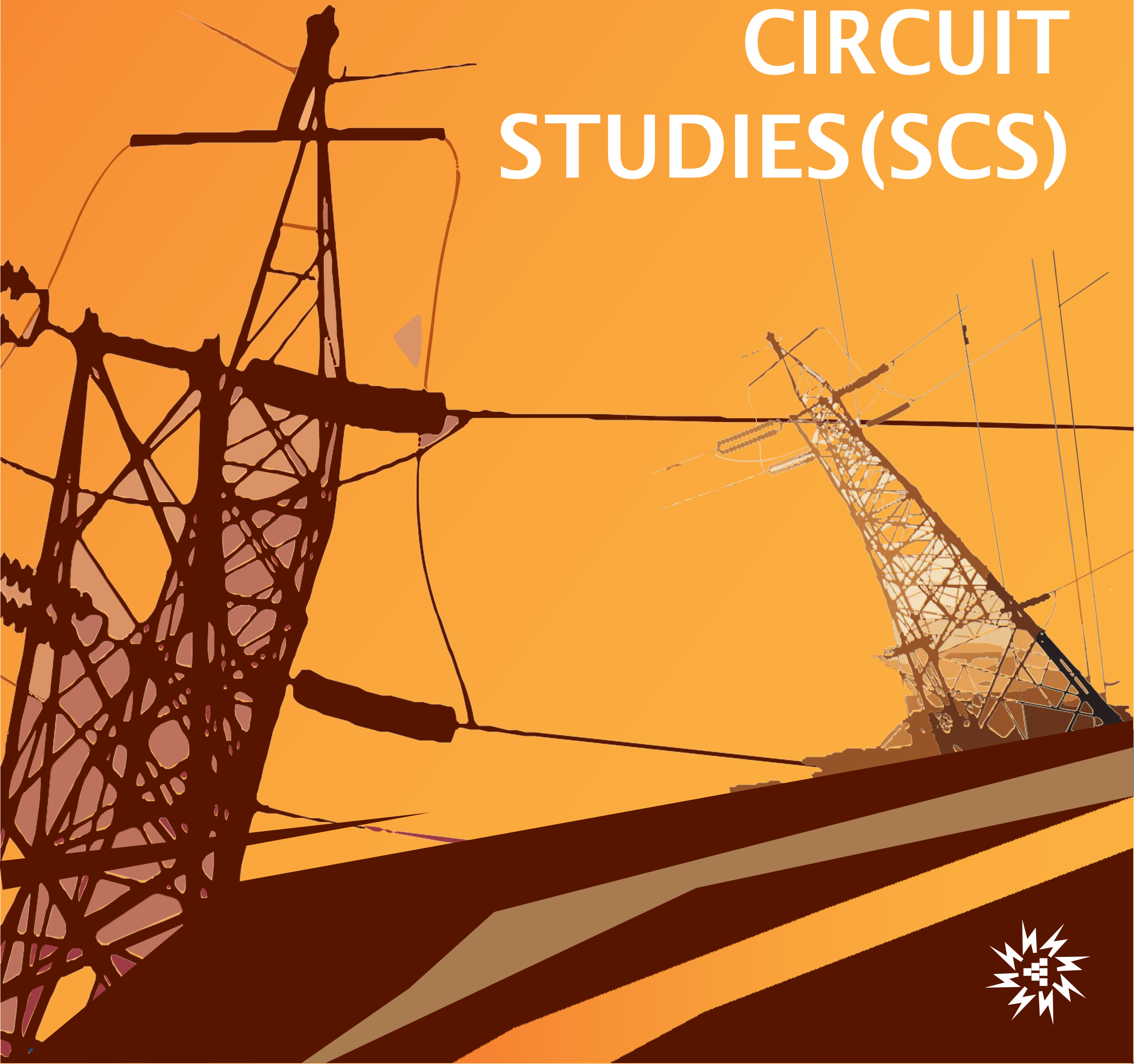
User Manual

PSCT | *Protection Analytic tool*

SHORT CIRCUIT STUDIES(SCS)



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1.INTRODUCTION

POWERSCS module is designed to perform the short circuit study for the given system. Short circuit studies are performed to determine the magnitude of the currents flowing throughout the power system at various time intervals after a fault occurs. The magnitudes of current flowing through the power system after a fault vary with time until they reach steady state condition. This behavior is due to system characteristics and dynamics. During this time, the protective system is called to detect, interrupt and isolate these faults. The various types of faults occurring in a system in the order of frequency of occurrence are single-line to ground, line to line, double line to ground, and three phase faults. Other types of faults include one conductor open and two conductors open, which can occur when conductors break or when one or two phases of a circuit breaker inadvertently open. The path for the fault current may have either zero impedance (dead short circuit) or impedance.

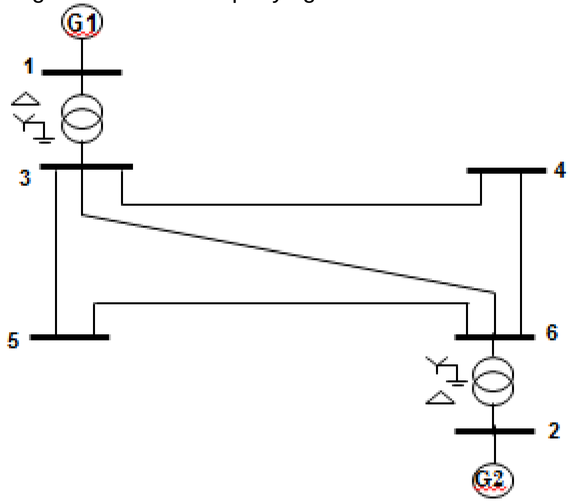
The current which flows in different parts of a power system immediately after the occurrence of a fault differs from that flowing a few cycles later just before circuit breakers are called upon to open the line on both sides of the fault, and both these currents differ widely from the current which would flow under steady state conditions, if the fault were not isolated from the rest of the system by the operation of circuit breakers. Two of the factors upon which the proper selections of circuit breakers depend are the current flowing immediately after the fault occurs and the current that the breaker must interrupt. Fault analysis consists of determining these currents for various type of fault at various locations in the system. The short circuit information is used to select fuses, breakers and switchgear ratings in addition to setting protective relays. The short circuit program computes the steady state fault current for the impedance considered.

Sparse storage and matrix ordering techniques are used in the program to reduce the memory requirements. Fast computational methods are employed to speed up the execution.

2.How to Solve SCS

EXAMPLE: SHORT CIRCUIT STUDY

Figure shows a single line diagram of a 6-bus system with two identical generating units, five lines and two transformers. Per-unit transmission line series impedances and shunt susceptances are given on 100 MVA base, generator's transient impedance and transformer leakage reactances are given in the accompanying table.



If a 3 - phase to ground fault occurs at bus 5 - find the fault MVA. The Transmission line data is given below.

Bus - code	Impedance Zpq	Line charging
p-q	**Zpq**	**Y'pq/2**
3 - 4	0.00 + j0.15	0
3 - 5	0.00 + j0.10	0
3 - 6	0.00 + j0.20	0
5 - 6	0.00 + j0.15	0
4 - 6	0.00 + j0.10	0

Generator details

MVA Rating of G1 & G2 = 100 MVA, 11 kV with X'_d = 10 %

Transformer details

KV Rating of T1 & T2 = 11/110 kV, 100 MVA, leakage reactance x = 5 %

**** All impedances are on 100 MVA base**

MiP-PSCT Data Interpretation:

SOLUTION:

In transmission line data, elements-3 – 4 & 5 – 6 have common parameters. Elements 3 - 5 & 4 – 6 have different parameters. Therefore 3 libraries are required for transmission line.

As generators G1 and G2 have same parameters, only one generator library is required. The same applies for transformers also.

Procedure to enter the data for performing studies using MiP-PSCT

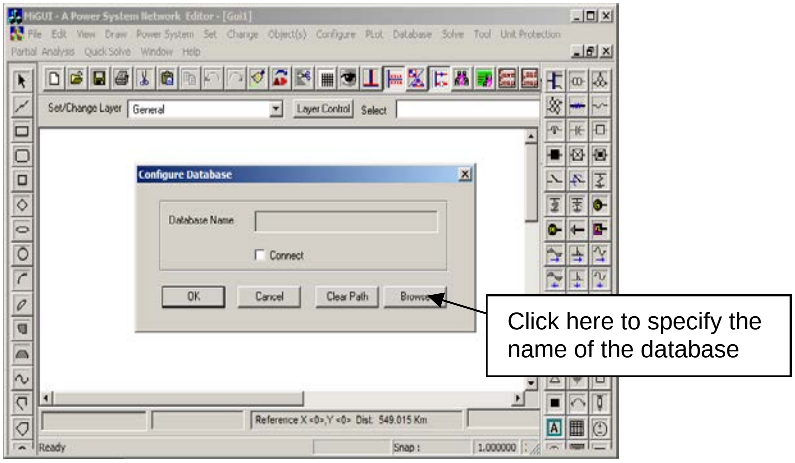
Following are the two methods.

1. Drawing single line diagram and entering corresponding data in database manager separately.
2. Drawing single line diagram and entering the data simultaneously.

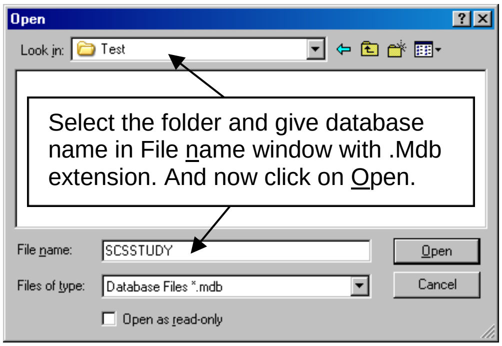
Method 2 follows:

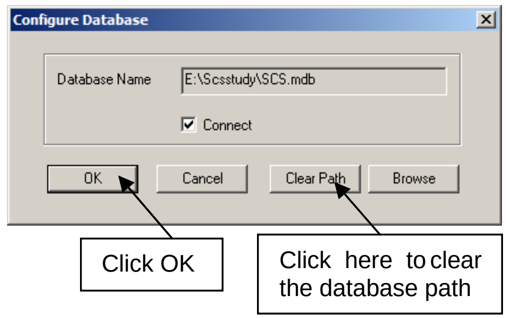
MiP-PSCT - Database Configuration

Open Power System Network Editor. Select menu option **Database → Configure**.

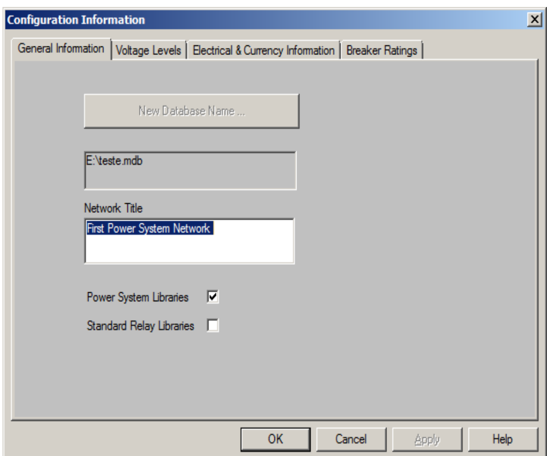


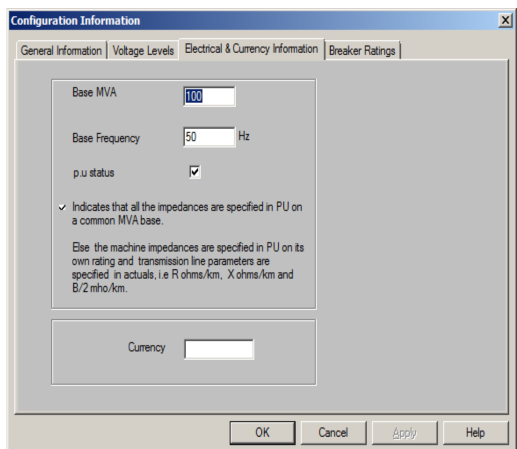
Configure Database dialog is popped up. Click **Browse** button. **Open** dialog box is popped up as shown below, where you are going to browse the desired directory and specify the name of the database to be associated with the single line diagram. Click **Open** button after entering the desired database name. **Configure Database** dialog will appear with path chosen.



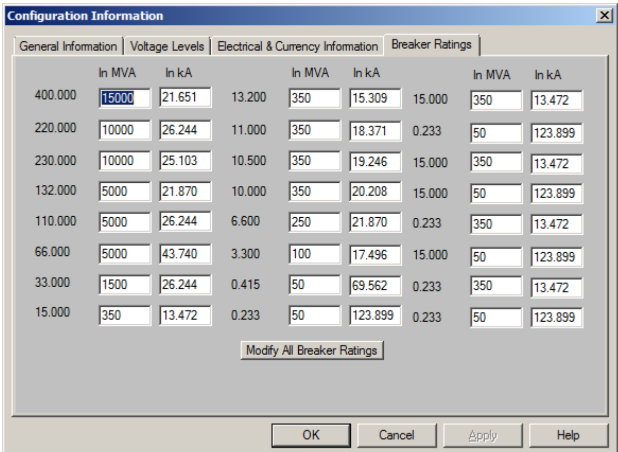


Click **OK** button on the **Configure database** dialog. The dialog shown below appears.





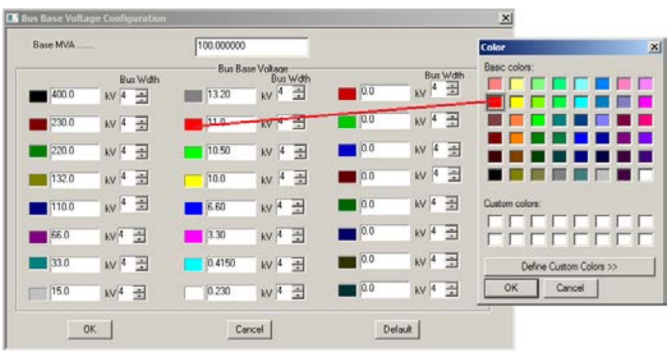
Uncheck the Power System Libraries and Standard Relay Libraries. For this example these standard libraries are not needed, because all the data is given on pu for power system libraries (like transformer, line\cable, generator) and relay libraries are required only for relay co- ordination studies. If Libraries are selected, standard libraries will be loaded along with the database. Click **Electrical Information** tab. Since the impedances are given on 100 MVA base, check the pu status as shown. Enter the Base MVA and Base frequency as shown below. ClickBreaker Ratings tab to modify the breaker ratings for required voltage levels, if the data is furnished. Otherwise accept the default values.



Click **OK** button to create the database to return to Network Editor.

Bus Base Voltage Configuration

In the network editor, configure the base voltages for the single line diagram. Select menu option **Configure→Base voltage.** The dialog shown below appears. If necessary change the

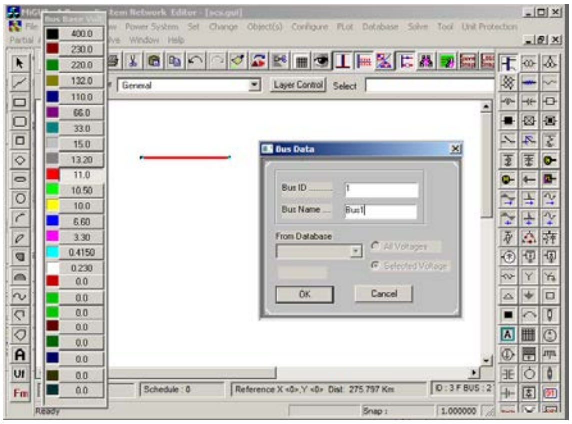


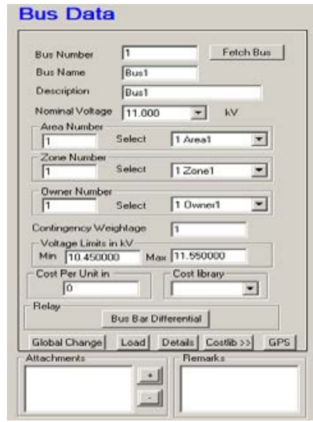
Base-voltages, color, Bus width and click **OK.**

Procedure to Draw First Element - Bus

Click on **Bus** icon provided on power system tool bar. Draw a bus and a dialog appears prompting to give the Bus ID number and Bus Name. Click OK. Database manager with corresponding **Bus Data** form will appear. Modify the area number, zone number and contingency weightage data if it is other than the default values. If this data is not furnished, keep the default values. Usually the minimum and maximum voltage ratings are ± 5% of the rated voltage. If these ratings are other than this, modify these fields. Otherwise keep the default values.

Bus description field can be effectively used if the bus name is more than 8 characters. If bus name is more than 8 characters, then a short name is given in the bus name fiel d and the bus description field can be used to abbreviate the bus name. For example let us say the bus name is **Northeast** then bus name can be given as **NE** and the bus description field can be **North East**.



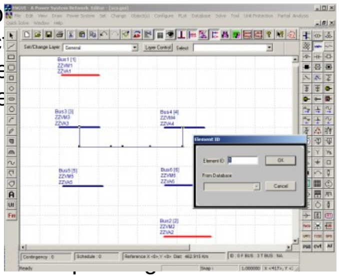


After entering data click **Save**, which invokes **Network Editor**. Follow the same procedure for remaining buses. Following table gives the data for other buses.

