POWERDRAW

DIGITAL SIMULATOR FOR POWER SYSTEMS

USERS' MANUAL

VOLUME - II

OFF LINE STUDIES OF POWER SYSTEMS

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Chapter 1

Digital Simulation of Power Systems

1.1 Introduction

This manual is to introduce the users to the power system simulation package, 'POWERDRAW' with all its power system related graphical and analytical capabilities. POWERDRAW is a comprehensive, versatile and easy-to-use software tool for different types of power system studies. The entire package is operated through a Graphical User Interface(GUI).

1.2 Organization of the Manual

The **Users' Manual** is divided into three volumes.

VOLUME ONE contains:

*** Introduction to POWERDRAW GUI**

*** Drawing of Single Line Diagram of Power Systems**

*** Generation of Data Files**

VOLUME TWO contains:

*** Off-Line Studies of Power System Operation**

VOLUME THREE contains

*** Real-Time Simulation of Power System**

In its present form the POWERDRAW software package has the following capabilities:

- Adheres strictly to **POSIX**©-compliant **UNIX**©, **X-WINDOWS**© and **OSF -MOTIF**© for platform and operating system independence
- Mapping of power system components to visual objects on the computer screen
- Constructing schematic maps of power system network with advanced features like drag & drop of various objects
- Provides animation to power system objects
- Display of schematic map at different tiers
- Manipulation of Network Data and attributes (color, position, status) through simple operation of mouse pointer
- Automatic preparation of Database from network connectivity for Real-Time/Off-line power system simulation study
- Automatic generation of user-defined substation diagram
- Dynamic representation of status changes of various objects on Graphical Display
- Displaying & reporting of current system conditions for better understanding on the part of operator

- Initiation of various in-built off-line system simulation engines & displaying results graphically for better insight

- On-line/Off-line scenario building

The entire overview of the POWERDRAW GUI is shown in Fig. 1.1
Each of these facilities will be described in detail later.

1.2.1 Communication with the Software

All communications with the software are through the graphical user interface (GUI). All commands either for developing the single line diagram or for carrying out any of the large number of system studies are to be communicated to the software through appropriate 'Dialog Boxes'. For this purpose a large number of necessary 'Child Windows' suitable for communicating with the software have been incorporated. Chapter-2 describes the 'POWERDRAW' graphical user interface with all the Menus, Sub-menus, Tools and other facilities available for communicating with the package.

1.2.2 Single Line Diagram of a Power System

One of the important features of the package is the drawing and development of a single line diagram of interconnected power systems. The network diagram may be drawn in a compact form. Alternatively, all the transmission lines and substations may be geographically disposed spatially. The drawing area can be expanded upto 32 window size X 32 window size. All these features are described in Chapter-3. That chapter also describes all the user-friendly facilities created to help the operator during running process. Predefined colour schemes for different voltage levels and specially created icons for different system components are also explained in this chapter.

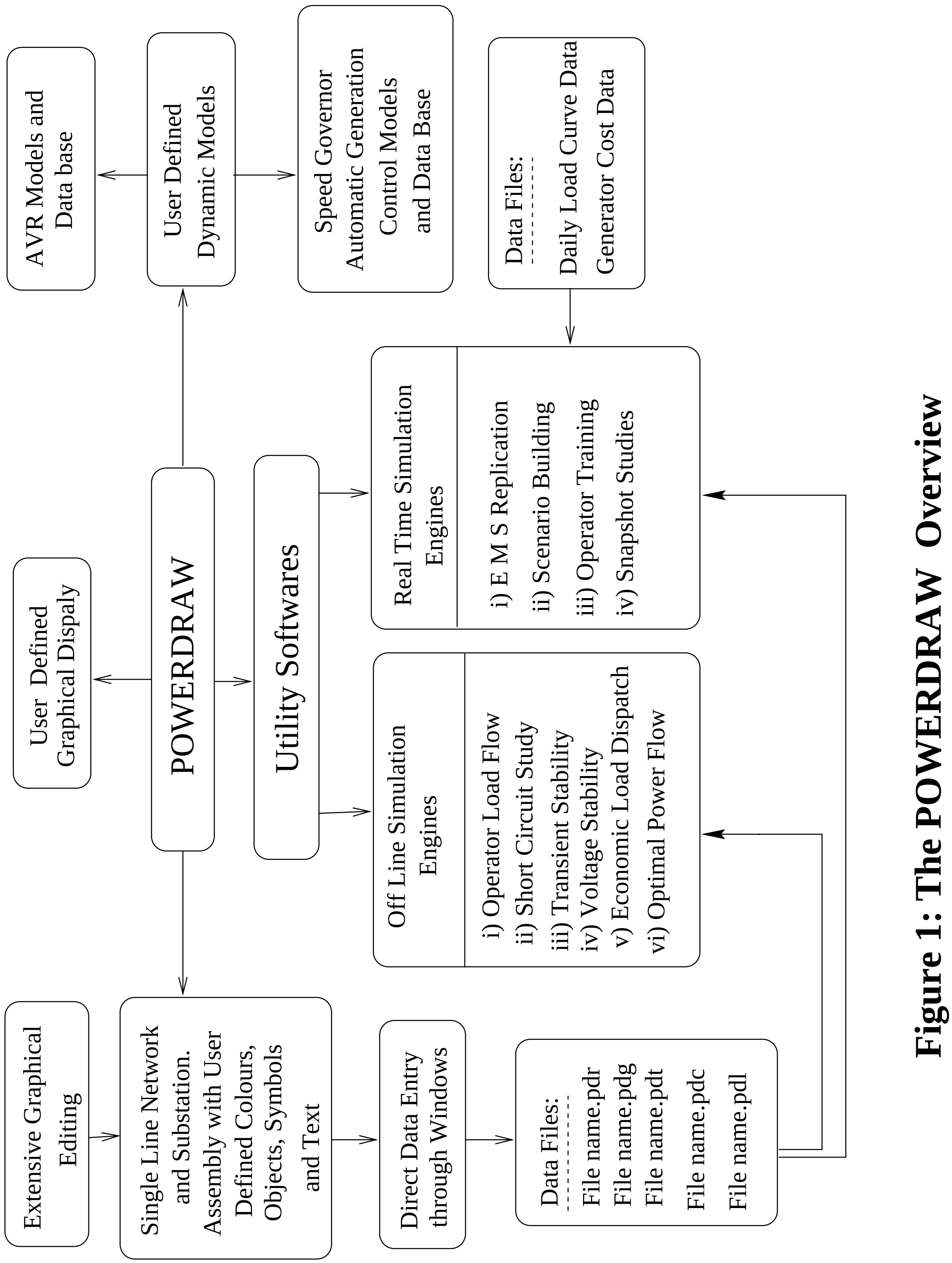

Figure 1.1: The POWERDRAW OVERVIEW

1.2.3 Generation of System Data Files

During the drawing process of the single line diagram, or even after completing the drawing process, there are facilities for generating the necessary data files for carrying out most of the studies. While data are provided through appropriate dialog boxes, the program generates three different data files as below:

<**filename.pdr**> ... File for the network drawing

<**filename.pdt**> ... File for the network data

<**filename.pdg**> ... File for generator data

<**filename.pdc**> ... File for load curve data

<**filename.pdl**> ... File for load model data

where

filename is a user-defined file describing the system to be supplied by the user.

The structure of these files will be described in detail in Chapter-4. For inputting data a large number of appropriate Dialog Boxes have been designed specially for easy understanding of the user. The data structure as stored in each of the files are also included. Detailed instructions about the way data are to be inputted are also described in that Chapter.

1.2.3.1 Modeling for Static Simulation

For static analyses such as Loadflow, Short Circuit etc. following modeling has been included:

Busbar with variable loads, shunt loads, generation etc.

Transmission Lines with line connected reactors

Transformer with variable and fixed taps

Static VAR System with controllable slopes and limits

High Voltage DC System with all types of connection and modes of operation

Six different models are available for load modeling. A user can use any one of them. These are as given below:

Load Model 1 = Basic Constant MVA model.

Load Model 2 = Voltage and Frequency sensitive MVA model

Load Model 3 = Includes Load Management in Model 1

Load Model 4 = Includes Load Management in Model 1

Load Model 5 = Includes Voltage Regulation in Model 1

Load Model 6 = Includes all (Voltage and frequency sensitivity, Load Management, Voltage Regulation.)

1.2.3.2 Modeling for Dynamic Simulation

The following components have been modeled as per the IEEE standard wherever available.

Automatic Excitation Control System of standard IEEE type

Speed Governing System for both hydro and steam plants

Boiler Turbine System for both hydro and steam plants

Automatic Generation Control System

Power System Stabilizer

Static VAR System

High Voltage DC System for different modes of operation control

Protection System over-current and impedance relay

Generating Units of round-rotor and salient pole type

1.3 Utility Softwares

Apart from the facilities for drawing single line diagram and data file preparation, this software package offers a large number of generalized and versatile programs for a variety of power system simulation studies. Theses studies are categorized into two groups:

Off-line Simulation Engines

Real Time Simulation Engines

1.3.1 Off-line simulation

The following is the list of off-line studies that can be carried out on a system whose single line diagram has been drawn and proper data files have been created:

* **Operator Load Flow**

* **Short Circuit Studies**

* **Transient Stability studies**

* **Voltage Stability Analysis**

* **Economic Load Despatch**

* **Optimal Power Flow**

1.3.2 Real time simulation

Real Time simulation can be carried out through either of the two alternatives:

* **Load Flow Analysis**

* **State Estimation**

For the purpose of using the Real Time Simulation engine through the State Estimation program it is necessary to connect the POWERDRAW GUI to an appropriate Data Acquisition System which will have to transmit the required data to the engine in the correct format and sequence.

1.4 Off-Line Simulation Engines

Different off-line studies are described in detail in different chapters. In this section only brief overview will be presented.

1.4.1 Operator Load Flow Studies

In Chapter-5 the facilities for carrying out load flow studies, be it off-line or on-line, is described. Load flow analyses can be carried out under the following three study modes:

* **Static Load Flow Analysis**

* **System Expansion Study**

* **Snap-shot on Real Time Operation**

In each mode a large number of changes, either in the topology of the network or in its parameters or in its operating states, can be incorporated and load flow can be repeated. The list of the changes is:

a. Change in Load

b. Change in Generation

c. Change in Shunt Load

d. Change in Feeder Data

e. Change in Phase Shifter Data

f. Change in Control Bus Data

g. Tripping of a Generator

h. Putting in a Generator

i. Switching out a Feeder

j. Switching in a Feeder

1.4.2 Short Circuit Studies

Short Circuit Analyses of electrical power systems network is an important requirement for both planning and operational purposes. The following types of faults can be applied as per the operator's requirement.

```
Type of fault           identifying number
*************           ******************

 SINGLE LINE TO GROUND FAULT      1
 LINE TO LINE  FAULT              2
 THREE PHASE FAULT                3
 DOUBLE LINE TO GROUND FAULT      4
```

After the solution, all the three different phase-voltages and phase-currents are displayed in the display windows as explained later. The details are described in a separate chapter.

1.4.3 Transient Stability Studies

Transient Stability Analyses fall under the category of large disturbance studies which are required for both system planning purposes as well as for creating system operation strategies. Following a large disturbance the rotor angles, rotor speeds and accelerations of all the generating units get disturbed. Depending on the location of electrical distances, different units are affected to different extent.

Since the entire solution of all the different components of the system cannot be achieved in real time, this is essentially an off-line study.

Descriptions about supplying data for, and running procedure of the transient stability program is presented in this chapter.

There are option to plot the transient variation of the following quantities in graphical form for the duration of the solution:

* **Rotor angles of selected generators**
* **Power output of selected generators**
* **Voltage magnitude at selected busbars**
* **Frequency variation at selected generator busbars**
* **Impedance seen by a distance relay of selected line**

In each plot it is possible to include as many monitoring points as desired.

1.4.3.1 Voltage Stability Study

Voltage collapse is characterized by a slow variation in system operating point due to increase in loads in such a way that the voltage magnitude gradually decreases until a sharp accelerated change takes place. The problem ofbf voltage collapse may simply be explained as the inability of the power system to supply the reactive power or by an excessive absorption of reactive power by the system itself. An effective voltage collapse bf proximity index which indicates how far the current operating is from voltage collapse and which busbars are the most vulnerable is of much help to the system operating engineer in taking corrective measures.

At any operating condition of the system this program selects a set of busbars which are, according to selected criteria, are vulnerable to voltage collapse. It shows the current load at those buses and also the approximate laodability margin along with the proximity index.

1.4.3.2 Optimal Power Flow

This analytical tool minimizes the active power losses in the transmission and distribution system. For a given optimum active power allocation based on economic generation schedules, this program minimizes the line losses by optimally rescheduling the reactive power outputs of the generating units. While doing this it also improves the system **voltage profile.**

1.5 Real Time Simulation of Power System

Real time simulation of power system is an important constituent of the Digital Simulation of power system. Apart from replicating the EMS environment, the real time simulation engine provides extensive facilities for the training of power system operators.

Two major needs for which training can be very effective are:

Training for Operation During Normal Condition

Training for Operation During Severe Disturbances

1.5.1 Scenario Building for Real Time Simulation

For the purpose of operator training pre-defined scenarios are generally created by the instructor so that the trainee can respond interactively for restorative purposes.

Fourteen different types of individual scenarios can be created with the help of this Dialog box. With suitable combination of these individual cases a large number of practically realizable scenarios can be created. These individual scenarios are:

1 Change in Load

2 Change in Pset Value

3 Change in Shunt load

4 Change in Feeder/Transformer Data

5 Change in Phase Shifter Data

6 Change in Control Bus data

7 Bringing back a generator

8 Tripping off a generator

9 Switching out a feeder/transformer

10 Switching in a feeder/transformer

11 Switching out a DC link

12 Switching in a DC link

13 Changing DC link power

14 Change in Governor Mode

All the scenarios as described above can also be created interactively during the time when real time simulation is proceeding.

The real time simulation of a power system under normal condition will generally follow a predicted load curve. A real time dynamic simulator will be the most effective mechanism to train control engineers in the handling of severe disturbances.

A real time dynamic simulator will be the most effective mechanism to train control engineers in the handling of severe disturbances to increase confidence, to improve knowledge of the technical characteristics of the system and to train for procedures for handling emergency situations.

This chapter describes in detail all the aspects of real time simulation of a power network. It highlights how and what data are to be supplied to the simulation program, how to run the program and how to interrupt the real time simulation to carry out snap-shot studies. It also describe the various aspects of operator training process such as the preparation of training scenarios, interpretation of results and how the trainee can take certain supervisory actions in an attempt to bring the system to healthy condition after some disturbances.

1.6 Intended Audience

This manual is intended as a guide for using the 'POWERDRAW' software package. Any person familiar with an electrical power network should be able to use the manual for going through various stages of the software package and use it for his own purpose purely mechanically. But for a better understanding of various functions and their inter-relationships among one another, it is assumed that the user will be familiar with the functioning of an integrated power system and different types of associated problems it is likely to face under normal and abnormal operating states. Some analytical background relating to power system modeling and simulation would be of advantage.

Some knowledge of UNIX operating system and its file structure is also a basic requirement.

The associated publication 'Technical Manual' provides the details of mathematical relationship involved in modeling and simulation of different components and systems as used in this package. Inter-relationship of the various processes are also available in that manual.

Those who would be involved in modifying and upgrading the package, would be expected have a thorough understanding of the Technical Manual. They should also be able to understand the source codes written in FORTRAN-77 and C language. The graphical aspects of the package has been developed using X-WINDOW and MOTIF library functions.

The POWERDRAW will be useful to:

Power system managers

Power system operators

Teachers

Researchers

Advanced students

1.7 Team of Personnel

The following personnel in the

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were involved in the development of the package:

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6 Mr. Pavan Kumar

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8 Mr. A K Kishore

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2 Kaushick Niyogi

Chapter 2

Operator Load Flow Studies

2.1 Introduction

The last two Chapters described how to draw a single line diagram of an electrical power network and how to supply various data required for carrying out Load Flow and other studies. This Chapter describes how to carry out load flow studies for a system which has been drawn and for which all the data have been supplied.

The Load Flow Analysis is one of several power system simulation engines available in this package. Among several special features of this engine is that Load flow studies are carried in the following sequence:

1. A base case load flow with the data supplied at the time of drawing the diagram.

2. Repeated load flow studies after making changes in the network operating condition or the topology of the network.

The display of load flow results are in a user friendly way both in graphical as well as in text mode.

2.1.1 Study Mode

There are three different situations when Operator Load flow solutions become useful.

Static Load Flow Analysis This is the case of a system operational planning study. Whether under steady state conditions a static network will operate within various constraints is the essential purpose of these studies. Different types of network modifications can be carried out and repeated load flows can be performed to predict the steady state stability of the system.

System Expansion Study For the purpose of system expansion studies where new substations, generating plants or new transmission line are to be added, the single line diagram has to be modified first and then additional data are to be supplied in the way as described in Chapters Two and Three.

In the next few Sections a step by step description will now be given about how to run the Operator Load Flow along with all the options available.

Snap-shot on Real Time Operation This is a part of the Operator Training Simulator. When a system is running in real time, it is possible to take a snap shot of the system operating condition at any instant and study the 'ROBUSTNESS' of the system by making various changes in the system operating conditions or on the network topology and then repeating load flow solutions.

In the next few Sections a step by step description will now be given about how to run the Operator Load Flow along with all the options available.

2.2 Base Case Load Flow

For the purpose of these studies it is assumed that the single line diagram for the system to be studied has already been drawn, data have been supplied and all the files have been 'Saved'.

To get the 'POWERDRAW' GUI into the screen give the command:

powerdraw

Immediately the POWERDRAW main window appears on the screen. Then using the 'Open' option of the 'File' Menu open the network system for which studies are to be done.

IT IS TO BE REMEMBERED THAT WHENEVER A SINGLE LINE DIGRAM IS OPENED IN THE DRAWING AREA THE FOLLOWING THREE FILES ARE AUTOMATICALLY OPENED BY THE GUI:

<**filename.pdr**> **...** File for the network drawing

<**filename.pdt**> **...** File for the network data

<**filename.pdg**> **...** File for generator data

<**filename.pdc**> **...** File for load curve data

<**filename.pdl**> **...** File for load model data

where

filename is a user-defined file describing the system to be supplied by the user.

The default filenames in the empty drawing area are:

'Unnamed.pdr

'Unnamed.pdt

'Unnamed.pdg etc.

In case you have just drawn the diagram and supplied and saved data, the system diagram and data files are already opened and the diagram is on the screen.

Suppose the system available on the drawing pad is the same 5-Bus Sample Power System shown in Fig.3.5. Now to carry out the base case load flow, place the cursor on the

Simulation

of the Main Menu Bar and press the left mouse button. Then to get the pull-down menu bar with all the options press

Off Line

This dialog box offers several study options from which select:

Operator Load Flow

Instantly a new window with the same system diagram but with the base case load flow solution of the system appears on top of the main window. This is shown in Fig. 5.10.

2.2.1 Viewing the Load Flow Results

In the new window the voltage magnitudes of all the bus bars after the converged solution are shown.

Busbar details For viewing other details of a busbar place the cursor on the bus whose details are to be displayed and press the left mouse button. The same dialog box through which data were supplied appears with all the details about load and generation on that busbar.

Line flows For viewing the line flow place the cursor on the feeder and again press the left mouse button to get the details about the flow through the line and other information.

Search The 'Search' tool in the main window is also available in the 'Operator Load Flow' window. To use this tool place the cursor anywhere in this window and press the right mouse button when a pop-up menu

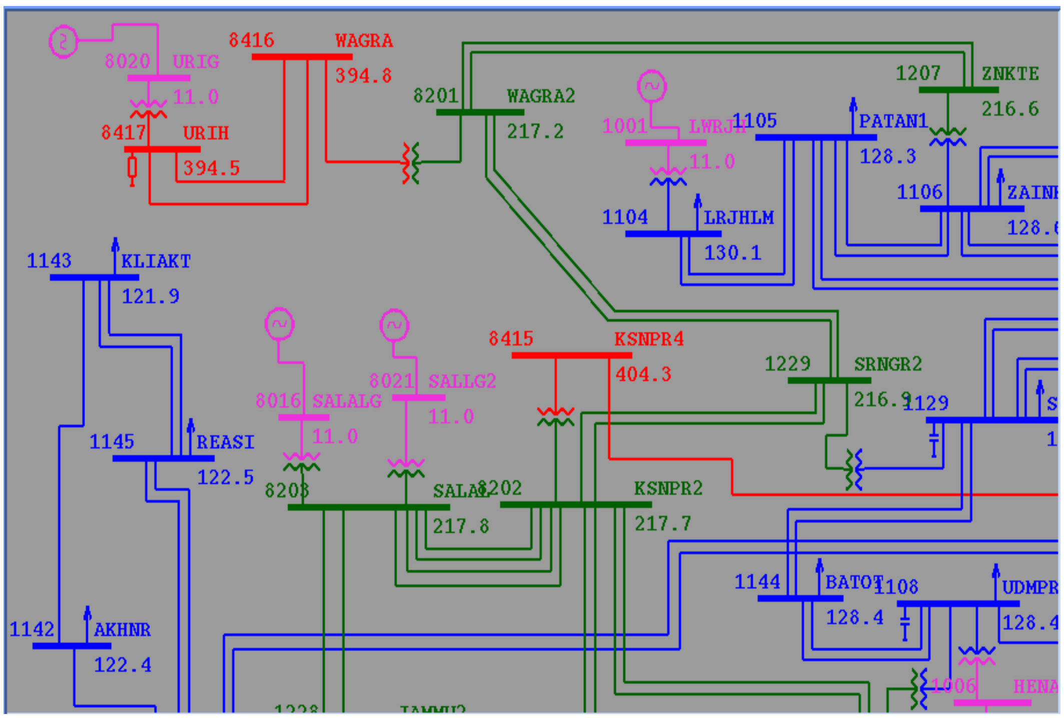


Figure 2.1: Operator Load Flow Solution

with the 'Search' option appears on the window. Keeping the mouse button pressed drag it to the option 'Search' and then release the button. Then the dialog box 'Search a Busbar' appears on the screen. In this window the busbars are arranged in alphabetical order only. When you click on any busbar name with the left mouse button, the single line diagram is shifted in such a way that the desired busbar comes at the middle of the display window.

