User Manual

PSCT | *Protection Analytic tool*

LOAD FLOW ANALYSIS (LFA)

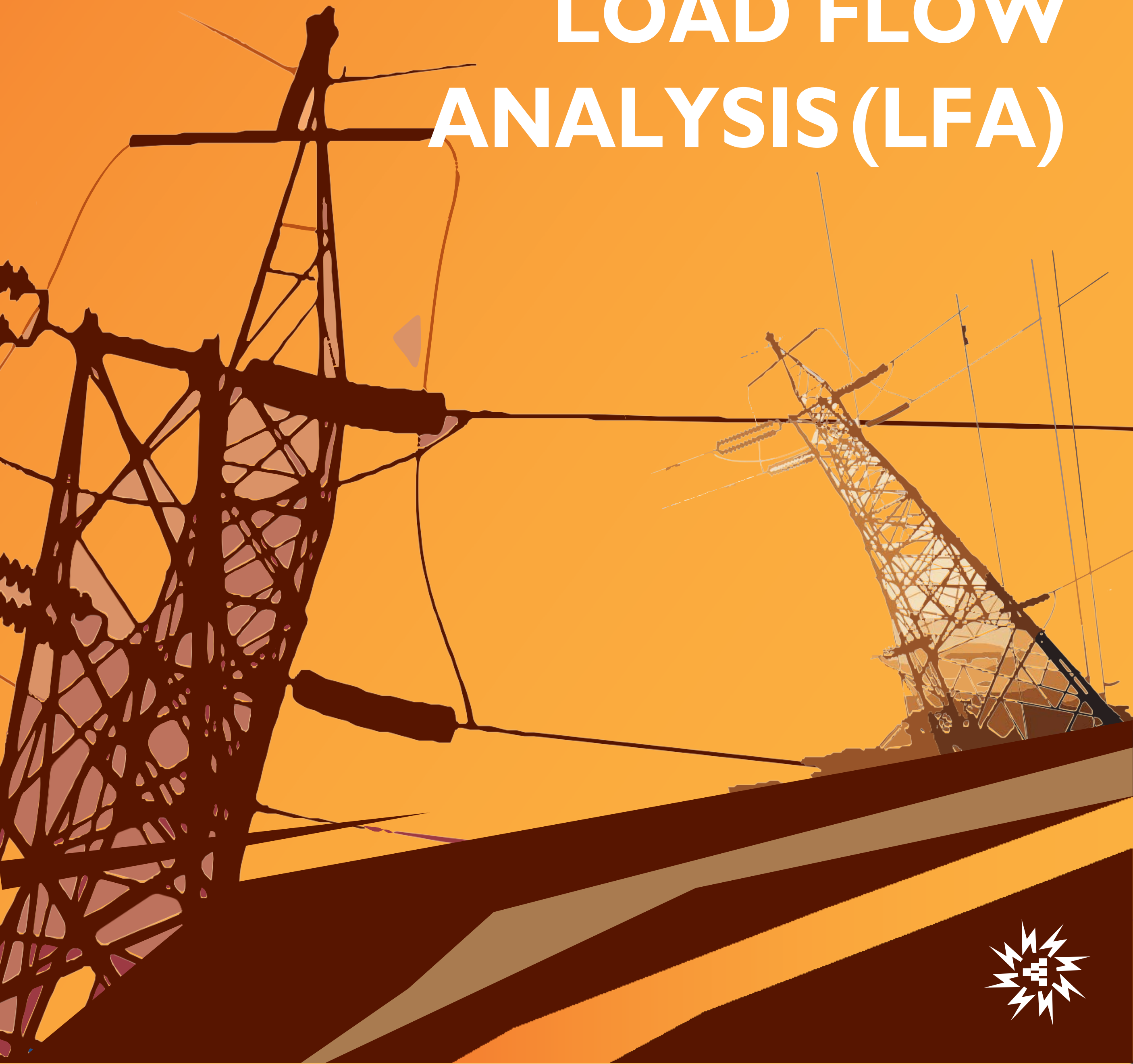


Table of Contents

1.INTRODUCTION

POWERLFA is designed to perform the steady state load flow analysis for the given system. Fast-decoupled load flow algorithm is used to solve the non-linear power flow problem. Sparse storage and matrix ordering techniques are used in the program to reduce the memory requirements. Fast computational methods are made used to speed up the execution. Generation and load regulation characteristics are considered in the model to determine the new system steady state frequency at which the loads and generation are balanced.

Power flow programs are used to study power system under both normal operating conditions and disturbance conditions. The essential requirements for successful power system operation under normal conditions require the following:

- Generators supply the load plus losses.
- Bus voltage magnitudes remain close to rated values.
- Generators operate within specified real and reactive power limits.
- Transmission lines and transformers are not overloaded.

The power flow computer program **POWERLFA**, commonly called, as load flow is the basic tool for investigating the above requirements. This program computes the voltage magnitude and angle at each bus in a power system under balanced steady state conditions. Real and reactive power flows for all equipment interconnecting the buses, as well as equipment losses, are also computed. Both existing power systems and proposed changes including new generation and transmission to meet projected load growth are of interest.

How to solve loadflow using MiP-PSCT is described in chapter 2. **POWERLFA** program input data is through an **ASCII** file, the format of which is described in Chapter 3. In Chapter 4 the various output files and the error massages generated by **POWERLFA** are listed. Finally in Chapter 5, case studies are given, wherein the data file preparation for typical load flow studies are discussed along with the analysis of the results.

2. HOW TO SOLVE LOAD FLOW

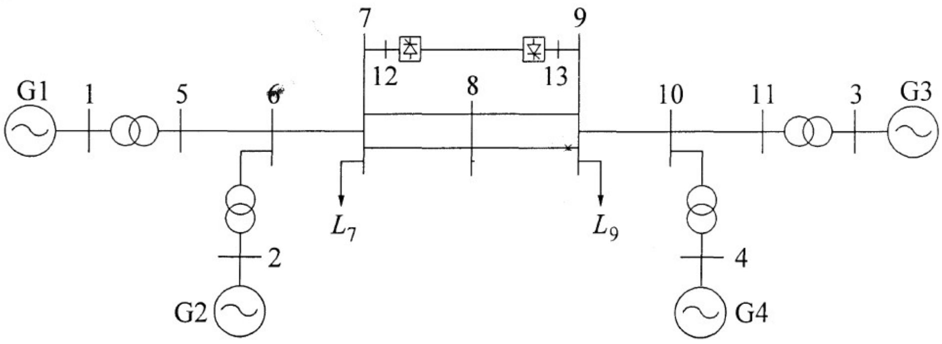
Example Load Flow Study

Figure shows a single line diagram of an 11 bus system with four generating units, four transformers and eight lines. Per-unit transmission line series impedances and shunt susceptances are given on 900 MVA base in Table 2.1. Real power generation, real and reactive power loads in MW and MVAR are given in Table 2.2.

With **bus 3** as the **slack bus**, the following method may be used to obtain a load flow solution:

- Fast-Decoupled using Ybus, with a tolerance of 0.001 per unit for the change in the real and reactive bus powers

Assume the system frequency as 60 Hz, with p.u. status checked.



Impedances and line charging for the sample system

Table : 2.1		
Bus code From - To	**Impedance R+jX (p.u.)**	**Line charging B/2 (p.u.)**
5-6	0.0225+j0.225	0.00243
6-7	0.009+j0.09	0.000972
7-8	0.099+j0.99	0.01069
8-9	0.099+j0.99	0.01069
9-10	0.009+j0.09	0.000972
10-11	0.0225+j0.225	0.00243

Generation, Loads and Bus Voltages for sample system

Table : 2.2					
Bus No	**Bus Voltage kV**	**Generation MW**	**Generation MVAR**	**Load MW**	**Load MVAR**
1	20	700	185	-	-
2	20	700	235	-	-
3	20	719	176	-	-
4	20	700	202	-	-
5	230	-	-	-	-
6	230	-	-	-	-
7	230	-	-	967	100
8	230	-	-	-	-
9	230	-	-	1767	100
10	230	-	-	-	-
11	230	-	-	-	-

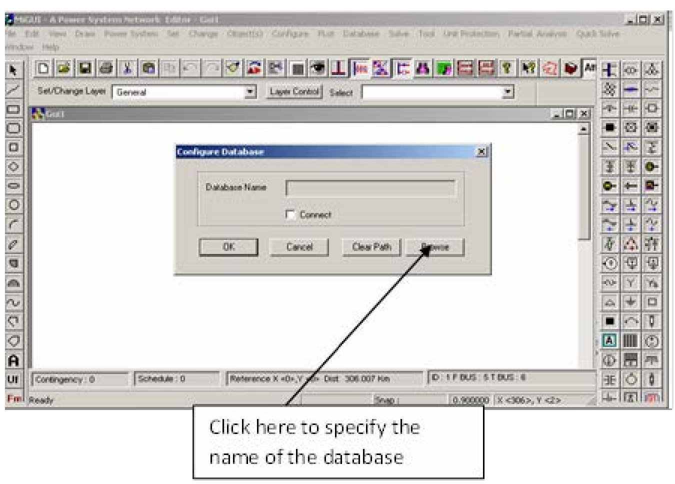
Procedure to enter the data for performing studies using MiP-PSCT.

Following are the two methods.

1. Entering the data directly in the database manager and executing for the required study.
2. Drawing single line diagram and entering the data simultaneously, then carrying out study.

Method 2 follows:

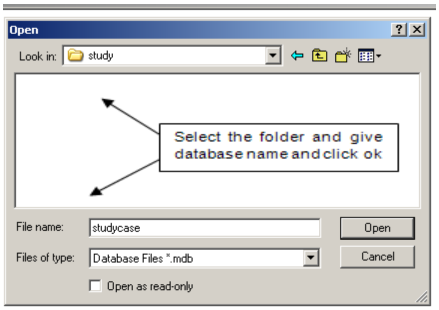
MiP-PSCT - Database Configuration

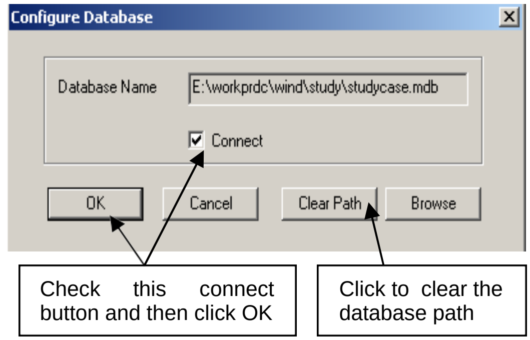


Open Power System Network Editor. Select menu option Database → **Configure**. Configure

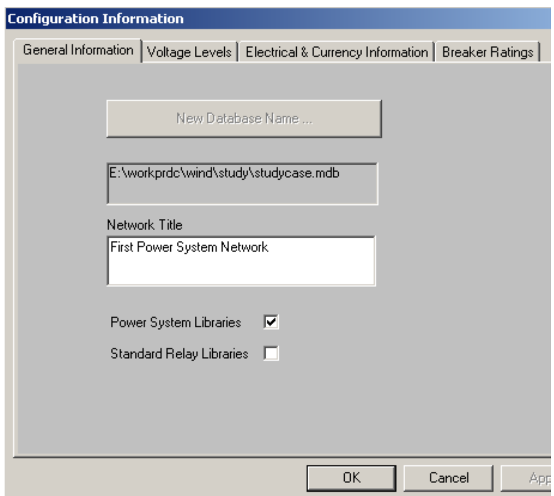
Database dialog is popped up as shown below. Click **Browse** button.

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.



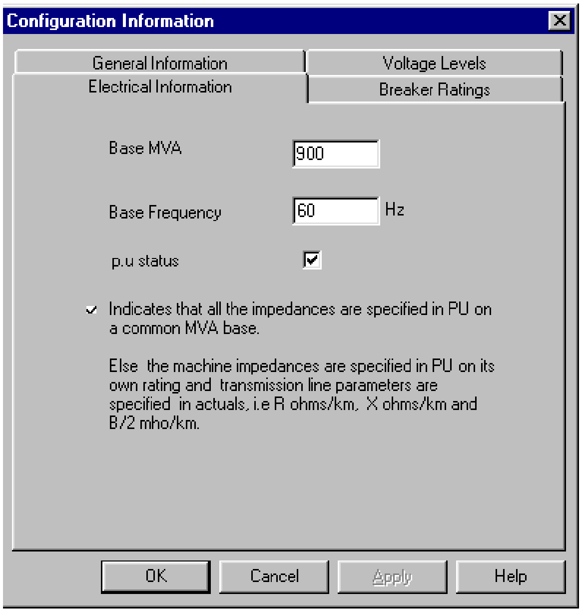


Click **OK** button on the **Configure database** dialog, the dialog shown below appears.



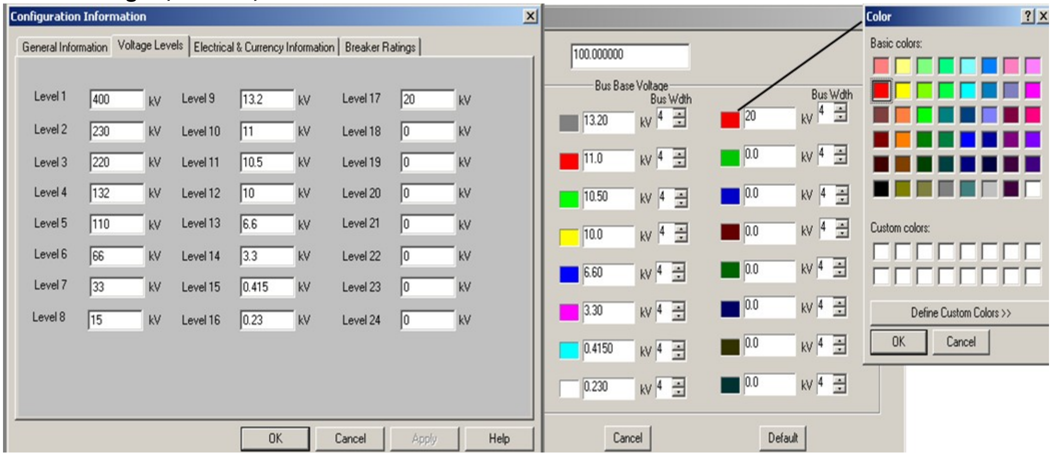
Uncheck the Power System Libraries and Standard Relay Libraries. For this example these standard libraries are not needed. Because all the data is given on pu for power system libraries (like transformer, line\cable, generator), and relay libraries are required only for relay co- ordination studies. Thus these libraries are not relevant for this case study. If Libraries are selected, standard libraries will be loaded along with the database. Click **Electrical Information** tab. Since the impedances are given on common 900 MVA base check the pu status as shown below. Enter the Base MVA and Base frequency as shown. Click OK button to create the database to return to

Network Editor. Click on Breaker Ratings button to give breaker ratings.