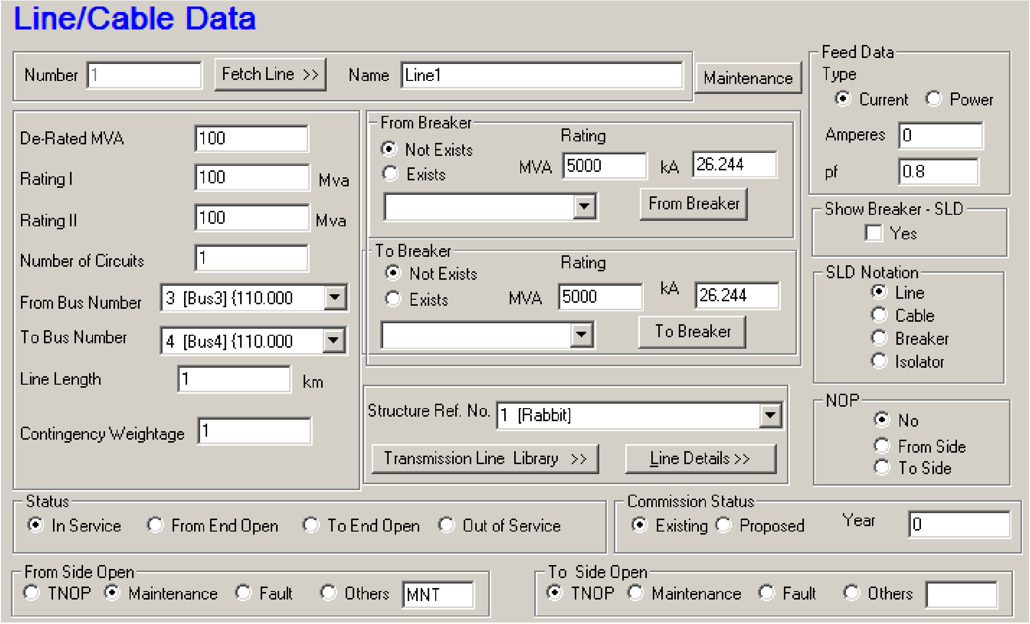
Bus data						
Bus Number	1	2	3	4	5	6
Bus Name	Bus1	Bus2	Bus3	Bus4	Bus5	Bus6
Nominal voltage	11	11	110	110	110	110
Area number	1	1	1	1	1	1
Zone number	1	1	1	1	1	1
Contingency weightage	1	1	1	1	1	1

Procedure to Draw Transmission Line

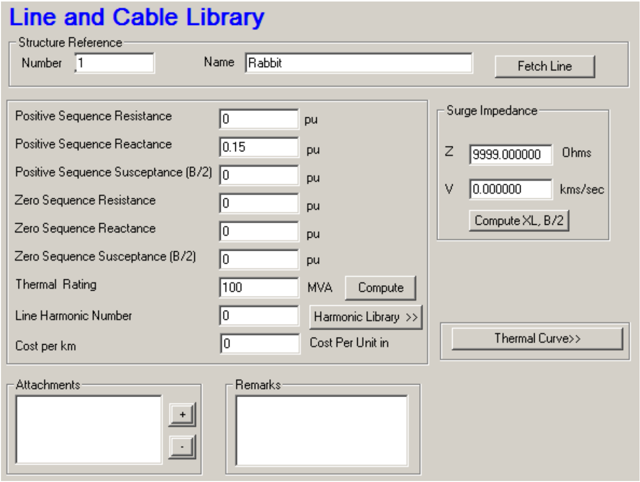
Click on **Transmission Line** icon provided on power system tool bar. To draw the line click in between two buses and to connect to the from bus, double click LMB (Left Mouse Button) on the **From Bus** and join it to another bus by double clicking the mouse button on the **To Bus**. **Element ID** dialog will appear.



Enter **Element ID** number and click OK. Database manager with form will be open. Enter the details of that line as shown below.



Enter **Structure Ref No. as 1** and click on **Transmission Line Library >>** button. **Line & Cable Library** form will appear. Enter transmission line library data in the form as shown for Line3-4.

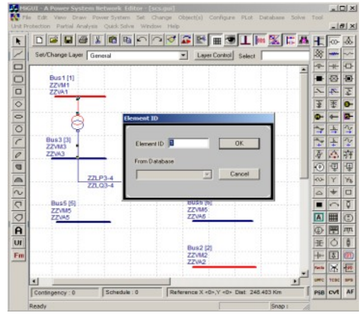


After entering data, **Save** and Close**. line\cable Data** form will appear. Click **Save ,** which invokes network editor. Data for remaining elements given in the following table. Follow the same procedure for rest of the elements.

Transmission Line Element Data					
Line Number	1	2	3	4	5
Line Name	Line3-4	Line3-5	Line3-6	Line4-6	Line5-6
De-Rated MVA	100	100	100	100	100
No. Of Circuits	1	1	1	1	1
From Bus No.	3	3	3	4	5
To Bus No.	4	5	6	6	6
Line Length	1	1	1	1	1
From Breaker Rating	5000	5000	5000	5000	5000
To Breaker Rating	5000	5000	5000	5000	5000
Structure Ref No.	**1**	**2**	**3**	**2**	**1**

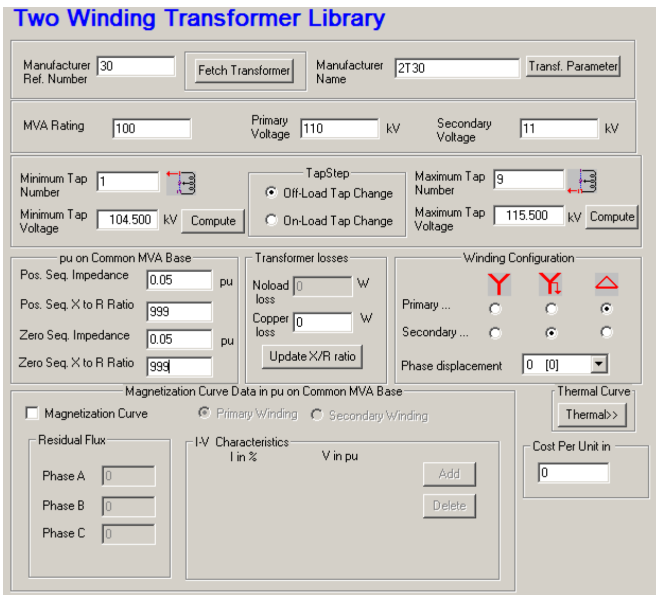
Transmission Line Library Data			
Structure Ref. No.	1	2	3
Structure Ref. Name	Line3-4 & 5-6	Line3-5 & 4-6	Line3-6
Positive Sequence Resistance	0	0	0
Positive Sequence Reactance	0.15	0.1	0.2
Positive Sequence Susceptance	0	0	0
Thermal Rating	100	100	100

Procedure to Draw Transformer

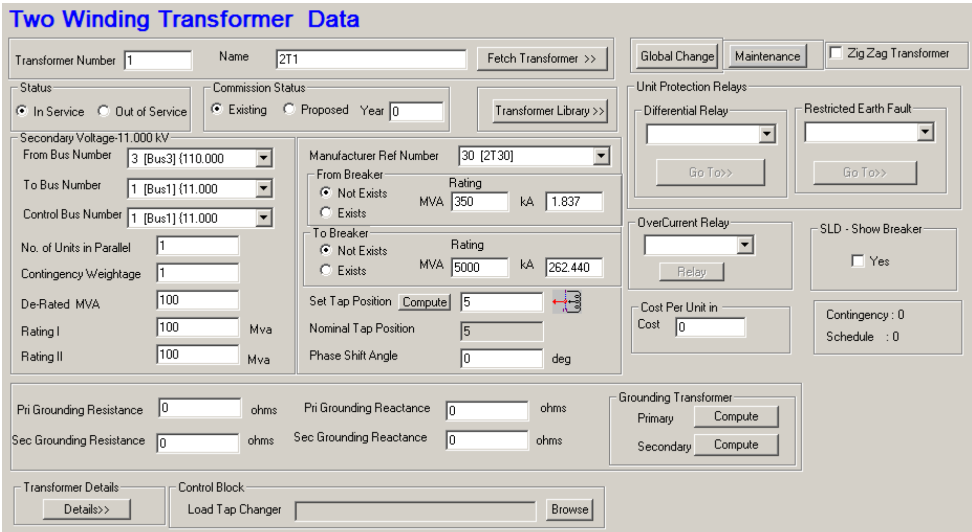


Click on **Two Winding Transformer** icon provided on power system tool bar. To draw the transformer click in between two buses and to connect to the from bus, double click LMB (Left Mouse Button) on the **From Bus** and join it to another bus by double clicking the mouse button on the **To Bus**. **Element ID** dialog will appear. Click OK.

Transformer Element Data form will be open. Enter the **Manufacturer Ref. Number as 30.** Enter Transformer data in the form as shown below. Click on **Transformer Library >>** button.



Transformer library form will be open. Enter the data as shown. **Save** 🖫 and **close** library screen.

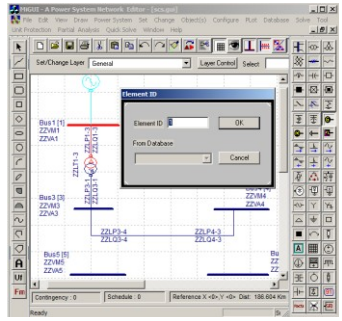


Transformer element data form will appear. Click **Save** button, which invokes Network Editor. In the similar way enter other transformer details.

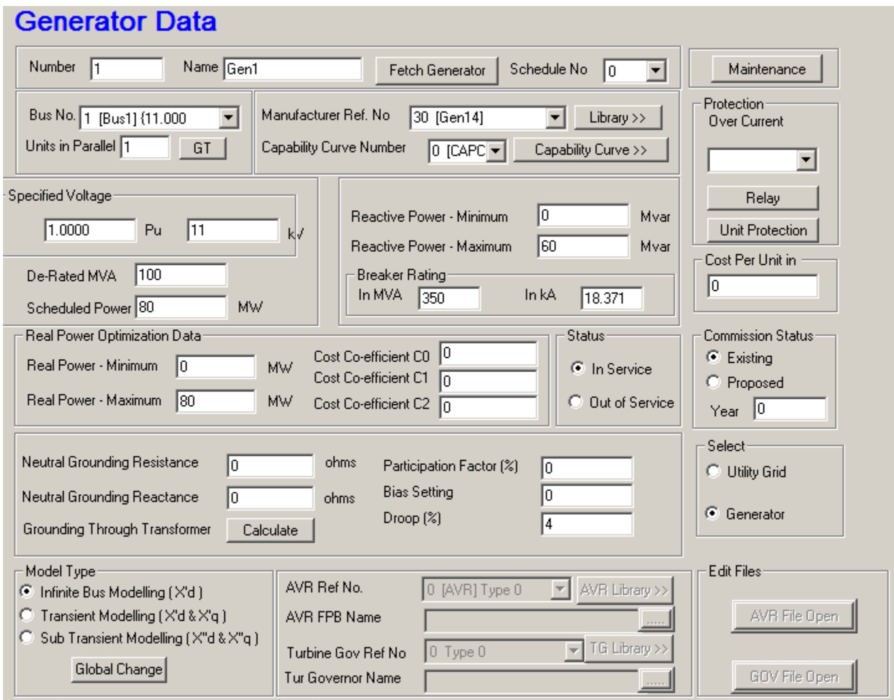
2nd Transformer details	
Transformer Number	2
Transformer Name	2T2
From Bus Number	6
To Bus Number	2
Control Bus Number	2
Number of Un its in Parallel	1
Manufacturer ref. Number	30
De Rated MVA	100
From Breaker Rating	5000
To Breaker Rating	350
Nominal Tap Position	5

Procedure to Draw Generator

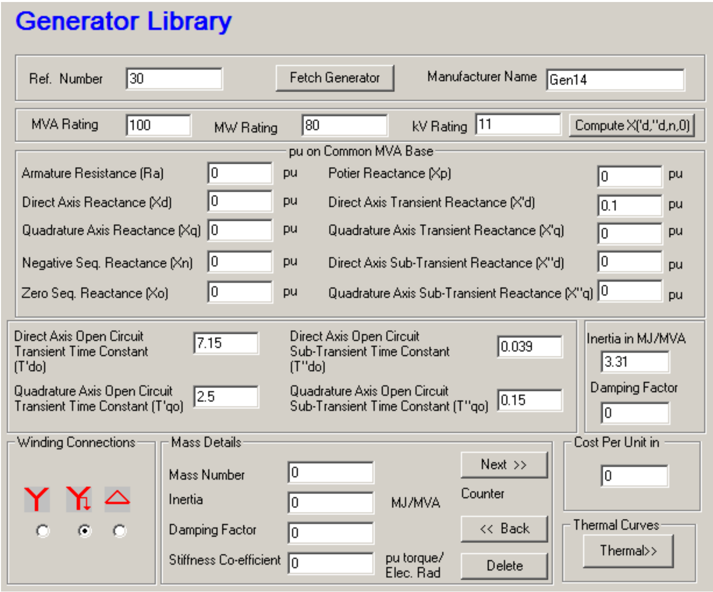
Click on **Generator** icon provided on power system tool bar. Draw the generator by clicking LMB (Left Mouse Button) on the **Bus1**. **Element ID** dialog will appear. Click OK.



Generator Data form will be opened. Enter the **Manufacturer Ref. Number as 20.** Enter generator data in the form as shown.



Click on **Library >>** button. Enter generator library details as shown below.

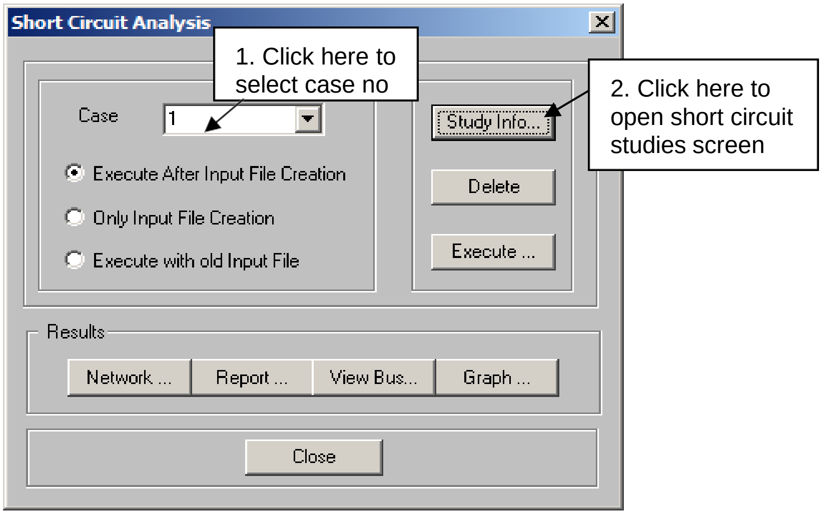


Save and **Close** the library screen. Generator data screen will be reopened. Click **Save** button, which invokes Network Editor. Connect another generator to Bus 2. Enter its details as given in the following table.