Buscode On/Off Along with the 'Search' facilities it is also possible to display the Busbar codes on the busbars in the display window. for this take the cursor to the 'Buscode On/Off' option and press the left mouse button. The codes are then shown in the window. If you press the option again the codes will be removed.

2.2.2 Dialog Box for Operator Load Flow

Along with the solution window another 'child window' also appears with various options as shown in Fig. 2.2.

Using the toggle buttons you can have multiple choices in this window. Details of the options are as follow:

```
Option                               Purpose
******                               *******

Editing of Data Required ........ When this button is
                                     toggled on a window
                                     with all edit options
                                     appears on th screen.
                                     This will be explained
                                     later

Execute Base Case Load Flow ..... This option allows you
```

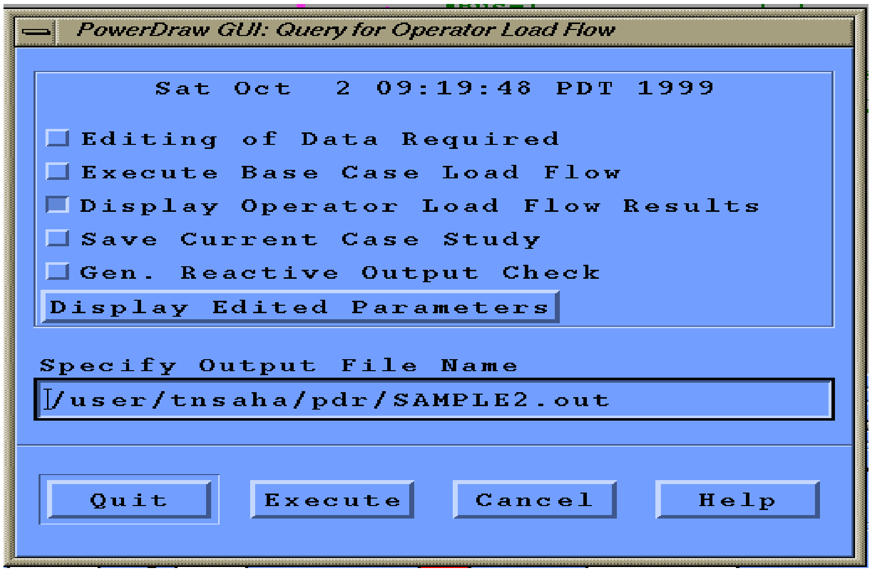


Figure 2.2: Query for Operator Load Flow

```
                                        to carry out base case
                                        load flow solution


Display Results in Text Mode .... When selected detailed
                                        results will be shown
                                        in a separate Text
                                        Windows

Save Current Case Study ......... In this option the data
                                        corresponding to the just
                                        carried out study will be
                                        saved in a file to be
                                        inputted through a dialog
                                        box.
```

```
Gen. Reactive Power Check ........ In this case generator
                                   reactive power violation
                                   will be checked and load
                                   flow will be repeated
                                   after keeping the reactive
                                   power at the limits

Display Edited Parameters ........ With this option you can
                                   see all the changes made
                                   in the parameters of the
                                   system through editing
```

Save Current Case Study

If you want to save the input data corresponding to load flow study just carried out with changes in the system you have to supply the filename for doing so. The Dialog box for inputting the filename for saving the is shown in Fig. 2.3. When you supply the new name, five new files with that name will be created and the data will be saved in them. These will be:

Newname.pdr

Newname.pdt

Newname.pdg

Newname.pdc

Newname.pdl

The name of the output file where the results of the load flow studies will be written is displayed as a default function. If you want a different name then name can be changed in the text window in the dialog box.

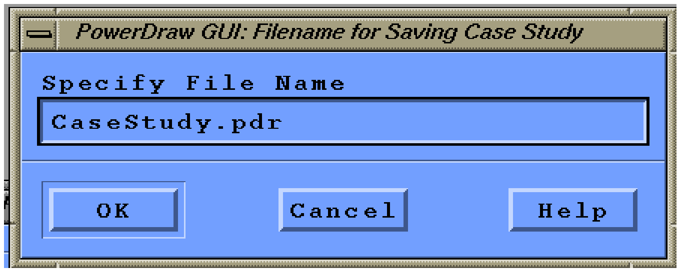


Figure 2.3: File Name for Saving Case Study

2.2.3 Functions of PushButtons

There are four push buttons at the bottom of the 'Query for Operator Load Flow' Dialog Box. They are:

Quit When this button is activated the process that was going on is discontinued. That means that the 'Query for Operator Load Flow' along with the display of the operator load flow solution in the child window are removed from the window.

Execute This option is to be used for running the 'Operator Load Flow' after completing the editing process.

Cancel Activating this button discontinue the current process of supplying data and removes the Dialog Box.

Help This pushbutton, when pressed, brings out the help messages in a separate window.

2.3 Analyses of Perturbed System

It is of importance to study how a power system will perform after certain changes in the system when it is operating at a particular stable condition. Such analyses are required both for real time operation as well as for system

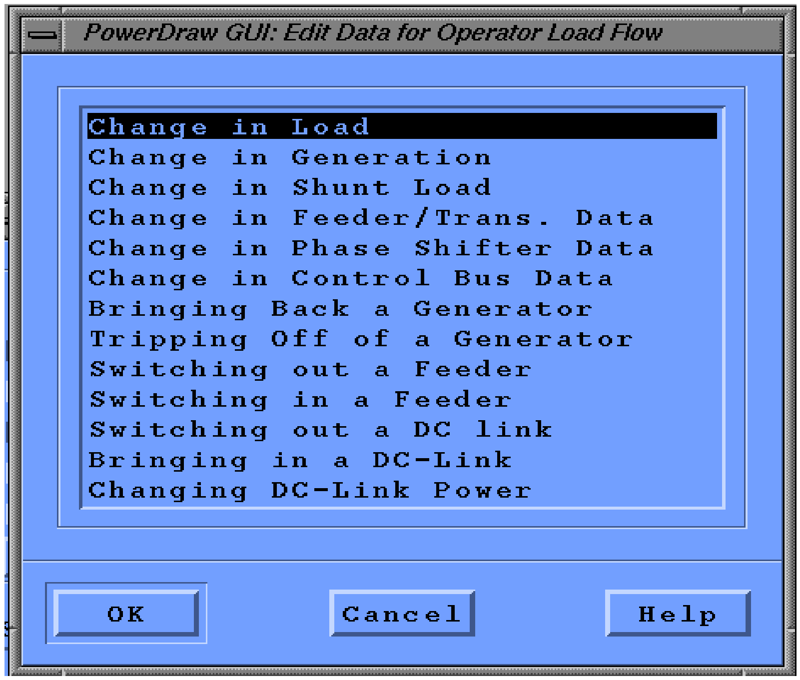


Figure 2.4: Editing Data for Operator Load Flow

planning purposes. With the editing facilities provided in the Operator Load Flow program all such studies can be carried out starting with the system condition of the base-case load flow. If you toggle the option 'Editing of Data Required', a new dialog box is provided for selecting several study options as shown in Fig. 2.4

1. **Change in Load**

2. **Change in Generation**

3. **Change in Shunt Load**

4. **Change in Feeder/Transformer Data**

5. **Change in Phase Shifter Data**

6. **Change in Control Bus Data**

7. **Bringing back a generator**

8. **Tripping off a generator**

9. **Switching out a Feeder**

10. **Switching in a Feeder**

11. **Switching out a DC-link**

12. **Switching in a DC-link**

13. **Switching out a DC-conv**

14. **Switching in a DC-conv**

15. **Changing operation mode of a DC-conv**

You can select any one of these options and after making suitable changes you can repeat the load flow solution. These studies can be used both for system design purposes as well as for system contingency tests.

You can select any one of them at a time for single contingency study. Alternatively, you can select any combination for multiple contingency analysis at a time. For example, you can change load at a busbar and take out a line somewhere else in the system.

Each of these contingencies will now be described individually.

2.3.1 Changing Load at a Busbar

When you select this option from the Editing Dialog Box, a new child dialog box appears as shown in Fig. 2.5.

In this dialog box only 'Bus Code' and 'Bus Name' fields are highlighted. When you enter the Buscode or the Busname and click the Pushbutton 'Prev' with left mouse button or press the 'Enter' button in the key board, the

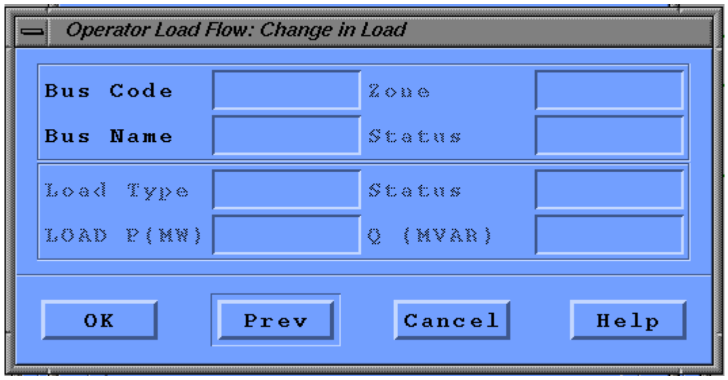


Figure 2.5: Change in Busbar Load

current values of the load and other information about the load and the busbar will be displayed as shown in Fig. 2.6.

Alternatively, if you take the cursor to the busbar whose information is required, and press with the left mouse button, again the current values of the load will be displayed.

You can now change the values of both active and reactive powers. Once the editing is complete, press the 'OK' button in the box to save the new values.

If you want to repeat the load flow analysis with this changed load condition then click the 'OK' button in the 'Edit Data' dialog box also to indicate that editing is complete. Then take the mouse to 'Query for Operator Load Flow' dialog box and press the 'Execute' button. Then the load flow analysis will be repeated and the new results will be displayed afresh in the Operator Load Flow Window.

2.3.2 Changing Generation at a Busbar

When you select this option from the Editing Dialog Box, another child dialog box appears as shown in Fig. 2.7.

In this dialog box the real and reactive power boxes are empty initially.

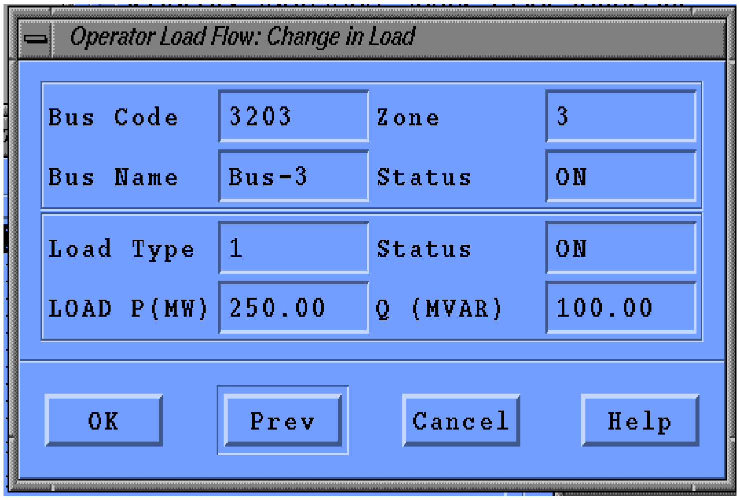


Figure 2.6: Current Load in Busbar

When you enter the Buscode and click button 'Prev' or click the busbar with left mouse button, the current values of generation at that busbar will be displayed.

Alternatively, if you take the cursor to the busbar whose information is required, and press with the left mouse button, again the current values of the generation will be displayed.

You can now change the values of both active and reactive powers. Once the editing is complete, press the 'OK' button in the box to save the new values. If you want to repeat the load flow analysis with this changed load condition then click the 'OK' button in the 'Edit Data' dialog box also to indicate that editing is complete. Then take the mouse to 'Query for Operator Load Flow' dialog box and press the 'Execute' button. Then the load flow analysis will be repeated and the results will be displayed afresh in the Operator Load Flow Window.

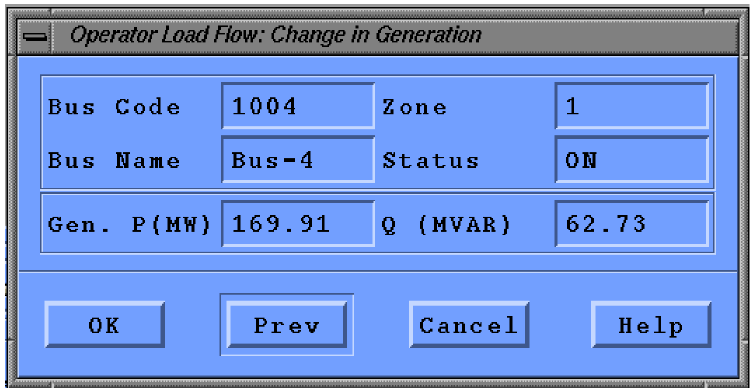


Figure 2.7: Current Generation in a Busbar

2.3.3 Changing Shunt Load Data

Capacitors and reactors banks connected at any busbars generally have discrete steps of values. These values can be changed with the help of this editing facility. The Dialog box for editing the shunt data is shown in Fig. 2.8. When you select this option, the dialog box appears on the screen.

The process of changing Shunt Load Data is similar to others as explained above. Again you input the Busbar code and press the 'Enter/Return' key the current values of the shunt load is is displayed in the next two small windows. You can now change these values and press the 'OK' button to save the changes. Then press the 'Edit Data for Operator Load Flow'. Finally, press the 'Execute' button on the Dialog box 'Query for Operator Load Flow'.A load flow analysis with the changes incorporated will be carried out and the new values will be displayed on the network diagram.

2.3.4 Change in Feeder/Transformer Data

The Dialog Box for editing feeder data is shown in Fig. 2.9. When the From Busbar, To Busbar codes and the circuit number are supplied and the Enter/Return button is pressed, the same Dialog Box get extended to display

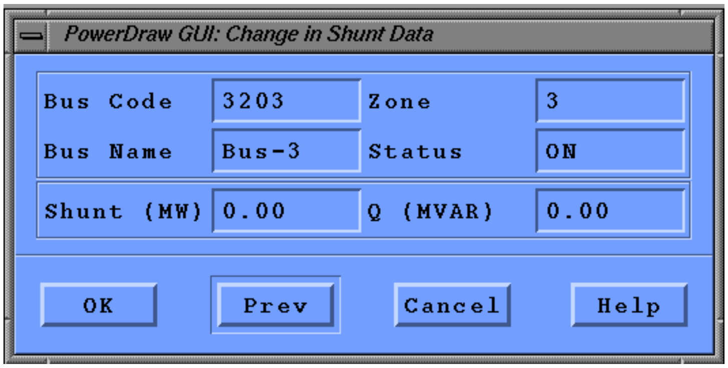


Figure 2.8: Dialog Box for Editing Shunt Load

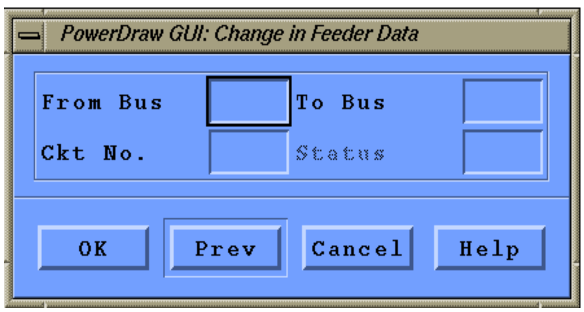


Figure 2.9: Change in Feeder Data

all the current values as shown in Fig. 2.11 and in Fig. ??. Alternatively, you can take the cursor to the feeder,irrespective of whether it is a transformer or a transmission line and press the left mouse button the data get entered into the appropriate dialog box.

If it is a transmission line, then line parameters are shown. In the case of the feeder being a transformer, all parameters including the tap details are displayed.

You can now edit any of those data and save the changes by pressing the 'OK' radio button with left mouse button.

To repeat the load flow solution press 'OK' radio buttons of the two dialog

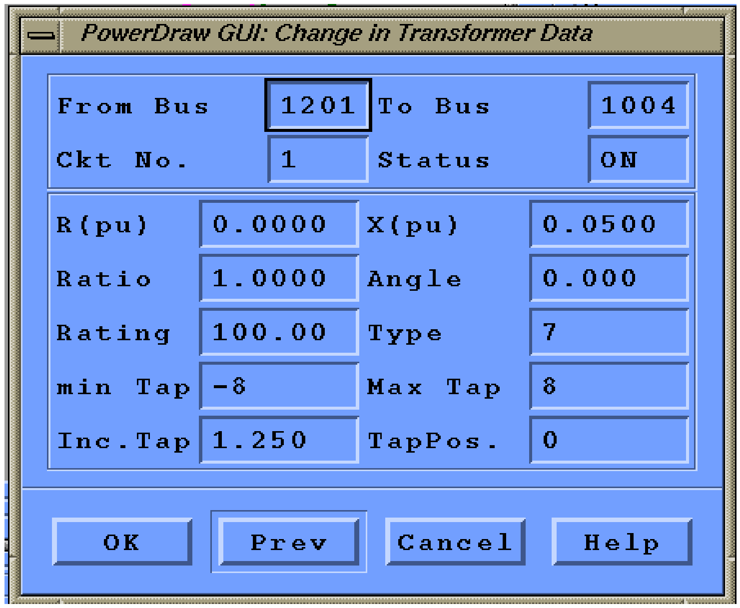


Figure 2.10: Values of Transformer Parameters

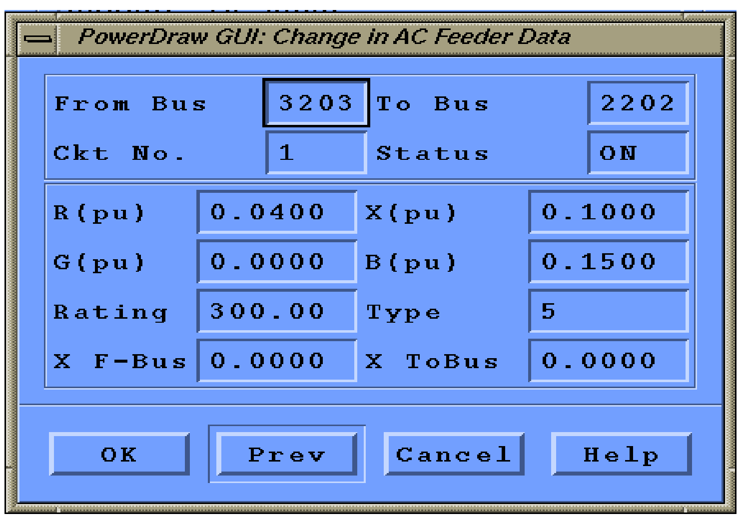


Figure 2.11: Current Values of Feeder Parameters

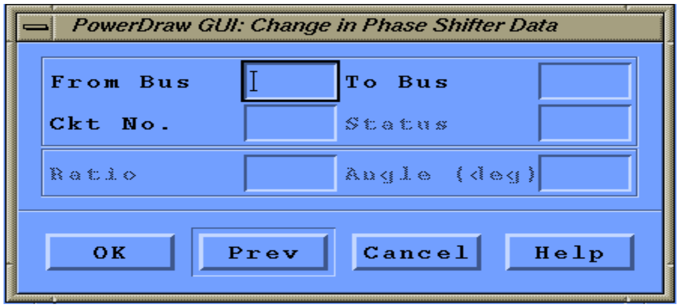


Figure 2.12: Changing Phase Shifting Data

boxes and then press the 'Execute' radio button of the 'Query for Operator Load Flow' child window with left mouse button. If the load flow converges, the results will again be displayed in the Operator Load Flow Window.

2.3.5 Changing Phase Shifter Data

Phase shifting transformers are generally used for controlling the active power flow. In this type of transformers both the ratio as well as the angular shift between the primary and the secondary voltage magnitudes can be changed. The dialog box for creating such changes is shown in Fig. 2.12.

The phase shift angle is to be given in degrees within the range of plus 30 degrees and minus 30 degrees. A positive value of 15 degrees means that the to-bus winding will be 15 degrees advanced in phase with respect to the from-bus end. The voltage ratio is to be given in per unit value.

To modify the phase shifter data you have to enter the from-busbar to-busbar data. After that if you press the 'PREV' option the current values will be displayed. You can now edit these values and press the 'OK' button. In case you do not want to make any change you can press the 'Cancel' button.

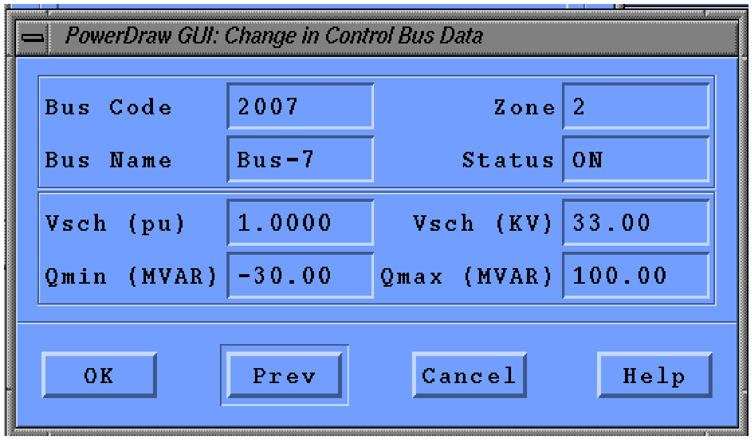


Figure 2.13: Modification of Control Busbar Data

2.3.6 Editing Control Busbar Data

indexEditing Control Busbar Data In load flow studies control busbars are those busbars that can control the busbar voltage magnitudes within a certain limit by injecting or absorbing reactive power at those busbars. Consequently, only those busbars can be treated as control busbars which have dispatchable reactive sources, such as generating busbars, busbars with synchronous or static VAR compensators or even simply with banks of switchable capacitors or reactors.

