][j]
        if j==0:
            conlst.append([srnum,nam,minvstp,maxvstp,minmvar,
                           maxmvar,maxmsm,dsc])
        else:
            conlst.append(['' ,'' ,'' ,'' ,'' ,'' ,'' ,dsc])

row += 1
bottomRow,rightCol = qvxls.set_range(row,col,conlst)
qvxls.font_color((row,col,row,rightCol), "dgreen")
qvxls.font((row,col+2,bottomRow,col+3),numberFormat='0.00')
qvxls.font((row,col+4,bottomRow,col+6),numberFormat='0.000')
```

```
qvxls.align((row,col),'right')
qvxls.font((row,col,row,rightCol),fontStyle=('Bold',))
qvxls.autofit_columns((row,col+1,row,rightCol))
# done qvsummary worksheet

# populate qvvolts worksheet
mvbuslabel = list(smry.mvbuslabel)
mvbuslabel.insert(0,'VOLTAGE SETPOINT->')

qvxls.set_active_sheet('qvvolts')
row, col = 1, 1

for lbl in colabel:
    soln =  pssarrays.qv_solution(qvfile,lbl)
    if soln==None: continue    # contingency solution not found
    if soln.ierr !=0: continue # solution with error

    contitle = 'CONTINGENCY: ' + lbl.strip()

    # assemble data in columns: 1st=MW Transfer, rest=bus voltages
    tmplst    = [ mvbuslabel ]
    for i in range(len(soln.vsetpoint)):
        t = list(soln.volts[i])
        t.insert(0,soln.vsetpoint[i])
        tmplst.append(t)

    col = 1
    qvxls.set_cell((row,col+1),contitle,fontStyle='bold',
                   fontSize=12,fontColor="dgreen")
    row += 1
    bottomRow,rightCol = qvxls.set_range(row,col,tmplst,trans-
pose=True)
    qvxls.font((row,col,row,rightCol),fontColor="red",font-
Style='bold')
   qvxls.font((row,col+1,bottomRow,rightCol),numberFormat="0.000")
```

```
    qvxls.align((row,col,row,rightCol),'h_center')
    qvxls.align((row,col),'right')
    qvxls.font((row+1,col,bottomRow,col),fontColor="blue",
               fontStyle='bold')
    row = bottomRow + 2 # one blank row

# format qvvolts worksheet
qvxls.autofit_columns((1,1))

# Save the workbook and close the Excel application
xlsfile = qvxls.save(xlsfile)
print "\n Excel workbook saved to file %(xlsfile)s.\n" % vars()
```

13.8.2 Write Data to Excel Spreadsheet

Following example code shows how to use excelpy functions and methods to create, populate and format Excel workbook from Python.

```
import excelpy

testxls = excelpy.workbook(r"test.xls","TestExcelPy")
testxls.show()
testxls.font_sheet()

testdata=[
    ['CON#', 'LABEL',       'Max MW', 'DESCRIPTION'],
    [' ',    'BASE CASE',    756.25, 'BASE CASE    '],
    ['1',    'TRIP1NUCLEAR', 1000.0, 'REMOVE UNIT 1'],
    ['2',    'TRIP2NUCLEAR',    0.0, 'REMOVE UNIT 1'],
    ['',                 '',     '', 'REMOVE UNIT 2'],
    ['3',    'ADDLARGELOAD',    0.0, 'INCREASE LOAD'],
    ['4',    'LOSEWESTGEN',   625.0, 'REMOVE UNIT 3'],
    ['5',    'LOSEWESTBIGT',  312.5, 'TRIP LINE 1  '],
    ]

row=1
col=1
testxls.set_cell(value="How to use EXCELPY module?",
     address=(row,col),fontName="Arial",fontSize=12,
     fontColor='red',fontStyle=('Bold','italic'))

row = row+2 #add one blank row
bottomRow, rightCol = testxls.set_range(row,col,testdata,trans-
pose=False)
testxls.font((row,1,row,rightCol),fontStyle='bold',font-
Color='blue')
testxls.align((row,1,row,rightCol),alignv='h_center')
testxls.align((row,1,bottomRow,2),alignv='h_center')
testxls.autofit_columns((row,2,row,rightCol))
testxls.font((row,3,bottomRow,3),numberFormat='0.000')
```

```
xlsfile = testxls.save(xlsfile)