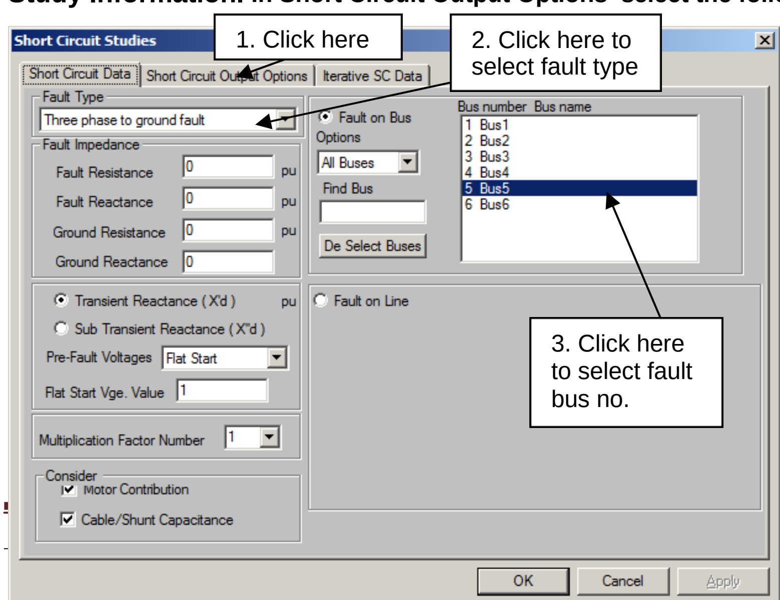
Name	GEN-2
Bus Number	2
Manufacturer Ref. Number	Gen20
Number of Generators in Parallel	1
Capability Curve Number	0
De-Rated MVA	100
Specified Voltage	11
Scheduled Power	80
Reactive Power Minimum	0
Reactive Power Maximum	60
Breaker Rating	350
Type of Modeling	Infinite

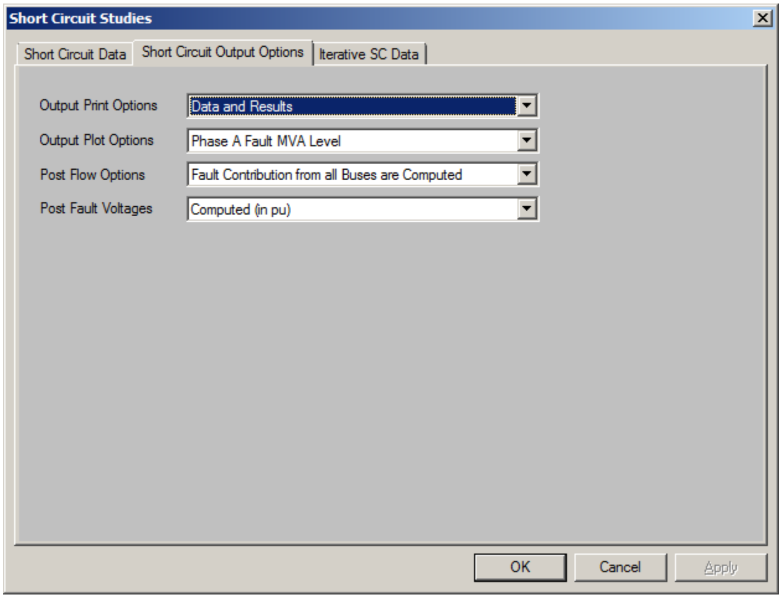
***Note :** To neglect the transformer resistance, in the multiplication factor table give the X to R Ratio as 9999.*

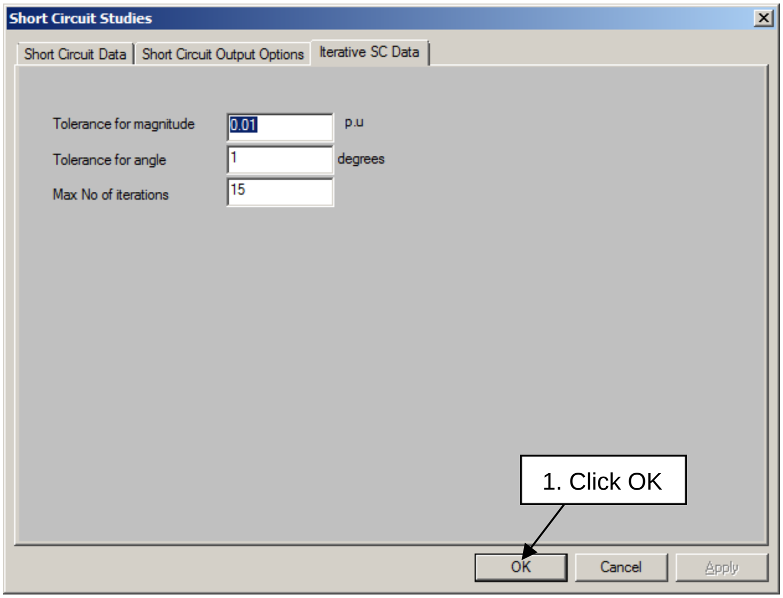
TO solve short circuit studies choose menu option **Solve → Short Circuit Analysis** or click on **SCS** button on the toolbar on the right side of the screen. Short circuit analysis screen appears.



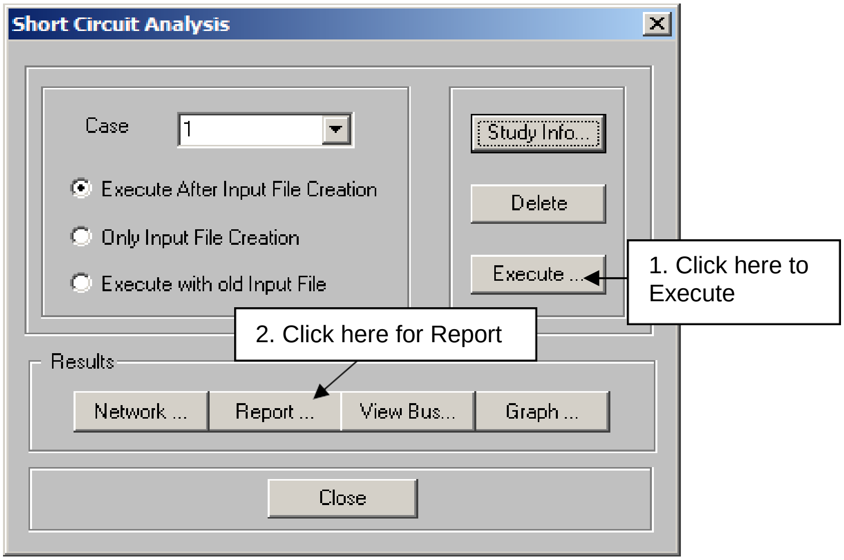
Study Information. In Short Circuit Output Options select the following.




Short Circuit Studies
Short Circuit Data
Short Circuit Output Options
Iterative SC Data
Output Print Options
Data and Results
Output Plot Options
Phase A Fault MVA Level
Post Flow Options
Fault Contribution from all Buses are Computed
Post Fault Voltages
Computed (in pu)
OK
Cancel
Apply


Short Circuit Studies
Short Circuit Data
Short Circuit Output Options
Iterative SC Data
Tolerance for magnitude
0.01
p.u
Tolerance for angle
1
degrees
Max No of iterations
15
1. Click OK
OK
Cancel
Apply

Afterwards click **Execute.** Short circuit study will be executed. Click on **Report** to view the report.



Part of the Report is shown below

```
---------------------------------------------------------------------------
FAULT AT BUS NUMBER     5 : NAME     Bus5
      CURRENT (AMPS/DEGREE)                             FAULT MVA
 SEQUENCE (1,2,0)    PHASE (A,B,C)      SEQUENCE (1,2,0)    PHASE (A,B,C)
MAGNITUDE   ANGLE  MAGNITUDE   ANGLE       MAGNITUDE          MAGNITUDE
--------- ------- --------- -------       ---------          ---------
     3870  -90.00      3870  -90.00             737                737
        0  -90.00      3870  150.00               0                737
        0  -90.00      3870   30.00               0                737
R/X RATIO OF THE SHORT CIRCUIT PATH      :  0.0000
PEAK ASYMMETRICAL SHORT-CIRCUIT CURRENT :     10947 AMPS
---------------------------------------------------------------------------
```

Exercise: Simulate single line to ground fault, line-to-line fault for the above case.

How to conduct an open conductor fault:-

To perform open-conductor fault –

1. Run a load flow study.
2. In short circuit analysis info, select one phase open fault or two phase open fault.
3. Select the line for open conductor fault.
4. Select pre-fault voltages option as **input from load flow** and then execute short circuit studies.

3. INPUT FILE FORMAT

Input file format of **POWERSCS** is explained in this chapter, which helps, in creating an input file or manipulating the input file created through integrated mode.

Input data to short circuit program (**POWERSCS**) is through an ASCII file. If **POWERSCS** is run in the integrated environment, input data file is automatically generated using the centralized database, whenever execution of **POWERSCS** is selected. The format of input filename is **1Grid0S.dat0**, where **1** represents Case Number, **Grid** -Database name, **0 -** Contingency Number, **S –** Study Code – Short circuit, **dat –** File Type - Input,**0 – schedule number** for case 1 of short circuit analysis. If the input file for **POWERSCS** is prepared by the user according to the format provided in this chapter, there is no restriction on the file names, it is user-defined name. The output files are generated with user defined filename plus default extensions. File extensions are explained in chapter 4, table 4.1.

In order to add/modify/delete device data refer user's guide for device data configuration. The input data is read in free format. Input data is divided into different heads called streams for explanation purposes. *'int'* is used to indicate that the data type is an integer. *`float'* is used to reference the floating point (real) variable. Character streams (string) are indicated by *`char'* type.

Stream 1: System Description

This consists of 3 lines of data for the description of the power system for which the study is conducted. Each line of data is of *char* type and maximum number of alphanumeric characters (including blanks) in a line should not exceed 80. Any useful information, which has to appear in the report file can be given in this stream.

After three lines of system description (stream 1), comment lines can be given in the data file by entering % in the first column. Comment line is not written in the output file. These lines are simply read and skipped. If the comment line has to appear in the output file then % should be given in the second column also.

% This comment line does not appear in the output file.
%% This comment line appears in the output file.

Stream 2: System Specification

This consists of 6 lines of data, which specifies the system. Data types/specifications are separated by blanks. Since the data is read in free format, data appearing in a line can be given in successive lines also. In line 1, system size specifications are given. Table 3.1 gives the data appearing under different columns of line 1.

Table 3.1 - System Specification – Line 1 : Size Definition

Col No.	Description	Type	Min	Max
1.	Maximum bus number	int	1	9999
2.	Actual number of buses	int	1	9999
3.	Number of 2 winding transformers	int	0	2000
4.	Number of 3 winding transformers	int	0	2000
5.	Number of transmission lines	int	0	500
6.	Number of series reactors (inductors)	int	0	2000
7.	Number of series capacitors	int	0	500
8.	Number of bus couplers	int	0	100
9.	Number of shunt reactors (inductors)	int	0	2000
10.	Number of shunt capacitors	int	0	2000
11.	Number of shunt impedances	int	0	2000
12.	Number of generators	int	0	2000
13.	Number of motors	int	0	2000
14.	Number of loads	int	0	2000
15.	Number of filters	int	0	20
16.	Number of HVDC converters	int	0	16
17.	Number of wind turbine generators	int	0	2000

Explanation for the entries in table 3.1 is as follows -

- In **POWERSCS** bus numbers need not be assigned continuously and there can be cases where in some buses are deleted. The entry in column 1 is the largest number used to represent the bus in the system considered for the study.

- Actual number of buses refers to total buses that are physically present in the system.

- Two winding transformers, three winding transformers, lines, series reactors (inductor), series capacitors and bus couplers are together referred as series elements (branches). Maximum number of series elements should not exceed 2500. Each three winding transformer results in three series elements, since equivalent *Star* connection data is considered. Sum of total number of two winding transformers and 3 times the number of 3 winding transformers should not exceed 2000. Although the terminology bus coupler is used in column 8 of table 3.1, it can refer to switches, isolators and disconnecting switches, and are modeled as low impedance paths.

- Shunt reactors (inductor), shunt capacitors and shunt impedances are together referred as shunt elements. Maximum number of shunt elements should not exceed 2000.

- A unique feature of specifying the user defined filter is provided in **POWERSCS**. Total number of filters should not exceed 20.

- Number of Wind turbine generators present in the system

- Numbers of shunt impedances are equal to the sum of number of actual shunt connections (whose data are given in impedance form) that exist in the system and the shunt impedances that result due to modeling of the induction motor.

Different control inputs are read by **POWERSCS** to control the program flow, results printing and model selection. These inputs are specified in lines 2 and 3. In table 3.2, the data appearing in different columns of line 2 are given.

Table 3.2 - System Specification - Line 2 : Control Option

Col No.	Description	Type	Min	Max
1.	Number of zones	int	0	20
2.	Print option	int	0	4
3.	Plot option	int	0	12
4.	Base MVA	float	0.1	10000.0
5.	Nominal system frequency	float	0.1	100.0
6.	Pre-fault voltage option	int	0	1
7.	Fault bus option	int	0	2
8.	Post fault flow option	int	0	3
9.	Fault type	int	1	7
10.	Post fault voltage option	int	0	1

Explanation to entries given in table 3.2 is as follows.

- In power system, the equipments are owned by different utilities, and in a same utility, equipments belong to different zones. Hence, each bus is associated with a number called zone.

All the equipments (shunt elements) connected to the bus are attributed to the zone of the bus. In case of series elements, the line belongs to the zone of the from bus (sending bus).

Number of zones in the given power system data are given in column 1.

- Print option in table 3.2 is interpreted as -

0	:	No printing of data or results.
1	:	Data printing only.
2	:	Results printing only.
3	:	Both data and results printing.
4	:	Detailed printing of data and results.

- Plot option is interpreted as –

0	:	No plot file is generated.
1	:	Plot file outputs are for phase A, magnitude in amperes and angle in degrees.
2	:	Plot file outputs are for phase B, magnitude in amperes and angle in degrees.
3	:	Plot file outputs are for phase C, magnitude in amperes and angle in degrees.
4	:	Plot file outputs are for positive sequence, magnitude in amperes and angle in degrees.
5	:	Plot file outputs are for negative sequence, magnitude in amperes and angle in degrees.
6	:	Plot file outputs are for zero sequence, magnitude in amperes and angle in degrees.
7	:	Plot file outputs are for phase A, magnitude in MVA and angle in degrees.
8	:	Plot file outputs are for phase B, magnitude in MVA and angle in degrees.
9	:	Plot file outputs are for phase C, magnitude in MVA and angle in degrees.
10	:	Plot file outputs are for positive sequence, magnitude in MVA and angle in degrees.
11	:	Plot file outputs are for negative sequence, magnitude in MVA and angle in degrees.
12	:	Plot file outputs are for zero sequence, magnitude in MVA and angle in degrees.

Plot file format is compatible to graphic user interface, so that the results of short circuit study can be displayed on the single line diagram.

- Network parameter (resistance, reactance etc.,) data to **POWERSCS** is in pu on a common MVA base. The common MVA base is provided in column 4 of table 3.2.

- Nominal system frequency for the study is provided.

- When the fault occurs in a system, the fault current depends on the location of the fault and on the pre-fault voltages in the system. Pre-fault voltages are computed by performing the load flow analysis for the system under consideration. Pre-fault voltage option in table 3.2 is interpreted as -

  0 : Flat start.
  1 : Pre-fault voltage is read from the load flow results.

Data for pre-fault voltage and operating condition of the system are given in bus data stream.

- It is possible to consider the fault at different buses, one at a time, in a single **POWERSCS** execution. Fault bus option in column 7 of table 3.2 is interpreted as -
  0 : Fault considered at all buses, one at a time.
  1 : Fault considered at specified number of buses, one at a time.
  2 : Fault considered at buses of specified voltage level.

For open fault simulation, fault bus option should be always 1.

- Post fault flow option in table 3.2 is interpreted as -

  0 : Fault contributions to faulted bus from lines are not computed.
  1 : Fault contributions are computed from adjacent buses.
  2 : Fault contributions are computed from adjacent and next adjacent buses.
  3 : Fault contributions are computed from all buses.

- **POWERSCS** is designed to perform different types of faults that are commonly observed in the power system. Required fault type is specified in column 9 of table 3.2. Fault type is interpreted as -

  1 : Three phase to ground fault.
  2 : Single line to ground fault at R phase.
  3 : Line to line fault between Y and B phases.
  4 : Double line (Y and B phases) to ground fault.
  5 : Opening one line (R phase).
  6 : Opening two lines (Y and B phases).
  7 : Fault study is done for both 3 phase and single line to ground fault, one after the other. Fault option is forced to zero (fault at all buses).

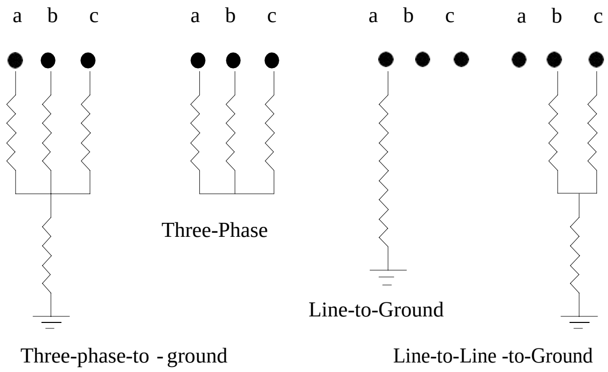
- As a consequence to fault, bus voltages close to fault are reduced. **POWERSCS** has the option to compute the post fault voltage at all the buses. Post fault voltage option is interpreted as –

0 : Post fault bus voltages are not computed.
1 : Post fault bus voltages are computed.

- In table 3.2, column 7, if the fault bus option is either 1 or 2, then line 3 under system specification is applicable. The data appearing in this line are all separated by blanks. Data appearing in this line depends on the fault bus option.

If the fault bus option is 1, first entry in this line is total number of user specified fault buses. Following this is the bus numbers, at which fault is to be considered. Maximum number of user specified fault buses should not exceed 10. All the entries in this line are of integer type. In case of open fault, bus number specified is the from node number of transmission line to be considered for open fault.

If the fault bus option is 2, fault is created at all the buses having the voltage specified in this line. The entry is of type float and the voltage is in Kilovolts.