The dialog box for creating such changes is shown in Fig. 2.13.

All the four data below the horizontal line are edit-able. For changing the scheduled voltage, you need change only the per unit value. The actual voltage in KV will automatically be changed after the load flow solution is complete.

2.3.7 Bringing Back a Generator

In a system when loads have increased, it may be necessary to add new generation by bringing in new units which might have been shut down during

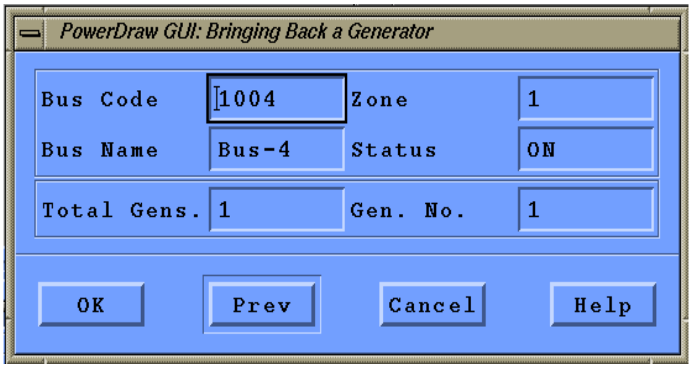


Figure 2.14: Dialog box for bringing in a generator

light load condition. From the base case solution it is possible to know which generating units are off and which units are connected to the system. If it is desired to bring any new unit into the system, go to 'Edit' window and press 'Bringing Back a Generator' with left mouse button. A new dialog box appears on the screen as shown Fig. 2.14.

To enter data for the unit to be brought into the system take the cursor to the 'object' representing that power station and press the left mouse button. Instantly, the details about the number of generators available in that power station is shown in the box. You can now type the generator number that you want to bring in to the system. It is important to remember that a generator can be brought into the system only if it is 'available' for operation. Finally, press the OK button when the data is accepted and the window disappears.

2.3.8 Tripping off a Generating unit

Generally a power station has more than one generators. It is not necessary that all the generators will be running all the times. Depending on the system loading conditions generators may have to be brought into the system or may have to be taken out of the system. A generator can be tripped out of the system easily with the help of the Dialog box shown in Fig. 2.15

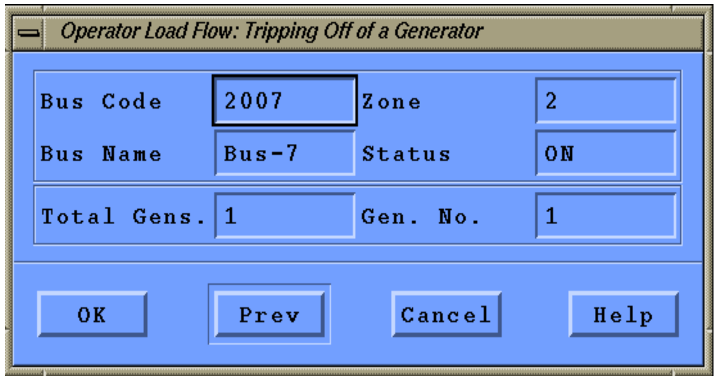


Figure 2.15: Dialog Box for Tripping a Generator

When the dialog box appears with the 'Generator Busbar Code' highlighted, you provide the code number of the busbar at which you want to trip the generator. Immediately the details about the total number of generators connected to that busbar will be shown. You then select the serial number of the generator that you want to trip. Finally, press the 'OK' radio buttons with the help of the left mouse button on the Dialog boxes 'Tripping of a Generator' and 'Edit Data for Operator Load Flow'. Then press the 'Execute' button on the Dialog box 'Query for Operator Load Flow'. A load flow analysis with the changes incorporated will be carried out and the new values will be displayed on the network diagram.

2.3.9 Switching out an AC Feeder

Quite often system contingency studies are to be carried by taking out feeders, be it transmission lines or transformers. This can be conveniently done with the help of the Dialog Box shown in Fig. 2.16

Here again for supplying the data for the feeder to be taken out, take the cursor to anywhere on the feeder and press the left mouse button. Feeder details in terms of 'From Bus', 'To Bus', Circuit Number and the current Status is displayed in the Dialog Box. Then take the cursor to the push

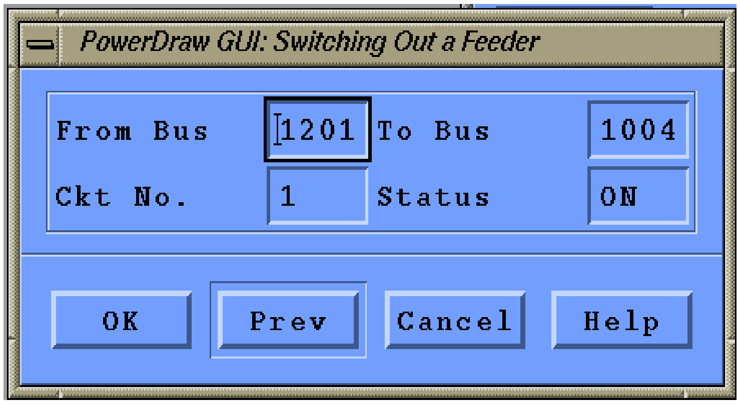


Figure 2.16: Dialog Box for Switching out a Feeder

button 'OK' and press the left mouse button. The data is now accepted for taking out this line for carrying out the load flow study.

2.3.10 Switching in an AC Feeder

The process of switching in a feeder is similar to that of switching out a feeder. When you activate this option a Dialog Box similar to that of switching out a feeder appears on the screen. Then take the cursor to feeder that you want to bring into the system and press the left mouse button. The details of the feeder will be shown in the Box. The Dialog Box is shown in Fig. 2.17

bf Please remember that the feeder that you want to connect to the system must be one of those that were earlier switched out and shown in white colour in the single line diagram.

2.3.11 Switching out a DC Feeder

The DC feeder connecting the two ends of the HVDC system may become inoperative for various reasons. There are many implications of a DC feeder going out of operation. In a bi-polar system the other feeder load will get changed. If there are other AC feeders in parallel, their power flow will also

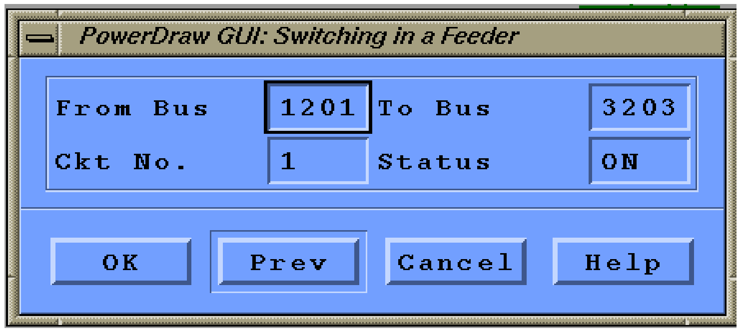


Figure 2.17: Dialog Box for Switching in a Feeder

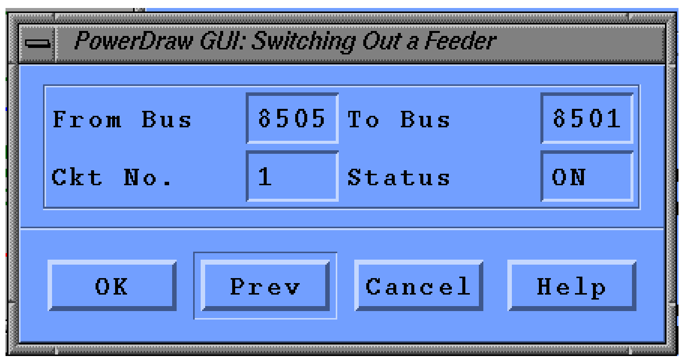


Figure 2.18: Dialog Box for Switching out a DC Feeder

change and may cause overloading. All these can be studied by taking out a DC feeder. All these depend on the operational strategy of the system.

Data for taking out a Dc feeder can be conveniently supplied through the Dialog box as shown in Fig. 2.18.

When you place the cursor against item 11(Switching out a DC Link) and press the left mouse button, this Dialog box will appear. Take the cursor to the DC feeder you want to trip out and again press the left mouse button. The details of the feeder will be shown in the Dialog box. If you want to switch out the feeder, press 'Add' pushbutton at the bottom of the window. The data is accepted. Do not forget to enter the time at which the feeder is to be taken out.

2.3.12 Switching in a HVDC-link

A HVDC link which was earlier taken out of the system, can be brought into the system. The Dialog box for doing so is similar to what has been shown in Fig. 2.18.

2.3.13 Changing operation mode of a DC-conv

2.3.14 Functions of the PushButton

At the bottom of all the Dialog Boxes for modifying the topology of the network or for changing the system states, there are four PushButtons. Their functions are as follows:

OK When you push this button, data in the Dialog Box are accepted.

Prev If you press this button after typing the information required in the Dialog Box the present values of the parameters and its status is displayed in the Box. Also, if you have have supplied some data and you are not sure whether you are correct, you can see the earlier data by pressing this button.

Cancel Activating this button discontinue the current process of supplying data and removes the Dialog Box.

Help This pushbutton, when pressed, brings out the help messages in a separate window.

2.3.15 Solving the Perturbed System

After you have finished all the editing and saved them, you are now ready for carrying out the the load flow solution of the modified system. If you feel you do not remember all the modifications you have made in the system you

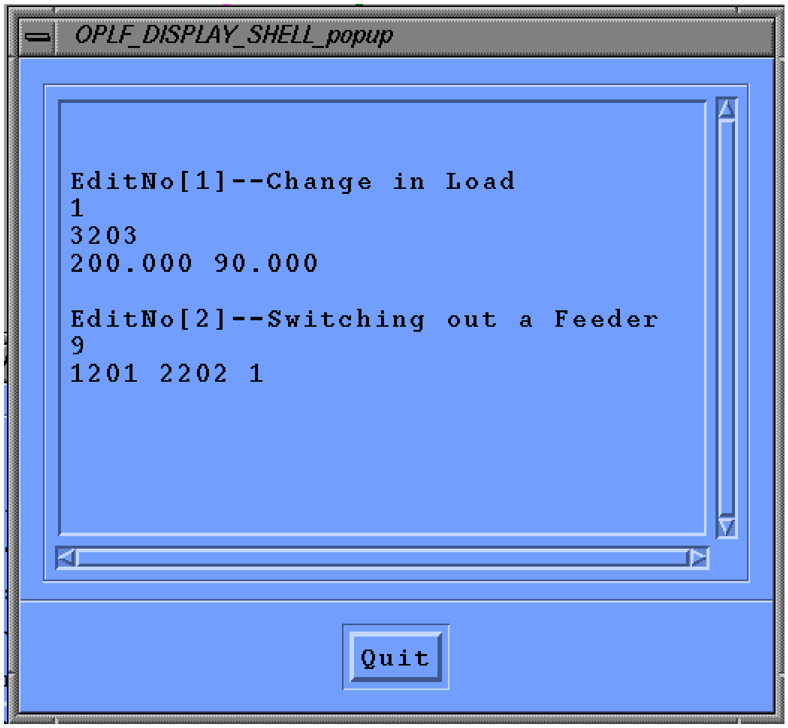


Figure 2.19: Display of Edited Parameters

can see them in a small Dialog box. For that you have to take the cursor to the 'Query for Operator Load Flow' and press 'Display Edited Parameters' radio button. Then a small window will appear displaying all the changes made in the system as shown Fig. 2.19. The contents of the window is self explanatory.

For running load flow solution of the modified system you have to go to the Dialog box 'Query for Operator Load Flow'. There you have the following options:

If you want the result to be displayed in text window, then press the option 'Display Results in Text Mode'.

If you want the input data for this study to be saved in a file, then click the option 'Save Current Case Study'. When you do that a window will

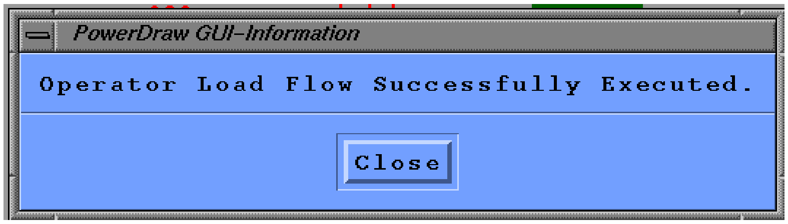


Figure 2.20: Successful Running of Load Flow

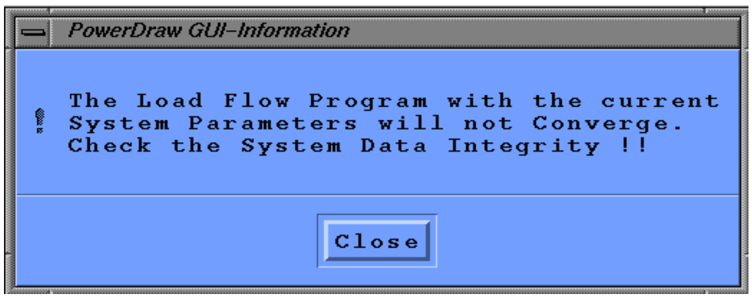


Figure 2.21: Unsuccessful Running of Load Flow

appear for inputting the filename where the data will be saved.

After providing all these information take the cursor to the push button 'Execute'. The load flow solution will be carried out. During this process there are two possibilities:

Solution Successful If the solution is successful, it will be reported in a small window as shown in Fig. 2.20. You are then ready for display of results in the graphical and text modes.

Solution Unsuccessful If, with all the changes done in the system the load flow solution does not converge then it will be reported in another small window as shown in Fig. 2.21. It will then carry out the base case load flow solution.

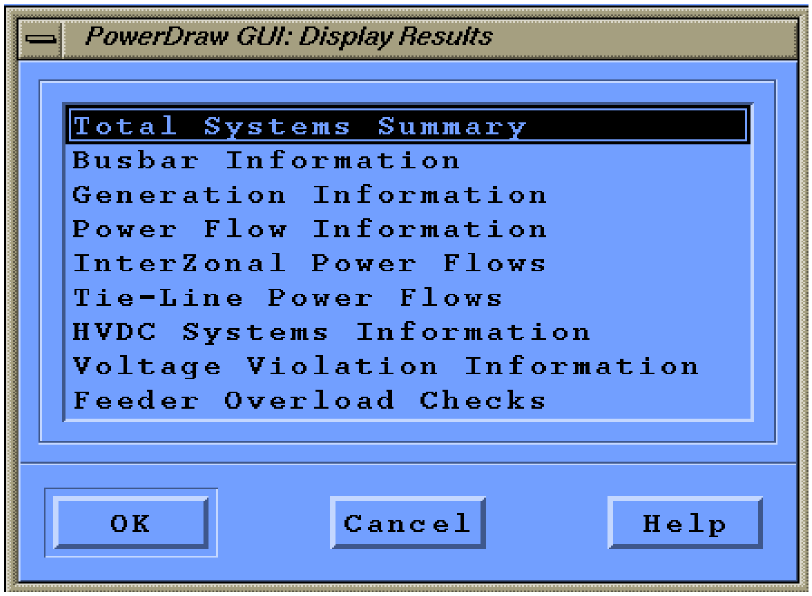


Figure 2.22: Query for Text Mode Display

2.3.16 Display Results in Text Mode

Apart from viewing the results in the single line diagram, it is also possible to see the results in Text Windows.

Results shown in the Text Window are much more in detail. For convenient viewing of results in the text mode several easy-to-understand windows have been incorporated as described below.

After inputting the data through the editing windows take the cursor to the 'Query for Operator Load Flow' window and first press the 'Display Operator Load Flow Results' toggle button and then press the 'Execute' button with left mouse button. The solution of the perturbed system will be shown in the Display window. A new Dialog Box also appears for interactive query for different types of text mode display of computed results as shown in Fig. 2.22.

This Dialog Box provides the following alternatives:

Total System Summary

Busbar Information

Generation Information

Power Flow Information

Interzonal Power Flows

Tie-Line Power Flows

HVDC Systems Information

Voltage Violation Information

Feeder Overload Checks

2.3.16.1 System summary

When this option is selected from the Dialog Box the summary of the solution of the perturbed system is shown as in Fig. 2.23. At the bottom of the summary there is an 'Option Menu' with 'Total System Summary' written on it. If you take the cursor on this menu and press the left mouse button a pop-up menu appears. From this menu you can select summary for any one of the zones.

To remove the Dialog Box from the screen press the 'Quit' button at the bottom of the box.

2.3.16.2 Busbar Information

With the help of this Dialog Box you can see the details of the busbars with their voltage magnitudes, phase angles, generation and loads at these at busbars. You can select the busbars according to different combinations of voltage levels and zones with the help of 'All Voltage Levels' and 'All Zones' option menus. This is shown in Fig. 2.24.

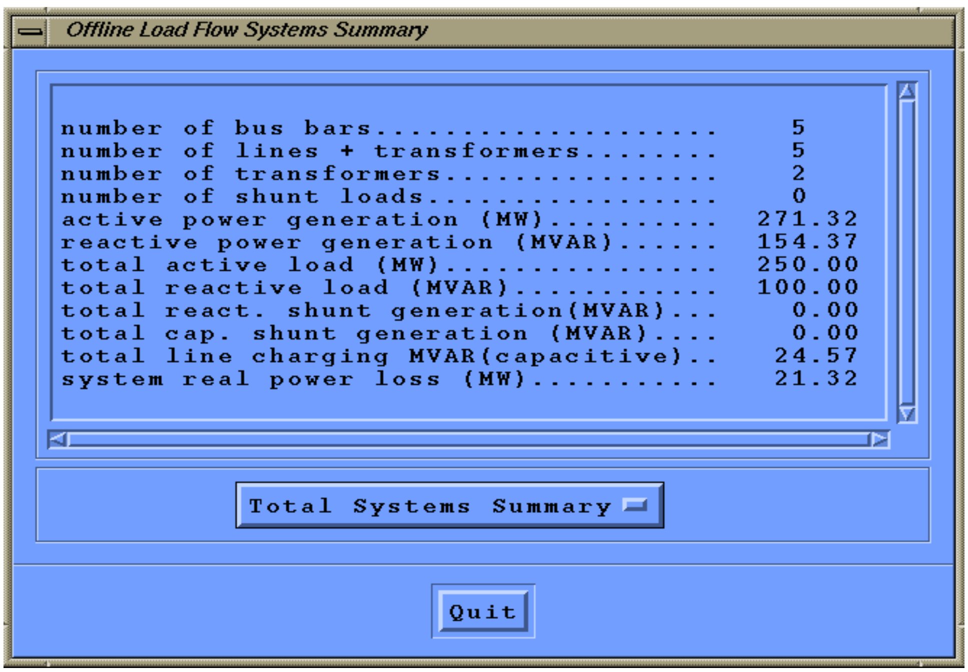


Figure 2.23: Display of system summary

If you press the 'All Voltage Levels' option menu, a pop-up menu is displayed from where you can select for display of busbars at any voltage level. Similarly, using the pop-up menu 'All Zones' you can select all the busbars at that selected voltage level in any particular zone.

2.3.16.3 Generation Information

For displaying the output of different generating stations in the system you have to select the 'Generation Information' option. Here again you can select the display of zone-wise generation information with the help of the 'All Zones' option button. This is shown in Fig. 2.25.

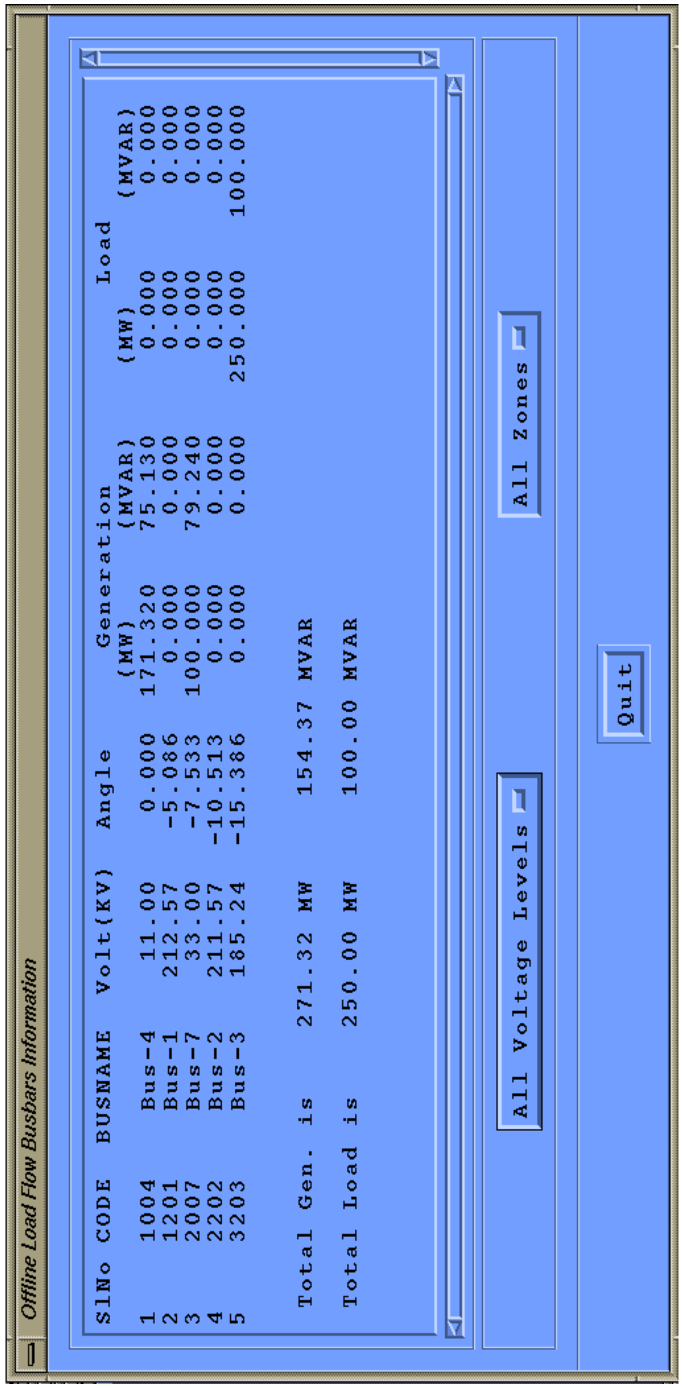
2.3.16.4 Power flow information

This text window is meant for displaying power flow through all the transmission lines and transformers from one substation to all other connected substations. This window has two sections, one for selecting the substation in terms of busbar name or busbar code through a scroll bar.