print "Excel workbook saved to ’%s’ file.\n"% xlsfile
```

Chapter 14

Dynamic Simulation Interface

14.1 Overview: Dynamics Interface

The interface elements for the Dynamics study elements of PSS™E are contained directly within the application. Switching between the two modes of analysis, steady state and stability, is done automatically, there is no need to worry about the mode of operation.

14.1.1 Dynamics Interface Elements

The use of the stability portion of PSS™E requires several new interface elements. These are described in the following sections.

14.1.1.1 Tree View Dynamics Tab

The Dynamics tab in the Tree View (Figure 14-1) provides a quick glance at all Dynamics data in the system. The Dynamics Tab is synchronized with the bus subsystem selector to enable the user to reduce the amount of Dynamics data presented at any one time. Folders can be expanded or collapsed to control the amount of data visible. Only one folder may be expanded at a time. Expanding a folder while another is already expanded will cause the expanded folder to collapse and the new folder to be expanded.

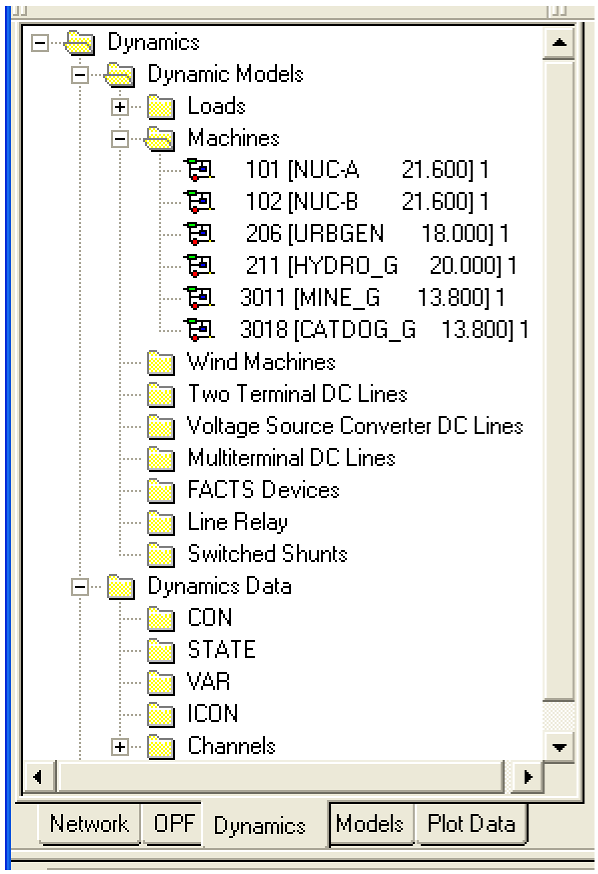


Figure 14-1. Dynamics Tab Tree View

All network elements that have Dynamics models attached to them will have an entry in the appropriate folder in the Dynamics tab.

Double-clicking on a data element (i.e. particular bus) activates the Dynamics Spreadsheet View, changes to the correct data tab, and places the focus on the first spreadsheet cell of the selected item (see Figure 14-2).

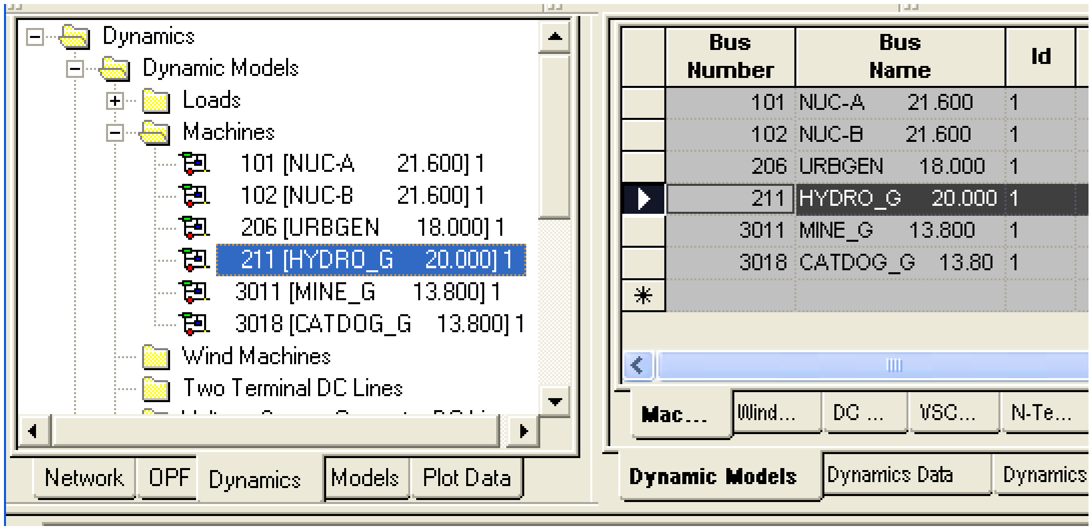
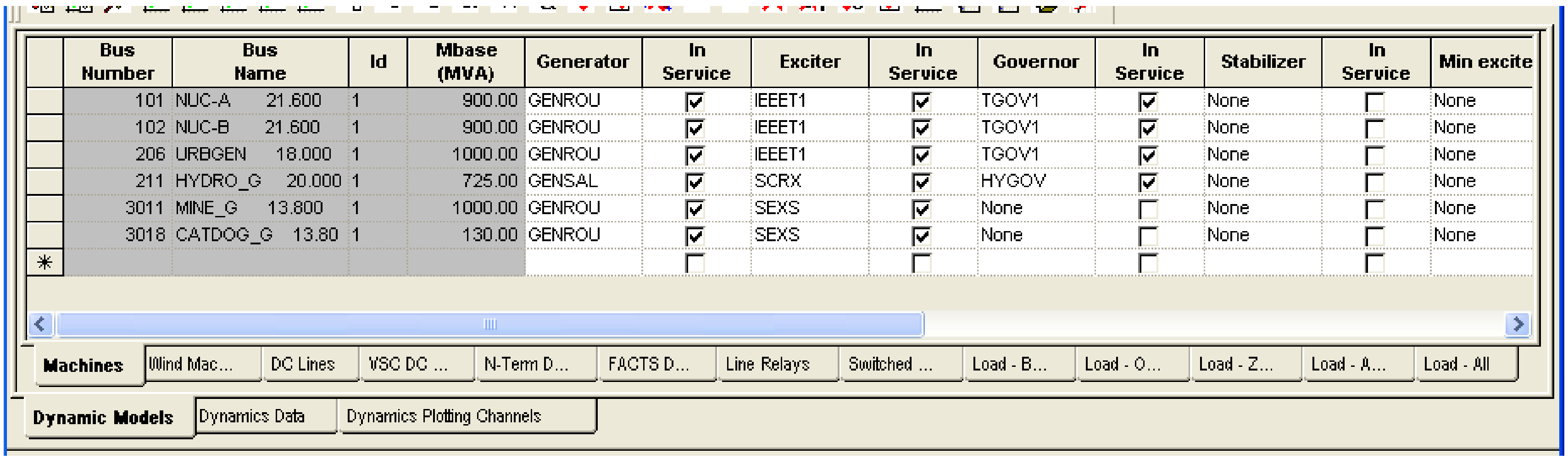


Figure 14-2. Double Clicking on an Item in the Dynamics Tree View

The Dynamics Tree View only displays network elements for which Dynamics models have been defined, either through the opening of a Snapshot or DYRE file or through the Dynamics Spreadsheet.

14.1.1.2 Dynamics Spreadsheet

The Dynamics spreadsheet is used to add, remove, edit and change the status of models attached to network elements. It is formatted in a tabbed fashion with three main tabs and a number of auxiliary tabs (see Figure 14-3).



Bus Number	Bus Name	Id	Mbase (MVA)	Generator	In Service	Exciter	In Service	Governor	In Service	Stabilizer	In Service	Min excite
101	NUC-A 21.600	1	900.00	GENROU	☑	IEEET1	☑	TGOV1	☑	None	☐	None
102	NUC-B 21.600	1	900.00	GENROU	☑	IEEET1	☑	TGOV1	☑	None	☐	None
206	URBGEN 18.000	1	1000.00	GENROU	☑	IEEET1	☑	TGOV1	☑	None	☐	None
211	HYDRO_G 20.000	1	725.00	GENSAL	☑	SCRX	☑	HYGOV	☑	None	☐	None
3011	MINE_G 13.800	1	1000.00	GENROU	☑	SEXS	☑	None	☐	None	☐	None
3018	CATDOG_G 13.80	1	130.00	GENROU	☑	SEXS	☑	None	☐	None	☐	None
*					☐		☐		☐		☐	

Figure 14-3. Dynamics Spreadsheet

If the Dynamics spreadsheet has been opened, it can be brought to the foreground, i.e. made the active view, by selecting ***Window>Dynamics Spreadsheet*** or the Dynamics Spreadsheet toolbar Icon found on the Spreadsheets toolbar (see Figure 14-4).

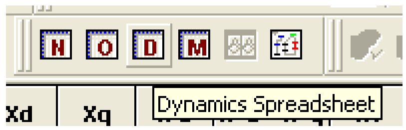


Figure 14-4. Dynamics Spreadsheet Toolbar Icon

14.1.1.3 Dynamics Models Tab

The first main Dynamics spreadsheet tab is the Dynamic Models tab. This tab contains sub-tabs for all network elements to which Dynamics models can be attached. Certain network elements, such as machines, must have Dynamics models defined. For these elements, the spreadsheets will contain an entry for every corresponding network element. Other elements, such as Branches and Two Winding Transformers, don't require a Line Relay Dynamics model and so these spreadsheets will be empty if no Dynamics models were defined for them in either the Snapshot or DYRE file. Models can be added for these elements by first selecting the network elements either by double-clicking on one of the identifier fields e.g. in the example of the Line Relay model, double-clicking on either the From Bus, To Bus or Id to bring up the Branch selector, or just entering the values by typing them into the spreadsheet.

Once the network element has been specified, models can be added by moving to the desired model location on the spreadsheet line and right-clicking. From the popup menu, select "Add/Replace Model" (see Figure 14-5).

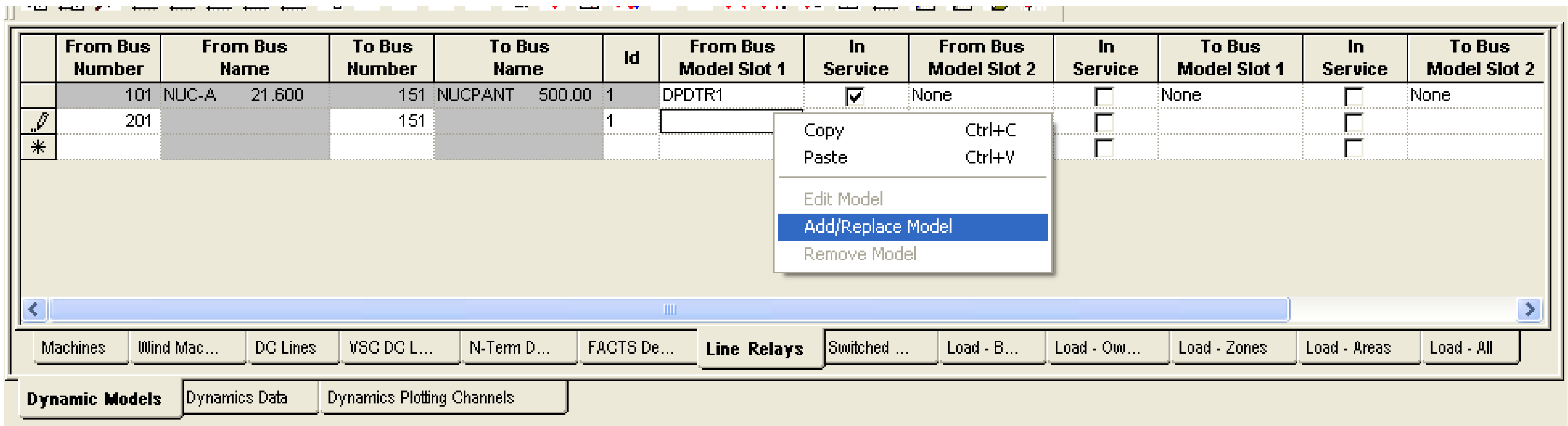


Figure 14-5. Dynamic Models Spreadsheet

Selecting “Add/Replace Model” will display a model selector that displays all the currently loaded models appropriate for the type of network element being modified (see Figure 14-6).

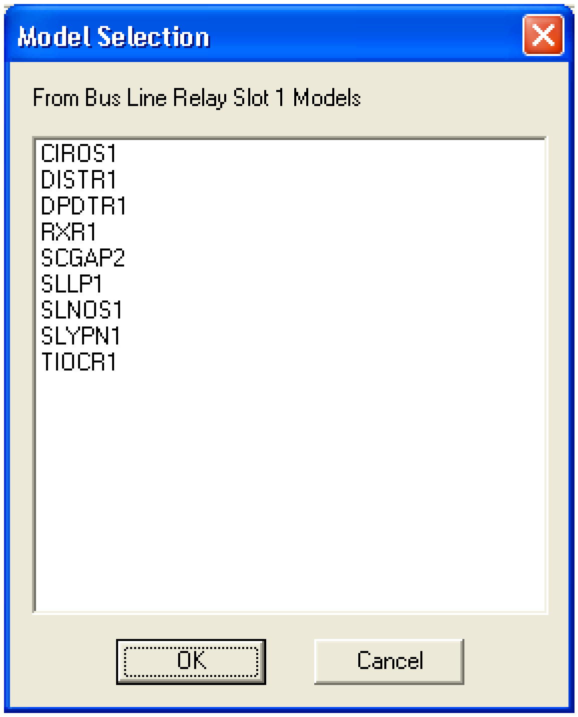


Figure 14-6. Dynamics Model Selection Dialog

Once all Dynamics models for the network element have been selected, move off the record to store the data. If you create a new entry for a network element in one of the spreadsheets without specifying any Dynamics models, the following message will appear (see Figure 14-7). Dynamics models must then be specified or the entry removed through the use of Edit>Undo record.

Figure 14-7. Dynamic Models Specification Message

To remove an existing Dynamics model from a network element, select the Dynamics model in the spreadsheet, right-click and select “Remove Model” from the popup menu and move off the record to store the data.

To edit the parameters for a particular Dynamics model, select the Dynamics model in the spreadsheet, right-click, and select “Edit Model” from the popup menu. Selecting “Edit Model” will display a dialog which can be used to modify any of the parameters (CONs/ICONs) associated with that particular instance of the model at that particular network element (see Figure 14-8).

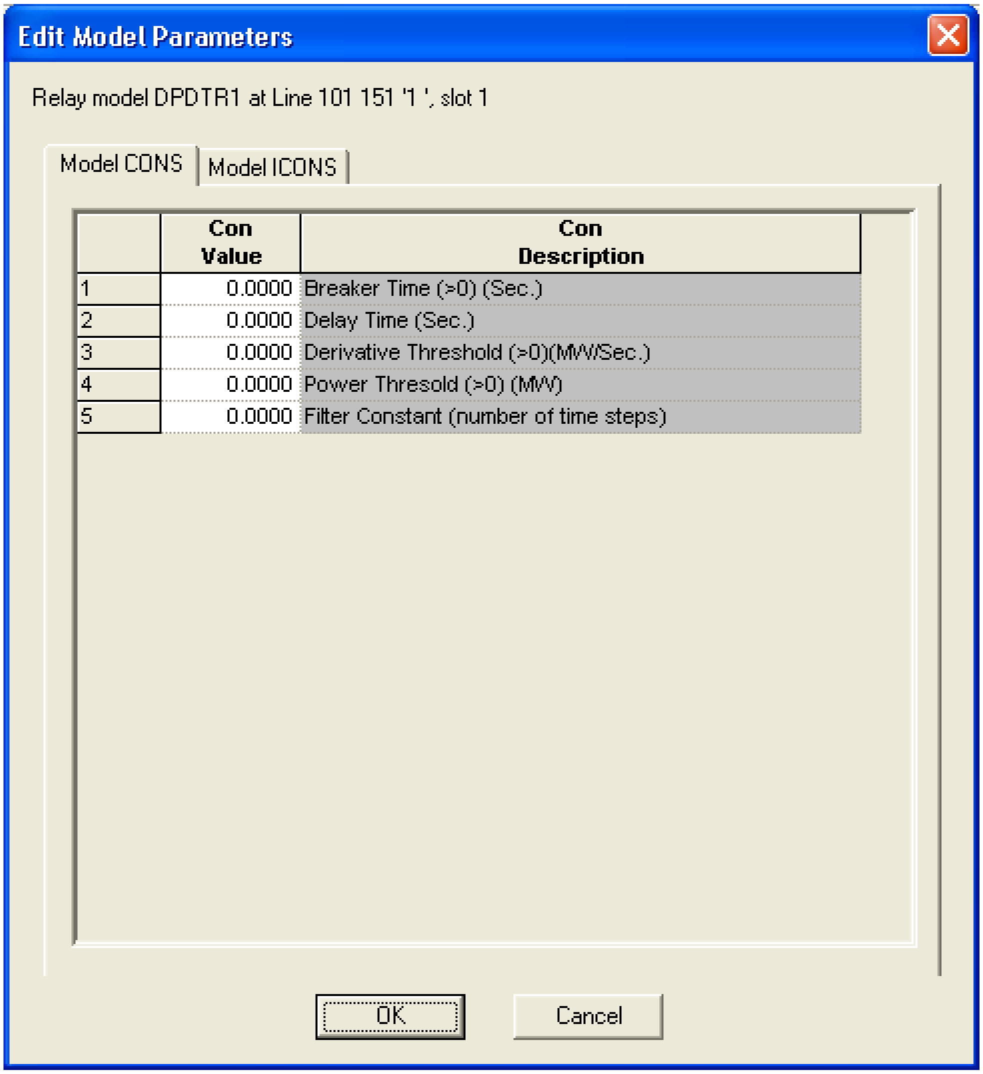


Figure 14-8. Edit Model Parameters dialog

To change the status of an existing Dynamics model, toggle the status check box located to the right of the Dynamics model of interest and move off the record to store the data (see Figure 14-9).

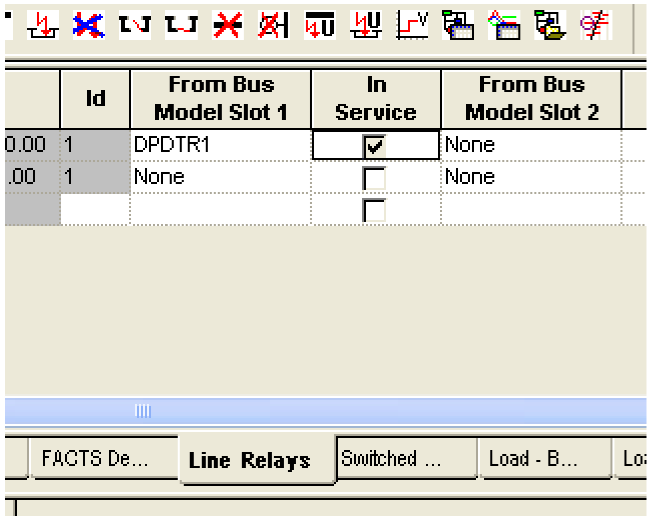


Figure 14-9. Changing the Status of a Dynamic Model

14.1.1.4 Dynamics Data Tab

The second main Dynamics spreadsheet tab is the Dynamics Data tab. This tab contains sub-tabs for all data elements associated with CONEC and CONET called models as well as all defined channels. The CONs, ICONs, STATEs and VARs associated with CONEC and/or CONET called models, as well as those associated with model logic that are in-line code (rather than model calls) in CONEC and/or CONET will appear in these spreadsheets and are available for edit (see Figure 14-10). Once a data value has been edited, move off the record to store the data.

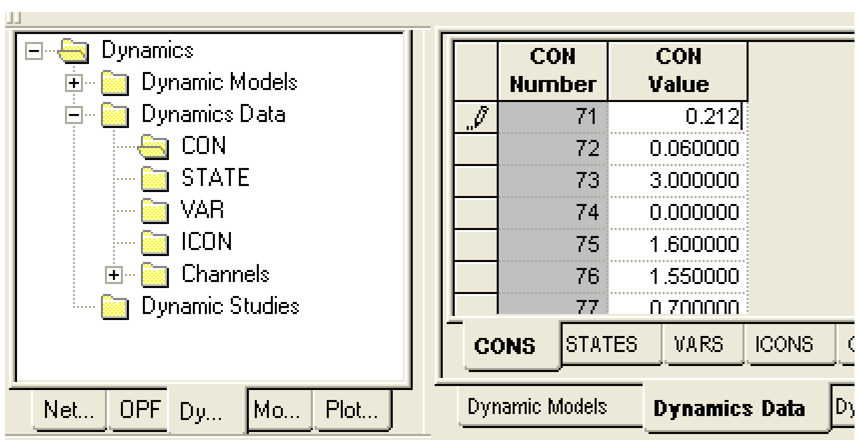


Figure 14-10. Dynamics Data Tab

If channels have been defined to collect the output of simulation results, they will appear in the spreadsheet for editing. Channels are defined for output through the dialogs available at ***Dynamics>Define simulation output (CHAN)...*** and ***Dynamics>Define simulation output by subsystem (CHSB)...***.

14.1.1.5 Dynamics Plotting Channels

Up to six channels can be defined for interactive plotting during the simulation run. Interactive plotting channels can be defined by first selecting the defined output channel either by double-clicking on the channel number field or just entering the channel number by typing it into the spreadsheet. The minimum and maximum scale values to use when plotting the channel are also defined in this spreadsheet (see Figure 14-11).

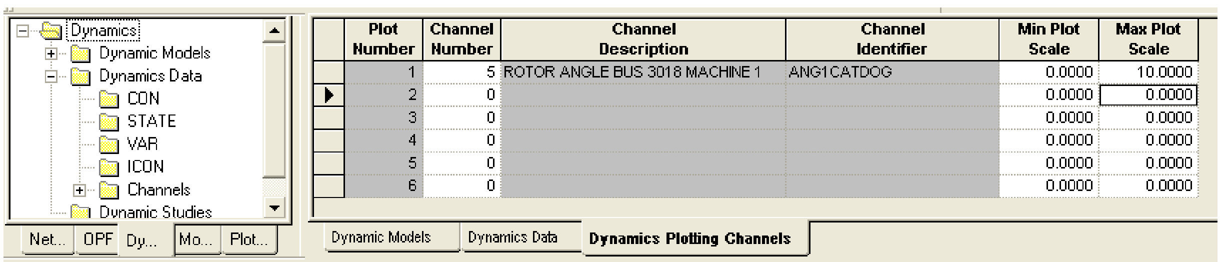


Figure 14-11. Dynamics Plotting Channels Spreadsheet

14.1.1.6 Tree View Models Tab

The Models tab in the Tree View provides a quick glance at all Dynamics models present in the current network (see Figure 14-12). Folders can be expanded or collapsed to control the amount of data visible. Only one folder may be expanded at a time. Expanding a folder while another is already expanded will cause the expanded folder to collapse and the new folder to be expanded.

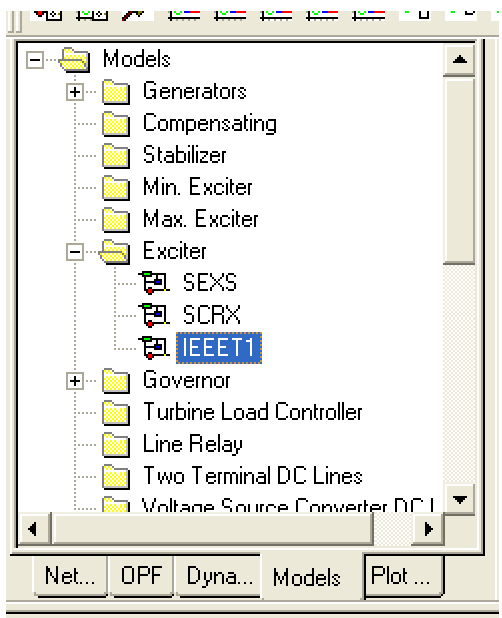


Figure 14-12. Tree View Models Tab

The Models tab is organized by Dynamics model types e.g. Generators, Stabilizers etc. Each model type contains a list of all models of that type present in the current network. Figure 14-12 shows that there are three types of exciter models present in the current network, SEXS, SCRX and IEEET1.

Double-clicking on a Dynamics model activates the Model Spreadsheet View and loads the spreadsheet with all network instances of that selected model (see Figure 14-13).

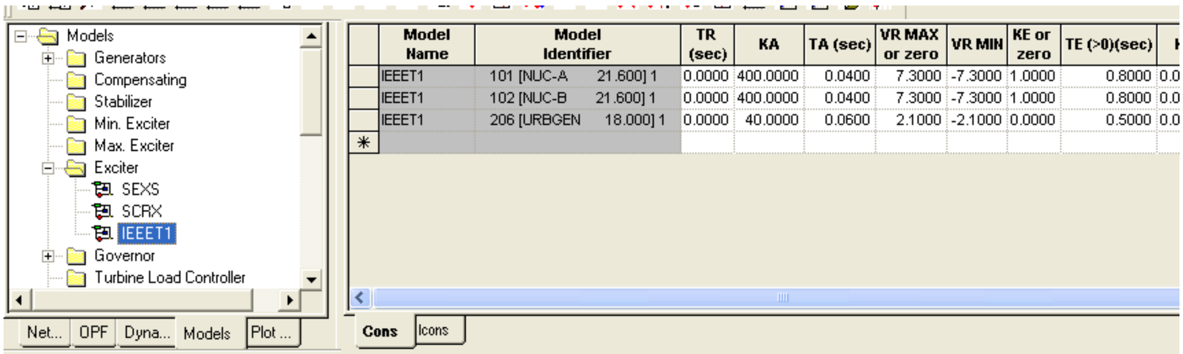


Figure 14-13. Dynamic Models Spreadsheet

14.1.1.7 Model Spreadsheet

The Model spreadsheet is used to modify the CONs and ICONs associated with the individual Dynamics models attached to network elements. Using the model spreadsheet, all the CONs and ICONS associated with all instances of a particular model in the current network can be examined at once, providing a way to make quick data value range checks or modifications. Once a data value has been edited, move off the record to store the data.

The columns containing a particular CON or ICON can be sorted by double-clicking the column header, just as in the Network spreadsheet. Copy/Paste operations work the same as described for the Network spreadsheet.

If the Model spreadsheet has been opened, it can be brought to the foreground, i.e., made the active view, by selecting ***Window>Model Spreadsheet*** or the Model Spreadsheet toolbar Icon found on the Spreadsheets toolbar (see Figure 14-14).

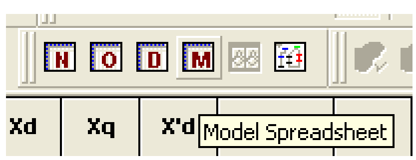


Figure 14-14. Model Spreadsheet Toolbar Icon

14.1.1.8 Tree View Plot tab

The Plot tab in the Tree View provides a quick glance at all channels defined in a channel output file (see Figure 14-15). Folders can be expanded or collapsed to control the amount of data visible.

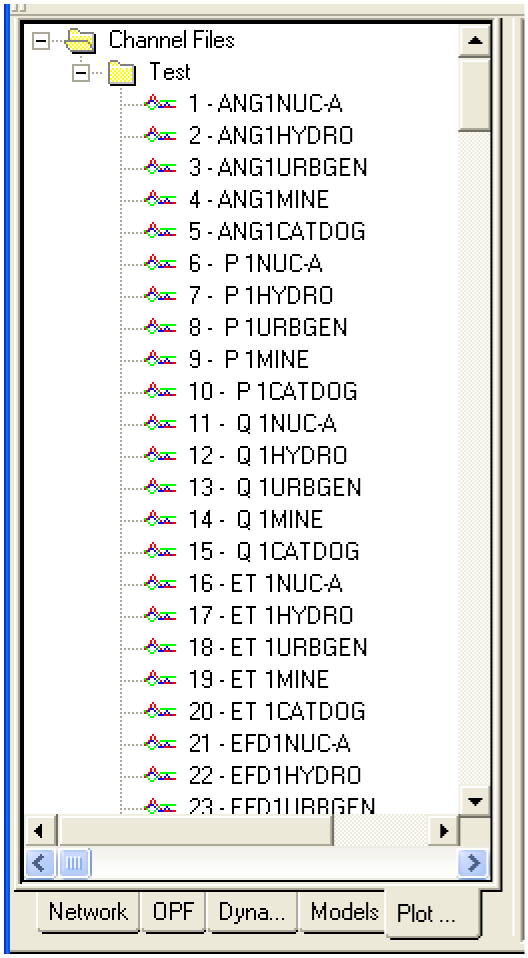


Figure 14-15. Tree View Plot Tab

Further details on using the integrated plot package can be found in Chapter 16.

14.1.1.9 Dynamics Menu Bar Item

The Dynamics entry on the menu bar is used to access all the Dynamics specific functions of PSS™E. Dynamics functions can be accessed and run at any time (see Figure 14-16). Unlike previous versions of PSS™E, where it was necessary to switch back and forth between the Dynamics and Power Flow modes using LOFL and RTRN, mode switching is now handled behind the scenes by PSS™E.

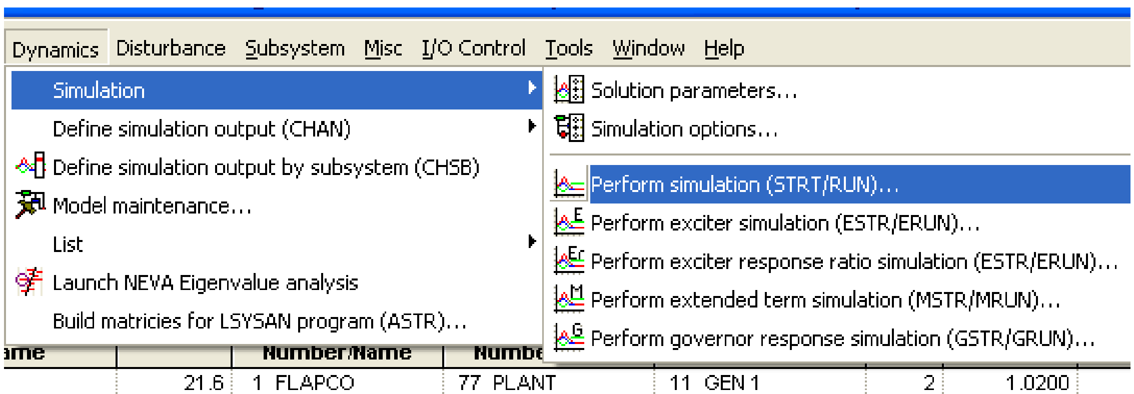


Figure 14-16. Dynamics Menu Bar

14.1.1.10 Disturbance Menu Bar

The Disturbance entry on the menu bar is used to access all the Dynamics Disturbance functions of PSS™E. Dynamics Disturbance functions can be accessed and run at any time (see Figure 14-17). Unlike previous versions of PSS™E, where it was necessary to switch back and forth between the Dynamics and Power Flow modes using LOFL and RTRN, mode switching is now handled behind the scenes by PSS™E. Several of the disturbance functions require that the Dynamics solution be initialized through the standard simulation or extended term simulation functions before they can be run.

Note that, in Figure 14-17, the last two entries, namely the 'Calculate and apply unbalanced bus fault' and the 'Calculate and apply branch unbalance' involve the calculation of the positive sequence equivalent of an unbalanced condition. For the unbalanced bus fault, activity SCMU (see *Program Operation Manual Volume I*, Section 4.99) is used; for the branch unbalance, activity SPCB (see *Program Operation Manual Volume I* Section 4.101) is used. The requirements and restrictions applicable to those activities must be recognized. Further, the use of these two fault calculations is applicable *only* to the application of a single unbalance. It would not be valid to apply a fault using *any* of the methods described in this section, and then, with that fault is still applied, calculate the positive sequence equivalent of another unbalanced condition.

The list of currently applied faults is not preserved in Snapshot Files or Saved Case Files. This list is initialized to "empty" when PSS™E is started up at its dynamic simulation entry point, and also during the simulation initialization activities STRT, MSTR, ASTR, ESTR and GSTR

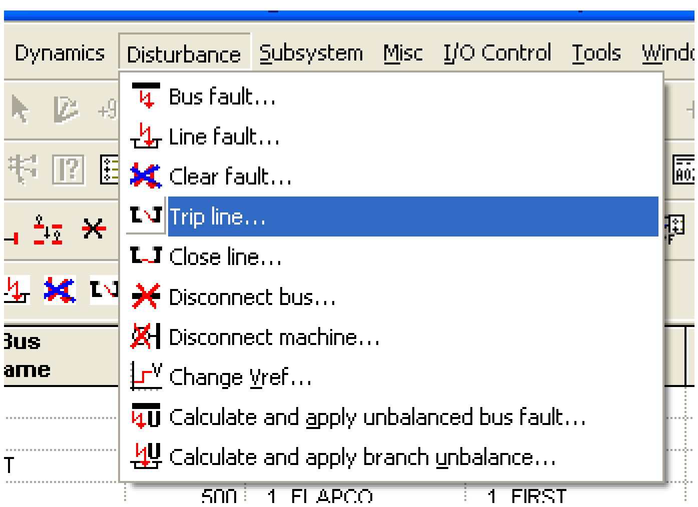


Figure 14-17. Disturbance Menu Bar

14.1.1.11 Dynamics Toolbar

All Dynamics and Dynamics Disturbance functions can be accessed from the Dynamics Simulation toolbar (see Figure 14-18). The Icons found on the Dynamics Simulation toolbar are also used to decorate the menu bar selections.

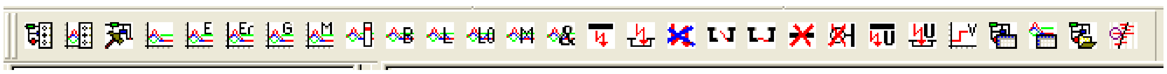


Figure 14-18. Dynamics Toolbar

The Dynamics Simulation toolbar can be customized using ***Tools>Customize Toolbars…***.

14.1.1.12 Opening Dynamics Files

Dynamics network data is contained within Snapshot and DYRE files, *.snp, *.dyr. These files are opened from File>Open…

14.1.1.12.1 Opening a Snapshot File

To open a Snapshot file, select Snapshot Data Files through the “Files of type” selection box at the bottom of the dialog and select the desired Snapshot file (see Figure 14-19).

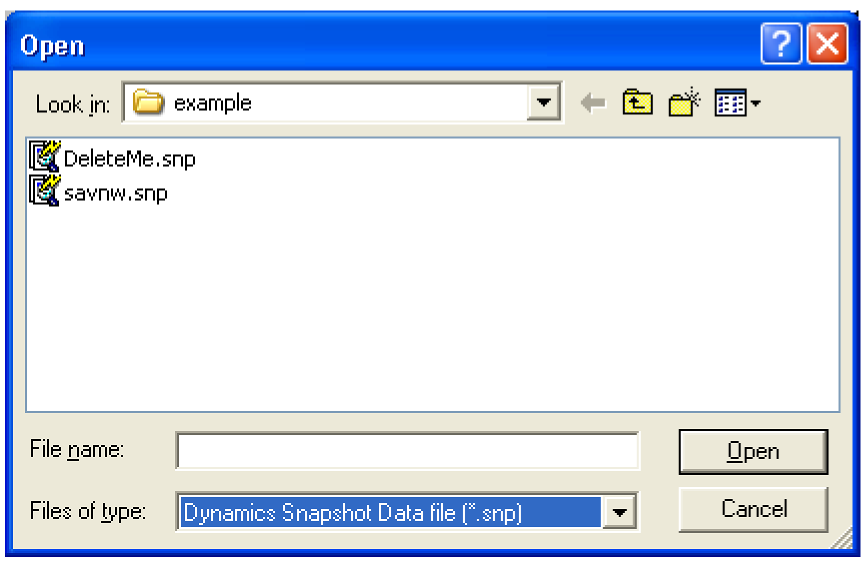


Figure 14-19. Snapshot File Open Dialog

14.1.1.12.2 Opening a DYRE File

To open a DYRE file, select Dynamics Model Raw Data file through the “Files of type” selection box at the bottom of the dialog and select the desired DYRE file (see Figure 14-20).

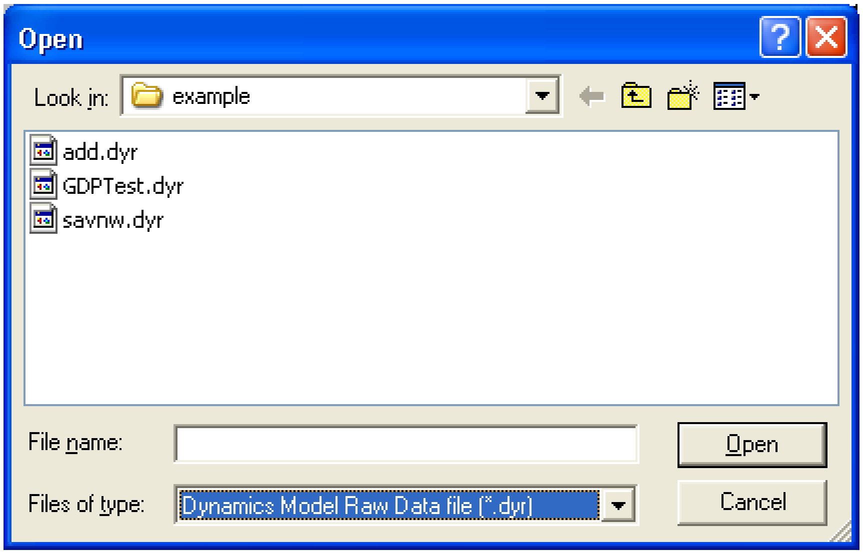


Figure 14-20. DYRE File Open Dialog

Once the DYRE file has been selected, the following dialog appears (see Figure 14-21). From this dialog CONEC and CONET files can be specified, as well as starting values for CONs, ICONs, STATEs and VARs. Clicking on OK will read the specified DYRE file and update the Dynamics Tree View and Spreadsheet with the Dynamics data contained in the file.

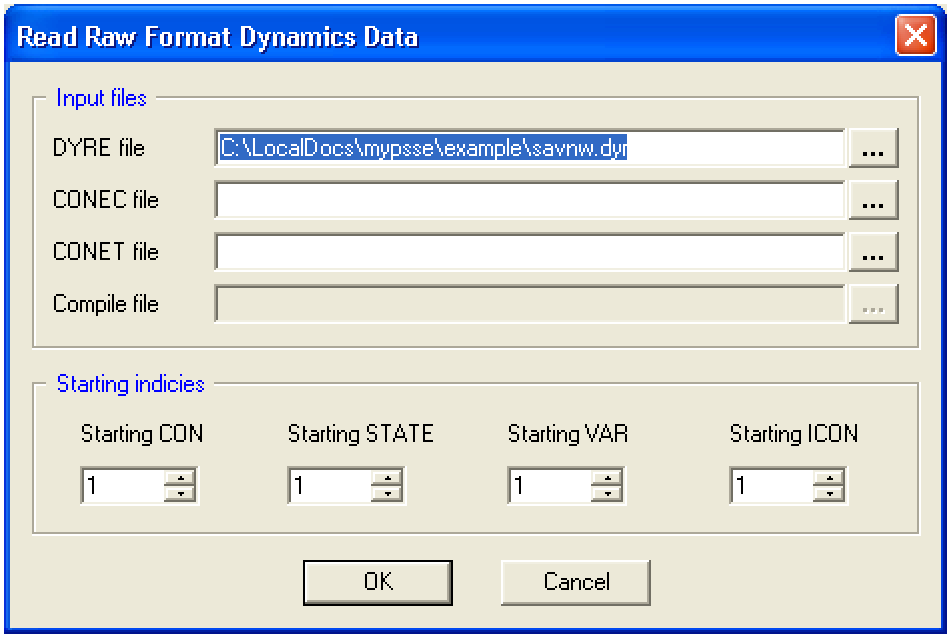


Figure 14-21. DYRE Dialog

14.1.1.12.3 Adding DYRE Data to Existing Dynamics Data

To add Dynamics data to an existing Dynamics network, select Add Dynamics Model Data through the “Files of type” selection box at the bottom of the dialog and select the desired DYRE file (see Figure 14-22).

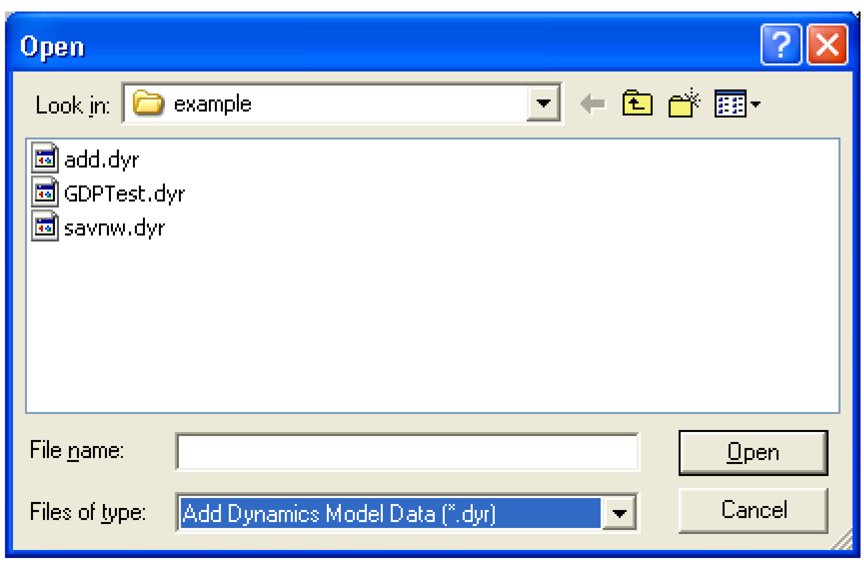


Figure 14-22. DYRE File Open dialog

Once the DYRE file has been selected, the following dialog appears (see Figure 14-23). From this dialog CONEC and CONET files can be specified, as well as starting values for the CONs, ICONs, STATEs and VARs contained within the DYRE file. Clicking on OK will read the specified DYRE file and update the Dynamics Tree View and Spreadsheet with the Dynamics data contained in the file.

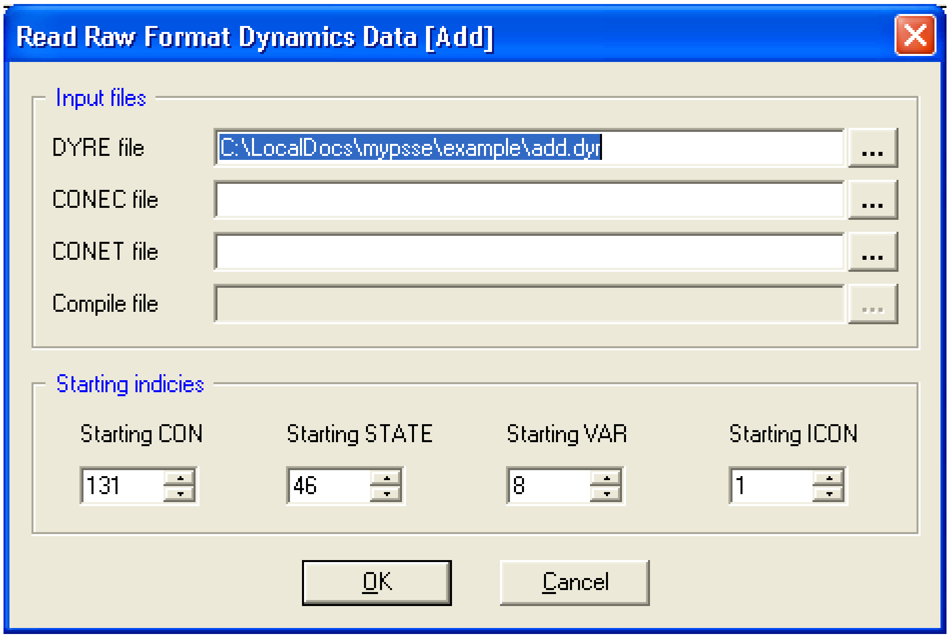


Figure 14-23. DYRE Dialog in Add Mode

14.1.2 Dynamic Menu Bar Entries

The following sections describe the dialogs found in the Dynamics Menu Bar entry of PSS™E.

14.1.2.1 Dynamic Solution Parameters

Dynamics solution parameters are set and modified using the Dynamics Solution Parameters dialog found under **Dynamics>Simulation>Solution parameters…**. From this dialog, numerous controls affecting network solutions in Dynamics simulations as well as the Dynamics simulation itself can be set (see Figure 14-24). The channel output file can also be specified through this dialog.

Commonly, a Dynamics simulation is run to a certain time, solution parameters are modified, and the run continued with the new parameters.

Select the ***OK*** button to use the new solution parameter settings. Select the ***Cancel*** button to dismiss the dialog without making any changes.

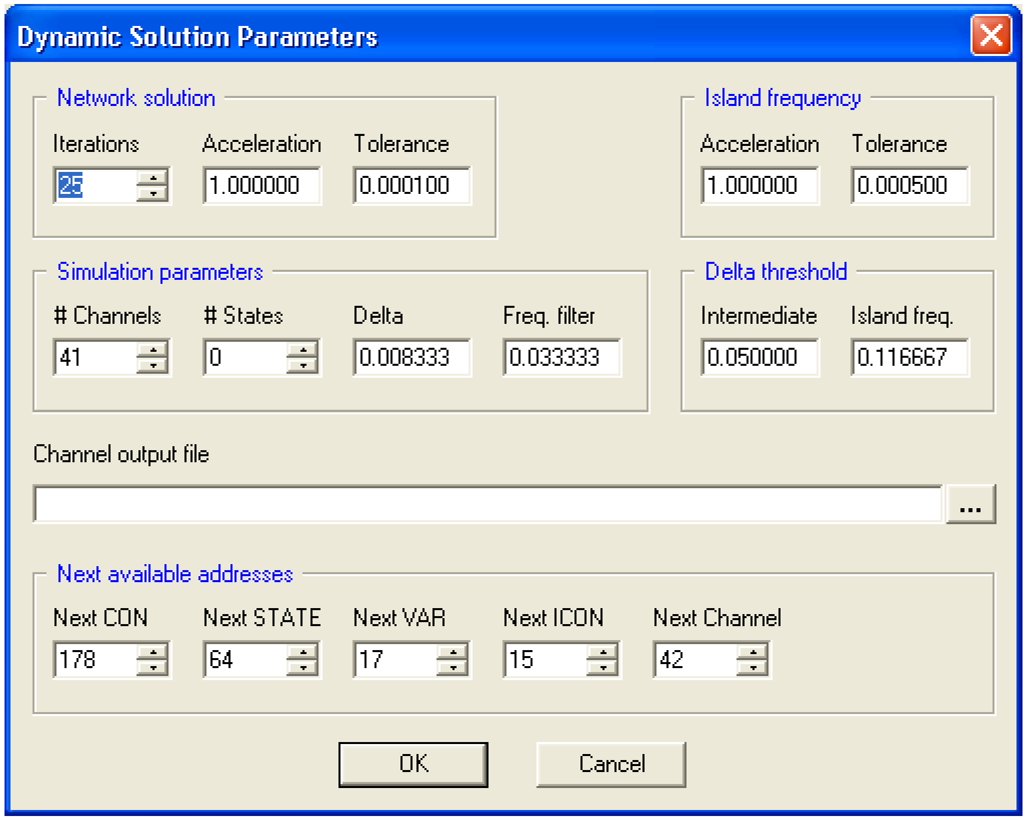


Figure 14-24. Dynamic Solution Parameters Dialog

14.1.2.2 Dynamic Simulation Options

System-wide monitoring and solution options may be set and modified using the Dynamics Simulation Options dialog found under **Dynamics>Simulation>Simulation options...**. From this dialog, numerous controls affecting Dynamic simulations options can be set (see Figure 14-25).

The network frequency dependence option results in both network parameters and the flux calculations of generator models made dependent on local frequency. The out-of-step relay scanning model checks every circuit in both directions for out-of-step conditions. The two generator scanning functions trip machines instantaneously if the specified threshold is violated. The voltage scanning model reports bus voltages outside of the specified band. The generic apparent impedance relay scanning model checks every circuit in both directions against generic relay characteristics. If machine angles are "relativized", reports which list machine angles, as well as any output channels containing machine angles, express them relative to the specified value rather than as absolute angles. For additional information, see the *Program Application Guide*.

Select the ***OK*** button to use the new simulation option settings. Select the ***Cancel*** button to dismiss the dialog without making any changes.

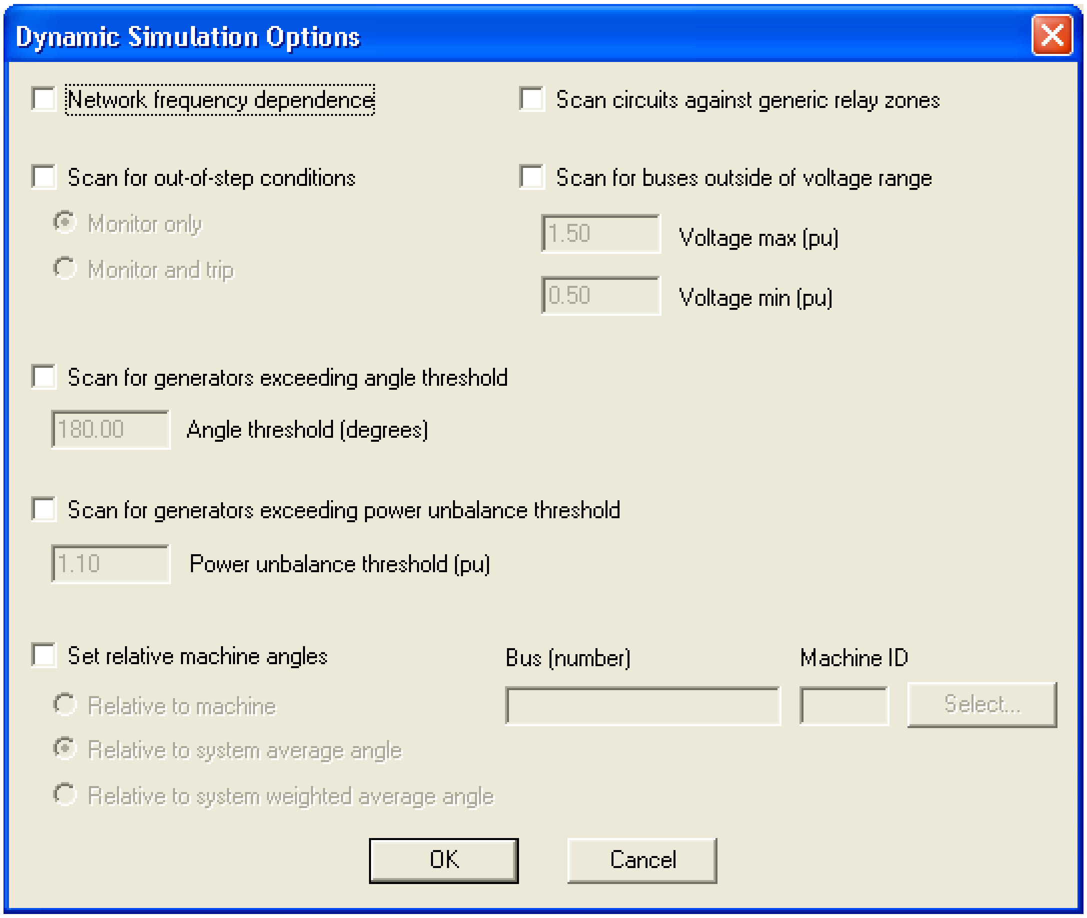


Figure 14-25. Dynamic Simulation Options Dialog

14.1.2.3 Perform Dynamic Simulation

A standard Dynamics simulation is performed using the Perform Dynamics Simulation dialog found under **Dynamics>Simulation>Perform simulation (STRT/RUN)...**. From this dialog, the Dynamics simulation can be initialized and run to any point in time (see Figure 14-26).

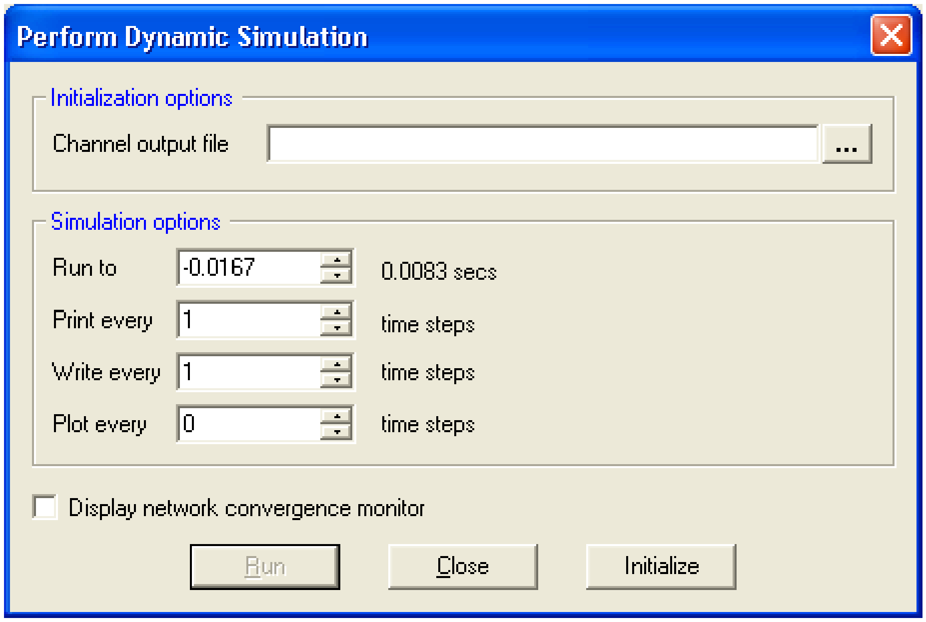


Figure 14-26. Perform Dynamic Simulation Dialog

The channel output file, used to capture the output of the Dynamics simulation, is specified in the “Channel output file” field. The channel output file can be selected by entering it directly in the field or by selecting the “browse” button to the right of the field and using a standard file selector dialog to select the file.

The "Run to" field defines the value of simulated TIME at which the simulation activity is to be terminated. When the dialog is brought up, this field contains the present value of simulated TIME.

The values of the "Print every", "Write every" and "Plot every" data items are integer values defining the interval, in units of the number of simulation time steps, between the recording of output channel values. Any changes to these settings are remembered and become their initial values the next time the dialog is brought up.

The "Print every" data item defines the interval to be used in tabulating the values of the output channels. This tabulation is directed to the defined progress output device.

The "Write every" data item defines the interval to be used in writing the values of the output channels to the current channel output file. This value is meaningful only if a channel output file had been specified when the ***Initialize*** button was selected.

The "Plot every" data item defines the interval to be used in plotting the values of the CRT plot channels at the user's CRT workstation. This value is meaningful only if: a channel output file had been specified when the ***Initialize*** button was selected and at least one of the six CRT plot channels listed in the Dynamics Plotting Channels tab of the Dynamics Spreadsheet has been selected.

When the dialog first appears, if the simulation has ***not*** been initialized, the ***Run*** button will be disabled. The simulation will first need to be initialized by selecting the ***Initialize*** button. Note that the file specified in the Channel output file field is used during the initialization process. Once the simulation has been initialized the ***Run*** button will be enabled.

Selecting the ***Run*** button will run the simulation out to the time specified in the “Run to” field. Once the simulation has been run out to the specified time, disturbances and faults can be applied and the simulation run again out to a new specified time.

The Perform Dynamic Simulation dialog is a modeless dialog. This means that it doesn’t have to be dismissed in order to access other program functions.

14.1.2.4 Perform Exciter Simulation Test

An excitation system testing is performed using the Perform Exciter Simulation Test dialog found under **Dynamics>Simulation>Perform exciter simulation (ESTR/ERUN)...**. From this dialog, the exciter test can be initialized and run to any point in time (see Figure 14-27).

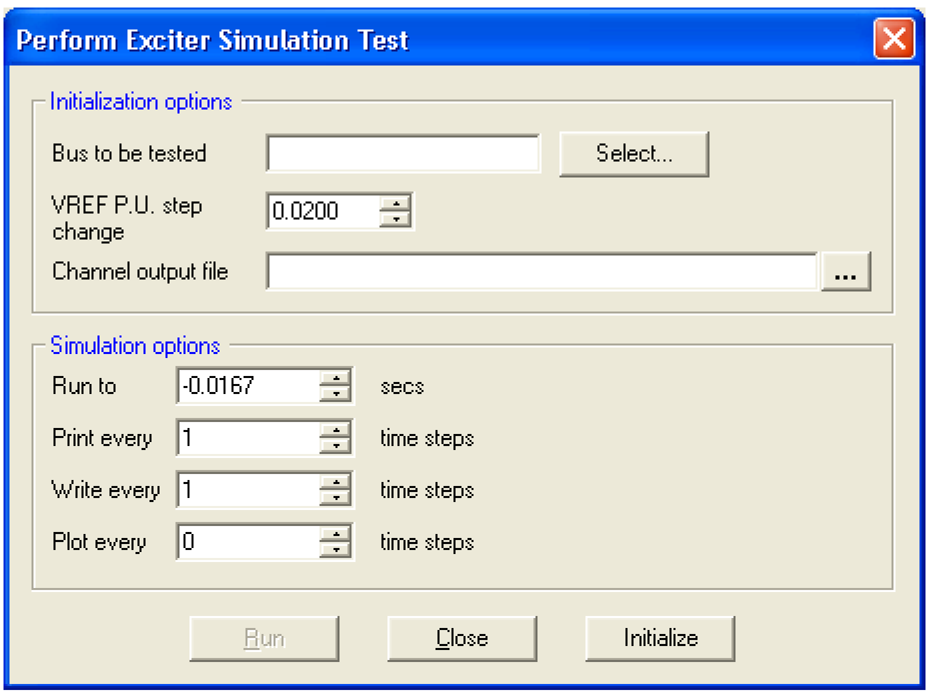


Figure 14-27. Perform Exciter Simulation Test Dialog

If a bus is specified in the “Bus to be tested” field, the excitation system response of all machines connected to the specified bus having connected excitation system models is tested. If no bus is specified, all machines with connected exciter models are tested. The bus can be specified by entering it directly in the Bus to be tested field or by selecting the ***Select*** button to the right of the field and using the standard bus selector dialog to select the bus.

The “VREF P.U. step change” field is used to specify the step to be applied to all voltage regulator setpoints, typically 0.02 to 0.1. The step magnitude should not exceed about ten percent (0.1) since the object of this test is to reveal small disturbance behavior.

The channel output file, used to capture the output of the Dynamics simulation, is specified in the "Channel output file" field. The channel output file can be selected by entering it directly in the field or by selecting the "browse" button to the right of the field and using a standard file selector dialog to select the file.

The "Run to" field defines the value of simulated TIME at which the simulation activity is to be terminated. When the dialog is brought up, this field contains the present value of simulated TIME.

The values of the "Print every", "Write every" and "Plot every" data items are integer values defining the interval, in units of the number of simulation time steps, between the recording of output channel values. Any changes to these settings are remembered and become their initial values the next time the dialog is brought up.

The "Print every" data item defines the interval to be used in tabulating the values of the output channels. This tabulation is directed to the defined progress output device.

The "Write every" data item defines the interval to be used in writing the values of the output channels to the current channel output file. This value is meaningful only if a channel output file had been specified when the ***Initialize*** button was selected.

The "Plot every" data item defines the interval to be used in plotting the values of the CRT plot channels at the user's CRT workstation. This value is meaningful only if: a channel output file had been specified when the ***Initialize*** button was selected and at least one of the six CRT plot channels listed in the Dynamics Plotting Channels tab of the Dynamics Spreadsheet has been selected.

When the dialog first appears, if the simulation has ***not*** been initialized, the ***Run*** button will be disabled. The simulation will first need to be initialized by selecting the ***Initialize*** button. Note that the file specified in the Channel output file field is used during the initialization process. Once the simulation has been initialized the ***Run*** button will be enabled. Selecting the ***Run*** button will run the simulation out to the time specified in the "Run to" field.

The Perform Exciter Simulation Test dialog is a modeless dialog. This means that it doesn't have to be dismissed in order to access other program functions.

14.1.2.5 Perform Exciter Response Ratio Simulation Test

An excitation system response ratio test is performed using the Perform Exciter Response Ratio Simulation Test dialog found under **Dynamics>Simulation>Perform exciter response ratio simulation (ESTR/ERUN)…**. From this dialog, the exciter response ratio test can be initialized and run to any point in time (see Figure 14-28).

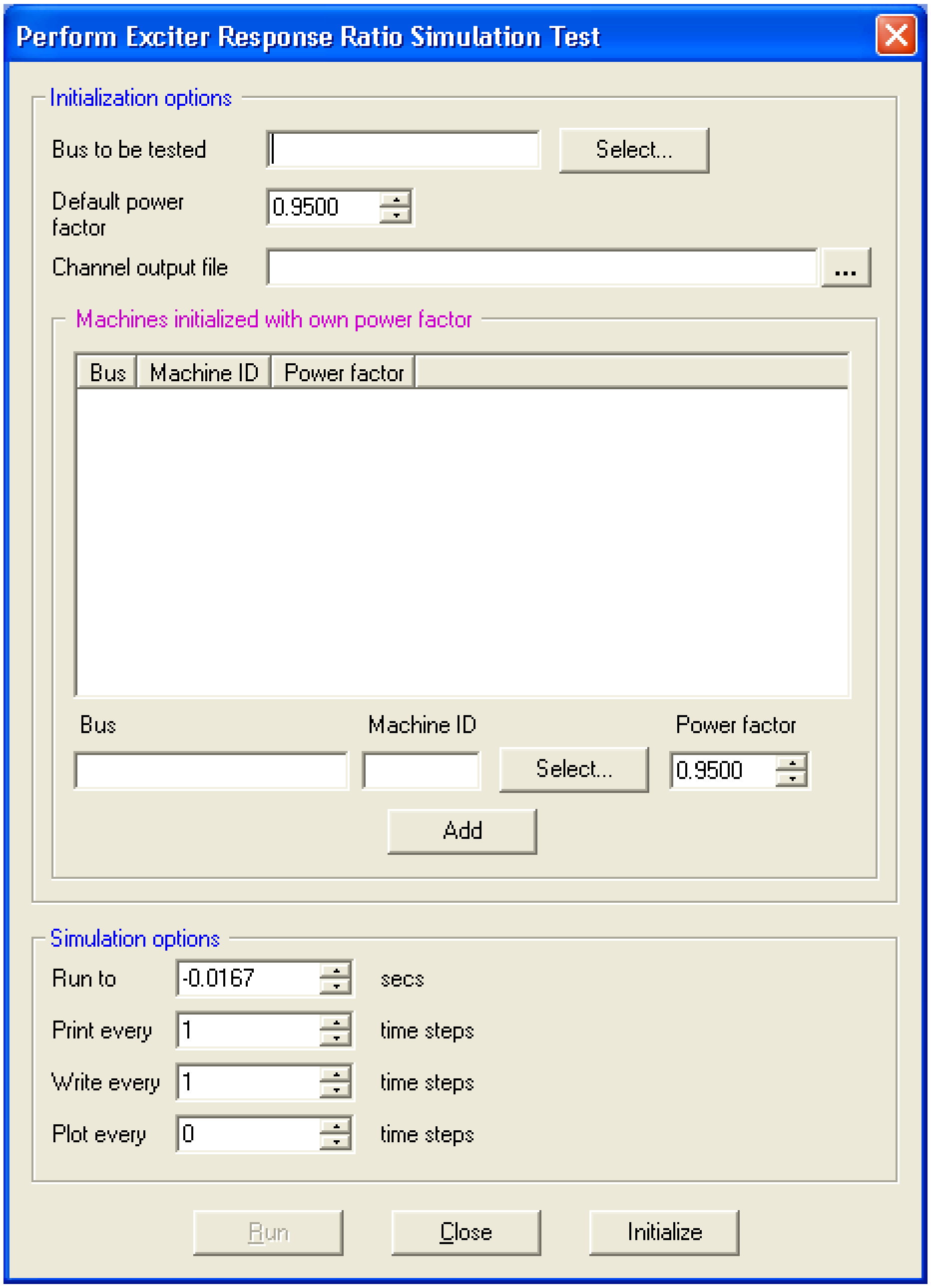


Figure 14-28. Perform Exciter Response Ratio SImulation Test Dialog

If a bus is specified in the “Bus to be tested” field, the excitation system response of all machines connected to the specified bus having connected excitation system models are tested. If no bus is specified, all machines with connected exciter models are tested. The bus can be specified by entering it directly in the Bus to be tested field or by selecting the ***Select*** button to the right of the field and using the standard bus selector dialog to select the bus.

The “Default power factor” field is used to specify the value used to initialize each generator to rated MVA (i.e., to MBASE as contained in the power flow generator data) at the specified power factor.

The channel output file, used to capture the output of the Dynamics simulation, is specified in the “Channel output file” field. The channel output file can be selected by entering it directly in the field or by selecting the “browse” button to the right of the field and using a standard file selector dialog to select the file.

Machines can be selected to be initialized with a power factor other than the “Default power factor” by adding them to the list of “Machines initialized with own power factor”. This is done by specifying the individual machine and its power factor in the fields in the middle of the dialog. The machine can be specified by entering it directly in the “Bus” and “Machine ID fields or by selecting the ***Select*** button to the right of the field and using the standard machine selector dialog to select the machine. When the machine is specified, change the “Power factor” field to specify the power factor at which to initialize the specified machine. Select the ***Add*** button to add it to the list of machines with unique initializations. To remove a machine from the list, select it in the list and press the **[Delete]** key.

The "Run to" field defines the value of simulated TIME at which the simulation activity is to be terminated. When the dialog is brought up, this field contains the present value of simulated TIME.

The values of the "Print every", "Write every" and "Plot every" data items are integer values defining the interval, in units of the number of simulation time steps, between the recording of output channel values. Any changes to these settings are remembered and become their initial values the next time the dialog is brought up.

The "Print every" data item defines the interval to be used in tabulating the values of the output channels. This tabulation is directed to the defined progress output device.

The "Write every" data item defines the interval to be used in writing the values of the output channels to the current channel output file. This value is meaningful only if a channel output file had been specified when the ***Initialize*** button was selected.

The "Plot every" data item defines the interval to be used in plotting the values of the CRT plot channels at the user's CRT workstation. This value is meaningful only if: a channel output file had been specified when the ***Initialize*** button was selected and at least one of the six CRT plot channels listed in the Dynamics Plotting Channels tab of the Dynamics Spreadsheet has been selected.

When the dialog first appears, if the simulation has ***not*** been initialized, the ***Run*** button will be disabled. The simulation will first need to be initialized by selecting the ***Initialize*** button. Note that the file specified in the Channel output file field is used during the initialization process. Once the simulation has been initialized the ***Run*** button will be enabled. Selecting the ***Run*** button will run the simulation out to the time specified in the “Run to” field.

The Perform Exciter Response Ratio Simulation Test dialog is a modeless dialog. This means that it doesn’t have to be dismissed in order to access other program functions.

14.1.2.6 Perform Governor Response Simulation

A governor response simulation is performed using the Perform Governor Response Simulation dialog found under **Dynamics>Simulation>Perform governor response simulation (GSTR/GRUN)...**. From this dialog, the governor response simulation can be initialized and run to any point in time (see Figure 14-29).

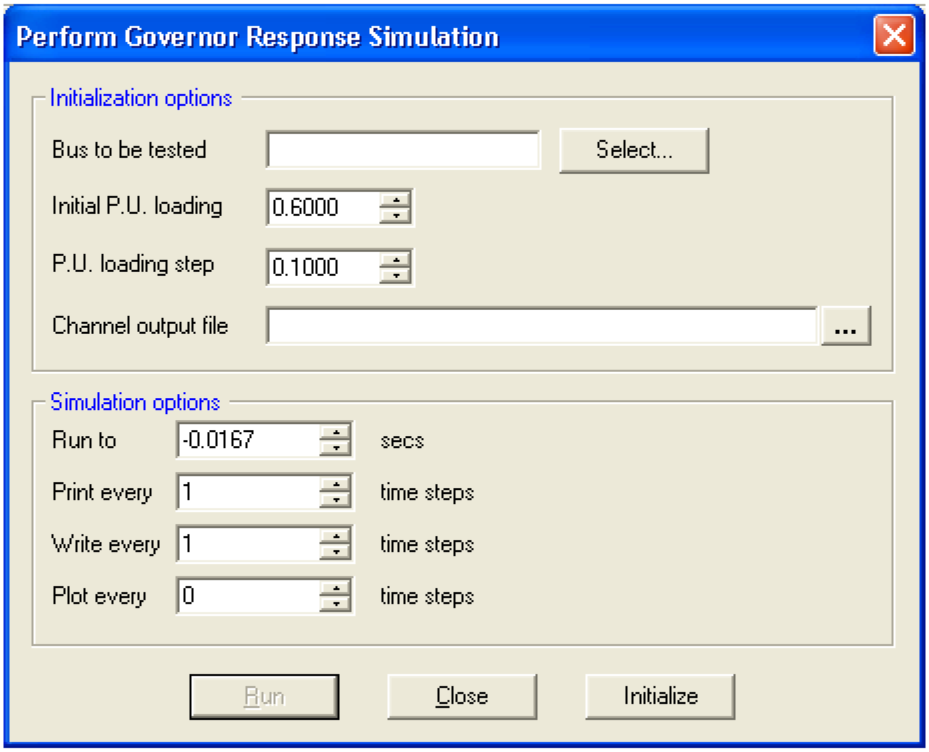


Figure 14-29. Perform Governor Response Simulation Dialog

If a bus is specified in the “Bus to be tested” field, the governor response of all machines connected to the specified bus having connected governor models is tested. If no bus is specified, all machines with connected governor models are tested. The bus can be specified by entering it directly in the Bus to be tested field or by selecting the ***Select*** button to the right of the field and using the standard bus selector dialog to select the bus.

The “Initial P.U. loading” field is used to specify the initial machine loading in per unit of machine base, MBASE. The “P.U. loading step” field is used to specify the load step change to be applied at TIME equals zero during the simulation. Here again, since the machine initialization to a specified fraction of rated MVA is based on the value specified as MBASE for each machine, this test assumes that generator and governor model parameters are entered on actual machine base.