Bus Base Voltage Configuration

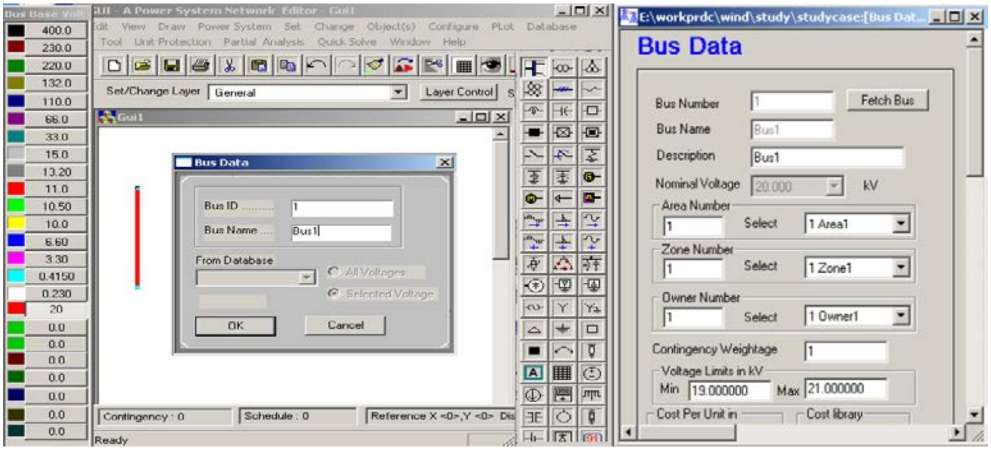
In the network editor, configure the base voltages for the single line diagram. Select menu option **Configure→Base voltage.** The dialog shown below appears. If necessary change the **Base-voltages, colour, Bus width** and click **OK.**



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 field and the bus description field can be used to abbreviate the bus name.



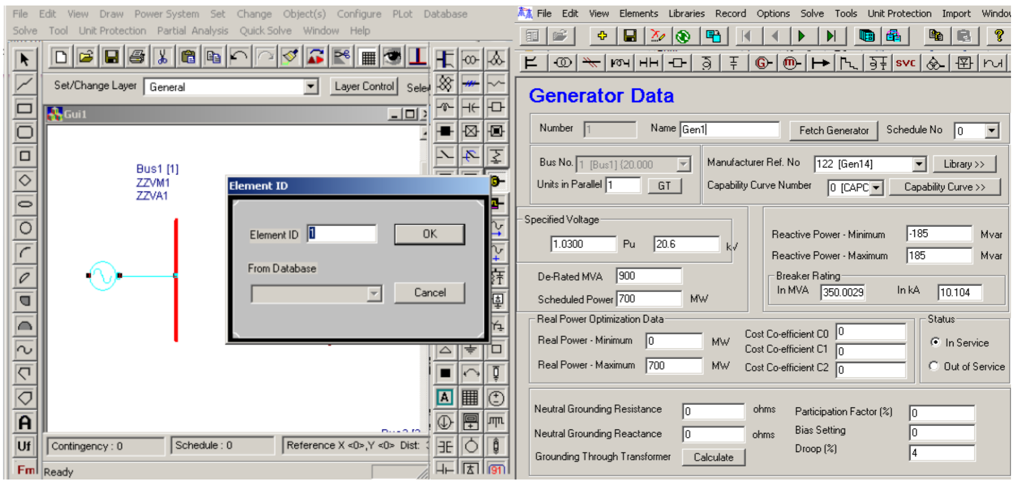
After entering data click **Save** , which invokes **Network Editor**. Follow the same procedure for remaining buses. Following Table gives the data for other buses.

Bus Number	Bus Name	Nominal Voltage(kV)
1	Bus1	20
2	Bus 2	20
3	Bus 3	20
4	Bus 4	20
5	Bus 5	230
6	Bus 6	230
7	Bus 7	230

8	Bus 8	230
9	Bus 9	230
10	Bus 10	230
11	Bus 11	230

Procedure to Draw Generator

Click on **Generator** icon provided on power system tool bar. Connect it to Bus 1 by clicking the LMB on Bus 1. **Element ID** Dialog will appear. Enter ID number and click OK. Database with corresponding **Generator Data** form will appear. Enter details as shown.

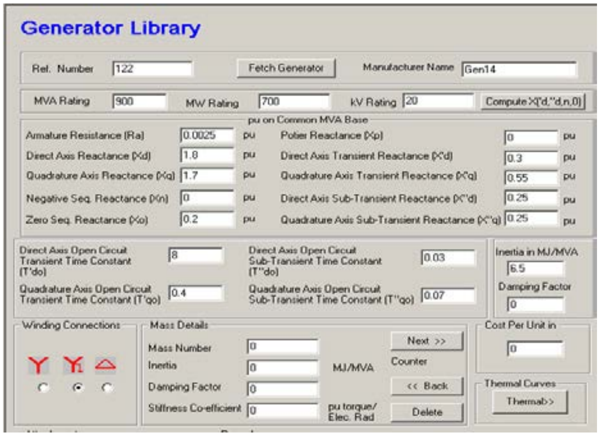


Since generator at bus 3 is mentioned as slack bus, only specified voltage will have importance.

Note: *At slack bus, only voltage and angle are mentioned. Scheduled power, real power minimum and maximum constraints do not have much importance*.

If the bus is a PV bus (like bus 2), then scheduled power, specified voltage, minimum and maximum real and reactive power data is a must.

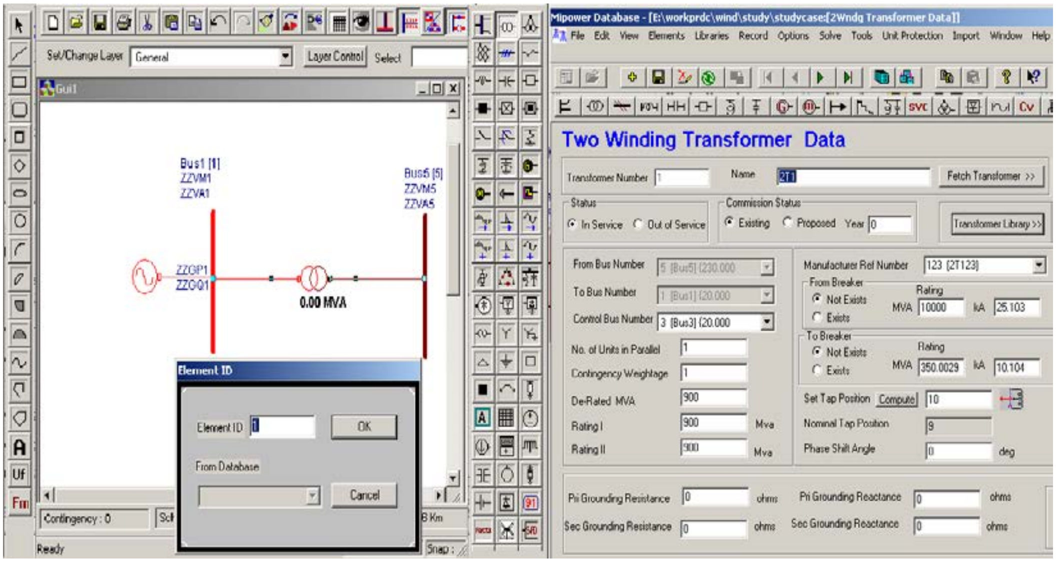
Enter Manufacturer Ref. No. as 1 and click on **Generator Library** button. Generator library form will appear. After entering data **Save** 🖫 and **close.** In **Generator Data** form, click **Save** 🖫**. Network Editor** screen will be invoked. Similarly connect Generator 2, 3 and 4 at respective Bus. Enter its details as given in the following Table.



Generator Element Data	G2	G3	G4
Manufacturer Ref. No	200	201	202
No. of Units parallel	1	1	1
Specified voltage (kV)	20	20	20
Derated MVA	900	900	900
Scheduled Power	700	719	700
Real Power Min.	0	0	0
Real Power Max.	700	719	700
Reactive Power Min	-235	0	-202
Reactive Power Max	235	176	202

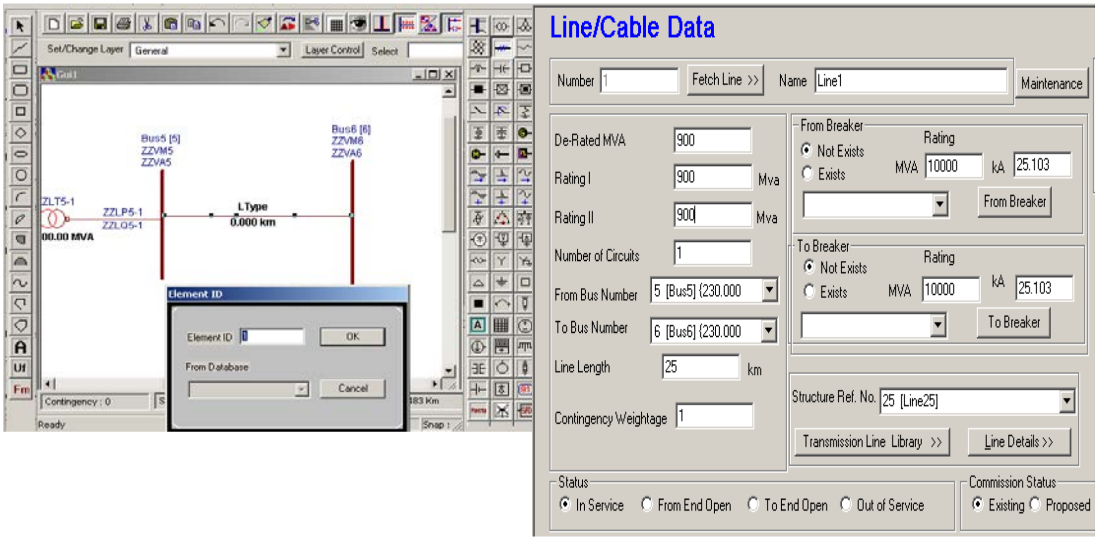
Generator Library Data	G2	G3	G4
MVA Rating	900	900	900
MW rating	700	719	700
kV rating	20	20	20
Xd	1.8	1.8	1.8
X'd	0.3	0.3	0.3
X"d	0.25	0.25	0.25
Manufacturer Name	Gen2	Gen3	Gen4

Procedure to Draw Transformer



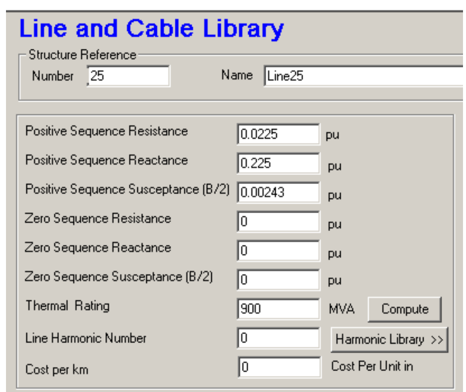
Procedure to Draw Transmission Line

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 clicking 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 corresponding **Line\Cable Data** form will open. Enter the details of that line as shown below.

Enter **Structure Ref No. as 25** and click on **Transmission Line Library >>** button. **Line & Cable Library** form will appear. Enter transmission line library data in the form as shown below for Line5-6.



After entering data **Save** 🖫 and **Close. Line \Cable Data** form will appear. Click **Save** 🖫, which invokes Network Editor to update next element. Data for remaining elements are given in the following Table.

Transmission Line Element Data

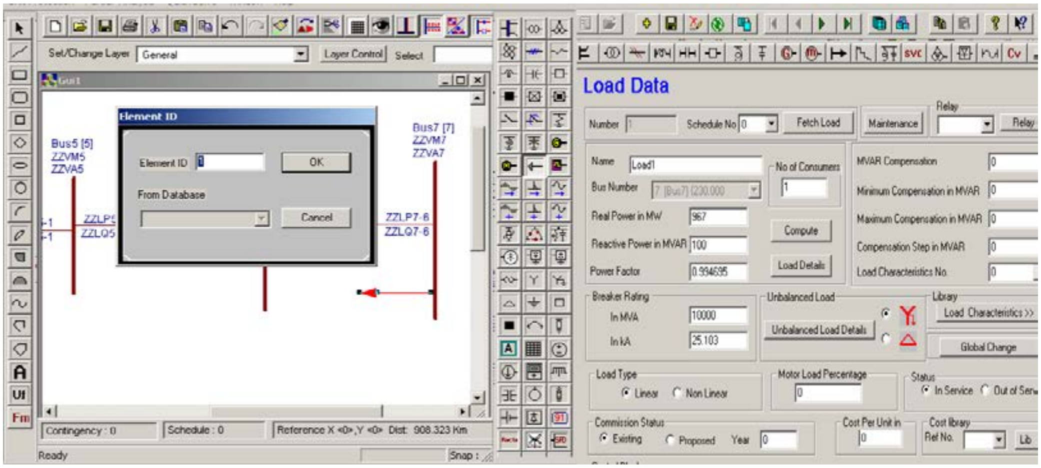
Line No	From Bus	To Bus	No. Of circuits	Line Length km	Structure Ref. No.
1	5	6	1	25	25
2	6	7	1	10	10
3	7	8	1	110	110
4	7	8	1	110	110
5	8	9	1	110	110
6	8	9	1	110	110
7	9	10	1	10	10
8	10	11	1	25	25

Transmission Line Library Data

Structure Ref. No	Structure Ref. Name	Resistance	Reactance	Line charging B/2	Thermal Rating
10	Line10	0.009	0.09	0.000972	900
25	Line25	0.0225	0.225	0.00243	900
110	Line110	0.099	0.99	0.01069	900

Procedure to Enter Load Data

Click on **Load** icon provided on power system tool bar. Connect load 1 at BUS7 by clicking the LMB on BUS7. **Element ID** dialog will appear. Give ID No as 1 and say OK. **Load Data** form will appear. Enter load details as shown below. Then click **Save** button which invokes Network Editor.

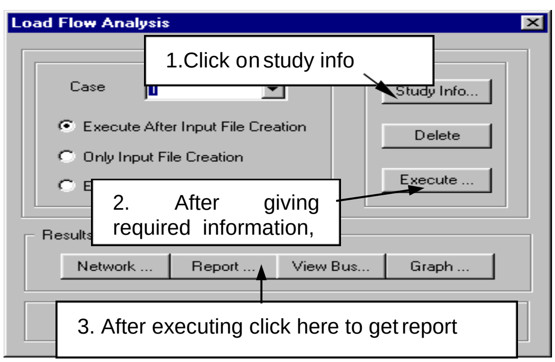


Connect the other load to bus9. Enter the other load details as given in the following Table.

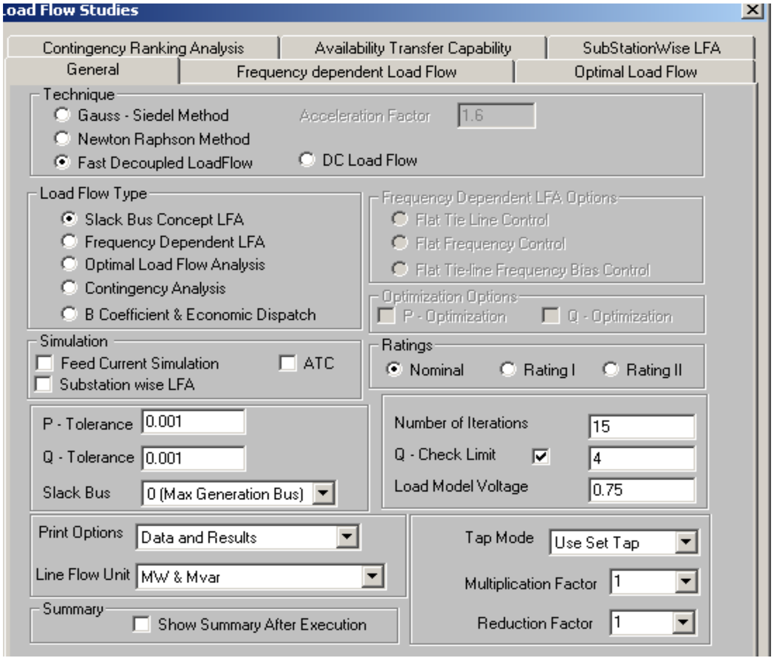
Load Details			
Load No	Bus No	MW	MVAR
1	7	967	100
2	9	1767	100

Solve Load Flow Analysis

Select menu option **Solve→Load Flow Analysis.** Following dialog will appear.