Once the busbar is selected, flows from that busbar to all other busbars are displayed at the top of the window. Active and reactive power flow from both the ends of lines and transformers along with losses in them are displayed as shown in Fig. 2.26.

2.3.16.5 Interzonal power flows

Through this Dialog box power flows among the different areas or zones can be displayed as shown in Fig. 2.27. In this window also there is a pop-up menu at the bottom through which you can select any of the zones and display how power is flowing between that and all other zones. These information are important for making an assessment of whether any utility is violating the contractual obligations as regards interzonal power transfer.



SlNo	CODE	BUSNAME	Volt(KV)	Angle	Generation (MW)	Generation (MVAR)	Load (MW)	Load (MVAR)
1	1004	Bus-4	11.00	0.000	171.320	75.130	0.000	0.000
2	1201	Bus-1	212.57	-5.086	0.000	0.000	0.000	0.000
3	2007	Bus-7	33.00	-7.533	100.000	79.240	0.000	0.000
4	2202	Bus-2	211.57	-10.513	0.000	0.000	0.000	0.000
5	3203	Bus-3	185.24	-15.386	0.000	0.000	250.000	100.000

Total Gen. is 271.32 MW 154.37 MVAR

Total Load is 250.00 MW 100.00 MVAR

Figure 2.24: Details of busbar information

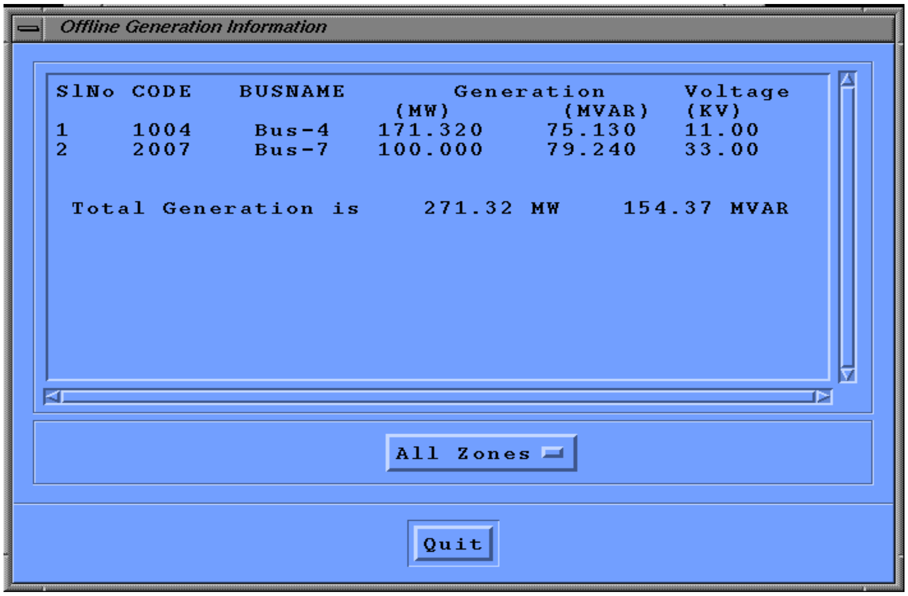


Figure 2.25: Details of Plant Generation

2.3.16.6 Tie-Line power flows

Tie-Line power flow gives the details of active and reactive power flows through all the transmission lines and transformers between the two selected zones. The two zones to be displayed about can be selected through the two pop-up menus available at the bottom of the Dialog box. This is essentially the details of power flows between any two zones through all the lines connecting the two zones.

The Dialog Box for the display of Tie-Line power flow information is shown in Fig. 2.28.

2.3.16.7 HVDC systems information

2.3.16.8 Voltage violation information

With this option you can check whether any of the substation voltages have violated upper or lower voltage limits. The limits can be defined by the

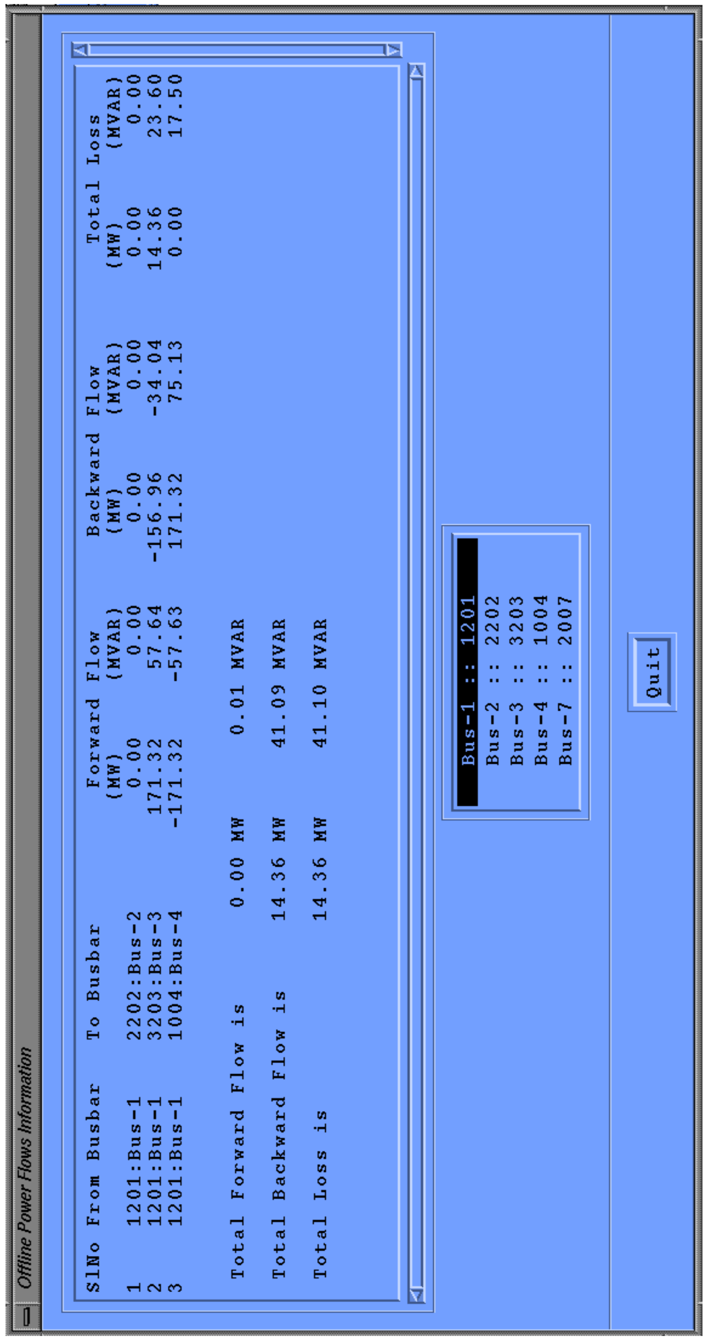


Figure 2.26: Details of Power Flow Information

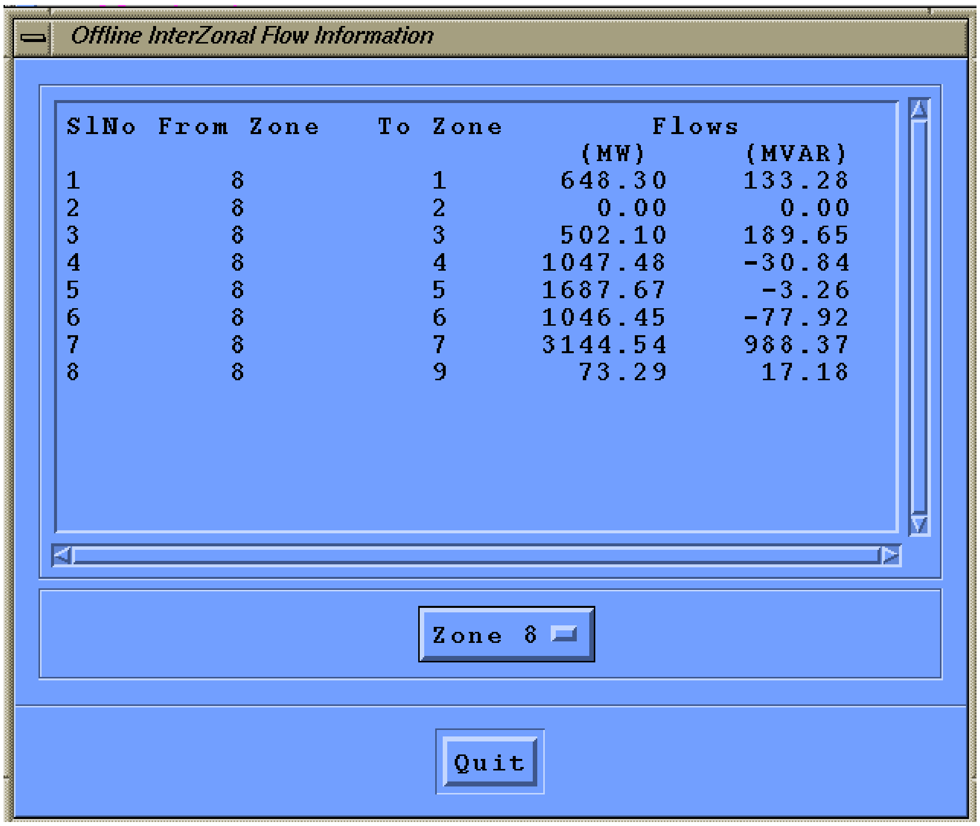


Figure 2.27: Details of Interzonal Flow

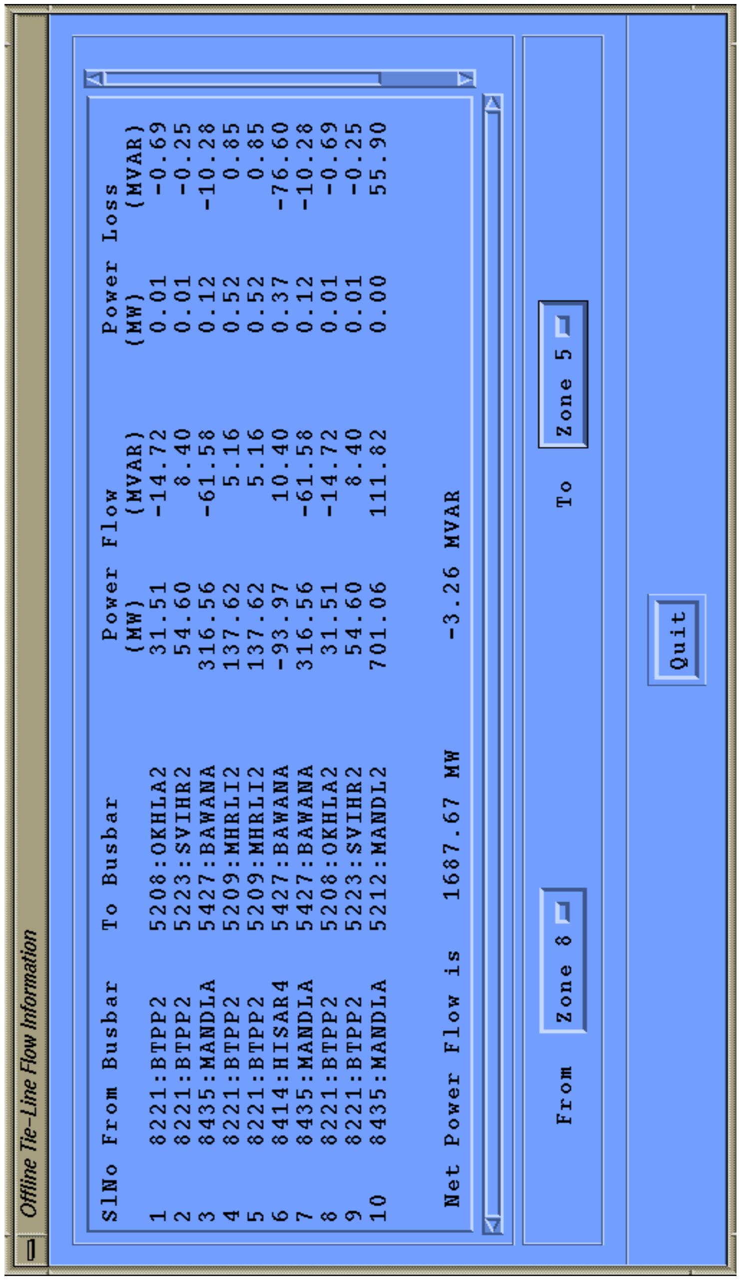


Figure 2.28: Details of Tie-Line Flows

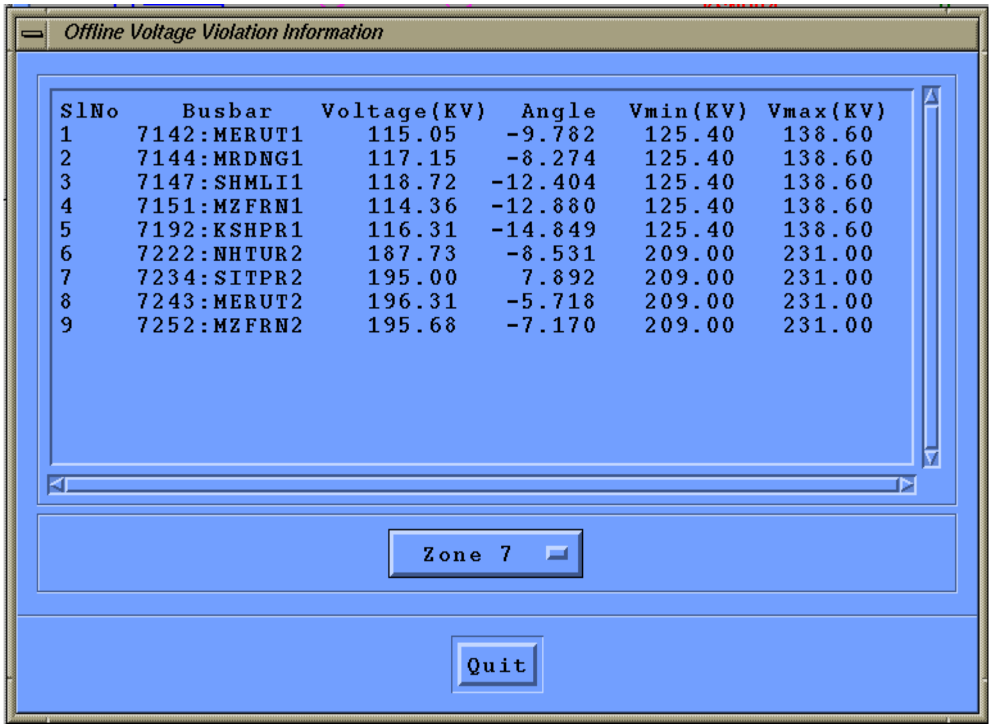


Figure 2.29: Display of Voltage Violation Checks

operator through a separate window. By default the limits are 0.90 pu for lower limit and 1.05 pu for upper limit. The overload checks are displayed through the Dialog box as shown in Fig. ??.

2.3.16.9 Feeder overload checks

The violation of current limit due to overloading of transformers and transmission lines can be displayed through the Dialog box as shown in Fig. 2.30. The overload checks also can be carried out for the entire system of for individual zones or areas.

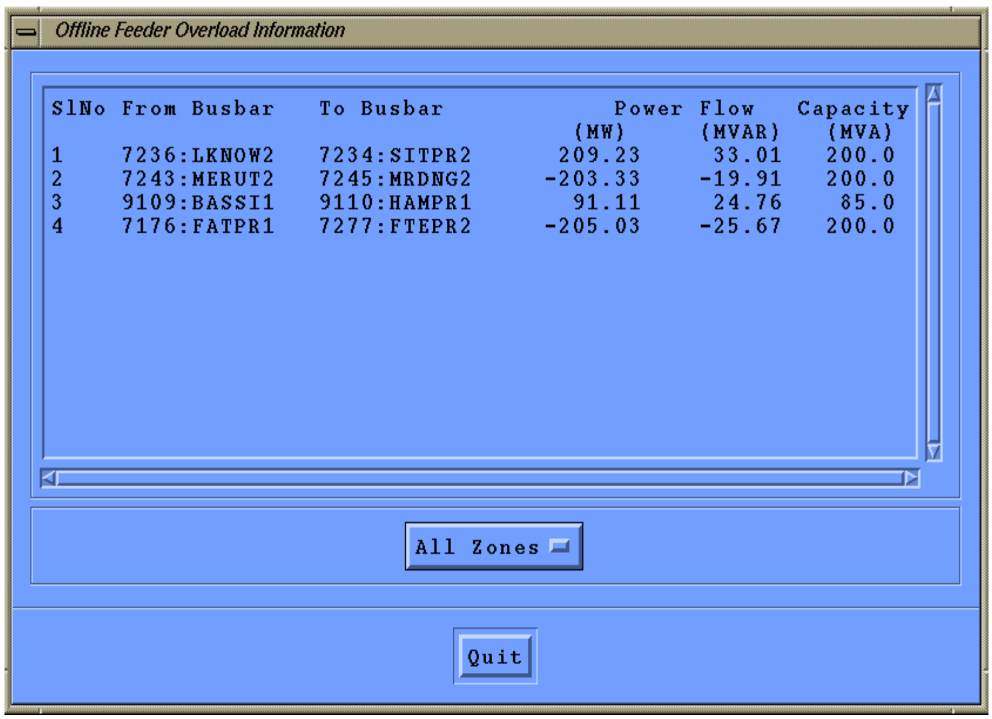


Figure 2.30: Display of Overload Checks

2.4 Conclusion

In this chapter a detail description has been given about the way an operator can carry out repetitive load flow by perturbing the system around a normally steady state condition. This allows the operator to make an assessment of the health of the system in terms of voltage and other electrical parameters.

This ‘Operator Load Flow’ in association with the facilities of network drawing and data supply facilities as described in Chapters 2 and 3 can also be used for system planning and development purposes.

Chapter 3

Economic Operation of Power System

3.1 Introduction

An integrated power network generally interconnects several power stations. Some of the power plants are fossil fuel or oil fired, some are hydro-electric while others may be nuclear or gas turbine driven. Even in the same power plant there may be several generating units, not necessarily, of the same size. Cost of generation and other operating characteristics also vary from unit to unit.

The electrical load in a power system varies throughout the day. Normally there are peak periods and there are lean periods. If a system has sufficient generating capacity to meet the peak load, then many generators will remain lightly loaded during the lean periods. In such a situation it may not be economical to keep all the generators connected to the system all the time.

3.1.1 A Two Stage Solution

There are two stages in the pre-determination of the economic operation of a power system for a given twenty four hour load curve. The first stage is

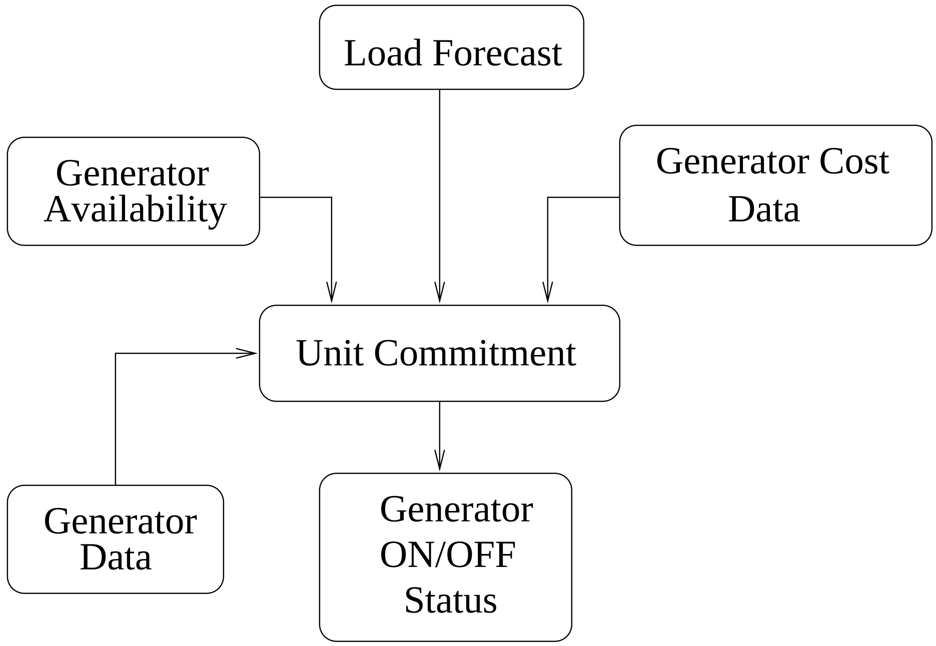


Figure 3.1: Structure of Unit Commitment Solution

to determine the unit commitment schedule and then to determine economic generation schedule based on the unit commitment schedule.

The unit commitment program determines the economically optimized combinations of generators to be committed to supplying the system throughout the 24 hour period for a given forecasted daily load curve. The structure of the solution process is shown in Fig. 3.1.