The channel output file, used to capture the output of the Dynamics simulation, is specified in the “Channel output file” field. The channel output file can be selected by entering it directly in the field or by selecting the “browse” button to the right of the field and using a standard file selector dialog to select the file.

The "Run to" field defines the value of simulated TIME at which the simulation activity is to be terminated. When the dialog is brought up, this field contains the present value of simulated TIME.

The values of the "Print every", "Write every" and "Plot every" data items are integer values defining the interval, in units of the number of simulation time steps, between the recording of output channel values. Any changes to these settings are remembered and become their initial values the next time the dialog is brought up.

The "Print every" data item defines the interval to be used in tabulating the values of the output channels. This tabulation is directed to the defined progress output device.

The "Write every" data item defines the interval to be used in writing the values of the output channels to the current channel output file. This value is meaningful only if a channel output file had been specified when the ***Initialize*** button was selected.

The "Plot every" data item defines the interval to be used in plotting the values of the CRT plot channels at the user's CRT workstation. This value is meaningful only if: a channel output file had been specified when the ***Initialize*** button was selected and at least one of the six CRT plot channels listed in the Dynamics Plotting Channels tab of the Dynamics Spreadsheet has been selected.

When the dialog first appears, if the simulation has ***not*** been initialized, the ***Run*** button will be disabled. The simulation will first need to be initialized by selecting the ***Initialize*** button. Note that the file specified in the Channel output file field is used during the initialization process. Once the simulation has been initialized the ***Run*** button will be enabled. Selecting the ***Run*** button will run the simulation out to the time specified in the “Run to” field.

The Perform Governor Response Simulation dialog is a modeless dialog. This means that it doesn’t have to be dismissed in order to access other program functions.

14.1.2.7 Perform Extended Term Dynamic Simulation

An extended term simulation is performed using the Perform Extended Term Dynamic Simulation dialog found under ***Dynamics>Simulation>Perform extended term simulation (MSTR/MRUN)...***. From this dialog, the extended term simulation can be initialized and run to any point in time (see Figure 14-30).

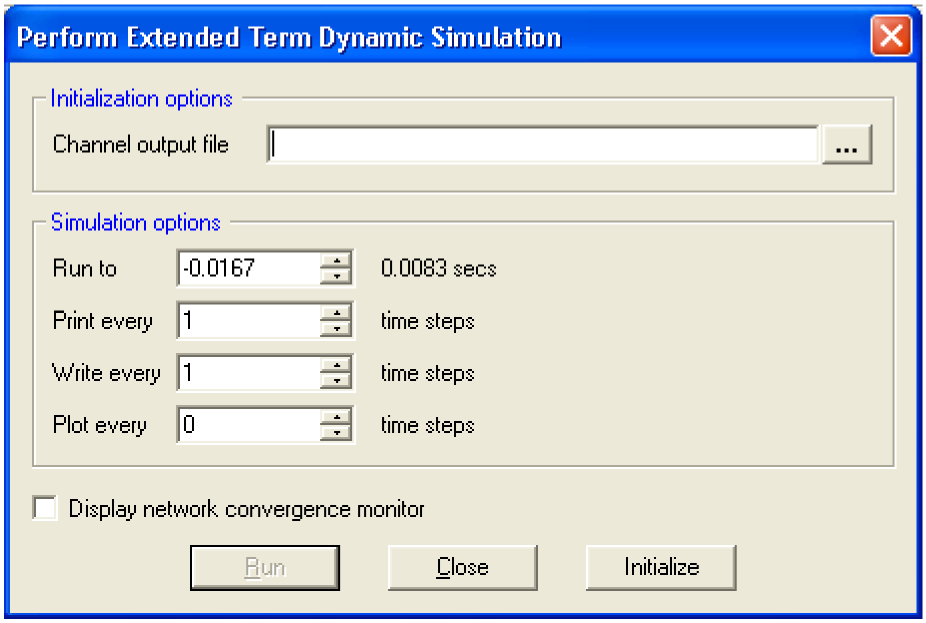


Figure 14-30. Perform Extended Term Dynamic Simulation Dialog

The channel output file, used to capture the output of the Dynamics simulation, is specified in the “Channel output file” field. The channel output file can be selected by entering it directly in the field or by selecting the “browse” button to the right of the field and using a standard file selector dialog to select the file.

The "Run to" field defines the value of simulated TIME at which the simulation activity is to be terminated. When the dialog is brought up, this field contains the present value of simulated TIME.

The values of the "Print every", "Write every" and "Plot every" data items are integer values defining the interval, in units of the number of simulation time steps, between the recording of output channel values. Any changes to these settings are remembered and become their initial values the next time the dialog is brought up.

The "Print every" data item defines the interval to be used in tabulating the values of the output channels. This tabulation is directed to the defined progress output device.

The "Write every" data item defines the interval to be used in writing the values of the output channels to the current channel output file. This value is meaningful only if a channel output file had been specified when the ***Initialize*** button was selected.

The "Plot every" data item defines the interval to be used in plotting the values of the CRT plot channels at the user's CRT workstation. This value is meaningful only if: a channel output file had been specified when the ***Initialize*** button was selected and at least one of the six CRT plot channels listed in the Dynamics Plotting Channels tab of the Dynamics Spreadsheet has been selected.

When the dialog first appears, if the simulation has ***not*** been initialized, the ***Run*** button will be disabled. The simulation will first need to be initialized by selecting the ***Initialize*** button. Note that the file specified in the Channel output file field is used during the initialization process. Once the simulation has been initialized the ***Run*** button will be enabled.

Selecting the ***Run*** button will run the simulation out to the time specified in the “Run to” field. Once the simulation has been run out to the specified time, disturbances and faults can be applied as well as changed to solution parameters and options, and the simulation run again out to a new specified time.

The Perform Extended Term Dynamic Simulation dialog is a modeless dialog. This means that it doesn’t have to be dismissed in order to access other program functions.

14.1.2.8 Assign Channels for Bus Quantities

Channels for bus quantities are defined using the Assign Channels for Bus Quantities dialog found under **Dynamics>Define simulation output (CHAN)>Bus quantity…**. From this dialog, buses can be specified for which previously designated simulation quantities can be selected for recording in output channels during Dynamic simulations (see Figure 14-31).

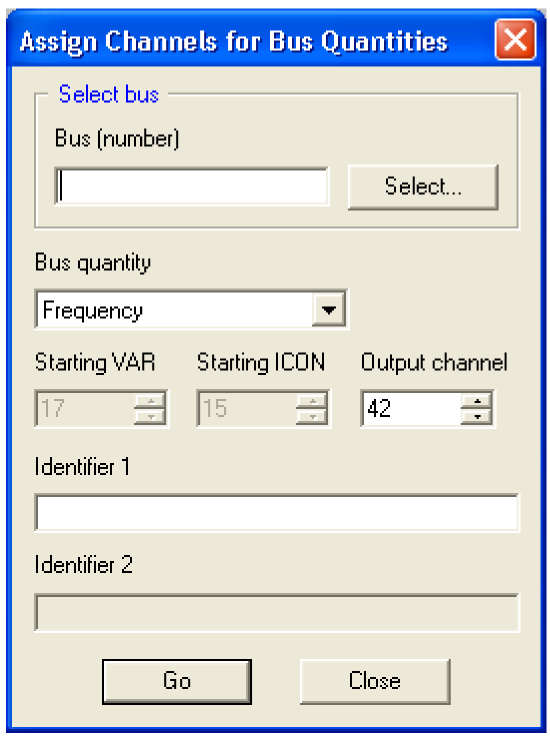


Figure 14-31. Assign Channels for Bus Quantities Dialog

The bus to assign the bus quantity is specified in the “Bus” field. The bus can be specified by entering it directly in the “Bus” field or by selecting the ***Select*** button to the right of the field and using the standard bus selector dialog to select the bus.

The bus quantity to record in the output channel is selected by the “Bus quantity” combo box. Clicking on this combo box will reveal a list of defined quantities to select from.

The “Starting VAR”, “Starting ICON” and “Output channel” fields are used to describe identifiable storage locations in the channel output file. These locations are used in other parts of PSS™E to access this data. The storage locations available for definition depend on the bus quantity selected.

Channel identifiers (two in case of the "Voltage and Angle" bus quantity) to be assigned to the output channel(s) can be specified by entering them in the appropriate fields. If an identifier field is blank, PSS™E generates an appropriate identifier.

Selecting the ***Go*** button will define the channel as specified in the input fields and then allow another channel definition. Selecting the ***Close*** button will close the dialog without defining any further channels.

14.1.2.9 Assign Channels for Line Quantities

Channels for line quantities are defined using the Assign Channels for Line Quantities dialog found under **Dynamics>Define simulation output (CHAN)>Line quantity…**. From this dialog, lines can be specified for which previously designated simulation quantities can be selected for recording in output channels during Dynamic simulations (see Figure 14-32).

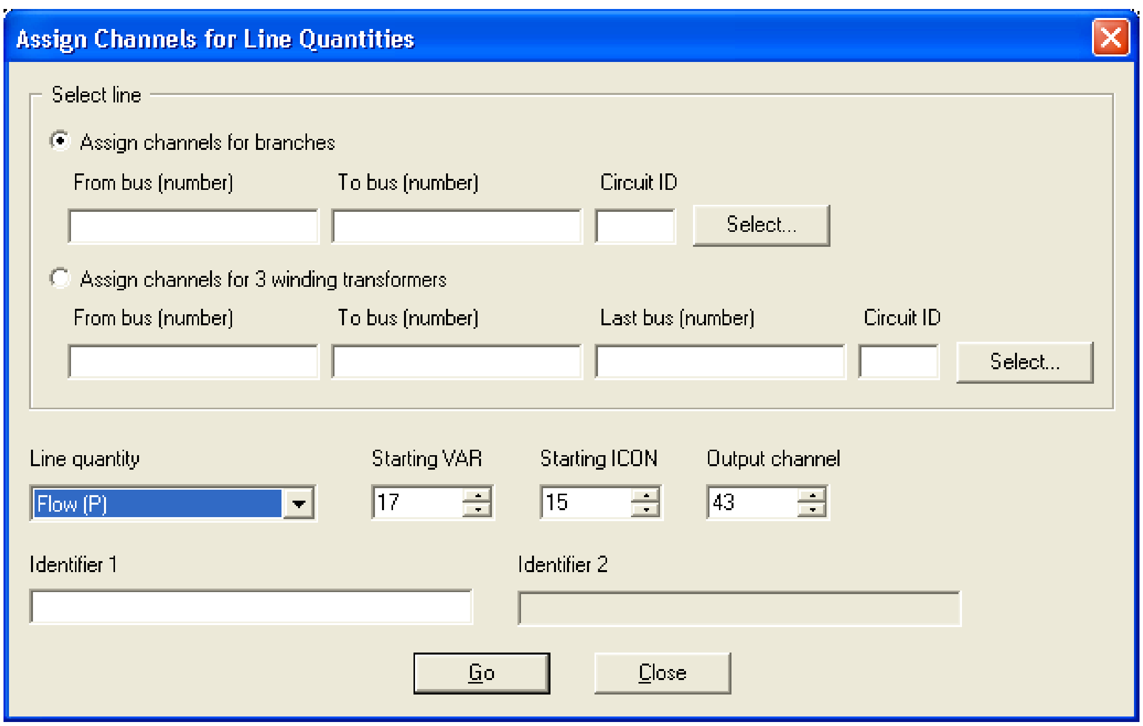


Figure 14-32. Assign Channels for Line Quantities Dialog

Quantities can be defined for either branches, 2 winding transformers or 3 winding transformers. Branches and 2 winding transformers are specified by selecting the “Assign channels for branches” toggle button. The branch or 2 winding transformer is then specified by entering the identifiers directly in the “From bus”, “To bus” and “Circuit ID” fields or by selecting the ***Select*** button to the right of the field and using the standard line selector dialog to select the line. 3 winding transformers are specified by selecting the “Assign channels for 3 winding transformers” toggle button. The 3 winding transformer is then specified by entering the identifiers directly in the “From bus”, “To bus”, “Last bus” and “Circuit ID” fields or by selecting the ***Select*** button to the right of the field and using the standard 3 winding transformer selector dialog to select the 3 winding transformer.

The line quantity to record in the output channel is selected by the “Line quantity” combo box. Clicking on this combo box will reveal a list of defined quantities to select from.

The “Starting VAR”, “Starting ICON” and “Output channel” fields are used to describe identifiable storage locations in the channel output file. These locations are used in other parts of PSS™E to access this data.

Channel identifiers (two in case of the "Flow (PQ)" and “Relay2 (R & X) line quantities) to be assigned to the output channel(s) can be specified by entering them in the appropriate fields. If an identifier field is blank, PSS™E generates an appropriate identifier.

Selecting the ***Go*** button will define the channel as specified in the input fields and then allow another channel definition. Selecting the ***Close*** button will close the dialog without defining any further channels.

14.1.2.10 Assign Channels for Load Quantities

Channels for load quantities are defined using the Assign Channels for Load Quantities dialog found under ***Dynamics>Define simulation output (CHAN)>Load quantity…***. From this dialog, loads can be specified for which previously designated simulation quantities can be selected for recording in output channels during Dynamic simulations (see Figure 14-33).

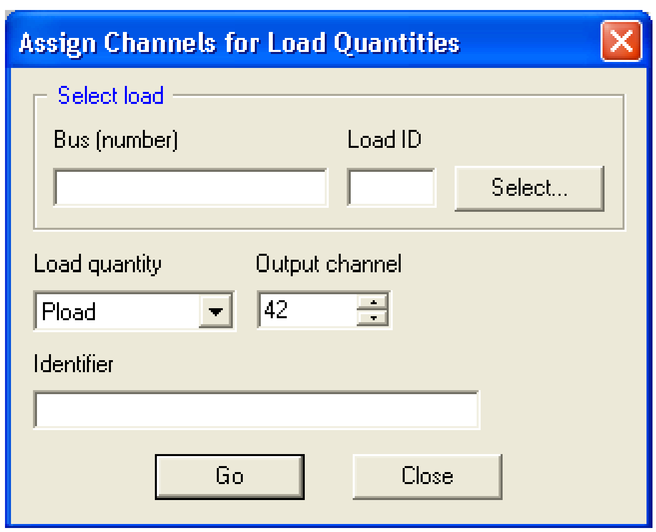


Figure 14-33. Assign Channels for Load Quantities Dialog

The load to assign the load quantity is specified in the “Bus” and “Load ID” fields. The load can be specified by entering it directly in the “Bus” and “Load ID” fields or by selecting the ***Select*** button to the right of the field and using the standard load selector dialog to select the load.

The load quantity to record in the output channel is selected by the “Load quantity” combo box. Clicking on this combo box will reveal a list of defined quantities to select from.

The “Output channel” field is used to describe identifiable channel storage location in the channel output file. This location is used in other parts of PSS™E to access this data.

The channel identifier can be specified by entering it in the appropriate fields. If the identifier field is blank, PSS™E generates an appropriate identifier.

Selecting the ***Go*** button will define the channel as specified in the input fields and then allow another channel definition. Selecting the ***Close*** button will close the dialog without defining any further channels.

14.1.2.11 Assign Channels for Machine Quantities

Channels for machine quantities are defined using the Assign Channels for Machine Quantities dialog found under **Dynamics>Define simulation output (CHAN)>Machine quantity…**. From this dialog, machines can be specified for which previously designated simulation quantities can be selected for recording in output channels during Dynamic simulations (see Figure 14-34).

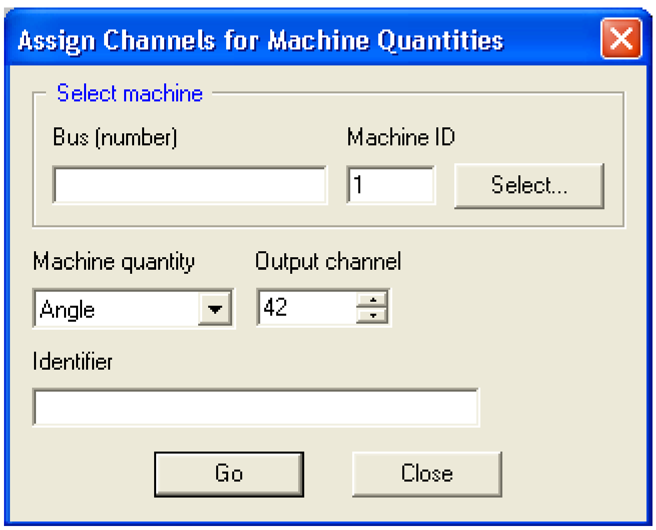


Figure 14-34. Assign Channels for Machine Quantities Dialog

The machine to assign the machine quantity is specified in the “Bus” and “Machine ID” fields. The machine can be specified by entering it directly in the “Bus” and “Machine ID” fields or by selecting the ***Select*** button to the right of the field and using the standard machine selector dialog to select the machine.

The machine quantity to record in the output channel is selected by the “Machine quantity” combo box. Clicking on this combo box will reveal a list of defined quantities to select from.

The “Output channel” field is used to describe identifiable channel storage location in the channel output file. This location is used in other parts of PSS™E to access this data.

The channel identifier can be specified by entering it in the appropriate fields. If the identifier field is blank, PSS™E generates an appropriate identifier.

Selecting the ***Go*** button will define the channel as specified in the input fields and then allow another channel definition. Selecting the ***Close*** button will close the dialog without defining any further channels.

14.1.2.12 Assign Channels for Misc. Quantities

Channels for miscellaneous quantities are defined using the Assign Channels for Misc. Quantities dialog found under **Dynamics>Define simulation output (CHAN)>Misc quantity…**. From this dialog, VARs and STATES can be specified for recording in output channels during Dynamic simulations (see Figure 14-35).

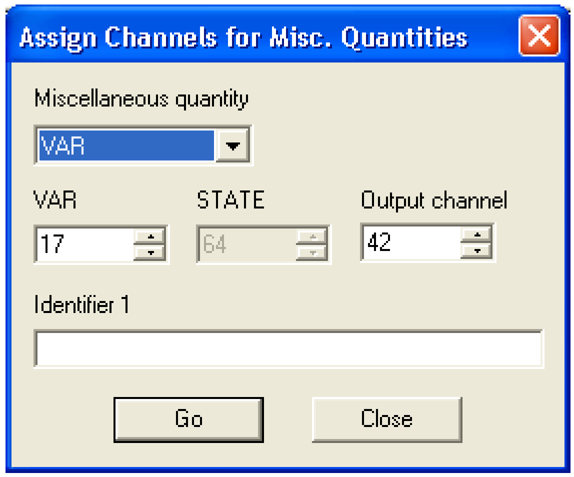


Figure 14-35. Assign Channels for Misc. Quantities Dialog

The miscellaneous quantity to record in the output channel is selected by the “Miscellaneous quantity” combo box. Clicking on this combo box will reveal a list of defined quantities to select from.

The “VAR”, “STATE” and “Output channel” fields are used to describe identifiable storage locations in the channel output file. These locations are used in other parts of PSS™E to access this data. The storage locations available for definition depend on the bus quantity selected.

The channel identifier can be specified by entering it in the appropriate fields. If the identifier field is blank, PSS™E generates an appropriate identifier.

Selecting the ***Go*** button will define the channel as specified in the input fields and then allow another channel definition. Selecting the ***Close*** button will close the dialog without defining any further channels.

14.1.2.13 Select Channels by Subsystem

Channels for all elements defined by a bus subsystem can defined using the Select Channels by Subsystem dialog found under **Dynamics>Define simulation output by subsystem (CHSB)…**. From this dialog, simulation variables which are to be monitored during the Dynamic simulation runs on a subsystem basis can be selected for recording in output channels during Dynamic simulations (see Figure 14-36). From this dialog, the following can be placed into channels: machine, bus, load and/or branch quantities for all machines, buses, loads and/or branches in the current bus subsystem; branch quantities for all tie lines from the current area or zone subsystem; subsystem totals for certain quantities for the current area, zone or owner subsystem; or machine angle statistics.

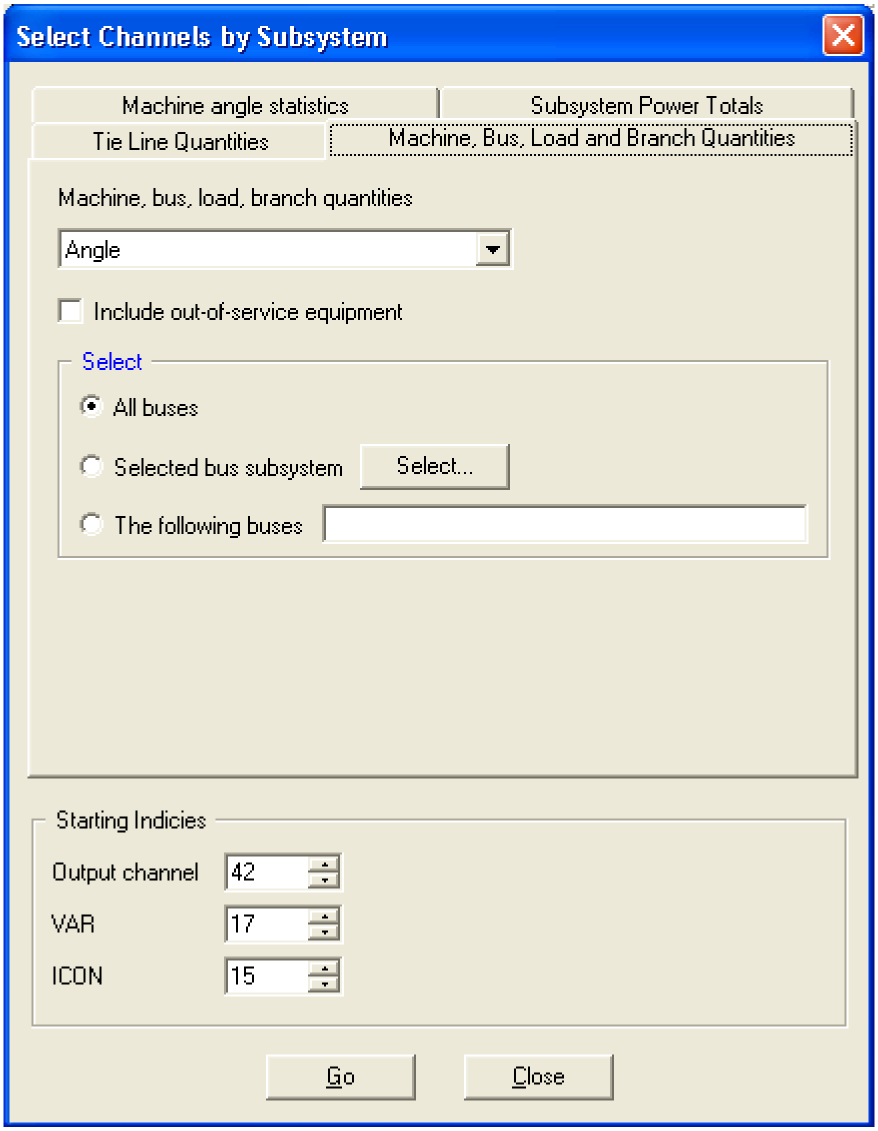


Figure 14-36. Select Channels by Subsystem

The category to define quantities for is determined by selecting the desired quantity tab at the top of the dialog which exposes and activates the appropriate controls.

When the "Machine, Bus, Load and Branch Quantities" tab is active, the bus subsystem to be processed may be specified as follows:

1. If the "All buses" toggle button is "depressed", all buses from the working case are selected.
2. If the "Selected bus subsystem" toggle button is "depressed", all buses in the current bus subsystem are selected. The current bus subsystem may be specified or changed either by "pressing" the "Select…" button to the right of the "Selected bus subsystem" toggle button, or by selecting the "Bus subsystem" entry from the "Subsystem" menu of the menu bar.

3. If "The following buses" toggle button is "depressed", buses may be specified in the input field to the right of the toggle button. Conventions for specifying buses follow those of the line mode method of bus selection described in Section 3.10.1.1 of the *PSS™E Program Operation Manual*.

When the "Tie Line Quantities" tab is active, the user may select area or zone ties by "depressing" the appropriate toggle button in the middle of the dialog. The appropriate pair of toggle buttons at the bottom of the window is enabled and the set of areas or zones to be processed may be specified as described in the following example. While this description is in terms of areas, the same approach applies to zones.

1. If the "All areas" toggle button is "depressed", all areas from the working case are selected.

2. If the "Selected areas" toggle button is "depressed", all areas in the current area subsystem are selected. The current area subsystem may be specified or changed either by "pressing" the "Select…" button to the right of the "Selected areas" toggle button, or by selecting the "Area subsystem" entry from the "Subsystem" menu of the menu bar.

With the "Machine, Bus, Load and Branch Quantities" and the "Tie Line Quantities" tabs, the user selects the simulation quantity for which data values are to be assigned to output channels by selecting it from the appropriate "…quantities" combo box. Clicking on this combo box will reveal a list of defined quantities to select from.

Data for out-of-service equipment may be included in the set of channels generated for a selected output category by "depressing" the “Include out-of-service equipment” toggle button.

When the "Subsystem Power Totals" is active, the user may select power totals by area, owner or zone, or power totals for all buses, by "depressing" the appropriate toggle button in the middle of the window. If the "Areas", "Zones" or "Owners" toggle button is "depressed" the appropriate pair of toggle is enabled and the set of areas, owners, or zones to be processed may be specified as described in the previous example. While the previous example is in terms of areas, the same approach applies to owners and zones. If the “All buses" toggle is "depressed", none of the subsystem selection toggle buttons at the bottom of the window are enabled. Five channels, containing totals of mechanical power, electrical power, accelerating power, load active power, and electrical power - load active power, are added for each area, owner, or zone selected, or for the entire network, as appropriate.

Assigning channels for "Subsystem Power Totals" requires no simulation quantity or out-of-service option selection.

When the "Machine angle statistics" tab is active, six channels summarizing machine angles are assigned. No simulation quantity, out-of-service option, or subsystem selection is required.

The "next available" channel number, VAR index and ICON index are displayed in fields in the "Starting Indices" group. The starting indices to be used may be specified by editing their values in the fields.

Selecting the ***Go*** button will define the channels as specified in the input fields and then allow another channel definition. Selecting the ***Close*** button will close the dialog without defining any further channels.

14.1.2.14 Model Maintenance

Basic Dynamic model maintenance is performed using the Model Maintenance dialog found under **Dynamics>Model Maintenance….** From this dialog, basic model and network maintenance can be performed (see Figure 14-37).

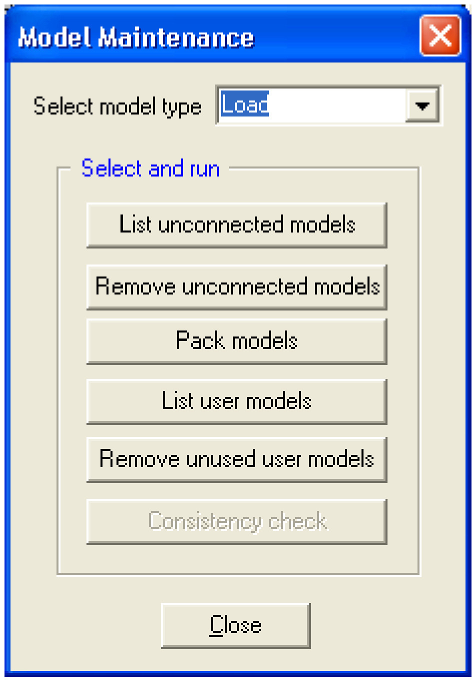


Figure 14-37. Model Maintenance Dialog

From the “Select model type” combo box, the Dynamics model type to be operated on is selected. All operations invoked from the buttons in the center of the dialog will be performed on the model type selected in the combo box.

Selecting “List unconnected models” will list all models of the selected type that are not connected to any network elements. The listing is printed at the progress report output device.

Selecting “Remove unconnected models” will remove all models of the selected type that are not connected to any network elements. They will no longer appear in any saved Snapshot or DYRE files. Each model reference removed from the model tables is reported at the progress report output device.

Selecting “Pack models” will pack the internal storage tables and removes "holes" (i.e., entries which are marked as unused) from the model connection table and the array allocation table for all models of the selected type. If these tables are packed, messages are printed at the progress report output device.

Selecting “List user models” will list all user models of the selected type found in the active User Dynamics Dll.

Selecting “Remove unused user models” will delete from the user model definition table any model definitions of the selected type that are not referenced from the array allocation table. Vacated slots are available for new model definitions.

Selecting “Consistency check” will perform an internal consistency check for all Plant and Wind model types. This button is only enabled when Plant or Wind is the selected model type. This check loops through all machines in the working case and alarms any invalid model combinations at the progress report output device. This report is in ascending bus number order when the "numbers" output option is in effect, and in alphabetical bus name order under the "names" option. Section 5.7.2 details the conditions which are alarmed by the consistency checking function for the Plant model type.

Selecting the ***Close*** button will close the dialog.

14.1.2.15 List Dynamics Model Data

Reports listing equipment models and their data for selected categories of models at buses in a specified subsystem of the working case can be generated **Dynamics>List>Models and data (DOCU)…** (see Figure 14-38).

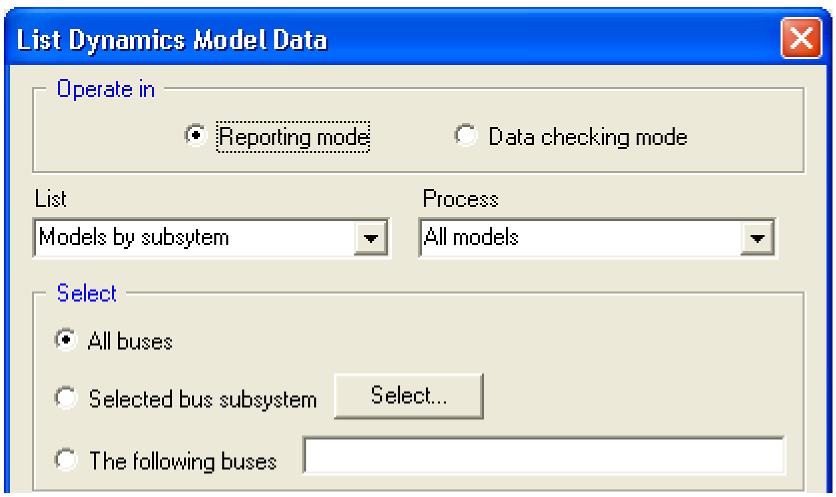


Figure 14-38. List Dynamics Model Data Dialog

The top set of toggle buttons allows the user to indicate whether the dynamics model data reporting function is to be executed in a "reporting mode" or a "data checking mode".

The "List" combo box allows the user to select output for either "All subroutine CONEC models", "All subroutine CONET models", "All CHAN models", or "Models by subsystem".

If the "Models by subsystem" category is selected, the "Model type to be processed" option menu and the three subsystem selection toggle buttons are enabled.

The model type to be processed is selected from the “Process” combo box.

The set of buses to be processed may be specified as follows:

1. If the "All buses" radio button is selected, all buses from the working case are selected.

2. If the "Selected bus subsystem" radio button is selected, all buses in the current bus subsystem are selected. When subsystem selection by owner is enabled, the owner assignments of each load, machine and branch, rather than the bus(es) to which they are connected, govern which elements are in the subsystem; for dc lines, FACTS

devices, and auxiliary signal models that are connected to dc lines and FACTS devices, the buses to which they are connected govern which elements are in the subsystem. The current bus subsystem may be specified or changed either by "pressing" the "Select…" button to the right of the "Selected bus subsystem" toggle button, or by selecting the "Bus subsystem" entry from the "Subsystem" menu of the menu bar.

3. If "The following buses" radio button is selected, buses may be specified in the input field to the right of the toggle button. Conventions for specifying buses follow those of the line mode method of bus selection described in Section 3.10.1.1 of the *PSS™E Program Operation Manual*.

Selecting the ***Go*** button will produce the selected report. When "The following buses" radio button is selected, selecting the **[Return]** or **[Enter]** key on the keyboard while the cursor is positioned in the input field is equivalent to selecting the ***Go*** button.

Selecting the ***Close*** button will close the dialog.

14.1.2.16 List Dynamics Data Common

Principle Dynamics data arrays, within defined index ranges, may be tabulated using the List Dynamics Data Common dialog found under ***Dynamics>List>Dynamics data (DLST)…*** (see Figure 14-39).

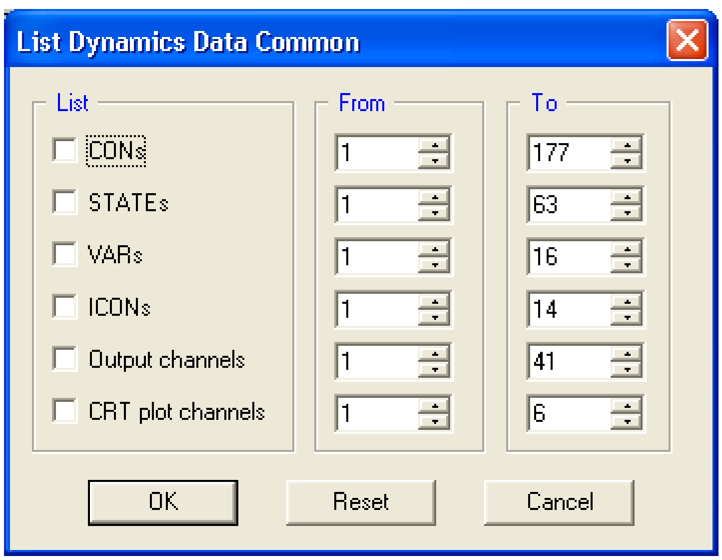


Figure 14-39. List Dynamics Data Common Dialog

A data category is selected for reporting by "selecting" the toggle button to the left of its description; any data category whose toggle button is not “selected” is omitted from the report.

"From" and "To" data items may be specified by editing their values in the corresponding input text fields. If the "To" index is greater than the "From” index, all entries in the corresponding data category between the "From" and "To" entries inclusive are reported; otherwise, only the "From" entry is printed.

Selecting the ***"OK"*** button will generate the report and dismiss the dialog. If no items are “selected” for reporting, selecting the ***OK*** button will have no effect.

Selecting the ***Reset*** button restores the "From" and "To" input text fields to values reflecting the number of elements being used in the current simulation setup.

Selecting the ***Cancel*** button will close the dialog.

14.1.2.17 List Model Storage Locations

A tabulation by model category of the storage locations (locations used to store the CONS, STATES, VARS, and ICONS) associated with table-driven models referenced in the user's simulation setup may be obtained by using the List Model Storage Locations dialog found under **Dynamics>List>Model storage locations…** (see Figure 14-40).

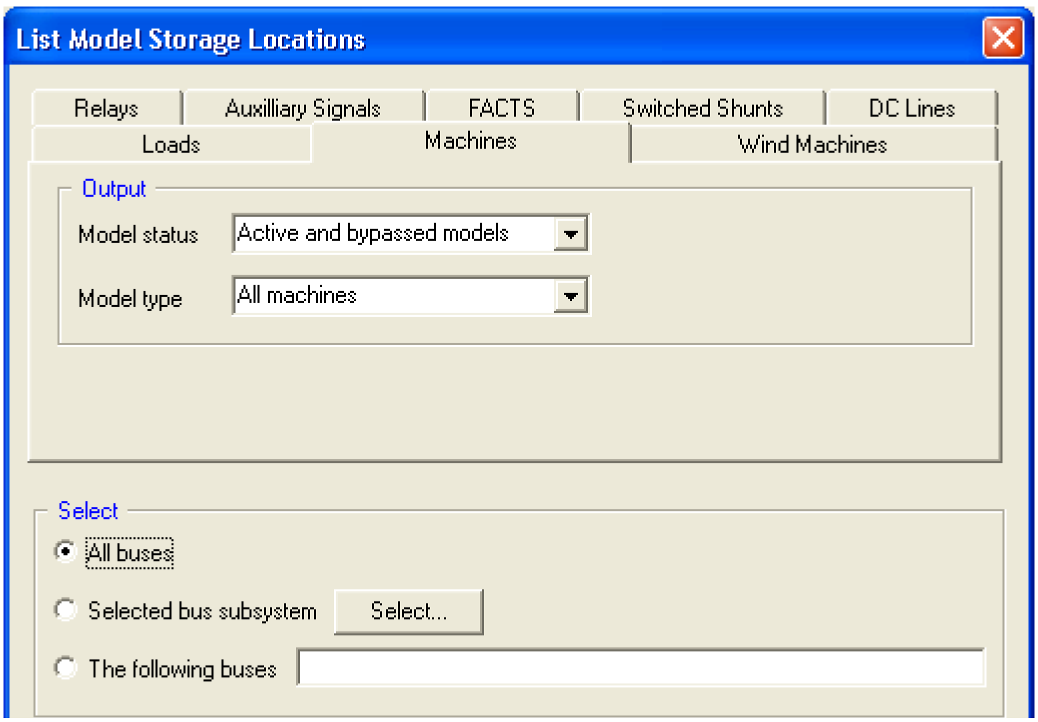


Figure 14-40. List Model Storage Locations Dialog

The model category to list storage locations for is determined by selecting the desired model category tab at the top of the dialog which exposes and activates the appropriate controls.

The following model categories can be reported on:

1. Load-related models connected to loads in a specified subsystem of the working case when the "Load" tab is active.

2. Plant-related models connected to machines in a specified subsystem of the working case when the "Plant" tab is active.

3. Line relay models connected to branches whose "from bus" is in a specified subsystem of the working case when the "Relay" tab is active.

4. Auxiliary signal models connected to dc lines or FACTS devices which have at least one of their buses in the specified subsystem of the working case when the "Aux. Sig." tab is active.

5. FACTS device models whose sending end bus is in the specified subsystem of the working case when the "FACTS dev" tab is active.

6. DC line models which have at least one of their ac buses in the specified subsystem of the working case when the "DC Line" tab is active.

7. Switched Shunt device models in a specified subsystem of the working case when the "Switched Shunt" tab is active.

8. Wind machine models in a specified subsystem of the working case when the "Wind Machines" tab is active.

For each of these model categories, the "Model status" combo box is used to restrict the tabulation to active models, bypassed models, or both. Bypassed models are identified either with an asterisk ("*") preceding the model name.

When the "Load” tab is active, the radio buttons under "Report On" allow the user to select a report organized by either models ("Loads connected to model") or loads ("Models connected to loads"). Selecting the ***Loads connected to model*** toggle results in a report organized by model, with load-characteristic models reported first followed by load-relay models. Within these two categories, models applied by bus are listed first, followed by those applied by subsystem other than bus in model precedence order (see *Program Operation Manual, Volume I*, Section 5.1.4). For each model reported, the loads to which the model is applied are listed. If a load model is not applied at any loads, it is omitted from the report.

Selecting the ***Models connected to loads*** toggle results in a report organized by load. For each load reported, the model(s) connected to it are listed. Any load with no load-related model connected to it is omitted from the report.

For either presentation, buses are tabulated in ascending numerical or alphabetical order, according to the bus output option currently in effect. Multiple loads at the same bus are tabulated in ascending load identifier order.

The "Model status" combo box functions as described above. However, in the case of load models, bypassed load models are identified either with an asterisk ("*") preceding the model name, or by following the load element description with the word BYPASSED. The latter format is employed for bypassed element instances of a subsystem model when the presentation hierarchy is ***Loads connected to model***.

When the "Machines" tab is active, the "Model status" combo box functions as described above, and the "Model type" combo box is used to select the type(s) of machine-related models to be reported.

When the "Relay", "Aux. Sig." or "FACTS dev" tab is active, the "Model status" combo box functions as described above.

When the "DC Line" tab is active, the "Model type" combo box allows the user to indicate the type of dc lines to be reported: two-terminal dc lines, multi-terminal dc lines, or VSC dc lines. The "Model status" combo box functions as described above.

When the "Switched Shunts" tab is active, the "Model status" combo box provides for listing all such models, only those which are active, or only those which are bypassed.