When **Study Info** button is clicked, following dialog will open. Select Fast Decoupled Method and P-Tolerance and Q-Tolerance as 0.001. Click OK.



Execute load flow analysis and click on **Report** in load flow analysis dialog to view report. Repeat the procedure with P and Q tolerances as 0.001 for Fast Decoupled Method.

Report

```
-------------------------------------------------------------------------------
Date and Time: Thu Dec 19 14:56:23  2013
-------------------------------------------------------------------------------
        LOAD FLOW ANALYSIS
CASE NO :   1     CONTINGENCY   : 0  SCHEDULE NO :  0
CONTINGENCY NAME : BaseCase         RATING CONSIDERED :  NOMINAL

-------------------------------------------------------------------------------
VERSION NUMBER :  8.1
%% First Power System Network
LARGEST BUS NUMBER USED        :    11    ACTUAL NUMBER OF BUSES         :   11
NUMBER OF 2 WIND. TRANSFORMERS :     4    NUMBER OF 3 WIND. TRANSFORMERS :    0
NUMBER OF TRANSMISSION LINES   :     8    NUMBER OF SERIES REACTORS      :    0
NUMBER OF SERIES CAPACITORS    :     0    NUMBER OF CIRCUIT BREAKERS     :    0
```

```
NUMBER OF SHUNT REACTORS       :    0    NUMBER OF SHUNT CAPACITORS     :    2
NUMBER OF SHUNT IMPEDANCES     :    0    NUMBER OF GENERATORS           :    4
NUMBER OF LOADS                :    2    NUMBER OF LOAD CHARACTERISTICS :    0
NUMBER OF UNDER FREQUENCY RELAY:    0    NUMBER OF GEN CAPABILITY CURVES:    0
NUMBER OF FILTERS              :    0    NUMBER OF TIE LINE SCHEDULES   :    0
NUMBER OF CONVERTORS           :    2    NUMBER OF DC LINKS             :    1
NUMBER OF SHUNT CONNECTED FACTS:    1    POWER FORCED LINES             :    0

NUMBER OF TCSC CONNECTED       :    0
NUMBER OF SPS CONNECTED        :    0
NUMBER OF UPFC CONNECTED       :    0

NUMBER OF WIND GENERATORS      :    0    NUMBER OF WTG CURVES           :    0
NUMBER OF WTG DETAILED CURVES  :    0

------------------------------------------------------------------------------- LOAD
FLOW - FAST DE-COUPLED TECHNIQUE                 :    0
NUMBER OF ZONES                                  :    1
PRINT OPTION                                     :    3 - BOTH DATA AND RESULTS PRINT
PLOT OPTION                                      :    1 - PLOTTING WITH PU VOLTAGE NO
FREQUENCY DEPENDENT LOAD FLOW, CONTROL OPTION:  0
BASE MVA                                         : 900.000000
NOMINAL SYSTEM FREQUENCY (Hzs)                   : 60.000000
FREQUENCY DEVIATION (Hzs)                        : 0.000000
FLOWS IN MW AND MVAR, OPTION                     : 0
SLACK BUS                                        :    0 (MAX GENERATION BUS)
TRANSFORMER TAP CONTROL OPTION                   :    0
Q CHECKING LIMIT  (ENABLED)                      :    4
REAL POWER TOLERANCE (PU)                        :  0.00100
REACTIVE POWER TOLERANCE (PU)                    :  0.00100
MAXIMUM NUMBER OF ITERATIONS                     :  100
BUS VOLTAGE BELOW WHICH LOAD MODEL IS CHANGED    :  0.75000
CIRCUIT BREAKER RESISTANCE  (PU)                 :  0.00000
CIRCUIT BREAKER REACTANCE   (PU)                 :  0.00010
TRANSFORMER R/X RATIO                            :  0.05000
------------------------------------------------------------------------------- ANNUAL
PERCENTAGE INTEREST CHARGES                      :  15.000
ANNUAL PERCENT OPERATION & MAINTENANCE CHARGES   :   4.000
LIFE OF EQUIPMENT IN YEARS                       :  20.000
ENERGY UNIT CHARGE (KWHOUR)                      :   2.500 Rs
LOSS LOAD FACTOR                                 :   0.300
COST PER MVAR IN LAKHS                           :   5.000 Rs
------------------------------------------------------------------------------- ZONE
WISE MULTIPLICATION FACTORS
```

ZONE	P LOAD	Q LOAD	P GEN	Q GEN	SH REACT	SH CAP	C LOAD
0	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1	1.000	1.000	1.000	1.000	1.000	1.000	1.000

```
------------------------------------------------------------------------------- BUS
DATA
```

BUS NO.	AREA	ZONE	BUS KV	VMIN-PU	VMAX-PU	NAME
1	1	1	20.000	0.950	1.050	Bus1
2	1	1	20.000	0.950	1.050	Bus2
3	1	1	20.000	0.950	1.050	Bus3
4	1	1	20.000	0.950	1.050	Bus4
5	1	1	230.000	0.950	1.050	Bus5

6	1	1	230.000	0.950	1.050	Bus6
7	1	1	230.000	0.950	1.050	Bus7
8	1	1	230.000	0.950	1.050	Bus8
9	1	1	230.000	0.950	1.050	Bus9
10	1	1	230.000	0.950	1.050	Bus10
11	1	1	230.000	0.950	1.050	Bus11

TRANSFORMER DATA

STATUS	CKT	FROM NODE	FROM NAME*	TO NODE	TO NAME*	IMPEDANCE R(P.U)	IMPEDANCE X(P.U.)	NOMINAL TAP	RATING MVA
	CTR					MINTAP	MAXTAP	TAPSTEP	SHIFT-DE
3	1	5	Bus5	1	Bus1	0.00002	0.15000	1.00000	900.00
	3					0.85000	1.05000	0.01250	0.000
3	1	6	Bus6	2	Bus2	0.00002	0.15000	1.00000	900.00
	11					0.85000	1.05000	0.01250	0.000
3	1	11	Bus11	3	Bus3	0.00002	0.15000	1.00000	900.00
	2					0.85000	1.05000	0.01250	0.000
3	1	10	Bus10	4	Bus4	0.00002	0.15000	1.00000	900.00
	3					0.85000	1.05000	0.01250	0.000

TRANSMISSION LINE DATA

STA	CKT	FROM NODE	FROM NAME*	TO NODE	TO NAME*	LINE PARAMETER R(P.U)	X(P.U.)	B/2(P.U.)	RATING MVA	KMS
3	1	5	Bus5	6	Bus6	0.02250	0.22500	0.00243	900	25.0
3	1	6	Bus6	7	Bus7	0.00900	0.09000	0.00097	900	10.0
3	1	7	Bus7	8	Bus8	0.09900	0.99000	0.01069	900	110.0
3	1	7	Bus7	8	Bus8	0.09900	0.99000	0.01069	900	110.0
3	1	8	Bus8	9	Bus9	0.09900	0.99000	0.01069	900	110.0
3	1	8	Bus8	9	Bus9	0.09900	0.99000	0.01069	900	110.0
3	1	9	Bus9	10	Bus10	0.00900	0.09000	0.00097	900	10.0
3	1	10	Bus10	11	Bus11	0.02250	0.22500	0.00243	900	25.0

TOTAL LINE CHARGING SUSCEPTANCE : 0.09913

TOTAL LINE CHARGING MVAR AT 1 PU VOLTAGE : 89.215

SHUNT CONNECTION (ADMITTANCE) DATA

MVAR* : +ve => Capacitive and -ve => Inductive

FROM NODE/LINE	FROM NAME*	ADMITTANCE IN P.U G(P.U)	B(P.U.)	MVAR*	STATUS 0/3	LOCATION 0/1/2
7	Bus7	0.00000	0.36000	324.000	3	0
9	Bus9	0.00000	0.52700	474.300	3	0

TOTAL CAPACITIVE SUSCEPTANCE : 0.88700 pu - 798.300 MVAR

TOTAL INDUCTIVE SUSCEPTANCE : 0.00000 pu - 0.000 MVAR

GENERATOR DATA

SL.NO*	FROM NODE	FROM NAME*	REAL POWER(MW)	Q-MIN MVAR	Q-MAX MVAR	V-SPEC P.U.	CAP. CURV	MVA RATING	STAT

```
------ ---- -------- --------- --------- --------- --------- ---- -------   ----
     1    1      Bus1  700.0000 -185.0000   185.0000    1.0300    0  900.00    3
     2    2      Bus2  700.0000 -235.0000   235.0000    1.0100    0  900.00    3
     3    3      Bus3  719.0000    0.0000   176.0000    1.0300    0  900.00    3
     4    4      Bus4  700.0000 -202.0000   202.0000    1.0100    0  900.00    3

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

  SLNO FROM FROM          REAL REACTIVE     COMP COMPENSATING MVAR VALUE CHAR   F/V
  *    NODE NAME*           MW     MVAR     MVAR      MIN      MAX    STEP   NO   NO
                                                                              STAT
  ---- ---- -------- -------- -------- -------- ------- ------- ------- ----   ----
     1    7      Bus7  967.000  100.000    0.000   0.000   0.000   0.000    0    0
                                                                            3    0
     2    9      Bus9 1767.000  100.000    0.000   0.000   0.000   0.000    0    0
                                                                            3    0
  ------------------------------------------------------------------------------- TOTAL
  SPECIFIED  MW GENERATION            : 2819.00000
  TOTAL MIN MVAR LIMIT  OF GENERATOR   : -622.00000
  TOTAL MAX MVAR LIMIT  OF GENERATOR   :  798.00000
  TOTAL SPECIFIED MW LOAD             : 2734.00000 changed  to 2734.00000 TOTAL
  SPECIFIED  MVAR LOAD                :  200.00000 changed  to  200.00000 TOTAL
  SPECIFIED MVAR COMPENSATION   :    0.00000 changed to      0.00000
  -------------------------------------------------------------------------------
  TOTAL (Including out of service  units)
  TOTAL  SPECIFIED  MW  GENERATION      :  2819.00000  TOTAL
  MIN MVAR LIMIT OF GENERATOR : -622.00000 TOTAL MAX MVAR
  LIMIT OF GENERATOR   :   798.00000
  TOTAL SPECIFIED MW LOAD             : 2734.00000 changed  to 2734.00000 TOTAL
  SPECIFIED MVAR LOAD                 :  200.00000 changed to   200.00000
  TOTAL SPECIFIED MVAR COMPENSATION   :    0.00000 changed to     0.00000
  -------------------------------------------------------------------------------

  -------------------------------------------------------------------------------
  GENERATOR DATA FOR FREQUENCY DEPENDENT LOAD  FLOW

  SLNO*  FROM FROM        P-RATE     P-MIN     P-MAX   %DROOP   PARTICI      BIAS
         NODE NAME*           MW        MW        MW              FACTOR   SETTING
                                                              C0        C1        C2
  ------ ---- -------- -------- --------- --------- --------- ---------   ---------
       1    1      Bus1  700.000    0.0000  700.0000    4.0000    0.0000    0.0000
                                                      0.0000    0.0000    0.0000
       2    2      Bus2  700.000    0.0000  700.0000    4.0000    0.0000    0.0000
                                                      0.0000    0.0000    0.0000
       3    3      Bus3  719.000    0.0000  719.0000    4.0000    0.0000    0.0000
                                                      0.0000    0.0000    0.0000
       4    4      Bus4  700.000    0.0000  700.0000    4.0000    0.0000    0.0000
                                                      0.0000    0.0000    0.0000

  -------------------------------------------------------------------------------
  CONVERTOR DATA FOR AC-DC LOAD  FLOW

  SLNO CONV AC   AC BUS       XC  CTRL CONTROL CONTROL  TAP  TAP   TAP
  *    NUMB NUMB NAME*       P.U. TYPE   VALUE   ANGLE  MIN  MAX  STEP
                                 Nb     Np     TrKV   TrMVA
  ---- ---- ---- -------- ------- ---- ------- ------- ---- ---- -----  1
          1    7     Bus7 0.18000    3 200.000   0.000 0.96 1.13 0.009
```

```
                              1    1 56.00000  235.00000
   2    2    9      Bus9 0.18000    1  56.000   0.000 0.85 1.13  0.015
                              1    1 56.00000  235.00000

------------------------------------------------------------------------------
DCLINK DATA FOR AC-DC LOAD FLOW

SLNO FROM FROM      TO   TO          R-DC
*    NUMB NAME*     NUMB NAME*       OHMS
---- ---- -------- ---- -------- -------
   1    1     Bus7    2     Bus9 1.50000
------------------------------------------------------------------------------



SHUNT FACTS DEVICES DATA

BUS NO. BUS_NAME  FACTS_TYPE V-REF     SLOPE    IND_MAXIMUM CAP_MAXIMUM TOLERANCE  STATUS
------- -------- ---------- --------- -------- ----------- ----------- --------- ------
      8     Bus8 1-     SVC     1.000    0.100     218.504     218.504    0.0010      0
------------------------------------------------------------------------------
------------------------------------------------------------------------------
Slack bus angle (degrees) :   0.00
------------------------------------------------------------------------------
TOTAL NUMBER OF ISLANDS IN THE  GIVEN SYSTEM          :    1
TOTAL NUMBER OF ISLANDS HAVING ATLEAST ONE  GENERATOR :    1
SLACK BUSES CONSIDERED FOR THE STUDY
ISLAND NO. SLACK BUS NAME     SPECIFIED MW
---------- --------- -------- ------------
         1         3     Bus3      719.000

------------------------------------------------------------------------------

ITERATION    MAX P BUS     MAX P    MAX Q BUS     MAX Q
    COUNT       NUMBER  PER UNIT       NUMBER  PER UNIT
---------    ---------  --------    ---------  --------
        1            9     1.759            5     0.169
        2            7     0.046            7     0.013
        3            7     0.008            7     0.002
        4            9     0.002            9     0.000
        5            9     0.000            7     0.000
Number of p iterations :   4 and Number of q iterations :   4
        6            9     0.001            7     0.004
        7            9     0.002            9     0.001
        8            9     0.000            9     0.001
Number of p iterations :   5 and Number of q iterations :   5
        9            9     0.000            9     0.002
       10            9     0.002            9     0.000
       11            9     0.000            9     0.000
Number of p iterations :   6 and Number of q iterations :   6
       12            9     0.000            9     0.001
Number of p iterations :   6 and Number of q iterations :   6
       13            9     0.000            9     0.001
Number of p iterations :   6 and Number of q iterations :   6
       14            9     0.000            9     0.001
Number of p iterations :   6 and Number of q iterations :   6
       15            9     0.000            9     0.001
Number of p iterations :   6 and Number of q iterations :   6
```

```
      16             9     0.000            9     0.001
Number of p iterations :    6 and Number of q iterations  :   6
      17             9     0.000            9     0.001
Number of p iterations :    6 and Number of q iterations  :   6
```

-- BUS VOLTAGES AND POWERS

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP
1	Bus1	1.0300	12.72	700.000	152.110	0.000	0.000	0.000
2	Bus2	1.0100	3.04	700.000	155.314	0.000	0.000	0.000
3	Bus3	1.0300	0.00	717.417	129.190	0.000	0.000	0.000
4	Bus4	1.0100	-10.02	700.000	90.244	0.000	0.000	0.000
5	Bus5	1.0117	6.29	0.000	0.000	0.000	0.000	0.000
6	Bus6	0.9911	-3.65	0.000	0.000	0.000	0.000	0.000
7	Bus7	0.9844	-11.81	0.000	0.000	967.000	100.000	0.000
8	Bus8	0.9986	-18.39	0.000	0.000	0.000	0.000	0.000
9	Bus9	1.0043	-24.71	0.000	0.000	1767.000	100.000	0.000
10	Bus10	1.0018	-16.65	0.000	0.000	0.000	0.000	0.000
11	Bus11	1.0157	-6.56	0.000	0.000	0.000	0.000	0.000

```
NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@  mark) :     0
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (#  mark) :     0
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (<  mark)  :     0
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (>  mark)  :     0
```