Economic generation of the committed generators can be determined in the next stage to minimize the cost of production over the entire period of operation of the system. This can be done apriori or in real time during the actual operation of the system. The structure of the solution process is shown in Fig. 3.2.

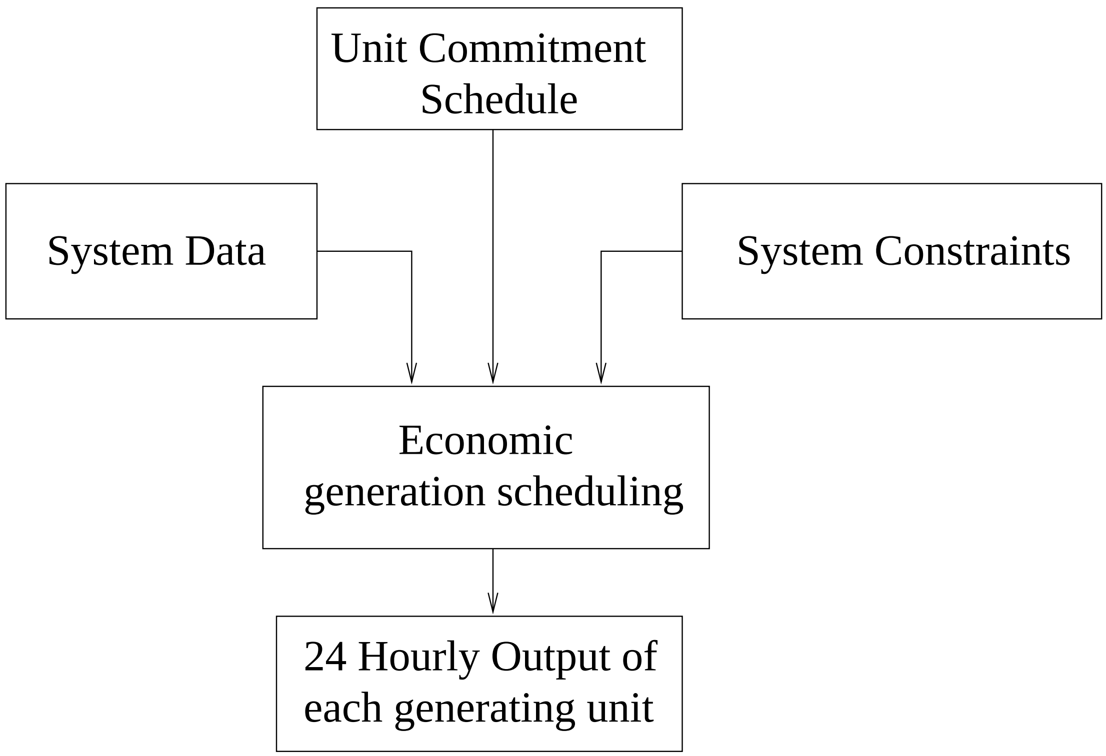


Figure 3.2: Economic Scheduling Program

3.2 Unit Commitment Schedule

A unit commitment schedule is a list of the electrical power generating units that are going to be involved in supplying the load demand for the time interval for which the schedule is prepared. The list is prepared for every hour or for every half-an-hour for the entire 24-hour periods of the day. The objective is to achieve economy of operation within all the constraints incident on the entire system.

The Unit Commitment schedule is part of the operational planning strategy. It is normally prepared in advance and the information is sent to the operators of different power plants so that they are prepared for meeting the expected load demand during the interval for which the schedule has been prepared. Normally, the schedule is done for a 24-hour period.

The satisfactory operation of an interconnected power system involves considerations of various constraints such as economy of operation system security, supply reliability, availability of primary energy at thermal and hydro plants, inter-zonal power and energy transfer contracts, reserve requirement and the total demands on the system. Quite often these constraints lead to conflicting requirement and a compromise is the ultimate solution.

Suppose a power system despatch engineer has to prepare his power plants and the network for supplying the load demand for the next 24 hours. He has to arrive at a solutions within all constraints and inform all the power plant engineers about how to schedule the generators under their control during the 24 hour period. This is in essence Unit Commitment(UC) scheduling problem. In this chapter a detailed description will be given about how to use the UC program available in this package and how to use the results.

3.2.1 Scheduling Constraints

Unit Commitment is a constrained optimization problem. A solution has to be found within various constraints. The first thing the despatch engineer requires is a forecasted Daily Load Curve for the 24-hour period. The short range forecasting principles are described in another chapter. Assuming that a predicted load curve is available, the engineer has to consider the following constraints:

* **Electrical network constraints**

* **Spinning reserve requirement**

* **Zone-wise reserve requirement, if any**

* **Inter Zonal transaction contracts, if any**

* **Time segment of hydro availability, if any**

All these constraints are also functions of time, in some cases varying continuously, in others at discrete time intervals. There are times when satisfying all the constraints may not be possible. In those cases prioritization of the constraints is also an important task in the scheduling process.

3.3 Input Data for Unit Commitment

A large volume of data are required for carrying out a Unit Commitment schedule. Some of the data are available in the 'filename.pdt' and 'filename.pdg' files. Other data as described below are to be supplied in the form of two other data files:

1. **filename.pdu**

2. **filename.pdl**

where filename is the name of the file describing the system.

3.3.1 File Structure

I. Generator Cost Data **filename.pdu**

The 'filename.pdu' file consists of four groups of data records. The first two groups describes the generator cost characteristics. The next two sets presents generator operational characteristics.

The cost characteristics are of the nature:

$$C_i = a_i.P_{Gi}^2 + b_i.P_{Gi} + c_i$$

where C= cost of generation in Rupees per hour
a b c are cost coefficients
P_{Gi} MW output of the ith generator

A. First Record (one column):

Total number of cost types.

B. Second Record (for each cost type, three columns)

a b c

There are as many rows as there are cost types.

C. Third Record (For each generator, 9 columns)

1. Sl No.
2. Bus Code
3. Generator Type:

```
thermal   = 0
hydro     = 1
gas       = 2
nuclear   = 3
```

4. Generator use type:

```
Base-committed plants = 0
Schedulable units     = 1
Peaking units         = 2
Unavailable           = 3
```

5. Generator start-up time(hr)
6. Generator shutdown time(hr)
7. Generator start-up cost(Rs)
8. Generator shutdown cost(Rs)
9. Number of starting slot(if any)

D. Fourth Record(For each starting slot, two columns)

1. Starting up time(hr)
2. Shutdown time(hr)

Time is shown in 24 hour time period. Hr 1 starts from midnight.
There are as many rows as the number of slots.

3.3.1.1 Sample data for filename.pdu

A few lines of a data file is shown below as an example.

A. First Record (one column):

6

B. Second Record (for each cost type, three columns)

```
0.0     0.0       0.0
0.01   40.0   15000.0
0.01   58.0   10000.0
0.01   80.0    7000.0
```

```
0.01   91.0    4000.0
0.01   128.0   5000.0
```

C. Third Record (For each generator, 9 columns)

```
 1   8020       0       1       5    2   800000.0   300000.0    0
 2   8020       0       1       5    2   800000.0   300000.0    0
 3   8020       0       1       5    2   800000.0   300000.0    0
 4   8020       0       1       5    2   800000.0   300000.0    0
 5   3008       0       1       5    2   800000.0   300000.0    0
 6   3008       0       1       5    2   800000.0   300000.0    0
 7   3008       0       1       5    2   800000.0   300000.0    0
 8   3008       0       1       5    2   800000.0   300000.0    2
```

D. Fourth Record for 3008(For each starting slot, two columns)

```
          10   13
          17   21
 9   8016       1       0       0    0     5000.0     1000.0    0
```

This indicates that the generator at busbar code 3008 has two starting slots, one between 10 and 13 hours and the other between 17 and 21 hours.

II. Daily Load Data **filename.pdl**

The 'filename.pdl' contains 24 hourly load data for the entire system, for different zones and 24 hourly exchange from or to different zones.

A. First Record: Total system load data(one column)

24 hourly entries(24 rows)

B. Second Record: Total number of zones(one column)

C. Third Record: Zone-wise load data (9 column maximum)

lz1, lz2, lz3, lz4, lz5, lz6, lz7, lz8, lz9

where: lz1 = Load of zone 1

24 hourly entries(24 rows)

D. Fourth Record:Zone-wise exchange data (9 column maximum)

lzx1,lzx2,lzx3,lzx4,lzx5,lzx6,lzx7,lzx8,lzx9

24 hourly entries(24 rows)

```
where: lzx1 = Power flowing into or out of zone 1
              (Positive value means flow out of the zone
               Negative value means flow into the zone)
```

3.3.1.2 Sample data for filename.pdl

A few lines of a data file is shown below as an example.

A. First Record (one column):

```
15085.000000
14978.000000
14860.000000
15066.000000
15935.000000
15454.000000
15447.000000
14339.000000
14263.000000
14500.000000
14529.000000
```

```
14339.000000
14926.000000
15076.000000
14159.000000
14165.000000
14110.000000
14740.000000
15703.000000
16620.000000
16519.000000
16270.000000
15607.000000
15346.000000
```

B. Second Record: Total number of zones(one column)

9

C. Third Record: Zone-wise load data (9 column maximum)

```
578.1  14.0 2843.6 1651.1 1777.1 2043.9 5821.4    0.0  355.4
574.0  13.9 2823.5 1639.4 1764.5 2029.4 5780.1    0.0  352.9
569.4  13.8 2801.2 1626.5 1750.6 2013.4 5734.6    0.0  350.1
577.3  14.0 2840.0 1649.0 1774.9 2041.3 5814.1    0.0  354.9
610.6  14.8 3003.9 1744.1 1877.2 2159.0 6149.2    0.0  375.4
 (only five sets out of 24 sets of data shown)
```

D. Fourth Record:Zone-wise exchange data (9 column maximum)

```
-492.3 1354.8 -1261.4 -1120.7 -1332.7 -1180.2 -2741.6 7082.4 -218.2
-488.8 1345.2 -1252.4 -1112.8 -1323.3 -1171.8 -2722.1 7032.1 -216.7
```

```
-484.9 1334.6 -1242.6 -1104.0 -1312.9 -1162.6 -2700.7 6976.7 -215.8
-491.2 1353.1 -1259.8 -1119.3 -1331.1 -1178.7 -2738.1 7073.5 -217.9
-520.0 1431.2 -1332.5 -1183.9 -1407.8 -1246.7 -2896.1 7481.5 -230.5
  (only five sets out of 24 sets of data shown)

Here negative sign indicates power is being received and
positive sign indicates power is delivered to other zones.
```

3.4 Procedure for Running Unit Commitment

Before running the program one has to make sure that the following data files are available to the program. For example, for the SAMPLE2 system the following files are essential apart from the diagram drawing data file, SAMPLE2.pdr.

For running the program take the cursor to the Simulation Menu and from there select 'Off Line' study button. Among the many options for off line studies take the cursor to the 'Economic Load Despatch' option and press the left mouse button. The program will be run and results will be presented as explained in next section.

- SAMPLE2.pdt
- SAMPLE2.out
- SAMPLE2.pdg
- SAMPLE2.pdd
- SAMPLE2.pdu
- SAMPLE2.pdl

3.4.1 Output Results of Unit Commitment

Chapter 4

Short Circuit Studies of Power System

This Chapter describes how to carry out short circuit studies of an electrical power system through the 'POWERDRAW' graphical user interface in off-line mode.

4.1 Introduction

Short Circuit Analyses of electrical power systems network is an important requirement for both planning and operational purposes of power systems. It is essentially a static analysis to the network and the solution provides the system conditions immediately after the disturbance has taken place.

At the planning stage short circuit studies are required for determining the ratings of the circuit breakers and also for assessing the severity to which transmission lines and other equipment will be subjected to.

During system operation, the state of the system continually changes because of the random nature of the load variation. In a situation of this nature it is necessary to regularly adjust relay settings for system protection purposes. For doing so it is imperative to carry out short circuit studies for different operating states of the system.

4.1.1 Types of Faults

In an electrical power network the following types of faults can take place.While carrying out the short circuit studies the operator can select any one of them in terms of their identifying numbers as shown against different types of faults.

```
Type of fault            identifying number
*************            ******************

 SINGLE LINE TO GROUND FAULT       1

 LINE TO LINE  FAULT               2

 THREE PHASE FAULT                 3

 DOUBLE LINE TO GROUND FAULT       4

 ONE OPEN-CONDUCTOR FAULT          5

 TWO OPEN-CONDUCTOR FAULT          6
```

The fault can be applied at any busbar in the system. After the solution, all the three different phase-voltages and phase-currents are displayed in the display windows as explained later.

4.2 Starting of Short Circuit Studies

For carrying out the short circuit studies, the single line diagram of the system along with the following data files should be available.

Filename.pdr

Filename.pdt

Filename.pdg

To get the 'POWERDRAW' GUI into the screen give the command:

powerdraw

Immediately the POWERDRAW main window appears on the screen. Then using the 'Open' option of the 'File' Menu open the network system for which studies are to be done.

4.2.1 Base Case Load Flow

As mentioned earlier, all off line studies starts by carrying out the base case load flow of the system with data available in the Filename.pdt file.

Suppose the system available on the screen is the same 5-Bus Sample Power System shown in Fig.3.5. Now to carry out the base case load flow, place the cursor on the

Simulation

of the Main Menu Bar and press the left mouse button. Then to get the pulldown menu bar with all the options press

Off Line

This dialog box offers several study options from which select:

Short Circuit Study

Instantly, a new window with the same system diagram but with the load flow solution of the system appears on top of the main window. This is shown in Fig. 6.1.

4.2.1.1 Viewing the results

In the new window the voltage magnitude of all the bus bars after the conversed solution is shown.

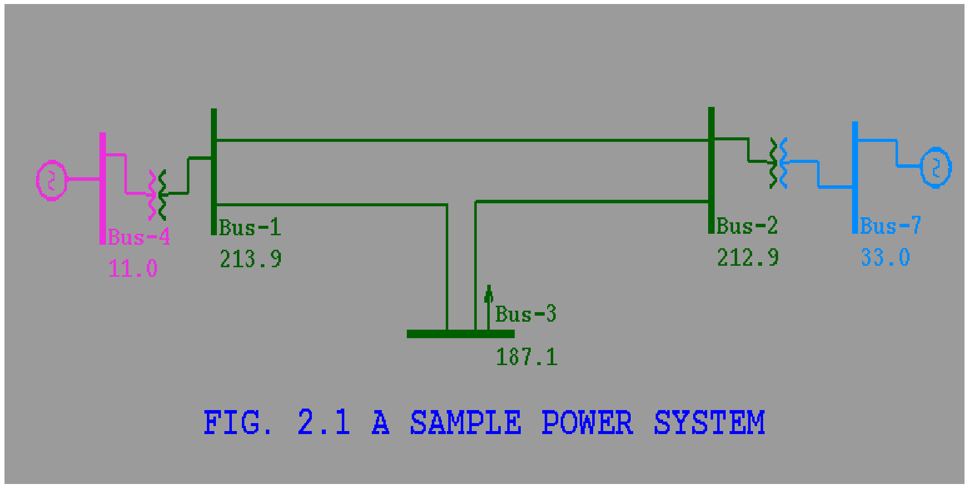


Figure 4.1: Display of Basecase Loadflow Solution

For viewing other details of a busbar place the cursor on the bus whose details are to be displayed and press the left mouse button.

The same dialog box through which data were supplied appears with all the details about load and generation on that busbar.

For viewing the line flow place the cursor on the feeder and again press the left mouse button to get the details about the flow through the line and other information.

In fact all the result available in this window are the same as in the case of the 'Operator Load Flow'.

Viewing the phase quantities

For short circuit study even for the base case solution it is possible to display the phase variables such as phase voltages and phase currents flowing through the lines. For this take the cursor to the busbar or to the line for which display is required and then press the MIDDLE mouse button. For a busbar the phase voltages will be be shown as in Fig. 4.6. For transmission lines and transformers phase currents will be shown as in Fig. 4.7.

Search option The 'Search' tool in the main window is also available in the Base-Case Load Flow window. To use this tool place the cursor anywhere in this window and press the right mouse button when a pop-up menu with the 'Search' and 'Buscode On/Off' options appear on the window. Keeping the mouse button pressed, drag it to the option 'Search' and then release the button. Then the dialog box 'Search a Busbar' appears on the screen. In this window the busbars are arranged in alphabetical order only. When you click on any busbar name with the left mouse button, the single line diagram is shifted in such a way that the desired busbar comes at the middle of the child window.

Buscode On/Off To use the 'Buscode On/Off' option take the cursor to this option and press the left mouse button. Instantly, the bus codes will be displayed on all the busbars. If you press the button again, bus codes will disappear.

4.2.2 Initiation of a Short Circuit Study

Before short circuit study can be carried out certain data are to be provided. For this purpose another child window appears on the screen along with the base case load flow solutions. This Dialog Box is shown in Fig. 4.2.

This Dialog Box has the following options:

Select a Type of Fault

Specify Output file Name

The default filename is also shown at the bottom.

4.2.3 Functions of PushButtons

This Dialog Box has the following PushButtons at the bottom of the Box and a File Selection Box for providing the name of the output file for saving the results of the study.

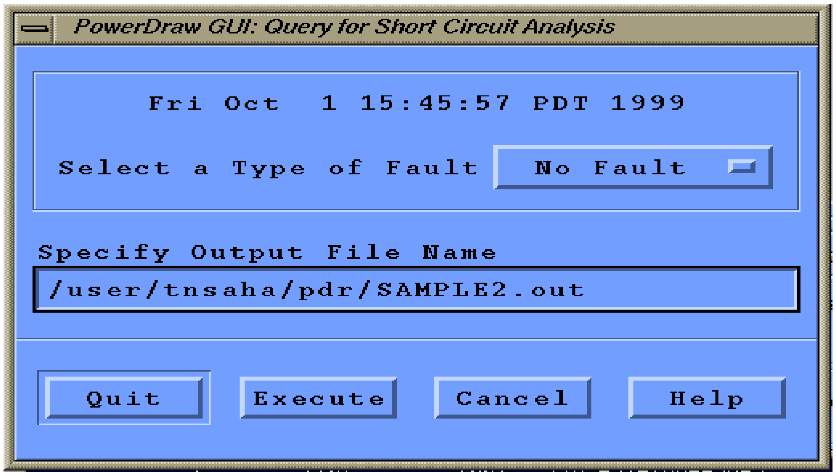


Figure 4.2: Query for Short Circuit Study

Quit When you press this button, you are discontinuing the present case study.

Execute Pressing this button will execute the present case study with all the data provided as explained below.

Cancel This command ignores all the data provided for carrying the transient stability study.

Help This button,when activated, will bring the 'Help' information in a separate window.

4.3 Initiation of a Fault

In the Dialog Box 'Query for Short Circuit Study' there is an option 'Select a Type of Fault'. Against this a Pushbutton shows a default status 'No Fault'. When you take the cursor to this button and press the left mouse button, it shows all the six types as explained earlier. You can select any one of these. As soon as you have selected any one of them, a new Dialog Box appears

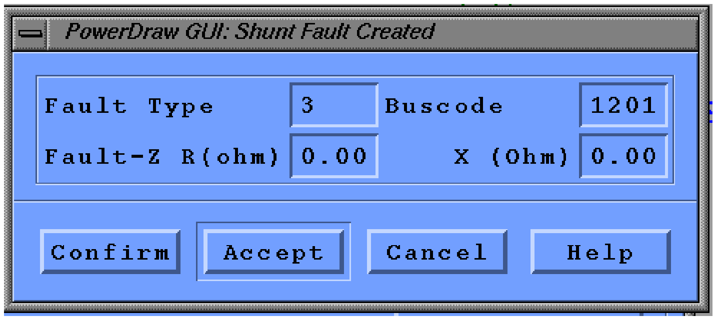


Figure 4.3: Query for Shunt Fault Details

for providing other details of the fault conditions as shown in Fig. 4.3 or in Fig. 4.4 depending on whether it is a shunt fault or a series fault.

To provide the details of the busbar where the fault is to be applied, take the cursor to the busbar and press the left mouse button. The corresponding busbar details will be shown in the window along with zero fault impedance as default values. you can change these values by new values in per unit. After that press the 'Accept' button and then the 'Confirm' button when the window will disappear.

To provide the details of the line where the series fault is to be applied, take the cursor to the line and press the left mouse button. The details will be registered in the fault initiation box. After that press the 'Accept' button and then the 'Confirm' button when the window will disappear.

If, by mistake, you have given wrong busbar details and you want to change them, press the 'Cancel' button in the fault initiation box when the window will disappear. Then go to the 'Query for Short Circuit Study' window and start afresh.

4.4 Running the Short Circuit Program

After supplying all the necessary data you are ready for running the short circuit program. For doing so take the cursor to the 'Query for Short Circuit

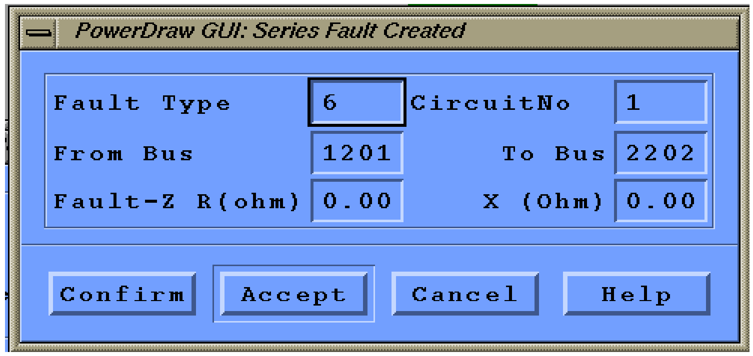


Figure 4.4: Query for Series Fault Details

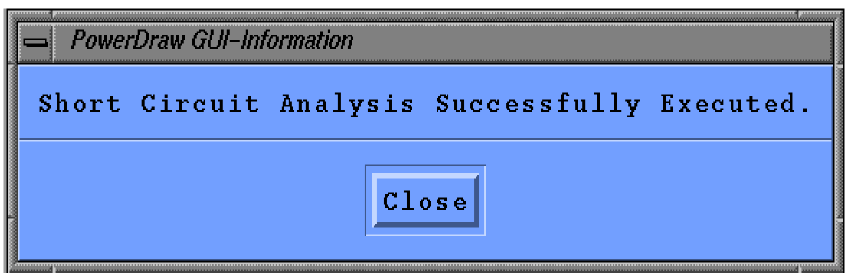


Figure 4.5: Display of Successful Execution

Analysis' window and press the 'Execute' button. The program will be run and a small window will display that 'Short Circuit Analysis Successfully Executed' as shown in Fig. 4.5. 'Close' this window and you are now ready for visualysing the results.