When the "WInd Machines" tab is active, the "Model status" combo box functions as described above., and the "Model type" combo box is used to select the type(s) of wind machine-related models to be reported.

The set of network elements whose models are to be reported may be specified as follows:

1. If the "All buses" radio button is selected, models at all buses in the working case are selected.
2. If the "Selected bus subsystem" radio button is selected, all loads, machines, branches, dc lines, FACTS devices, switched shunt, and/or wind machines as appropriate, in the current bus subsystem are selected. When owners are part of the selection criteria, the owner assignments of each load, machine, and branch, (rather than the bus(es) to which it is connected) govern which elements are in the subsystem; for dc lines, FACTS devices, and their auxiliary signals, the owner assignments of the buses to which they are connected govern which elements are in the subsystem. The current bus subsystem may be specified or changed either by "pressing" the "Select…" button to the right of the "Selected bus subsystem" toggle button, or by selecting the "Bus subsystem" entry from the "Subsystem" menu of the menu bar.
3. If "The following buses" radio button is selected, buses may be specified in the input field to the right of the toggle, and all loads, machines, branches, dc lines, FACTS devices, switched shunt, and/or wind machines as appropriate, at the designated buses are processed. Conventions for specifying buses follow those of the line mode method of bus selection described in Section 3.10.1.1 of the *PSS™E Program Operation Manual*.

Selecting the ***Go*** button will generate the selected report. When "The following buses" radio button is selected, selecting the **[Return]** or **[Enter]** key on the keyboard while the cursor is positioned in the input field is equivalent to selecting the ***Go*** button

The tabulation for each model includes a listing of the locations in the various dynamics data arrays used by the model, and a flag for models which are bypassed. Models which are connected to elements which are not contained in the working case are excluded from the report.

Selecting the ***Close*** button closes the dialog.

14.1.2.18 Launch NEVA Eigenvalue Analysis

To perform an Eigenvalue analysis using the optional NEVA module, select **Dynamics>Launch NEVA Eigenvalue analysis**. The current Dynamics simulation setup will then be transferred into NEVA and the Eigenvalue analysis can be performed. For more on the use of NEVA, see the NEVA documentation.

14.1.2.19 Build Matrices for LSYSAN

The input file containing the “A” and “H” system matrices used in the LSYSAN program is created by the “Build Matrices for LSYSAN” dialog found under **Dynamics>Build matrices for LSYSAN program (ASTR)…** (see Figure 14-41).

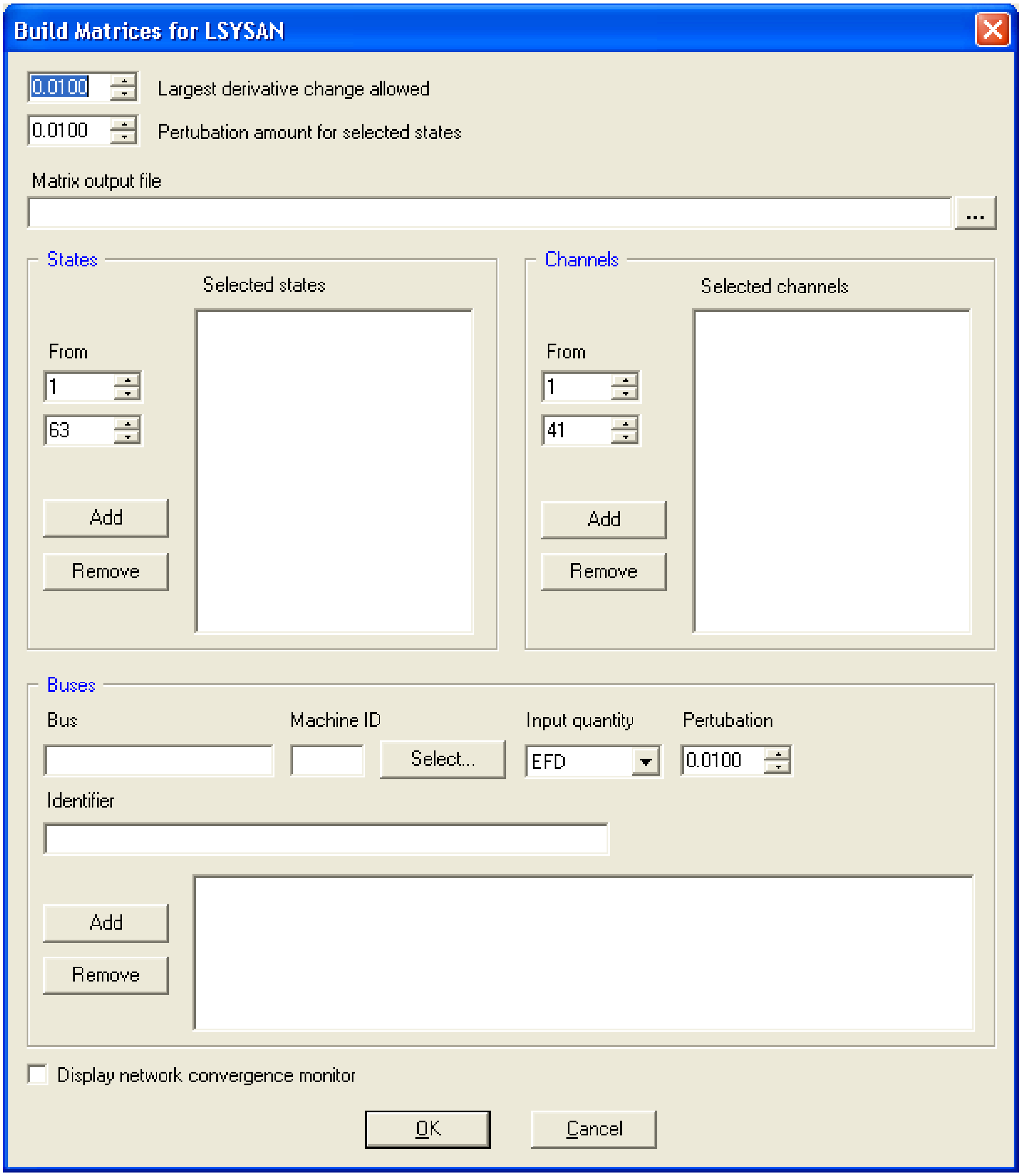


Figure 14-41. Build Matrices for LSYSAN Dialog

The "Largest derivative…" and "Perturbation amount…" data items may be specified by editing their values in the edit fields in the appropriate field.

The file into which the results for use by the auxiliary program LSYSAN is specified in the "Matrix output file" field. Alternatively, the "Select…" button to the right of the edit field may be selected to allow the specification of the file via a file selector window.

The state variables to be included in the system matrices are specified using a pair of input fields ("From…" and "…To") with increment/decrement arrows and an "Add" button. These are used to construct a list of STATE numbers and/or ranges of STATE numbers. The user may either edit the values in the edit fields or "press" the increment/decrement arrows to the right of the edit fields; selecting the ***Add*** button then adds the specified STATEs to the "Selected States" list. All STATEs between the "From…" and "…To" STATE numbers inclusive are added to the scrolled list if the "…To" STATE number exceeds the "From…" STATE number. Otherwise, the "From…" STATE is added to the list. Selecting a list entry so that it is highlighted and selecting the ***Remove*** button is used to remove an entry from the list.

The output channels to be used as system outputs are specified using a similar approach.

The “Buses” section at the bottom of the dialog allows the specification of a system input variable whose value is to be perturbed. The resulting calculation is used to construct columns of the "B" and "F" system matrices. Up to 20 items may be specified.

The "Input quantity" combo box allows the selection of the quantity to be perturbed. Either “EFD”, “Pmech”, “Vothsg”, “Vref” or “Var” may be selected.

The perturbation data value may be modified by editing the value in the “Perturbation” edit field.

If a machine quantity is selected (any “Input quantity other than “Var”), the user must designate the machine whose selected quantity is to be perturbed. The machine to apply the perturbation to is specified in the “Bus” and “Machine ID” fields. The machine can be specified by entering it directly in the “Bus” and “Machine ID” fields or by selecting the ***Select*** button to the right of the field and using the standard machine selector dialog to select the machine.

If “Var” is selected in the “Input quantity” combo box, the user must designate its index in the "Var number" edit field.

An identifier can be assigned to the input quantity in the "Identifier" edit field. If this field is blank, PSS™E generates an appropriate identifier.

Selecting the ***OK*** button processes the selected items and creates the Matrix output file for use in the LSYSAN program. Selecting the ***OK*** button with no file specified in the "Matrix output file" field is invalid. If no entries are in the "Selected States" scrolled list at the time the ***OK*** button is "pressed", activity ASTR includes all STATEs in the system matrices. If no entries are in the "Selected Channels" list at the time the ***OK*** button is selected, all channels (or the first fifty if the system model contains more than fifty output channels) are included as system outputs.

Selecting the ***Cancel*** button closes the dialog without performing any processing.

14.1.3 Disturbance Menu Bar Entries

The following sections describe the dialogs found in the Disturbance Menu Bar entry of PSS™E.

14.1.3.1 Apply a Bus Fault

A fault at a specified in-service bus (i.e., the bus type code must be one or two) can be applied using the Apply a Bus Fault dialog found under **Disturbance>Bus fault…** (see Figure 14-42).

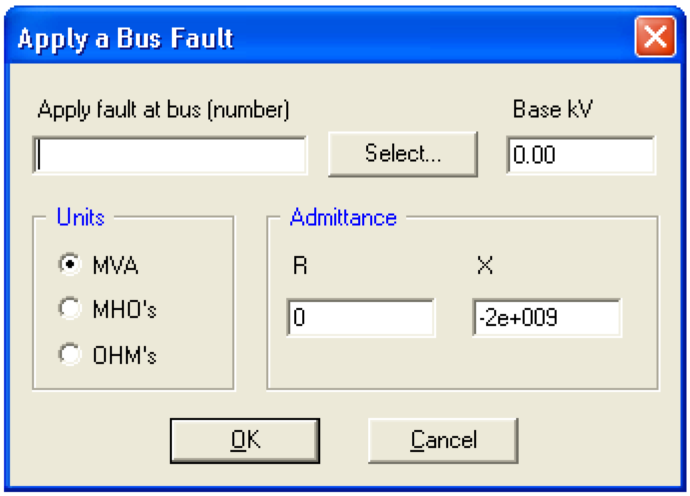


Figure 14-42. Apply a Bus Fault Dialog

The bus to fault is specified in the “Apply fault at bus” field. The bus can be specified by entering it directly in the “Apply fault at bus” field or by selecting the ***Select*** button to the right of the field and using the standard bus selector dialog to select the bus.

The "Base kV" field is set to the base voltage of the specified bus as contained in the current network.

The value of fault admittance is calculated based the settings of the "Units" radio button, the impedance or admittance edit fields, and, except for faults specified in MVA, the "Base kV" edit field. The "MHO's" and "OHM's" radio buttons are enabled only if the "Base KV" field contains a positive value. When the dialog is opened, these fields are set such that a three phase fault is applied. The specification of these data items is identical to that used in the APPLY FAULT BUS command of activity PSAS.

Selecting the ***OK*** button replaces the fixed shunt at the designated bus with the MVA admittance equivalent to the values entered in the fault specification edit fields. The bus faulting dialog is then dismissed.

Selecting the ***Cancel*** button dismisses the dialog without faulting any bus.

14.1.3.2 Apply a Line Fault

A fault at the "from" bus end of a specified branch can be applied using the Apply a Line Fault dialog found under **Disturbance>Line fault…** (see Figure 14-43). If the branch to be faulted is a non-transformer branch or a two-winding transformer, it must be in-service; if the branch to be faulted is a three-winding transformer, the winding connected to the first bus specified must be in-service.

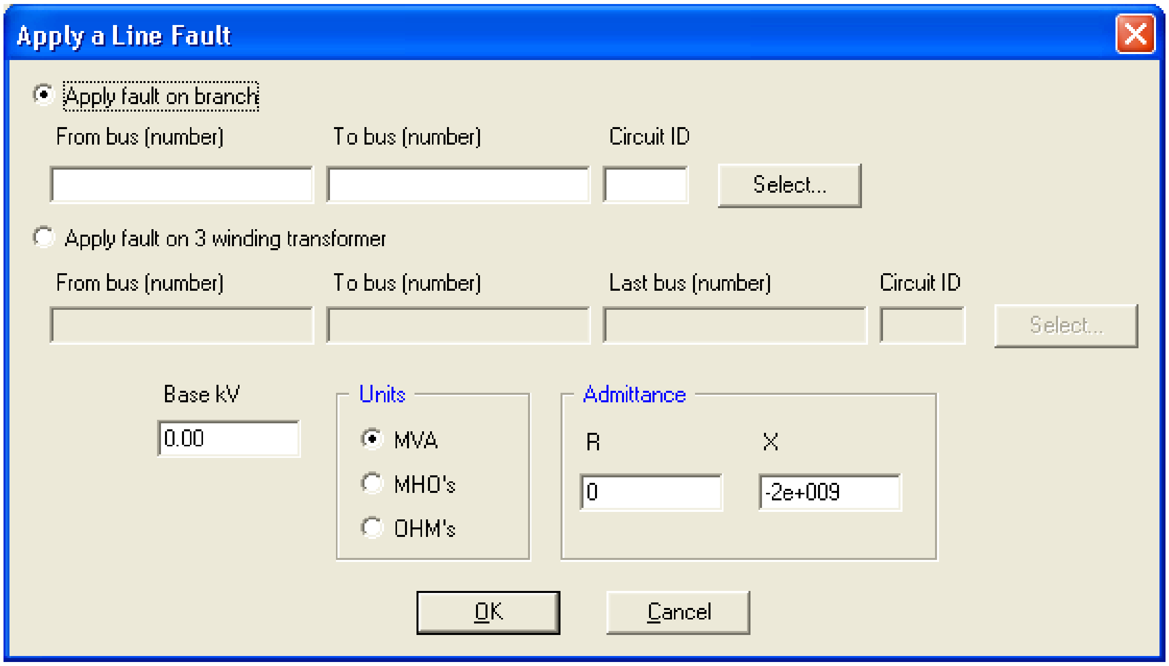


Figure 14-43. Apply a Line Fault Dialog

The branch or 2 winding transformer to fault is specified in the “Apply fault on branch” fields. These fields are enabled by selecting the “Apply fault on branch” radio button. The branch or 2 winding transformer can be specified by entering it directly in the ”From bus”, “To bus” and ”Circuit ID” fields or by selecting the ***Select*** button to the right of the fields and using the standard branch/2 winding transformer selector dialog to select the branch or 2 winding transformer.

The 3 winding transformer to fault is specified in the “Apply fault on 3 winding transformer” fields. These fields are enabled by selecting the “Apply fault on 3 winding transformer” radio button. The 3 winding transformer can be specified by entering it directly in the ”From bus”, “To bus”, “Last bus” and ”Circuit ID” fields or by selecting the ***Select*** button to the right of the fields and using the standard 3 winding transformer selector dialog to select the 3 winding transformer.

The "Base kV" field is set to the base voltage of the specified "From" bus as contained in the working case.

The value of fault admittance is calculated based the settings of the "Units" toggle switches, the impedance or admittance input fields, and, except for faults specified in MVA, the "Base kV" input field. The "MHO’s" and "OHM's" toggle buttons are enabled only if the "Base KV" field contains a positive value. When the window is brought up, these fields are set such that a three phase fault is applied. The specification of these data items is identical to that used in the APPLY FAULT BRANCH command of activity PSAS.

Selecting the ***OK*** button replaces the line shunt at the "from" bus end of the designated branch with the p.u. admittance equivalent to the values entered in the fault specification edit fields. The branch faulting dialog is then dismissed.

Selecting the ***Cancel*** button dismisses the dialog without faulting any line.

14.1.3.3 Clear Fault

The faults applied using the “Apply a Bus Fault”, “Apply a Line Fault”, "Calculate and Apply a Bus Fault" and "Calculate and Apply Branch Unbalance" dialogs can all be cleared using the Clear Fault dialog found under **Disturbance>Clear fault…** (see Figure 14-44).

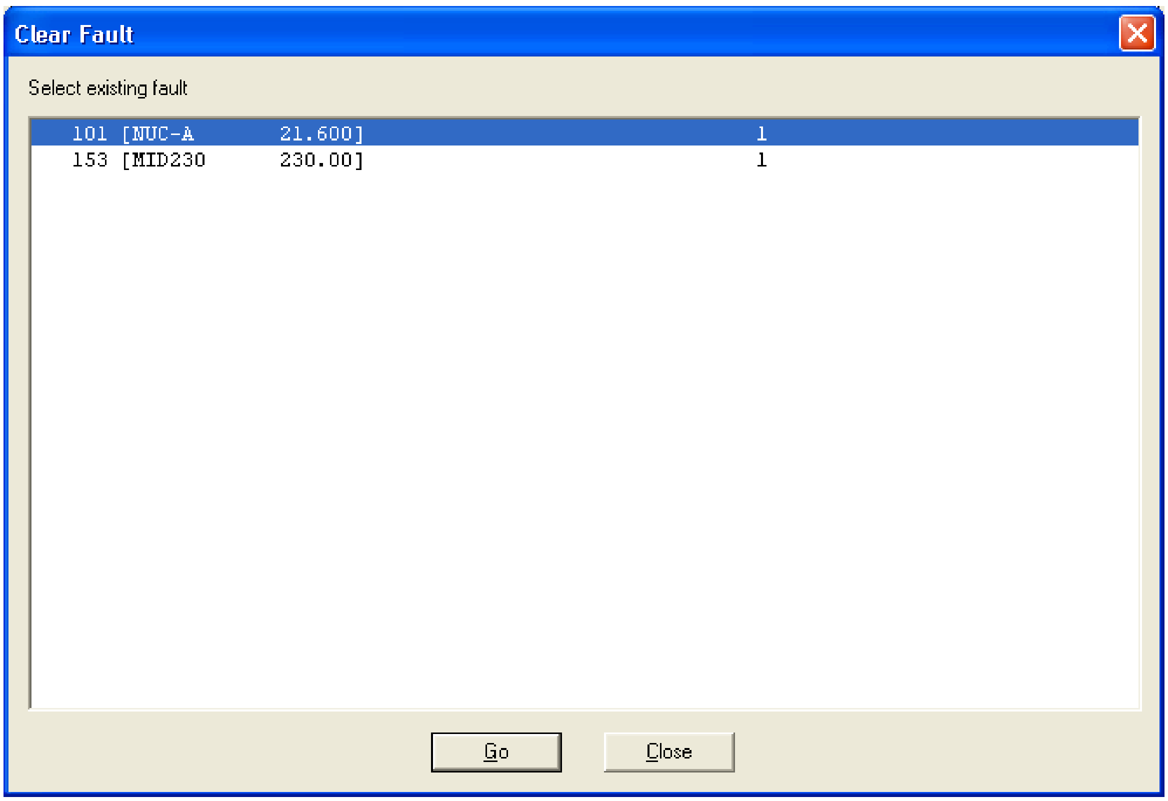


Figure 14-44. Clear Fault Dialog

The scrolled list in the window lists those buses and/or branches which have been faulted in the current execution of PSS™E but which have not as yet been cleared. When the dialog is opened, the last entry in the list is automatically selected (i.e., it is highlighted). The user may select another fault for clearing by "single clicking" on its description.

Selecting the ***Go*** button clears the selected fault by returning the data items of the faulted bus or branch to the values that were present at the time the fault was applied and leaves the dialog active for another selection. Selecting the ***Go*** button with no fault selected from the scrolled list is invalid.

Selecting the ***Close*** button dismisses the dialog without clearing any faults.

14.1.3.4 Trip a Line

The status of a line can be set to out-of-service using the Trip a Line dialog found under **Disturbance>Trip line…** (see Figure 14-45).

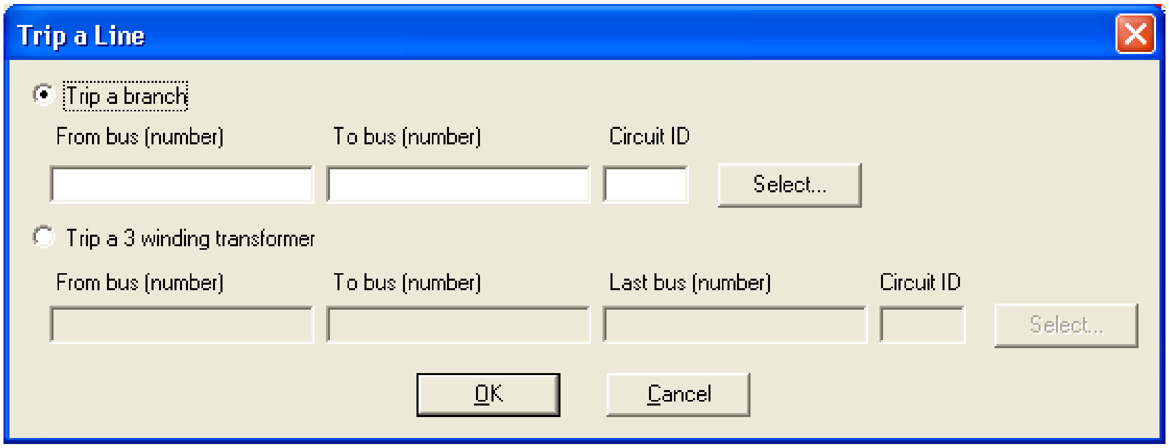


Figure 14-45. Trip a Line Dialog

The branch or 2 winding transformer to trip is specified in the “Trip a branch” fields. These fields are enabled by selecting the “Trip a branch” radio button. The branch or 2 winding transformer can be specified by entering it directly in the ”From bus”, “To bus” and ”Circuit ID” fields or by selecting the ***Select*** button to the right of the fields and using the standard branch/2 winding transformer selector dialog to select the branch or 2 winding transformer.

The 3 winding transformer to trip is specified in the “Trip a 3 winding transformer” fields. These fields are enabled by selecting the “Trip a 3 winding transformer” radio button. The 3 winding transformer can be specified by entering it directly in the ”From bus”, “To bus”, “Last bus” and ”Circuit ID” fields or by selecting the ***Select*** button to the right of the fields and using the standard 3 winding transformer selector dialog to select the 3 winding transformer.

Selecting the ***OK*** button sets the status of the designated branch to zero (out-of-service) and dismisses the dialog.

Selecting the ***Cancel*** button dismisses the dialog without tripping any branch.

14.1.3.5 Close a Tripped Line

The status of a line can be set to in-service using the Close a Tripped Line dialog found under **Disturbance>Close line…** (see Figure 14-46). The type code of each bus connected by the branch must be one or two.

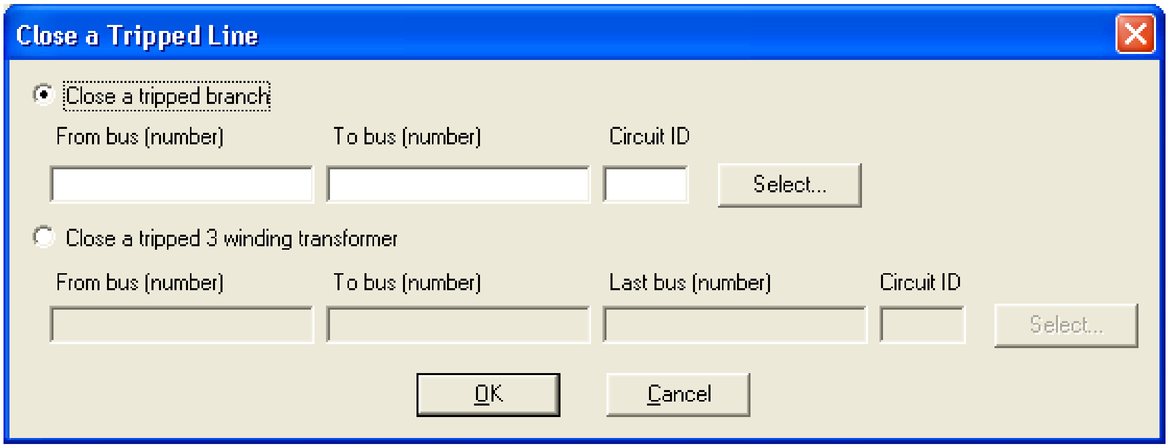


Figure 14-46. Close a Tripped Line Dialog

The branch or 2 winding transformer to close is specified in the “Close a tripped branch” fields. These fields are enabled by selecting the “Close a tripped branch” radio button. The branch or 2 winding transformer can be specified by entering it directly in the ”From bus”, “To bus” and ”Circuit ID” fields or by selecting the ***Select*** button to the right of the fields and using the standard branch/2 winding transformer selector dialog to select the branch or 2 winding transformer.

The 3 winding transformer to close is specified in the “Close a tripped 3 winding transformer” fields. These fields are enabled by selecting the “Close a tripped 3 winding transformer” radio button. The 3 winding transformer can be specified by entering it directly in the ”From bus”, “To bus”, “Last bus” and ”Circuit ID” fields or by selecting the ***Select*** button to the right of the fields and using the standard 3 winding transformer selector dialog to select the 3 winding transformer.

Selecting the ***OK*** button sets the status of the designated branch to one (in-service) and dismisses the dialog.

Selecting the ***Cancel*** button dismisses the dialog without closing any branch.

14.1.3.6 Disconnect a Bus

An in-service bus (i.e., a bus with a type code of one or two) can be electrically disconnected using the Disconnect a Bus dialog found under **Disturbance>Disconnect bus…** (see Figure 14-47).

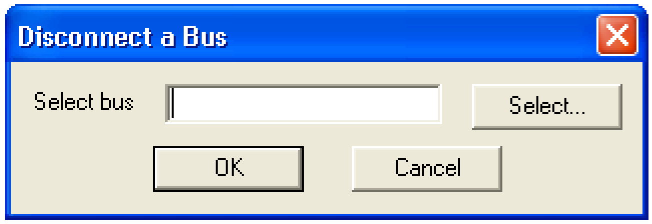


Figure 14-47. Disconnect a Bus Dialog

The bus to disconnect is specified in the “Select bus” field. The bus can be specified by entering it directly in the “Select bus” field or by selecting the ***Select*** button to the right of the field and using the standard bus selector dialog to select the bus.

Selecting the ***OK*** button electrically disconnects the specified bus and dismisses the dialog.

Selecting the ***Cancel*** button dismisses the dialog without disconnecting any bus.

14.1.3.7 Disconnect a Machine

An in-service machine (i.e., a machine with a service status of one, and the bus to which it is connected must have a type code of two) can be electrically disconnected using the Disconnect a Machine dialog found under **Disturbance>Disconnect machine…** (see Figure 14-48).

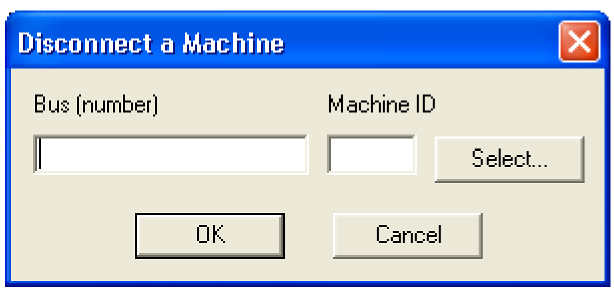


Figure 14-48. Disconnect a Machine Dialog

14.1.3.8 Vref Step Change

The voltage reference (Vref) for any specified machine can be changed using the Vref Step Change dialog found under **Disturbance>Change Vref…** (see Figure 14-49).

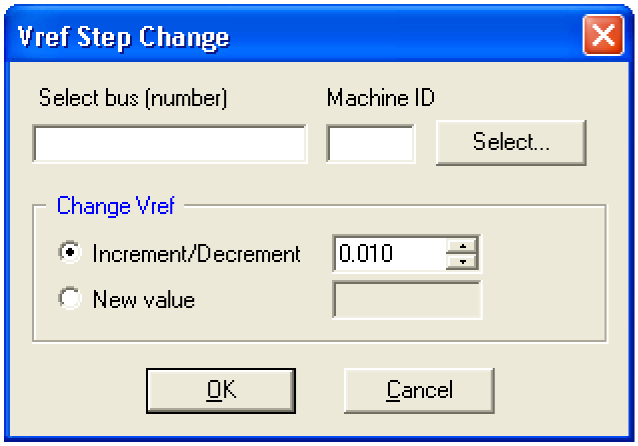


Figure 14-49. Vref Step Change Dialog

The machine to change the Vref for is specified in the “Bus” and “Machine ID” fields. The machine can be specified by entering it directly in the “Bus” and “Machine ID” fields or by selecting the ***Select*** button to the right of the field and using the standard machine selector dialog to select the machine.

The existing Vref value for the specified machine can either be incremented/decremented or a totally new value specified. If the “Increment/Decrement” radio button is selected, the edit field to the right of the radio button contains the value to increment/decrement the existing Vref value by. A positive value will increment the existing Vref, a negative value will decrement the existing Vref.

If the “New value” radio button is selected, the edit field to the right of the radio button contains the new Vref value to use for the specified machine.

Selecting the ***OK*** button will set the specified machines Vref value as indicated and dismisses the dialog.

Selecting the ***Cancel*** button dismisses the dialog without changing any Vref values.

14.1.3.9 Calculate and Apply a Bus Fault

The fault admittance for a specified bus can be calculated and applied during the dynamic simulations using the Apply a Bus Fault dialog found under **Disturbance>Calculate and apply unbalanced bus fault…** (see Figure 14-50). The fault calculation is similar to that of activity SCMU except that a flat voltage profile of 1.0 is assumed.

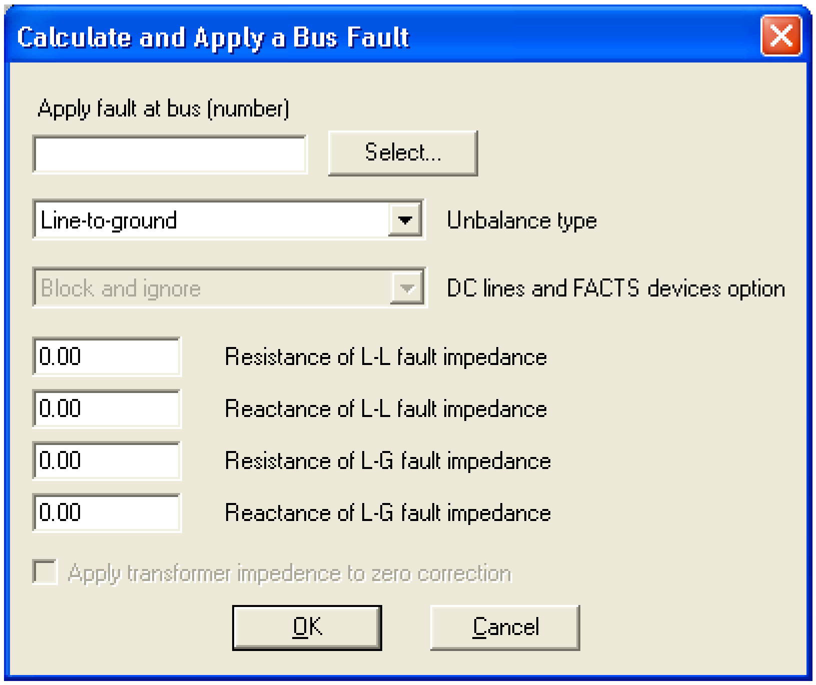


Figure 14-50. Calculate and Apply a Bus Fault Dialog

The bus to fault is specified in the “Apply fault at bus” field. The bus can be specified by entering it directly in the “Apply fault at bus” field or by selecting the ***Select*** button to the right of the field and using the standard bus selector dialog to select the bus.

The type of unbalance to be applied is selected with the "Unbalance type" combo box.

Fault impedances are displayed in edit fields which may be edited using standard windows techniques.

If the single line-to-ground fault is specified in the "Unbalance type" combo box, the complex fault impedance (Rl-g + jXl-g) is specified in the two "L-G fault impedance" edit fields.

If the double line-to-ground fault is specified in the "Unbalance type" combo box, the line-to-ground impedance (Rl-g + jXl-g) is specified in the two "L-G fault impedance" input fields, and the line-to-line impedance (Rl-l + jXl-l) is specified in the two "L-L fault impedance" edit fields.

If DC lines and/or FACTS devices are present in the network, the “DC line and FACTS devices option” combo box is enabled. The user has the option of block loading unblocked DC lines and in-service FACTS devices or converting constant admittance load on them by selecting the appropriate element from the combo box.

If the actual positive sequence impedance of any transformer in the working case differs from its nominal value, the user has the option of applying the same correction factor to the zero sequence impedances of all such transformers by selecting the "Apply transformer impedance to zero correction" toggle button; if this button is not selected the zero sequence impedances of all such transformers are left at their nominal values.

Selecting the ***OK*** button initiates the fault calculation. The calculated equivalent positive sequence fault admittance is added to the fixed shunt at the designated bus and the dialog is dismissed.

Selecting the ***Cancel*** button dismisses the dialog without faulting any bus.

14.1.3.10 Calculate and Apply Branch Unbalance

A positive sequence pi-equivalent for a single transmission line unbalance can be calculated and applied during the dynamic simulations using the Calculate and Apply Branch Unbalance dialog found under **Disturbance>Calculate and apply branch unbalance…** (see Figure 14-51). The fault calculation is similar to that of activity SPCB except that a flat voltage profile of 1.0 is assumed.

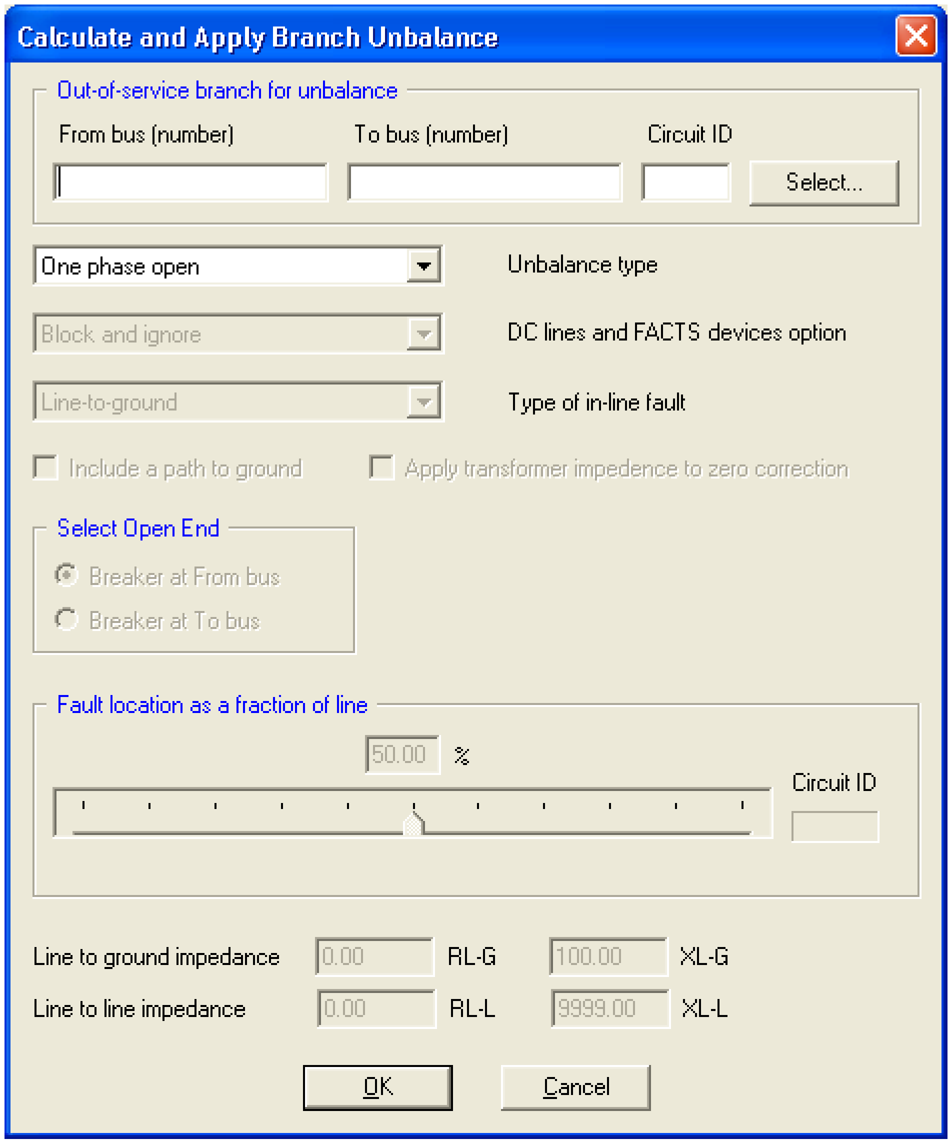


Figure 14-51. Calculate and Apply Branch Unbalance Dialog

The non-transformer branch to be subjected to the unbalance can be specified by entering it directly in the ”From bus”, “To bus” and ”Circuit ID” fields or by selecting the ***Select*** button to the right of the fields and using the standard non- transformer branch selector dialog to select the non-transformer branch.

The type of unbalance to be applied is selected with the "Unbalance type" combo box.

One Phase Open Unbalance

For the one phase open unbalance, the open phase may be grounded (faulted) or ungrounded. If the "Include a path to ground" toggle button is selected the fault location "slider bar" and the "Line to ground impedance" specification fields are enabled; if it is un-selected, they are disabled.

If the user elects to ground the open phase, the grounding impedance (Rl-g+ jXl-g) is specified in the two "Line to ground impedance" edit fields. The location of the fault is defined in per unit of total line length from the specified "from" bus. The "slider bar" is used to define the fault location. "Clicking" on either side of the slider bar handle increments or decrements the slider bar position by about one tenth of its total range.

Two Phases Open Unbalance

For the two phases open unbalance, no fault impedance input is required and all remaining fault specification widgets are disabled.

In-Line Fault

For the in-line fault unbalance, either a line-to-ground, a double line-to-ground, or a three phase fault may be applied. The user selects the type of fault by the use of the "Type of in-line fault" combo box.

If the user selects the single line-to-ground fault, the complex fault impedance (Rl-g + jXl-g) is specified in the two "Line to ground impedance" input fields.

If the user selects the double line-to-ground fault, the line-to-ground impedance (Rl-g + jXl-g) is specified in the two "Line to ground impedance" input fields, and the line-to-line impedance (Rl-l + jXl-l) is specified in the two "Line to line impedance" input fields.

If the user selects the three phase fault, no fault impedance input is required.

The location of the fault is defined in per unit of total line length from the specified "from" bus. The "slider bar" near the center of the window is used to define the fault location. "Clicking" on either side of the slider bar handle increments or decrements the slider bar position by about one tenth of its total range.

One Breaker Open Unbalance

For the single breaker on one phase open unbalance, the phase with one end open may be grounded (faulted) or ungrounded. If the "Include a path to ground" toggle button is "pressed", the fault location "slider bar" and the "Line to ground impedance" specification fields are enabled; if it is "released", they are disabled.

If the user elects to ground the open phase, the grounding impedance (Rl-g + jXl-g) is specified in the two "Line to ground impedance" edit fields. The location of the fault is defined in per unit of total line length from the specified "from" bus. The "slider bar" near the center of the window is used to define the fault location. "Clicking" on either side of the slider bar handle increments or decrements the slider bar position by about one tenth of its total range.

The "Select open end" radio button is used to designate the end of the line at which the breaker is open: either the "from" bus or "to" bus as specified in the edit fields at the top of the dialog.

All Unbalance Types

If DC lines and/or FACTS devices are present in the network, the “DC line and FACTS devices option” combo box is enabled. The user has the option of block loading unblocked DC lines and in-service FACTS devices or converting constant admittance load on them by selecting the appropriate element from the combo box.

If the actual positive sequence impedance of any transformer in the working case differs from its nominal value, the user has the option of applying the same correction factor to the zero sequence impedances of all such transformers by selecting the "Apply impedance correction table to zero sequence transformers" toggle button; if this button is not selected, the zero sequence impedances of all such transformers are left at their nominal values.

Selecting the ***OK*** button initiates the fault calculation. The calculated positive sequence pi-equivalent replaces the branch parameters of the branch subjected to the unbalance and the dialog is dismissed.

Selecting the ***Cancel*** button dismisses the dialog without calculating any branch unbalance.

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Chapter 15

Compiling and Creating User DLL

15.1 Overview: Createusrdll

‘createusrdll’ is an application program used for creating PSS™E dynamic simulation user dll. This combines the functions of ‘compile.bat’ and ‘cload4.bat’ of PSS™E dynamic simulation.

15.2 Using createusrdll

PSS™E installation creates "createusrdllxx" (xx is the PSS™E version number) icon on the desktop. The "createusrdllxx" is also accessible from ***Start -> Programs -> PSS™E- xx -> createusrdll*** menu item. Either of these can be used to launch the application.

When the application is launched, the dialog that appears will be as shown in Figure 15-1.

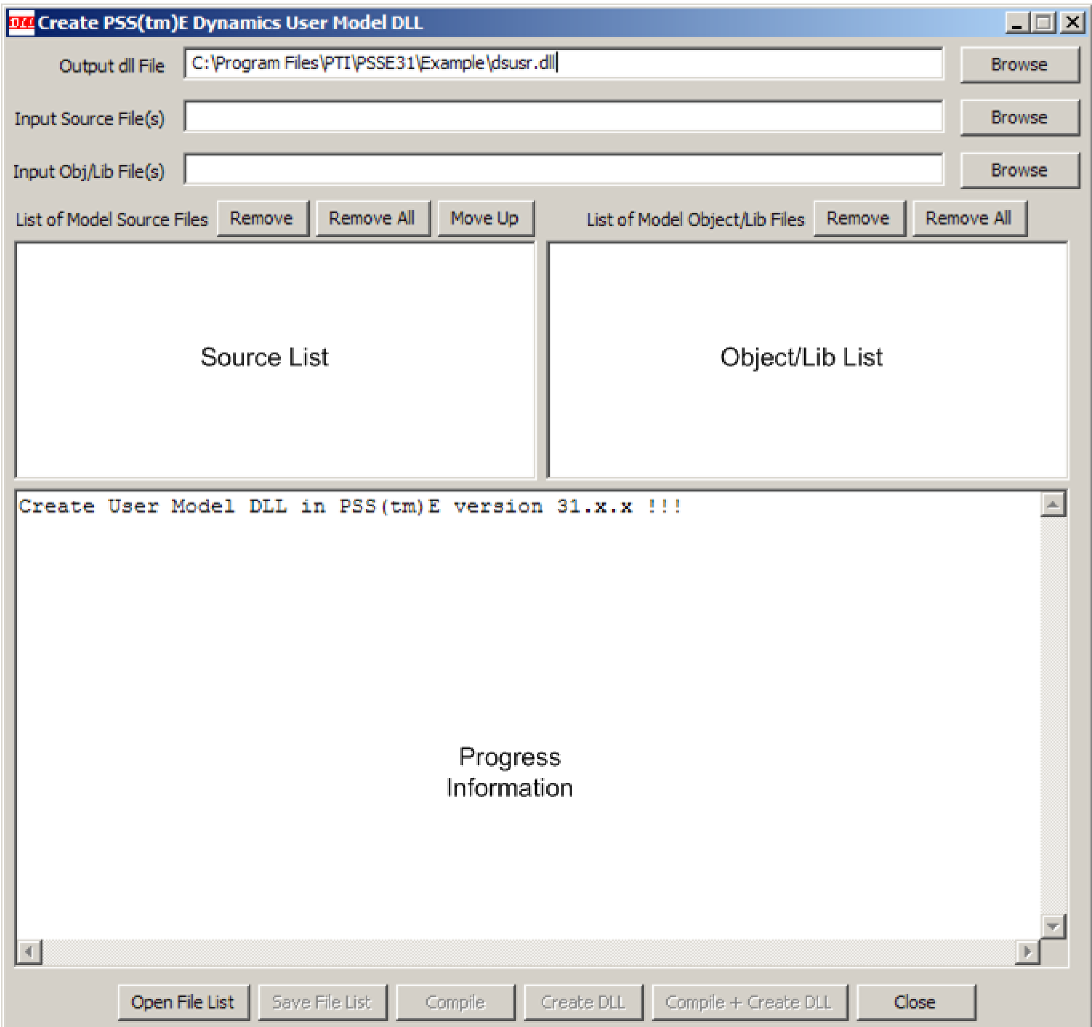

Figure 15-1. Dialog to Create Dynamic Simulation User dll

The various pieces of information to be input by the user is explained below.

15.2.1 Output dll File

This is the name of the dll file to be created.

The default name is dsusr.dll. However, it can be any name. To edit the dll name, type the dll file name or select the dll file name using ‘Browse’ button.

If the name is anything other than ‘dsusr.dll’, then after opening PSS™E, but before running dynamic simulation, users have to load this dll using the ‘addmodellibrary’ API. For example, if a user dll called ’myusrmodel.dll’ is created in the ’work_dir’ folder, this dll can be loaded using the psspy module as follows:

ierr = psspy.addmodellibrary(r"c:\work_dir\myusrmodel.dll’)

15.2.2 Input Source File(s)

‘Input Source Files’ refers to the FORTRAN or FLX source file names.

Use either of the steps below to add source files.

- If the names of all the source files that would be needed to create the user DLL was saved in a text file, then use the ‘Open File List’ button and select the text file name.
- Select one or more files using ‘Browse’ button.
- Type the file name.

Addition of a source file by either of these methods will populate the left side box titled “List of Model Source Files”.

15.2.3 Input Object/Library File(s)

The successful compilation of the source files, corresponding “object” codes are automatically added to “List of Model Object/Lib Files”.

Additionally, other pre-compiled (i.e., existing) object/library files can be added to the list using either of the steps below.

- Object/Library files from input text file when opened using ‘Open File List’ button
- Select one or more files using ‘Browse’ button.
- Type the file name.

This will populate the right side box titled “List of Model Object/Lib Files”.

15.2.4 Remove and Remove All

This is used for removing Source or Object/Lib Files from Selection.

The steps to remove files from the ’List of Model Source Files’, or from the ’List of Object/Lib Files’ are as follows.

- Select a file and use “Remove” button to remove selected file.
- Use “Remove All” to remove all files.
- Double click on a file name to remove selected file.

When a file is removed from “List of Model Source Files” the corresponding file from the “List of Model Object/Lib Files” is not removed.

15.2.5 Move Up

The ’Move Up’ is used to move one or more source file up the ’List of Model Source Files’. When a fortran source file is a fortran module file, this file needs to compiled first, so that the “.mod” created by compiler is available for other fortran source files during their compilation.

To move a file up, select the appropriate source file in “List of Model Source Files” and use ‘Move Up’ button to bring the selected file ahead of other fortran file.

15.2.6 Compile

Compiles all the files in “List of Model Source Files”, and adds the resulting objects to “List of Model Object/Lib Files”.

15.2.7 Create DLL

This creates a dll by linking all the files in “List of Model Object/Lib Files”. The dll thus created will be stored in the file whose name was specified in ’Output dll File’.

15.2.8 Compile+Create DLL

Compiles all the files in “List of Model Source Files”, adds objects to “List of Model Object/Lib Files”, and creates a dll by linking all the files in “List of Model Object/Lib Files”.

15.2.9 Open File List

Specification of the user dll file name, the source files to be compiled, and the names of object/library files (collectively called the ’File List’) that are needed for creating the user dll can be done via GUI as explained above. Having specified the files needed for creating the dll, the ’File List’ can be saved in a text file using the "Save File List". Alternatively the text file containing the ’File List’ can be created using a text editor in a format as given in section 15.3.

15.2.10 Save File List

This saves the source file names, object/library file names and dll name (i.e., the ’File List’) to a text file. This file then can be opened using ‘Open File List’ button. The file is saved in a format described in section 15.3.

15.3 Application Notes

The format of Input Text File is as given below.