TRANSFORMER FLOWS AND TRANSFORMER LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	FORWARD MVAR	LOSS MW	LOSS MVAR	% LOADING
1	1	5	Bus5	1	Bus1	-699.992	-71.497	0.0081	80.6135	77.3#
2	1	6	Bus6	2	Bus2	-699.994	-71.315	0.0084	83.9993	78.9#
3	1	11	Bus11	3	Bus3	-717.409	-45.711	0.0083	83.4790	78.6#
4	1	10	Bus10	4	Bus4	-699.993	-8.856	0.0081	81.3883	77.6#

```
! NUMBER OF TRANSFORMERS LOADED  BEYOND  125%           :    0
@ NUMBER OF TRANSFORMERS LOADED BETWEEN 100% AND  125% :    0
# NUMBER OF TRANSFORMERS LOADED BETWEEN  75% AND  100% :    4
$ NUMBER OF TRANSFORMERS LOADED  BETWEEN  50% AND  75% :    0
^ NUMBER OF TRANSFORMERS LOADED  BETWEEN  25% AND  50% :    0
& NUMBER OF TRANSFORMERS LOADED  BETWEEN   1% AND  25% :    0
* NUMBER OF TRANSFORMERS LOADED  BETWEEN   0% AND   1% :    0
```

-- LINE FLOWS AND LINE LOSSES

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	FORWARD MVAR	LOSS MW	LOSS MVAR	% LOADING
5	1	5	Bus5	6	Bus6	699.996	71.474	12.1000	116.6134	77.3#
6	1	6	Bus6	7	Bus7	1387.901	26.073	19.6171	194.4638	155.6!
7	1	7	Bus7	8	Bus8	100.627	-26.227	1.1819	-7.0968	11.7&
8	1	7	Bus7	8	Bus8	100.627	-26.227	1.1819	-7.0968	11.7&

```
    9  1    8     Bus8    9     Bus9    99.442  -19.143   1.1009  -8.2875    11.3&

   10  1    8     Bus8    9     Bus9    99.442  -19.143   1.1009  -8.2875    11.3&
   11  1    9     Bus9   10     Bus10 -1385.16  261.971  19.7098 195.3378   156.0!
   12  1   10    Bus10   11     Bus11 -704.898   75.226  12.5273 120.8215    78.6#
--------------------------------------------------------------------------------
! NUMBER OF LINES LOADED  BEYOND  125%          :    2
@ NUMBER OF LINES LOADED BETWEEN 100% AND 125%  :    0
# NUMBER OF LINES LOADED BETWEEN  75% AND 100%  :    2
$ NUMBER OF LINES LOADED  BETWEEN   50% AND  75% :    0
^ NUMBER OF LINES LOADED  BETWEEN   25% AND  50% :    0
& NUMBER OF LINES LOADED  BETWEEN    1% AND  25% :    4
* NUMBER OF LINES LOADED  BETWEEN    0% AND   1% :    0

--------------------------------------------------------------------------------
SHUNT CAPACITOR AND REACTOR  INJECTION

NODE      FROM       V-MAG  ANGLE         MW     MVAR
NO.       NAME        P.U. DEGREE        GEN      GEN
-------- --------  ------ ------  -------- --------
       7     Bus7   0.984 -11.81     0.000  313.948
       9     Bus9   1.004 -24.71    -0.000  478.341

--------------------------------------------------------------------------------
CONVERTOR OUTPUT FOR AC-DC LOADFLOW

CONV AC       AC BUS        V-DC      P-DC      Q-DC      I-DC  CONTROL      TAP
NUMB NUMB     NAME            KV        MW      MVAR      AMPS    ANGLE  SETTING
---- -------- -------- -------- -------- -------- -------- --------   --------
   1        7     Bus7   64.042  200.000   97.205  3122.941     0.000   0.9565
   2        9     Bus9   59.358 -185.371   93.777 -3122.941     0.000   0.8759

--------------------------------------------------------------------------------
DCLINK RESULT FOR AC-DC LOADFLOW

SLNO FROM     FROM     TO   TO          I-LINK  P-LINK  P-LOSS
     NUMB     NAME     NUMB NAME          AMPS      MW      MW
---- -------- -------- ---- -------- ------- ------- -------
   1        1     Bus7    2     Bus9 3122.938   200.0  14.629
--------------------------------------------------------------------------------

--------------------------------------------------------------------------------
SHUNT FACTS DEVICES OUTPUT
-ve: Inductive, +ve:  Capacitive

BUSNO BUS NAME REF-VOLTAGE BUS-VOLTAGE COMPENSATION CURRENT  OUTPUT-B  DEVICE
                PU          PU           MVAR          AMPERE pu-SYSTEM
----- -------- ----------- ----------- ------------ -------- --------- -------
    8     Bus8      1.0000      0.9986        0.000    0.000     0.000 SVC
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
BUSES BETWEEN WHICH ANGLE DIFFERENCE IS > 30 degrees ARE:  ZERO
--------------------------------------------------------------------------------
ISLAND FREQUENCY SLACK-BUS   CONVERGED(1)
------ --------- ----------- ------------
     1  60.00000           3       1

--------------------------------------------------------------------------------
Summary of results
TOTAL REAL POWER  GENERATION (CONVENTIONAL)    :   2817.417  MW
```

```
TOTAL REAL POWER INJECT,-ve L                :      0.000 MW TOTAL
REACT. POWER GENERATION (CONVENTIONAL) :     526.858 MVAR GENERATION
pf                                           :      0.983

TOTAL REAL POWER GENERATION (WIND)           :      0.000 MW TOTAL
REACT. POWER GENERATION (WIND)               :      0.000 MVAR
TOTAL REAL POWER GENERATION (SOLAR)          :      0.000 MW TOTAL
REACT. POWER GENERATION (SOLAR)              :      0.000 MVAR
TOTAL SHUNT REACTOR INJECTION                :     -0.000 MW
TOTAL SHUNT REACTOR INJECTION                :     -0.000 MVAR

TOTAL SHUNT CAPACIT.INJECTION                :      0.000 MW
TOTAL SHUNT CAPACIT.INJECTION                :    792.289 MVAR

TOTAL TCSC REACTIVE DRAWL                    :      0.000 MVAR

TOTAL SPS REACTIVE DRAWL                     :      0.000 MVAR

TOTAL UPFC FACTS. INJECTION                  :    -0.0000 MVAR

TOTAL SHUNT FACTS.INJECTION                  :      0.000 MVAR
TOTAL SHUNT FACTS.DRAWAL                     :      0.000 MVAR

TOTAL REAL POWER LOAD                        :   2734.000 MW
TOTAL REAL POWER DRAWAL -ve g                :      0.000 MW
TOTAL REACTIVE POWER LOAD                    :    200.000 MVAR
LOAD pf                                      :      0.997
TOTAL COMPENSATION AT LOADS                  :      0.000 MVAR
TOTAL HVDC REACTIVE POWER                    :    190.982 MVAR

TOTAL REAL POWER LOSS (AC+DC)                :  83.181941 MW (  68.552828+ 14.629113)
PERCENTAGE REAL  LOSS (AC+DC)                :      2.952
TOTAL REACTIVE POWER  LOSS                   : 925.948036 MVAR

--------------------------------------------------------------------------------
Zone wise distribution
Description         Zone # 1
---------------- ----------
MW generation      2817.4172

MVAR generation     526.8579

MW wind. gen.         0.0000

MVAR wind. gen.       0.0000

MW solar. gen.         0.0000

MVAR solar. gen.       0.0000

MW load            2734.0000
MVAR load           200.0000

MVAR compensation     0.0000

MW loss              83.1819
```

```
MVAR loss           925.9480

MVAR - inductive      0.0000

MVAR - capacitive  792.2889

-------------------------------------------------------------------------------
Zone wise export(+ve)/import(-ve)
Zone #   1 MW & MVAR
------ -------- --------
     1       -----

Area wise distribution
Description        Area # 1
---------------- ----------
MW generation      2817.4172

MVAR generation     526.8579

MW wind gen.          0.0000

MVAR wind gen.        0.0000

MW solar gen.         0.0000

MVAR solar gen.       0.0000

MW load            2734.0000

MVAR load           200.0000

MVAR compensation     0.0000

MW loss              83.1819

MVAR loss           925.9480

MVAR - inductive      0.0000

MVAR - capacitive   792.2889

-------------------------------------------------------------------------------
Date and Time : Thu Dec 19 14:56:23  2013
-------------------------------------------------------------------------------
```

3. INPUT FILE FORMAT

This chapter gives the input file format, which helps, in creating an input file or manipulating the input file created by integrated mode.

Input data to Load flow program **(POWERLFA)** is through an ASCII file. If **POWERLFA** is run in the MiP-PSCT integrated environment, input file is automatically generated using the centralised database, whenever execution of **POWERLFA** is selected. The format of input filename is **1Grid0L.dat0**, where **1** represents Case Number, **Grid** -Database name, **0 -** Contingency Number, **L –** Study Code - Load Flow, **dat –** File Type - Input, **0 -** for schedule number of case 1 of Load Flow Analysis. If the input file is prepared by the user according to the format provided in this chapter, there is no restriction on the file name. It is user-defined name. The output files are generated with user defined filename plus default extensions. About file extensions it has been explained in chapter 4, Table 4.1.

The input data is read in free format. Input data is divided into different heads called streams for explanation purpose. *`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 done. Each line 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.

The comment lines can be given in the data file by entering ‘%’ sign in the first column. Comment line is not written in the output file. These lines are simply read and skipped. However, if the comment line has to appear in the output file also, then one more ‘%’ sign should appear in the second column. In the two statements appearing below, the first line does not appear in the output file, while the second line appears in the output file.

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

Stream 2 : System Specification

In this stream system specification or system size is specified. 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. Table 3.1 gives the data appearing under different columns.

Table 3.1 : System Specification

Col. No.	Description	Type	Min	Max.
1.	Maximum bus number	int	1	99999999
2.	Actual number of buses	int	1	99999
3.	Number of 2 winding transformers	int	0	5000
4.	Number of 3 winding transformers	int	0	1000
5.	Number of transmission lines	int	0	5000
6.	Number of series reactors (inductors)	int	0	5000
7.	Number of series capacitors	int	0	5000
8.	Number of bus couplers	int	0	5000
9.	Number of shunt reactors (inductors)	int	0	5000
10.	Number of shunt capacitors	int	0	5000
11.	Number of shunt impedances	int	0	5000
12.	Number of generators	int	0	5000
13.	Number of loads	int	0	5000
14.	Number of load characteristics	int	0	5000
15.	Number of under frequency relay	int	0	1000
16.	Number of generator capability curves	int	0	500
17.	Number of filters	int	0	20
18.	Number of scheduled ties	int	0	5
19.	Number of HVDC converters	int	0	20
20.	Number of DC links	int	0	10
21.	Number of SVC/STATCOM (Shunt FACTS)	int	0	100
22.	Number of Feed currents	int	0	50
23.	Number of TCSC (Series FACTS)	int	0	50
24.	Number of SPS (Series FACTS)	int	0	50
25.	Number of UPFC (Series-Shunt FACTS)	int	0	50
26.	Number of Wind Turbines	int	0	5000
27.	Number of Curves in Wind Turbine	int	0	5000
28.	Number of Detailed Curves in Wind Turbine	int	0	100
29.	Number of Solar PV Plants	int	0	5000

Explanations for the entries in Table 3.1 are as follows -

- In **POWERLFA** bus numbers need not be assigned continuously and there can be cases wherein some buses are deleted. The entry in column 1 is the largest bus number.
- 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 99500. 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 6000. Even though the terminology bus coupler is used in column 8 of Table 3.1, it can refer to switches, isolators and disconnecting switches, and are modelled 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 5000.

- Specify the number of generators in the system under study. Maximum of 5000 generators can be represented.

- Actual number of loads. In **POWERLFA** loads can be modelled as constant power load or constant current load or constant impedance load or a combination of all the three, along with frequency correction. Different loads can refer to the same load characteristic. Number of load characteristics is equal to the different characteristics referenced in the load data.

- **POWERLFA** has an input option, with which it is possible to compute the steady state system frequency for the given load and generation conditions. Also, if the frequency goes below the specified limit, it is possible to trip the loads partly or completely. Tripping is sensed by the under frequency relay. Under frequency relays are associated with the loads. Different loads can refer to the same relay characteristic. Number of frequency relays is equal to different relays referenced in the load data.

- Reactive power limits (both maximum and minimum) of a generator are obtained from the generator capability curve. Generator capability curve is a plot of reactive power of generator (both lead and lag) plotted along x-axis against the real power generation plotted along y-axis. At any operating point, for the specified real power generation, it is possible to obtain the reactive power limits from the capability curve. Different generators can refer to same capability curve, since the real power (y-axis) specified is the percentage of its full load rating. Number of generator capability curve refers to the sets of data provided, and which are referenced in the generator data.

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

- In **POWERLFA,** it is possible to specify the internal area, and net tie line interchange from the internal area to other areas. Number of such tie line schedules is given in column 18.

- Specify the number of HVDC converters and DC links present in the system under study.

- Specify the number of Shunt FACTS (SVC/STATCOM) devices present in the system under study.
- Specify the number of Series FACTS (TCSCs, SPSs, and UPFCs) present in the system under study.
- Specify the number of Wind Generators and its corresponding curves and detailed curves present in the system under study.
- Total number of generators is the sum of total number of conventional generators and total number of wind generators.
- Total number of detailed wind generators, field 26, does not include number of simple wind generators. This number specifies only number of detailed wind generators.
- Specify the number of Solar PV plants and its corresponding solar PV model data including temperature and location data of the plant present in the system under study.

Stream 3 : Control Options

Different control inputs are read by **POWERLFA** to control the program flow, results printing and model selection. These inputs are specified in Table 3.2.

Table 3.2 Control Options

Col No.	Description	Type	Min	Max
1.	Load flow option	int	0	11
2.	Number of zones	int	0	350
3.	Print option	int	0	100
4	Plot option	int	0	3
5.	Frequency control option	int	0	2
6.	Base MVA	float	0.0	10000.0
7.	Nominal system frequency	float	0.0	100.0
8.	Frequency deviation	float	-10.0	10.0
9.	Line flow unit option	int	0	5
10.	Slack bus number	int	0	99999
11.	Transformer tap change mode	int	0	1
12.	Available Transfer Capability (ATC)	int	0	1
13.	Q checking limit	int	0	500
14.	Real power tolerance	float	1.0e-4	1.0
15.	Reactive power tolerance	float	1.0e-4	1.0
16.	Maximum number of iterations	int	0	500
17.	Voltage for impedance model	float	0.0	1.0
18.	Circuit breaker resistance in pu	float	0.0	1.0
19.	Circuit breaker reactance in pu	float	1.0e-5	1.0
20.	Transformer r/x ratio	float	0.0	1.0

Explanation to entries given in Table 3.2 is as follows -

- Load flow option in Table 3.2 is interpreted as –

Option	Description
0	Only Slack bus concept with Fast Decoupled
1	Load flow with reactive power optimization
2	Load flow with real power optimization
3	Load flow with both real and reactive power optimization
4	Contingency analysis
5	Load flow analysis by Gauss Seidel
6	Load flow analysis by Newton Raphson
66	DC Power flow
700	Substation wise Load flow by Fast Decoupled
705	Substation wise Load flow by Gauss Seidel
706	Substation wise Load flow by Newton Raphson

- 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 end bus). Number of zones in a given power system data is given in column 2.