4.4.1 Displaying the phase variable

The three phase busbar voltages and the currents in the three phases of a transmission line and or transformers after the fault has taken place can be seen. For viewing the phase variables you follow the same procedure as in the case of unfaulted system but use the MIDDLE mouse button. For example,

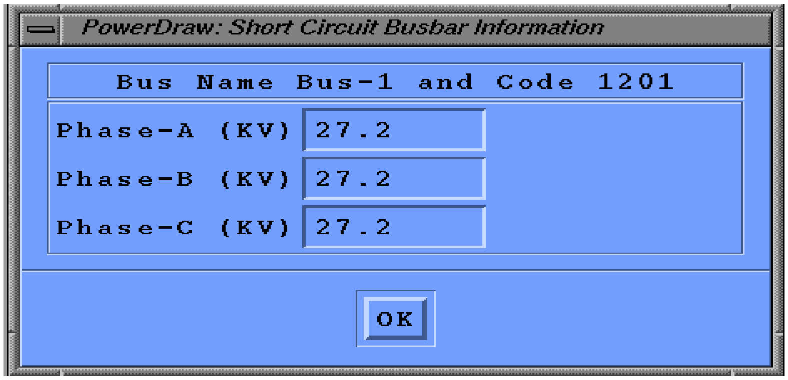


Figure 4.6: Phase Voltage Display

take the cursor to a busbar and press the middle button when the voltages in the three phases will be displayed. If you, instead, press the left mouse button, the results of the base case load flow studies will be displayed.

If you want to clear any one of these windows press the 'OK' button at the bottom of the window.

4.4.2 Repeating Short Circuit Studies

You can carry out short circuit studies repetitively with out coming out of the process. For doing so follow the steps mentioned below:

Step 1 Go to the 'Select a type of Fault' option and press the 'Type - 1' radio button to input the type of fault.

Step 2 Take the cursor to the busbar at which shunt fault is to be applied or to the transmission line where series fault is to be applied. Then press the left mouse button to input the fault details. The default fault impedances can be modified as explained earlier.

Step 3 Press the 'Accept' and 'Confirm' buttons in this window.

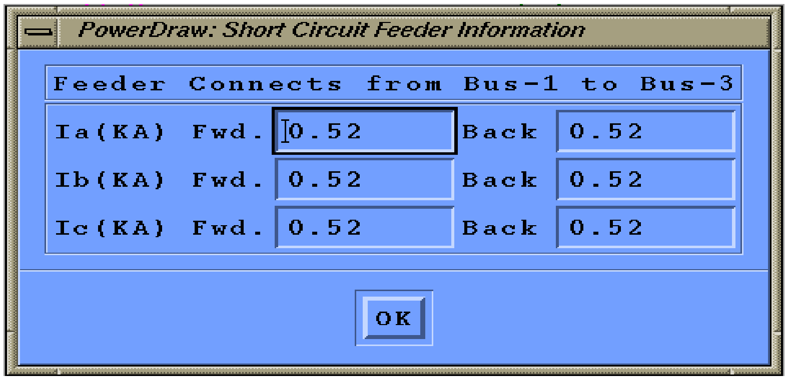


Figure 4.7: Phase Current Display

Step 4 Go to the 'Query for Short Circuit Study' Dialog Box and press the button 'Execute' with left mouse button. The program will be executed.

Chapter 5

Transient Stability Studies

5.1 Introduction

Transient Stability Analyses fall under the category of large disturbance studies which are required for both system planning purposes as well as for creating system operation strategies. It is essential to analyses in advance whether a system under certain contingencies is going to return to a stable operating condition after the transients have died down.

Following a large disturbance the rotor angles, rotor-speeds and accelerations of all the generating units, electrical power outputs of he generators, bus voltages- in fact the entire state of the system get disturbed. Depending on the electrical distances, different units are affected to different extent.

Automatic excitation control systems(AVR) have pronounced effect on the transient stability of a system, both in extending the stability limit as well as damping the oscillations of the system. It is possible to carry out transient stability studies with or without the presence of AVRs attached to different generating units. IEEE standard AVR models are available to be attached to different generating units. This is done in the **Filename.pdg** file.

For the purpose of this electro mechanical transient analyses comprehensive modeling of the power network and all the components connected to it are necessary. The modeling descriptions are given in the Technical manual.

In this program it is possible to:

Application of Faults Apply one or more faults, sequentially or simultaneously at any substation(s)

Clear the faults You can clear the fault(s) by removing faulted line(s) after desired time interval

Reclose the line The faulted line may be, if desired, reclosed after the fault is cleared.

The faults can be symmetrical or asymmetrical and can be applied at any time when the system is operating
(i) in real time or
(ii) as part of an off-line study

The transient analysis can be carried out for any length of time, but a time period of five seconds is normally sufficient to observe the trend of the system behavior.

There are options to plot the transient response of the following quantities in graphical form for the duration of the solution:

Generator rotor angle

Generator electric power output

Voltage magnitude at a busbar

Frequency variation at a busbar

Impedance seen by a distance relay

In each plot it is possible to include as many equipment as desired for the purpose of monitoring the response of their output. However, plotting too many graphs in the same window makes the presentation clumsy.

5.2 Initiation of Transient Stability Studies

For carrying out the transient stability studies, the single line diagram of the system along with the following data files should be available.

Filename.pdr

Filename.pdt

Filename.pdg

To get the 'POWERDRAW' GUI into the screen give the command:

powerdraw

Immediately the POWERDRAW main window appears on the screen. Then using the 'Open' option of the 'File' Menu open the network system for which studies are to be done.

5.2.1 Base Case Load Flow

Suppose the system available on the screen is the same 5-Bus Sample Power System shown in Fig.3.5. Now to carry out the base case load flow, place the cursor on the

Simulation

of the Main Menu Bar and press the left mouse button. Then to get the pulldown menu bar with all the options press

Off Line

This dialog box offers several study options from which select:

tRansient Stability Study

Instantly a new window with the same system diagram but with the load flow solution of the system appears on top of the main window. This is shown in Fig. 6.1.

In the new window the voltage magnitudes of all the bus bars after the conversed solution are shown.

For viewing other details of a busbar place the cursor on the bus whose details are to be displayed and press the left mouse button.

The same dialog box through which data were supplied appears with all the details about load and generation on that busbar.

For viewing the line flow place the cursor on the feeder and again press the left mouse button to get the details about the flow through the line and other information.

The 'Search' tool in the main window is also available in the Base Case Load Flow window. To use this tool place the cursor anywhere in this window and press the right mouse button when a pop-up menu with the 'Search' option appears on the window. Keeping the mouse button pressed drag it to the option 'Search' and then release the button. Then the dialog box 'Search a Busbar' appears on the screen. In this window the busbars are arranged in alphabetical order only. When you click on any busbar name with the left mouse button, the single line diagram is shifted in such a way that the desired busbar comes at the middle of the child window.

5.2.2 Data for Transient Stability Study

Before transient stability study can be carried out certain data are to be provided. For this purpose another child window appears on the screen along with the base case load flow solutions. This Dialog Box is shown in Fig. 5.1.

This Dialog Box has the following options:

Initiation of a Fault

Back to Base Case

Display Results in Text Mode

Save Current Case Study

Display Scenario

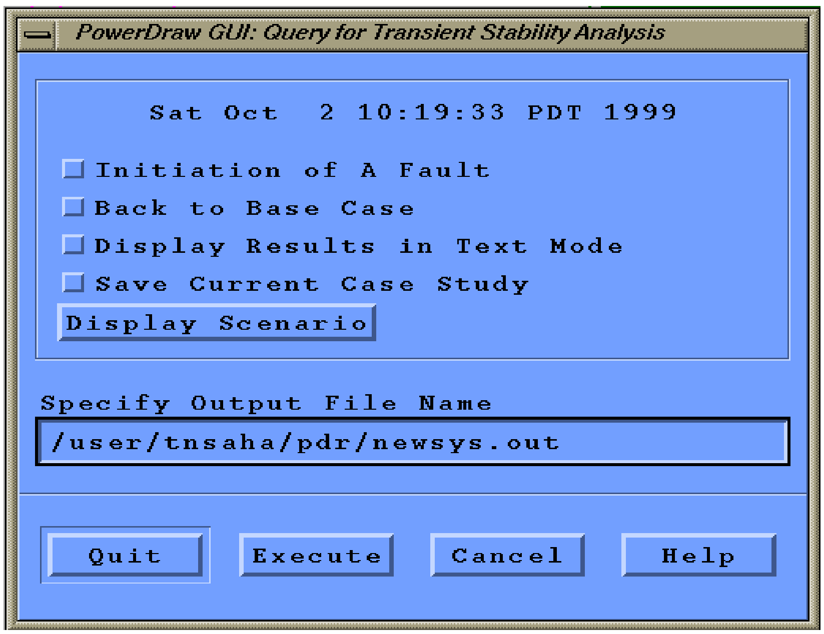


Figure 5.1: Query for Transient Stability Analysis

5.2.3 Functions of PushButtons

This Dialog Box has the following PushButtons at the bottom of the Box and a File Selection Box for providing the name of the output file for saving the results of the study.

Quit When you press this button, you are discontinuing the present case study.

Execute Pressing this button will execute the present case study with all the data provided as explained below.

Cancel This command ignores all the data provided for carrying the transient stability study.

Help This button,when activated, will bring the 'Help' information in a separate window.

5.3 Initiation of a Fault

When you press this option, a new Dialog Box appears for supplying all the information for the case study. This window is shown in Fig. 5.2.

This Dialog Box has nine data fields and six 'Add' fields. For each fault data fields are to be supplied with data only once. The 'Add' fields can accept more than one data for each fault as explained below. The default value in the 'Total Faults' field is zero because no data has so far been supplied.

There are five PushButtons at the bottom of the window for manipulating the data. The functions of these are also described below.

5.3.1 Data Items

Through this Dialog Box you can provide all the data for carrying out a transient stability case study. Following data are to be provided:

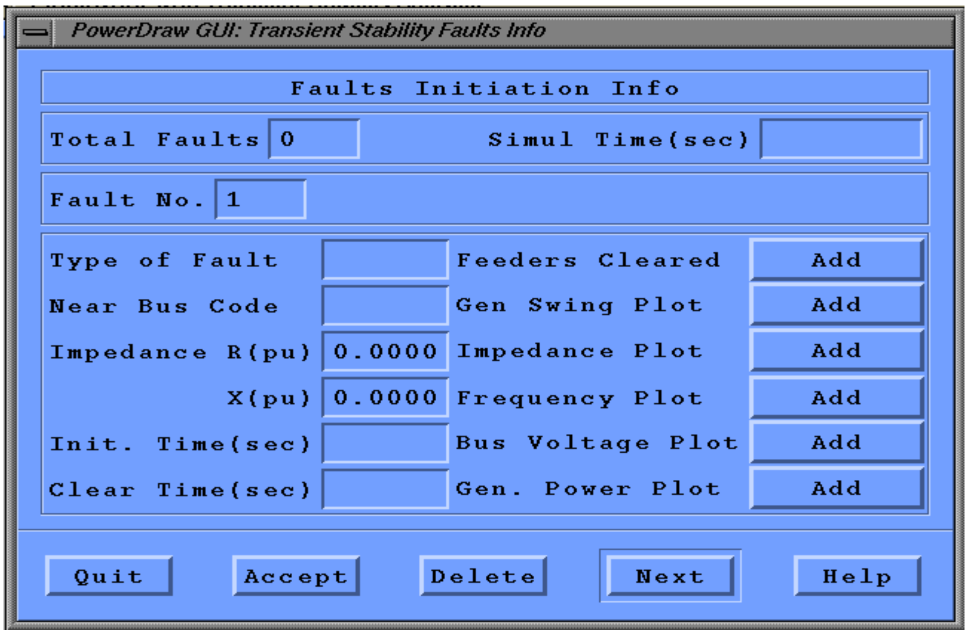


Figure 5.2: Transient Stability Fault Information

Total Faults This information will be generated by the GUI after you have entered all other data in the Box. The default value of zero gets modified as data for each fault are supplied.

Simulation Time(sec) Here you enter the time period for which you want to carry out the study. Normally, three to five seconds are enough.

Fault No. 1 This data is also generated by the GUI. All the data that will be entered in the rest of the data fields will be stored for the first fault when a study with multiple faults will be studied.

Type of Fault Several types of faults can be applied at any one particular location. Fault types and their identifiers are as follows:

```
Three phase symmetrical fault          3
Single line to ground fault            1
Line to line fault                     2
```

You have to enter the correct identifier for this particular fault.

Near Bus Code You have to enter the code number of the busbar near which fault is to be applied. Taking the cursor to a particular busbar and clicking the mouse button is not acceptable in this case.

Impedance R(pu) Here you enter the resistive component of the fault impedance, if any.

X(pu) Here you enter the reactance component of the fault impedance, if any.

Init. Time(sec) The fault can be initiated at any time during the simulation time period. If it is delayed by a certain time period, the solution for the delayed period will be steady state without any variation of the system variables. Normally delaying the solution by 0,1 second is convenient to check the numerical stability of the solution.

Clear Time(sec) This is the time for clearing the fault. Faults may be permanent or temporary. Most of the faults in an electrical power network are of temporary in nature. The stability of a power system quite often depend on whether the fault is temporary in nature and whether the faulty part of the system can be cleared successfully by circuit breaker operation. Clearing time is directly related to the circuit breaker operating time. A knowledge of the circuit breaker operating characteristics is essential in entering the data.

Feeders Cleared If the fault is on a busbar it may be necessary to clear the fault by removing several feeders. On the other hand a fault on a transmission line or a transformer can be removed by removing one transmission line or a transformer. For transient stability study generally a Bus Fault is simulated by initiating a fault on a feeder or a transformer very close to the busbar assuming that it is electrically equivalent to a fault on the busbar. However, in this GUI scope has been provided to clear more that one line to clear the fault.

When you press the 'Add Field' a new Dialog Box appears as shown in Fig. 5.3. To supply data for this window take the cursor to the feeder to be cleared and press the left mouse button. Instantly data for this feeder is entered into the Dialog Box. If there is only one feeder to be cleared, take the cursor to the 'Quit' pushbutton and press. The window will then removed after accepting the data. In case you have more than one feeder to be cleared, then take the cursor to the button 'Add' and press. The window will be refreshed for accepting data for the Feeder number 2. This way you can supply data for as many feeders as you wish.

5.3.1.1 The functions of PushButtons

The Dialog Box as shown in Fig. 5.2 has the following five push buttons.

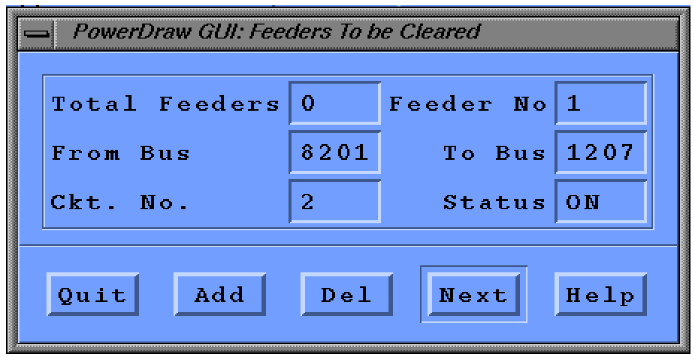


Figure 5.3: Information for feeder to be cleared

Quit Activating this button will terminate the process of supplying data in the current window.

Accept This button is to be used for saving the data for use in the stability program.

Delete You can delete all the entry displayed in the window by pressing this button.

Next By pressing this button you can see all the sets of data entered so far in this window.

Help This button,when activated, will bring the 'Help' information in a separate window.

If you are not interested in graphical display of results these data are sufficient for running the Transient Stability study. Output is normally written on a text output file. However, if you want the results to be graphically displayed then you have to supply additional data through the other 'Add fields' as shown in Fig. 5.2.

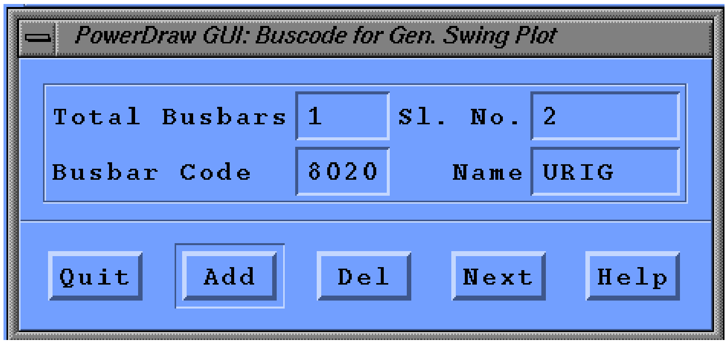


Figure 5.4: Information for generator swing plot

5.4 Data for Graphic Display of Results

For supplying data for plotting the variables as functions of time five sets of dialog boxes are available. These are described below.

5.4.1 Generator Swing Plot

This dialog box for entering the busbar information for which the plot is required is shown in Fig. 5.4.

It is IMPORTANT to note that this window will accept only the generating busbars for plotting.

For supplying the busbar names and the code numbers take the cursor to the generating busbar whose plot is required and press the left mouse button. Before entering additional busbar information press the 'Add' push button and then take the cursor to the concerned busbar for selecting it.You have to press the 'Add' push button after entering every new data. Finally, to come out of the window you have to press the 'Quit' button when the window disappear from the screen. But before that another small dialog box appears for inputting whether the rotor angle plots will be in absolute value or relative to another busbar angle. The default value is absolute angle, but you can change it to relative also. You have then to input the busbar code

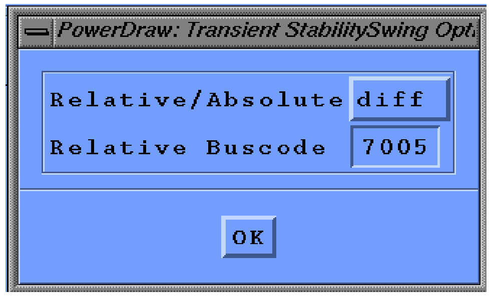


Figure 5.5: Data for Type of Rotor Angle Plot

with relative to which the plots should be made. Generally, rotor angles are plotted in absolute angles. But quite often they may be plotted relative to the slack busbar. The Dialog Box for inputting these information is shown in Fig. 5.5.

5.4.2 Impedance Plot of Lines and Feeders

Distance protections installed in high voltage transmission lines generally operate on the basis of impedance or its components 'seen' by the relay. During the transient period following large disturbances this impedance seen by the relay may encroach within the operating zone of the relay. It is, therefore, important that an estimate of the impedance seen by the relays on some selected feeders, particularly near the location of the disturbance is made.

In this program the impedance is measured at the 'From Bus' end of the lines.

The Dialog Box used for entering these data is shown in Fig. 5.6. To get the Dialog Box place the cursor on the 'Add' push button against item 'Impedance Plot'.

This window is similar to the one shown in Fig. 5.3. Data are also to be entered in the same way as explained for inputting data for feeder to be cleared.

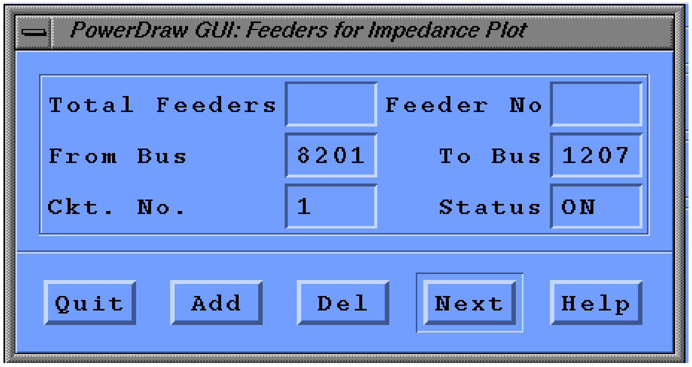


Figure 5.6: Information for impedance plot

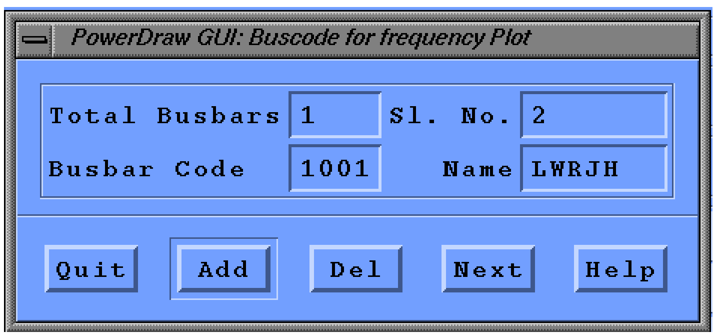


Figure 5.7: Information for frequency plot

5.4.3 Frequency Plot of Generating Busbars

During large disturbances theoretically the frequency of all the busbar will be varying. But it is the generating busbars whose frequency will be perturbed most from the rated frequency. Many generators are fitted with under- and over-frequency sensitive relays along with rate of frequency variation. To get a graphical plot of the frequency variation, data are to be entered through the Dialog Box as shown in Fig. 5.7.