```
# File: mymodelfiles.txt

# Input to "createusrdll" program.

# Any text on a line after "#" is treated as comment.

# The file has three sets data records, with each record title as:

# [dll name], [source file names] and  [object/lib file names].

# Provide only one dll name in [dll name] record.

# Provide each source file name (.flx, .for, .f90, .f) on a separate
line in [source file names]

# record.

# Provide each object (.obj) or library (.lib) on a separate line
in [source file names] record.


[dll name]

c:\work_dir\myusrmodel.dll


[source file names]

c:\work_dir\mymodel_module.for

c:\work_dir\mymodel.for

c:\work_dir\mycontroller.flx


[object/lib file names]

c:\work_dir\mymodel.dll

c:\work_dir\pssewind.lib

c:\work_dir\myother.obj
```

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Chapter 16

Creating and Viewing the Results of Dynamic Simulations

16.1 Overview: Creating and Viewing the Results of Dynamic Simulations

The channels captured during the Dynamic Simulation can be viewed and plotted directly from within PSS™E. Multiple channel output files can be open simultaneously and the channels from these multiple channel files combined on a single plot. Currently, the plotting functionality is only a subset of the plotting capabilities found in PSS™PLT. In future releases, the full functionality of PSS™PLT will be incorporated into PSS™E. Therefore, PSS™PLT is still installed and can be used in the same manner as in previous releases of PSS™E.

16.1.1 General Workflow to View Dynamic Results

The results of Dynamic Simulations are the plot channels of various PSS™E quantities that are selected prior to performing the Dynamic Simulation. The plot channels captured during any Dynamic Simulation are contained in a plot channel output file which is in a binary form. The plotting functions contained within PSS™E can be used to read these binary channel files and display the plots.

In order to view the plots, a Plot Book has to be created. The Plot Book is configured like an Excel Worksheet with multiple Plot Pages each capable of displaying several Plots. A Plot in turn can contain several channels/curves/traces. A Plot Book by default will contain on Page with one Plot on that Page.

After a Plot Book is created, a channel output file has to be opened. The channel output file will appear in the Tree View, which, when expanded, will display all the channel outputs that were selected prior to the Dynamic Simulation run.

Any channel output quantity can be viewed by dragging and dropping into the Plot Page.

16.1.2 Recording

Many of the interactions involved in creating and customizing the Plot Book are recordable and can be played back through the use of Automation files. In future releases, most of the Plot Book interactions will be recordable and available for playback.

16.2 Dynamics Results Interface Elements

The use of the plotting portion of PSS™E requires several new interface elements. These are described in the following sections.

16.2.1 Tree View Plot Data Tab

The Plot Data tab in the Tree View (Figure 16-1) provides a quick glance at all the defined output channels in the opened channel files. The Plot Data Tab is synchronized with the open channel files and displays all the channels currently defined in the channel files. Folders can be expanded or collapsed to control the amount of data visible.

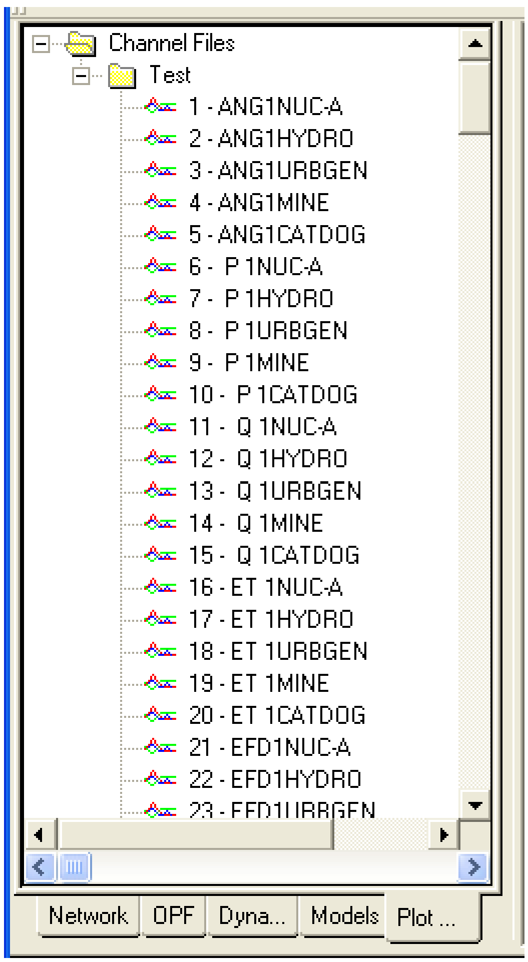

Figure 16-1. Plot Data Tab Tree View

16.2.2 Plot Book

The Plot Book is used to display and print the channels captured during the Dynamic simulation. Multiple channel files may be displayed simultaneously. The Plot Book is configured like an Excel Worksheet, with multiple Pages each capable of containing multiple Plots (Figure 16-2). The configuration of the Plot Book is left to the user. Future releases will support a plotting configuration file that will be used to pre-configure a Plot Book whenever one is opened.

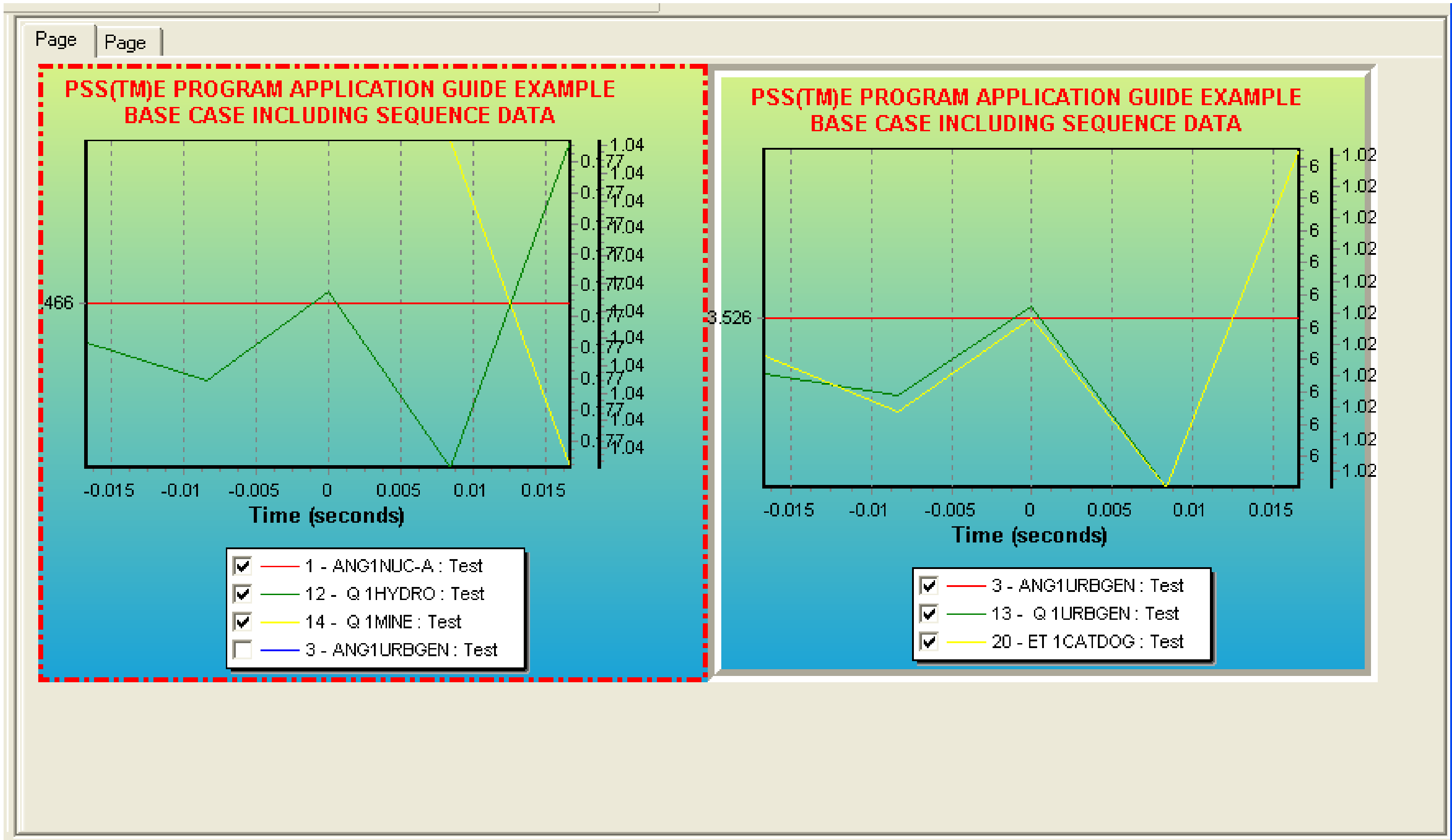

Figure 16-2. Plot Book

The active Plot on the Plot Page is indicated by the red-border that surrounds the plot. All interactive actions, such as adding channels or changing the Plot appearance take place in the active Plot.

16.2.3 Plotting Menu Bar

The Edit entry on the menu bar is used to access all the plotting specific functions of PSS™E. Plotting functions can be accessed and run whenever the Plot Book is the active view (Figure 16-3).

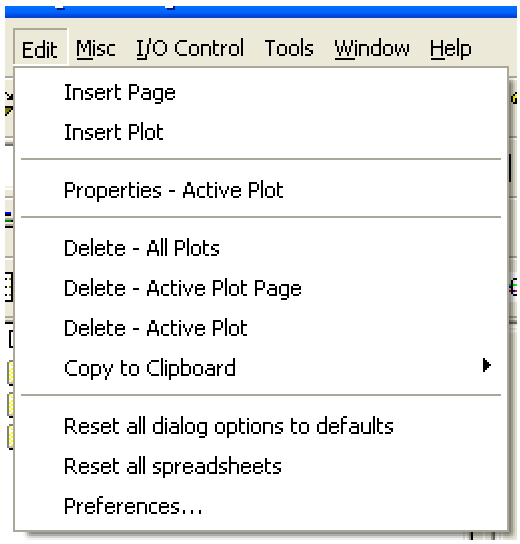

Figure 16-3. Plotting Menu

16.2.4 Plot Book Editor

The Plot areas on the Plot Book are also configurable through the Plot Editor. This Editor is accessed by bringing up the context menu in the active Plot and selecting Show Editor (Figure 16-4). The context menu is accessed through the secondary mouse button. This is usually the right button though it can be configured to be the left.

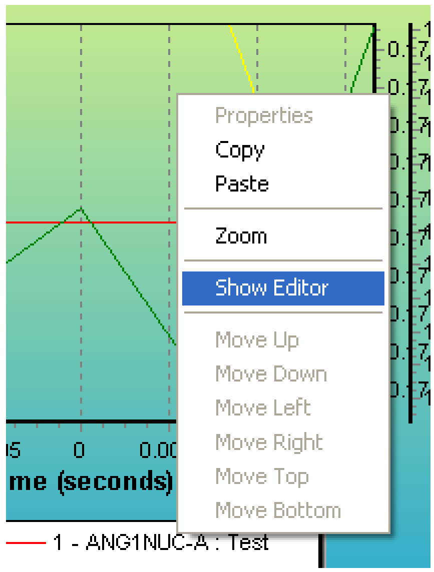

Figure 16-4. Accessing the Plot Editor through the Context Menu

The Plot Editor allows the configuration of various properties of the Plot, such as Axis, Titles, Legend, colors etc. (Figure 16-5).

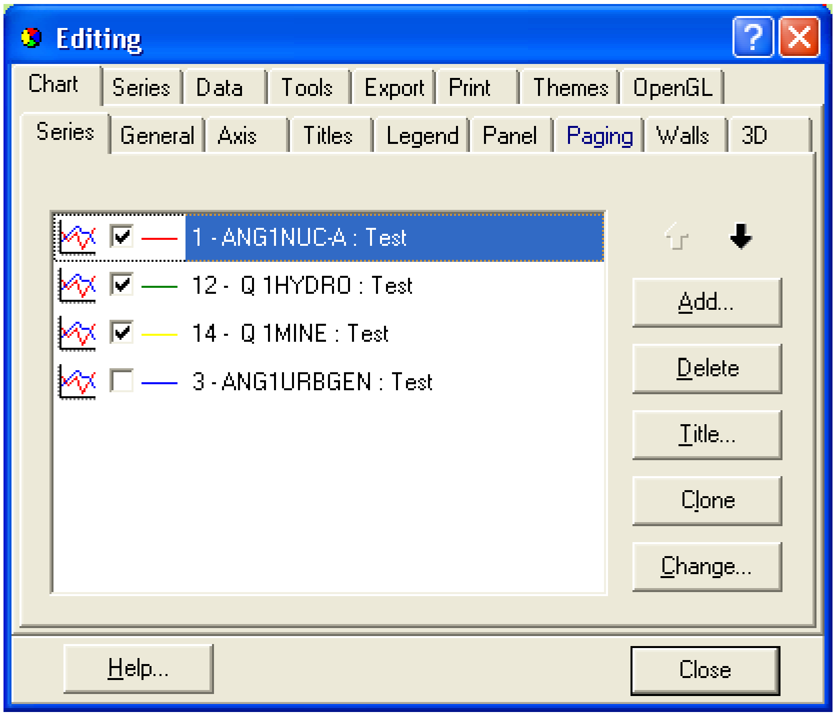

Figure 16-5. Plot Editor

16.2.5 Plotting Channel Drag and Drop

Channels of interest are added to Plots by dragging the channel from the Tree View Plot Data Tab and dropping it on the Plot Page (Figure 16-6). Channels are always added to the active Plot regardless of where they are dropped on the Plot Page. As mentioned before, the active Plot is indicated by the red border around it. Items are dragged and dropped using the "primary" mouse button. This is usually the left button though it can be configured to be the right.

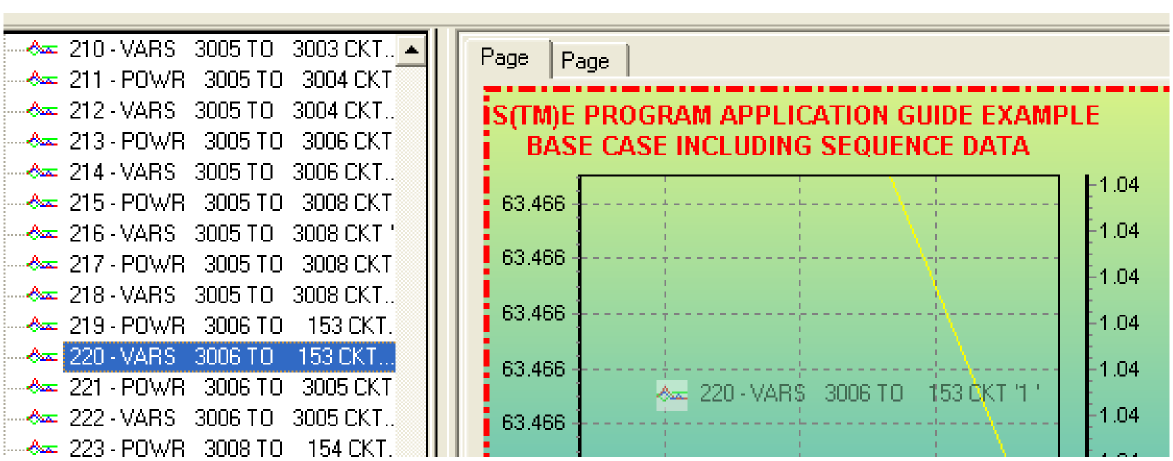

Figure 16-6. Channel Drag and Drop

16.2.6 Additional Plot Page Interactions

Selecting the context menu on a Plot Page outside of any of the Plots on that Page will present selections to allow the insertion of a new Plot Page, the deletion of the active Plot Page or the renaming of the identifier on the top of the Plot Page.

16.2.7 Plotting Menu Bar Entries

The following sections describe the entries found in the Plotting Menu Bar entry of PSS™E.

16.2.7.1 Creating a Plot Book

The use of any of the Plot Book functions first requires the creation of the Plot Book itself. This is done by selecting **File>New** and then **Plot Book** from the dialog. A new Plot Book with one Plot Page and one Plot on the page will then be created.

16.2.7.2 Opening a Channel File

An existing channel file is opened by selecting **File>Open Channel File - Binary**. The selected channel file will then appear as a named folder in the Channel Files tree. This channel file folder may then be expanded to show the channels defined in that file (Figure 16-1).

16.2.7.3 Closing a Channel File

Open channel files may be closed in several ways. A single channel file can be selected in the Plot Data Tab Tree View and then closed by selecting **File>Close Channel File**. Selecting **File>Close All Channel Files**. You may also close a channel file by selecting it in the Plot Data Tab Tree View, bringing up the context menu as described above, and selecting **Close**.

16.2.7.4 Exporting a Plot

The active Plot may be exported to several different file formats by selecting **File>Export** and then selecting the desired format from the popup menu. A standard file save dialog will appear prompting for the name and location of the exported Plot. Currently, four file formats are available for export, Windows Metafile, Bitmap, JPEG and PDF. Future release will add other graphic formats.

16.2.7.5 Printing a Plot

Plot Books may be printed in several ways. Selecting **File>Print All Plots** will print every Plot on every Plot Page in the Plot Book. Selecting **File>Print Active Plot Page** will print every Plot on the active Plot Page. Selecting **File>Print Active Plot** will print the active Plot on the Plot Page.

16.2.7.6 Creating a Plot Page

A new Plot Page is created in a Plot Book by selecting **Edit>Insert Page**. The new Plot Page automatically becomes the active Plot Page.

16.2.7.7 Creating a Plot

A new Plot is created on the active Plot Page by selecting **Edit>Insert Plot**. The new Plot automatically becomes the active Plot.

16.2.7.8 Changing Plot Properties

Selecting **Edit>Properties - Active Plot** will present a Plot Editor dialog that can be used to modify the properties of the active Plot on the Plot Page (Figure 16-5).

16.2.7.9 Deleting Plots

Plots may be deleted from the Plot Book in several ways. Selecting **Edit>Delete - All Plots** will delete every Plot on every Plot Page in the Plot Book. Selecting **Edit>Delete - Active Plot Page** will delete every Plot on the active Plot Page. Selecting **Edit>Delete - Active Plot** will delete the active Plot on the Plot Page.

16.2.7.10 Copying Plots to the Clipboard

The active Plot can be copied to the system clipboard for use in creating reports in other applications. Several formats, Windows MetaFile and Bitmap, are supported. To copy the active Plot to the clipboard, select **Edit>Copy to Clipboard** and select the desired format. The active Plot is then placed in the system clipboard, in the selected format, for use elsewhere.

Chapter 17

Event Studies

17.1 Overview: Event Studies

Event Studies are a user defined series of events that can be replayed over and over with data values and settings changed interactively. Event Studies consist of one or more Event Items. Event Items currently consist of network equipment connection and disconnection Events and Fault Events.

When the Event Study is run as a Dynamics Event Study, Event Items are implemented as Disturbance APIs when a match is available, and as general Network APIs when no defined disturbance API exists e.g. Load connect/disconnect events. Event Items in a Dynamics Event Study have a time element associated with them and are performed in ascending time sequence.

When the Event Study is run as a Power Flow Study, Fault Event Items are mapped to SCMU APIs and network Event Items are mapped to Network APIs. Currently, simultaneous Fault Events are not supported and so any simultaneous Events in the Event Study are de-activated and only the first encountered Fault Event is performed.

Dynamics and Power Flow event studies can be accessed in several different ways. Event studies can be added and viewed by accessing the Dynamics tab in the Tree View. Individual event items can be added to the active study from the tree view, from the diagram, and from the event spreadsheet. The event spreadsheet enables the user to edit the events belonging to the active study.

Event Studies are preserved in an external file with an *.evs suffix. Through the use of the Event Study file, defined Event Studies maybe used with more than one set of files.

17.1.1 Event Item Type

The following table describes the supported Event Types and their implementation when run in Dynamics and Power Flow Study modes.

Table 17-1. Supported Event Types

Event Type	Dynamics Implementation	Power Flow Implementation
Connect Bus	Re-connect Bus - RECN	Re-connect Bus - RECN
Disconnect Bus	Disconnect Bus - DSCN	Disconnect Bus - DSCN
Connect Machine	Machine Status switch	Machine Status switch
Disconnect Machine	Machine Status switch	Machine Status switch
Connect Load	Load Status switch	Load Status switch
Disconnect Load	Load Status switch	Load Status switch
Connect/Close Line	Branch/Transformer Close Disturbance	Branch/Transformer Status switch
Disconnect/Trip Line	Branch/Transformer Trip Disturbance	Branch/Transformer Status switch
Bus Fault	Bus Fault Disturbance	Multiple unbalanced network solution - SCMU
Line Fault	Branch/Transformer Line Fault Disturbance	Multiple unbalanced network solution - SCMU
Unbalanced Bus Fault	Calculate and Apply Unbalanced Bus Fault	Multiple unbalanced network solution - SCMU
Unbalanced Line Fault	Calculate and Apply Branch Fault	Multiple unbalanced network solution - SCMU
Vref Change	Vref Change Disturbance	(not applicable)

17.2 Dynamics Tab Tree View

The Dynamics tab in the Tree View provides a quick glance at all the Event Studies contained in the current event studies file (see Figure 17-1).

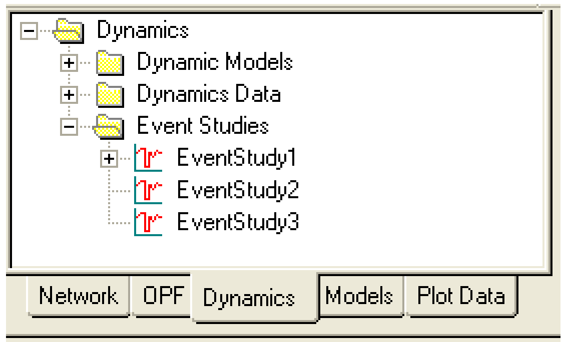

Figure 17-1. Dynamics Tree

If an event studies file has not been opened, or if no studies are listed, a right-click will bring up a popup menu (see Figure 17-2). If "Add Event Study" is selected, the user will be prompted to select an existing event studies file, or to create a new file.

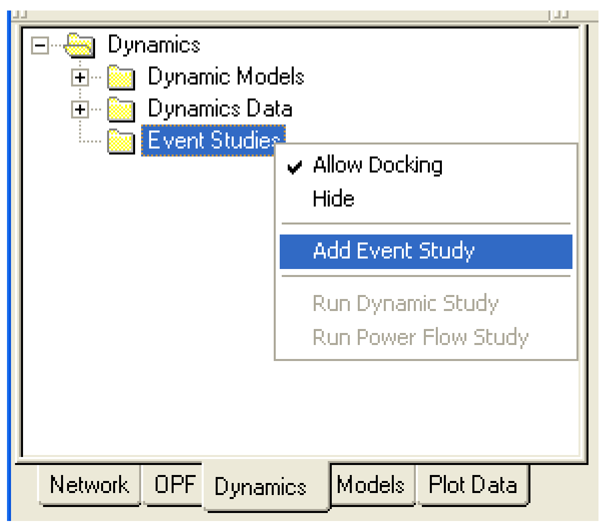

Figure 17-2. Add Event Study Popup Menu

17.2.1 Add Event Study

If an Event Studies file (*.evs) has not been opened before selecting the "Add Event Study" item from the popup menu, the user will be prompted to select an existing file, or to create a new file (see Figure 17-3).

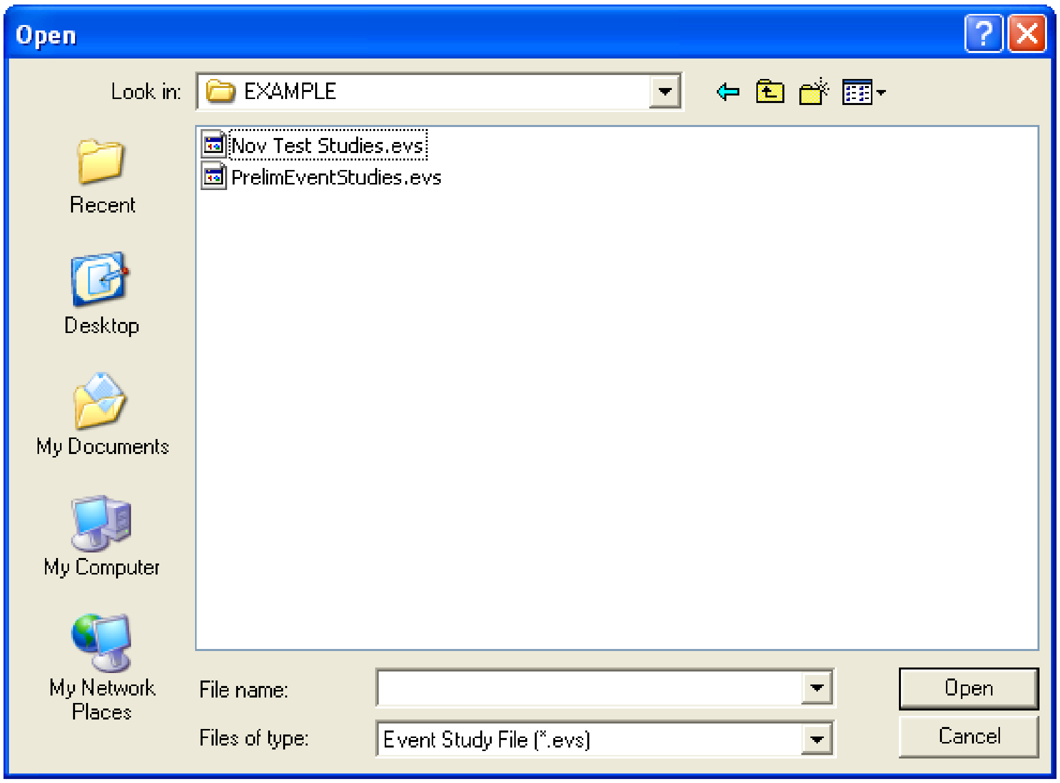

Figure 17-3. Open Event Studies File Dialog

Once an existing file has been selected or a new file has been named, the Event Studies Properties dialog will be displayed (see Figure 17-4).

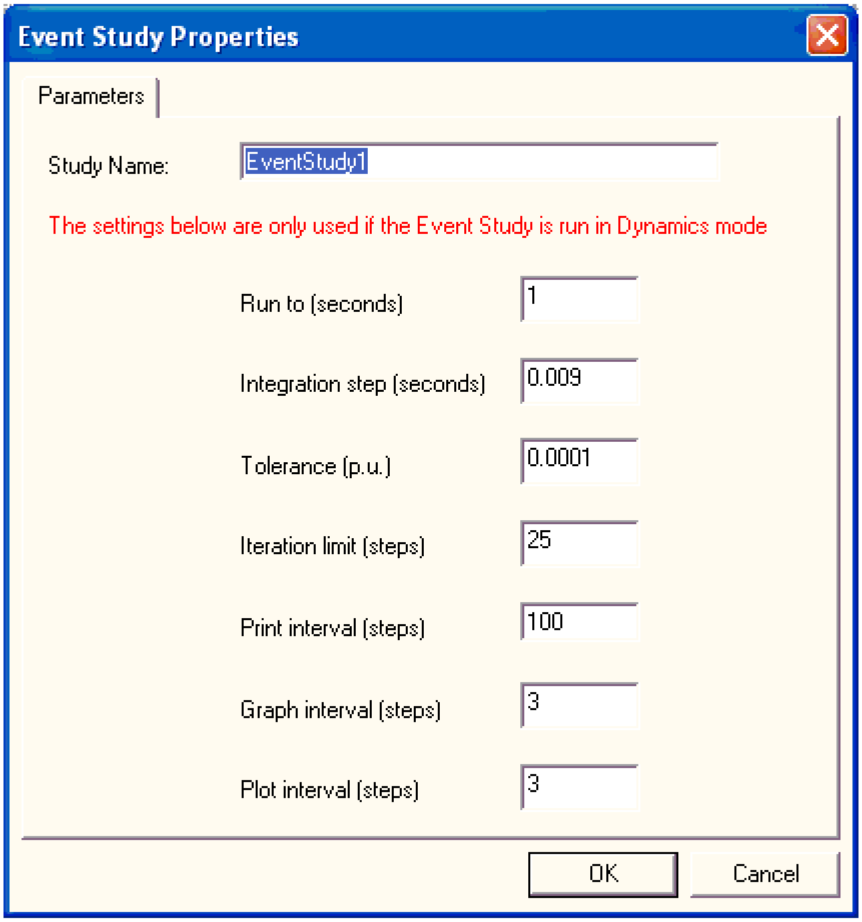

Figure 17-4. Event Study Properties Dialog

17.2.2 Event Study Properties Dialog

The Event Study Properties dialog allows the user to specify the general parameters which will be used when the event study is run. All fields are initially filled with default values, however the user may edit them all.

The following fields are used only if the Event Study is run as a Dynamics Event Study. The values in these fields have no significance if the Event Study is run as a Power Flow Event Study. The "Study length" field specifies, in seconds, the total duration of the event study. The "Integration step" is the time interval, in seconds, between steps. The "Tolerance" field specifies the PSS™E dynamic simulation convergence tolerance, and the "Iteration limit" field specifies the PSS™E dynamic simulation iteration limit. The "Print interval", "Graph interval" and "Plot interval" fields specify the number of steps between text outputs, channel file outputs, and plot results output. Click the ***OK*** button and the defined study will be added to the event study tree. The new study just added becomes the ***active study***. The ***active study*** is the only study to which event items can be added from the diagram and from the network tree.

17.2.2.1 Active Event Study

There are two ways in which an event study becomes the ***active study***. The event study currently being added automatically becomes the active study displays a popup menu containing an option to set a particular event study to the ***active study***. The ***active study*** is the one which will be executed when the option to "Run Dynamic Study" or "Run Power Flow Study" is selected. When you exit the program, the studies are saved to the named file. A flag indicating which of the studies is the ***active study*** is also saved, so that when the file is read back in, the same event study will still be the ***active study***. If the ***active study*** is deleted from the tree view, no study is active until another is added or a remaining one is made active by selecting the "Make Active Study" choice on the popup menu.

17.2.3 Add Event Item

A right-click on an event study label brings up the popup menu (see Figure 17-5).

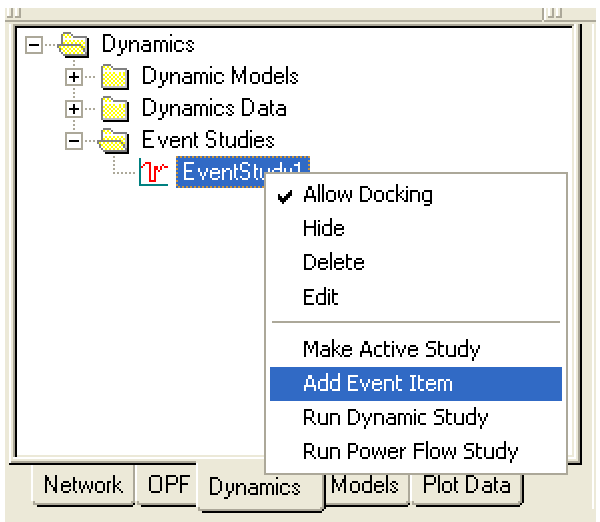

Figure 17-5. Add Event Item Popup Menu

When "Add Event Item" is selected from the popup menu, the Event Item Properties Dialog is displayed (see Figure 17-6).

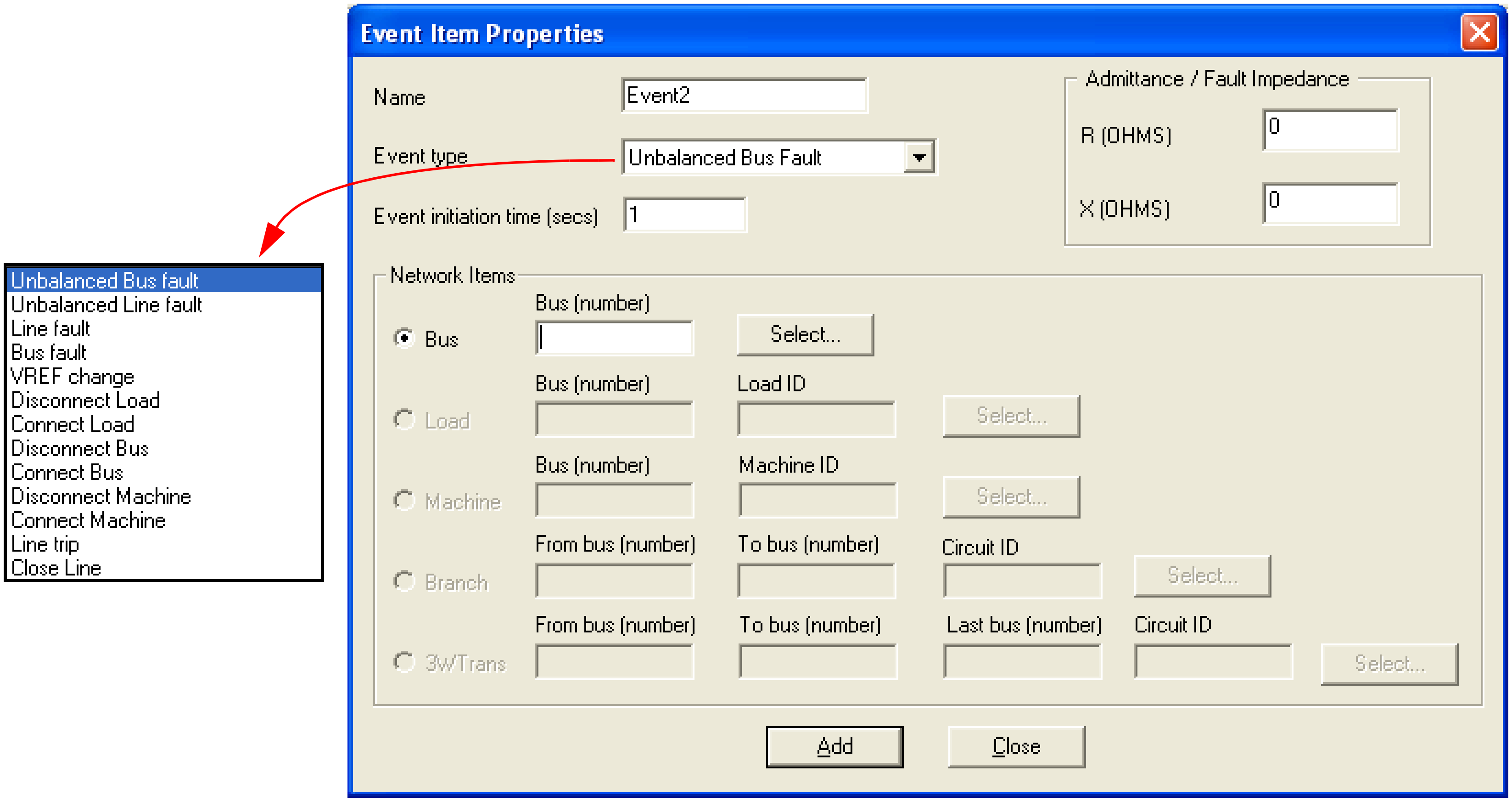

Figure 17-6. Event Item Properties Dialog

The Event Item Properties dialog allows the user to specify the Event Items which will be part of the selected study. The "Name" field can be edited to suit the user. The "Time" field contains the time at which this event item occurs. As mentioned previously, the "Time" field is only used if the Event Study is run as a Dynamics Event Study (ensure that this value is less than the total time duration of the entire event study.) A drop-down list of available "Event Types" is available (see Figure 17-6).

When an "Event type" is selected, the appropriate "Network Item" lines will become enabled for selection. For example, if the "Event Type", **Disconnect Machine** is selected from the list, all of the Machine fields will become enabled. Click on the ***Select*** button to bring up the standard machine selector dialog (see Figure 17-7).

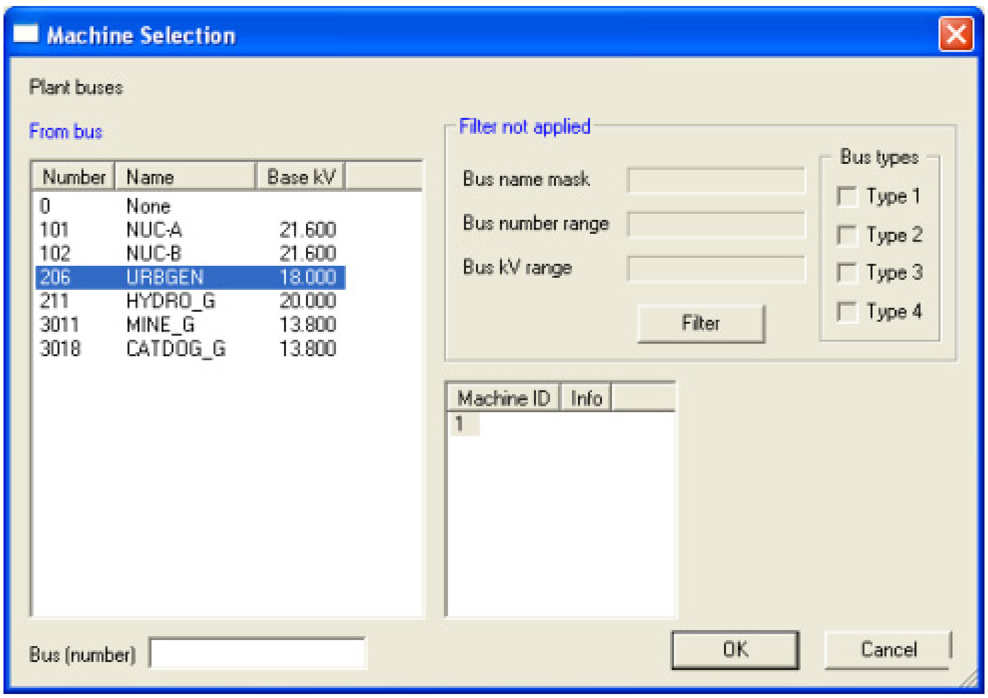

Figure 17-7. Machine Selection Dialog

Select a machine, click the ***OK*** button, and the Machine "Bus (number)" and "Machine ID" fields will be filled in on the Event Item Properties dialog (see Figure 17-8).

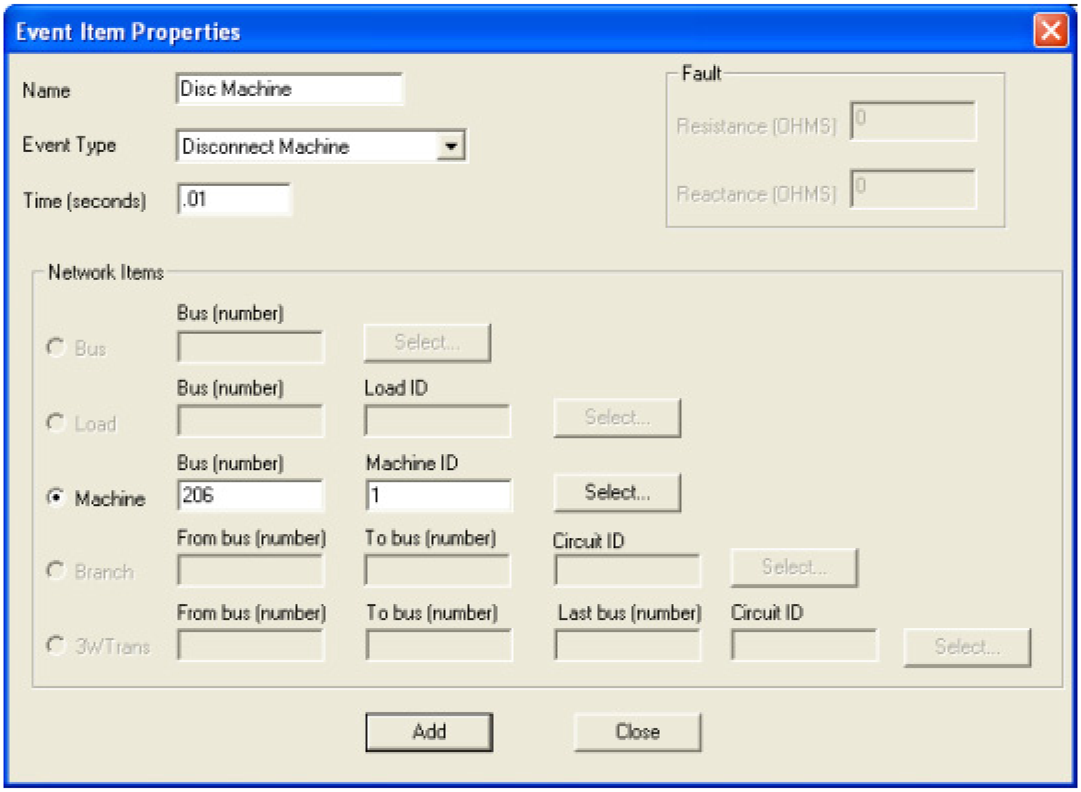

Figure 17-8. Selection of a Machine Event

Click the ***Add*** button to save the event and to configure another event item. If an "Event Type" that pertains to a *line* is selected, both the "Branch" and the "3WTrans" fields will be enabled. When the selected "Event Type" requires Fault data, the "Resistance" and "Reactance" fields will be enabled. When finished, click the ***Close*** button. The configured event items are displayed on the Event Studies tree (see Figure 17-9).

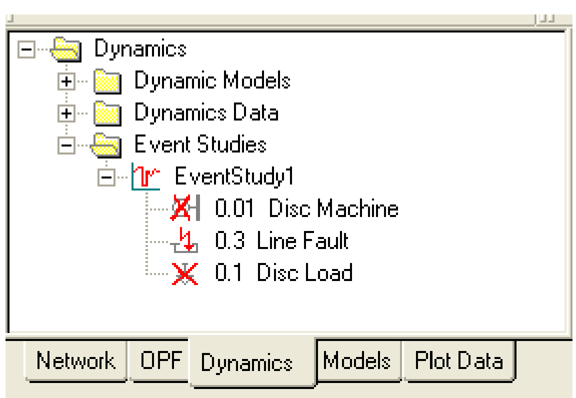

Figure 17-9. Event Study and Event Items

17.2.4 Editing the Event Item Data

Right-clicking an event item activates a popup menu (see Figure 17-10).

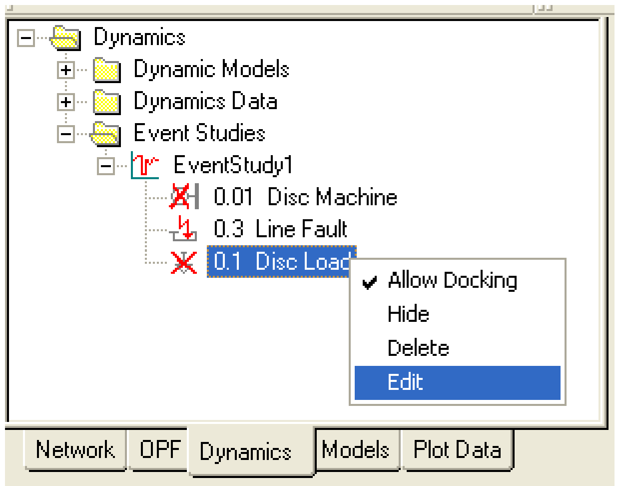

Figure 17-10. Event Item Popup Menu

Selecting the "Edit" option brings up an Event Spreadsheet (see Figure 17-11).

	Active	Event Type	Event Name	Time	From Bus Number	From Bus Name	To Bus Number	To Bus Name	Last Bus Number	Last Bus Name	Id	Phase Imped	Phase Imped	Faulted Phase 1	Faulted Phase 2	Admittance R Fault Imped R (L-G)	Admittance X Fault Imped X (L-G)
	☑	Discon Mach	Disc Machine	0.0100	206	URBGEN 18.000					1						
	☑	Line Fault	Line Fault	0.3000	203	EAST230 230.00	205	SUB230 230.0			2	0.00	0			0.00	-2e+009
	☑	Discon Load	Disc Load	0.1000	3007	RURAL 230.00					1						
*	☑																

Figure 17-11. Event Spreadsheet

The Event Spreadsheet displays the parameters for those event items which belong to the ***active study***. All data items which are not grayed out can be modified. The values will be saved when the cursor moves to another line of data. If more than one event study exists in a file, only those items belonging to the ***active study*** will appear in the spreadsheet (see Figure 17-12).

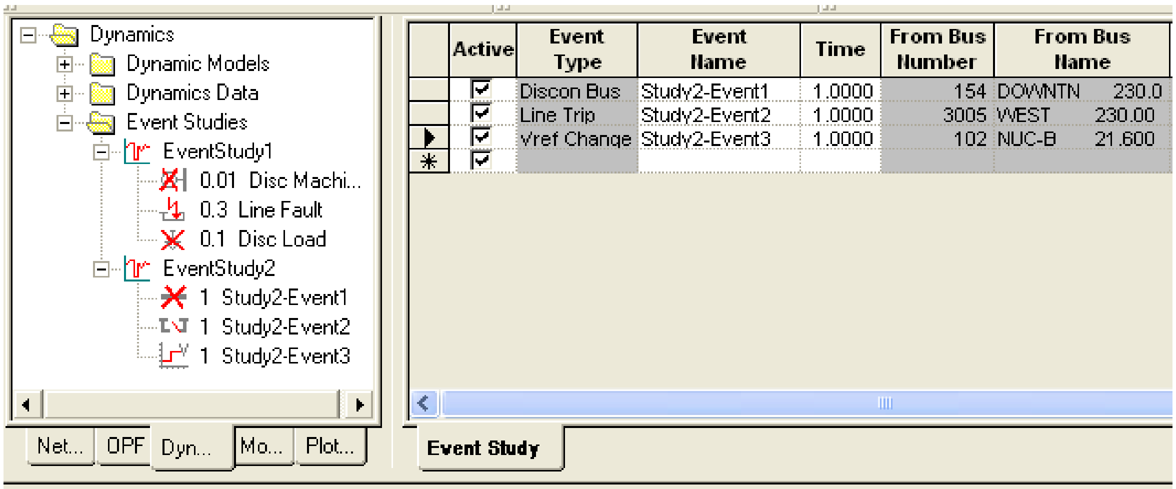

Figure 17-12. Active Study Event Spreadsheet

17.2.4.1 Active vs. Inactive Event Items

If there is an event which should not be included when an event study is executed, it can easily be deactivated in the event spreadsheet. This eliminates having to delete and reconfigure events which may be needed at another time. To deactivate an event, *un*check the "Active" box. Note in Figure 17-13 that the event's icon in the tree view is now grayed out.

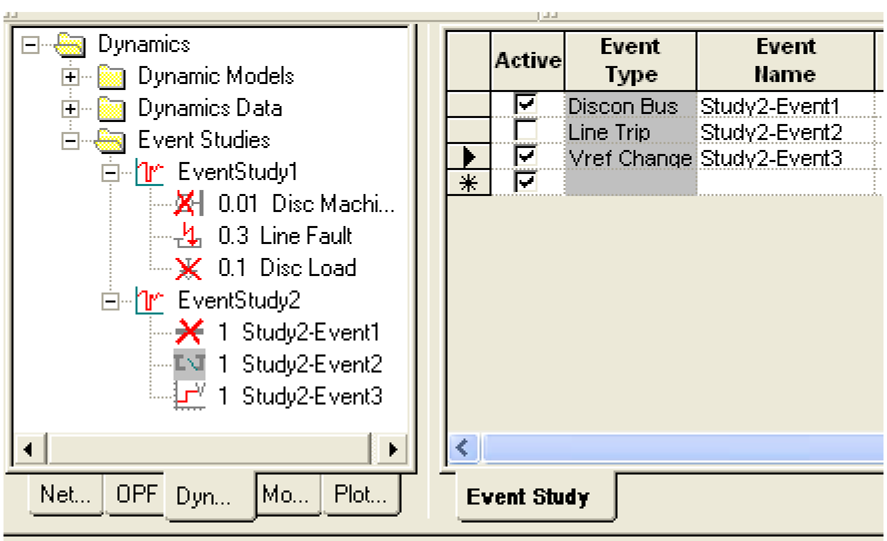

Figure 17-13. Inactive Event

17.2.5 Run an Event Study

There are two types of event studies, a dynamic study and a power flow study. Right-click on the "Event Studies" tree to activate the popup menu which displays the run event study options (see Figure 17-14).

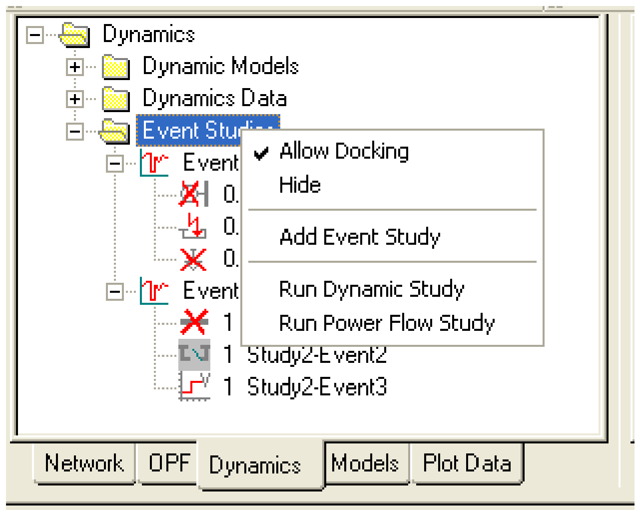

Figure 17-14. Event Studies Popup Menu

If there is more than one study available, selecting either the "Run Dynamic Study" or the "Run Power Flow Study" option will bring up the Select Event Study dialog from which you can select the desired study (see Figure 17-15).

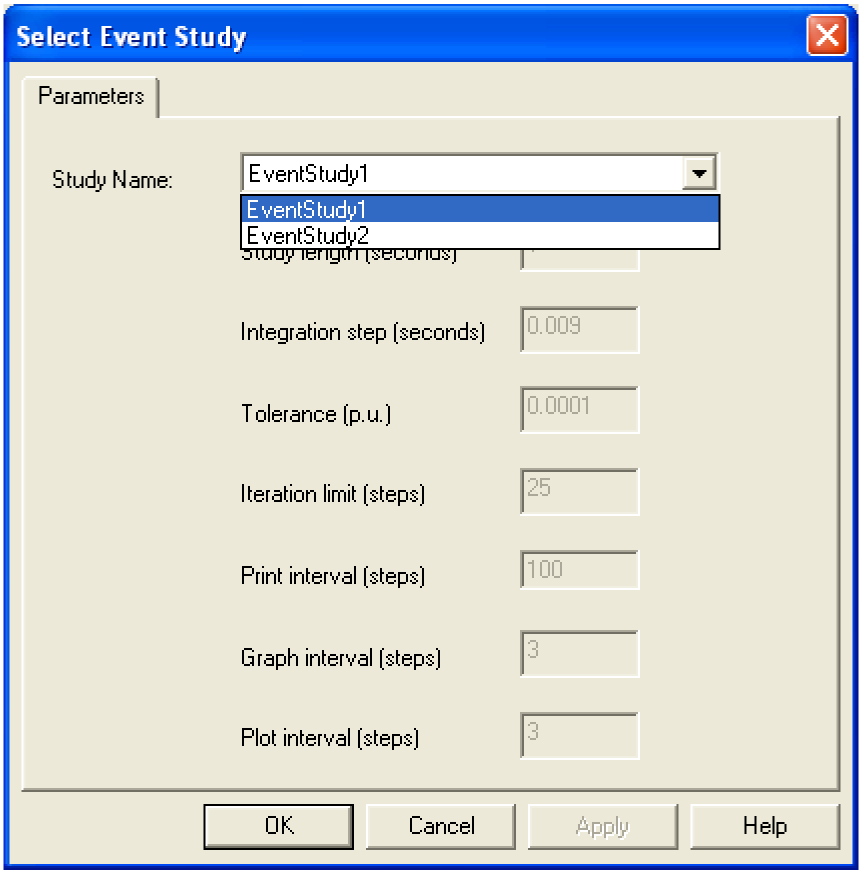

Figure 17-15. Select Event Study Dialog

When the desired study has been selected, click the ***OK*** button, and execution of the chosen study type will begin. Note that in order to run a Dynamic Study, dynamics data must be present.

17.3 Network Tab Tree View

If an event study file has been read into the program, event items belonging to the ***active study*** will be indicated on the network tree view (see Figure 17-16). More that one Event Item can be associated with any Network Item.

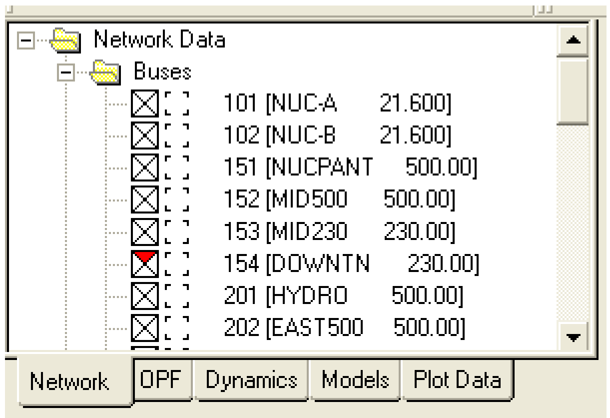

Figure 17-16. Event Item Indication on Bus

17.3.1 Add Events From Network Tree View

A right-click on any network data component activates a popup menu, which allows events appropriate for the component type to be added to the ***active study*** (see Figure 17-17). If there is not an ***active study*** currently present in the network, event items cannot be added.

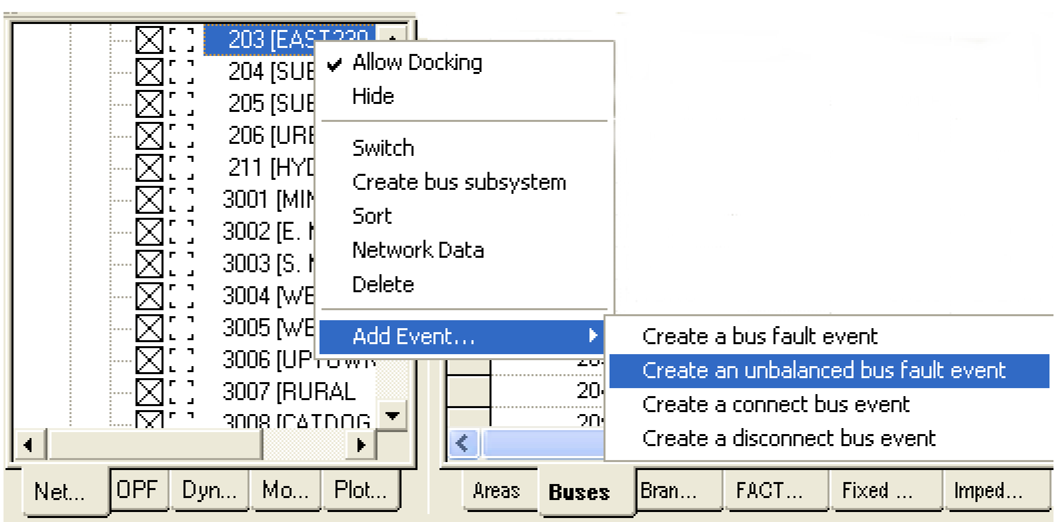

Figure 17-17. Add Events from Network Tree View

Select one of the available Events to be created. A dialog for data input will be activated (see Figure 17-18). Modify the default values and click on the ***OK*** button to add the event to the **active study**. The title of the dialog and the data values available will depend on the type of Event being added.

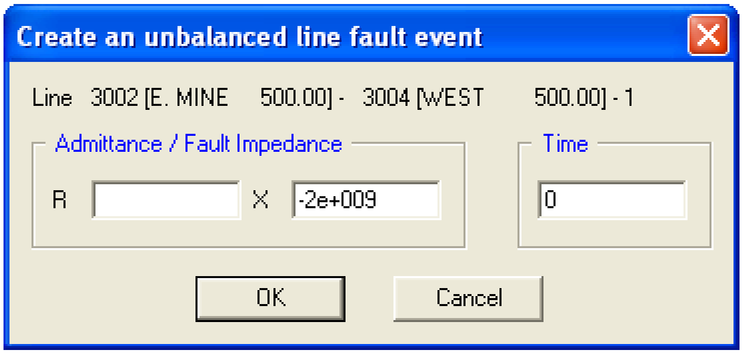

Figure 17-18. Event Input Dialog

17.3.2 Edit Event Data from Network Tree View

If a network data component has an event indicator, the popup menu also includes an option to view that data (see Figure 17-19). Selection of the "Event Data" option will activate the Event Spreadsheet for viewing or editing of the event data.

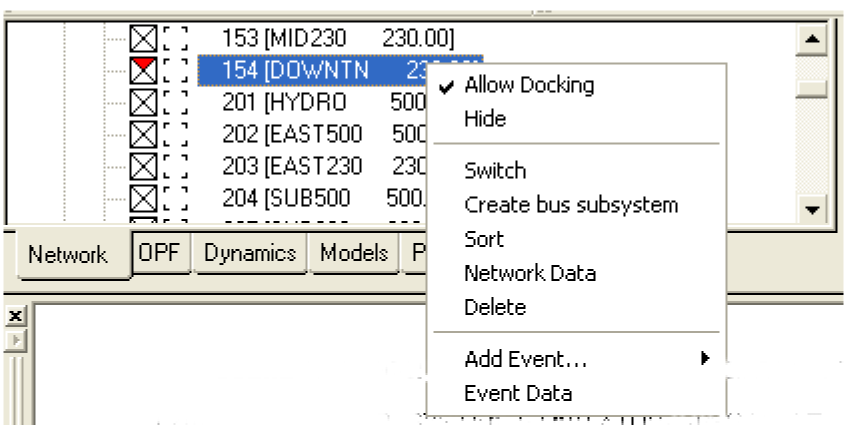

Figure 17-19. Edit Event Data from Network Tree View

17.4 One-line Diagrams

If an event study file has been read into the program, event items belonging to the ***active study*** will also be indicated on the one-line diagram (see Figure 17-20). More that one Event Item can be associated with any Network Item and only one Event symbol will be displayed on the Network Item in the diagram. Double-clicking on any Event symbol in the Diagram will take you to the Event Spreadsheet for viewing or editing of the Event data.

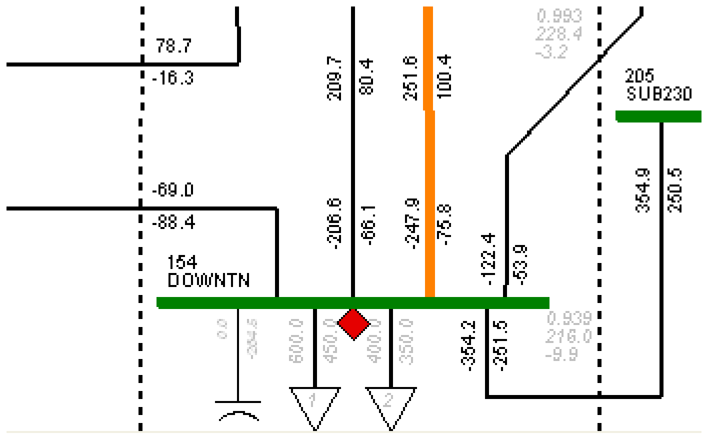

Figure 17-20. Event Indicator on One-line Diagram

17.4.1 Add Events from the One-line Diagram

Events can be added to the ***active study*** from the one-line diagram (see Figure 17-21).

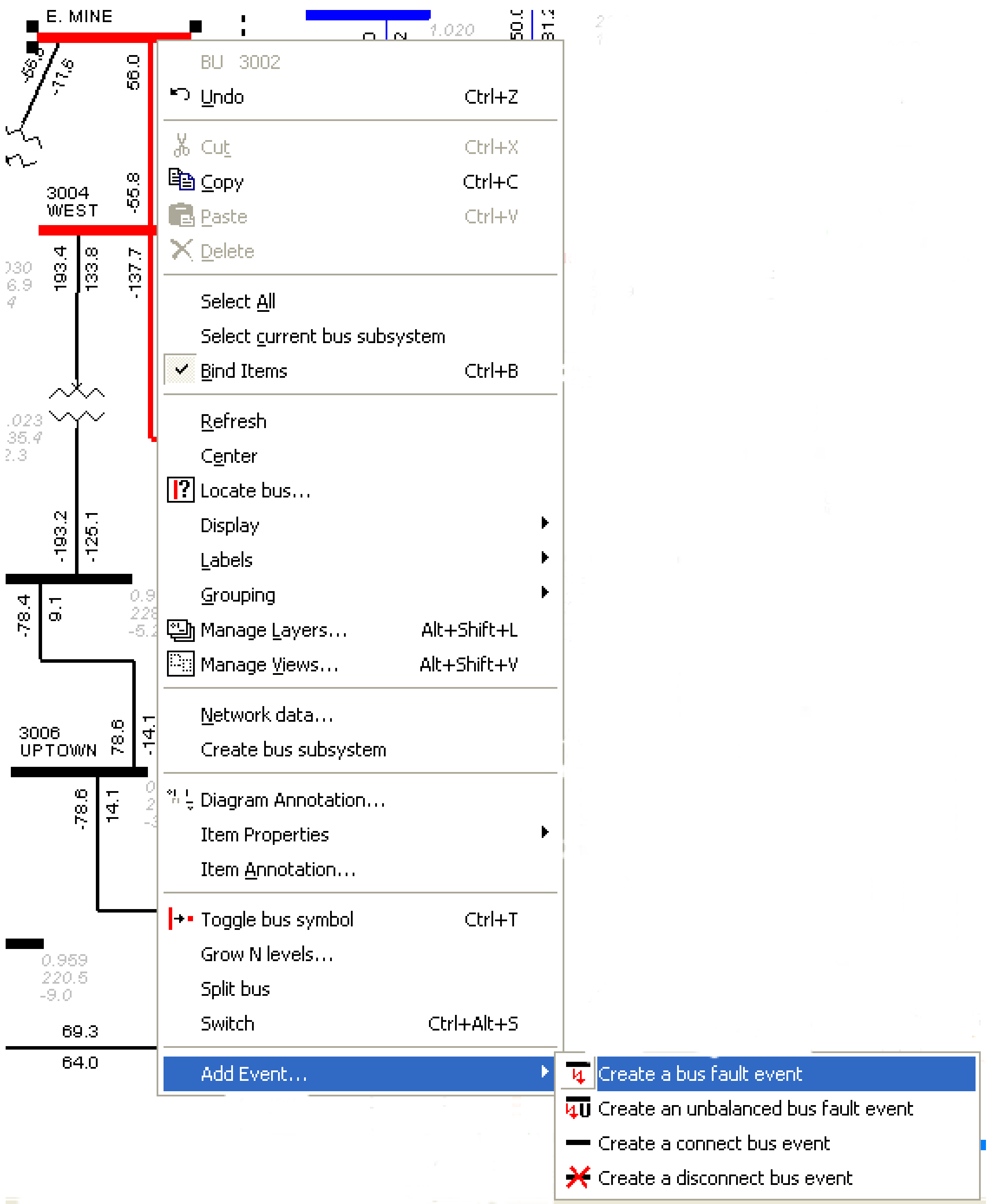

Figure 17-21. Adding Events from the One-line Diagram

Selection of an available event type will bring up an event data dialog (see Figure 17-22).

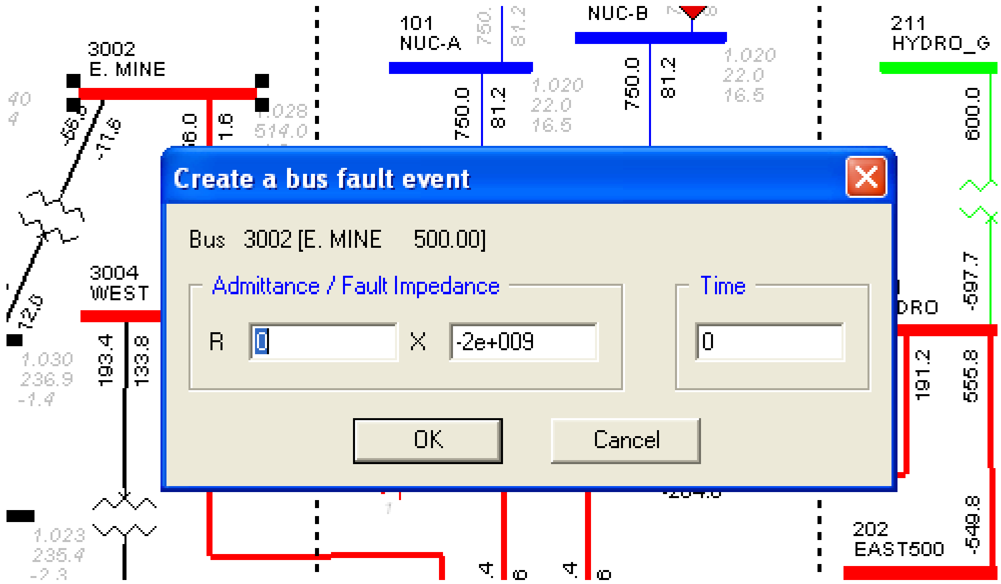

Figure 17-22. Event Data Dialog

When finished editing values, click the ***OK*** button to add the event to the ***active study***.

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Chapter 18

Scenarios

18.1 Overview: Scenarios

Scenarios are groups of files that are used to perform a single study. They can consist of the network files, both Power Flow and Dynamics, in both the raw and binary forms, Slider Diagrams, Bus Location and Subsystem configuration files, Contingency analysis files (Subsystem definition file, Monitored Element file, Contingency file, Distribution Factors file) and Sequence and OPF data files. All the files used in the study can be stored in a Scenario file. The Scenario file is based on XML so that it is easily readable by all text editors (see Figure 18-1). When a Scenario file is opened, all the files described in the Scenario file are either opened or set for other functions that use them. Scenario files provide a convenient way to manage the myriad number of files associated with a PSS™E study, loading/opening them all with only a few commands.

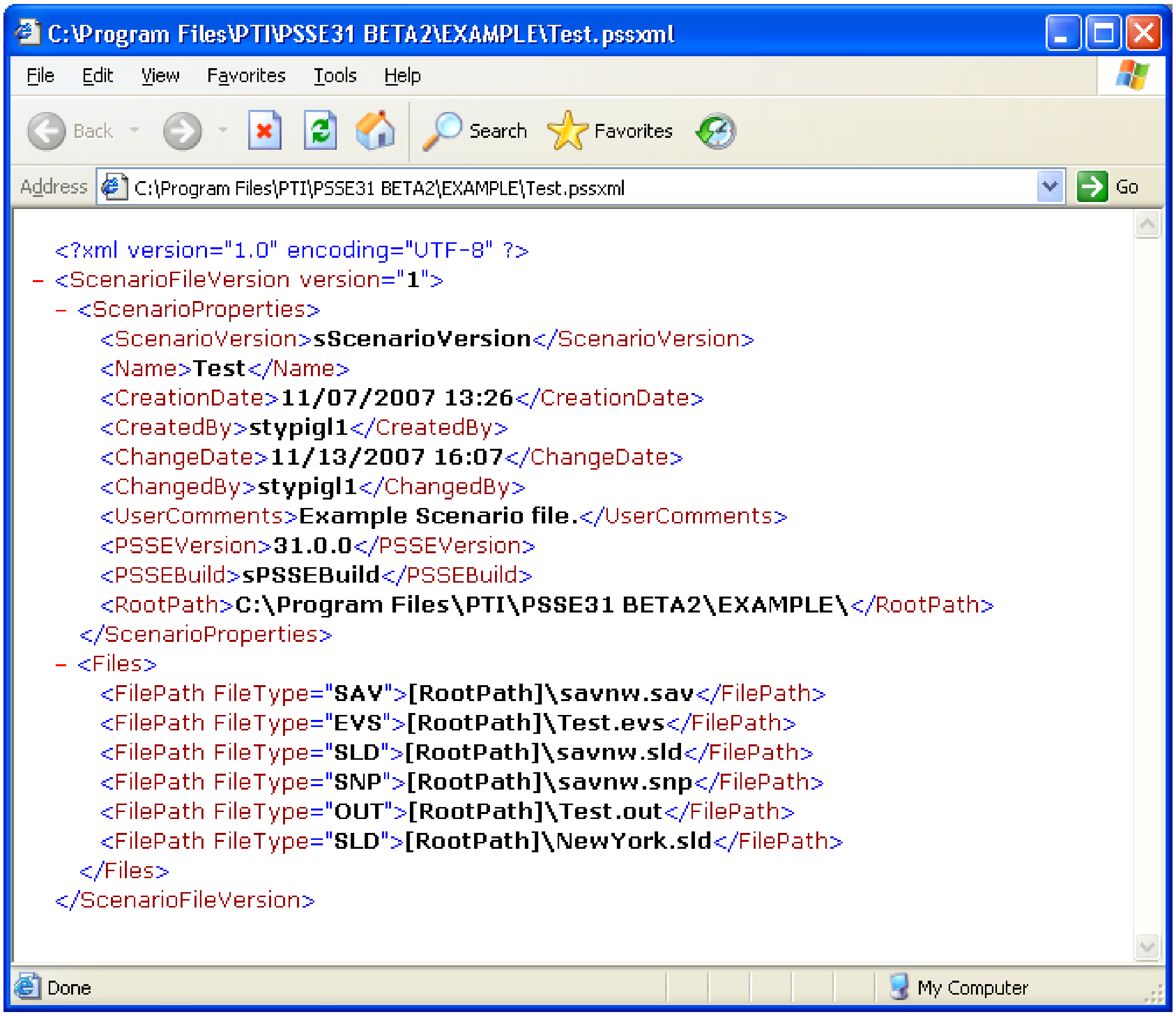

Figure 18-1. Scenario XML File

18.1.1 General Workflow using Scenarios

The following outline the general workflow using Scenarios. To begin using Scenarios, a New Scenario file is defined. A name is assigned for the Scenario file as well as it's location in the directory structure. This location is important as it serves as the Root Path for all files in the Scenario. If files that are added to the Scenario are located in the same directory as the Scenario file itself, then they're saved as the filename plus the Root Path (see Figure 18-1). The Root Path itself is defined in the Scenario file and can be changed to a different location. This allows us to move the entire Scenario to another machine and use the Scenario file without having to replicate the directory structure that existed on the original machine. All that need to be done is to open the Scenario file, open the Scenario Editor, change the Root Path, save it and then re-open the Scenario file. Now all the files contained within the Scenario file will be opened/loaded automatically.

If a Scenario file already exists, it can be opened through a file selection dialog and all the files contained within will be opened/loaded automatically.

Once a Scenario file has been opened, opening and referencing files in PSS™E will automatically add them to the Scenario.

The Scenario file can be saved at any time, either to the same name or to a different name.

Closing an open Scenario file will close/unload all files contained in the Scenario.

Files may also be added or removed from an open Scenario through the use of the Scenario Editor.

18.2 Scenario Menu Bar Entries

The following sections describe the Scenario entries found in the Menu Bar of PSS™E.

18.2.1 Creating a New Scenario File

The use of any of the Scenario functionality requires the creation of the Scenario file itself. This is done by selecting ***File>Scenarios>New Scenario…*** and then specifying a Scenario file. The location of the Scenario file is important as this provides the initial Root Path whose use is described above. The most common location for creating a Scenario file is the directory in which most of the files to be used in the study are located. Scenario files are created with, and identified by, a *.pssxml suffix.

18.2.2 Opening an Existing Scenario File

An existing Scenario file is opened by selecting ***File>Scenarios>Open Scenario…***. All files contained within the Scenario file will then be opened/loaded automatically.

18.2.3 Saving a Scenario File

An open Scenario file is saved by selecting ***File>Scenarios>Save Scenario…*** or ***File>Scenarios>Save Scenario As…***.

18.2.4 Closing a Scenario File

An open Scenario file is closed by selecting ***File>Scenarios>Close Scenario…***. Closing the Scenario file will close/unload all files contained in the Scenario

18.2.5 Editing a Scenario File

An open Scenario file may be edited, with files being added or removed and the Root Path changed. A Scenario file is edited by selecting ***File>Scenarios>Edit Scenario…***. From this dialog, the Scenario file may be edited (see Figure 18-2).

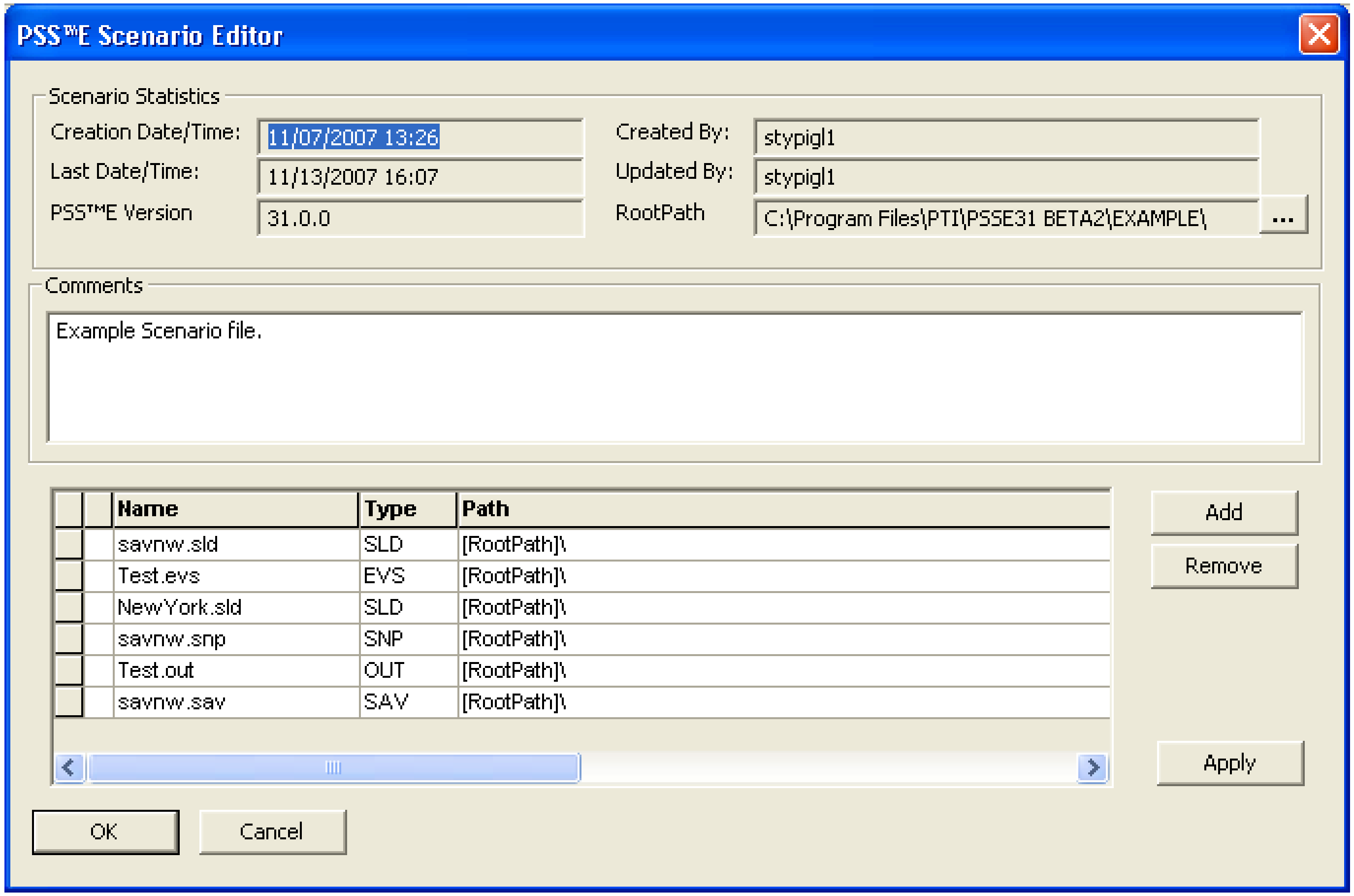

Figure 18-2. Scenario File Editor

The fields at the top of the dialog list the creation and modification dates of the Scenario as well as the version of PSS™E for which the Scenario was originally created. They also show the login ID of the user who created and last updated the Scenario. The RootPath field shows the file path which is used to complete the files listed in the Scenario. The RootPath is changed by selecting the “browse” button to the right of the field and using a standard file directory selector dialog to select the new RootPath. If a file was added to the Scenario in a directory other than that described by the RootPath, the full path will be described for this file.

Files can be added to the Scenario by selecting the ***Add*** button. The File Add dialog (see Figure 18-3) can then be used to select the individual files to add to the Scenario. The file type combo box is used to specify the type of file to add to the scenario. Certain file types, such as RAW, SAV, DYR and SNP can only have one instance in a Scenario file. If one already exists, adding a new one will replace the existing file. Other files types, such as SLD file, can have multiple instances in the Scenario File.

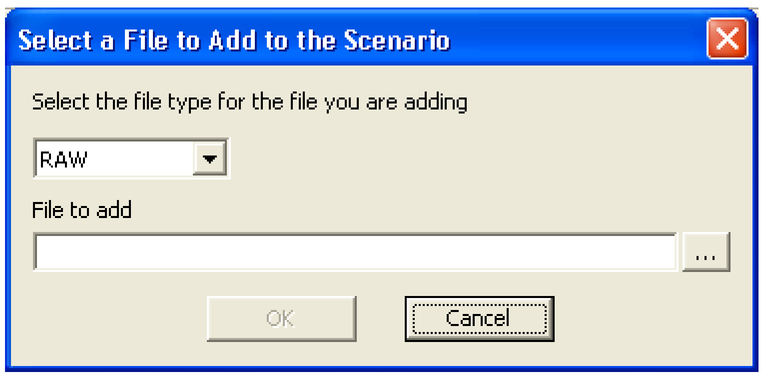

Figure 18-3. Adding Files to the Scenario

Files are removed from the Scenario by selecting the file (see Figure 18-4) and selecting the ***Remove*** button.

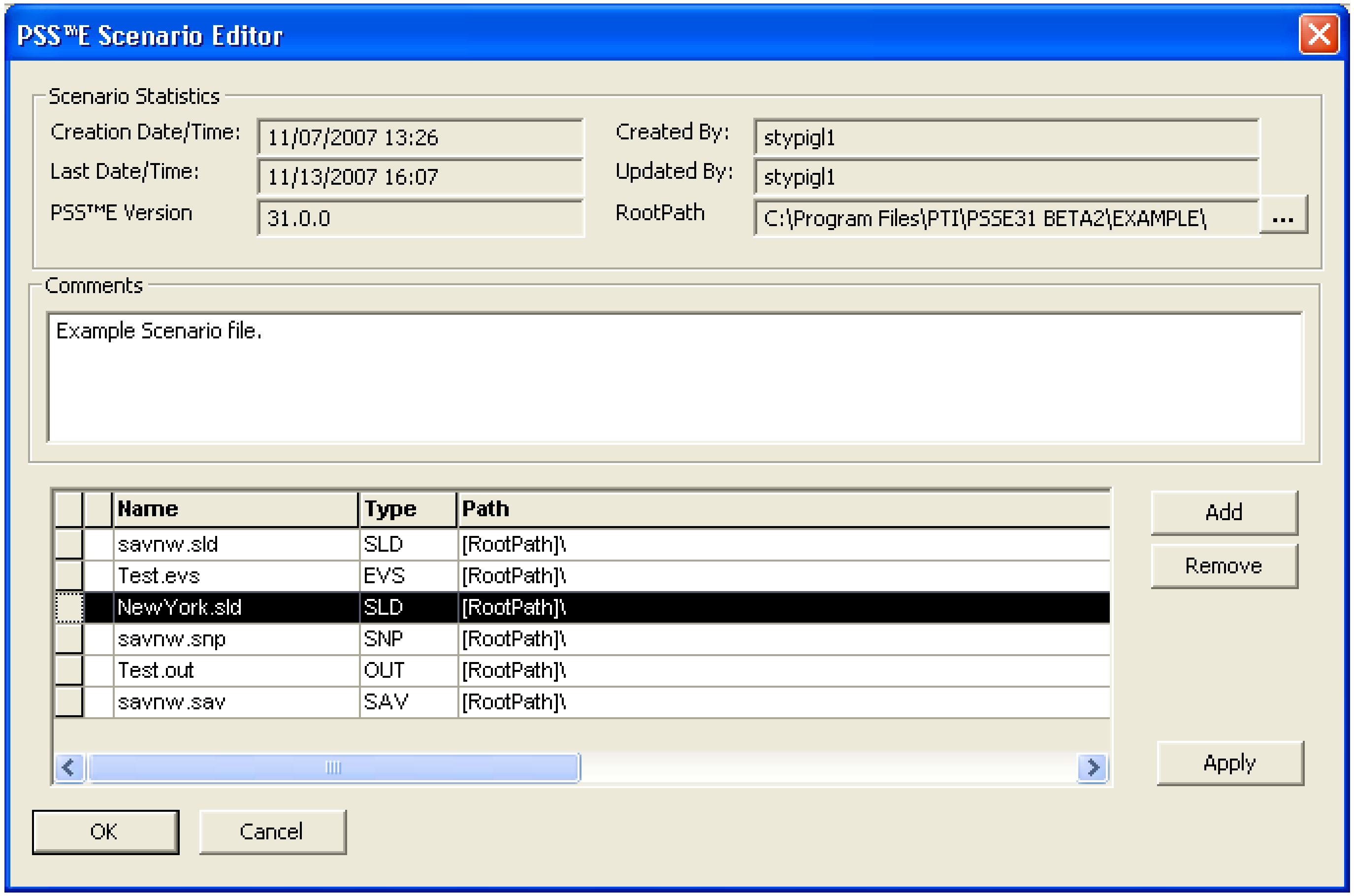

Figure 18-4. File Selected for Removal from Scenario

Changes made to the Scenario can be saved directly from the Scenario Editor dialog by selecting the ***Apply*** button. If the changes are not saved in this dialog, they can be saved from the Menu Bar as previously described.

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Appendix A

Activity Map

Users of previous versions of PSS™E will be familiar with the four letter activity name interface. The "Activities" which comprise all analytical functions, I/O control and program automation can be initiated via the pull-down menus or by typing in the four letter activity name in the command line.

The Activity Selector has been replaced with a Microsoft® Windows-based graphical user interface for all analysis. In future versions of PSS™E there will be diminished use of four letter names.

In order to assist users of previous versions of the program to navigate the user interface, Activity names are mapped to the appropriate menu item and/or toolbar button as shown in the following tables.

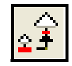
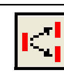
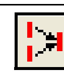
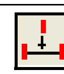
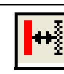
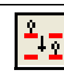
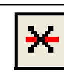
A.1 Load Flow Input

Activity	Menu Item	Toolbar Button
READ	***File>Open…*** Select files of type: • Power Flow Raw Data file (*.raw*) • Power Flow Data file, Options (*.raw*)	
RDCH	***File>Open…*** Select files of type "Power Flow Data file, Options (*.raw*)"	
TREA	Obsolete (replaced with Spreadsheet View)	OBSOLETE
MCRE	***File>Open…*** Select files of type "Machine Impedance Data file (*.rwm*)"	
RETI	***File>Import>Long title (RETI)…***	n.a.*

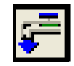
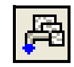
* Not applicable.

A.2 Load Flow Data Changes

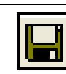
Activity	Menu Item	Toolbar Button
CHNG	Obsolete (replaced with Spreadsheet View)	OBSOLETE
XLIS	Obsolete (replaced with Spreadsheet View)	OBSOLETE
MBID	Obsolete (replaced with Spreadsheet View)	OBSOLETE

Activity	Menu Item	Toolbar Button
CHTI	***File>Case titles, short & long (CHTI)…***	n.a.
SCAL	***Power Flow>Changing>Scale generation, load, shunt (SCAL)…***	
CNTB	***Power Flow>Check data>Check / Change controlled bus scheduled voltages (CNTB)…***	n.a.
TPCH	***Power Flow>Check data>Check / Change transformer adjustment data (TPCH)…***	n.a.
TFLG	***Power Flow>Changing>Transformer adjustment flags (TFLG)…***	n.a.
BGEN	***Power Flow>Equivalence Networks…*** Select tab "Net boundary bus mismatches (BGEN)"	n.a.
ECDI	***Power Flow>Changing>Economic dispatch (ECDI)…***	n.a.
ARNM LDAR ZONM LDZO OWNM	***Power Flow>Renumbering Areas / Owners / Zones…***	n.a.
BSNM	***Power Flow>Renumber buses***	n.a.
RNFI	***File>Renumber buses in auxiliary files (RNFI)…*** or ***File>Renumber buses in Diagram (RNFI)…***	n.a.
SPLT	***Power Flow>Changing>Split buses (SPLT)…***	
JOIN	***Power Flow>Changing>Join buses (JOIN)…***	
LTAP	***Power Flow>Changing>Tap line (LTAP)…***	
DSCN RECN	***Power Flow>Changing>Disconnect / Reconnect Bus (DSCN/RECN)…***	
MOVE	***Power Flow>Changing>Move network elements (MOVE)…***	
PURG	***Power Flow>Changing>Delete network elements (PURG/EXTR)…***	
MODR	Supported by command line interface only	n.a.
FLAT FLAT,CL FLAT,IEC	***Fault>Set up for special fault calculations (FLAT)…*** Select desired option	n.a.
DRED	Obsolete (replaced with Diagram View)	OBSOLETE

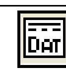
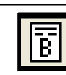
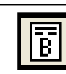
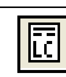
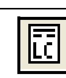
A.3 Load Flow Solution Activities

Activity	Menu Item	Toolbar Button
SOLV MSLV FNSL FDNS NSOL	***Power Flow>Solution>Solve (NSOL/FNSL/FDNS/SOLV/MSLV)…***	
ACCC	***Power Flow>Solution>AC contingency solution (ACCC)…***	