- Print option in Table 3.2 is interpreted as -

Option	Description
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.
5	Bus wise flow print.

If the print option is greater than 10, then the zone number for which the print is required is obtained by subtracting number 10 from the print option. In this case, the print option is forced to 3 as above.

- Plot option is interpreted as -

Option	Description
0	No plot file is generated.
1	Plot file is generated with plotting in pu.
2	Plot file is generated with plotting in actual voltage.

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

- Conventional methods of steady state load flow analysis using the swing bus concept are based on the following assumptions :

  * System frequency remains constant.
  * Load is constant.
  * Swing bus voltage magnitude and phase angle are fixed.
  * The swing bus generator meets the entire active power imbalance in the system only.
  * Generation at all the generators except the swing bus generator remains constant.
  * In case of inter-connected power systems, the tie-line flows are assumed to be constant.

However, none of these assumptions are valid for a practical power system operation; more so in power system operating with very tight spinning reserve/tie-line support. **POWERLFA** is specially designed to overcome the above assumptions by modelling the generation and load regulation characteristics.

- Frequency control option in column 5 of Table 3.2 is interpreted as-

Option	Description
0	Conventional power flow with slack bus concept.
1	**Flat tie line control (FTC)** - In this case the tie-line powers are considered to be fixed. The purpose of flat tie-line control is to regulate the difference between actual and scheduled interchanges to zero, or within certain limits. Frequency in the area is no longer a constant and the new system frequency is the point at which the load and generation characteristics intersect.
2	**Flat frequency control (FFC)** - In this case the system is operated at nominal frequency or any other frequency specified by the user. Tie-line exchange changes depending on the tie-line participation factor.

Frequency control option is zero for load flow options other than zero, i.e., other than "only load flow" option.

- Load and generation data are accepted in actual values i.e., MW for real power and Mvar for reactive power etc. Series and shunt elements' parameters given in the data file are in pu system. Base MVA is the power base considered to compute the pu quantities.

- Nominal system frequency given in column 7 of Table 3.2 corresponds to frequency in Hz., at which the impedances are computed. Load and generation characteristics also correspond to this base frequency.

- In the normal load flow, it is possible to obtain the solution at a frequency other than the base frequency. Frequency deviation in Hz, is used to compute the system frequency at which the solution is desired. In **POWERLFA**, an assumption is made that the electrical parameters (resistance and reactance) remain constant around the base frequency.

- Line flow unit option is interpreted as -

Option	Description
0	Flows computed are in MW and Mvar.
1	Flows computed are in MVA and angle in degree.
2	Flows computed are in Ampere and angle in degree.
3	Flows computed are in pu. impedance, on the given base.
4	Flows computed are in kW & kVAR
5	Flows computed are in kW & angle in degrees

- In Table 3.2, if the slack bus entry is zero, then program determines the slack bus as that for which the absolute value of the specified generation is maximum. If it is other than zero, then that number is considered as slack bus number. In case of multiple islands in the given data, program determines the slack buses for each island based on the maximum generation bus at each island.
- Transformer tap control option is interpreted as -

Option	Description
0	Fixed tap
1	Tap is adjusted during solution to realise the desired voltage at the control bus.

- Available Transfer Capability is a measure of the transfer capability remaining in the physical transmission network for further commercial activity over and above already committed users.

Option	Description
0	No ATC Computed
1	ATC Computed.

- Q checking limit corresponds to the iteration number, after which the generators are checked for Q-limit violations. Normal value is 4. A value less than 4 usually results in oscillations during solution and a value greater than 4 results in more iteration s to get the solution. If the Q checking limit is greater than the maximum number of iterations, then the Q checking is disabled.

- Real and reactive power tolerances are in pu on the given base. These values are used to check the convergence of fast-decoupled load flow. During each iteration, maximum real and reactive power mismatch at all buses are computed. When maximum real power mismatch is less than the real power tolerance and the maximum reactive power mismatch is less than the reactive power tolerance, convergence is achieved. On hundred MVA base 0.001 pu is generally an acceptable value for tolerance, which results in 0.1 MW real power error. If all the load values are relatively large, then tolerance value can be as high as 0.1 pu on 100 MVA base.

- Maximum number of iterations refers to the iteration number after which the fast decoupled power flow iteration is terminated. This number is usually in the range 15-20. If the convergence trend is observed (power mismatches are decreasing) then larger value can be given for this entry to achieve the convergence. Even if the program reports that the load flow is not converging, after reaching the maximum number of iterations, if the power mismatches are in the acceptable range, then power-flow solution can be treated as converged.

- If the voltage magnitude at a particular bus goes below a specified value, the load model is gradually changed from the given type to impedance type (i.e., impedance factor in the load model is varied linearly from the given value to unity) as the voltage magnitude varies from the specified value to zero. Accordingly the constant power and constant current factors are lowered to zero. This specified voltage value is given in column 16 of Table 3.2.

- 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 modelling of circuit breakers in **POWERLFA**. In this model the resistance value of circuit breaker is zero and reactance value is 0.0001 pu (A very small reactance value). 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 17 and 18 of Table 3.2, respectively. In some applications (especially for distribution systems), when load flow convergence is not obtained with smaller values of circuit breaker impedance, higher values can be used.

- 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 19 of Table 3.2 corresponds to transformer **R/X** ratio.

Stream 4 : Cost Factors

In this stream the various cost factors read by the **POWERLFA** are given. In Table 3.3 data appearing under different columns are described.

Table 3.3 : Cost Factors

Col No.	Description	Type	Min	Max
1.	Annual interest charges in %	float	0.0	50.0
2.	Annual operation and maintenance charges in %	float	0.0	50.0
3.	Life of equipment in years	float	0.0	50.0
4.	Energy charge per kWh in Rupees	float	0.0	500.0
5.	Loss load factor	float	0.0	1.0
6.	Cost per Mvar in Lakhs	float	0.0	100.0
7.	Currency	Character	0	2 bytes

Explanations for the entries in the Table 3.3 are as follows -

- When the investment is made on the capacitor banks, the capital investment carries the interest on it. The annual percentage interest on the capital investment is given in column 1. Interest values are in the range 5% - 20% depending on the source of capital investment.

- Operation and maintenance charge on the capacitor banks in percentage is given in column 2. Normal values are in the range 5% - 10%.

- Life of equipment given in column 3 is used in the present worth analysis. In the present worth calculation, the return due to the savings in losses and annual expenditures are calculated for the investment year, based on the interest charge.

- Energy charge varies from time to time and utility to utility. It is assumed that the energy charge remains constant for the entire duration.

- Loss load factor (L_{lf}) is the ratio of the average power loss to the peak-load power loss during a specified period of time. Hence,

$$L_{lf} = \frac{average\ power\ loss}{peak\ load\ power\ loss}$$

An approximate formula to relate the loss load factor to the load factor L_f is given by

$$L_{lf} = 0.3L_f + 0.7L_f$$

- It is assumed that the energy charge per Mvar is same irrespective of the type of capacitor banks.

- Currency is computed in Indian Rupee (Rs) or Dollars ($)

Stream 5 : Zonewise Multiplication Factors

In this stream zone wise multiplication factors are given. In Table 3.4 data appearing under different columns are described. **POWERLFA** has the facility to change the given data (generation, load, compensation) globally or zone wise. The change is governed by the multiplication factors given in Table 3.4.

- The total number of lines of data appearing in this stream is equal to (n+1) where n stands for number of zones.

- First line entry is a must, indicating the global multiplication factors.

- For zone wise change all the entries in the first line should be zero. Otherwise, the change is considered globally. For example, if the load at a bus is 100 MW, the multiplication factor for that zone (or global change) is 0.8, then the actual load considered is 80 MW.

Table 3.4 : Zone Wise Multiplication Factors

Col No.	Description	Type	Min	Max
1.	Zone number	int	0	351
2.	Factor for real power load	float	0.0	10.0
3.	Factor for reactive power load	float	0.0	10.0
4.	Factor for real power generation	float	0.0	10.0
5.	Factor for reactive power generation	float	0.0	10.0
6.	Factor for shunt reactor	float	0.0	10.0
7.	Factor for shunt capacitor	float	0.0	10.0
8.	Compensation Load	float	0.0	10.0

Explanations for the entries in the Table 3.4 are as follows -

- Specify the zone number
- Indicate the multiplication for the real power load.
- Indicate the multiplication for reactive power load.
- Indicate the multiplication for the real power generation.
- Indicate the multiplication for reactive power generation.
- Indicate the multiplication for shunt reactor.
- Indicate the multiplication for shunt capacitor.
- Indicate the multiplication for compensation in load.

Stream 6 : 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 3.5.

Table 3.5 : Bus Data

Col No.	Description	Type	Min	Max
1.	Bus number	int	1	99999
2.	Area number	int	1	99999
3.	Zone number	int	1	351
4.	Bus voltage in kV	float	0.001	9999.9
5.	Bus minimum voltage is pu.	float	0.5	1.5
6.	Bus maximum voltage in pu.	float	0.5	1.5
7.	Bus name	char	1	8

Explanations to entries given in Table 3.5 are as follows -

- Bus number refers to the number by which the buses are identified. Bus numbers need not be contiguous 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 zone 2 can have the numbers from 201 to 300 and so on). When "**POWERLFA**" file is created through integrated environment, the buses are numbered automatically and the numbers are transparent to the user.
- Area number field refers to the Area number to which the bus belongs.
- As explained earlier, zone field refers to the zone number to which the bus belongs.
- Bus voltage entry given in column 4 of Table 3.5 is in Kilo Volts and it is also the base voltage for the bus.
- Minimum and maximum bus voltages in pu are used while modifying the transformer tap settings, reactive power injections at buses to achieve the desired voltage. While generating the report file, buses whose voltage magnitude exceeds the minimum and maximum limits are marked by distinct attributes.
- Buses are more commonly referred 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.

Stream 7 : Transformer Data

In this stream of data, transformer details are given. Figures 3.1 and 3.2 give the modelling of the transformer with off nominal turns ratio and phase shift respectively for two winding transformer. Three winding transformers are modelled using equivalent star connection between the windings. Figure 3.3 shows the modelling of 3 winding transformer. 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 appearing in different columns of each line are given in Table 3.6.

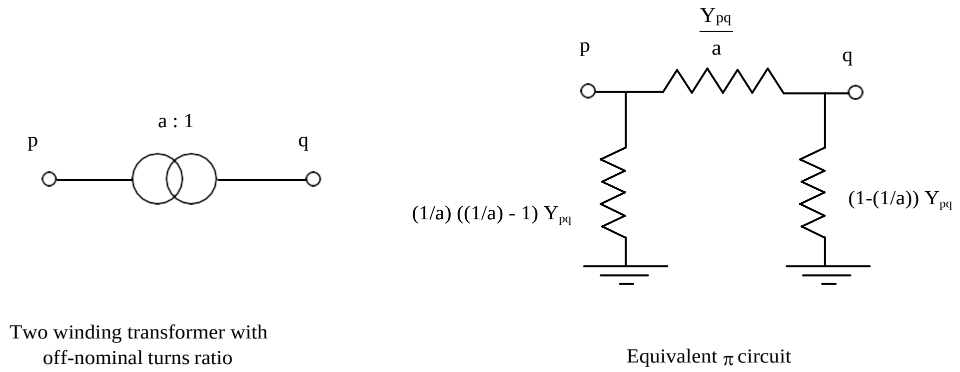


Figure 3.1: Two Winding Transformer Representation

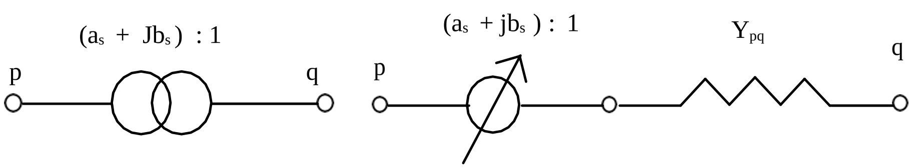
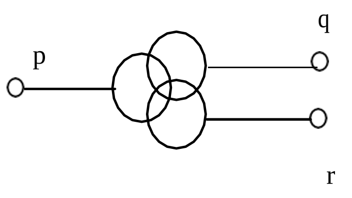
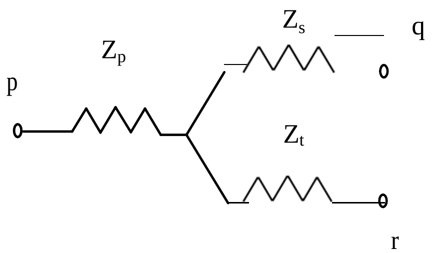


Figure 3. 2: Phase Shifting Transformer Representation



Three winding transformer with off-nominal turns ratio



Equivalent π Circuit

Figure 3.3: Three Winding Transformer Representation

Table 3.6 – Transformer Data				
Col No.	**Description**	**Type**	**Min**	**Max**
1.	Connection status	int	0	3
2.	Numbers in parallel	int	1	20
3.	From bus number	int	1	99999
4.	To bus number	int	1	99999
5.	Resistance in pu.	float	-1.0e3	1.0e3
6.	Reactance in pu.	float	-1.0e3	1.0e3
7.	Nominal tap setting in pu.	float	0.5	1.5
8.	Rating in MVA	float	0.001	1.0e5
9.	Voltage control bus number	int	1	99999
10.	Minimum tap in pu	float	0.5	1.0
11.	Maximum tap in pu	float	1.0	1.5
12.	Tap step in pu	float	0.0	0.25
13.	Phase shift angle	float	-180	180
14.	MVA1	float	0.001	1.0e5

Explanations to entries given in Table 3.6 are as follows -

- Connection status is interpreted as -

Option	Description
0	Transformer is open on either end.
1	Transformer is open on from end.
2	Transformer is open on to end.
3	Transformer is closed on either end.

Option 0 and 3 are of significance. If the status value is 3, then only the transformer is modelled in the analysis.

- Numbers in parallel is used for information purpose only.
- 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 exists 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.

- Transformer rating in MVA is for the equivalent circuit, if the impedance value is given for equivalent circuit. This is used to find the overloading on the transformer.

- In **POWERLFA** facility is provided to modify the transformer tap setting to improve the voltage at the desired bus. The bus number at which voltage is to be monitored, and accordingly modify the transformer tap is given in column 9. Usually this bus number is same as the to bus number of the transformer.

- Minimum tap setting, maximum tap setting and tap setting step values are used while controlling the voltage at the voltage control bus. Tap control is effective only when the tap control option is set to 1. If the tap control is effective, and for some transformers the tap should be held at the nominal tap setting, then the tap minimum and maximum values are given same as the nominal tap setting, and the tap step is set to zero.
- Phase shift/rotation is always counter clockwise (internationally adopted convention) and indicates multiples of 30 degree lag for low voltage winding using the high voltage winding as the reference.

  Thus 1 = 30°, 2 = 60°, 3 = 90°, 6 = 180° and 12 = 0° or 360°.

  As per IEC60076-1 standard, the notation is HV-LV in sequence. For example, a step-up transformer with a delta-connected primary, and wye-connected secondary, is not written as 'dY11', but 'Yd11'. The 11 indicates the LV winding leads the HV by 30 (lags 330) degrees.

  Graphical representation for computing phase angle difference between Yd11 is as given in

Figure 3.4.