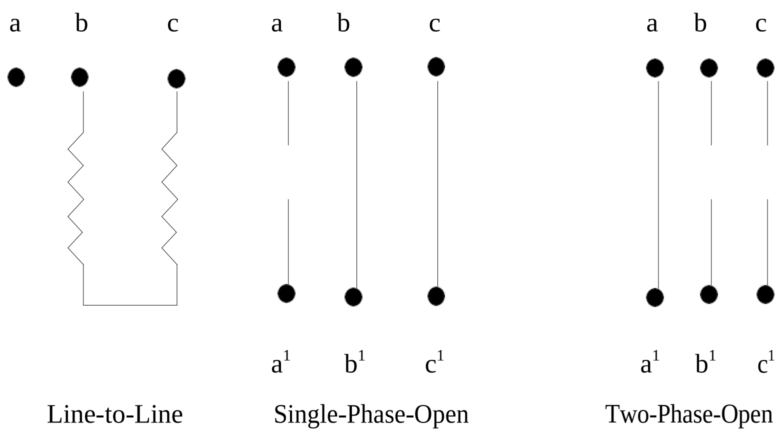


Figure 3.1: Representation of various types of faults

In line 4, fault impedance data are given. Table 3.3 gives the entries appearing in different columns of line 4. Fault impedance values are in pu on a common MVA and voltage base. Figure 3.1 represents different types of faults.

Table 3.3 - System Specification - Line 4 : Fault Impedance				
Col No.	**Description**	**Type**	**Min**	**Max**
1.	Resistance (Zf.re) in pu	float	0.0	1.0e5
2.	Reactance (Zf.im) in pu	float	0.0	1.0e5
3.	Ground fault resistance (Zg.re)	float	0.0	1.0e5
4.	Ground fault reactance (Zg.im)	float	0.0	1.0e5

After entering the data for fault impedances, convergence data pertaining to wind turbine contribution to faults is to be entered. Wind turbines of converter technology contribute reactive currents to faults depending upon the grid code followed. The solution for the ac tual contribution is obtained by iterating short circuit analysis with specific tolerances for wind turbine bus voltage magnitude and angle. The flag for limiting the prefault load current supplied by wind turbines is used to compute the actual current injection during fault. The data includes the streams shown in Table 3.4.

Table 3.4 - System Specification – Line 5 : Wind Turbine Convergence Data				
Col No.	**Description**	**Type**	**Min**	**Max**
1.	Voltage magnitude tolerance in p.u.	double	0.0001	1.0
2.	Voltage angle tolerance in degrees	double	0.0001	10
3.	Number of Iterations	Int	1	1000
4.	Load Limiter function	Int	0	1

POWERSCS is designed such that even if exact values of certain parameters are not known, some approximate values can be considered. In line 6 of this stream, multiplication factor values and default values are given. Entries appearing in different columns of this line are given in table 3.5.

Table 3.5 - System Specification – Line 6 : Multiplication factors				
Col	**Description**	**Type**	**Min**	**Max**
1.	Circuit breaker resistance in pu	float	0.0	1.0
2.	Circuit breaker reactance in pu	float	1.0e-5	1.0
3.	Transformer R/X ratio	float	0.0	1.0
4.	Transformer zero sequence impedance multiplication factor	float	0.5	1.0
5.	Number of transmission voltage levels	int	1	20
6.	Transmission line voltage in kV	float	0.001	1.0e4
7.	Transmission line zero sequence resistance multiplication factor	float	0.0	10.0
8.	Transmission line zero sequence reactance multiplication factor	float	1.0	10.0
9.	Transmission line zero sequence admittance multiplication factor	float	0.5	1.0
10.	Generator negative sequence resistance multiplication factor	float	0.0	2.0
11.	Generator negative sequence reactance multiplication factor	float	0.5	2.0
12.	Generator zero sequence resistance multiplication factor	float	0.0	2.0
13.	Generator zero sequence reactance multiplication factor	float	0.5	2.0
14.	Load negative sequence impedance multiplication factor	float	0.1	2.0
15.	Load zero sequence impedance multiplication factor	float	0.1	2.0
16.	Series reactor zero sequence impedance multiplication factor	float	0.5	2.0
17.	Shunt reactor zero sequence impedance multiplication factor	float	0.5	2.0

Explanations to entries given in table 3.5 are as follows -

- Two techniques are used to model the circuit breaker or switches in closed position. One technique is to merge buses connected between the circuit breakers and treat the buses as single bus for all computation purposes. Other technique is to consider the circuit breaker as a low impedance path. Later is used in the modeling of circuit breakers in **POWERSCS**. In this model the resistance value of circuit breaker is zero and reactance value is 0.0001 pu But if the impedances of other elements are relatively large, then the circuit breaker impedance can also be of higher value. Resistance and reactance values of circuit breaker in pu are given in columns 1 and 2 of table 3.5, respectively. In some applications (especially for distribution systems), higher values have to be used. Typical values are 0.0 and 0.0001 respectively for resistance and reactance of the circuit breaker.

- Transformer **R/X** ratio (ratio of resistance to reactance) is usually 0.05. In certain cases the resistance value is unknown and hence **R/X** ratio is used to compute the resistance value, when the reactance value is given. If the transformer resistance is 0.0 then the resistance is computed as the product of **R/X** ratio and the transformer reactance. **R/X** ratio should be given as zero to neglect the transformer resistance in the computation. Entry in column 3 of table 3.5 corresponds to transformer **R/X** ratio. 0.05 is the typical value.

- Transformer negative sequence impedance is same as positive sequence impedance. Zero sequence impedance of the transformer is approximately 90% of the transformer positive sequence impedance. If the transformer zero sequence resistance and reactance values are 0.0, then zero sequence values are computed by multiplying the positive sequence values by the factor given in column 4 of table 3.5. Transformer zero sequence value between the connected buses exists only if the transformer is star grounded on either side. Hence this computation is valid when both the transformer windings are solidly grounded (Star Grounded). Typical value for this multiplication factor is 0.9.

- In case of transmission lines, zero sequence multiplication factors depend on the transmission line voltage level. Hence for each voltage level, separate multiplication factors are given. In column 5 of table 3.5, number of voltage levels is given.

- In column 6, transmission line voltage level in kV is given.
- Transmission line negative sequence impedance is same as positive sequence impedance. Zero sequence impedance of the transmission line depends on the ground wires, and earth resistivity. Normally the zero sequence impedance is 2.5 to 3 times the positive sequence impedance. If the zero sequence resistance and reactance of the transmission lines are 0.0, then the values are computed by multiplying the positive sequence values by the factor given in column 8 of table 3.5. Typical value for this multiplication factor is 2.5.

- Zero sequence susceptance of the transmission line is much lesser compared to positive sequence susceptance. It is normally 0.6 to 0.8 times the positive sequence susceptance. If the zero sequence susceptance entry is 0.0, then the value is computed by multiplying the positive sequence susceptance by the factor given in column 9 of table 3.5. Typical value for this multiplication factor is 0.75.

- Column 6, 7, 8 and 9 are repeated for number of voltage levels specified. If the voltage levels are more than 1, then the column numbers referred below gets shifted.

- For rotating machines, negative sequence reactance differs from the positi ve sequence reactance. In case of generators, negative sequence reactance is approximately equal to the subtransient reactance. Negative sequence resistance is same as positive sequence resistance. The multiplication factors to compute the negative sequence resistance and reactance from the positive sequence values are given in columns 10 and 11 respectively. Typical value for the multiplication factors is 1.0.

- Multiplication factors to compute the zero sequence resistance and reactance of the generator from the positive sequence values are given in columns 12 and 13 respectively. Typical value for the multiplication factors is 1.0. Loads are normally neglected in short circuit study. But facility is provided in **POWERSCS** to consider the loads for short circuit study. Multiplication factors for negative and zero sequence load values are given in columns 14 and 15 respectively. Typical value for the multiplication factors is 1.0.

- Negative sequence impedance of the series reactor (inductor or capacitor) is sam e as positive sequence impedance. In most of the studies, zero sequence impedance value is taken same as positive sequence impedance value. Multiplication factor given in column 16 is used to compute the zero sequence impedance from the positive sequence impedance. Typical value for the multiplication factor is 1.0.

- Negative sequence impedance of the shunt reactor (inductor or capacitor) is same as positive sequence impedance. In most of the studies, zero sequence impedance value is taken same as positive sequence impedance value. Multiplication factor given in column 17 is used to compute the zero sequence impedance from the positive sequence impedance. Typical value for the multiplication factor is 1.0.

In **POWERSCS**, it is possible to create the fault at specified distance from the sending end of a transmission line. This information is given in line 7. The entries in line 7 are given in table 3.6.

Table 3.6. - Traveling Fault Data

Col No.	Description	Type	Min	Max
1.	Line number	int	1	1000
2.	Percentage distance	float	5.0	95.0

Explanation to the entries in table 3.6 is as follows -

- Line number in column 1 of table 3.6 is the transmission line number (serial number counted starting from the first line in the transmission line data) on which the fault is to be created. A Value 0 is given in this field if no traveling shunt fault is to be considered. To consider the traveling shunt fault, it is required to give the data independently for each circuit. Thus if there are 3 circuits between two nodes, then data for each circuit is to be given distinctly or equivalent data for two circuits are given together and per circuit data for the other line is given separately.

- Distance in percentage from the sending end of the line is given in column 2 of table 3. 6. If the percentage distance is notwithin the limits, then the option is ignored.

- In case of open fault, entry in column 1 corresponds to the series element number (serial number counted starting from the first transformer in the series element data). In this case, column 2 data is read, but it is ignored.

Stream 3: Bus Data

In this stream of data, bus details are given. Total number of lines of data is equal to actual number of buses as given at system specification. The data in columns of each line is given in table 3.7.

Table 3.7 - Bus Data

Col No.	Description	Type	Min	Max
1.	Bus number	int	1	9999
2.	Bus status	int	0	1
3.	Zone number	int	1	20
4.	Bus voltage in kV	float	0.001	1.0e5
5.	Bus name	char	1	8
6.	Voltage magnitude in pu	float	0.5	2.0
7.	Voltage angle in degrees	float	-360.0	360.0
8.	Real power generation at bus in MW	float	-1.0e6	1.0e6
9.	Reactive power generation at bus in Mvar	float	-1.0e6	1.0e6
10.	Real power load at bus in MW	float	-1.0e6	1.0e6
11.	Reactive power load at bus in Mvar	float	-1.0e6	1.0e6
12.	Reactive compensation provided at bus in Mvar	float	-1.0e6	1.0e6

Explanations to entries given in table 3.7 are as follows -

Bus number refers to the number by which the buses are identified. Bus numbers need not be continuous and buses belonging to different zones can be referenced by having different starting numbers (i.e., buses in zone 1 can have the bus numbers from 1 to 200, buses in zone2 can have the numbers from 201 to 300 and so on).

- Status field is interpreted as -

  0: Bus doesn't exist.
  1: Bus exists.

- As explained earlier, zone field refers to the zone number to which the bus belongs.

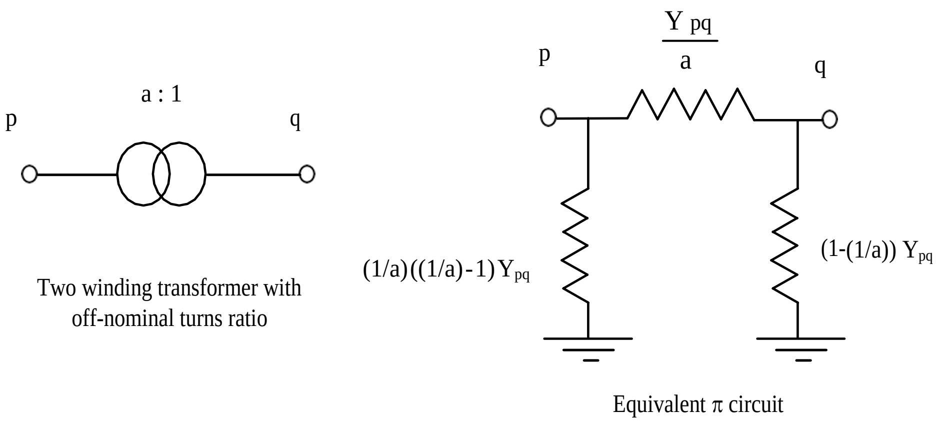
- Bus voltage entry given in column 4 of table 3.7 is in Kilovolts and it is also the base voltage for the bus. Buses are referred more commonly by names rather than numbers. Bus name is a string of maximum 8 characters. Any alphanumeric characters can constitute the bus name. Bus name should be unique.

- Columns 6 to 12 in table 3.7 are of significant only if the pre-fault voltage option is selected as one. Even though the fields are to be present for pre-fault voltage option equal to zero, numerical values are ignored. If the pre-fault voltage option is zero, voltage magnitude at all the buses are initialized to 1.0 pu and voltage angles are initialized to 0.0.

- Pre-fault bus voltage magnitude, voltage angle, power generation at the bus, load at the bus are obtained from the initial load flow run on the system under consideration. When **POWERSCS is** executed from integrated environment after executing the **POWERLFA** program (program for load flow analysis), columns 6 to 12 is automatically generated.

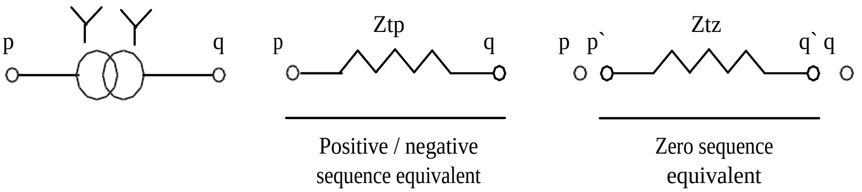
Stream 4: Transformer Data

In this stream of data, transformer details are given. Figure 3.2 shows the modeling of the transformer with off nominal turns ratio. Figure 3.3 shows the modeling of phase shifting



transformer.

Star / Star Connection



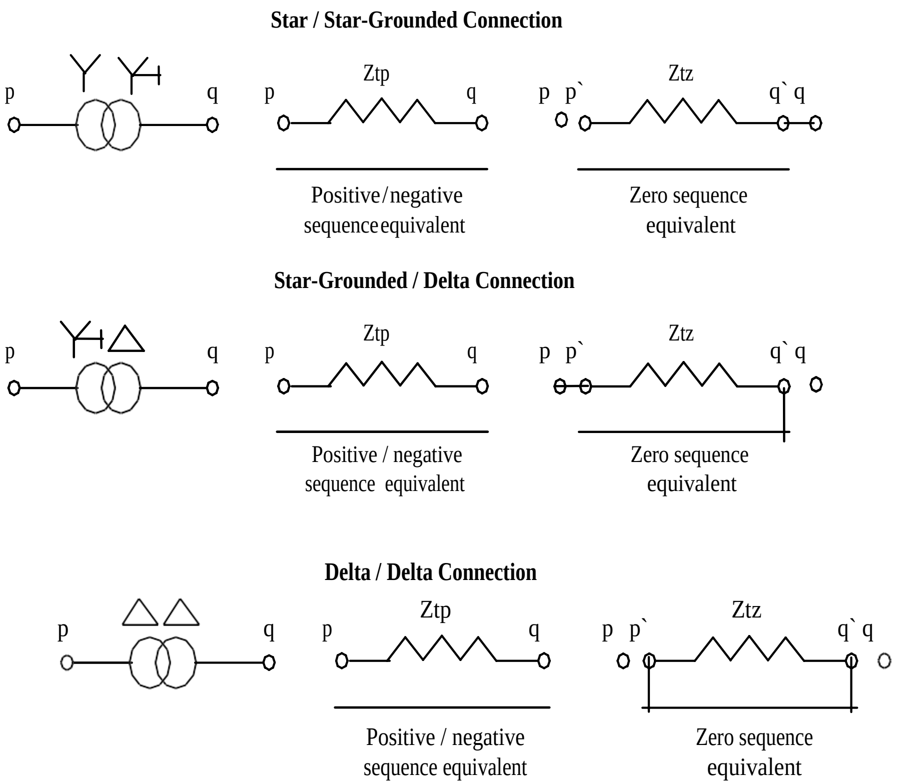


Figure 3.2: positive, negative and zero sequence representation of two winding transformer

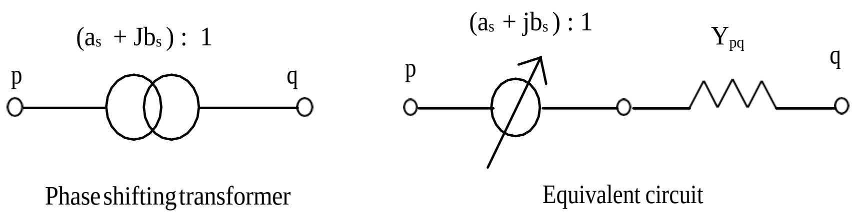


Figure 3.3 : Phase shifting transformer representation

Figure 3.4 shows the modeling of 3 winding transformer.

Three winding transformers are modeled using equivalent **star** connection between the windings.