Data are to be entered in the same way as that mentioned for Generator Swing Plot in Fig. 5.4. Only difference is that there is no restrictions on the

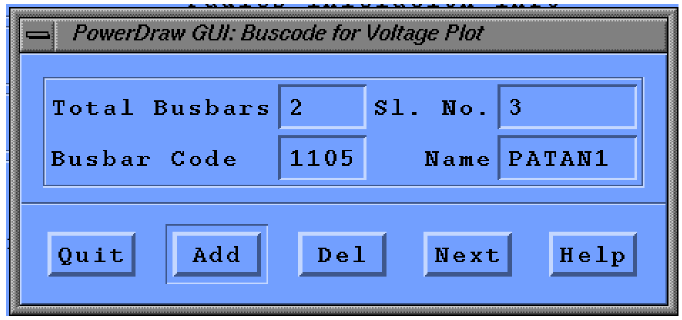


Figure 5.8: Information for busbar voltage plot

type of busbars that can be entered as in the case of swing plot.

5.4.4 Display of Busbar Voltage Magnitude

Busbar voltages undergo large variation during large disturbances. The effect on the voltage magnitude depends on the electrical distances of the busbar from the fault location.

The Dialog Box used for entering these data is shown in Fig. 5.8. To get the Dialog Box place the cursor on the 'Add' push button against item 'Bus Voltage Plot'.

Data are to be entered in the same way as that mentioned for Generator Swing Plot in Fig. 5.4. Only difference is that there is no restrictions on the type of busbars that can be entered as in the case of swing plot.

5.4.5 Display of Generator Power Output

Electrical power output of generating plants probably gets disturbed the most during a fault in the power network. The frequency and rotor angle variations are the direct result of this excursion of electrical power.

The Dialog Box used for entering these data is shown in Fig. 5.9. To get the Dialog Box place the cursor on the 'Add' push button against item 'Gen. Power Plot'.

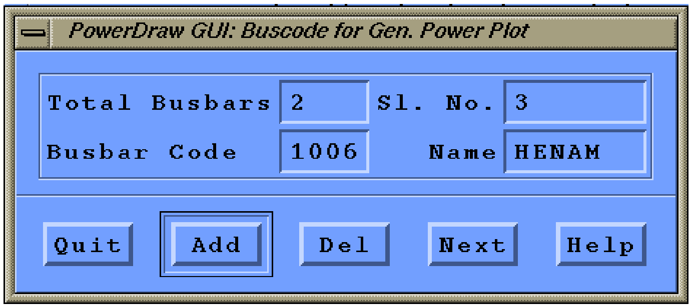


Figure 5.9: Information for generator power plot

Data are to be entered in the same way as that mentioned for Generator Swing Plot in Fig. ??. Here also you can enter only the generating busbar information. Other busbar data will not be accepted by the Dialog Box.

After entering all the data for Fault No. 1 take the cursor to the push-button 'Accept' and press the left mouse button. This means that all the data are accepted for use in the program. If you so desire, you can now enter data for the next fault and proceed in the same way as explained above.

5.4.6 Functions of PushButtons

All the 'Add' push button Dialog Boxes have five PushButtons for controlling the data entry. Their functions are described below.

Quit When you press this button, you are discontinuing the process of data entry. Whatever data have been entered will be saved for next activity.

Add This button is to be used for supplying data for more than one set of data. For example, after entering one set of data the window will be refreshed for the next set of data if you press the 'Add' button.

Del You can delete all the entry displayed in the window by pressing this button. You can then enter new data again.

Next By pressing this button you can see all the sets of data entered so far in this window one after another.

Help This button,when activated, will bring the 'Help' information in a separate window.

5.5 Execution of Transient Stability Study

After supplying all the necessary data through different Dialog Boxes as explained above you are ready for executing the transient stability program.

To run the program take the cursor to the Dialog Box as shown in Fig. 5.1. Then press the push button 'Execute' with the left mouse button. The program will be executed and all the results will be displayed graphically as described below.

5.5.1 Graphical Display of Results

The graphical display of results that will be presented in this section will be on the transient stability study carried out on the NREB system as shown in Fig. 5.10. A three-phase fault is created on the line between buses 8201 and 1207 close the WAGRA2. The fault is cleared by removing the this line 0.1 second after the fault inception. The transient variations of different quantities for a few seconds subsequent to the fault are shown here.

5.5.1.1 Generator swing plot

Generator swing plot in absolute angle is shown in Fig. 5.12.

For a larger system more number of angle-plots can be accommodated in the graph. The busbar codes for which the graphs are plotted are also mentioned on the right hand side for easy identification.

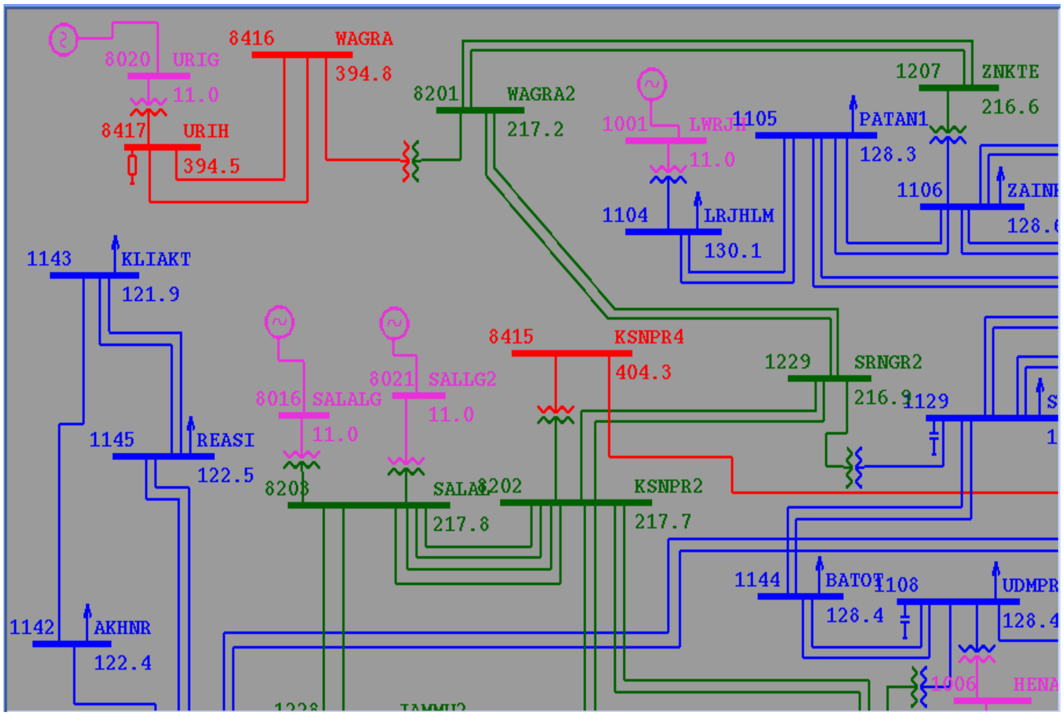


Figure 5.10: Part of the NREB System

At the end of the running of the job a display is shown that the program has been run successfully and the results are being displayed as shown in Fig. 5.11.

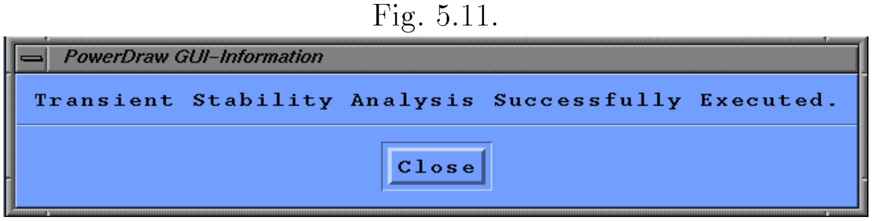


Figure 5.11: Successful Execution of Stability

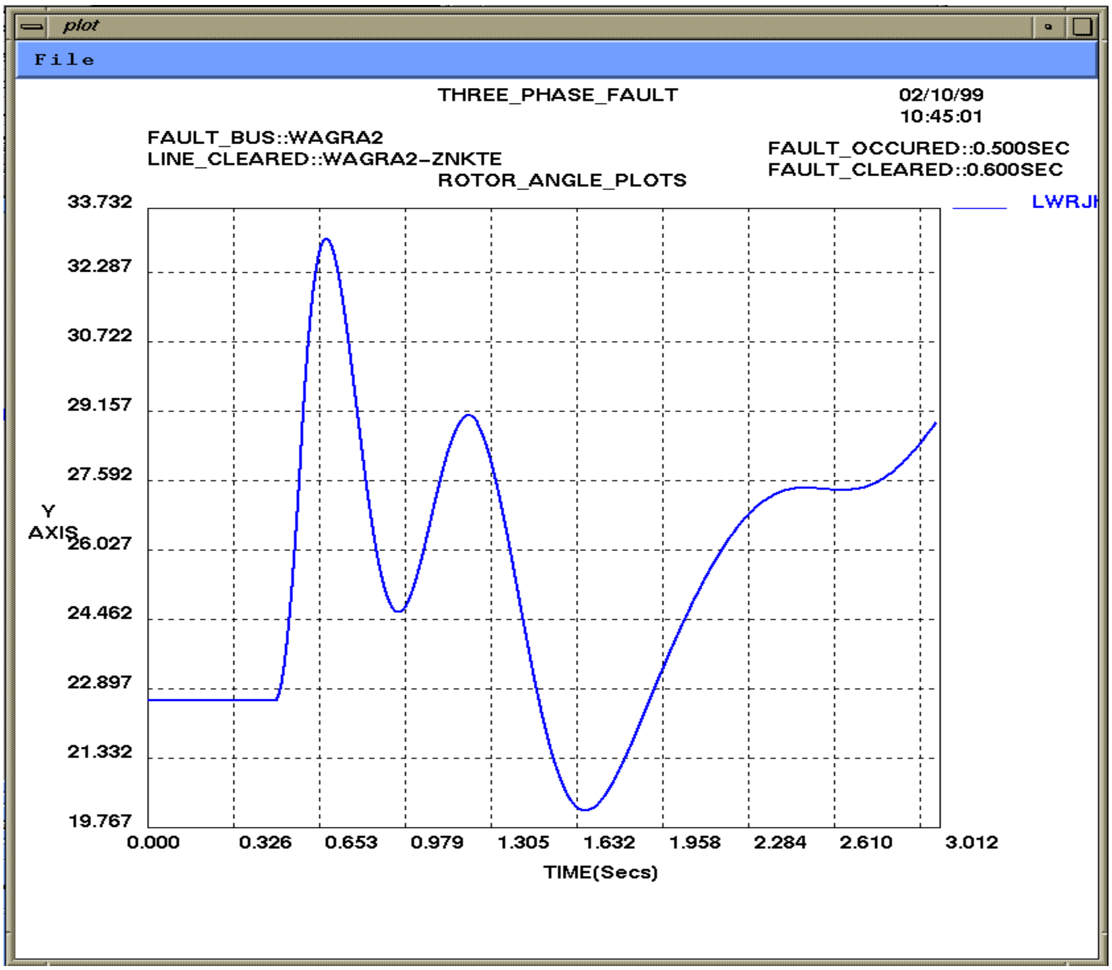


Figure 5.12: Rotor angle plot in absolute angle

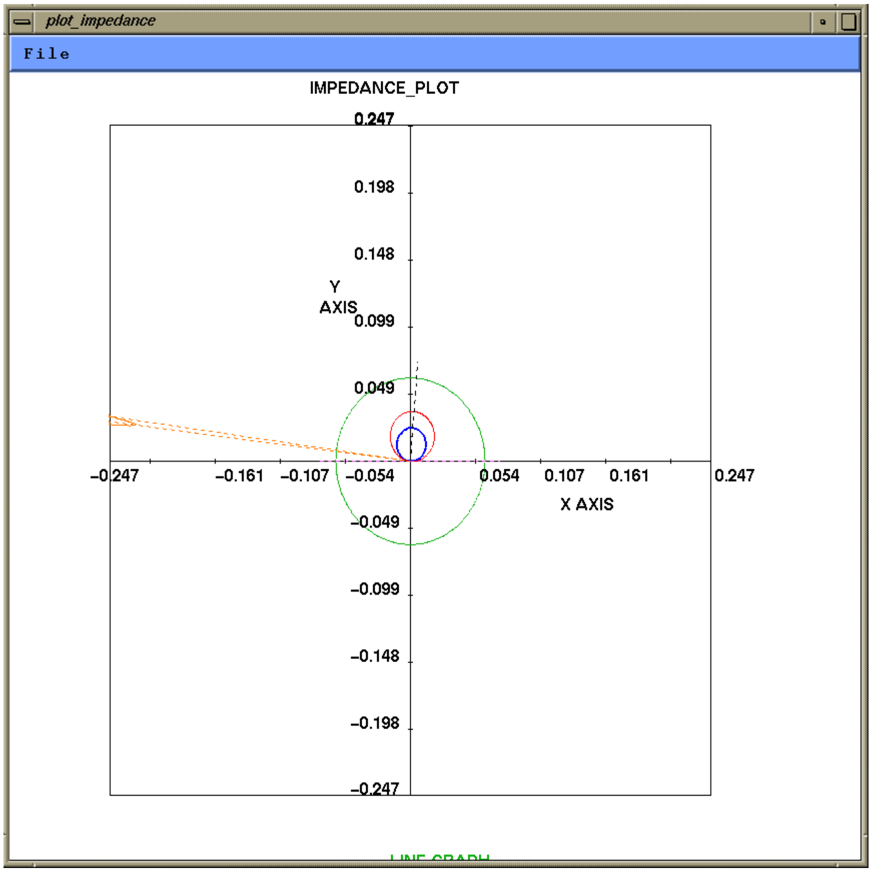


Figure 5.13: Impedance Seen by a Distance Relay

5.5.1.2 Impedance 'seen' by distance relays

Distance relays used for the protection of the transmission lines perform on the basis of impedance or some of its components 'seen' by the relays. During large disturbances impedance seen by any relay fluctuates over a wide range. In the Fig. 5.13 impedance 'seen' by the distance relay situated at the Bus-1 end of the feeder connecting Bus-1 and Bus-3 is shown.

5.5.1.3 Frequency Plot of Generating Busbars

The variation of frequency during the transient following the short circuit for the two generating busbars are shown in Fig. **??**.

5.5.1.4 Voltage Transient During Large Disturbance

The transient variation of voltages at the Bus-1, Bus-2 and Bus-3 are shown in Fig. 5.15 below.

5.5.1.5 Transient Power Output of Generators

Because of the topological changes and also other changes created by large disturbances the electrical power output of generators are subjected to large transient variation. For the sample system the bus voltage transients are shown in Fig. **??**

5.6 Further Studies

When it is required to carry out further studies creating faults at new locations or with different types of faults, you follow the steps given below:

Step 1 Press the 'Quit' push button in the 'Fault Initiation Info' dialog box with left mouse button. The dialog box will disappear.

Step 2 Press the 'Quit' push button in the 'Query for Transient Stability Analysis' dialog box with left mouse button. The dialog box will disappear.

Step 3 Take the cursor to the 'Simulation' menu in the main menu bar and press the left mouse button. A pop-up menu with the different off-line studies will appear as before.

Step 4 From there select the 'Transient Stability Study' option and proceed as before.