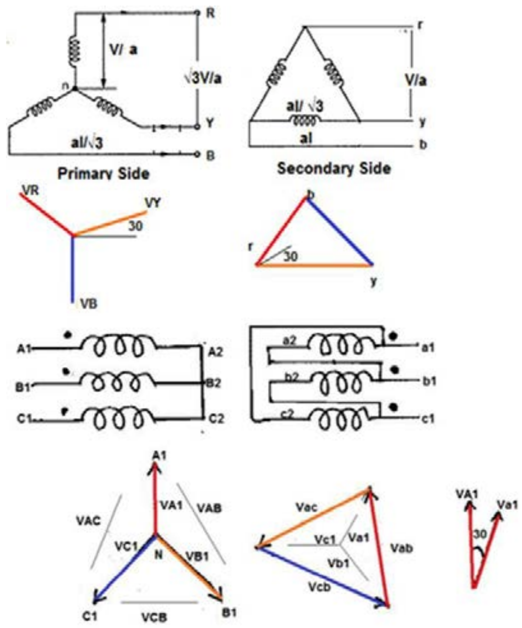


Figure 3.4 : Phase Rotation Representation

- MVA1 rating field is used to find the overloading on the transformer. This field is written into the input file only while ATC calculations need to be done.

Stream 8 : Transmission Line Data

In this stream of data, transmission line details are given. Lines/Cables are modelled using equivalent π circuit as shown in figure 3.5. 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 3.7.

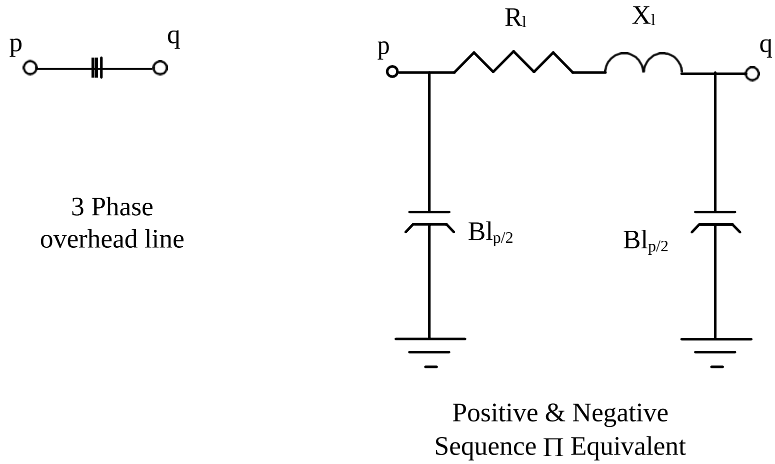


Figure 3.5 : Three phase over head line modeling

Table 3.7 - 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	99999
4.	To bus number	int	1	99999
5.	Resistance in pu.	float	-1.0e3	1.0e3
6.	Reactance in pu.	float	-1.0e3	1.0e3
7.	Susceptance (B/2) in pu	float	-1.0e3	1.0e3
8.	Rating in MVA	float	0.001	1.0e6
9.	Line length in kms	float	0.001	10000
10.	Rating1 in MVA	float	0.001	1.0e6

Explanations to entries given in Table 3.7 are as follows -

- Connection status is interpreted as

Option	Description
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.

- Number of circuits is used for information purpose only.
- 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 Parameters 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.
- Line rating in MVA is for the equivalent circuit, if impedance value is given for equivalent circuit. This is used to find the overloading on the line.
- Length of the line is specified in kms.
- Rating1 in MVA field is used to find the overloading on the line. This field is written into the input file only while ATC calculations need to be done.

Stream 9 : Series Reactor and Capacitor Data

In this stream, data for series reactor and capacitor are given. Series reactor and capacitor are modelled as series element consisting of resistance (usually zero or negligible value) in series with the reactance. Figure 3.6 and 3.7 show the modelling of series inductor and capacitor respectively.

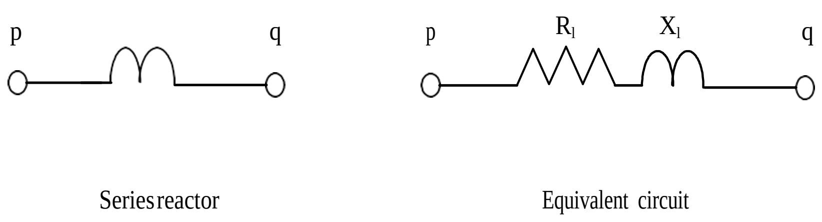


Figure 3.6 : Series Reactor (inductor) Representation

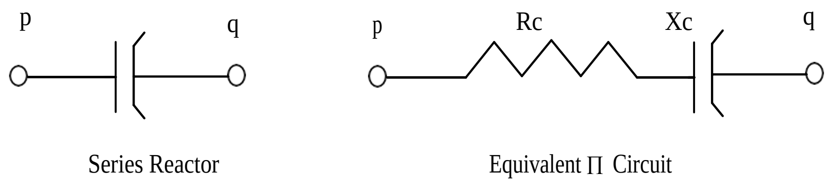


Figure 3.7 : Series capacitor representation

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 are given in Table 3.8.

Table 3.8 - Series Reactor/Capacitor Data

Col No.	Description	Type	Min	Max
1.	Connection status	int	0	3
2.	From bus number	int	1	99999
3.	To bus number	int	1	99999
4.	Resistance in pu.	float	0.0	1.0e3
5.	Reactance in pu.	float	-1.0e3	1.0e3
6.	Rating in MVA	float	0.01	5000.0

Explanations to entries given in Table 3.8 are as follows -

- Connection status is interpreted as -

Option	Status
0	Series reactor/capacitor is open on either end.
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 end.

  Values 0 and 3 are of significance. If the status value is 3, then only the reactor/capacitor is modelled 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.
- Reactor/capacitor rating in MVA is for the equivalent circuit. This is used to find the overloading on the reactor/capacitor.

Stream 10 : Circuit Breaker Data

In this stream, data for circuit breakers and isolating switches are given. Switches are modelled 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. 8 shows the circuit breaker in closed position.

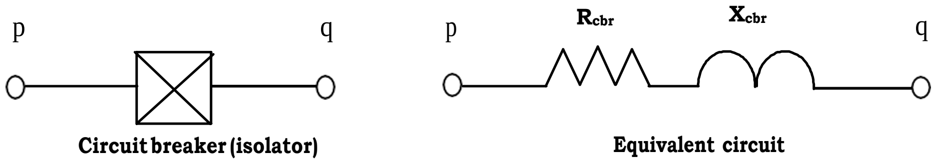


Figure 3.8 : Circuit breaker representation in closed position

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 3.9.

Table 3.9 - Circuit Breaker Data

Col No.	Description	Type	Min	Max
1.	Connection status	int	0	3
2.	From bus number	int	1	99999
3.	To bus number	int	1	99999

Explanations to entries given in Table 3.9 are as follows -

- Connection status is interpreted as :

Option	Description
0	Circuit breaker is opened.
3	Circuit breaker is closed.

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

Stream 11: Thyristor Controlled Series Compensator Data

A Thyristor Controlled Series Compensator (TCSC) is a series-controlled capacitive reactance that can provide continuous control of power on the ac line over a wide range. From the system viewpoint, the principle of variable-series compensation is simply to increase the fundamental-frequency voltage across a fixed capacitor (FC) in a series compensated line through appropriate variation of the firing angle. This enhanced voltage changes the effective value of the series-capacitive reactance. Equivalent circuit of TCSC is given in figure 3.9.

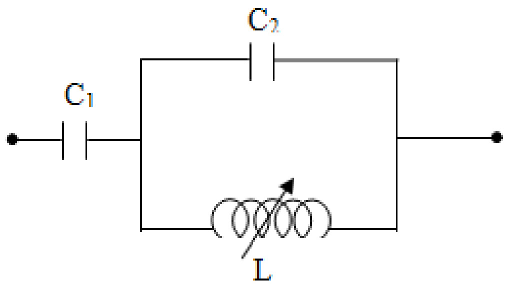


Figure 3.9 : Equivalent circuit of TCSC

The behaviour of the TCSC is similar to that of the parallel LC combination. Because TCSC is a parallel LC circuit there are chances of occurrence of resonance at one or many firing angles. The resonant band of TCSC is shown in Figure 3.10.

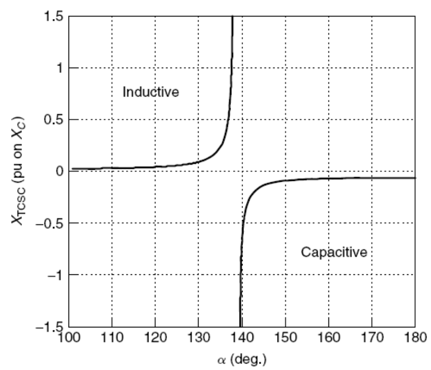


Figure 3.10: Resonant Band of TCSC

The firing angle at which the resonance occurs can be found using below equation

$$\alpha = \pi - (2m - 1)\frac{\pi\omega}{2\omega_r} \qquad m = 1, 2 \ldots$$

ω is system frequency in radians/sec.

ω_r is $\frac{1}{\sqrt{LC}}$, L and C are inductance and capacitance of TCSC.

In characteristics shown above the resonance occurs around a firing angle of 139 degrees. The inductive and capacitive limits of TCSC are given in Figure 3.11.

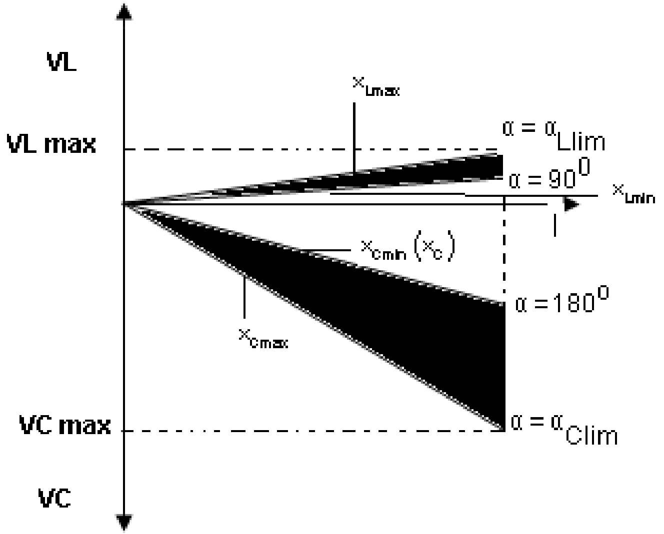


Figure 3.11 : Inductive and Capacitive limits of TCSC

The input file fields for TCSC are given in Table 3.10.

Table 3.10 TCSC Data

Col No.	Description	Type	Min	Max
1.	Status	int	0	3
2.	From bus number	int	0	99999
3.	To bus number	int	0	99999
4.	Rating in MVA	float	0.001	1.0e5
5.	Real Power reference (MW)	float	0.001	1.0e5
6.	Minimum Inductive reactance (p.u)	float	0	1
7.	Maximum Inductive reactance (p.u)	float	0	1
8.	Minimum Capacitive reactance (p.u)	float	0	1
9.	Maximum Capacitive reactance (p.u)	float	0	1
10.	Tolerance (MW)	float	1.0e-4	1.0
11.	X_L in MVA	float	0	9999
12.	X_{C1} in MVA	float	0	9999
13.	X_{C2} in MVA	float	0	9999
14.	Compute X_L Flag	int	0	1

Explanations to entries given in Table 3.10 are as follows –

- TCSC status is interpreted as -

Option	Status
0	Shunt reactor does not exist.
3	Shunt reactor exists.

- From Bus Number is the bus number to which the from end of the TCSC is connected. The bus ID should be present in bus data. It should not be the same as To bus number.
- To Bus number is the bus number to which the to end of the TCSC is connected. The bus ID should be present in bus data. It should not be the same as From bus number.
- MVA rating of TCSC is required to convert the TCSC reactance limits to common MVA base. When user computes the TCSC reactance limits, it automatically takes the maximum of XL MVA, XC1 MVA, XC2 MVA to convert the TCSC reactance limits to common MVA base considering the TCSC kV Rating.
- Real Power Reference is the power flow desired through the transmission line in which TCSC is connected. Connecting a TCSC on transmission lines reduces/increases the effective series reactance of the line which enables us to push more/less power through the line.
- Tolerance value is to check for TCSC convergence. It checks the TCSC power flows in the present iteration and compares with the flow in the previous iteration. If the difference in power flows is less than this tolerance value TCSC power flow is said to have converged.

- Capacitive Min is the minimum capacitive reactance offered by TCSC when the parallel inductor is blocked from service. If the user wants to compute the limits then the values of XL, XC1, XC2 and its corresponding MVA ratings are to be entered and compute button is to be clicked. The reactance limits will be automatically computed.
- Capacitive Max is the maximum capacitive reactance offered by TCSC when the parallel inductor reactance is just slightly greater than the parallel capacitor reactance. Generally, TCSC is not operated in the region between Capacitive and Inductive maximum since it will cause parallel resonance. If the user wants to compute the limits then the values of XL, XC1, XC2 and its corresponding MVA ratings are to be entered and compute button is to be clicked. The reactance limits will be automatically computed.
- Inductive Min is the minimum inductive reactance offered by TCSC when the parallel inductor is completely in service. If the user wants to compute the limits then the values of XL, XC1, XC2 and its corresponding MVA ratings are to be entered and compute button is to be clicked. The reactance limits will be automatically computed.
- Inductive Max is the maximum inductive reactance offered by TCSC when the parallel inductor reactance is just slightly less than the parallel capacitor reactance. Generally, TCSC is not operated in the region between Capacitive and Inductive maximum since it will cause parallel resonance. If the user wants to compute the limits then the values of XL, XC1, XC2 and its corresponding MVA ratings are to be entered and compute button is to be clicked. The reactance limits will be automatically computed.
- XL MVA is the MVA rating of the parallel inductor. This value needs to be entered only if user wants to compute the TCSC reactance limits.
- XC1 MVA is the MVA rating of the series capacitor. This value needs to be entered only if user wants to compute the TCSC reactance limits.
- XC2 MVA is the MVA rating of the parallel capacitor. This value needs to be entered only if user wants to compute the TCSC reactance limits.
- Computed flag has to be checked if the user wants to compute the controllable inductive reactance value and view in the output report. This flag has to be checked only when the user wants to compute the TCSC reactance limits by entering the values of XL, XC1, XC2, XL MVA, XC1 MVA and XC2 MVA.
- Compute X_L status is interpreted as -

Option	Status
0	Do not display the value of X_L in the output report
1	Compute and display the value of X_L in the output report

Stream 12: Static Phase Shifter

A Static Phase Shifter (SPS) is basically a phase shifting transformer adjusted by thyristor switches to provide a rapidly variable phase angle. In general, phase shifting is obtained by adding a perpendicular voltage vector in series with a phase. This vector, which can be made variable using a number of power electronics topologies, is derived from the other two phases via a shunt connected transformer. Thus, by varying the phase angle of the system, power flow through the network can be controlled. A typical phase shifting transformer circuit is represented in Figure 3.12.