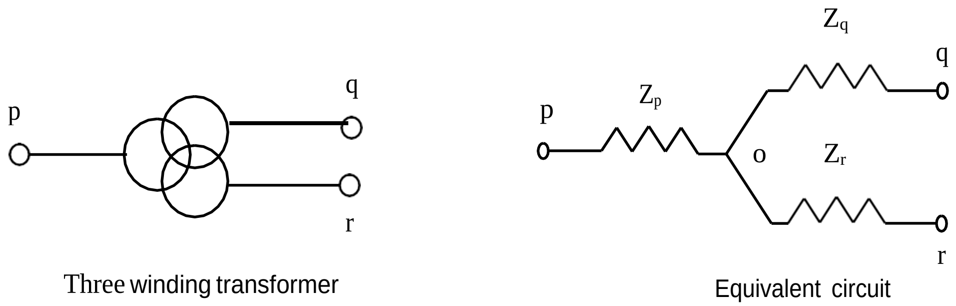


Figure 3.4 Three winding transformer representation

Table 3.8 - Transformer Data				
Col No.	**Description**	**Type**	**Min**	**Max**
1.	Connection status	int	0	3
2.	Numbers in parallel	int	1	10
3.	From bus number	int	1	9999
4.	To bus number	int	1	9999
5.	Positive sequence resistance in pu	float	0.0	1.0e2
6.	Positive sequence reactance in pu	float	1.0e-4	1.0e2
7.	Zero sequence resistance in pu	float	0.0	1.0e2
8.	Zero sequence reactance in pu	float	0.0	1.0e2
9.	Nominal tap setting in pu	float	0.5	1.5
10.	Phase shift	float	0.0	360.0
11.	From side breaker MVA rating	float	1.0	1.0e6
12.	To side breaker MVA rating	float	1.0	1.0e6
12.	To side breaker MVA rating	float	1.0	1.0e6
13.	Primary winding connection	char	1	1
14.	Secondary winding connection	char	1	1

Total number of lines of data in this stream is equal to sum of number of 2 winding transformers and three times the number of three winding transformers. The data in columns of each line is given in table 3.8.

Explanations to entries given in table 3.8 are as follows –

- Connection status is interpreted as
  0: Transformer is open on either ends.
  1 : Transformer is open on from end.
  2 : Transformer is open on to end.
  3 : Transformer is closed on either ends.

  Values 0 and 3 are of significant. If the status value is 3, then only the transformer is modeled in the analysis.

- Numbers in parallel is used to determine whether the fault level exceeds the breaker MVA rating. The impedance value is for the equivalent circuit.

- From bus number and to bus number are the buses on either side to which the transformer is connected. The numbers must be present in the bus data stream.

- Transformer impedance values are in pu on a common base. If `n' number of transformers exist between same nodes, then a transformer can be represented as a single equivalent transformer, or individual transformer data can be specified between the same nodes `n' times. For the equivalent circuit i.e., the impedance value per transformer on its own rating is divided by n and then converted to common base. If the resistance value is zero, effective resistance is computed by multiplying the transformer reactance by the **r/x** ratio.

- Nominal tap setting is the tap setting at which the study is to be carried out. It is assumed that the transformer tap is provided on the from bus side. Hence, since the transformer taps are usually provided on the high voltage winding, it is always preferred to specify the from bus side as the high voltage bus number. In case of three winding transformer, tap is specified from the HT winding to additional node arising because of the equivalent star connection representation. For branches from other two windings, the nominal tap is unity. At unity tap setting, one pu voltage applied at the from bus produces one pu voltage at the to bus on no load. In case of phase shifting transformers, the phase shift is represented in polar form. The phase shift magnitude is entered in the nominal tap position, while phase shift angle is provided in the phase shift position. Phase shift angle is in degrees.

- The transformer zero sequence data is normally equal to positive sequence data. If the transformer neutral is grounded three times, the grounding impedance is added to the zero sequence impedance. Based on the transformer winding connection, the zero sequence network is modeled.

- Primary and secondary winding connections are interpreted as -
  D/d : Delta connection.
  S/s/Y/y/ : Star ungrounded connection.
  G/g : Star grounded connection.

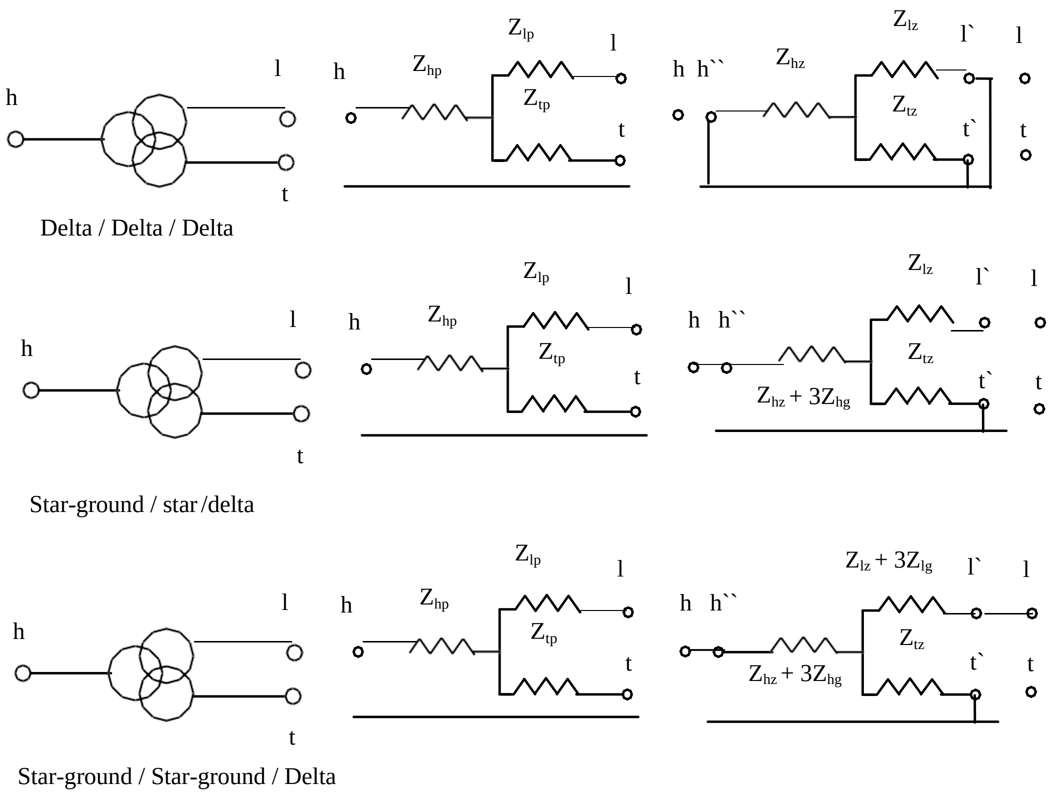


Figure 3.5: Positive and Zero Sequence network of Three winding transformer

Stream 5: Transmission Line Data

In this stream of data, transmission line details are given. Lines/Cables are modeled using equivalent **pi** circuit as shown in figure 3.6.

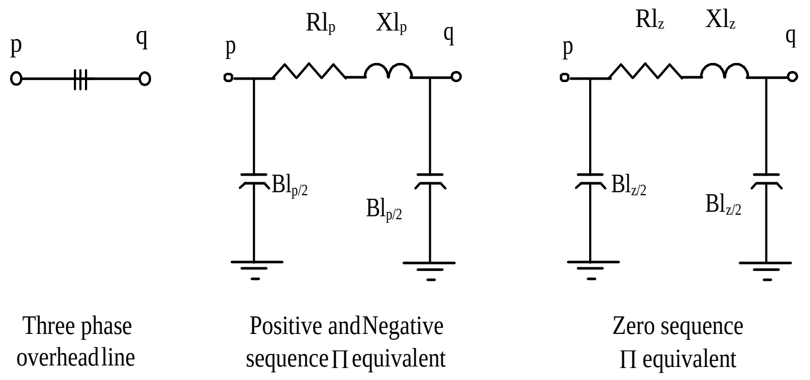


Figure 3.6 : Three phase over head line modeling

Total number of lines of data in this stream is equal to number of transmission lines as given in specification stream. The data that appears in different columns of each line is given in table 3.9.

Explanations to entries given in table 3.9 are as follows -

- Connection status is interpreted as
  - 0 : Line is open on either ends.
  - 1 : Line is open on from end.
  - 2 : Line is open on to end.
  - 3 : Line is closed on either ends.

  Values 0 and 3 are of significant. If the status value is 3, then only the line is modeled in the analysis.

- Number of circuits is used to find whether the fault level exceeds the circuit breaker MVA rating.

Table 3.9 - Transmission Line Data				
Col No.	**Description**	**Type**	**Min**	**Max**
1.	Connection status	int	0	3
2.	Numbers of circuits	int	1	10
3.	From bus number	int	1	9999
4.	To bus number	int	1	9999
5.	Positive sequence resistance in pu	float	-1.0e3	1.0e3
6.	Positive sequence reactance in pu	float	-1.0e3	1.0e3
7.	Positive sequence susceptance (B/2) in pu	float	0.0	1.0e3
8.	Zero sequence resistance in pu	float	-1.0e3	1.0e3
9.	Zero sequence reactance in pu	float	-1.0e3	1.0e3
10.	Zero sequence susceptance (B/2) in pu	float	0.0	1.0e3
11.	From side breaker MVA rating	float	1.0	1.0e6
12.	To side breaker MVA rating	float	1.0	1.0e6

- From bus number and to bus number are the buses on either side to which the line is connected. The numbers must be present in the bus data stream.

- Line values are in pu on a common base. If `n' number of lines exists between same nodes, then a line can be represented as a single equivalent line, or individual line data can be specified between the same nodes n times. For the equivalent circuit i.e., the impedance value per line is divided by `n', the susceptance value per line is multiplied by n and then converted to common base.

- If the zero sequence impedance entries are 0.0, then the value is computed from the positive sequence impedance value using the multiplication factors discussed in multiplication factor stream.

Stream 6 : Series Reactor and Capacitor Data

In this stream, data for series reactor and capacitor are given. Series reactor and capacitor are modeled as series element consisting of resistance (usually zero or negligible value) in series with the reactance. Reactance value is positive for inductor and negative for capacitor. Figure 3.7 and 3.8 show the modeling of series inductor and capacitor respectively.

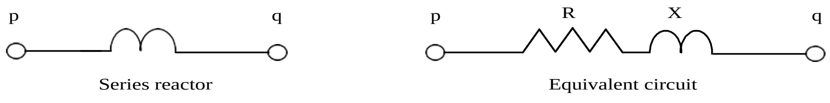


Figure 3.7: Series reactor (inductor) representation

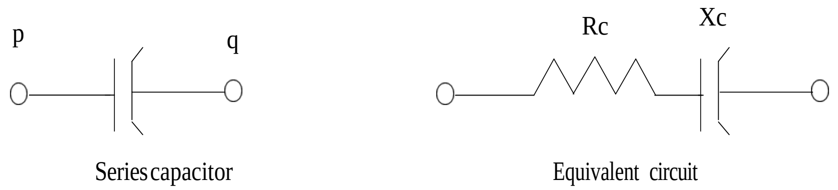


Figure 3.8: Series capacitor representation

Total number of lines of data in this stream is equal to the sum of number of series reactors and capacitors as given in specification stream. The data that appears in different columns of each line is given in table 3.10.

Table 3.10 - Series Reactor/Capacitor Data

Col No.	Description	Type	Min	Max
1.	Connection status	int	0	3
2.	From bus number	int	1	9999
3.	To bus number	int	1	9999
4.	Positive sequence resistance in pu	float	0.0	1.0e3
5.	Positive sequence reactance in pu	float	-1.0e3	1.0e3
6.	Zero sequence resistance in pu	float	0.0	1.0e3
7.	Zero sequence reactance in pu	float	0.0	1.0e3
8.	From side breaker MVA rating	float	1.0	1.0e6
9.	To side breaker MVA rating	float	1.0	1.0e6

Explanations to entries given in table 3.10 are as follows -

- Connection status is interpreted as
  0 : Series reactor/capacitor is open on either ends.
  1 : Series reactor/capacitor is open on from end.
  2 : Series reactor/capacitor is open on to end.
  3 : Series reactor/capacitor is closed on either ends.

Values 0 and 3 are of significant. If the status value is 3, then only the reactor/capacitor is modeled in the analysis.

- From bus number and to bus number are the buses on either side to which the reactor/capacitor is connected. The numbers must be present in the bus data stream.

- Reactor/capacitor impedance values are in pu on a common base. (negative for capacitance) Resistance value of the reactor/capacitor is usually zero or of negligible value.

- If the zero sequence impedance entries are 0.0, then the values are computed from the positive sequence values using the multiplication factors.

Stream 7: Circuit Breaker Data

In this stream, data for circuit breakers and isolating switches are given. Switches are modeled as series element consisting of resistance (usually zero or of negligible value) and reactance (small non zero value) whose values are given in system specifications. Figure 3.9 shows the circuit breaker in closed position.

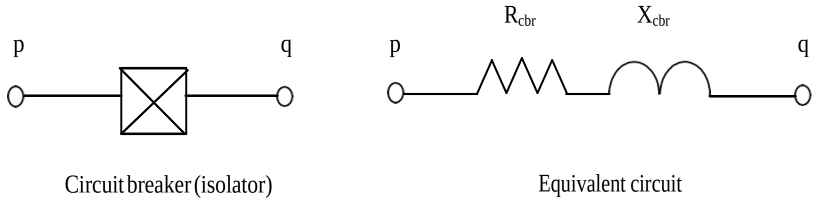


Figure 3.11: Circuit breaker representation in closed position

Total number of lines of data in this stream is equal to the number of circuit breakers. The data that appears in different columns of each line is given in table 3.11.

Table 3.11 - Circuit Breaker Data				
Col No.	**Description**	**Type**	**Min**	**Max**
1.	Connection status	int	0	3
2.	From bus number	int	1	9999
3.	To bus number	int	1	9999
4	Breaker MVA rating	float	1	1.0e6

Explanations to entries given in table 3.10 are as follows -

- Connection status is interpreted as
  0: Circuit breaker is opened.
  3: Circuit breaker is closed.

- From Bus Number
  The breaker from bus number

- To Bus Number
  The bus to which the breaker is connected
- Breaker MVA rating
  MVA rating of the breaker

Stream 8 : Shunt Connection (Admittance) Data

In this stream, data for shunt reactors and capacitors in admittance form is given. Admittance value in pu consists of conductance and susceptance. For shunt inductive reactor, susceptance is negative and for shunt capacitor, susceptance value is positive. Conductance value is zero or of negligible value. Total number of lines of data in this stream is equal to the sum of shunt reactors and capacitors, whose values are given in admittance form. The data that appears in different columns of each line is given in table 3.12.

Table 3.12 - Shunt Reactor/Capacitor (Admittance form) Data

Col No.	Description	Type	Min	Max
1.	From bus number	int	1	9999
2.	Positive sequence conductance in pu	float	-1.0e-4	1.0e4
3.	Positive sequence susceptance in pu	float	-1.0e4	1.0e4
4.	Zero sequence conductance in pu	float	-1.0e-4	1.0e4
5.	Zero sequence susceptance in pu	float	-1.0e4	1.0e4
6	Breaker MVA rating	float	1	1.0e6
7	Shunt status	int	0	3
8	Shunt location	int	0	2

Explanations to entries given in table 3.12 are as follows -

- From bus number is the bus number to which the shunt inductor/capacitor is connected (if the reactor is a bus reactor). The entry in this column is the series element number if the reactor is a line reactor. Usually the reactor value will be specified in Mvar at the rated voltage. If the rated voltage is the base voltage at the bus, then the magnitude of susceptance value in pu is equal to the specified Mvar value in pu The sign is positive for capacitive reactor and negative for inductive reactor. Thus the susceptance value of 63 Mvar inductor at 420 kV is -0.57143 pu on 100 MVA base at 400 kV. Similarly susceptance value of 50 Mvar capacitor at 420 kV is 0.45351 pu on 100 MVA base at 400 kV. If the zero sequence entries are 0.0, then the zero sequence values are obtained from the positive sequence values using the multiplication factor.

- Shunt status is interpreted as -
  0: Reactor does not exist.
  3: Reactor exists.

- Shunt location is interpreted as
  0: Reactor is connected to bus.
  1: Line reactor connected to the from side of the series element.
  2: Line reactor connected to the to side of the series element.

Stream 9: Shunt Connection (Impedance) Data

In this stream, data for shunt reactors and capacitors in impedance form is given. Impedance value in pu consists of resistance and reactance. For shunt inductive reactor, reactance is positive and for shunt capacitor, reactance value is negative. Resistance is zero or of negligible value. In some particular system studies, shunt element data is readily available in impedance form. In addition, in some studies loads are represented in impedance form. When a network is reduced, all the loads can be lumped at a bus as impedance load. In these cases, this stream of data is used. Total number of lines of data in this stream is equal to the shunt impedance number as given in specification stream.

The data that appears in different columns of each line is given in table 3.13.

Table 3.13 - Shunt Impedance Data

Col No.	Description	Type	Min	Max
1.	From bus number	int	1	9999
2.	Positive sequence resistance in pu	float	0.00	1.0e3
3.	Positive sequence reactance in pu	float	-1.0e3	1.0e4
4.	Zero sequence resistance in pu	float	0.00	1.0e3
5.	Zero sequence reactance in pu	float	-1.0e3	1.0e4
6.	Shunt status	int	0	3
7.	Shunt location	int	0	2

Explanations to entries given in table 3.13 are as follows –

- From bus number is the bus number to which the shunt impedance is connected, if shunt impedance location is bus. If the location of the shunt impedance is series element, then line number corresponding to the series element is given in place of bus number. The line number is started counting from first transmission line.