INLF	***Power Flow>Solution>N-R solution with inertial / governer dispatch (INLF)…***	n.a.

A.4 Database Interaction

Activity	Menu Item	Toolbar Button
CASE	***File>Open…*** Select files of type "Save Case file (**.sav*)"	
SAVE	***File>Save or Show…*** Select tab "Case Data"	

A.5 Load Flow Case Documentation

Activity	Menu Item	Toolbar Button
LIST	***Power Flow>List Data…*** Select "Power Flow"	
POUT LOUT LAMP	***Power Flow>Reports>Bus based reports…*** Select "Power Flow output and desired options"	
SUBS	***Power Flow>Reports>Bus based reports…*** Select "Subsystem summary / totals"	
MTDC	***Power Flow>Reports>Multi-terminal DC line solution output (MTDC)***	n.a.
EXAM	***Power Flow>List data…*** Select "Examine Power Flow / sequence data"	
RATE OLTL OLTR RAT3	***Power Flow>Reports>Limit checking reports…*** Select tab "Branches"	
TLST	***Power Flow>Reports>Limit checking reports…*** Select tab "Controlling transformer"	
REGB	***Power Flow>Reports>Limit checking reports…*** Select tab "Regulated buses"	
VCHK	***Power Flow>Reports>Limit checking reports…*** Select tab "Out-of-limit bus voltage"	

Activity	Menu Item	Toolbar Button
GENS	***Power Flow>Reports>Limit checking reports…*** Select tab "Generator bus"	
GEOL	***Power Flow>Reports>Limit checking reports…*** Select tab "Machine terminal"	
GCAP	***Power Flow>Reports>Limit checking reports…*** Select tab "Reactive capability"	
SHNT	***Power Flow>List data…*** Select "Bus shunts"	
DIFF DFTI CMPR	***File>Compare…*** Select tab "Power Flow Cases" for DIFF, "Tie Lines" for DFTI, and "Case Totals" for CMPR	n.a.
AREA OWNR ZONE	***Power Flow>Reports>Area / owner / zone totals…*** Select desired report and subsystem	
TIES TIEZ INTA INTZ	***Power Flow>Reports>Area / zone based reports…*** Select desired report and subsystem	
SIZE	***File>File information (SIZE/SHOW/BUSN)…*** Select "List the number of system components"	n.a.
OUTS	***Power Flow>List data…*** Select "Outaged equipment"	
BRCH	***Power Flow>Check data>Branch parameters (BRCH)…***	n.a.
TREE	***Power Flow>Check data> Buses not in swing bus tree (TREE)***	
ALPH	***Power Flow>List data…*** Select "Bus names"	
BUSN	***File>File information (SIZE/SHOW/BUSN)…*** Select "List unused bus numbers in a range"	n.a.
PRTI	Supported by command line interface only	n.a.
FIND	Obsolete (replaced with Spreadsheet View)	OBSOLETE

A.6 Matrix Handling Activities

Activity	Menu Item	Toolbar Button
ORDR	***Power Flow>Solution>Order network for matrix operations (ORDR)…***	n.a.
FACT	***Power Flow>Solution>Factorize admittance matrix (FACT)***	n.a.

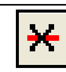
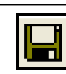
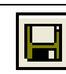
A.7 Switching Studies

Activity	Menu Item	Toolbar Button
TYSL	***Power Flow>Solution>Solution for switching studies (TYSL)…***	n.a.

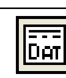
A.8 Load/Generator Conversion

Activity	Menu Item	Toolbar Button
CONL RCNL CONG	***Power Flow>Convert Loads and Generators…***	n.a.

A.9 Equivalent Construction and Data Handling

Activity	Menu Item	Toolbar Button
EXTR	***Power Flow>Changing>Delete network elements (PURG/EXTR)…*** Select "Remove Buses from Case"	
RAWD	***File>Save or Show…*** Select tab "Power Flow Raw Data"	
RWMA	***File>Save or Show…*** Select tab "Machine Impedance Data"	
READ	***File>Open…*** Select files of type: • Power Flow Raw Data file (**.raw*) • Power Flow Data file, Options (**.raw*)	
NETG GNET EQRD RDEQ SCEQ EEQV	***Power Flow>Equivalence Networks…*** Select appropriate tab	n.a.

A.10 Unbalanced Fault Analysis (Short Circuit)

Activity	Menu Item	Toolbar Button
RESQ	***File>Open…*** Select files of type "Sequence Data File (**.seq)"*	
TRSQ	Obsolete (replaced with Spreadsheet View)	OBSOLETE
SQLI	***Power Flow>List Data…*** Select "Sequence data"	

Activity	Menu Item	Toolbar Button
SQEX	***Power Flow>List Data…*** Select "Examine Power Flow / sequence data" and "Sequence data"	
SQCH	Obsolete (replaced with Spreadsheet View)	OBSOLETE
RWSQ	***File>Save or Show…*** Select tab "Sequence Data"	
SEQD	***Fault>Setup network for unbalanced solution (SEQD)…*** May also be performed from the SCMU and SPCB dialogs	
SCMU	***Fault>Solve and report network with unbalances (SCMU/SCOP)…***	
SCOP	***Fault>Unbalanced network tabular output (SCOP)…*** or ***Fault>Solve and report network with unbalances (SCMU/SCOP)…*** Select tab "Solution Output"	
ASCC	***Fault>Automatic sequence fault calculation (ASCC)…***	
ANSI	***Fault>ANSI fault calculation (ANSI)…***	n.a.
IECS	***Fault>IEC 60909 fault calculation (IECS)…***	
BKDY	***Fault>Circuit breaker interrupting duty (BKDY)…***	n.a.
SPCB	***Fault>Separate pole circuit breaker (SPCB)…***	n.a.
FLAT,IEC FLAT,CL	***Fault>Set up for special fault calculations (FLAT)…*** Select desired option	n.a.

A.11 Dynamics Data

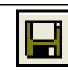
Activity	Menu Item	Toolbar Button
RSTR	***File>Open…*** Select files of type "Dynamics Snapshot Data File (**.snp)"*	
DYRE DYRE,ADD	***File>Open…*** Select files of type "Dynamics Model Raw Data File (**.dyr)"*	
SRRS	***File>Open…*** Select files of type "Dynamics Snapshot Raw Data File (**.srs)"*	
SNAP	***File>Save or Show…*** Select tab "Snapshot Data"	
DYDA	***File>Save or Show…*** Select tab "Dynamics Model Data"	
DMPC	***File>Save or Show…*** Select tab "Dump Output Channels"	
DOCU	***Dynamics>List>Models and data…***	

Activity	Menu Item	Toolbar Button
DLST	***Dynamics>List>Dynamics data…***	
MLST etc.	***Dynamics>List>Model storage locations…***	
DYCH	***Dynamics>Model maintenance…***	
ALTR	***Dynamics spreadsheet*** Select tab "Dynamics Data"	n.a.
CHAN	***Dynamics>Define simulation output…*** For Bus channels, select "Bus quantity"	
CHAN	***Dynamics>Define simulation output…*** For Line channels, select "Line quantity"	
CHAN	***Dynamics>Define simulation output…*** For Load channels, select "Load quantity"	
CHAN	***Dynamics>Define simulation output…*** For Machine channels, select "Machine quantity"	
CHAN	***Dynamics>Define simulation output…*** For Miscellaneous channels, select "Misc quantity"	n.a.
CHSB	***Dynamics>Define simulation output by subsystem…***	
Edit	All data editing functions are available in the Dynamics and Network spreadsheets.	n.a.

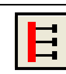
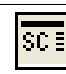
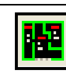
A.12 Dynamics Simulation

Activity	Menu Item	Toolbar Button
Simulation options	***Dynamics>Simulation>Simulation options…***	
STRT, RUN	***Dynamics>Simulation>Perform simulation…***	
MSTR, MRUN	***Dynamics>Simulation>Perform extended term simulation…***	
ESTR, ERUN	***Dynamics>Simulation>Perform exciter simulation…*** or ***Dynamics>Simulation>Perform exciter response ratio simulation…***	
GSTR, GRUN	***Dynamics>Simulation>Perform governor response simulation…***	
ASTR	***Dynamics>Build matrices for LSYSAN program…***	n.a.

A.13 External Interfaces

Activity	Menu Item	Toolbar Button
RWCM	***File>Save or Show…*** Select tab "IEEE Format Power Flow Data"	
BMAT	No longer exists	OBSOLETE

A.14 Graphical Output Activities

Activity	Menu Item	Toolbar Button
DRAW	***File>Import>DRAW file…*** Diagram View must be open	n.a.
GEXM GOUT	***Diagram>Generate graphical power flow bus display (GOUT/GEXM)…***	
GDIF	***Diagram>Results>Graphical difference data…***	
SCGR	***Diagram>Results>Fault analysis results…***	
GRPG	***Diagram>Generate graphical report (GRPG)…***	

A.15 Digitizing Activities

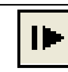
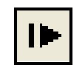
Activity	Menu Item	Toolbar Button
DRED	Obsolete (replaced with Diagram View)	OBSOLETE
GRED	Not supported in Revision 31.	n.a.

A.16 Linearized Network Analysis Activities

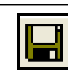
Activity	Menu Item	Toolbar Button
DCLF	***Power Flow>Linear Network>DC network solution and report (DCLF)…***	n.a.
RANK	***Power Flow>Linear Network>Single contingency ranking (RANK)…***	n.a.
DFAX	***Power Flow>Linear Network>Build distribution factor data file (DFAX)…***	n.a.
OTDF	***Power Flow>Linear Network>Calculate and print distribution factors (OTDF)…***	n.a.
DCCC	***Power Flow>Linear Network>DC contingency checking (DCCC)…***	n.a.
TLTG	***Power Flow>Linear Network>Transmission interchange limits calculation (TLTG)…***	n.a.
SPIL	***Power Flow>Linear Network>Sequential participation interchange limit (SPIL)…***	n.a.

Activity	Menu Item	Toolbar Button
POLY	***Power Flow>Linear Network>Interchange limits with two opposing systems (POLY)…***	n.a.
MWMI	***Power Flow>Linear Network>Midwest MW-mile calculation (MWMI)…***	n.a.

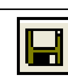
A.17 Load Flow User-Tailored Execution

Activity	Menu Item	Toolbar Button
PSEB	***I/O Control>Run program Automation file…*** Select files of type "PSEB Command File (*.pse)"	
EXEC	***I/O Control>Run program Automation file…*** Select files of type "IPLAN File (*.irf)"	
USER	Not supported in Revision 31.	OBSOLETE

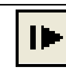
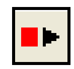
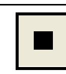
A.18 Transmission Pricing and Open Access Activities

Activity	Menu Item	Toolbar Button
REMM	***File>Open…*** Select files of type "Transactions Raw Data File (*.mwm)"	
REMM,CH	***Trans Access>Data…***	n.a.
RWMM	***File>Save or Show…*** Select tab "Transaction Data"	
ALOC	***Trans Access>Allocations*** or ***Trans Access>Summaries>Summary of branch mileage by owner***	n.a.
IMPC	***Trans Access>Calculators>Impact on monitored elements…***	n.a.
LLRF	***Trans Access>Calculators>Line loading relief by transaction adjustment…***	n.a.

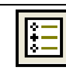
A.19 Optimal Power Flow Activities

Activity	Menu Item	Toolbar Button
ROPF	***File>Open…*** Select files of type "Optimal Power Flow Data File (*.rop)"	
LSTO	***Power Flow>List data…*** Select "OPF"	
NOPF	***OPF>Solve…***	
RWOP	***File>Save or Show…*** Select tab "Optimal Power Flow Data"	

A.20 I/O Control

Activity	Menu Item	Toolbar Button
IDEV,file	***I/O Control>Run program Automation file…*** Select files of type "Response file (*.idv)"	
ODEV	***I/O Control>Direct Prompt output…*** and ***I/O Control>Direct Alert output…***	n.a.
PDEV	***I/O Control>Direct Progress output (PDEV)…***	n.a.
OPEN CLOS	***I/O Control>Direct Report output (OPEN)…***	n.a.
ECHO	***I/O Control>Start recording…*** Select files of type "Response file (*.idv)"	
ECHO,OFF	***I/O Control>Stop recording***	

A.21 Miscellaneous

Activity	Menu Item	Toolbar Button
OPTN	***Misc>Change program settings (OPTN)…***	
SHOW	***File>File information (SIZE/SHOW/BUSN)…*** Select "List Save case and Snapshot titles"	n.a.
EDTR	***File>Case titles, short & long (CHTI)…***	n.a.
PATH	***I/O Control>Set path for use with "&" filenames (PATH)…***	n.a.
TIME	***Misc>Display timing statistics (TIME)***	n.a.
TIME,INIT	***Misc>Reset timeing statistics to zero (TIME,INIT)***	n.a.
TEXT	***Misc>Insert text into Progress stream (TEXT)***	n.a.
STOP	***File>Exit***	n.a.

Appendix B

Compatibility Issues

As PSS™E continues to evolve, one of our primary concerns is to ensure backward compatibility so that current studies can be transferred to the latest program release with minimum disruption. With each new release of PSS™E, users are usually required to generate a new set of working files. In addition, dynamic simulation users need to recompile their connection subroutines and user-written models, and relink them into the main body of PSS™E.

While the vast majority of program dialog remains unchanged, the introduction of new program features can affect the dialog. Accordingly, it is recommended that the first use in a new program release of *any* existing Response File or IPLAN program be monitored closely to ensure that it performs as intended.

The following sections discuss compatibility issues pertaining to the previous releases of PSS™E. Users upgrading from a release earlier than the one immediately preceding the current release are strongly encouraged to review the notes below pertaining to *all* intervening program releases.

B.1 PSS™E-30.0

B.1.1 General

With the exception of the Power Flow Raw Data File format and a few data input files in which buses may be specified using their extended bus names (see Chapter 3), there is complete compatibility between PSS™E-29 and PSS™E-30 at the data input file level. That is, any other binary or source data file which could be successfully accessed by PSS™E-29 should also be able to be read by PSS™E-30.

At PSS™E-30, provision is made for "calling" new sets of auxiliary-signal, dc line and FACTS device models from internal PSS™E tables; that is, the use of these models requires no calls in subroutines CONEC and/or CONET. Further, additional statements that were needed in CONEC to place the auxiliary-signal "VAR" into the dc line and FACTS device "other signal VAR", are no longer required. Nonetheless, a dynamics setup used in PSS™E-29 is able to be used in PSS™E-30 almost without any change. Dynamic simulation snapshot files from PSS™E-20 through PSS™E-29 can be read by PSS™E-30.

Other than the addition of the "USRAUX", "USRDCL", and "USRFCT" routines (see Section B.1.3), a dynamics setup used in PSS™E-29, PSS™E-28 or PSS™E-27 is able to be used in PSS™E-30 without change. The connection routines (CONEC, CONET, USRXXX, USRLOD and USRREL) and user-written models used in PSS™E-29, PSS™E-28 or PSS™E-27, along with the new USRAUX, USRDCL, and USRFCT routines, need only be recompiled.

The connection routines and user-written models used in PSS™E-26 also require the addition of the USRREL routine (see *Program Operation Manual*, Section D.5.4); the connection routines and user-written models used in PSS™E-25 also require the addition of the USRLOD routine (see *Program Operation Manual*, Section D.6.2); those used in PSS™E-20 through PSS™E-24 may require additional minor modifications (see *Program Operation Manual*, Section D.7.2). To access simulation setups from PSS™E-19 or earlier, see the PSS™E-20 update notes below. While a mid-run Snapshot File written by PSS™E-22 or earlier may be accessed with activity RSTR of PSS™E-30, it may not be used for the purpose of continuing the interrupted run; the entire simulation must be executed.

At PSS™E-30 the BMATRIX program section is no longer supplied.

At PSS™E-31 the MATLAB interface connection (PMSI) is no longer supported.

The majority of PSS™E-30 activities and functions are identical in dialog to PSS™E-29. Dialog changes that have occurred as a result of new program features are described below (new program features are summarized in Section B.1.6 and chapters in this *Users Manual*). Any Response Files and IPLAN programs used with PSS™E-29 that contain any of these line mode dialog streams and/or "BAT_" commands need to be modified before they can be used in PSS™E-30.

- In activities READ, RDCH and TREA, the switched shunt and FACTS device data record formats have been changed. Refer to Section B.1.2.
- In activities READ,NAME, RDCH,NAME and TREA,NAME, any extended bus names in the input stream must be converted so as to recognize the widening of bus names from 8 to 12 characters. Refer to Section B.1.2.
- In specifying buses with the bus input program option setting in its names mode, extended bus names must be converted so as to recognize the widening of bus names from 8 to 12 characters. Refer to Section B.1.2.
- In the BAT_SWITCHED_SHUNT_DATA command, the dimension of the REALAR array is increased from 11 to 12 in order to accommodate the new RMPCT data item. Refer to Section B.1.2, Chapter 3, and the manual *PSS™E Application Program Interface (API).*
- In the BAT_FACTS_DATA command, the dimension of the REALAR array is increased from 12 to 13 in order to accommodate the new RMPCT data item. Refer to Section B.1.2, Chapter 3, and the manual *PSS™E Application Program Interface (API).*
- In changing switched shunt data in activity CHNG, the new RMPCT data item is inserted between the controlled bus number and the VSC dc line name data items in numbers input mode, and between the present switched shunt admittance and the VSC dc line name data items in names input mode.
- In changing three-winding transformer data in activity CHNG, two additional groups of data, adjustment data for windings two and three, are presented for possible modification by the user. These appear before the final group of data, the ownership data.
- In executing activity DIFF in line mode, an additional prompt to specify the transformer ratio and angle thresholds is issued when the transformer difference check is selected. In the BAT_DIFF command, THRESH(2) and THRESH(3) are the ratio and angle thresholds, respectively, when APIOPT is 2 and STATUS(2) is 22. Refer to the manual *PSS™E Application Program Interface (API).*

- In the BAT_ECDI command, new APIOPT values are introduced. While the format of the command is unchanged, the number of consecutive references required is changed. Refer to the manual *PSS™E Application Program Interface (API).*
- In the BAT_DCLF command, the dimension of the STATUS array is increased from 3 to 4 in order to accommodate the user's specification of a continue/abort selection when the initial active power mismatch exceeds 0.5 MW. Refer to the manual *PSS™E Application Program Interface (API).*
- The graphical output of activity POLY is now available only in the new interface. In the BAT_POLY command, an additional data item to specify a Results output file is required. Refer to the manual *PSS™E Application Program Interface (API).*
- In the BAT_SEQ_TWO_WINDING_DATA command, the dimension of the REALAR array is increased from 4 to 6 in order to accommodate the new winding two side grounding impedance when the connection code is 8. Refer to Chapter 3 and the manual *PSS™E Application Program Interface (API).*
- In the BAT_SEQD command, the dimension of the OPTIONS array is reduced from 3 to 2; the old usage of the OPTIONS(1) entry is removed since there is no longer a double precision option (see Section B.1.6). Refer to *PSS™E Application Program Interface (API).*
- Similarly, in the BAT_SCMU command when APIOPT is 1, the first 2 rather than the first 3 elements of the OPTIONS array are used; the old usage of the OPTIONS(1) entry is removed since there is no longer a double precision option (see Section B.1.6). Refer to *PSS™E Application Program Interface (API).*
- The format of the ASCC Relay Output File has been modified as a result of the wider bus number and name fields. Results for winding faults of three-winding transformer windings are now included.
- In activities DOCU and DYDA, the numeric response codes in the model type selection prompt for CONEC models and CONET models (and CHAN models in activity DOCU) have each been increased by five. Corresponding changes have been made in the values used in the STATUS(3) value passed to the BAT_DOCU command and in the STATUS(2) value passed to the BAT_DYDA command.
- Four PSS™E option setting commands introduced at PSS™E-29 have had their names changed as follows: BAT_AREA_INTERCHANGE_CONTROL to
  BAT_CONTROL_AREA_INTERCHANGE; BAT_SIZE_LEVEL to
  BAT_BUS_SIZE_LEVEL; BAT_SAVE_OPTION_SETTINGS to
  BAT_WRITE_OPTIONS_FILE; and BAT_MULTISECTION_LINE_REPORTING to
  BAT_MULTISECTION_REPORTING.
- The following load flow data changing commands have had their names changed as follows: BAT_TWO_TERMINAL_DC_CONVERTER_DATA to
  BAT_TWO_TERM_DC_CONVR_DATA;
  BAT_VSC_DC_LINE_CONVERTER_DATA to
  BAT_VSC_DC_CONVERTER_DATA;
  BAT_MULTI_TERMINAL_DC_BUS_DATA to
  BAT_MULTI_TERM_DC_BUS_DATA;
  BAT_MULTI_TERMINAL_DC_CONVERTER_DATA to
  BAT_MULTI_TERM_DC_CONVR_DATA;
  BAT_MULTI_TERMINAL_DC_LINE_DATA to
  BAT_MULTI_TERM_DC_LINE_DATA;

and BAT_MULTI_TERMINAL_DC_LINK_DATA to BAT_MULTI_TERM_DC_LINK_DATA.

B.1.2 Power Flow Raw Data File and Other Input Files

The following are the changes to the Power Flow Raw Data File format:

- The switched shunt data record contains an additional data item. An RMPCT field is inserted between the SWREM and RMIDNT fields (see Chapter 3).
- The FACTS device data record contains an additional data item. An RMPCT field is inserted between the LINX and OWNER fields (see Chapter 3).
- The fourth and fifth records of the three-winding transformer data input block have been extended to accommodate adjustment data for the windings two and three (see Chapter 3). Their formats are identical to that of the third record which contains data that applies to winding one.

In addition, any Power Flow Raw Data File or any Response File containing power flow raw data input records in which extended bus names are specified (i.e., they require the "names" input option of activity READ, TREA or RDCH) need to have each extended bus name modified to reflect the increase in bus name width from 8 to 12 characters. That is, old extended bus names consisted of the 8 character bus name followed by up to 6 characters containing the bus base voltage; new extended bus names consist of the 12 character bus name followed by up to 6 characters containing the bus base voltage. Thus, old extended bus names are converted to new extended bus names by inserting four blanks between the old 8 character name and the base voltage field.

A format conversion program, CNV30, is supplied with PSS™E-30. It converts Power Flow Raw Data Files from the format required in PSS™E-29 to that required in PSS™E-30. CNV30 includes provision for expanding extended bus names to the form required by PSS™E-30.

Similarly, in using Response Files, IPLAN programs, and several data input files when the PSS™E bus input option is at its "names" setting, bus identifiers are either allowed or required to be specified as extended bus names. Data input files to which this applies include Dynamics Data Files used by activity DYRE, Linear Network Analysis Data File used by activities DFAX and RANK, Drawing Coordinate Data Files used by activities DRED, GDIF and SCGR, PSEB and PSAS Command Files used by activities PSEB and PSAS respectively, and Graphical Report Definition Files used by activity GRPG. Such input files may be brought up to the form required by PSS™E-30 by manually editing them to insert four blanks between the name and base voltage portions of any extended bus names.

Alternatively, PSS™E-30 includes provision for *temporarily* instructing the extended bus name search routine to accept as input the extended bus name form used at PSS™E-29 and earlier releases (eight character alphanumeric bus name plus up to six characters containing the bus base voltage), and then convert it to the PSS™E-30 form by inserting four blanks between the name and base voltage portions of the PSS™E-29 extended bus name. The extended bus name form flag may be placed in either the PSS™E-29 or PSS™E-30 setting by using:

- the BAT_REV29_NAMES batch command; or
- the ***Misc>Select extended bus name input format*** option

When PSS™E-30 is started up, the extended bus name form flag is always set to its standard PSS™E-30 setting. To use a Response File, IPLAN program, or one of the data input files listed above which uses the PSS™E-29 form of extended bus names, the following approach may be used:

- Place the extended bus name form flag in its PSS™E-29 setting by using the batch command or menu entry listed above.
- Execute the Response File, IPLAN program, or data input activity.
- Place the extended bus name form flag back in its PSS™E-30 setting by using the batch command or menu entry listed above. **Do not omit this step.**

This approach should always be successful for the processing of data input files. However, the execution of Response Files and IPLAN programs should be checked to verify that they behaved as intended.

B.1.3 Co-Existence with Previous Versions

At PSS™E Revision 30 the program SAV29 is not necessary. The PSS™E files have been renamed (e.g., psslf430.exe) to allow multiple versions of PSS™E to exist on any platform.

B.1.4 Simulation Model Library

The following new models are added to the simulation model library:

- GGOV1 – General purpose turbine-governor model developed by GE
- VSCDCT – VSC dc (HVDC Light) model

B.1.4.1 Table Driven Models

At PSS™E-30, new sets of models for dc line, FACTS device, and auxiliary-signal models have been developed which are called from internal PSS™E tables. This is similar to the approach used for plant-related, load related, and line relay models in that the use of these models do not require calls in subroutine CONEC and/or CONET. The new set of models supersedes the pre-PSS™E-30 set of CONEC and CONET models.

Each Dynamics Data Input File model data record referencing one of the old dc line, and FACTS device models is converted internally by activity DYRE to one of the corresponding new table-driven dc line and FACTS device models respectively. Activity DYRE notifies the user of each conversion that takes place. The new versions of these models do not require calls in CONEC and CONET; rather they are called from internal tables in the same manner that the other "table-ized" plant-related models are called.

The following table summarizes the conversion process:

Old Model	New Model
CDC1	CDC1T
CDC4	CDC4T
CDC6	CDC6T
CDC6A	CDC6TA
CDCAB1	CDCABT
CEELR2	CEEL2T
CEEL	CEELT

Old Model	New Model
MTDC01	MTDC1T
MTDC03	MTDC3T
CSTCON	CSTCNT

In all cases, there is a one-to-one correspondence between the CON data list for the old model and the new model to which it is converted. In all, except in the FACTS device model CSTCNT, the ICON list between the old model and the new model to which it is converted is modified. The old model set for CDC1, CDC4, CDC6, CDC6A, CDCAB1, CEELR2, CEEL, MTDC01, and MTDC03 contained ICON space for PSS™E internal memory. In the table-ized model, this has been removed from the ICON data list. Hence while using the corresponding new models CDC1T, CDC4T, CDC6T, CDC6TA, CDCABT, CEEL2T, CEELT, MTDC1T, and MTDC3T, the user need not input ICON data for memory.

Unlike in the case of dc lines and FACTS devices, each Dynamics Data Input File model data record referencing one of the old auxiliary-signal models is not converted internally by activity DYRE to the corresponding new table-driven model. The reason for this is that the auxiliary-signal models in the table-driven form require additional data to be input in the Dynamics Data Input File. Activity DYRE notifies the user to convert the old auxiliary-signal model name to the corresponding new model. The following table lists the correspondence between the old and new auxiliary-signal model names.

Old Model	New Model
CPPAUX	CPPAUT
DCVREF	DCVRFT
PAUX1	PAUX1T
PAUX2	PAUX2T
SQBAUX	SQBAUT
CHAAUX	CHAAUT
DCCAUX	DCCAUT
HVDCAU	HVDCAT
RBKELR	RBKELT

In all cases, there is a one-to-one correspondence between the CON data list for the old model and the new model to which it is converted. In all cases, except in RBKELR model, there is a one-to-one correspondence between the ICON data list for the old model and the new model to which it is converted. Model RBKELR contained ICON space for PSS™E internal memory. In the table-ized model, this has been removed from the ICON data list. Hence while using the corresponding new model RBKELT, the user need not input ICON data for memory.

At PSS™E-30, two options for handling dynamic simulation setups from PSS™E-29 which include calls in CONEC and/or CONET to any of the old dc line, FACTS device, or auxiliary-signal models listed above are available:

1. The old setup may be used. The only change required is the addition of the following codes to the bottom of the file containing the FLECS code of subroutine CONEC:

   ```
   SUBROUTINE USRAUX(IDVX, IDVT, ISGX, SLOT, IT)
   INTEGER IDVX, IDVT, ISGX, SLOT, IT
   SELECT (IT)
   (OTHERWISE) CALL UAALRM(IDVX, IDVT, ISGX,IT)
   FIN
   RETURN
   END
   SUBROUTINE USRDCL(IDC, SLOT, IT)
   INTEGER IDC, SLOT, IT
   SELECT (IT)
   (OTHERWISE) CALL UDALRM(IDC, IT)
   FIN
   RETURN
   END
   SUBROUTINE USRFCT(NF, SLOT, IT)
   INTEGER NF, SLOT, IT
   SELECT (IT)
   (OTHERWISE) CALL UFALRM(NF, IT)
   FIN
   RETURN
   END
   ```

   Then the modified CONEC file, the original CONET file, and any user-written models used in the simulation need to be recompiled, and PSS™E relinked. Using this approach, dynamic simulations are executed using the old auxiliary-signal, dc line and FACTS device models called from subroutines CONEC and CONET.

   The file conec.flx in the PSS™E "Example" subdirectory contains the default version of the USRAUX, USRDCL, and USRFCT subroutines as well as those of USRXXX, USRLOD and USRREL subroutines.

2. Proceed as if the old setup is to be used as above. Pick up the old Snapshot File and use activity DYDA to produce a Dynamics Data Input File, which will include data records for the models. There are two possible cases:

   - If the case does not have any old auxiliary-signal models, use activity DYRE to read the Dynamics Data Input File. If there are old dc line and FACTS device models, activity DYRE internally converts the old model data records to models from the new set.
   - If the case has old auxiliary-signal models, the auxiliary-signal model records in the Dynamics Data Input File created as a result of activity DYDA needs to be edited. If the old auxiliary-signal model is any one of the following: CPPAUX, DCVREF, PAUX1, PAUX2, CHAAUX, DCCAUX, or HVDCAU, the Dynamics Data Input File created as a result of activity DYDA would have the corresponding new model names, and would look as follows:

     ```
     **DevId    ' New Model Name'    **DevType     **AuxIndex     data
     items /
     ```

This has to be edited to specify the device index in place of "**DevId", the device type in place of "**DevType", and the auxiliary signal index (or the signal injection point) in place of "**AuxIndex".

If the old auxiliary-signal model is any one of the following: SQBAUX or RBKELR (these can be used only with two-terminal dc line models), the Dynamics Data Input File created as a result of activity DYDA would already have the device index, the device type (which is "1" for two-terminal dc lines), and the corresponding new model name. The only editing that would be needed is to specify the auxiliary signal index (or the signal injection point) in place of "**AuxIndex".

In addition to editing the data records corresponding to the auxiliary-signal models as described above, DYRE data records for user-written models of auxiliary-signals, dc lines and FACTS devices will have to be edited to use the corresponding new DYRE data categories ("USRAUX", "USRDCL", and "USRFCT" - this implies that user-written model codes for auxiliary-signals, dc lines, and FACTS devices need to be modified to ensure that model subroutine arguments are compatible with the model call arguments generated by PSS™E). Then use activity DYRE to read the Dynamics data Input File. If there are old dc line and FACTS device models, activity DYRE internally converts the old model data records to models from the new set.

Dynamics memory should then be preserved with activity SNAP, the new CONEC and CONET files recompiled, any user-written models used in the simulation recompiled, and PSS™E re-linked.

Siemens PTI recommends that the second procedure, or an equivalent variant thereof, eventually be employed. The old models are considered obsolete and will be removed from PSS™E at a future program release.

Multi-terminal dc line model "MTDC02" in pre-PSS™E-30 versions was not recognized by activity DYRE, and the call to this model had to be introduced manually in CONEC and CONET. At PSS™E-30, this model is called MTDC2T, and is a standard model that is recognized by activity DYRE. The new model does not require calls in CONEC and CONET; rather it is called from internal PSS™E tables.

B.1.4.2 User-Written Two-Machine Models

Any user-written cross-compound governor or other two-machine models need to be modified in the method used to unpack the machine indices from the MACNUM array. The machine index of the high pressure (or first) machine is unpacked via a statement such as:

```
K1=IBITS(MACNUM(ISLOT),0,16)
```

and the machine index of the low pressure (or second) machine is obtained via a statement such as:

```
K2=IBITS(MACNUM(ISLOT),16,16)
```

where IBITS is the FORTRAN intrinsic function for extracting consecutive bits from an integer variable, and ISLOT is the second argument of the model's SUBROUTINE statement (refer to the *Program Operation Manual*, Sections 9.4 and 9.6).

B.1.4.3 Optimal Power Flow

The following changes have been made to the PSS™E OPF at PSS™E-30:

- The CNVOPF auxiliary program is no longer supplied.
- The INTGAR and REALAR values in the following OPF BAT_ commands have been condensed and/or reordered for easier entry and consistency. Previous commands within Response files will need to be updated, or the Response file regenerated. Refer to the manual *PSS™E Application Program Interface (API)*.

  BAT_OPF_ADJBRX_INDV, BAT_OPF_ADJBRX_SUBSYS

  BAT_OPF_ADJVAR_INDV, BAT_OPF_ADJVAR_SUBSYS

  BAT_APDSP_TBL

  BAT_BRFLW_3WT_INDV, BAT_BRFLW_BRN_INDV

  BAT_BRFLW_SUBSYS

  BAT_BUS_INDV, BAT_BUS_SUBSYS

  BAT_GEN_RCAP_INDV, BAT_GEN_RCAP_SUBSYS

  BAT_GENDSP_INDV, BAT_GENDSP_SUBSYS

  BAT_INTFLW_MAIN

B.1.5 New Features

The following new features are added at PSS™E-30.0:

- PSS™E now allows six digit bus numbers (through 999997). In addition, bus, area, zone, owner, transformer, dc bus, and VSC dc line names have been increased from eight to twelve characters. As a result, all report formats have been modified, some drastically (for example, activities LIST and SQLI have additional data categories).
- Two additional control strategies for switched shunts have been implemented. Remote voltage control to a setpoint by switched shunts is now allowed. A switched shunt may be used to control the reactive power setting of another switched shunt (see Chapter 3.)
- Multiple setpoint mode voltage controlling devices (generation, switched shunts, VSC dc line converters, and the shunt elements at the sending end of FACTS devices) are allowed on the same bus and on buses connected by zero impedance lines. Similarly, different types of setpoint mode voltage controlling devices connected to the same or different buses may be controlling the same bus voltage.
- An RMPCT data item is now associated with switched shunts and FACTS devices.
- Any or all windings of three-winding transformers may be specified as being automatically adjusted during power flow solutions. In the area interchange control monitor of the power flow solution activities, slack bus active power limits are now listed. Further, if an old or new active power setting is outside of its active power limits, the active power is followed by an asterisk ("*").
- The AC Contingency Calculation solution (ACCC) now processes the SET, CHANGE, INCREASE, DECREASE, MOVE and ADD contingency events.

- In looking for non-converged contingency cases which are "close to" convergence, the AC Contingency Report function now applies the "Bus mismatch tolerance" and the "System mismatch tolerance" only to those contingency cases which were terminated by the non-divergent solution option or due to reaching the iteration limit. Those system conditions which converged in the AC Contingency Calculation function are always considered converged by the reporting function.
- In reporting two-winding transformers in activities POUT, LOUT and LAMP, the winding two tap ratio, rather than the winding one tap ratio and phase shift angle, is printed in the output block of the winding two bus (i.e., when the winding two bus is the "*from bus*"). That is, the tap settings reported are always those adjacent to the bus being reported.
- In activity DIFF, windings of three-winding transformers are included in the branch related checks. In the transformer check, the user may now specify difference thresholds for reporting ratio and angle differences.
- In activity BRCH, ratings are included in the output of the parallel transformer report.
- In the new interface, the Optimal Power Flow (OPF) is able to import an Economic Dispatch Data File, as used by activity ECDI, into the OPF cost curve data structure.
- The fault analysis activities SEQD, SCMU, ASCC, SCGR and SPCB now use double precision arithmetic for their fault calculations. These calculations are much faster than the old double precision option of activities ASCC, SCGR and SEQD,DP.
- The "flat" option of activities ASCC and SCGR no longer uses a matrix modification technique, which would occasionally fail, for calculating line out and line end faults.
- The Disturbance>Calculate and Apply Branch Unbalance option of the dynamic simulation activity selector calculates and applies a single branch unbalance. The unbalance calculation is identical to that of activity SPCB.
- The maximum bus dimensional capacity has been increased to 150,000 buses. The maximum number of areas, owners, and zones which may be represented has been increased to 1,200, 1,200, and 2,000, respectively (see Table 1-1).
- Two new auxiliary programs have been added: CNV30 converts a PSS™E-29 Raw Data File to a Raw Data File in the form required by PSS™E-30; RAW29 outputs a PSS™E Saved Case in PSS™E-29 Raw Data File form.
- The PSS™E interface routines for use in IPLAN programs include several new subroutines. The SWSDT1 subroutine returns floating point data of switched shunts. SC3WND may be used to access short circuit currents on three-winding transformer windings following a fault calculation by activity SCMU. AREUSE, ZONUSE and OWNUSE indicate if any equipment is assigned to a specified area, zone or owner, respectively. Further, several new STRING values are recognized by subroutines XFRDAT, DC2DAT, DCNDAT and FCDDAT. See the *IPLAN Program Manual*.
- New sets of models for dc line, FACTS device, and auxiliary-signal models have been developed which are called from internal PSS™E tables. This is similar to the approach used for plant-related, load related, and line relay models in that the use of these models do not require calls in subroutine CONEC and/or CONET. The new set of models supersedes the pre-PSS™E-30 set of CONEC and CONET models.
- Three new DYRE data record categories called "USRAUX", "USRDCL", and "USRFCT" have been introduced for user written models of auxiliary-signal models, dc line models and FACTS device models respectively.

- The following new models are added to the simulation model library:

  GGOV1 – General purpose turbine-governor model developed by GE

  VSCDCT – VSC dc (HVDC Light) model

  CIM6xx ('xx' could be BL/OW/ZN/AR/AL) – Induction motor model with motor starting capability (as in the existing CIM5xx load models), and also detailed load torque representation (as in the existing CIMWxx load models)

- Updates and new features of the Optimal Power Flow are described in the *PSS™E Optimal Power Flow (OPF) Manual*.

B.1.6 Program Corrections

The following program errors have been detected and corrected in PSS™E-30.0:

In moving a single machine (via the ***Edit>Changing>Move>Machine to another bus*** option or the BAT_MOVEMAC command) or load (via the ***Edit>Changing>Move>Load to another bus*** option or the BAT_MOVELOAD command) to another bus with a new identifier specified, the new identifier was ignored unless there already existed at least one machine (or load, as appropriate) at the destination bus.

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Appendix C

Start-up Commands

The following arguments can be specified on the command line when starting the program:

-buses	Used to specify startup size of PSS™E, 1K->150k.
-rspfile	Immediately run a Response file.
-pyfile	Immediately run a Python file.
-argstr	Specify arguments for automation files.
-embed	Run without display (until automation file terminates).
-inifile	Run program with alternative ini file.

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Appendix D

Line Mode Interpreter

The historic command line interface to PSS™E has been replaced with a modern, event-driven GUI. There exist many response files, representing many man-hours of development effort that use the command line "language", as well as IPLAN programs that also utilize it via the PUSH set of commands. An interpreter (LMI) has been developed to support these usages that read in sequences of the command line "language" and calls the appropriate PSS™E API routine - the same API routines that are called by the PSS™E GUI. This is desirable for recording and translation purposes, consistency of behavior, and quality of maintenance. Given this mode of operation the imitation cannot be perfect. This document attempts to capture and summarize the differences.

D.1 Differences in Behavior

D.1.1 General

1. Activities that are not permitted (i.e., optional purchase, activity selector, required data, etc.) will absorb all inputs, and produce errors only afterwards.

2. Some prompts are reorganized (very few).

3. Many warning or informative messages that would have appeared during the dialog will no longer be displayed, or will be displayed at the end of the dialog. In general, if a message presented information needed to respond to a prompt it was maintained; if it was strictly informational, it was not (although many are later produced by the API routines).

4. Many data errors that depended on values from the case that could short-circuit the activity dialog will no longer occur (the errors will still occur, but later in the dialog) (see some omitted activity data checks, below). In general, if data values could generate additional prompts, or modify the sequence of prompts, those checks are maintained; if the data values produced errors that simply aborted the activity, they were not (for exceptions, see differences in behavior: by activity, below).

5. Bus subsystems with multiple base kV ranges not supported (actually, this is a limitation of the entire interface).

6. Activities that output data files will have report or printer selections directed to progress window instead (actually, this is a limitation of the API design). Only file and terminal choices are presented. The LMI dialog will still absorb printer/copies/etc. inputs, even though those choices will not be presented in the initial menu.

7. Device selection menus no longer present the with or without page breaks alternative; use lines-per-page to control.

8. Next page dialog for report output is ignored. It compares to running the old interface with the CRT lines per page (OPTN option 23) set to the maximum.

9. Terminal input of data will not verify any values until all data is entered. Some prompts may then be repeated (as progress information).

10. Inputs that could accept certain characters or numeric input will not produce data type errors for other character inputs, but will be treated as zero (e.g., CHNG allows 'Q' for data change lines. Entering, say, 'x' will be treated as zero.)

11. Names input is allowed, but all APIs are called with bus numbers (means that if you record your input, you will see bus numbers, not names) (this is true of the entire interface). Quoted strings are allowed for bus names, which is a new feature, but within that string the length of the "name" portion of the extended name is still fixed.

12. Names input mode would generate extra input lines (i.e., the bus names would always be requested on a separate line from everything else). The interpreter simply accepts bus names instead of bus numbers when in names input mode.

D.1.2 By Activity

Other than the general differences cited in Section D.1.1.

1. MENU, HELP, DRED, and GRED will be ignored, except for HELP, NEW.

2. IDEV, EXEC will be recognized in response files and IPLAN programs only.

3. Immediate (@) commands will be recognized in response files and IPLAN programs only.

4. ECHO works as always, but this is misleading. What ECHO does and always did was to make a copy of all inputs received from the terminal, or standard input device. In the LMI implementation, the only such inputs are responses to prompts generated from IPLAN INPUT and INPUTLN calls, and the equivalent Python API calls.

5. PSAS and PSEB run only in CHECK mode when entered interactively; when used from a response file or an IPLAN program they can automatically invoke the created response file.

6. PSAS and PSEB HELP commands will not process until command input is terminated.

7. OPTN option for graphics device will not record.

8. EDTR will not record.

9. EXEC can no longer be abbreviated EXE.

10. SIZE and CATA output to the report device, not the progress device.

11. CATA and EDTR will not be recorded.

12. ODEV does not show its menu when redirected.

13. Entering * for CASE only works in old interface if entered on same line as CASE. In the LMI it can also be entered later; similarly for SAVE, SNAP, RSTR.

14. GOUT/GEXM will use line mode dialog for CRT display.

15. There is no support for binary coordinate data files.

16. DRAW options to plot by page (or Cycle Through All Pages option) or by bus are not supported (dialog will be absorbed).

17. All DRAW dialog subsequent to plot, other than device and options selections, are ignored (but absorbed). Line mode commands generated from the diagram are not recognized.

18. DRAW options are ignored, except for CHECK. However, the one-line drawing functions are philosophically different. In DRAW, drawing elements were required to match network elements, unless DRAW was run in ACCEPT mode, in which case the entire drawing was simply considered a picture, with no correspondence to the network case. The new one-line diagram allows for bound and unbound items on the diagram, and the coordinate data file input process attempts to bind what it can, and draws all remaining items as unbound.

19. DCLF/DCCC/RANK/TLTG/SPIL/MWMI will not ask the question "ENTER 0 TO EXIT, 1 TO CONTINUE" when the largest mismatch is greater than the MW mismatch tolerance on startup.

20. The "SS" option is assumed for ALOC.

21. CHNG will not print "new" (changed data) line.

22. TLTG/SPIL will ask for the study and opposing systems by label rather than by number; also it will always ask for these labels, even if the DFAX file has only 1 or 2 subsystems specified.

23. RDEQ/EQRD/SCEQ will ask whether to 'APPLY TRANSFORMER IMPEDANCE CORRECTION TO ZERO SEQUENCE' if any appropriate transformer exists in case, and prior to the subsystem selection dialog (line mode asked only after the first such transformer was selected for the subsystem).

24. EEQV will ask whether to 'SUPPRESS EQUIVALENCING OF PHASE SHIFTER' if any appropriate transformer exists in case, and prior to the subsystem selection dialog (line mode asked only after the first such transformer was selected for the subsystem).

25. LIST/SQLI by subsystem, the interpreter strictly presents the prompt:

    ```
    ENTER 0 TO EXIT, 1 FOR NEW DATA CATEGORY, 2 FOR NEW SUBSYSTEM:
    ```

    after each data category is listed.

26. MCRE permits 'Q' to end terminal data input.

27. SPLT presents loads, machines, and branches at a bus in ID order rather than in load order.

28. Block data records in terminal input mode will always generate prompts.

29. STRT always asks for an OUTPUT file, and skips asking for a snapshot file if errors are returned from the STRT API.

30. DYRE will not check whether the CONEC and CONET filenames are the same.

31. ALTR will reject an IPRINT value of zero.

Appendix E

Sample Data Files

E.1 SAVNW Case Data Input Files

SAVNW case comprises a simple power system network. It shows how to build a case in PSS™E and the kind of data input required to study load flow, fault analysis and dynamic behavior of power system network. A PSS™E File Planning Sheet is shown on the next page.

PSS™E File Planning Sheet

Name of Study: SAVNW Case from POM Chapter 8

Directory Name: C:\Program Files\PTI\PSSE31\Example
or
$INSTALLHOME$\PTI\PSSE31\Example

	Filename	Description
1.	**Power Flow Raw Data Files (input data, source)**	
a.	savnw.raw	PSS™E savnw case
b.		
2.	**Diagram Data Files (input data, source and/or binary)**	
a.	savnw.sld	Oneline diagram.
b.		
3.	**Dynamics Data Files (input data, source)**	
a.	savnw.dyr	GENROU, GENSAL, TGOV1, HYGOV, IEEET1,
b.		SCRX, SEXS
4.	**Load Flow Saved Case Files (saved case, binary)**	
a.	savnw.sav	
b.	savcnw.sav	All loads converted to 100% Constant I and B.
c.		All generators converted using ZSOURCE.
d.		
5.	**Simulation Snapshot Files (snapshot, binary)**	
a.	savnw.snp	
b.		
6.	**Sequence Data Files (input data, source)**	
a.	savnw.seq	
b.		
7.	**Optimal Power Flow Data Files (input data, source))**	
a.		
b.		
8.	**Other Auxiliary Files (input data, source)**	
a.	savnw.bkd	Generated using RWDY.
b.		
c.		
d.		
9.	**Linear Network Analysis Data Files (input data, source)**	
a.	savnw.sub	ACCC files
b.	savnw.mon	
c.	savnw.con	
d.		
10.	**Channel Output Files (output, binary)**	
a.	savnw.out	
b.		
11.	**CONEC and CONET Subroutine Files (FORTRAN, source)**	
a.	conec.flx	
b.	conet.flx	

```
0,   100.00          / PSS™E-30.0    FRI, JUL 16 2004  11:17
PSS™E PROGRAM APPLICATION GUIDE EXAMPLE
BASE CASE INCLUDING SEQUENCE DATA
   101,'NUC-A       ',  21.6000,2,     0.000,     0.000,   1,  77,1.02000,  16.5466,  11
   102,'NUC-B       ',  21.6000,2,     0.000,     0.000,   1,  77,1.02000,  16.5466,  11
   151,'NUCPANT     ', 500.0000,1,     0.000,  -600.000,   1,   1,1.01190,  10.8887,   1
   152,'MID500      ', 500.0000,1,     0.000,     0.000,   1,   1,1.01707,  -1.1152,   1
   153,'MID230      ', 230.0000,1,     0.000,     0.000,   1,   1,0.99300,  -3.2357,   1
   154,'DOWNTN      ', 230.0000,1,     0.000,   300.000,   1,   1,0.93892,  -9.8857,   1
   201,'HYDRO       ', 500.0000,1,     0.000,   300.000,   2,   2,1.04000,   6.1599,  22
   202,'EAST500     ', 500.0000,1,     0.000,     0.000,   2,   2,1.00879,  -1.3172,   2
   203,'EAST230     ', 230.0000,1,     0.000,    50.000,   2,   2,0.96651,  -6.9180,   2
   204,'SUB500      ', 500.0000,1,     0.000,     0.000,   2,   2,0.97873,  -3.7331,   2
   205,'SUB230      ', 230.0000,1,     0.000,   300.000,   2,   2,0.94902,  -9.1798,   2
   206,'URBGEN      ',  18.0000,2,     0.000,     0.000,   2,   2,1.02361,  -2.9699,  22
   211,'HYDRO_G     ',  20.0000,2,     0.000,     0.000,   2,   2,1.04045,  12.9201,  22
  3001,'MINE        ', 230.0000,1,     0.000,     0.000,   5,   5,1.02979,  -1.3728,  55
  3002,'E. MINE     ', 500.0000,1,     0.000,     0.000,   5,   5,1.02791,  -1.8253,   5
  3003,'S. MINE     ', 230.0000,1,     0.000,     0.000,   5,   5,1.02332,  -2.2538,   5
  3004,'WEST        ', 500.0000,1,     0.000,     0.000,   5,   5,1.01647,  -3.4289,   5
  3005,'WEST        ', 230.0000,1,     0.000,     0.000,   5,   5,0.99478,  -5.1800,   5
  3006,'UPTOWN      ', 230.0000,1,     0.000,     0.000,   5,   5,0.99404,  -3.7922,   5
  3007,'RURAL       ', 230.0000,1,     0.000,     0.000,   5,   5,0.96370,  -8.5380,   5
  3008,'CATDOG      ', 230.0000,1,     0.000,     0.000,   5,   5,0.95861,  -9.0489,  55
  3011,'MINE_G      ',  13.8000,3,     0.000,     0.000,   5,   5,1.04000,   0.0000,  55
  3018,'CATDOG_G    ',  13.8000,2,     0.000,     0.000,   5,   5,1.02177,  -4.0804,  55
0 / END OF BUS DATA, BEGIN LOAD DATA
   153,'1 ',1,   1,   1,   200.000,   100.000,     0.000,     0.000,     0.000,     0.000,   1
   154,'1 ',1,   2,   1,   600.000,   450.000,     0.000,     0.000,     0.000,     0.000,   1
   154,'2 ',1,   2,   1,   400.000,   350.000,     0.000,     0.000,     0.000,     0.000, 100
   203,'1 ',1,   2,   2,   300.000,   150.000,     0.000,     0.000,     0.000,     0.000,   2
   205,'1 ',1,   2,   2,  1200.000,   700.000,     0.000,     0.000,     0.000,     0.000,   2
  3005,'1 ',1,   5,   5,   100.000,    50.000,     0.000,     0.000,     0.000,     0.000,   5
  3007,'1 ',1,   5,   5,   200.000,    75.000,     0.000,     0.000,     0.000,     0.000,   5
  3008,'1 ',1,   5,   5,   200.000,    75.000,     0.000,     0.000,     0.000,     0.000,   5
0 / END OF LOAD DATA, BEGIN GENERATOR DATA
   101,'1 ',   750.000,    81.194,   600.000,  -100.000,1.02000,     0,   900.000,   0.01000,   0.30000,   0.00000,   0.00000,1.00000,1,  100.0,   810.000,     0.000,  11,0.6667,   1,0.3333
   102,'1 ',   750.000,    81.194,   600.000,  -100.000,1.02000,     0,   900.000,   0.01000,   0.30000,   0.00000,   0.00000,1.00000,1,  100.0,   810.000,     0.000,  11,0.6667,   1,0.3333
   206,'1 ',   800.000,   600.000,   600.000,     0.000,0.98000,   205,  1000.000,   0.01000,   0.25000,   0.00000,   0.00000,1.00000,1,  100.0,   900.000,     0.000,   2,0.4000,  22,0.6000
   211,'1 ',   600.000,    17.750,   400.000,  -100.000,1.04000,   201,   725.000,   0.01000,   0.26000,   0.00000,   0.00000,1.00000,1,  100.0,   616.250,     0.000,   2,0.4000,  22,0.6000
  3011,'1 ',   258.656,   104.043,   600.000,  -100.000,1.04000,     0,  1000.000,   0.01000,   0.35000,   0.00000,   0.00000,1.00000,1,  100.0,   900.000,     0.000,  55,0.3846,   5,0.3077,  22,0.2308,  11,0.0769
  3018,'1 ',   100.000,    80.000,    80.000,     0.000,1.02000,  3008,   130.000,   0.01000,   0.35000,   0.00000,   0.00000,1.00000,1,  100.0,   117.000,     0.000,  55,0.5556,   5,0.4444
0 / END OF GENERATOR DATA, BEGIN BRANCH DATA
   151,    152,'1 ',   0.00260,   0.04600,   3.50000, 1200.00, 1300.00,    1.00,  0.00000,  0.00000,  0.00000,  0.00000,1,   0.00,   1,1.0000
   151,    152,'2 ',   0.00260,   0.04600,   3.50000, 1200.00, 1300.00,    1.00,  0.00000,  0.00000,  0.00000,  0.00000,1,   0.00,   1,1.0000
   151,    201,'1 ',   0.00100,   0.01500,   1.20000, 1200.00, 1300.00,    1.00,  0.00000,  0.00000,  0.00000,  0.00000,1,   0.00,   1,1.0000
   152,   -202,'1 ',   0.00080,   0.01000,   0.95000, 1200.00, 1300.00,    1.00,  0.00000,  0.00000,  0.00000,  0.00000,1,   0.00,   1,1.0000
   152,   3004,'1 ',   0.00300,   0.03000,   2.50000,    0.00,    0.00,    1.00,  0.00000,  0.00000,  0.00000,  0.00000,1,   0.00,   1,1.0000
   153,    154,'1 ',   0.00500,   0.04500,   0.10000,  300.00,  350.00,    1.00,  0.00000,  0.00000,  0.00000,  0.00000,1,   0.00,   1,0.7500, 100,0.2500
   153,    154,'2 ',   0.00600,   0.05400,   0.15000,  300.00,  350.00,    1.00,  0.00000,  0.00000,  0.00000,  0.00000,1,   0.00,   1,1.0000
   153,   3006,'1 ',   0.00100,   0.01200,   0.03000,    0.00,    0.00,    1.00,  0.00000,  0.00000,  0.00000,  0.00000,1,   0.00,   1,1.0000
   154,    203,'1 ',   0.00400,   0.04000,   0.10000,  200.00,  250.00,    1.00,  0.00000,  0.00000,  0.00000,  0.00000,1,   0.00,   1,1.0000
   154,    205,'1 ',   0.00033,   0.00333,   0.09000,  600.00,  660.00,    1.00,  0.00000,  0.00000,  0.00000,  0.00000,1,   0.00,   1,1.0000
   154,   3008,'1 ',   0.00270,   0.02200,   0.30000,  400.00,  440.00,    1.00,  0.00000,  0.00000,  0.00000,  0.00000,1,   0.00,   1,1.0000
   201,    202,'1 ',   0.00200,   0.02500,   2.00000, 1200.00, 1300.00,    1.00,  0.00000,  0.00000,  0.00000,  0.00000,1,   0.00,  22,1.0000
   201,    204,'1 ',   0.00300,   0.03000,   2.50000, 1200.00, 1300.00,    1.00,  0.00000,  0.00000,  0.00000,  0.00000,1,   0.00,  22,1.0000
   203,   -205,'1 ',   0.00500,   0.04500,   0.08000,  200.00,  250.00,    1.00,  0.00000,  0.00000,  0.00000,  0.00000,1,   0.00,   2,1.0000
   203,   -205,'2 ',   0.00500,   0.04500,   0.08000,  200.00,  250.00,    1.00,  0.00000,  0.00000,  0.00000,  0.00000,1,   0.00,   2,1.0000
  3001,   3003,'1 ',   0.00000,   0.00800,   0.00000,    0.00,    0.00,    1.00,  0.00000,  0.00000,  0.00000,  0.00000,1,   0.00,  55,1.0000
  3002,   3004,'1 ',   0.00600,   0.05400,   0.09000,    0.00,    0.00,    1.00,  0.00000,  0.00000,  0.00000,  0.00000,1,   0.00,   5,1.0000
  3003,   3005,'1 ',   0.00600,   0.05400,   0.09000,    0.00,    0.00,    1.00,  0.00000,  0.00000,  0.00000,  0.00000,1,   0.00,   5,1.0000
  3003,   3005,'2 ',   0.00600,   0.05400,   0.09000,    0.00,    0.00,    1.00,  0.00000,  0.00000,  0.00000,  0.00000,1,   0.00,   5,1.0000
  3005,   3006,'1 ',   0.00350,   0.03000,   0.07000,    0.00,    0.00,    1.00,  0.00000,  0.00000,  0.00000,  0.00000,1,   0.00,   5,1.0000
  3005,   3007,'1 ',   0.00300,   0.02500,   0.06000,    0.00,    0.00,    1.00,  0.00000,  0.00000,  0.00000,  0.00000,1,   0.00,   5,1.0000
  3005,   3008,'1 ',   0.00600,   0.05000,   0.12000,    0.00,    0.00,    1.00,  0.00000,  0.00000,  0.00000,  0.00000,1,   0.00,   5,1.0000
  3007,   3008,'1 ',   0.00300,   0.02500,   0.06000,    0.00,    0.00,    1.00,  0.00000,  0.00000,  0.00000,  0.00000,1,   0.00,   5,1.0000
```

Figure E-1. SAVNW Load Flow Raw Data File savnw.raw (1 of 2 Sheets)

```
0 / END OF BRANCH DATA, BEGIN TRANSFORMER DATA
   151,   101,     0,'1 ',1,1,1,   0.00000,   0.00000,2,'            ',1,   1,1.0000
   0.00030,   0.01360,  100.00
1.00000,   0.000,   0.000, 1250.00, 1350.00, 1750.00, 0,      0, 1.10000, 0.90000, 1.10000, 0.90000,   5, 0, 0.00000, 0.00000
1.00000,   0.000
   151,   102,     0,'1 ',1,1,1,   0.00000,   0.00000,2,'            ',1,   1,1.0000
   0.00030,   0.01360,  100.00
1.00000,   0.000,   0.000, 1250.00, 1350.00, 1750.00, 0,      0, 1.10000, 0.90000, 1.10000, 0.90000,   5, 0, 0.00000, 0.00000
1.00000,   0.000
   152,   153,     0,'1 ',1,1,1,   0.00000,   0.00000,2,'            ',1,   1,1.0000
   0.00000,   0.00500,  100.00
1.01000,   0.000,   0.000, 2500.00, 3000.00, 3500.00, 1,    154, 1.05000, 0.95000, 1.00000, 0.98000,  33, 0, 0.00000, 0.00000
1.00000,   0.000
   201,   211,     0,'1 ',1,1,1,   0.00000,   0.00000,2,'            ',1,  22,1.0000
   0.00070,   0.02125,  100.00
1.00000,   0.000,   0.000,  800.00, 1000.00, 1120.00, 0,    201, 1.10000, 0.90000, 1.05000, 0.95000,   5, 0, 0.00000, 0.00000
1.00000,   0.000
   202,   203,     0,'1 ',1,1,1,   0.00000,   0.00000,2,'            ',1,   2,1.0000
   0.00040,   0.01625,  100.00
1.00000,   0.000,   0.000,  800.00, 1040.00, 1200.00, 3,      0,30.00000,-30.0000,555.0000,545.0000,  33, 0, 0.00000, 0.00000
1.00000,   0.000
   204,   205,     0,'1 ',1,1,1,   0.00000,   0.00000,2,'            ',1,   2,1.0000
   0.00030,   0.01500,  100.00
1.00000,   0.000,   0.000,  800.00, 1040.00, 1200.00, 1,    205, 1.05000, 0.95000, 1.00000, 0.98000,  33, 0, 0.00000, 0.00000
1.00000,   0.000
   205,   206,     0,'1 ',1,1,1,   0.00000,   0.00000,2,'            ',1,   2,1.0000
   0.00026,   0.01333,  100.00
1.00000,   0.000,   0.000,  900.00, 1080.00, 1350.00, 0,      0, 1.10000, 0.90000, 1.10000, 0.90000,   5, 0, 0.00000, 0.00000
1.00000,   0.000
  3001,  3002,     0,'1 ',1,1,1,   0.00000,   0.00000,1,'            ',1,  55,1.0000
   0.00030,   0.01500,  100.00
1.00000,   0.000,   0.000,  800.00, 1040.00, 1200.00, 0,      0, 1.10000, 0.90000, 1.05000, 0.95000,  33, 0, 0.00000, 0.00000
1.00000,   0.000
  3001,  3011,     0,'1 ',1,1,1,   0.00000,   0.00000,2,'            ',1,  55,1.0000
   0.00020,   0.01000,  100.00
1.00000,   0.000,   0.000, 1300.00, 1560.00, 1820.00, 0,      0, 1.10000, 0.90000, 1.05000, 0.95000,   5, 0, 0.00000, 0.00000
1.00000,   0.000
  3004,  3005,     0,'1 ',1,1,1,   0.00000,   0.00000,1,'            ',1,   5,1.0000
   0.00040,   0.01625,  100.00
1.00000,   0.000,   0.000,  800.00, 1040.00, 1200.00, 0,      0, 1.10000, 0.90000, 1.05000, 0.95000,  33, 0, 0.00000, 0.00000
1.00000,   0.000
  3008,  3018,     0,'1 ',1,1,1,   0.00000,   0.00000,2,'            ',1,  55,1.0000
   0.00021,   0.08500,  100.00
1.00000,   0.000,   0.000,  150.00,  200.00,  250.00, 0,      0, 1.10000, 0.90000, 1.05000, 0.95000,   5, 0, 0.00000, 0.00000
1.00000,   0.000
0 / END OF TRANSFORMER DATA, BEGIN AREA DATA
   1,   101,   250.000,    10.000,'FLAPCO      '
   2,   206,  -100.000,    10.000,'LIGHTCO     '
   5,  3011,  -150.000,    10.000,'WORLD       '
0 / END OF AREA DATA, BEGIN TWO-TERMINAL DC DATA
0 / END OF TWO-TERMINAL DC DATA, BEGIN VSC DC LINE DATA
0 / END OF VSC DC LINE DATA, BEGIN SWITCHED SHUNT DATA
0 / END OF SWITCHED SHUNT DATA, BEGIN IMPEDANCE CORRECTION DATA
0 / END OF IMPEDANCE CORRECTION DATA, BEGIN MULTI-TERMINAL DC DATA
0 / END OF MULTI-TERMINAL DC DATA, BEGIN MULTI-SECTION LINE DATA
   201,    205,'&1',   204
  3005,  -3008,'&1',  3007
0 / END OF MULTI-SECTION LINE DATA, BEGIN ZONE DATA
   1,'FIRST       '
   2,'SECOND      '
   5,'FIFTH       '
  77,'PLANT       '
0 / END OF ZONE DATA, BEGIN INTER-AREA TRANSFER DATA
   1,   2,'A',    70.00
   1,   2,'B',    30.00
   1,   5,'A',   100.00
   1,   5,'B',    50.00
0 / END OF INTER-AREA TRANSFER DATA, BEGIN OWNER DATA
   1,'TRAN 1      '
   2,'TRAN 2      '
   5,'TRAN 5      '
  11,'GEN 1       '
  22,'GEN 2       '
  55,'GEN 5       '
 100,'NO BUSES    '
0 / END OF OWNER DATA, BEGIN FACTS DEVICE DATA
0 / END OF FACTS DEVICE DATA
```

Figure E-1 (Cont). SAVNW Load Flow Raw Data File savnw.raw (2 of 2 Sheets)

```
0          / PSS™E-30.0    FRI, JUL 16 2004  11:17
   101,'1 ',     0.01000,     0.60000
   102,'1 ',     0.01000,     0.60000
   206,'1 ',     0.01000,     0.50000
   211,'1 ',     0.01000,     0.40000
  3011,'1 ',     0.01000,     0.70000
  3018,'1 ',     0.01000,     0.70000
0  / END OF POSITIVE SEQ. MACHINE IMPEDANCE DATA, BEGIN NEGATIVE SEQ. MACHINE DATA
   101,'1 ',     0.01000,     0.60000
   102,'1 ',     0.01000,     0.60000
   206,'1 ',     0.01000,     0.50000
   211,'1 ',     0.01000,     0.40000
  3011,'1 ',     0.01000,     0.70000
  3018,'1 ',     0.01000,     0.70000
0  / END OF NEGATIVE SEQ. MACHINE IMPEDANCE DATA, BEGIN ZERO SEQ. MACHINE DATA
   101,'1 ',  8000.00000,     0.60000
   102,'1 ',  8000.00000,     0.60000
   206,'1 ', 12000.00000,     0.50000
   211,'1 ',  7000.00000,     0.40000
  3011,'1 ', 14000.00000,     0.70000
  3018,'1 ',  2000.00000,     0.70000
0  / END OF ZERO SEQ. MACHINE IMPEDANCE DATA, BEGIN NEGATIVE SEQ. SHUNT DATA
0  / END OF NEGATIVE SEQ. SHUNT DATA, BEGIN ZERO SEQ. SHUNT DATA
0  / END OF ZERO SEQ. SHUNT DATA, BEGIN ZERO SEQ. NON-TRANSFORMER BRANCH DATA
   151,   152,'1 ',    0.00700,    0.12000,    7.00000,  0.00000,  0.00000,  0.00000,  0.00000
   151,   152,'2 ',    0.00700,    0.12000,    7.00000,  0.00000,  0.00000,  0.00000,  0.00000
   151,   201,'1 ',    0.00300,    0.04500,    3.60000,  0.00000,  0.00000,  0.00000,  0.00000
   152,   202,'1 ',    0.00250,    0.03000,    1.80000,  0.00000,  0.00000,  0.00000,  0.00000
   152,  3004,'1 ',    0.00800,    0.08000,    5.00000,  0.00000,  0.00000,  0.00000,  0.00000
   153,   154,'1 ',    0.01500,    0.13000,    0.20000,  0.00000,  0.00000,  0.00000,  0.00000
   153,   154,'2 ',    0.01800,    0.16000,    0.30000,  0.00000,  0.00000,  0.00000,  0.00000
   153,  3006,'1 ',    0.00300,    0.03500,    0.05000,  0.00000,  0.00000,  0.00000,  0.00000
   154,   203,'1 ',    0.01000,    0.10000,    0.20000,  0.00000,  0.00000,  0.00000,  0.00000
   154,   205,'1 ',    0.00100,    0.01000,    0.20000,  0.00000,  0.00000,  0.00000,  0.00000
   154,  3008,'1 ',    0.00800,    0.06500,    0.60000,  0.00000,  0.00000,  0.00000,  0.00000
   201,   202,'1 ',    0.00500,    0.07000,    4.00000,  0.00000,  0.00000,  0.00000,  0.00000
   201,   204,'1 ',    0.00800,    0.08000,    5.00000,  0.00000,  0.00000,  0.00000,  0.00000
   203,   205,'1 ',    0.01500,    0.13000,    0.15000,  0.00000,  0.00000,  0.00000,  0.00000
   203,   205,'2 ',    0.01500,    0.13000,    0.15000,  0.00000,  0.00000,  0.00000,  0.00000
  3001,  3003,'1 ',    0.00000,    0.00800,    0.00000,  0.00000,  0.00000,  0.00000,  0.00000
  3002,  3004,'1 ',    0.01600,    0.16000,    0.20000,  0.00000,  0.00000,  0.00000,  0.00000
  3003,  3005,'1 ',    0.01600,    0.16000,    0.20000,  0.00000,  0.00000,  0.00000,  0.00000
  3003,  3005,'2 ',    0.01600,    0.16000,    0.20000,  0.00000,  0.00000,  0.00000,  0.00000
  3005,  3006,'1 ',    0.00800,    0.08000,    0.15000,  0.00000,  0.00000,  0.00000,  0.00000
  3005,  3007,'1 ',    0.00700,    0.07500,    0.12000,  0.00000,  0.00000,  0.00000,  0.00000
  3005,  3008,'1 ',    0.01400,    0.15000,    0.24000,  0.00000,  0.00000,  0.00000,  0.00000
  3007,  3008,'1 ',    0.00700,    0.07000,    0.12000,  0.00000,  0.00000,  0.00000,  0.00000
0  / END OF ZERO SEQ. NON-TRANSFORMER BRANCH DATA, BEGIN ZERO SEQ. MUTUAL DATA
   151,   152,'1 ',   151,   152,'2 ',   0.00200,   0.02000, 0.00000, 1.00000, 0.00000, 1.00000
   153,   154,'1 ',   153,   154,'2 ',   0.00300,   0.02500, 0.00000, 1.00000, 0.00000, 1.00000
   203,   205,'1 ',   203,   205,'2 ',   0.00200,   0.02000, 0.00000, 1.00000, 0.00000, 1.00000
  3003,  3005,'1 ',  3003,  3005,'2 ',   0.00250,   0.02500, 0.00000, 1.00000, 0.00000, 1.00000
   154,   203,'1 ',   203,   205,'1 ',  -0.00100,  -0.01000, 0.70000, 1.00000, 0.00000, 0.35000
   154,   203,'1 ',   203,   205,'2 ',  -0.00100,  -0.01000, 0.70000, 1.00000, 0.00000, 0.35000
0  / END OF ZERO SEQ. MUTUAL DATA, BEGIN ZERO SEQ. TRANSFORMER DATA
   101,   151,     0,'1 ',  2,    0.00000,    0.00000,    0.00030,    0.01360
   102,   151,     0,'1 ',  2,    0.00000,    0.00000,    0.00030,    0.01360
   152,   153,     0,'1 ',  1,    0.00000,    0.00000,    0.00000,    0.00500
   201,   211,     0,'1 ',  2,    0.00000,    0.00000,    0.00070,    0.02130
   202,   203,     0,'1 ',  1,    0.00000,    0.00000,    0.00040,    0.01630
   204,   205,     0,'1 ',  1,    0.00000,    0.00000,    0.00030,    0.01500
   205,   206,     0,'1 ',  2,    0.00000,    0.00000,    0.00030,    0.01330
  3001,  3002,     0,'1 ',  1,    0.00000,    0.00000,    0.00030,    0.01500
  3001,  3011,     0,'1 ',  2,    0.00000,    0.00000,    0.00020,    0.01000
  3004,  3005,     0,'1 ',  1,    0.00000,    0.00000,    0.00040,    0.01630
  3008,  3018,     0,'1 ',  2,    0.00000,    0.00000,    0.00020,    0.08500
0  / END OF ZERO SEQ. TRANSFORMER DATA, BEGIN ZERO SEQ. SWITCHED SHUNT DATA
0  / END OF ZERO SEQ. SWITCHED SHUNT DATA
```

Figure E-2. SAVNW Sequence Data File savnw.seq

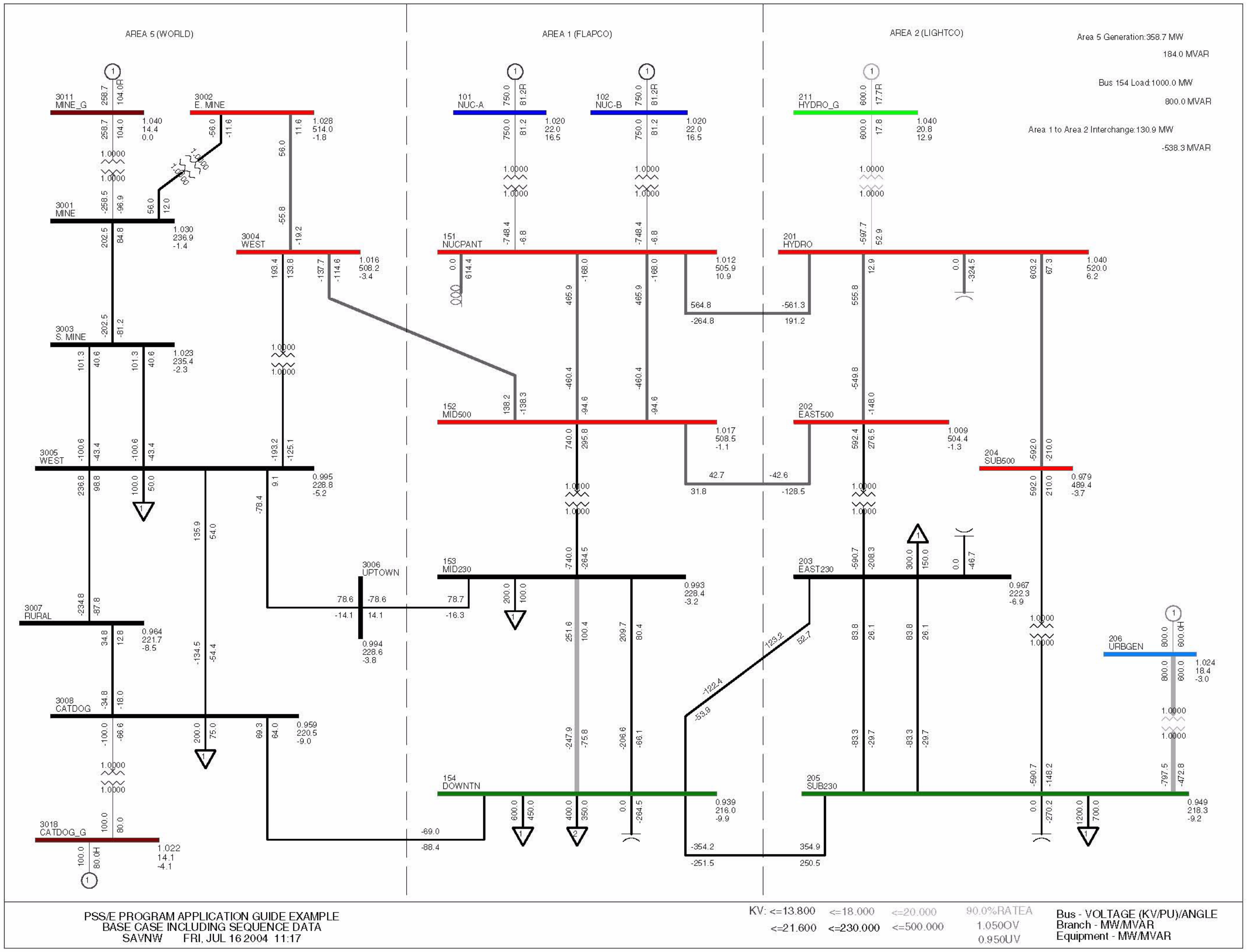

Figure E-3. SAVNW Slider Diagram File savnw.sld

```
 101 1 6.5 0.06 0.20 0.050 1.80 1.75 0.60 0.80 0.30 /GENROU
 102 1 6.5 0.06 0.20 0.050 1.80 1.75 0.60 0.80 0.30 /GENROU
 206 1 4.5 0.07 0.15 0.050 1.40 1.35 0.50 0.70 0.25 /GENROU
 211 1 5.0 0.05  0.0 0.200 1.00 0.75 0.40 0.00 0.26 /GENSAL
3011 1 5.0 0.06 0.20 0.060 1.60 1.55 0.70 0.85 0.35 /GENROU
3018 1 5.0 0.06 0.20 0.060 1.60 1.55 0.70 0.85 0.35 /GENROU
0
```

Figure E-4. SAVNW Breaker Duty Data File savnw.bkd

```
  101 'GENROU'  1      6.5000      0.60000E-01  0.20000      0.50000E-01
        4.0000      0.0000      1.8000       1.7500       0.60000
       0.80000     0.30000     0.15000      0.90000E-01  0.38000     /
  101 'IEEET1'  1      0.0000      400.00      0.40000E-01   7.3000
       -7.3000      1.0000     0.80000      0.30000E-01   1.0000
        0.0000      2.4700     0.35000E-01   4.5000      0.47000     /
  101 'TGOV1'   1   0.50000E-01  0.50000E-01   1.0500      0.30000
        1.0000      1.0000      0.0000    /
  102 'GENROU'  1      6.5000      0.60000E-01  0.20000      0.50000E-01
        4.0000      0.0000      1.8000       1.7500       0.60000
       0.80000     0.30000     0.15000      0.90000E-01  0.38000     /
  102 'IEEET1'  1      0.0000      400.00      0.40000E-01   7.3000
       -7.3000      1.0000     0.80000      0.30000E-01   1.0000
        0.0000      2.4700     0.35000E-01   4.5000      0.47000     /
  102 'TGOV1'   1   0.50000E-01  0.50000E-01   1.0500      0.30000
        1.0000      1.0000      0.0000    /
  206 'GENROU'  1      4.5000      0.70000E-01  0.15000      0.50000E-01
        2.5000      0.0000      1.4000       1.3500       0.50000
       0.70000     0.25000     0.10000      0.90000E-01  0.38000     /
  206 'IEEET1'  1      0.0000      40.000      0.60000E-01   2.1000
       -2.1000      0.0000     0.50000      0.80000E-01  0.80000
        0.0000      2.4700     0.35000E-01   3.5000      0.60000     /
  206 'TGOV1'   1   0.50000E-01  0.50000E-01   0.9000      0.30000
        3.0000      9.0000      0.0000    /
  211 'GENSAL'  1      5.0000      0.50000E-01  0.20000       5.0000
        0.0000      1.0000     0.75000      0.40000      0.26000
       0.10000     0.11000     0.62000    /
  211 'SCRX'    1   0.10000      10.000       200.00      0.50000E-01
       -5.0000      5.0000      1.0000       10.000    /
  211 'HYGOV'   1   0.50000E-01  0.30000       5.0000      0.50000E-01
       0.50000     0.20000      1.0000       0.0000       1.2500
        1.2000     0.50000     0.80000E-01/
 3011 'GENROU'  1      5.0000      0.60000E-01  0.20000      0.60000E-01
        3.0000      0.0000      1.6000       1.5500      0.70000
       0.85000     0.35000     0.20000      0.90000E-01  0.38000     /
 3011 'SEXS'    1   0.10000      10.000       100.00      0.10000
        0.0000      4.0000    /
 3018 'GENROU'  1      5.0000      0.60000E-01  0.20000      0.60000E-01
        3.0000      0.0000      1.6000       1.5500      0.70000
       0.85000     0.35000     0.20000      0.90000E-01  0.38000     /
 3018 'SEXS'    1   0.10000      10.000       100.00      0.10000
        0.0000      4.0000    /
```

Figure E-5. SAVNW Dynamics Data File savnw.dyr

E.2 SAMPLE Case Data Input Files

Sample case shows the capabilities of PSS™E in modelling of various power system components. It depicts all power system components that can be modelled in PSS™E.