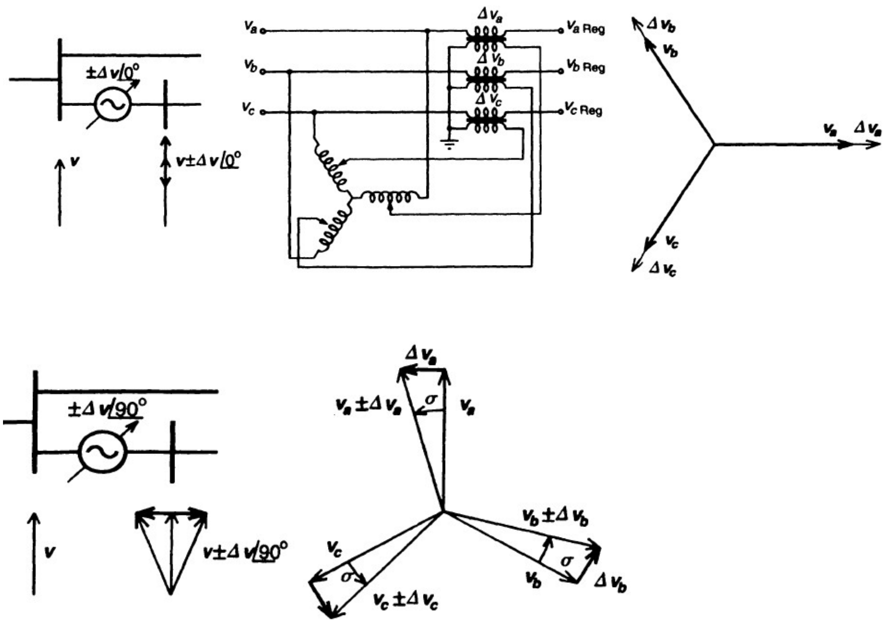


Figure 3.12 : Phase shifting transformer circuit

Table 3.11 – SPS Data				
Col No.	**Description**	**Type**	**Min**	**Max**
1.	Status	int	0	3
2.	From bus number	int	0	99999
3.	To bus number	int	0	99999
4.	Rating in MVA	float	0	9999

5.	Real Power reference (MW)	float	0	9999
6.	Phase shifter reactance (pu)	float	0.01	0.2
7.	Min angle shift (Degree)	float	-180^o	180^o
8.	Max angle shift (Degree)	float	-180^o	180^o
9.	Tolerance (MW)	float	1.0e-4	1.0

Explanations to entries given in Table 3.11 are as follows –

- SPS status is interpreted as -

Option	Status
0	Shunt reactor does not exist.
3	Shunt reactor exists.

- From Bus Number is the bus number to which the from end of the SPS is connected. The bus ID should be present in bus data. It should not be the same as To bus number.
- To Bus number is the bus number to which the to end of the SPS is connected. The bus ID should be present in bus data. It should not be the same as From bus number.
- MVA rating of SPS is required to convert the SPS reactance to common MVA base when user has unchecked p.u. status.
- Real Power reference is the power flow desired through the transmission line in which SPS is connected.
- Phase shifter reactance field accepts the value of the SPS transformer's reactance.
- The minimum and the maximum angle limits of SPS are to be specified in degrees.
- Tolerance value is to check for SPS convergence. It checks the SPS power flows in the present iteration and compares with the flows in previous iteration. If the difference in power flows is less than this tolerance value SPS power flow is said to be converged.

Stream 13: Unified Power Flow Controller

A unified power flow controller (UPFC) is a combination of a static synchronous compensator (STATCOM) and a static synchronous series compensator (SSSC) which are coupled via a common dc link, to allow bidirectional flow of real power between the series output terminals of the SSSC and the shunt output terminals of the STATCOM, and are controlled to provide concurrent real and reactive series line compensation without an external electric energy source. The UPFC, by means of angularly unconstrained series voltage injection, is able to control, concurrently or selectively, the transmission line voltage, impedance, and angle or, alternatively, the real and reactive power flow in the line. The UPFC may also provide independently controllable shunt-reactive power compensation. A typical UPFC circuit is represented in Figure 3.13.

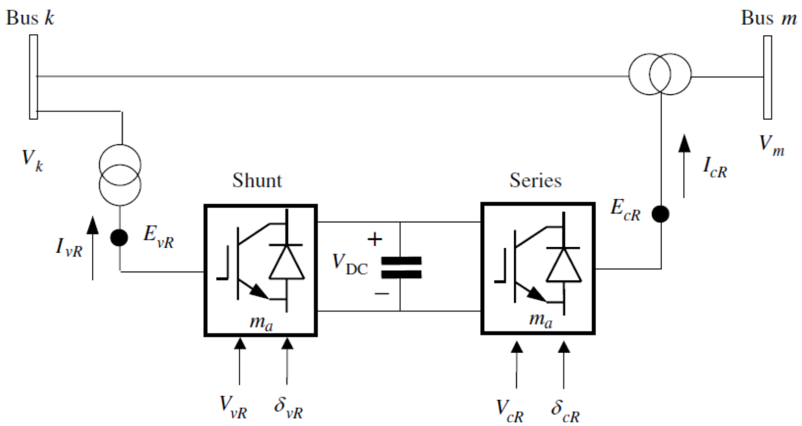


Figure 3.13 : Unified power flow controller circuit

Table 3.12 – UPFC Data				
Col No.	**Description**	**Type**	**Min**	**Max**
1.	Status	int	0	3
2.	From bus number	int	0	99999
3.	To bus number	int	0	99999
4.	MVA Rating	float	0	9999
5.	kV Rating	float	0	9999
6.	Real Power reference (MW)	float	0	9999
7.	Reactive Power reference (Mvar)	float	0	9999
8.	Voltage reference (pu)	float	0.95	1.05
9.	Series converter reactance (pu)	float	0.01	0.2
10.	Shunt converter reactance (pu)	float	0.01	0.2
11.	Series converter Min. voltage (pu)	float	0.01	0.2
12.	Series converter Max. voltage (pu)	float	0.01	0.2
13.	Shunt converter Min. voltage (pu)	float	0.95	1.05
14.	Shunt converter Max. voltage(pu)	float	0.95	1.05
15.	UPFC tolerance (MW)	float	1.0e-4	1.0
16.	Check limit	Int	0	1

Explanations to entries given in Table 3.12 are as follows –

- UPFC status is interpreted as -

Option	Status
0	Shunt reactor does not exist.
3	Shunt reactor exists.

- From Bus Number field is used to specify the From bus number to which the UPFC is connected. This bus can be selected from the list box provided, which displays all the buses present in the database. In the case of UPFC, 'From bus' is the voltage control bus.
- To Bus Number field is to specify the To bus number to which the UPFC is connected. This bus can be selected from the list box provided, which displays all the buses present in the database.
- MVA Rating field is to specify the MVA rating of the device. This MVA rating is used in parameter conversions into Common MVA base.
- kV Rating field is used to specify the kV rating of the device on which the device's parameters are derived.
- Real Power Reference is the value of MW power desired to be transferred through the UPFC, and thereby through the line to which the UPFC is connected.
- Reactive Power Reference is the value of Mvar power to be transferred through the UPFC, and thereby through the line to which the UPFC is connected.
- Voltage Reference is the value of voltage in p.u. to be set to the UPFC From bus.
- The model of UPFC demonstrated here has a series connected converter whose reactance alone is considered. Series converter's resistance is assumed to be negligible. The reactance value cannot be '0' and its ranges between 0.01-0.2 p.u.
- The series converter injects or absorbs some voltage in series with the line. The minimum voltage it must inject/absorb is specified in Series Converter Min. Voltage field.
- The series converter injects or absorbs some voltage in series with the line. The maximum voltage it must inject/absorb is specified in Series Converter Max. Voltage field.
- The model of UPFC demonstrated here has a shunt connected converter whose reactance alone is considered. Shunt converter's resistance is assumed to be negligible. The reactance value cannot be '0' and it ranges between 0.01-0.2 p.u.
- The minimum voltage in pu that the shunt converter must have is specified in Shunt Converter Min. Voltage field.
- The maximum voltage in pu that the shunt converter must have is specified in Shunt Converter Max. Voltage field.

- UPFC tolerance is the maximum real power error in PU on the given MVA base. This is used to check the UPFC device's convergence. For this device, tolerance is the sum of real power injection in the shunt and series converters. The amount of real power taken from the shunt converter is given to the series converter, assuming no real power losses in the converters. Generally an acceptable value of tolerance is 0.001 PU.
- UPFC Check-Limit:
- If the user does not check this box, the UPFC series and shunt converter's voltage limits are not taken into account, and the reference powers 'P-REF' and 'Q-REF' will flow through the line even if voltage limit violations occur.
- If the user checks this box, the UPFC voltage limits will be taken into account, and the reference powers 'P-REF' and 'Q-REF' will flow through the line only if there are no voltage limit violations. If there are limit violations the 'P-REF' and 'Q-REF' will be reset to best possible values, ensuring voltage limit violations are avoided.

Stream 14: 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 3.13.

Table 3.13 – Shunt Reactor/Capacitor (Admittance form) Data

Col No.	Description	Type	Min	Max
1.	From bus number	int	1	99999
2.	Conductance in pu.	float	-1.0e-4	1.0e4
3.	Susceptance in pu.	float	-1.0e4	1.0e4
4.	Shunt status.	int	0	3
5.	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 inductor/capacitor is connected if it is a bus reactor. The entry in this column corresponds to 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.

- Shunt status is interpreted as -

Option	Status
0	Shunt reactor does not exist.
3	Shunt reactor exists.

- Shunt location is interpreted as –

Option	Status
0	Shunt reactor is connected to the bus.
1	Shunt reactor is connected to the ‘from’ side of the series element.
2	Shunt reactor is connected to the ‘to’ side of the series element.

Stream 15 : 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. Induction motor are represented in shunt impedance form, the impedance value is obtained after simplifying the exact equivalent circuit. Also, 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 3.14.

Table 3.14 - Shunt Impedance Data

Col No.	Description	Type	Min	Max
1.	From bus number	int	1	99999
2.	Resistance in pu.	float	0.001	9999.9
3.	Reactance in pu.	float	0.001	9999.9
4.	Shunt status.	int	0	3
5.	Shunt location.	int	0	2

Explanations to entries given in Table 3.14 are as follows -

- From bus number is the bus number to which the shunt impedance is connected. The entry in this column is the series element number if the impedance is connected to the series element.

- 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 1.6 respectively on 100 MVA base.

- Shunt status is interpreted as -

Option	Status
0	Shunt impedance does not exist.
3	Shunt impedance exists.

- Shunt location is interpreted as -

Option	Shunt location
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 16 : Generator Data

In this stream of data, generator details are given. 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 3.15.

Table 3.15 - Generator Data

Col No.	Description	Type	Min	Max
1.	Generator bus number	int	1	99999
2.	Scheduled real power generation in MW	float	-1.0e6	1.0e6
3.	Minimum reactive power in Mvar	float	-1.0e6	1.0e6
4.	Maximum reactive power in Mvar	float	-1.0e6	1.0e6
5.	Specified voltage in pu.	float	0.5	1.5
6.	Generator capability curve no.	int	0	500
7.	MVA rating of generator.	float	0.0	1.0e6
8.	Generator status.	int	0	3
9.	Type	int	1	3

Explanations to entries given in Table 3.15 are as follows -

- Generator bus number refers to the bus number at which the generator is connected. The bus number should exist in the bus data stream.

- Scheduled real power generation in MW is the generator real power at the operating condition. Depending on the load flow option, the scheduled power changes as follows.

  1. In case of normal load flow (frequency independent), the scheduled power at the slack bus is computed. Slack bus is the maximum generation bus if the slack bus is selected by the program. For all other buses, the scheduled power is held constant.

  2. In case of flat tie line control, the tie line flows (treated also as generating buses) are held constant. Real power generation at all the other buses are computed as -

$$P_i^G = P_i^{Gset} - \frac{\Delta f}{R_i}$$

Where,

P_i^G is the active power generation at the bus *i* in p.u.
P_i^{Gset} is the scheduled power generation at the bus *i* in p.u.
Δf is steady state frequency deviation in p.u given by

$$\Delta f = f - f_0$$

Where,

f is the actual system frequency.
f_0 is the scheduled system frequency in pu.
R_i is the speed-droop setting of turbine governor in generating plant connected to bus i in pu.

Unit speed regulation R is defined as

$$R = \frac{\Delta f_{pu}}{\Delta P_{pu}} = \frac{\Delta f_{Hz} / \Delta f_o}{\Delta P_{MW} / P_{rated\ MW}}$$

Thus if a generator's percentage droop is 4%, it implies that for 2 Hz, change in system frequency at f_0 = 50 Hz., the real power generation changes by its rating. The generation increases for the decrease in the frequency from the scheduled frequency and vice-versa.

3. In case of flat frequency control, the system frequency remains the same. Hence the tie line flows (generator real power generation) changes depending on the total area control error (mismatch in the generation and load in the given area) and the tie line participation factor of the generators participating in the flat frequency control. For these generators, the generation is computed as

$$P_i^T = P_i^{Tset} + \alpha_i \Delta G$$

Where,

P^T is the active power generation at tie line bus i, in pu
P_i^{Tset} is the generation schedule at tie line bus i. Also $\sum \alpha_i = 1.0$ in pu
ΔG is the static area control error given by:

$$\Delta G = P_T - P_{To} + B \Delta f$$

Where,
P_T is the actual tie line power flow in p.u
P_{To} is the scheduled tie line power flow in p.u
B is the bias factor setting of the automatic generation control regulator, which is a constant for the area load frequency characteristics.

4. In case of optimal real power program, the generator scheduled power changes depending on the generator cost function.

However, to model a synchronous condenser, scheduled real power is given as zero.

- Minimum and maximum reactive power limits on the generator are imposed because of the stability constraints and thermal constraints respectively. For the given real power generation, from the generator capability curve supplied by the manufacturer, the reactive limits are read. Values given under this column are of significance only if the capability curve number referred by the generator is zero. In case of normal load flow, since the scheduled power is known, the capability curve number can be given as zero, and limits are manually computed and given. If a particular generator bus is to be treated as load bus (where P and Q are specified, and voltage magnitude and angles are unknowns), then same value is given for both minimum and maximum reactive power limits. If at a load bus, it is required to determine the reactive power injection, to achieve the specified voltage magnitude, a fictitious generator is considered at that bus. Real power generation is given as zero and minimum and maximum reactive power limits are given as large negative and large positive values respectively. By determining the reactive power requirements at the bus for various operating conditions (loading conditions), the required capacitor bank sizes (including inductive) can be determined.

- Specified voltage in pu is voltage magnitude at the generator bus, which is held constant in the study, provided the reactive power generation at the bus lies within its minimum and maximum limits. The scheduled voltage is in the range 0.95 pu to 1.05 pu and normally above 1.0 pu. If the reactive power limits are violated, then the specified voltage is no more held constant and it is computed, keeping the reactive power generation for the generator at the limit value.

- Generator capability curve number is the curve number to be referred for the generator. It is explained under "capability curve data" stream. If the capability curve number is zero, then reactive power limits provided under this stream are considered.

- Generator MVA rating is used to determine the reactive power limits from the capability curve.
- Generator status is interpreted as –

Option	Status
0	Generator does not exist.
3	Generator exists.

- Generator Type is interpreted as –

Option	Status
1	Conventional
2	Wind
3	Solar

Stream 17 : Wind Generator Data

Wind Turbine Generator is a non-conventional generator. A basic wind turbine generator will have an aerodynamic system to convert wind energy to mechanical energy, and an electrical system to convert mechanical energy to electrical energy. The entire system include a turbine, electric machine, aerodynamic-mechanical and electrical control systems, converter-inverter model in some cases. This wind turbine generator is very much different from conventional generators as the stability and controllability characteristics are quite different for a wind turbine generator. The real power generation of a wind turbine will be basically dependent on the site climatic conditions like wind speed, air density, etc. And the reactive power generation of a wind turbine is basically dependent on the terminal voltage of the generator, as most of the wind generators are having induction machines. So the wind turbine generator cannot be represented as a PV or Vδ bus. It has to be represented as a PQ bus but the effect of other factors like wind speed, site air density, grid bus voltage, etc. The detailed wind turbine model is developed for the purpose of power system simulation studies with wind turbine. The schematic diagram of wind turbine model is shown in the figure 3.14.