- If the load power at the nominal voltage (base voltage) is known, then the impedance value in pu is computed as the reciprocal of the conjugate of the complex power in pu Thus the pu resistance and reactance values of 80 MW and 60 Mvar load are 0.8 and 0.6 respectively on 100 MVA base.

- Shunt status is interpreted as -
  0 : Shunt impedance does not exist.

3 : Shunt impedance exists.

- Shunt location is interpreted as
  0 : Shunt impedance is connected to the bus.
  1 : Shunt impedance is connected to the from side of the series element.
  2 : Shunt impedance is connected to the to side of the series element.

Stream 10: Generator/Motor Data

In this stream of data, generator impedances are given. Usually generator sub-transient reactance is considered for the fault study. While preparing the data file, either transient or subtransient reactance value can be given. Even though negative sequence reactance value is close to subtransient reactance value, negative sequence network is modeled separately to cater to greater flexibility. Total number of lines of data in this stream is equal to number of generators as given in specification stream. The data that appears in different columns of each line is given in table 3.14.

Table 3.14 - Generator Data

Col No.	Description	Type	Min	Max
1.	Generator bus number	int	1	1000
2.	Positive sequence resistance in pu	float	0.0	9999.9
3.	Positive sequence reactance in pu	float	0.0001	9999.9
4.	Negative sequence resistance in pu	float	0.00	9999.9
5.	Negative sequence reactance in pu	float	0.00	9999.9
6.	Zero sequence resistance in pu	float	0.00	9999.9
7.	Zero sequence reactance in pu	float	0.00	9999.9
8.	Breaker MVA rating	float	1.0	1.0e6
9.	Shunt status	int	0	3
10	Classification code	int	0	3

Explanations to entries given in table 3.14 are as follows –

- Generator / Motor bus number is the bus number to which the generator is connected. This number should exist in the bus data stream.
- If the negative and zero sequence entries are 0.0, then the values are computed from the positive sequence values using the multiplication factors.
- For asynchronous motors, the initial ac short circuit current is obtained from the locked rotor current of the motor at the rated voltage. For motors, the impedance **Z_m** is computed as –

$$Z_m = R_m + jX_m = \frac{U_{nm}}{\sqrt{3I_{an}}} = \left(\frac{1}{I_{an} / I_{nm}}\right) \frac{U_{nm}^2}{S_{nm}}$$

Where,
U_{nm} = rated voltage of motor
I_{an} = locked rotor current of motor
I_{nm} = rated motor current
S_{nm} = rated apparent power of motor

Hence for induction motors, **Z_m** as above is computed in pu and the values are given along with the generator data.

- Shunt status is interpreted as -
  0: Generator does not exist.
  3: Generator exists.

- Classification Code: This identifies the type of Motor. Based upon the classification the impedance required performing the calculation of first cycle and interrupting fault duties is modified. Table 3.14(a) identifies the modifications made to the impedance input data based on the calculation type being used and the group classification assigned for each type of equipment when creating the input data file.

Table 3.14 (a): Classification Code Table

Types of Calculation	**Generator**	**Large Induction Motor**	**Induction Motor ≥ 50 hp (Not Code 4)**	**Induction Motor <50 hp**
Group Classification	0	1	2	3
FCYHV - Calculation of first cycle fault duties for evaluation of high and medium voltage breakers in accordance with IEEE C7.010-1979 - Calculation of first cycle fault duties for evaluation of medium voltage fused contactors	$R+jX^{\|\|}_{d}$	$R+jX^{//}$	$1.2(R+jX^{//})$	
INTHV - Calculation of interrupting fault duties for evaluation of medium voltage breakers in accordance with IEEE C37,010-1979 [1] and IEE c37.5-1979 [3]	$R+jX^{\|\|}_{d}$	$1.5(R+jX^{//})$	$3(R+jX^{//})$	-

FCYLV - Calculation of first cycle fault duties for evaluation of low voltage breakers in accordance with IEEE C37.13-1981 [2] or for calculation of first cycle fault duties on multi-voltage systems in accordance with IEEE Std 141-1986[4] Chapter 6	$R+jX''_d$	$R+jX''$	$1.2(R+jX'')$	$1.67(R+jX'')$

Stream 11: Wind Turbine Generator Data

Wind turbine generator data is specified in this stream of data. For type 1, 2 and type 3 machine with crowbar function active, the model of the machine used is similar to that of an induction motor. Therefore the impedances are specified in p.u. For type 3 machines without crowbar and type 4 machines, converter model is used. Therefore, data pertaining to grid code characteristics and prefault powers are used for modeling. Simple wind generator model (modeled as negative load) is considered as type 0 and does not contribute to faults. The data that appears in different columns of each line for type 1/2/3 with crowbar is given in table 3.15 (a).

Table 3.15 (a) – Wind Turbine Generator Data (for type 1/2/3 with crowbar)

Col No.	Description	Type	Min	Max
1.	Wind turbine generator bus number	int	1	1000
2.	Type of machine	int	0	4
3.	Crowbar function	int	0	1
4.	Number of Turbines	int	1	1000
5.	Positive sequence resistance in pu	float	0.0	9999.9
6.	Positive sequence reactance in pu	float	0.0001	9999.9
7.	Negative sequence resistance in pu	float	0.00	9999.9
8.	Negative sequence reactance in pu	float	0.00	9999.9
9.	Zero sequence resistance in pu	float	0.00	9999.9
10.	Zero sequence reactance in pu	float	0.00	9999.9
11.	Breaker MVA rating	float	1.0	1.0e6
12.	Shunt status	int	0	3

The data that appears in different columns of each line for type 3 without crowbar/type 4 machine is given in table 3.15 (b).

Table 3.15 (b) – Wind Turbine Generator Data (for type 3 without crowbar/type 4)				
Col No.	**Description**	**Type**	**Min**	**Max**
1.	Wind turbine generator bus number	int	1	1000
2.	Type of machine	int	0	4
3.	Crowbar function	int	0	1
4.	Number of Turbines	int	1	1000
5.	Rated MVA	float	0.0001	9999.9
6.	Real Power	float	0.0001	9999.9
7.	Reactive Power	float	0.00	9999.9
8.	Change in voltage low limit (p.u.)	float	0.00	9999.9
9.	Reactive current low limit (p.u.)	float	0.00	9999.9
10.	Change in voltage upper limit (p.u.)	float	0.00	9999.9
11.	Reactive current upper limit (p.u.)	float	0.00	9999.9
12.	Breaker MVA rating	float	1.0	1.0e6
13.	Shunt status	int	0	3

In table 3.15 (b), columns 8, 9, 10 and 11 correspond to the grid code characteristics. The wind turbine current injection is dependent on the voltage seen at its terminal during fault. Note that the injection is for positive sequence voltage improvement.

- Shunt status is interpreted as -
  0: Wind Turbine Generator does not exist.
  3: Wind Turbine Generator exists.

Stream 12 : Load Data

In this stream of data, load details are given. Total number of lines of data in this stream is equal to number of loads as given in specification stream. The data appearing in different columns of each line are given in table 3.16.

Table 3.16 - Load Data				
Col No.	**Description**	**Type**	**Min**	**Max**
1.	Load bus number	int	0	2000
2.	Shunt status	int	0	3

Explanation to entries given in table 3.16 is as follows.

- The load bus number is given in this column. The load given in the bus data stream is taken as the load value. At the specified bus voltage, load values are converted to equivalent impedances to model in the short circuit study. Negative and zero sequence values are obtained from the multiplication factors specified in system specification stream.

- Shunt status is interpreted as -
  - 0: Load does not exist.
  - 3: Load exists.

Stream 13: Filter Data

In this stream of data filter details are given. For each filter, the bus numbers to which the filter is connected and the numbers of branch elements (Resistor, Inductor, and Capacitor) that constitute the filter are given followed by the actual filter data. Hence total number of lines of data in this stream is equal to sum of number of filters as given in the specification stream and sum of number of filter branches of each filter. The data that appears in different columns of each line for a filter branch is given in table 3.17.

Table 3.17 - Filter data

Col No.	Description	Type	Min	Max
1.	Filter branch number	int	0	20
2.	From node	int	0	10
3.	To node	int	0	10
4.	Filter element type	int	1	3
5.	Element value	float	0.0	1.0e4

Explanation to entries in the table 3.17 are as follows –

- Branch number is the serial number of the filter branch. Total number of branches per filter should be less than 20.

- Filter nodes are numbered in order considering the reference node (ground) as 0 and the bus to which the filter is connected as 1. `From' and `To' filter nodes refer to the node numbers of the filter, between which the basic filter element is connected.
- Filter element type is interpreted as -
  - 1: Resistor, element value unit is in Ohm.
  - 2: Inductor, element value unit is in Henry.
  - 3: Capacitor, element value unit is in Farad.

- In the short circuit study, the equivalent shunt admittance in pu, from the filter bus to the ground is computed at the specified system frequency, bus voltage and base MVA. If a filter at bus say 8, consists of resistor, inductor and capacitor connected as shown if figure 3.12, then the data appearing for the filter is as follows:

- In the short circuit study, the equivalent shunt admittance in pu, from filter bus to the ground is computed at the specified system frequency, bus voltage and base **MVA**.

- If a filter at bus say 8, consists of resistors, inductor and a capacitor connected as shown in the figure 3.10, then the data appearing for the filter is as follows.

Bus no 8 and filter branch elements = 15

Branch No.	From Node	To Node	Branch Element type	Active Valive
1	1	2	3	000.417e-6
2	2	3	2	000.947
3	3	0	1	037.000
4	1	4	3	000.417e-6
5	4	4	2	000.497
6	5	0	1	026.600
7	1	6	3	000.417e-6
8	6	7	2	000.201
9	7	0	1	016.900
10	1	8	3	000.417e-6
11	8	9	2	000.145
12	9	0	1	014.400
13	1	10	3	000.417e-6
14	10	0	2	0.085
15	10	0	1	452.000

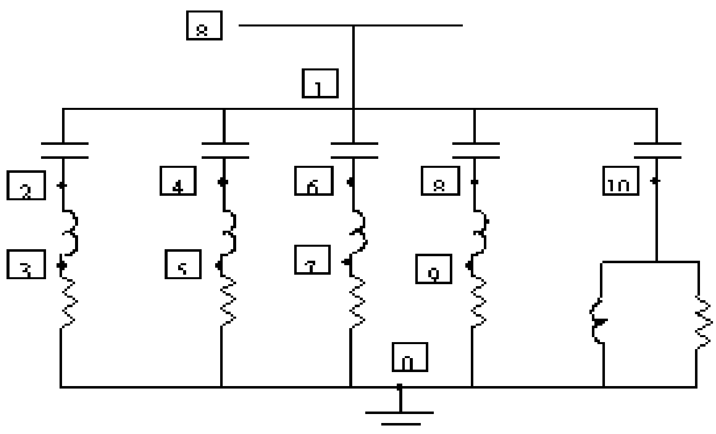


Figure 3.10: Example of a Filter Data

Stream 14: HVDC Converter Data

One of the advantages of using HVDC system is that HVDC system will not contribute to AC system faults. If the AC system is relatively weak, i.e., low Short Circuit Ratio (SCR), then the AC fault level is comparable to HVDC rating. Because of the Voltage Dependent Current Order

Limiter (VDCOL), even the power is also reduced. A provision is provided to consider DC system in fault study. For each HVDC converting station, corresponding AC bus number, real power in MW, reactive power in Mvar and shunt status are specified in this stream. At the specified bus voltage, load values are converted to equivalent impedances to model in the short circuit study.

- Shunt status is interpreted as -
  0 : HVDC converter does not exist.
  3 : HVDC converter exists.

4. INPUT/OUTPUT FILES

Table 4.1 gives extensions of different input and output files used by POWERSCS.

Table 4.1 - Input and Output Files of POWERSCS

Sl. No.	File Extension	Mode	Description
1.	".datX "	input	Program input file
2.	".outX "	output	Program output (general report) file
3.	".pltX "	output	Plot file compatible to graphic utility.
4.	“scs.acd”	output	Plot file compatible to MiGUI

X represents schedule no.
".outX " file contains -

- Input data to the program, in the order the data is read.
- New order for the buses, if the report option is 4.
- Ybus element values for the system, if the report option is 4.
- Zbus element values if the report option is 4.
- Fault MVA at the bus in both magnitude and angle.
- Fault contribution to faulted bus depending on the flow option selection.
- Post fault bus voltages at all the buses, if the option selected is 1.

" **.pltX** " file contains -

- For buses: Bus number, fault level magnitude (unit depends on the plot option) and angle if fault is selected at more than one bus at a time, and post fault bus voltage magnitude in pu and angle in degrees if fault at a single bus is selected (3 fields) all separated by blanks.

- For series elements: Series element number, forward fault flow magnitude (unit depends on plot option) and angle, reverse fault magnitude and angle, percentage loading on the breaker (i.e., fault MVA divided by the breaker rating expressed in percentage) on from bus side, percentage loading on the breaker on to bus side (7 fields) all separated by blanks.

- For shunt reactors, capacitors, loads and generators in order : Bus number, fault quantity (unit depends on the plot option) injected to the bus in magnitude and angle, and breaker loading.

Error Messages

If the program while execution traces any error, an error message is written to the report file and further execution of the program is terminated. The error messages, which are traced by the program, are printed in the following format -

Error Number Error Message Error Description

Error number is a number by which the error is identified. The nature of error is given in the error message. An error description specific to user/application is also given. The errors identified by the program are -

- [**Error no 0**] Parameter passing error : If there is an error in passing parameters to the program, then an error is reported. In the description, the missing parameter is named. bf [Error no 1] Input file opening error : If the input data file name specified by the user is not found or if an error occurs while the input file is opened, this message is generated. If there are more than one input file for the program then, the description specifies missing input file.

- [**Error no 2**] Output file opening error: If an error occurs while opening the output file, this message is generated.

- [**Error no 3**] Too less parameters to read : If the data provided is insufficient then, this error is displayed. The input data 'stream' for which data is insufficient is also described in the error message.

- [**Error no 4**] Memory allocation error : If memory is not allocated for a variable for which dynamic memory allocation is done, this error message is given. The variable for which memory allocation is not successfully done is mentioned in the error description.

- [**Error no 5**] Invalid character : If an invalid character data is present in the input data file then this message is generated. The data item for which invalid character is entered is also mentioned in the error message.

- [**Error no 6**] Invalid number : If an invalid integer data is present in the input data file then this message is displayed. The data item for which invalid integer data is given is also mentioned in the error message.

- [**Error no** 7] Invalid value : If the data given exceeds the limits mentioned for each item mentioned under different streams, an error message is given along with a description of the data item.

- [**Error no 8**] Division by zero : During a mathematical operation, if division by zero occurs, then this error is generated. The variable, which may have caused this condition, is mentioned in the error description.

- [**Error no 9**] Diverging error : This message is generated if no convergence is observed after a specified number of iterations.

- [**Error no 10**] Error in data, Results not okay : If an erroneous input data is present which doesn't come under any of the above mentioned categories as a result of which wrong results are obtained, then this message is generated.

These errors are displayed in the output file mentioned by the user. Some of the common error messages and their probable reasons for occurrence are -

ERROR [1] : Input file opening error - Input file not opened for reading. is written to the report file. If the program expects data to be read from input file, but has not provided data and end of file is reached, then this error message.

ERROR [3] : Too less parameters to read - Insufficient data provided for Stream is written to the report file. If the from/to bus of a transformer specified by the user doesn't exist in the bus data stream, then an error message.

ERROR [6] : Invalid number - Invalid bus id specified is written to the report file.

5. CASE STUDY

In this section, a sample IEEE power system network (Reference : J. Duncan Glover, “A Personal Computer Software package for Power Engineering Education, IEEE Transactions on Power System, Vol. 3, No. 4, November 1988, PP. 1864 - 1871) is considered to explain the **POWERSCS** results. The single line diagram of the test system is shown in figure 5.1 To view the short circuit results on the single line diagram, the single line diagram should have the proper “ZZ” code as shown in the figure 5.1. In the Power system network editor, open the single line diagram with ZZ code, select plot - results in the menu. This will pop up a window where user has to give the scs.acd file generated by the same short circuit case. The results looks as shown in figure 5.2, fault level shown in MVA and angle.

A three phase to ground fault is considered at all buses considered one at a time. Listing of input and output files for this case is given below. Under three phase to ground fault if user wants to observe the symmetrical components of the fault current then user can create a three phase to ground fault at desired bus with the print option 4.