```
0,   100.00          / PSS™E-30.0    FRI, JUN 04 2004  17:30
PSS™E-30 SAMPLE CASE
ALL DATA CATEGORIES WITH SEQUENCE DATA
   101,'NUC-A       ',  21.6000,2,     0.000,     0.000,   1,   1,1.01000, -10.8648,   1
   102,'NUC-B       ',  21.6000,2,     0.000,     0.000,   1,   1,1.01000, -11.2168,   1
   151,'NUCPLNT     ', 500.0000,1,    11.120,  -600.000,   1,   1,1.00217, -14.0048,   1
   152,'MID500      ', 500.0000,1,     1.630,    50.000,   1,   2,1.04364, -23.8464,   1
   153,'MID230      ', 230.0000,1,     0.000,     0.000,   1,   3,1.05683, -25.5912,   1
   154,'DOWNTN      ', 230.0000,1,     2.450,   200.000,   1,   3,0.99173, -33.0040,   1
   155,'FACTS TE    ', 230.0000,1,     0.000,     0.000,   1,   4,1.01710, -24.1507,   1
   201,'HYDRO       ', 500.0000,1,     3.670,  -500.000,   2,   7,0.98998, -19.1700,   2
   202,'EAST500     ', 500.0000,1,     0.000,     0.000,   2,   2,1.02100, -26.1103,   2
   203,'EAST230     ', 230.0000,1,     0.000,    50.000,   2,   8,1.00000, -29.5852,   2
   204,'SUB500      ', 500.0000,1,     0.000,     0.000,   2,   8,1.03022, -31.3855,   2
   205,'SUB230      ', 230.0000,1,     2.780,   300.000,   2,   8,1.00000, -33.6890,   2
   206,'URBGEN      ',  18.0000,2,     0.000,     0.000,   2,   8,1.00000, -31.2341,   2
   207,'DUPONT      ', 500.0000,1,     0.000,     0.000,   2,   7,1.01388, -25.4541,   2
   211,'HYDRO_G     ',  20.0000,2,     0.000,     0.000,   2,   7,1.00000, -14.5144,   2
   212,'INVERT1     ', 230.0000,1,     5.130,   400.000,   2,   7,1.02695, -32.0655,   2
   213,'INVERT2     ', 230.0000,1,     5.140,   400.000,   2,   7,1.10677, -35.3311,   2
   214,'LOADER      ', 230.0000,1,     0.000,     0.000,   2,   7,1.07726, -36.7610,   2
   215,'URBANEAST1  ',  18.0000,1,     0.000,     0.000,   2,   8,0.98539, -33.6275,   2
   216,'URBANEAST1  ', 230.0000,1,     0.000,     0.000,   2,   8,0.99637, -33.6660,   2
   217,'URBANEAST1  ', 230.0000,1,     0.000,     0.000,   2,   8,0.99733, -33.6721,   2
   218,'URBANEAST1  ', 230.0000,1,     0.000,     0.000,   2,   8,0.99769, -33.6743,   2
   301,'NORTH       ', 765.0000,3,     0.000,     0.000,   3,   5,1.00000,   0.0000,   3
   401,'COGEN-1     ', 500.0000,3,     0.000,     0.000,   4,   9,1.00000,   0.0000,   4
   402,'COGEN-2     ', 500.0000,3,     0.000,     0.000,   6,   9,1.00000,   0.0000,   4
  3001,'MINE        ', 230.0000,1,     0.000,     0.000,   5,   6,1.02324,  -4.0850,   5
  3002,'E. MINE     ', 500.0000,1,     0.000,     0.000,   5,   6,0.99915,  -2.4001,   5
  3003,'S. MINE     ', 230.0000,1,     0.000,     0.000,   5,   6,1.01851,  -7.5681,   5
  3004,'WEST        ', 500.0000,1,     0.000,     0.000,   5,   6,1.01416, -18.5345,   5
  3005,'WEST        ', 230.0000,1,     0.000,     0.000,   5,   2,1.00500, -19.5401,   5
  3006,'UPTOWN      ', 230.0000,1,     0.000,     0.000,   5,   4,1.05683, -25.5912,   5
  3007,'RURAL       ', 230.0000,1,     0.000,     0.000,   5,   4,0.98409, -23.8203,   5
  3008,'CATDOG      ', 230.0000,1,     0.000,     0.000,   5,   4,0.99000, -25.3430,   5
  3009,'URBANWEST1  ', 230.0000,1,     0.000,     0.000,   5,   4,0.99048, -25.3626,   5
  3010,'URBANWEST2  ',  21.6000,1,     0.000,     0.000,   5,   4,0.96664,   1.6733,   5
  3011,'MINE_G      ',  19.4000,3,     0.000,     0.000,   5,   6,1.00000,   0.0000,   5
  3018,'CATDOG_G    ',  13.8000,2,     0.000,     0.000,   5,   4,0.99000, -21.5731,   5
  3021,'WDUM        ',  18.0000,1,     0.000,  1320.000,   3,   5,1.00000, -20.3546,   3
  3022,'EDUM        ',  18.0000,1,     0.000,  1080.000,   3,   5,1.00000, -19.6655,   3
0 / END OF BUS DATA, BEGIN LOAD DATA
   152,'1 ',1,   1,   1,  1200.000,   360.000,   868.340,   360.502,   837.794,  -351.338,   1
   153,'1 ',1,   1,   1,   200.000,   100.000,     0.000,     0.000,     0.000,     0.000,   1
   154,'1 ',1,   1,   1,   400.000,   200.000,     0.000,     0.000,     0.000,     0.000,   1
   154,'2 ',1,   1,   1,   250.000,   200.000,     0.000,     0.000,     0.000,     0.000,   1
   154,'3 ',1,   1,   1,   250.000,   100.000,     0.000,     0.000,     0.000,     0.000,   1
   154,'MO',1,   1,   1,   100.000,    80.000,     0.000,     0.000,     0.000,     0.000,   1
   203,'1 ',1,   2,   2,   500.000,   250.000,     0.000,     0.000,     0.000,     0.000,   2
   205,'1 ',1,   2,   2,  1800.000,   600.000,     0.000,     0.000,     0.000,     0.000,   2
   205,'B ',1,   2,   2,    90.000,     5.000,   110.000,    25.000,    20.000,    10.000,   2
   205,'C ',1,   2,   2,    60.000,    15.000,    45.000,     5.000,    35.000,    30.000,   2
   214,'1 ',1,   2,   2,   500.000,    75.000,     0.000,     0.000,     0.000,     0.000,   2
   215,'U1',1,   2,   4,     0.000,   140.000,     0.000,     0.000,     0.000,     0.000,   2
   216,'U1',1,   2,   4,     0.000,    12.000,     0.000,     0.000,     0.000,     0.000,   2
   217,'U1',1,   2,   4,     0.000,    10.000,     0.000,     0.000,     0.000,     0.000,   2
   218,'U1',1,   2,   4,     0.000,     9.000,     0.000,     0.000,     0.000,     0.000,   2
  3005,'1 ',1,   5,   5,   100.000,    50.000,     0.000,     0.000,     0.000,     0.000,   5
  3007,'1 ',1,   5,   5,   200.000,    75.000,     0.000,     0.000,     0.000,     0.000,   5
  3008,'1 ',1,   5,   5,   200.000,    75.000,     0.000,     0.000,     0.000,     0.000,   5
  3009,'1 ',1,   5,   4,     1.100,     0.900,     0.000,     0.000,     0.000,     0.000,   5
  3010,'1 ',1,   5,   4,    12.000,     5.000,     0.000,     0.000,     0.000,     0.000,   5
0 / END OF LOAD DATA, BEGIN GENERATOR DATA
```

Figure E-6. SAMPLE Load Flow Raw Data File sample.raw (1 of 4 Sheets)

```
   101,'1 ',   750.000,   104.978,   400.000,  -100.000,1.01000,     0,   900.000,   0.01000,   0.30000,   0.00000,   0.00000,1.00000,1,  100.0,   800.000,    50.000,   1,0.1289,   2,0.2524,   3,0.1031,   4,0.5156
   102,'1 ',   650.000,   112.745,   410.000,  -110.000,1.01000,     0,   950.000,   0.01050,   0.32000,   0.00000,   0.00000,1.00000,1,  100.0,   700.000,    33.000,   1,0.3647,   2,0.1838,   3,0.0751,   4,0.3764
   206,'1 ',   800.000,   283.913,   500.000,  -400.000,1.00000,     0,  1000.000,   0.01060,   0.25100,   0.00000,   0.00000,1.00000,1,  100.0,   850.000,    50.000,   1,0.1034,   2,0.4006,   3,0.0825,   4,0.4135
   211,'1 ',   600.000,    87.292,   510.000,  -100.000,1.00000,     0,   725.000,   0.01080,   0.26200,   0.00000,   0.00000,1.00000,1,  100.0,   616.000,    30.000,   1,0.1423,   2,0.2210,   3,0.1842,   4,0.4525
   301,'1 ',   996.883,   299.543,   700.000,  -650.000,1.00000,     0,  1067.000,   0.01090,   0.23000,   0.01400,   0.12600,1.02500,1,   98.0,  1010.000,   320.000,   1,0.1118,   2,0.2184,   3,0.0893,   4,0.5805
   301,'2 ',   996.883,   299.543,   710.000,  -600.000,1.00000,     0,  1070.000,   0.01100,   0.24000,   0.01100,   0.12700,1.02600,1,   98.0,  1011.000,   321.000,   1,0.1173,   2,0.3200,   3,0.0936,   4,0.4691
   301,'3 ',   996.883,   299.543,   720.000,  -600.000,1.00000,     0,  1075.000,   0.00800,   0.25000,   0.01200,   0.12800,1.02700,1,   98.0,  1012.000,   322.000,   1,0.1260,   2,0.2268,   3,0.1827,   4,0.4644
   401,'1 ',   321.000,   142.325,   600.000,  -100.000,1.00000,     0,   600.000,   0.01230,   0.22230,   0.00000,   0.00000,1.00000,1,   90.0,   350.000,    25.000,   1,0.1625,   2,0.2423,   3,0.0990,   4,0.4962
   402,'1 ',   321.000,   142.325,   610.000,  -110.000,1.00000,     0,   610.000,   0.00450,   0.24320,   0.00000,   0.00000,1.00000,1,   91.0,   351.000,    26.000,   1,0.1588,   2,0.2117,   3,0.1959,   4,0.4335
  3011,'1 ',  1316.962,   148.216,   620.000,  -120.000,1.00000,     0,  1050.000,   0.00760,   0.35430,   0.00000,   0.00000,1.00000,1,   92.0,  1400.000,   100.000,   1,0.1452,   2,0.1926,   3,0.2677,   4,0.3945
  3018,'1 ',   400.000,    -0.628,   300.000,  -150.000,0.99000,     0,   530.000,   0.08700,   0.35630,   0.00000,   0.00000,1.00000,1,   92.5,   500.000,    50.000,   1,0.1043,   2,0.2037,   3,0.2749,   4,0.4171
  3018,'2 ',   100.000,    -0.157,    75.000,   -75.000,0.99000,     0,   120.000,   0.02400,   0.35530,   0.00000,   0.00000,1.00000,1,   92.5,   110.000,    20.000,   1,0.3003,   2,0.1358,   3,0.2857,   4,0.2782
0 / END OF GENERATOR DATA, BEGIN BRANCH DATA
   151,   -152,'1 ',   0.00260,   0.04600,   3.50000, 1200.00, 1100.00, 1000.00,  0.01000, -0.25000,  0.01100, -0.15000,1, 150.00,   1,0.2000,   2,0.3000,   3,0.4000,   4,0.1000
   151,   -152,'2 ',   0.00261,   0.04610,   3.51000, 1205.00, 1105.00, 1005.00,  0.01300, -0.25100,  0.01200, -0.02000,1, 149.00,   5,0.2315,   1,0.3056,   2,0.3704,   3,0.0926
   151,   -201,'1 ',   0.00100,   0.01500,   1.20000, 1206.00, 1106.00, 1006.00,  0.00000,  0.00000,  0.00000, -1.00000,1, 100.00,   2,0.3600,   3,0.2400,   4,0.3200,   5,0.0800
   152,    202,'1 ',   0.00080,   0.01000,   0.95000, 1207.00, 1107.00, 1007.00,  0.00000,  0.00000,  0.00000,  0.00000,1, 200.00,   1,0.3939,   2,0.2273,   3,0.3030,   4,0.0758
   152,  -3004,'1 ',   0.00300,   0.03000,   2.50000,    0.00,    0.00,    0.00,  0.00000,  0.00000,  0.00000,  0.00000,1, 201.00,   5,0.2379,   1,0.3033,   2,0.3667,   3,0.0922
   153,   -154,'2 ',   0.00600,   0.05400,   0.15000,  350.00,    0.00,    0.00,  0.00000,  0.00000,  0.00000,  0.00000,1,  80.00,   2,0.2727,   3,0.2727,   4,0.3636,   5,0.0909
   153,  -3006,'1 ',   0.00000,   0.00010,   0.00000,    0.00,    0.00,    0.00,  0.00000,  0.00000,  0.00000,  0.00000,1,   0.00,   1,0.3443,   2,0.2459,   3,0.3279,   4,0.0820
   154,    155,'1 ',   0.00500,   0.04500,   0.10000,  400.00,    0.00,    0.00,  0.00000,  0.00000,  0.00000,  0.00000,1,  81.00,   5,0.1914,   1,0.2535,   2,0.3065,   3,0.2486
   154,   -203,'1 ',   0.00400,   0.04000,   0.10000,  400.00,    0.00,    0.00,  0.00000,  0.00000,  0.00000,  0.00000,1, 100.00,   2,0.2000,   3,0.3000,   4,0.4000,   5,0.1000
   154,   -205,'1 ',   0.00033,   0.00333,   0.09000,  600.00,    0.00,    0.00,  0.00000,  0.00000,  0.00000,  0.00000,1, 120.00,   1,0.1667,   2,0.2500,   3,0.3333,   4,0.2500
   154,  -3008,'1 ',   0.00270,   0.02200,   0.30000,  800.00,    0.00,    0.00,  0.00000,  0.00000,  0.00000,  0.00000,1, 119.00,   5,0.1925,   1,0.2550,   2,0.3083,   3,0.2442
   201,   -202,'1 ',   0.00200,   0.02500,   2.00000, 1200.00,    0.00,    0.00,  0.00000,  0.00000,  0.00000,  0.00000,1, 300.00,   2,0.1905,   3,0.2857,   4,0.3810,   5,0.1429
   201,   -207,'C1',   0.00150,   0.01500,   1.25000, 1200.00,    0.00,    0.00,  0.00000,  0.00000,  0.00000,  0.00000,1, 250.00,   1,0.2500,   2,0.3750,   3,0.2500,   4,0.1250
   203,    205,'1 ',   0.00500,   0.04500,   0.08000,  200.00,    0.00,    0.00,  0.00000,  0.00000,  0.00000,  0.00000,1,  70.00,   5,0.1925,   1,0.2550,   2,0.3083,   3,0.2442
   204,   -207,'C2',   0.00150,   0.01500,   1.25000, 1200.00,    0.00,    0.00,  0.00000,  0.00000,  0.00000,  0.00000,1, 300.00,   2,0.2000,   3,0.3000,   4,0.4000,   5,0.1000
   205,    212,'1 ',   0.00000,   0.01000,   0.00000, 1250.00,    0.00,    0.00,  0.00000,  0.00000,  0.00000,  0.00000,1,  71.00,   1,0.2000,   2,0.3000,   3,0.4000,   4,0.1000
   205,   -214,'2 ',   0.00200,   0.02500,   2.00000, 1200.00,    0.00,    0.00,  0.00000,  0.00000,  0.00000,  0.00000,1, 100.00,   5,0.2100,   1,0.2782,   2,0.3364,   3,0.1755
   205,   -216,'3 ',   0.00500,   0.04500,   0.08000,  200.00,    0.00,    0.00,  0.00000,  0.00000,  0.00000,  0.00000,1,  81.00,   2,0.1818,   3,0.2727,   4,0.3636,   5,0.1818
   205,   -217,'4 ',   0.00500,   0.04500,   0.08000,  200.00,    0.00,    0.00,  0.00000,  0.00000,  0.00000,  0.00000,1,  80.00,   1,0.1667,   2,0.2500,   3,0.3333,   4,0.2500
   205,   -218,'5 ',   0.00500,   0.04500,   0.08000,  200.00,    0.00,    0.00,  0.00000,  0.00000,  0.00000,  0.00000,1,  59.00,   5,0.1650,   1,0.2186,   2,0.2643,   3,0.3521
   213,   -214,'1 ',   0.00000,   0.01000,   0.00000, 1250.00,    0.00,    0.00,  0.00000,  0.00000,  0.00000,  0.00000,1,   0.50,   2,0.1429,   3,0.2143,   4,0.2857,   5,0.3571
  3001,  -3003,'1 ',   0.00000,   0.00800,   0.00000,    0.00,    0.00,    0.00,  0.00000,  0.00000,  0.00000,  0.00000,1,  70.00,   1,0.1639,   2,0.2459,   3,0.3279,   4,0.2623
  3002,  -3004,'1 ',   0.00600,   0.05400,   0.09000,    0.00,    0.00,    0.00,  0.00000,  0.00000,  0.00000,  0.00000,1, 200.00,   5,0.1925,   1,0.2550,   2,0.3083,   3,0.2442
  3003,  -3005,'1 ',   0.00600,   0.05400,   0.09000,    0.00,    0.00,    0.00,  0.00000,  0.00000,  0.00000,  0.00000,1,  90.00,   2,0.2000,   3,0.3000,   4,0.4000,   5,0.1000
  3003,  -3005,'2 ',   0.00600,   0.05400,   0.09000,    0.00,    0.00,    0.00,  0.00000,  0.00000,  0.00000,  0.00000,1,  90.00,   1,0.1333,   2,0.2000,   3,0.2667,   4,0.4000
  3005,  -3006,'1 ',   0.00350,   0.03000,   0.07000,    0.00,    0.00,    0.00,  0.00000,  0.00000,  0.00000,  0.00000,1,  70.00,   5,0.1650,   1,0.2186,   2,0.2643,   3,0.3521
  3005,  -3007,'1 ',   0.00300,   0.02500,   0.06000,    0.00,    0.00,    0.00,  0.00000,  0.00000,  0.00000,  0.00000,1,  80.00,   2,0.1527,   3,0.2290,   4,0.3053,   5,0.3130
  3005,  -3008,'1 ',   0.00600,   0.05000,   0.12000,    0.00,    0.00,    0.00,  0.00000,  0.00000,  0.00000,  0.00000,0,  60.00,   1,0.1802,   2,0.2703,   3,0.3604,   4,0.1892
  3007,  -3008,'1 ',   0.00300,   0.02500,   0.06000,    0.00,    0.00,    0.00,  0.00000,  0.00000,  0.00000,  0.00000,1,  60.00,   5,0.1858,   1,0.2462,   2,0.4023,   3,0.1657
  3008,  -3009,'1 ',   0.00300,   0.02500,   0.06000,   25.00,   22.00,   18.00,  0.00000,  0.00000,  0.00000,  0.00000,1,  60.00,   1,0.1797,   2,0.2695,   3,0.3594,   4,0.1914
0 / END OF BRANCH DATA, BEGIN TRANSFORMER DATA
   101,   151,     0,'T1',2,2,1,   0.17147,   0.10288,2,'NUCA GSU    ',1,   1,0.3200,   2,0.3900,   3,0.1400,   4,0.1500
   0.00110,   0.09100, 1200.00
21.6000,  21.600,   0.000, 1200.00, 1100.00, 1000.00, 1,    101,22.68000,20.52000, 1.05000, 0.95000,  25, 0, 0.00021, 0.00051
500.000, 500.000
   102,   151,     0,'T2',2,1,2,    453750,   0.00260,2,'NUCB GSU    ',1,   1,0.2100,   2,0.2500,   3,0.2200,   4,0.3200
   0.00012,   0.00760, 1210.00
21.6000,  21.600,   0.000, 1210.00, 1125.00, 1025.00, 1,    102,22.57200,20.62800, 1.04500, 0.95500,  27, 0, 0.00022, 0.00052
500.000, 500.000
   152,   153,     0,'T3',2,1,1,   0.00021,   0.00012,2,'MID LTC     ',1,   1,0.3500,   2,0.2200,   3,0.2500,   4,0.1800
   0.00017,   0.00775,  800.00
475.000, 500.000,   0.000,  800.00,  750.00,  700.00, 1,    154,525.0000,475.0000, 1.00000, 0.98000,  10, 0, 0.00023, 0.00053
230.000, 230.000
   152,  3021,     0,'T4',1,2,2,    562500,   0.00280,2,'WDUM DC     ',1,   1,0.3900,   2,0.3200,   3,0.1500,   4,0.1400
   0.00130,   0.06300, 1500.00
1.10000, 500.000,   0.000, 1500.00, 1400.00, 1350.00, 4,      0,22.57200,20.62800, 1.10000, 0.90000,  33, 2, 0.00000, 0.00000
1.00000,  18.000
   152,  3022,     0,'T5',1,2,1,   0.00040,   0.00021,2,'EDUM DC     ',1,   1,0.2200,   2,0.2500,   3,0.2100,   4,0.3200
   0.00170,   0.07400, 1510.00
1.10000, 500.000,   0.000, 1510.00, 1410.00, 1393.00, 4,      0, 1.10000, 0.90000, 1.10000, 0.90000,  33, 0, 0.00000, 0.00000
1.00000,  18.000
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Figure E-6 (Cont). SAMPLE Load Flow Raw Data File sample.raw (2 of 4 Sheets)

```
   201,   211,     0,'T6',2,1,2,    262500,   0.00300,2,'HYDRO_G XMER',1,   1,0.1400,   2,0.1500,   3,0.3200,   4,0.3900
   0.00026,   0.01343,  700.00
500.000, 500.000,   0.000,  700.00,  650.00,  611.00, 0,      0, 1.10000, 0.90000, 1.10000, 0.90000,   5, 0, 0.00000, 0.00000
20.0000,  20.000
   203,   202,     0,'T7',1,2,1,   0.00095,   0.00046,1,'EAST PS     ',1,   1,0.2754,   2,0.3261,   3,0.2899,   4,0.1087
   0.00210,   0.05400,  750.00
0.99000, 230.000,   0.143,  750.00,  700.00,  657.00, 3,      0,12.00000,-11.0000,-900.000,-950.000,  33, 1, 0.00000, 0.00000
1.00000, 500.000
   204,   205,     0,'T8',1,2,1,   0.00113,   0.00052,2,'SUB LTC     ',1,   1,0.3019,   2,0.4245,   3,0.1321,   4,0.1415
   0.00370,   0.04500,  800.00
1.03667, 500.000,   0.000,  800.00,  775.00,  717.00, 1,    205, 1.05000, 0.95000, 1.00000, 0.98000,  16, 0, 0.00024, 0.00054
1.00000, 230.000
   205,   206,     0,'T9',1,2,1,   0.00113,   0.00052,2,'URB TX      ',1,   1,0.1905,   2,0.4643,   3,0.1667,   4,0.1786
   0.00160,   0.04800,  900.00
1.01591, 230.000,   0.000,  900.00,  850.00,  799.00, 2,      0, 1.05000, 0.97500,-175.000,-250.000,  12, 0, 0.00000, 0.00000
1.00000,  18.000
   205,   215,   216,'3 ',1,2,2,     34200,   0.00228,2,'3WNDSTAT3   ',3,   2,0.2540,   2,0.1746,   3,0.3333,   4,0.2381
   0.00103,   0.10000,  150.00,   0.00138,   0.12000,   20.00,   0.00068,   0.07500,   15.00,1.02605, -33.7608
1.00000, 230.000,   0.000,  150.00,  130.00,  120.00,-1,    215, 1.10000, 0.90000, 1.10000, 0.90000,  33, 0, 0.00025, 0.00064
1.10000,  18.000,   0.000,   20.00,   18.00,   15.00,-2,      0, 1.20000, 0.90120,150.0000,80.00000,  33, 0, 0.00012, 0.00046
1.00000, 230.000,   0.000,   15.00,   13.00,   10.00, 0,      0, 1.10000, 0.90000, 1.10000, 0.90000,  33, 0, 0.00000, 0.00000
   205,   217,   218,'4 ',2,3,2,      6840,   0.00163,2,'3WNDSTAT4   ',4,   2,0.4671,   2,0.1250,   3,0.2379,   4,0.1700
    228000,   0.10001,   30.00,    190000,   0.09000,   25.00,    266000,   0.07500,   35.00,0.99757, -33.6734
230.000, 230.000,   0.000,   30.00,   20.00,   10.00, 0,      0, 1.10000, 0.90000, 1.10000, 0.90000,  33, 0, 0.00031, 0.00784
230.000, 230.000,   0.000,   25.00,   18.00,   12.00,-1,    217,253.0000,207.0000,20.90000,18.88000,  33, 0, 0.00021, 0.00862
230.000, 230.000,   0.000,   35.00,   26.00,   14.00, 0,      0, 1.10000, 0.90000, 1.10000, 0.90000,  33, 0, 0.00024, 0.00394
  3002,  3001,  3011,'1 ',1,1,1,   0.00120,   0.00420,2,'3WNDSTAT1   ',1,   1,0.1238,   2,0.2477,   3,0.1548,   5,0.4737
   0.00020,   0.02500, 1000.00,   0.00030,   0.01000, 1000.00,   0.00040,   0.01100, 1000.00,0.99014,   1.5613
1.01010, 500.000,   0.000, 1200.00, 1150.00, 1090.00, 1,   3002, 1.10020, 0.92000, 1.16000, 0.93000,  33, 0, 0.00013, 0.00016
1.05000, 230.000,   0.000, 1250.00, 1175.00, 1112.00, 0,      0, 1.10010, 0.90000, 1.14000, 0.91000,  22, 0, 0.00012, 0.00015
1.01000,  19.400,   0.000, 1280.00, 1200.00, 1157.00, 0,      0, 1.10000, 0.91000, 1.10000, 0.92000,  11, 0, 0.00011, 0.00014
  3005,  3004,     0,'10',1,1,2,    206250,   0.00340,1,'WEST TX     ',1,   1,0.2645,   2,0.4959,   3,0.1157,   4,0.1240
   0.00035,   0.00964,  550.00
1.00000, 230.000,   0.000,  550.00,  500.00,  455.00, 0,      0, 1.10000, 0.90000, 1.10000, 0.90000,   3, 0, 0.00000, 0.00000
1.00000, 500.000
  3008,  3018,     0,'11',2,1,2,    196875,   0.00350,2,'CATDOG_XMER ',1,   1,0.2051,   2,0.2500,   3,0.4487,   4,0.0962
   0.00044,   0.01276,  525.00
230.000, 230.000,   0.000,  525.00,  475.00,  423.00, 0,      0, 1.10000, 0.90000, 1.10000, 0.90000,  22, 2, 0.00000, 0.00000
13.8000,  13.800
  3008,  3009,  3010,'2 ',2,1,1,   0.00021,   0.00012,1,'3WNDSTAT2   ',2,   5,0.8000,   3,0.0500,   2,0.1000,   1,0.0500
   0.00515,   0.50000,   20.00,   0.00920,   0.80000,   15.00,   0.00375,   0.41667,   25.00,0.98665, -25.7544
230.000, 230.000,   0.000,   20.00,   18.00,   14.00, 0,      0, 1.10000, 0.90000, 1.10000, 0.90000,  33, 0, 0.00000, 0.00000
230.000, 230.000,   0.000,   15.00,   13.00,    9.00, 0,      0, 1.10000, 0.90000, 1.10000, 0.90000,  33, 0, 0.00000, 0.00000
21.6000,  21.600,  30.000,   25.00,   19.00,   16.00, 0,      0, 1.10000, 0.90000, 1.10000, 0.90000,  33, 0, 0.00000, 0.00000
0 / END OF TRANSFORMER DATA, BEGIN AREA DATA
   1,   101, -2800.000,    10.000,'CENTRAL     '
   2,   206, -1600.000,    10.000,'EAST        '
   3,   301,  2900.000,    55.000,'CENTRAL_DC  '
   4,   401,   300.000,    15.000,'EAST_COGEN1 '
   5,  3011,   900.000,    10.000,'WEST        '
   6,   402,   300.000,    20.000,'EAST_COGEN2 '
0 / END OF AREA DATA, BEGIN TWO-TERMINAL DC DATA
  1,1,    7.8543,   1490.65,    525.00,    400.00,    3.9420,   0.15560,'I',      0.00,  20,   1.00000
   301, 2,13.00, 7.50, 0.0111, 3.8800, 500.0,0.44000,1.06275,1.10000,0.90000,0.00525,     0,     0,     0,'1 ', 2.0034
  3021, 2,21.00,18.50, 0.0000, 3.0470, 230.0,0.95652,1.07500,1.10000,0.80000,0.00625,     0,   152,  3021,'T4', 2.0000
  2,1,    8.2000,   1500.00,    525.00,    400.00,    4.1000,   0.15000,'I',      0.00,  20,   1.00000
   301, 2,12.00, 8.00, 0.0110, 3.8800, 500.0,0.44000,1.05450,1.11200,0.90000,0.00515,     0,     0,     0,'1 ', 0.0098
  3022, 2,20.00,18.00, 0.0120, 3.0470, 230.0,0.95652,1.06250,1.10000,0.80000,0.00625,     0,   152,  3022,'T5', 0.0074
0 / END OF TWO-TERMINAL DC DATA, BEGIN VSC DC LINE DATA
'VDCLINE1    ',1,    0.7100,   1,0.3204,   2,0.3883,   3,0.1942,   4,0.0971
  3005,2,2,   -209.00, 0.95000,   100.000,     0.100,    50.000,    400.00,   1200.00,0.10000,    100.00,   -110.00,     0,  100.0
  3008,1,1,    100.00, 0.99000,    90.000,     0.150,    40.000,    350.00,   1200.00,0.15000,    150.00,   -140.00,     0,  100.0
'VDCLINE2    ',1,    0.3500,   1,0.3705,   2,0.3597,   3,0.1799,   4,0.0899
   203,2,1,   -100.00, 1.00000,   100.000,     0.150,   123.000,    200.00,   1200.00,1.00000,    200.00,   -150.00,     0,  100.0
   205,1,1,    100.00, 1.00000,    93.000,     0.120,    98.000,    250.00,   1250.00,1.00000,    225.00,   -250.00,     0,   99.0
0 / END OF VSC DC LINE DATA, BEGIN SWITCHED SHUNT DATA
```

Figure E-6 (Cont). SAMPLE Load Flow Raw Data File sample.raw (3 of 4 Sheets)

```
   152,1,1.04500,0.95500,     0,  100.0,'            ', -233.00, 1, -15.00, 2,  -5.00, 3, -10.00, 4,  -8.00, 5,  -7.00, 6,  -5.00, 7,  -7.00, 8,  -4.00
   154,1,1.04480,0.96500,     0,  100.0,'            ',  124.00, 1,  25.00, 2,  10.00, 2,  15.00, 1,  15.00, 2,   5.00, 3,   3.00, 2,   4.00, 1,   7.00
  3005,4,0.98000,0.64000,  3005,  100.0,'VDCLINE1    ',    0.00, 1,  33.35
  3021,2,1.00000,1.00000,     0,  100.0,'            ',  499.66, 2, 200.00, 1, 100.00, 2,  50.00, 4,  25.00
  3022,2,1.00000,1.00000,     0,  100.0,'            ',  599.58, 4, 100.00, 2,  50.00, 4,  25.00, 3,  20.00, 2,  20.00
0 / END OF SWITCHED SHUNT DATA, BEGIN IMPEDANCE CORRECTION DATA
 1, -30.00, 1.10000, -24.00, 1.09100, -18.00, 1.08400, -12.00, 1.06300,  -6.00, 1.03200,   0.00, 1.00000,   6.00, 1.03000,  12.00, 1.06000,  18.00, 1.08000,  24.00, 1.09000,  30.00, 1.11000
 2,0.60000, 1.06000,0.70000, 1.05000,0.80000, 1.04000,0.90000, 1.03000,0.95000, 1.02000,1.00000, 1.01000,1.05000, 0.99000,1.10000, 0.98000,1.20000, 0.97000,1.30000, 0.96000,1.40000, 0.95000
0 / END OF IMPEDANCE CORRECTION DATA, BEGIN MULTI-TERMINAL DC DATA
 1, 4, 5, 4, 1,   212,    400.00,     0
   402, 4,10.00, 8.00, 0.0000,19.0000, 500.0,0.22000,1.01000,1.10000,0.97000,0.01000,   321.00, 1.0000,  0.15000, 3
   401, 4,10.00, 8.00, 0.0000,19.0000, 500.0,0.22000,1.01000,1.10000,0.97000,0.01000,   321.00, 1.0000,  0.15000, 3
   212, 4,20.00,18.00, 0.0000,10.0000, 230.0,0.45200,1.04000,1.10000,0.90000,0.01000,   500.00, 1.0000,  0.00000, 1
   213, 4,20.00,18.00, 0.0000,10.0000, 230.0,0.45200,1.10000,1.10000,0.90000,0.01000,  -303.80, 1.0000,  0.00000, 4
  1,   401,   4,   4,'DC1         ', 0,   0.0000,   4
  2,   212,   2,   2,'DC2         ', 0,   0.0000,   2
  3,   402,   4,   4,'DC3         ', 0,   0.0000,   4
  4,   213,   2,   2,'DC4         ', 0,   0.0000,   2
  5,     0,   4,   4,'DC5         ', 0,   0.0000,   4
  1,  5,'1',   29.0000,     0.00
  2,  5,'1',   29.0000,     0.00
  3,  5,'1',   29.0000,     0.00
  4,  5,'1',   29.0000,     0.00
0 / END OF MULTI-TERMINAL DC DATA, BEGIN MULTI-SECTION LINE DATA
   201,   -204,'&1',   207
0 / END OF MULTI-SECTION LINE DATA, BEGIN ZONE DATA
   1,'NORTH_A1    '
   2,'MID_A1_A2_A5'
   3,'DISCNT_IN_A1'
   4,'SOUTH_A1_A5 '
   5,'ALL_A3      '
   6,'NORTH_A5    '
   7,'NORTH_A2    '
   8,'SOUTH_A2    '
   9,'ALL_A4_A6   '
0 / END OF ZONE DATA, BEGIN INTER-AREA TRANSFER DATA
   1,   2,'A',  1000.00
   1,   5,'B', -3800.00
   2,   4,'C',  -300.00
   2,   6,'E',  -300.00
   3,   5,'D',  2900.00
0 / END OF INTER-AREA TRANSFER DATA, BEGIN OWNER DATA
   1,'OWNER 1     '
   2,'OWNER 2     '
   3,'OWNER 3     '
   4,'OWNER 4     '
   5,'OWNER 5     '
0 / END OF OWNER DATA, BEGIN FACTS DEVICE DATA
 1,   153,     0,1,     0.000,     0.000,1.01500,    50.000,   100.000,0.92630,1.13400,1.00000,     0.000, 0.05652,  100.0,   1,   0.00000,   0.00000,0
 2,   153,   155,1,   350.000,    40.000,1.01500,    25.000,  9999.000,0.90000,1.10000,1.00000,     0.000, 0.05000,  100.0,   1,   0.00000,   0.00000,0

0 / END OF FACTS DEVICE DATA
```

Figure E-6 (Cont). SAMPLE Load Flow Raw Data File sample.raw (4 of 4 Sheets)

```
0          / PSS™E-30.0    FRI, JUN 04 2004  17:30
   101,'1 ',     0.01101,     0.30001
   102,'1 ',     0.01051,     0.32001
   206,'1 ',     0.01061,     0.25101
   211,'1 ',     0.01081,     0.26201
   301,'1 ',     0.01091,     0.23001
   301,'2 ',     0.01101,     0.24001
   301,'3 ',     0.00801,     0.25001
   401,'1 ',     0.01231,     0.22231
   402,'1 ',     0.00451,     0.24321
  3011,'1 ',     0.00761,     0.35431
  3018,'1 ',     0.08701,     0.35631
  3018,'2 ',     0.02401,     0.35531
0  / END OF POSITIVE SEQ. MACHINE IMPEDANCE DATA, BEGIN NEGATIVE SEQ. MACHINE DATA
   101,'1 ',     0.01102,     0.30002
   102,'1 ',     0.01052,     0.32002
   206,'1 ',     0.01062,     0.25102
   211,'1 ',     0.01082,     0.26202
   301,'1 ',     0.01092,     0.23002
   301,'2 ',     0.01102,     0.24002
   301,'3 ',     0.00802,     0.25002
   401,'1 ',     0.01232,     0.22232
   402,'1 ',     0.00452,     0.24322
  3011,'1 ',     0.00762,     0.35432
  3018,'1 ',     0.08702,     0.35632
  3018,'2 ',     0.02402,     0.35532
0  / END OF NEGATIVE SEQ. MACHINE IMPEDANCE DATA, BEGIN ZERO SEQ. MACHINE DATA
   101,'1 ',     0.01103,     0.30003
   102,'1 ',     0.01053,     0.32003
   206,'1 ',     0.01063,     0.25103
   211,'1 ',     0.01083,     0.26203
   301,'1 ',     0.01093,     0.23003
   301,'2 ',     0.01103,     0.24003
   301,'3 ',     0.00803,     0.25003
   401,'1 ',     0.01233,     0.22233
   402,'1 ',     0.00453,     0.24323
  3011,'1 ',     0.00763,     0.35433
  3018,'1 ',     0.08703,     0.35633
  3018,'2 ',     0.02403,     0.35533
0  / END OF ZERO SEQ. MACHINE IMPEDANCE DATA, BEGIN NEGATIVE SEQ. SHUNT DATA
   154,   1.00240,   1.04210
   201,   0.99240,   0.99042
  3005,   1.00920,  -1.00340
0  / END OF NEGATIVE SEQ. SHUNT DATA, BEGIN ZERO SEQ. SHUNT DATA
   154,   0.99670,   0.98230
   201,   0.99267,   0.98423
  3005,   0.99467,  -0.98423
0  / END OF ZERO SEQ. SHUNT DATA, BEGIN ZERO SEQ. NON-TRANSFORMER BRANCH DATA
   151,   152,'1 ',    0.00710,    0.12100,    3.34000,  0.00710,  0.12121,  0.00713,  0.13211
   151,   152,'2 ',    0.00712,    0.13200,    3.34200,  0.00712,  0.13232,  0.00724,  0.14323
   151,   201,'1 ',    0.00300,    0.04500,    3.60000,  0.00000,  0.00000,  0.00000,  0.00000
   152,   202,'1 ',    0.00250,    0.03000,    1.80000,  0.00000,  0.00000,  0.00000,  0.00000
   152,  3004,'1 ',    0.00800,    0.08000,    5.00000,  0.00000,  0.00000,  0.00000,  0.00000
   153,   154,'2 ',    0.01800,    0.16000,    0.30000,  0.00000,  0.00000,  0.00000,  0.00000
   154,   155,'1 ',    1.00000,    0.20000,    2.00000,  0.30000,  3.00000,  0.40000,  4.00000
   154,   203,'1 ',    5.00000,    0.23100,    1.00000,  0.30600,  2.00000,  0.37000,  3.00000
   154,   205,'1 ',    2.00000,    0.20000,    3.00000,  0.30000,  4.00000,  0.40000,  5.00000
   154,  3008,'1 ',    0.00800,    0.06500,    0.60000,  0.00000,  0.00000,  0.00000,  0.00000
   201,   202,'1 ',    0.00500,    0.07000,    4.00000,  0.00000,  0.00000,  0.00000,  0.00000
   201,   207,'C1',    0.00450,    0.04500,    0.40000,  0.00000,  0.00000,  0.00000,  0.00000
   203,   205,'1 ',    0.01500,    0.13000,    0.15000,  0.00000,  0.00000,  0.00000,  0.00000
   204,   207,'C2',    0.00450,    0.45000,    0.40000,  0.00000,  0.00000,  0.00000,  0.00000
   205,   214,'2 ',    0.00600,    0.07500,    0.80000,  0.00000,  0.00000,  0.00000,  0.00000
   205,   216,'3 ',    0.01500,    0.13000,    0.15000,  0.00000,  0.00000,  0.00000,  0.00000
   205,   217,'4 ',    0.01500,    0.13000,    0.15000,  0.00000,  0.00000,  0.00000,  0.00000
   205,   218,'5 ',    0.01500,    0.13000,    0.15000,  0.00000,  0.00000,  0.00000,  0.00000
   213,   214,'1 ',    0.00000,    0.01000,    0.00000,  0.00000,  0.00000,  0.00000,  0.00000
  3001,  3003,'1 ',    0.00000,    0.00800,    0.00000,  0.00000,  0.00000,  0.00000,  0.00000
  3002,  3004,'1 ',    0.01600,    0.16000,    0.20000,  0.00000,  0.00000,  0.00000,  0.00000
  3005,  3006,'1 ',    0.00800,    0.08000,    0.15000,  0.00000,  0.00000,  0.00000,  0.00000
  3005,  3007,'1 ',    0.00700,    0.07500,    0.12000,  0.00000,  0.00000,  0.00000,  0.00000
  3007,  3008,'1 ',    0.00700,    0.07000,    0.12000,  0.00000,  0.00000,  0.00000,  0.00000
  3008,  3009,'1 ',    0.00700,    0.07000,    0.12000,  0.00000,  0.00000,  0.00000,  0.00000
0  / END OF ZERO SEQ. NON-TRANSFORMER BRANCH DATA, BEGIN ZERO SEQ. MUTUAL DATA
   151,   152,'1 ',   151,   152,'2 ',   0.00210,   0.02200, 0.00000, 1.00000, 0.00000, 1.00000
   154,   203,'1 ',   203,   205,'1 ',   0.00110,   0.01200, 0.75000, 1.00000, 0.00000, 0.25000
0  / END OF ZERO SEQ. MUTUAL DATA, BEGIN ZERO SEQ. TRANSFORMER DATA
   101,   151,     0,'T1',  3,    0.00480,    0.00720,    0.00010,    0.00771
   102,   151,     0,'T2',  3,    0.00481,    0.00721,    0.00013,    0.00773
   152,   153,     0,'T3',  1,    0.00000,    0.00000,    0.00019,    0.00794
   152,  3021,     0,'T4',  2,    0.00482,    0.00722,    0.00021,    0.00815
   152,  3022,     0,'T5',  2,    0.00483,    0.00723,    0.00012,    0.00523
   201,   211,     0,'T6',  2,    0.00484,    0.00724,    0.00026,    0.00343
   202,   203,     0,'T7',  1,    0.00000,    0.00000,    0.00072,    0.00743
   204,   205,     0,'T8',  6,    0.00374,    0.00652,    0.00046,    0.00563
   205,   206,     0,'T9',  7,    0.00375,    0.00653,    0.00018,    0.00533
   205,   215,   216,'3 ',  2,    0.00000,    0.00000,   -0.00015,    0.05833,    0.00530,    0.44166,    0.00390,    0.35834
   205,   217,   218,'4 ',  2,    0.00000,    0.00000,    0.00324,    0.00451,    0.00153,    0.08333,    0.00537,    0.05167
  3002,  3001,  3011,'1 ',  1,    0.00000,    0.00000,    0.00345,    0.00251,    0.00456,    0.00125,    0.00789,    0.00187
  3004,  3005,     0,'10',  5,    0.00376,    0.00654,    0.00036,    0.00991
  3008,  3018,     0,'11',  4,    0.00000,    0.00000,    0.00044,    0.01276
  3008,  3009,  3010,'2 ',  2,    0.00000,    0.00000,    0.00000,    0.00010,    0.00000,    0.00010,    0.00000,    0.00010
0  / END OF ZERO SEQ. TRANSFORMER DATA, BEGIN ZERO SEQ. SWITCHED SHUNT DATA
   152,  -0.00900,  -0.00910,  -0.00920,  -0.00930,  -0.00940,  -0.00950,  -0.00960,  -0.00970
   154,   0.00810,   0.00820,   0.00830,   0.00840,   0.00850,   0.00860,   0.00870,   0.00880
  3005,   0.00950
  3021,   0.00000,   0.00000,   0.00000,   0.00000
  3022,   0.00000,   0.00000,   0.00000,   0.00000,   0.00000
0  / END OF ZERO SEQ. SWITCHED SHUNT DATA
```

Figure E-7. SAMPLE Sequence Data File sample.seq

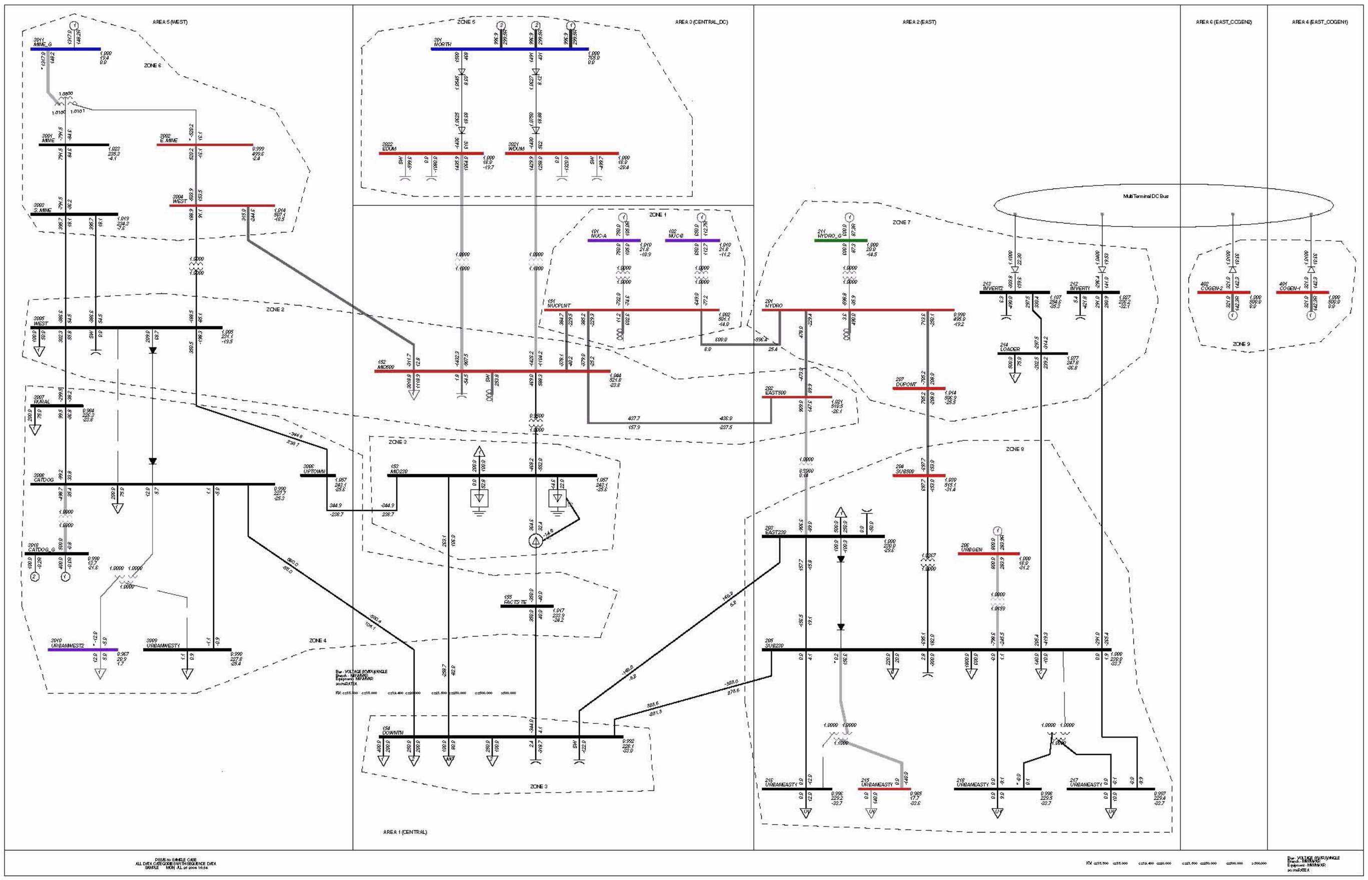

Figure E-8. SAMPLE Slider File sample.sld

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