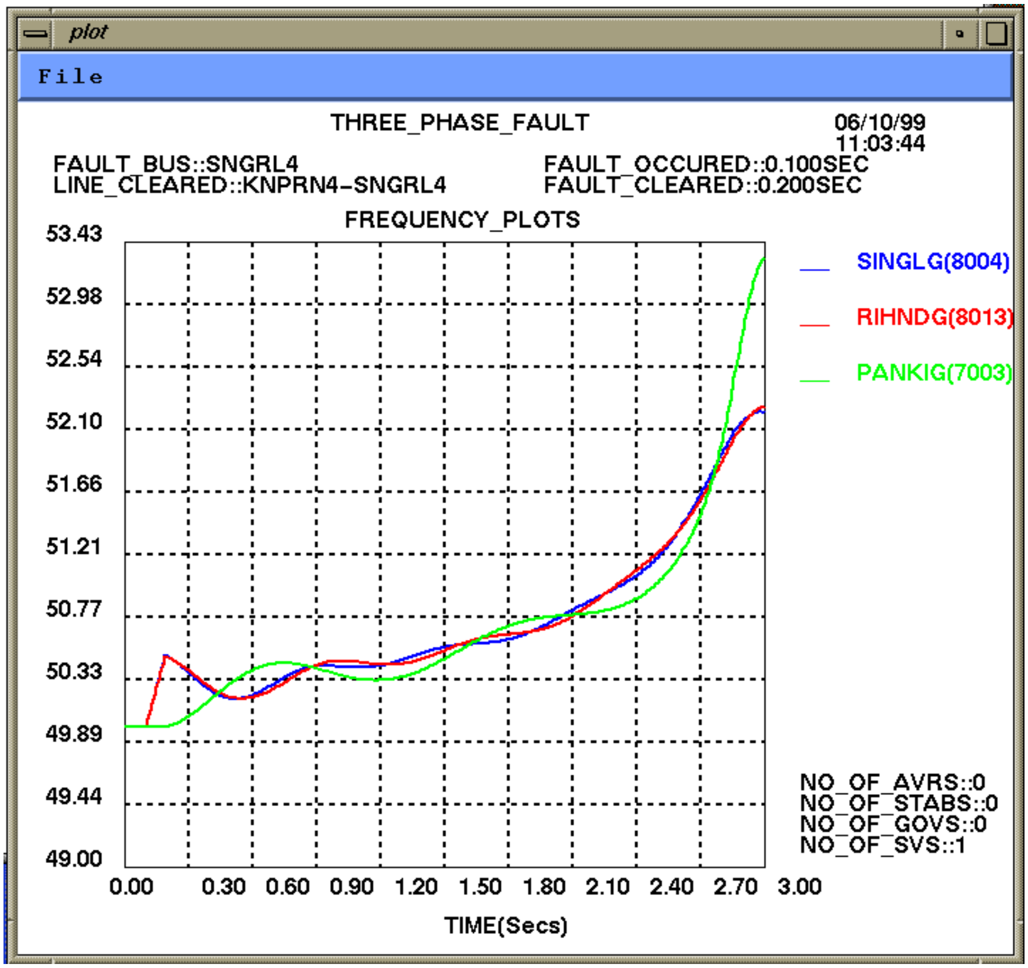


Figure 5.14: Frequency variation of generating buses

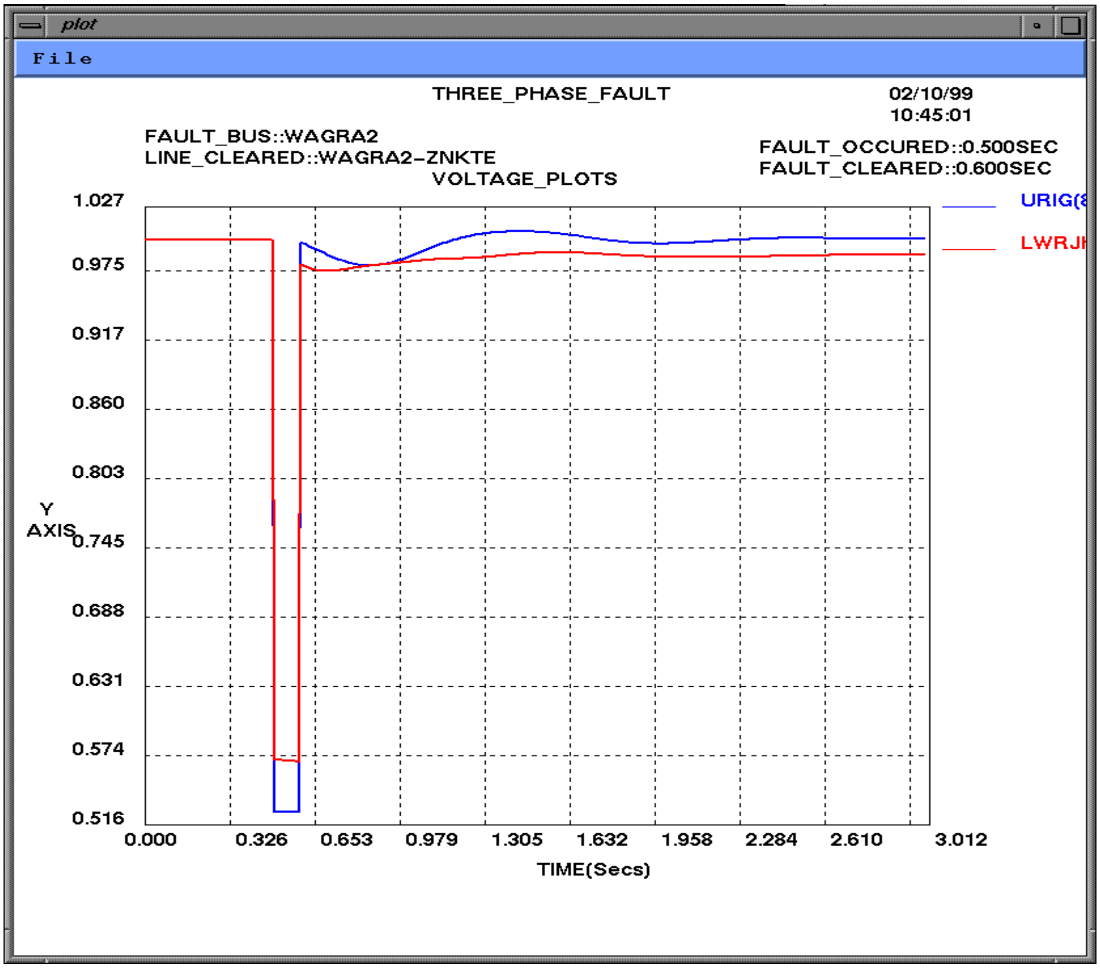


Figure 5.15: Transient Voltage Variation Display

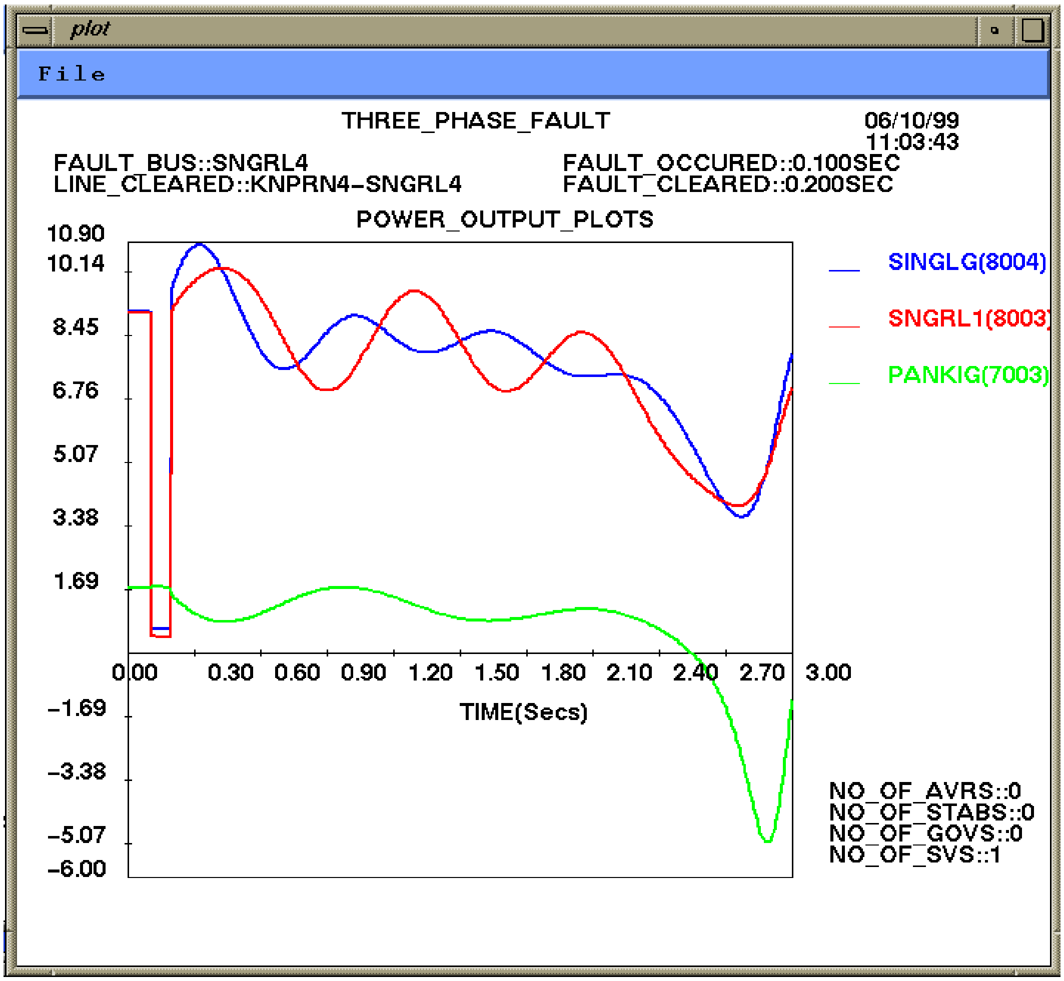


Figure 5.16: Transient Power Output of Generators

Chapter 6

Voltage Stability Analysis

6.1 Introduction

Voltage instability in power system has become a major concern in power system operation and planning. Voltage collapse is characterized by a slow variation in system operating point, due to increase in the loads, in such a way that the voltage magnitude gradually decreases until a sharp accelerated change occurs. The problem of voltage collapse may simply be explained as the inability of the power system to supply the reactive power or by an excessive absorption of reactive power by the system itself. It has been found that voltage magnitudes do not give a good indication of proximity to voltage stability limit. An effective voltage collapse proximity index which indicates how far the current operating condition is from voltage collapse and which buses are the most vulnerable ones will go a long way in helping power system operators in taking proper corrective action to prevent voltage collapse in the system.

6.1.1 Limiting Value of Stability Index

In this Chapter a voltage stability index which indicate the proximity of voltage collapse at a load bus are proposed. This voltage stability index is based on the fact that with increase in load at a load bus the value of diagonal elements of the load flow Jacobian matrix reduces. This reduction is quite considerable as the voltage collapse point is approached. The proposed index uses this change in value of diagonal elements of the Jacobian matrix with respect to the fast decoupled equivalent value corresponding to its no load condition. The proposed indices are very simple to compute as they are based on the load flow Jacobian matrix.

Both analysis and simulation show that at the point of collapse index becomes 0.5. Therefore, the threshold value for index can be taken as 0.5.

6.1.2 Determination of Load Margin

It is vary important to know the load margin of a load bus with respect to its voltage stability limit. As the voltage stability behavior is a non-linear phenomena, accurate prediction of load margin at a load bus based on its operating condition is a difficult task. In this algorithm a simple linearized method has been used for the determination of the limiting loading capacity of the busbar.

As the prediction is based on the linearized model, the critical load value is always around this predicted value at present operating point. Therefore, a corrective step is required to correct the predicted value of load margin at different operating operating point.

6.2 Base Case Load Flow

For the purpose of these studies it is assumed that the single line diagram for the system to be studied has already been drawn, data have been supplied and all the files have been 'Saved'.

To get the 'POWERDRAW' GUI into the screen give the command:

powerdraw

Immediately the POWERDRAW main window appears on the screen. Then using the 'Open' option of the 'File' Menu open the network system for which studies are to be done.

IT IS TO BE REMEMBERED THAT WHENEVER A SINGLE LINE DIGRAM IS OPENED IN THE DRAWING AREA THE FOLLOWING THREE FILES ARE AUTOMATICALLY OPENED BY THE GUI:

<filename.pdr> ... File for the network drawing

<filename.pdt> ... File for the network data

<filename.pdg> ... File for generator data

<filename.pdc> ... File for load curve data

<filename.pdl> ... File for load model data

where

filename is a user-defined file describing the system to be supplied by the user.

Now to carry out the base case load flow, place the cursor on the

Simulation

of the Main Menu Bar and press the left mouse button. Then to get the pull-down menu bar with all the options press

Off Line

This dialog box offers several study options from which select:

Voltage Stability Study

Instantly a new window with the same system diagram but with the base case load flow solution of the system appears on top of the main window. This is shown in Fig. 6.1.

6.2.1 Viewing the Load Flow Results

In the new window the voltage magnitudes of all the bus bars after the converged solution are shown.

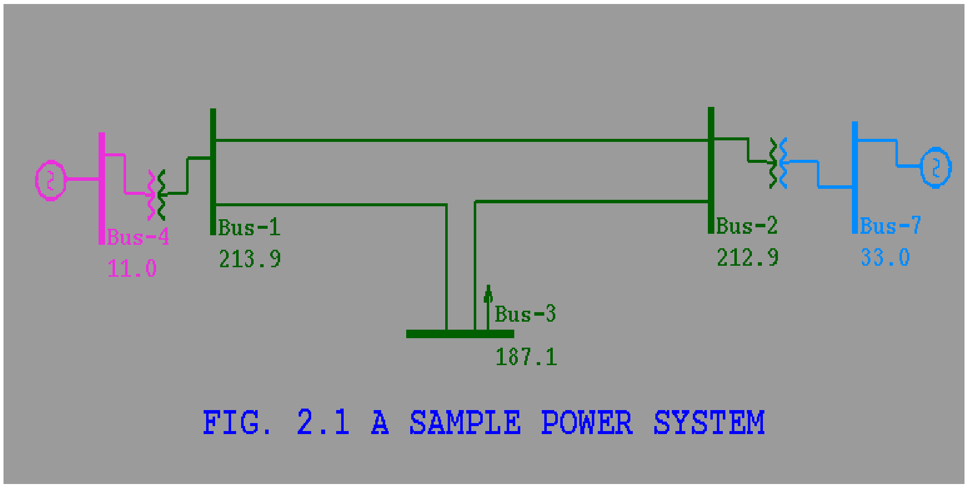


Figure 6.1: Operator Load Flow Solution

Busbar details For viewing other details of a busbar place the cursor on the bus whose details are to be displayed and press the left mouse button.

The same dialog box through which data were supplied appears with all the details about load and generation on that busbar.

Line flows For viewing the line flow place the cursor on the feeder and again press the left mouse button to get the details about the flow through the line and other information.

Search The 'Search' tool in the main window is also available in the 'Operator Load Flow' window. To use this tool place the cursor anywhere in this window and press the right mouse button when a pop-up menu with the 'Search' option appears on the window. Keeping the mouse button pressed drag it to the option 'Search' and then release the button. Then the dialog box 'Search a Busbar' appears on the screen. In this window the busbars are arranged in alphabetical order only. When you click on any busbar name with the left mouse button, the single line diagram is shifted in such a way that the desired busbar comes at

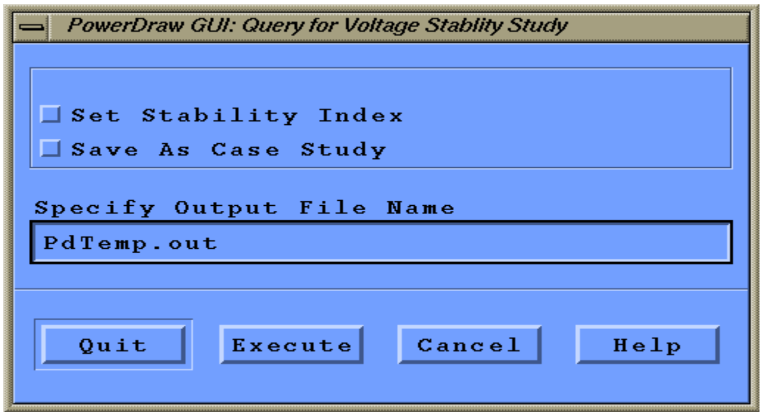


Figure 6.2: Query for Voltage Stability Study

the middle of the display window.

Buscode On/Off Along with the 'Search' facilities it is also possible to display the Busbar codes on the busbars in the display window. for this take the cursor to the 'Buscode On/Off' option and press the left mouse button. The codes are then shown in the window. If you press the option again the codes will be removed.

6.2.2 Dialog Box for Voltage Stability Study

Along with the solution window another 'child window' also appears with various options as shown in Fig. 6.2.

Using the toggle buttons you can have multiple choices in this window. Details of the options are as follow:

```
Option                               Purpose
******                               *******

Set Stability Index ............. When this button is
```

	`pressed a new window appears for supplying the index upto which display is required.`
`Save as Case Study ..............`	`With this option the data corresponding to the just carried out study will be saved in supplied file named.`

6.2.3 Functions of PushButtons

There are four push buttons at the bottom of the 'Query for Operator Load Flow' Dialog Box. They are:

Quit When this button is activated the process that was going on is discontinued. That means that the 'Query for Operator Load Flow' along with the display of the operator load flow solution in the child window are removed from the window.

Execute This option is to be used for running the 'Operator Load Flow' after completing the editing process.

Cancel Activating this button discontinue the current process of supplying data and removes the Dialog Box.

Help This pushbutton, when pressed, brings out the help messages in a separate window.

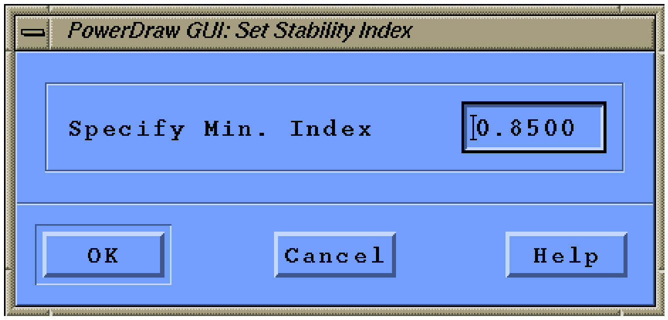


Figure 6.3: Query for Voltage Stability Index

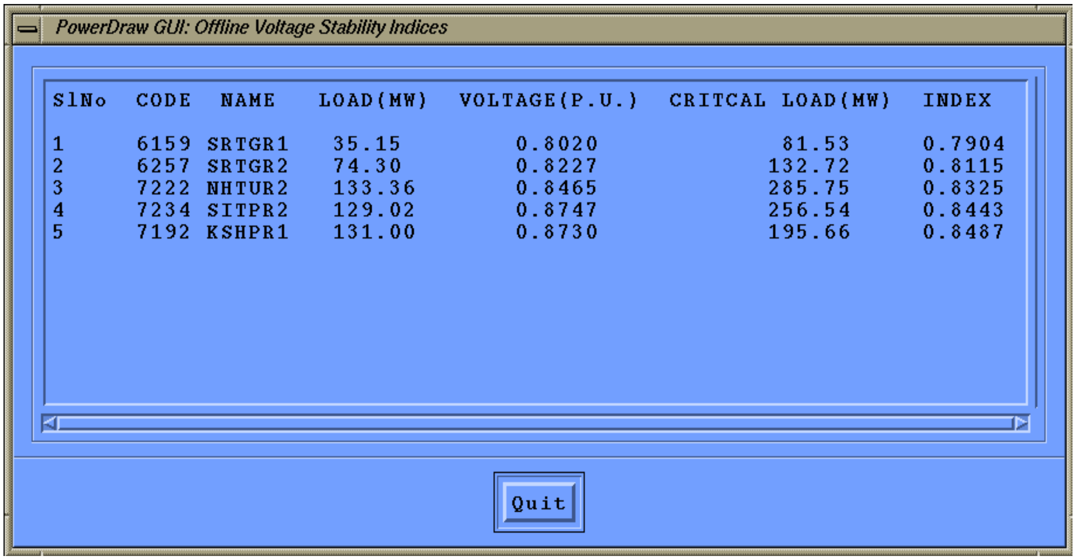
6.3 Analyses of Voltage Stability Problem

When you press the option 'Set Stability Index', a new Dialog box appears for supplying the value of the stability index upto which analyses are required. The dialog box is shown in Fig. 6.3.

Before supplying the value of this information one has to be aware of what one is trying to achieve. As mentioned earlier, the theoretically minimum value of stability index below which voltage collapse will definitely take place is 0.5. If a system is critically loaded such that the index is likely to be less than or near about this value for any busbar, it is possible that the loadflow solution may not even converge. At the same time the maximum value is 1.0. The user has to select a value within this range. If a system is operating well above the margin and the user select a value very near to the lower limit, there may not be any display of the results at all. On the other hand if a system is critically loaded and a value near to the higher limit is selected a very large number of busbars may be displayed. As a default value 0.85 is included in the window. The user has modify this value depending on the condition of the system he is studying.

The results are shown in Fig. 6.4.

The results shown in the Text Window have seven columns. In the fourth and fifth columns the active power load and the voltage magnitudes of the



SlNo	CODE	NAME	LOAD(MW)	VOLTAGE(P.U.)	CRITCAL LOAD(MW)	INDEX
1	6159	SRTGR1	35.15	0.8020	81.53	0.7904
2	6257	SRTGR2	74.30	0.8227	132.72	0.8115
3	7222	NHTUR2	133.36	0.8465	285.75	0.8325
4	7234	SITPR2	129.02	0.8747	256.54	0.8443
5	7192	KSHPR1	131.00	0.8730	195.66	0.8487

Figure 6.4: Results for Selected Voltage Stability Index

current loading conditions of the system are shown.

In the sixth column the approximate limiting active power loads are shown for the busbars which have stability index below the selected value. **It is to remembered that in all these analyses the POWER FACTORS of the loads are assumed to remain constant.**

The seventh column shows the stability indices of the selected busbars in descending order of severity. For example, the condition of the busbar in serial number 1 is more critical the busbar number 2.

Appendix A

Error and Warning Messages

A.1 ERROR MESSAGES

```
Error Code      Error Message

/* 9001 */ {"Operation Not Permitted."}
            You may not have permission to execute this command.

/* 9002 */ {"No Such File or Directory"}
            The file or directory you want to access is not
            in your current path.

/* 9003 */ {"No such process"}
            The process that you are trying to call does not
            exist in the current directory.

/* 9004 */ {""}
/* 9005 */ {"Error in Fixing Busbar Code"}
            The inputted Busbar code is not according to the
            specified format. Read the relevant part of
```

```
            Operator's Manual.

/* 9006 */ {"Invalid Character !!"}
            The inputted character is not according to
            specified format. Read the relevant part of
            Operator's Manual.

/* 9007 */ {"Arg list too long"}
            The length of the inputted argument is longer
            than the specified format.

/* 9008 */ {"Exec format error"}
/* 9009 */ {"Invalid Busbar Code."}
            The inputted Busbar code does not conform to the
            norms followed for forming Busbar code. Read the
            relevant part of Operator's Manual.

/* 9010 */ {"Duplication of Busbar Code."}
            The inputted Busbar code already exists and
            therefore it is not accepted.

/* 9011 */ {"Unable to Save the Current Contents."}
            This may be due to:
            Permission may not be there to write
            Not enough space in the hard disc

/* 9012 */ {"Not enough space"}
            Not enough space in the hard disc

/* 9013 */ {"Permission denied to Open"}
            This may be due to:
```

```
            There may not be permission to open
            There can be format mismatch

/* 9014 */ {"Cannot Load the Drawing Contents."}
/* 9015 */ {"Advised to Change the Busbar Code."}
/* 9016 */ {""}
/* 9017 */ {"File exists !!"}
/* 9018 */ {""}
/* 9019 */ {""}
/* 9020 */ {"Not a directory"}
/* 9021 */ {"Error in Retrieving Directory Name"}
/* 9022 */ {"Could not Create Accessory Files."}
/* 9023 */ {""}
/* 9024 */ {""}
/* 9025 */ {""}
/* 9026 */ {"Text file busy"}
/* 9027 */ {"File too large To Load"}
/* 9028 */ {""},
/* 9029 */ {""},
/* 9030 */ {"File Opened Read only."},
/* 9031 */ {"Writing Error for Busbar Info."},
/* 9032 */ {"Writing Error for Feeder Info."},
/* 9033 */ {"Writing Error in Transformer Info."},
/* 9034 */ {"Writing Error in Voltage Control Busbar Info."},
/* 9035 */ {"Writing Error in Slack Busbar Info."},
/* 9036 */ {"Writing Error in Shunt Load Info."},
/* 9037 */ {"Writing Error in Phase Shifter Info."},
/* 9038 */ {"Writing Error in SVS info."},
/* 9039 */ {"Writing Error in DC System Information."},
/* 9040 */ {""},
/* 9041 */ {""},
```

```
/* 9042 */ {""},
/* 9043 */ {""},
/* 9044 */ {""},
/* 9045 */ {""},
/* 9046 */ {"Mismatch in Slack Busbar Code Information."},
/* 9047 */ {"Not an Appropriate Data File"},
/* 9048 */ {"Not an Appropriate PowerDraw File"},
/* 9049 */ {"Could not get Corresponding data file"},
/* 9050 */ {"Could not get Corresponding Generator Info File"},
/* 9051 */ {"Format Mismatch in the PowerDraw File"},
/* 9052 */ {"Error in Opening the File"},
/* 9053 */ {"Error in reading No. of Objects"},
/* 9054 */ {"Error in reading No. of Line Segments"},
/* 9055 */ {"Error in reading No. of Texts"},
/* 9056 */ {"Error in Reading No. of Busbars"},
/* 9057 */ {"Error in Reading No. of Feeder Structures"},
/* 9058 */ {"Error in Reading No. of Generator Structures"},
/* 9059 */ {"Error in Reading No. of Transformer Structures"},
/* 9060 */ {"Error in Reading No. of SVS Structures"},
/* 9061 */ {"Reading Error in No. of Generators"},
/* 9062 */ {"Reading Error in Object Component"},
/* 9063 */ {"Reading Error in Line Segment"},
/* 9064 */ {"Reading Error in Text Component"},
/* 9065 */ {"Reading Error in Busbar Component"},
/* 9066 */ {"Reading Error in Transformer Component"},
/* 9067 */ {"Reading Error in Feeder Component"},
/* 9068 */ {"Reading Error in Generator"},
/* 9069 */ {"Reading Error in SVS Component"},
/* 9070 */ {"Reading Error in Master Record in Data File"},
/* 9071 */ {"Reading Error in Busbar Record in Data File"},
/* 9072 */ {"Reading Error in Feeder Record in Data File"},
```

```
/* 9073 */ {"Reading Error in Transformer Rec/* 9088 */ {""},
/* 9074 */ {"Reading Error in Voltage-Control Busbar Record in Data File"},
/* 9075 */ {"Reading Error in Slack Bus Record in Data File"},
/* 9076 */ {"Reading Error in Shunt Load Record in Data File"},
/* 9077 */ {"Reading Error in Phase Shifter Record in Data File"},
/* 9078 */ {"Reading Error in SVS Record in Data File"},
/* 9079 */ {"Reading Error in DC System in Data File"},
/* 9080 */ {"Reading Error in Generator Data File."},
/* 9081 */ {"Reading inconsistency in Master Record of Data File."},
/* 9082 */ {"Reading inconsistency in Busbar Information Records."},
/* 9083 */ {"Reading inconsistency in Feeder Information Records."},
/* 9084 */ {"Reading inconsistency in PV Busbar Records"},
/* 9085 */ {""},
/* 9086 */ {""},
/* 9087 */ {""},
/* 9088 */ {""},
/* 9089 */ {""},
/* 9090 */ {"Reading inconsistency in GenData File Records"},
/* 9091 */ {"Busbar Code Specified for Slack Bus does not exist !!!"},
/* 9092 */ {""},
/* 9093 */ {""},
/* 9094 */ {""},
/* 9095 */ {""},
/* 9096 */ {""},
/* 9097 */ {""},
/* 9098 */ {""},
/* 9099 */ {""},
/* 9100 */ {""},
```

A.2 WARNING MESSAGES

```
Warning Code   Warning Message

/* 9101 */ {"file opened read only."},
/* 9108: */{ Click on a Feeder and Press Return.}
```

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