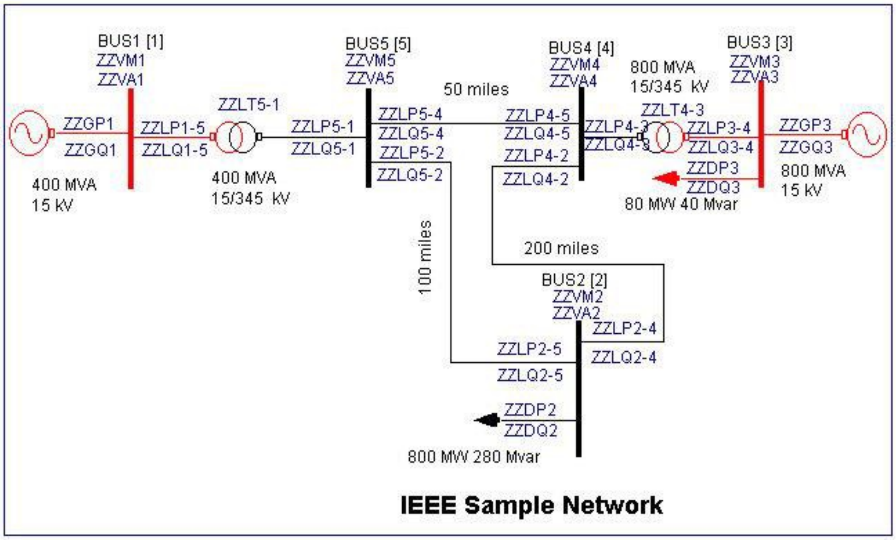

BUS1 [1]
ZZVM1
ZZVA1
ZZGP1
ZZGQ1
ZZLP1-5
ZZLQ1-5
400 MVA
15 kV
ZZLT5-1
400 MVA
15/345 kV
ZZLP5-1
ZZLQ5-1
BUS5 [5]
ZZVM5
ZZVA5
50 miles
ZZLP5-4
ZZLQ5-4
ZZLP5-2
ZZLQ5-2
100 miles
BUS4 [4]
ZZVM4
ZZVA4
ZZLP4-5
ZZLQ4-5
ZZLP4-2
ZZLQ4-2
ZZLP4-3
ZZLQ4-3
800 MVA
15/345 kV
ZZLT4-3
ZZLP3-4
ZZLQ3-4
ZZDP3
ZZDQ3
80 MW 40 Mvar
BUS3 [3]
ZZVM3
ZZVA3
ZZGP3
ZZGQ3
800 MVA
15 kV
200 miles
BUS2 [2]
ZZVM2
ZZVA2
ZZLP2-4
ZZLQ2-4
ZZLP2-5
ZZLQ2-5
ZZDP2
ZZDQ2
800 MW 280 Mvar
IEEE Sample Network

Figure 5.1

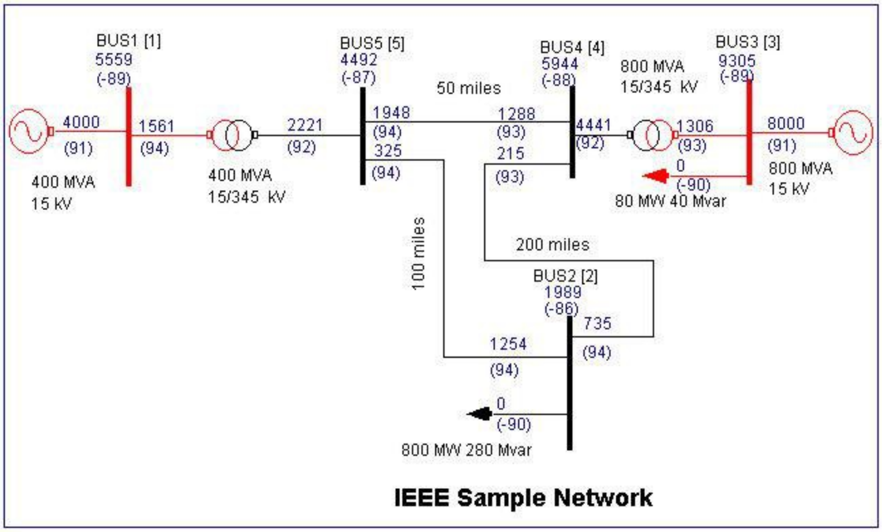


Figure 5.2

In put File : "1Glove02.dat0 " file for 3 phase fault.

```
      SHORT CIRCUIT STUDIES
CASE NO :  1     CONTINGENCY  : 0   SCHEDULE NO : 0
CONTINGENCY NAME : Base Case
VERSION 8.1
%%
% Common System Specifications
   5     5     2     0     3     0     0     0     0     0    0
    2    0    2     0     0    0

   1 4 7     400.000000  50.00000  0 0 1    1 0
1.000000
0.00000e+000  0.00000e+000  0.00000e+000  0.00000e+000
%  Magnitude_Tolerance  Angle_Tolerance  Max_No_of_Iterations  (For  controlled
current injection sources)
 1.000000e-002 1.000000e+000        15   0
% CBResistance CBReactance Trans R/X
0.000000e+000  1.000000e-004   0.050000

% Multiplication Factors
% 1. Transformer Zero Seq Impedance Factor
% 2. No Of Voltage Levels
```

```
%      i. Transmission Line Voltage
%     ii. Transmission Line Zero Seq Res Mult Factor
%    iii. Transmission Line Zero Seq Rea Mult Factor
%     iv. Transmission Line Zero Seq Adm Mult Factor
% 3. Generator Negative Seq Resistance Mult Fact
% 4. Generator Negative Seq Reactance Mult Fact
% 5. Generator Zero Seq Resistance Mult Fact
% 6. Generator Zero Seq Reactance Mult Fact
% 7. Load Negative Seq Imp Mult Fact
% 8. Load Zero Seq Imp Mult Fact
% 9. Series Reactor Zero Seq Imp Mult Fact
%10. Shunt Reactor Zero Seq Imp Mult Fact
 0.90000   4
 345.0000      0.0000      0.0000     0.0000
   15.0000      2.5000      2.5000     0.0000
   15.0000      2.5000      2.5000     0.0250
   15.0000      2.5000      2.5000     0.6000
    0.1750      0.1750      0.0375      0.0375
    0.8100      1.6000      1.0000      0.6250
     0       0.0000
% Bus Data
% BusId  AreaNo    BaseVolt   BusName   VMag        VAng
%         PGen(mw)  QGen(mvar) PLoad(mw) QLoad(mvar) QComp(mvar)
   1 1  1  15.000     BUS1  1.000000000000e+000 0.000000000000e+000
          0.00     0.00     0.00     0.00   0.00
   2 1  1 345.000     BUS2  1.000000000000e+000 0.000000000000e+000
          0.00     0.00     0.00     0.00   0.00
   3 1  1  15.000     BUS3  1.000000000000e+000 0.000000000000e+000
          0.00     0.00     0.00     0.00   0.00
   4 1  1 345.000     BUS4  1.000000000000e+000 0.000000000000e+000
          0.00     0.00     0.00     0.00   0.00
   5 1  1 345.000     BUS5  1.000000000000e+000 0.000000000000e+000
          0.00     0.00     0.00     0.00   0.00

% Two Winding Transformer Data
% 1. Status  2. NoOfCkts  3. FromBus 4. ToBus   5. +ve R
% 6. +ve X   7. Zero R    8. Zero X  9. NomTap 10. PhaseShift
%11. FromBreaker MVARat  12. ToBreaker MVARat
%13. FromWindConn        14. ToWindConn
3    1       5      1   5.999665e-003 7.999533e-002 5.399836e-003  7.199779e-002
1.12000      0.0    50.0000   50.0000 G D
0
3    1       4      3   2.999832e-003 3.999766e-002 2.699918e-003  3.599890e-002
1.00000      0.0    50.0000   50.0000 G D
0

% Transmission Line
% 1.Status  2.NoOfCkts  3.FromBus  4.ToBus  5.+veR  6.+veX  7.+veB/2
% 8.ZeroR   9.ZeroX    10.ZeroB/2
%11.FromCBMVARating    12.ToCBMVARating
```

```
3   1       5      4 8.999594e-003  9.997447e-002  0.000000e+000   2.249899e-002
2.499226e-001 0.000000e+000   50.000   50.000
3   1       4      2 3.599838e-002  3.998979e-001  0.000000e+000   8.999594e-002
9.996905e-001 0.000000e+000   50.000   50.000
3   1       5      2 1.799919e-002  1.999489e-001  0.000000e+000   4.499797e-002
4.998453e-001 0.000000e+000   50.000   50.000


% Generator Data
% 1.BusNo 2.+ve R  3.+veX  4.-veR  5.-veX  6.ZeroR  7.ZeroX
% 8.CBMVA
   1   1.000000e-003 1.000000e-001   1.000000e-003 0.000000e+000   0.000000e+000
9.999000e+006 5000.000    3  0
   3   5.000000e-004 5.000000e-002   5.000000e-004 0.000000e+000   0.000000e+000
9.999000e+006 5000.000    3  0

% Load Data
% LoadBus
   3   3
   2   3
```

Output of the POWERSCS program for the above input file

```
--------------------------------------------------------------------------------
Date and Time : Thu Mar 06 13:10:20 2014
File Name & Path : C:\MiP-PSCT\Samples\DatabaseManager\Glover\SCS\1GLOVE0S.out0
----------------------------------------------------------------------------
       SHORT CIRCUIT STUDIES
CASE NO :  1     CONTINGENCY  : 0   SCHEDULE NO : 0
CONTINGENCY NAME : Base Case
VERSION NUMBER :  8.1

--------------------------------------------------------------------------------
%%
LARGEST BUS NUMBER USED        :    5    ACTUAL NUMBER OF BUSES          :    5
NUMBER OF 2 WIND. TRANSFORMERS :    2    NUMBER OF 3 WIND. TRANSFORMERS :    0
NUMBER OF TRANSMISSION LINES   :    3
NUMBER OF SERIES REACTORS      :    0    NUMBER OF SERIES CAPACITORS    :    0
NUMBER OF BUS COUPLERS         :    0
NUMBER OF SHUNT REACTORS       :    0    NUMBER OF SHUNT CAPACITORS     :    0
NUMBER OF SHUNT IMPEDANCES     :    0    NUMBER OF GENERATORS           :    2
NUMBER OF MOTORS               :    0
NUMBER OF LOADS                :    2
NUMBER OF FILTERS              :    0
NUMBER OF HVDC CONVERTORS      :    0
NUMBER OF WIND GENERATORS     :    0

----------------------------------------------------------------------------
NUMBER OF ZONES         :  1
PRINT OPTION            :  4 DETAILED REPORT PRINT
PLOT OPTION             :  7 (PLOT FILE - PHASE A,  MVA)
BASE MVA                :  400.000
```

```
NOMINAL SYSTEM FREQUENCY:   50.000
PREFAULT VOLTAGE OPTION :  0 (VOLTAGE OF 1.00 PU IS ASSUMED)
FAULT OPTION            :  0 (FAULT CONSIDERED AT ALL BUSES, ONE AT A TIME)
FLOW OPTION             :  1 (FAULT CONTRIBUTION COMPUTED FROM ADJACENT BUSES)
FAULT TYPE              :  1 (3 PHASE TO GROUND FAULT)
POST FAULT VOLT OPTION  :  0 (NO COMPUTATION)
--------------------------------------------------------------------------------
----------------------------------------------------------------------------
FAULT RESISTANCE - PHASE  -   0.000000 (PU)
FAULT  REACTANCE  -  PHASE  - 0.000000  (PU)
FAULT  RESISTANCE  -  GROUND  - 0.000000  (PU)
FAULT REACTANCE  - GROUND -   0.000000 (PU)
--------------------------------------------------------------------------------
MAGNITUDE TOLERANCE (PU)                                :   0.010000
ANGLE TOLERANCE (degrees)                               :   1.000000
MAX NO OF ITERATIONS                                    :       15
CIRCUIT BREAKER RESISTANCE (PU)                         :   0.000000
CIRCUIT BREAKER REACTANCE  (PU)                         :   0.000100
TRANSFORMER R/X RATIO                                   :   0.050000
TRANSFORMER ZERO SEQUENCE IMPEDANCE MULT FACTOR         :   0.900000

NUMBER OF TRANSMISSION VOLTAGE LEVELS                   : 4
TRANSMISSION LINE VOLTAGE - KV                          : 345.000000
TRANSMISSION LINE ZERO SEQUENCE RES. MULT. FACTOR       :   0.000000
TRANSMISSION LINE ZERO SEQUENCE REA. MULT. FACTOR       :   0.000000
TRANSMISSION LINE ZERO SEQUENCE ADM. MULT. FACTOR       :   0.000000
TRANSMISSION LINE VOLTAGE - KV                          :  15.000000
TRANSMISSION LINE ZERO SEQUENCE RES. MULT. FACTOR       :   2.500000
TRANSMISSION LINE ZERO SEQUENCE REA. MULT. FACTOR       :   2.500000
TRANSMISSION LINE ZERO SEQUENCE ADM. MULT. FACTOR       :   0.000000
TRANSMISSION LINE VOLTAGE - KV                          :  15.000000
TRANSMISSION LINE ZERO SEQUENCE RES. MULT. FACTOR       :   2.500000
TRANSMISSION LINE ZERO SEQUENCE REA. MULT. FACTOR       :   2.500000
TRANSMISSION LINE ZERO SEQUENCE ADM. MULT. FACTOR       :   0.025000
TRANSMISSION LINE VOLTAGE - KV                          :  15.000000
TRANSMISSION LINE ZERO SEQUENCE RES. MULT. FACTOR       :   2.500000
TRANSMISSION LINE ZERO SEQUENCE REA. MULT. FACTOR       :   2.500000
TRANSMISSION LINE ZERO SEQUENCE ADM. MULT. FACTOR       :   0.600000

GENERATOR NEGATIVE SEQUENCE RESISTANCE MULT. FACTOR  :    0.175000
GENERATOR NEGATIVE SEQUENCE REACTANCE  MULT. FACTOR  :    0.175000
GENERATOR ZERO SEQUENCE RESISTANCE MULT. FACTOR      :    0.037500
GENERATOR ZERO SEQUENCE REACTANCE MULT. FACTOR       :    0.037500
LOAD      NEGATIVE SEQUENCE IMPEDANCE  MULT. FACTOR  :    0.810000
LOAD      ZERO SEQUENCE IMPEDANCE  MULT. FACTOR      :    1.600000
SERIES REACTOR ZERO SEQUENCE IMPEDANCE MULT. FACTOR  :    1.000000
SHUNT  REACTOR ZERO SEQUENCE IMPEDANCE MULT. FACTOR  :    0.625000
----------------------------------------------------------------------------
FAULT CONSIDERED FROM SENDING END OF LINE NUMBER    0 AT  0.00%
----------------------------------------------------------------------------
BUS DATA
```

```
NODE STAT ZONE BUS-KV    NAME      VMAG-PU  VANG-DEG  PGEN-MW  QGEN-MR
                                            PLOAD-MW QLOAD-MR QCOMP-MR
---- ---- ---- -------- -------- -------- -------- -------- --------
   1    1    1   15.000     BUS1   1.0000    0.000    0.000    0.000
                                             0.000    0.000    0.000
   2    1    1  345.000     BUS2   1.0000    0.000    0.000    0.000
                                             0.000    0.000    0.000
   3    1    1   15.000     BUS3   1.0000    0.000    0.000    0.000
                                             0.000    0.000    0.000
   4    1    1  345.000     BUS4   1.0000    0.000    0.000    0.000
                                             0.000    0.000    0.000
   5    1    1  345.000     BUS5   1.0000    0.000    0.000    0.000
                                             0.000    0.000    0.000
---------------------------------------------------------------------------
TRANSFORMER DATA

STAT CKTS FROM FROM       TO TO              POSITIVE             ZERO   PRI
SEC TYPE
          NODE NAME     NODE NAME       R(P.U)  X(P.U.)  R(P.U.)  X(P.U.  )
                                           TAP    PHASE   FB-MVA   TB-MVA
---- ---- ---- -------- ---- -------- -------- -------- -------- -------- --- -
-- ----
   3    1    5     BUS5    1     BUS1  0.00600  0.08000  0.00540  0.07200
                                       1.12000    0.000       50       50   G
D
   3    1    4     BUS4    3     BUS3  0.00300  0.04000  0.00270  0.03600
                                       1.00000    0.000       50       50   G
D

---------------------------------------------------------------------------
TRANSMISSION LINE DATA

STAT CKTS FROM FROM      TO TO
          NODE NAME     NODE NAME      RP(P.U)  XP(P.U) BP/2(PU)
                                       RZ(P.U)  XZ(P.U) BZ/2(PU) FB-MVA TB-MVA
---- ---- ---- -------- ---- -------- -------- -------- -------- ------ ------
   3    1    5     BUS5    4     BUS4  0.00900  0.09997  0.00000
                                       0.02250  0.24992  0.00000     50     50
   3    1    4     BUS4    2     BUS2  0.03600  0.39990  0.00000
                                       0.09000  0.99969  0.00000     50     50
   3    1    5     BUS5    2     BUS2  0.01800  0.19995  0.00000
                                       0.04500  0.49985  0.00000     50     50

---------------------------------------------------------------------------
GENERATOR/MOTOR DATA

Classification Code :
0 : Generator
1 : Large Motor  >1000 hp for <= 1800 rpm, >250 hp for 3600 rpm
2 : Medium Motor >= 50 hp
3 : Small Motor  < 50 hp
```

```
FROM  FROM                       POSITIVE              NEGATIVE                 ZERO
CLASS
NODE NAME        R(P.U)  X(P.U.)  R(P.U.)  X(P.U.)  R(P.U.)  X(P.U.) CB-MVA STAT
CODE
---- -------- -------- -------- -------- -------- -------- -------- ------ ----
-----
   1      BUS1  0.00100  0.10000  0.00100  0.00000  0.00000 9999000.00000    5000
3     0
   3      BUS3  0.00050  0.05000  0.00050  0.00000  0.00000 9999000.00000    5000
3     0

---------------------------------------------------------------------------
LOAD DATA

NODE NAME     STATUS
---- -------- ------
   3     BUS3      3
   2     BUS2      3
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
 OLD-NUMBER   NEW-NUMBER
 ----------   ----------
          1           1
          2           3
          3           2
          4           4
          5           5
 NEW-NUMBER   OLD-NUMBER
 ----------   ----------
          1           1
          2           3
          3           2
          4           4
          5           5
---------------------------------------------------------------------------
POSITIVE SEQUENCE Y BUS IN OLD AND NEW NUMBERING
   NEW-NUMBER     OLD-NUMBER     ADMITTANCE
   ROW COLUMN     ROW COLUMN YBUS.re    YBUS.im
------ ------ ------ ------ ---------- ----------
     1      1      1      1     1.0323   -22.4298
     1      5      1      5    -0.9323    12.4308
     2      2      3      3     2.0646   -44.8596
     2      4      3      4    -1.8646    24.8616
     3      3      2      2     0.6699    -7.4416
     3      4      2      4    -0.2233     2.4805
     3      5      2      5    -0.4466     4.9611
     4      4      4      4     2.9811   -37.2643
     4      5      4      5    -0.8932     9.9222
     5      5      5      5     2.2721   -27.3140
-------------------------------------------------------------------------------
```

```
NEGATIVE SEQUENCE Y BUS IN OLD AND NEW NUMBERING
   NEW-NUMBER    OLD-NUMBER     ADMITTANCE
   ROW COLUMN    ROW COLUMN YBUS.re    YBUS.im
------ ------ ------ ------ ---------- ----------
     1      1      1      1     4.1870   -69.3877
     1      5      1      5    -0.9323    12.4308
     2      2      3      3     8.3740  -138.7754
     2      4      3      4    -1.8646    24.8616
     3      3      2      2     0.6699    -7.4416
     3      4      2      4    -0.2233     2.4805
     3      5      2      5    -0.4466     4.9611
     4      4      4      4     2.9811   -37.2643
     4      5      4      5    -0.8932     9.9222
     5      5      5      5     2.2721   -27.3140
---------------------------------------------------------------------------
ZBUS SEQUENCE IMPEDANCE VALUES FOR COLUMN (BUS) :     1
                   POSITIVE                NEGATIVE                    ZERO
ROWNO    ZBUS.re    ZBUS.im    ZBUS.re    ZBUS.im    ZBUS.re    ZBUS.im
----- ---------- ---------- ---------- ---------- ---------- ----------
    1     0.0019     0.0719     0.0010     0.0162
    2     0.0007     0.0414     0.0005     0.0080
    3    -0.0004     0.0140     0.0000     0.0007
    4    -0.0001     0.0253     0.0002     0.0037
    5     0.0011     0.0494     0.0006     0.0101
---------------------------------------------------------------------------
FAULT AT BUS NUMBER     1 : NAME     BUS1
      CURRENT (AMPS/DEGREE)                              FAULT MVA
 SEQUENCE (1,2,0)    PHASE (A,B,C)      SEQUENCE (1,2,0)    PHASE (A,B,C)
MAGNITUDE   ANGLE  MAGNITUDE   ANGLE        MAGNITUDE         MAGNITUDE
--------- -------  --------- -------        ---------         ---------
   213960  -88.51     213960  -88.51             5559              5559
        0  -90.00     213960  151.49                0              5559
        0  -90.00     213960   31.49                0              5559
R/X RATIO OF THE SHORT CIRCUIT PATH        :   0.0261
PEAK ASYMMETRICAL SHORT-CIRCUIT CURRENT :   588120 AMPS
PASCC = k x sqrt(2) x If , k =   1.9436
---------------------------------------------------------------------------
FAULT CONTRIBUTION
FROM FROM         TO TO              CURRENT (AMPS/DEGREE)          MVA
NODE NAME       NODE NAME       SEQUENCE (1,2,0)   PHASE (A,B,C)   PHASE(A,B,C)
                               MAGNITUDE   ANGLE MAGNITUDE   ANGLE MAGNITUDE
---- --------  ---- --------   --------- ------- --------- ------- ---------
   1     BUS1     5     BUS5       60079   93.85     60079   93.85      1561
                                       0  -90.00     60079  -26.15      1561
                                       0  -90.00     60079 -146.15      1561
---------------------------------------------------------------------------
FAULT CONTRIBUTION FROM SHUNT CONNECTION
FROM FROM              CURRENT (AMPS/DEGREE)         MVA
NODE NAME       SEQUENCE (1,2,0)    PHASE (A,B,C)    PHASE(A,B,C)
```

```
                MAGNITUDE   ANGLE  MAGNITUDE   ANGLE  MAGNITUDE
---- --------   --------- -------  --------- -------



   1     BUS1      153952   90.57     153952   90.57       4000
                        0  -90.00     153952  -29.43       4000
                        0  -90.00     153952 -149.43       4000
---------------------------------------------------------------------------
ZBUS SEQUENCE IMPEDANCE VALUES FOR COLUMN (BUS) :     2
                    POSITIVE              NEGATIVE                   ZERO
ROWNO    ZBUS.re    ZBUS.im    ZBUS.re    ZBUS.im    ZBUS.re    ZBUS.im
----- ---------- ---------- ---------- ---------- ---------- ----------
    1     0.0007     0.0414     0.0005     0.0080
    2     0.0149     0.2005     0.0148     0.1718
    3     0.0001     0.0293     0.0003     0.0048
    4     0.0018     0.0528     0.0018     0.0265
    5     0.0035     0.0745     0.0033     0.0445
---------------------------------------------------------------------------
FAULT AT BUS NUMBER     2 : NAME     BUS2
      CURRENT (AMPS/DEGREE)                           FAULT MVA
 SEQUENCE (1,2,0)    PHASE (A,B,C)      SEQUENCE (1,2,0)    PHASE (A,B,C)
MAGNITUDE   ANGLE  MAGNITUDE   ANGLE        MAGNITUDE         MAGNITUDE
--------- -------  --------- -------        ---------         ---------
     3329  -85.75       3329  -85.75             1989              1989
        0  -90.00       3329  154.25                0              1989
        0  -90.00       3329   34.25                0              1989
R/X RATIO OF THE SHORT CIRCUIT PATH        :  0.0743
PEAK ASYMMETRICAL SHORT-CIRCUIT CURRENT :     8660 AMPS
PASCC = k x sqrt(2) x If , k =   1.8394
---------------------------------------------------------------------------
FAULT CONTRIBUTION
FROM FROM        TO TO               CURRENT (AMPS/DEGREE)        MVA
NODE NAME      NODE NAME      SEQUENCE (1,2,0)   PHASE (A,B,C)   PHASE(A,B,C)
                             MAGNITUDE   ANGLE MAGNITUDE   ANGLE MAGNITUDE

---- --------   ---- --------  --------- ------- --------- ------- ---------
   2     BUS2     4     BUS4        1230   94.32      1230   94.32       735
                                       0  -90.00      1230  -25.68       735
                                       0  -90.00      1230 -145.68       735
   2     BUS2     5     BUS5        2099   94.21      2099   94.21      1254
                                       0  -90.00      2099  -25.79      1254
                                       0  -90.00      2099 -145.79      1254
---------------------------------------------------------------------------
FAULT CONTRIBUTION FROM SHUNT CONNECTION
FROM FROM              CURRENT (AMPS/DEGREE)         MVA
NODE NAME       SEQUENCE (1,2,0)    PHASE (A,B,C)
               PHASE(A,B,C)  MAGNITUDE        ANGLE  MAGNITUDE
               ANGLE  MAGNITUDE

---- --------   --------- -------  --------- -------  ---------
   2     BUS2           0  -90.00          0  -90.00          0
                        0  -90.00          0  -90.00          0
                        0  -90.00          0  -90.00          0
```

```
--------------------------------------------------------------------------
ZBUS SEQUENCE IMPEDANCE VALUES FOR COLUMN (BUS) :     3
                   POSITIVE                NEGATIVE                  ZERO
ROWNO    ZBUS.re    ZBUS.im    ZBUS.re    ZBUS.im    ZBUS.re    ZBUS.im
----- ---------- ---------- ---------- ---------- ---------- ----------



    1    -0.0004     0.0140     0.0000     0.0007
    2     0.0001     0.0293     0.0003     0.0048
    3     0.0007     0.0430     0.0005     0.0084
    4     0.0005     0.0374     0.0004     0.0069
    5    -0.0001     0.0253     0.0002     0.0037
--------------------------------------------------------------------------
FAULT AT BUS NUMBER     3 : NAME     BUS3
      CURRENT (AMPS/DEGREE)                           FAULT MVA
 SEQUENCE (1,2,0)    PHASE (A,B,C)      SEQUENCE (1,2,0)    PHASE (A,B,C)
MAGNITUDE   ANGLE  MAGNITUDE   ANGLE        MAGNITUDE         MAGNITUDE
--------- -------  --------- -------        ---------         ---------
   358136  -89.04     358136  -89.04             9305              9305
        0  -90.00     358136  150.96                0              9305
        0  -90.00     358136   30.96                0              9305
R/X RATIO OF THE SHORT CIRCUIT PATH        :   0.0167
PEAK ASYMMETRICAL SHORT-CIRCUIT CURRENT :   994653 AMPS
PASCC = k x sqrt(2) x If , k =   1.9638
--------------------------------------------------------------------------
FAULT CONTRIBUTION
FROM FROM        TO TO              CURRENT (AMPS/DEGREE)        MVA
NODE NAME      NODE NAME       SEQUENCE (1,2,0)   PHASE (A,B,C)   PHASE(A,B,C)
                              MAGNITUDE   ANGLE MAGNITUDE   ANGLE MAGNITUDE
---- -------- ---- -------- --------- ------- --------- ------- ---------
   3     BUS3     4     BUS4      50281   93.32     50281   93.32      1306
                                      0  -90.00     50281  -26.68      1306
                                      0  -90.00     50281 -146.68      1306
--------------------------------------------------------------------------
FAULT CONTRIBUTION FROM SHUNT CONNECTION
FROM FROM              CURRENT (AMPS/DEGREE)          MVA
NODE NAME       SEQUENCE (1,2,0)    PHASE (A,B,C)    PHASE(A,B,C)
               MAGNITUDE   ANGLE  MAGNITUDE   ANGLE  MAGNITUDE
---- --------  --------- -------  --------- -------  ---------
   3     BUS3     307905   90.57     307905   90.57       8000
                       0  -90.00     307905  -29.43       8000
                       0  -90.00     307905 -149.43       8000
   3     BUS3          0  -90.00          0  -90.00          0
                       0  -90.00          0  -90.00          0
                       0  -90.00          0  -90.00          0
--------------------------------------------------------------------------
ZBUS SEQUENCE IMPEDANCE VALUES FOR COLUMN (BUS) :     4
                   POSITIVE                NEGATIVE                  ZERO
ROWNO    ZBUS.re    ZBUS.im    ZBUS.re    ZBUS.im    ZBUS.re    ZBUS.im
----- ---------- ---------- ---------- ---------- ---------- ----------
    1    -0.0001     0.0253     0.0002     0.0037
```

2	0.0018	0.0528	0.0018	0.0265
3	0.0005	0.0374	0.0004	0.0069
4	0.0029	0.0672	0.0028	0.0385
5	0.0012	0.0455	0.0013	0.0205

FAULT AT BUS NUMBER 4 : NAME BUS4

CURRENT (AMPS/DEGREE)				FAULT MVA	
SEQUENCE (1,2,0)		PHASE (A,B,C)		SEQUENCE (1,2,0)	PHASE (A,B,C)
MAGNITUDE	ANGLE	MAGNITUDE	ANGLE	MAGNITUDE	MAGNITUDE
9948	-87.53	9948	-87.53	5944	5944
0	-90.00	9948	152.47	0	5944
0	-90.00	9948	32.47	0	5944

R/X RATIO OF THE SHORT CIRCUIT PATH : 0.0431
PEAK ASYMMETRICAL SHORT-CIRCUIT CURRENT : 26827 AMPS
PASCC = k x sqrt(2) x If , k = 1.9069

FAULT CONTRIBUTION

FROM NODE	FROM NAME	TO NODE	TO NAME	CURRENT (AMPS/DEGREE) SEQUENCE (1,2,0) MAGNITUDE	ANGLE	PHASE (A,B,C) MAGNITUDE	ANGLE	MVA PHASE(A,B,C) MAGNITUDE
4	BUS4	3	BUS3	7432	92.23	7432	92.23	4441
				0	-90.00	7432	-27.77	4441
				0	-90.00	7432	-147.77	4441
4	BUS4	5	BUS5	2156	93.17	2156	93.17	1288
				0	-90.00	2156	-26.83	1288
				0	-90.00	2156	-146.83	1288
4	BUS4	2	BUS2	359	93.17	359	93.17	215
				0	-90.00	359	-26.83	215
				0	-90.00	359	-146.83	215

FAULT CONTRIBUTION FROM SHUNT CONNECTION

FROM FROM CURRENT (AMPS/DEGREE) MVA
NODE NAME SEQUENCE (1,2,0) PHASE (A,B,C)
PHASE(A,B,C) MAGNITUDE ANGLE MAGNITUDE
ANGLE MAGNITUDE

ZBUS SEQUENCE IMPEDANCE VALUES FOR COLUMN (BUS) : 5

	POSITIVE		NEGATIVE		ZERO	
ROWNO	ZBUS.re	ZBUS.im	ZBUS.re	ZBUS.im	ZBUS.re	ZBUS.im
1	0.0011	0.0494	0.0006	0.0101		
2	0.0035	0.0745	0.0033	0.0445		
3	-0.0001	0.0253	0.0002	0.0037		
4	0.0012	0.0455	0.0013	0.0205		
5	0.0046	0.0889	0.0043	0.0565		

```
-------------------------------------------------------------------------------
FAULT AT BUS NUMBER     5 : NAME     BUS5
      CURRENT (AMPS/DEGREE)                                 FAULT MVA
 SEQUENCE (1,2,0)    PHASE (A,B,C)      SEQUENCE (1,2,0)    PHASE (A,B,C)
MAGNITUDE   ANGLE  MAGNITUDE   ANGLE        MAGNITUDE         MAGNITUDE
--------- -------  --------- -------        ---------         ---------
     7518  -87.05       7518  -87.05             4492              4492
        0  -90.00       7518  152.95                0              4492
        0  -90.00       7518   32.95                0              4492
R/X RATIO OF THE SHORT CIRCUIT PATH        :   0.0515
PEAK ASYMMETRICAL SHORT-CIRCUIT CURRENT :    20080 AMPS

PASCC = k x sqrt(2) x If , k =   1.8887
--------------------------------------------------------------------------------
FAULT CONTRIBUTION
FROM FROM        TO TO               CURRENT (AMPS/DEGREE)        MVA
NODE NAME      NODE NAME       SEQUENCE (1,2,0)   PHASE (A,B,C)   PHASE(A,B,C)
                              MAGNITUDE   ANGLE MAGNITUDE   ANGLE MAGNITUDE
---- --------  ---- --------  --------- ------- --------- ------- ---------
   5     BUS5     1     BUS1       3716   92.23      3716   92.23      2221
                                      0  -90.00      3716  -27.77      2221
                                      0  -90.00      3716 -147.77      2221
   5     BUS5     4     BUS4       3259   93.65      3259   93.65      1948
                                      0  -90.00      3259  -26.35      1948
                                      0  -90.00      3259 -146.35      1948
   5     BUS5     2     BUS2        543   93.65       543   93.65       325
                                      0  -90.00       543  -26.35       325
                                      0  -90.00       543 -146.35       325
--------------------------------------------------------------------------------
FAULT CONTRIBUTION FROM SHUNT CONNECTION
FROM FROM               CURRENT (AMPS/DEGREE)         MVA
NODE NAME       SEQUENCE (1,2,0)    PHASE (A,B,C)
               PHASE(A,B,C)  MAGNITUDE         ANGLE  MAGNITUDE
               ANGLE  MAGNITUDE
---- --------  --------- -------  --------- -------  ---------
------------------------------------------------------------------------------------
3 phase fault level
Bus No. Name     BUS kV   3PH-fMVA Fault I
                 NOMINAL           kA
-------  -------- --------  -------- --------
      1     BUS1   15.000   5558.9  213.967
      2     BUS2  345.000   1989.2    3.329
      3     BUS3   15.000   9304.7  358.147
      4     BUS4  345.000   5944.3    9.948
      5     BUS5  345.000   4492.4    7.518
------------------------------------------------------------------------------------
Date and Time : Thu Mar 06 13:10:20 2014
File Name & Path : C:\MiP-PSCT\Samples\DatabaseManager\Glover\SCS\1GLOVE0S.out0
------------------------------------------------------------------------------------
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