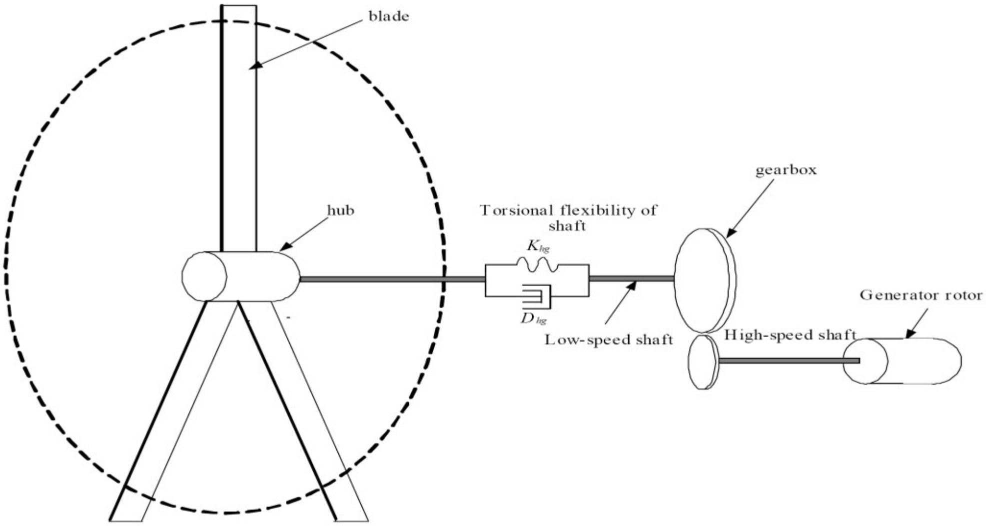


Figure 3.14 : Aerodynamic-mechanical-electric system of a wind generator schematic

There are basically four IEEE standard models. They are as mentioned below.

Wind Turbine Model	Description
WT1	Squirrel cage induction generator type wind turbine
WT2	Variable rotor resistance induction generator type wind turbine (WT2)
WT3	Doubly fed induction generator type wind turbine (WT3) generally called as DFIG type model
WT4	Full converter type wind turbine (WT4)

The data entry format for each model is different. The data that appears in different columns of each line for each model are given in Table 3.16 - 3.19 respectively.

Table 3.16 – Wind Generator Data for WT1

Col No.	Description	Type	Min	Max
1	WT Generator bus number	Int	1	9999
2	WT Generator model number	Int	1	4
3	No. of Turbines in the wind farm	Int	1	9999
4	MVA rating	Double	0.0	1.0e6
5	Operating power factor	Double	-1	1
6	Minimum real power generation (MW)	Double	-1.0e6	1.0e6
7	Maximum real power generation (MW)	Double	-1.0e6	1.0e6

8	Minimum reactive power generation (MVAR)	Double	-1.0e6	1.0e6
9	Maximum reactive power generation (MVAR)	Double	-1.0e6	1.0e6
10	No. of steps	Int	1	9999
11	No. of poles (only even numbers)	Int	2	9999
12	Turbine Rated Speed (RPM)	Double	-1.0e6	1.0e6
13	Gearbox ratio	Double	0.001	1.0e6
14	Average wind speed (m/s)	Double	0.1	50
15	Air density (kg/m3)	Double	0.1	10
16	Turbine diameter (m)	Double	-1.0e6	1.0e6
17	Cut in speed(m/s)	Double	0	50
18	Cut out speed(m/s)	Double	0	50
19	This variable specifies format of the power curve	Int	0	999
20	Power Curve No.	Int	0	999
21	Operating mechanical power to operating rotor speed curve No.	Int	0	999
22	Operating mechanical power to wind speed curve No.	Int	0	999
23	Stator resistance, Rs (p.u.)	Double	0	1.0e6
24	Stator reactance, Xr (p.u.)	Double	0	1.0e6
25	Rotor resistance, Rr (p.u.)	Double	0	1.0e6
26	Rotor reactance, Xr (p.u.)	Double	0	1.0e6
27	Magnetising reactance, Xm (p.u.)	Double	0	1.0e6

Table 3.17 – Wind Generator Data for WT2

Col No.	Description	Type	Min	Max
1	WT Generator bus number	Int	1	9999
2	WT Generator model number	Int	1	4
3	No. of Turbines in the wind farm	Int	1	9999
4	MVA rating	Double	0.0	1.0e6
5	Operating power factor	Double	-1	1
6	Minimum real power generation (MW)	Double	-1.0e6	1.0e6
7	Maximum real power generation (MW)	Double	-1.0e6	1.0e6
8	Minimum reactive power generation (MVAR)	Double	-1.0e6	1.0e6
9	Maximum reactive power generation (MVAR)	Double	-1.0e6	1.0e6
10	No. of steps	Int	1	9999
11	No. of poles (only even numbers)	Int	2	9999
12	Turbine Rated Speed (RPM)	Double	-1.0e6	1.0e6
13	Gearbox ratio	Double	0.001	1.0e6
14	Average wind speed (m/s)	Double	0.1	50
15	Air density (kg/m3)	Double	0.1	10

16	Turbine diameter (m)	Double	-1.0e6	1.0e6
17	Cut in speed(m/s)	Double	0	50
18	Cut out speed(m/s)	Double	0	50
19	This variable specifies format of the power curve	Int	0	999
20	Power Curve No.	Int	0	999
21	Operating mechanical power to operating rotor speed curve No.	Int	0	999
22	Operating mechanical power to wind speed curve No.	Int	0	999
23	Stator resistance, Rs (p.u.)	Double	0	1.0e6
24	Stator reactance, Xr (p.u.)	Double	0	1.0e6
25	Rotor resistance, Rr (p.u.)	Double	0	1.0e6
26	Rotor reactance, Xr (p.u.)	Double	0	1.0e6
27	Magnetising reactance, Xm (p.u.)	Double	0	1.0e6
28	Rotor reactance minimum, Rrmin (p.u.)	Double	0	1.0e6
29	Rotor reactance maximum, Rrmax (p.u.)	Double	0	1.0e6

Table 3.18 – Wind Generator Data for WT3

Col No.	Description	Type	Min	Max
1	WT Generator bus number	Int	1	9999
2	WT Generator model number	Int	1	4
3	No. of Turbines in the wind farm	Int	1	9999
4	MVA rating	Double	0.0	1.0e6
5	Operating power factor	Double	-1	1
6	Minimum real power generation (MW)	Double	-1.0e6	1.0e6
7	Maximum real power generation (MW)	Double	-1.0e6	1.0e6
8	Minimum reactive power generation (MVAR)	Double	-1.0e6	1.0e6
9	Maximum reactive power generation (MVAR)	Double	-1.0e6	1.0e6
10	No. of poles (only even numbers)	Int	2	9999
11	Turbine Rated Speed (RPM)	Double	-1.0e6	1.0e6
12	Gearbox ratio	Double	0.001	1.0e6
13	Average wind speed (m/s)	Double	0.1	50
14	Air density (kg/m3)	Double	0.1	10
15	Turbine diameter (m)	Double	-1.0e6	1.0e6
16	Cut in speed(m/s)	Double	0	50
17	Cut out speed(m/s)	Double	0	50
18	This variable specifies format of the power curve	Int	0	999
19	Power Curve No.	Int	0	999
20	Operating mechanical power to operating rotor speed curve No.	Int	0	999

21	Operating mechanical power to wind speed curve No.	Int	0	999
22	Stator resistance, Rs (p.u.)	Double	0	1.0e6
23	Stator reactance, Xr (p.u.)	Double	0	1.0e6
24	Rotor resistance, Rr (p.u.)	Double	0	1.0e6
25	Rotor reactance, Xr (p.u.)	Double	0	1.0e6
26	Magnetising reactance, Xm (p.u.)	Double	0	1.0e6
27	Converter side voltage rating (p.u.)	Double	0	1.0e6
28	Inverter side voltage rating (p.u.)	Double	0	1.0e6
29	Converter current rating (p.u.)	Double	0	1.0e6

Table 3.19 – Wind Generator Data for WT4

Col No.	Description	Type	Min	Max
1	WT Generator bus number	Int	1	9999
2	WT Generator model number	Int	1	4
3	No. of Turbines in the wind farm	Int	1	9999
4	MVA rating	Double	0.0	1.0e6
5	Real power specified	Double	0.0	1.0e6
6	Operating power factor	Double	-1	1
7	Minimum real power generation (MW)	Double	-1.0e6	1.0e6
8	Maximum real power generation (MW)	Double	-1.0e6	1.0e6
9	Minimum reactive power generation (MVAR)	Double	-1.0e6	1.0e6
10	Maximum reactive power generation (MVAR)	Double	-1.0e6	1.0e6
11	No. of poles (only even numbers)	Int	2	9999
12	Turbine Rated Speed (RPM)	Double	-1.0e6	1.0e6
13	Gearbox ratio	Double	0.001	1.0e6
14	Average wind speed (m/s)	Double	0.1	50
15	Air density (kg/m3)	Double	0.1	10
16	Turbine diameter (m)	Double	-1.0e6	1.0e6
17	Cut in speed(m/s)	Double	0	50
18	Cut out speed(m/s)	Double	0	50
19	This variable specifies format of the power curve	Int	0	999
20	Power Curve No.	Int	0	999
21	Operating mechanical power to operating rotor speed curve No.	Int	0	999
22	Operating mechanical power to wind speed curve No.	Int	0	999
23	Converter side voltage rating (p.u.)	Double	0	1.0e6
24	Inverter side voltage rating (p.u.)	Double	0	1.0e6
25	Converter current rating (p.u.)	Double	0	1.0e6

Explanations to common entries given in Table 3.16-3.19 are as follows -

- Generator bus number refers to the bus number at which the generator is connected. The bus number should exist in the bus data stream.
- Generator model corresponds to the Turbine type i.e., WT1 – WT4.
- MVA rating will specify rating of one individual turbine. Number of units specifies the number of similar wind turbine available in the farm.
- Real power specified will be significant only in the case of WT4 model. Because this model can generate the power as specified by the operator, with in the limit of available power generation.
- The wind farm/turbine tends to maintain the specified operating power factor within the reactive power limits. If operating power factor is –ve then lagging and leading for +ve.
- The reactive power compensation for WT1, WT2 will be with switchable capacitors at its terminal. So the compensation will be in terms of steps of capacitor bank.
- The No. of steps field is for WT1, WT2 models only. This field specifies No. of reactive power steps.
- The reactive power compensation for WT3, WT4 will be continuous control.
- In case of wind farm the reactive power limits are specified for the entire wind farm.
- System operating frequency should be less than the product of Turbine Rated Speed (rps), number of poles, gear box ratio/120. If this validation is not checked the program will give error.
- A general power curve can be represented as below.

$$P_m = \frac{1}{2} \cdot C(\lambda, \beta) \cdot \rho \cdot \pi \cdot R^2 V_w^3$$

$$\lambda = \frac{\omega_R R}{V_w}$$

$$\omega_R = \frac{2\pi n}{60}$$

Where, Pm is the total power absorbed by the aerodynamic system
ρ is air density (kg/m3)
R is radius of the turbine blade (m)
Vm is wind speed (m/s)
λ is tip speed ratio, i.e. ratio between speed of tip of the blade to the wind speed
β is the pitch angle
Cp is coefficient of power
ωR is mechanical angular velocity of the turbine rotor (rad/s)
n is rotational speed of wind turbine (RPM)

- Power curve can be represented in four ways. They are
  1. Power curve is represented in formula 1
  2. Power curve is represented in formula 2
  3. Power curve is represented in power curve data
  4. Power curve is represented in detailed power curve data

First three types of power curve representations will be in curve data library. Fourth type of representation will be in detailed curve data library.

The generalized formula 1 is as below:

$$C_p = C_0 \left\{ \frac{C_1}{\lambda_i} + C_2\lambda_i + C_3\beta^{?} + C_4\beta^{?} + C_5 \right\} e^{\left(?\lambda_i + \frac{?}{\lambda_i}\right)}$$

$$\lambda_i = \frac{1}{\frac{1}{\lambda + a_0\beta} - \frac{a_1}{\beta^3 + 1}}$$

Where C_p is the coefficient of power
λ is tip speed ratio
β is pitch angle
All other coefficients in the equation are constant values and to be entered by the user.

The generalized formula 2 is as below:

$$P = \sum_{i=0}^{4} \sum_{j=0}^{4} (\alpha_{ij} \beta^{i} \lambda^{j})$$

Where P_w is mechanical power generation
αij coefficients for i = 0 to 4 and j = 0 to 4 need to be given in the input data
β is the pitch angle
λ is the tip speed ratio

- Variable number 20 specifies the format of power curve.

Value of variable 20	Respective power curve format
1	Formula 1
2	Formula 2
3	Power curve
4	Detailed power curve

- Variable number 21, 22 and 23 specify the three curves reference numbers to curve libraries. First is Power curve(wind speed(m/s) vs mechanical power generation(p.u.)), second is operating mechanical power(p.u.) vs operating rotor speed(p.u.) and third is operating wind speed(m/s) vs operating rotor speed(p.u.).

- When the variable 20 is 1-3 the power curve represented is of curve library. When the variable 20 is 4 the power curve represented is of detailed curve library.

Option	Status
0	Load does not exist.
3	Load exists.

Stream 18 : Solar PV PlantData

Solar photo voltaic plants comprises of several solar panels that generates electricity when sunlight falls upon it. This electricity from sunlight is generated through an electronic process that occurs in some semiconductor devices. Sunlight comprises of minuscule particles known as photons, when strikes the semiconductor material it loses its energy and break free from their atomic bonds.

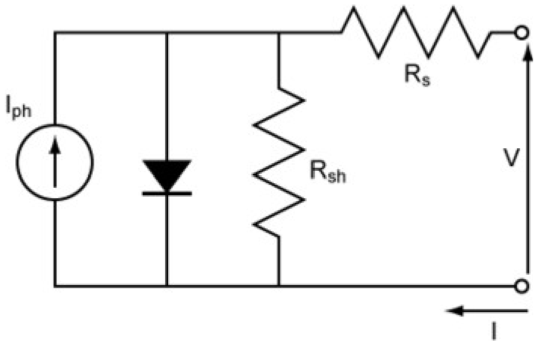


Figure 3.15: The equivalent circuit diagram of a solar cell

There are two types of PV model:

1. Simple Model
2. Detailed Model

In the Simple model, the data appearing under different columns of each line is given below in Table 3.20:

Table 3.20 – Solar PV Data for Simple Model

Col No.	Description	Type	Min	Max
1.	Status	int	0	3
2.	Bus number	int	1	99999999
3.	Plant MVA	double	0	1.0e6
4.	P specified	double	0	1.0e6
5.	Mode of operation	int	0	1
6.	Power factor	double	0	1
7.	pf flag	int	0	1
9.	Specified voltage in p.u.	double	0	1.0e6
10.	Minimum compensating MVAr	double	-1.0e6	1.0e6
11.	Maximum compensating MVAr	double	-1.0e6	1.0e6

Explanations to the entries given in Table 3.20 are as follows –

- Initial status number determines whether the solar PV plant is inservice or out of service.

Option	Status
0	In service
3	Out of service

- Bus number is the bus number to which the Solar PV plant is connected. This number should exist in the bus data stream.
- Plant MVA is the rating of the Solar PV plant expressed in MVA.
- P specified is the specified power expressed in MW.
- Mode of operation flag determines the operating mode of PV plant i.e. either constant power factor mode (0) or voltage control mode (1).

The rest of the entries are discussed in explanation of Table 3.21.

In the Detailed model of Solar PV plant, the data appearing under different columns of each line is given in Table 3.21.

Table 3.21 – Solar PV Data for Detailed Model

Col No.	Description	Type	Min	Max
1.	Bus number	int	1	99999999
2.	Solar Irradiance on tilted plane	double	0	1.0e6

3.	Solar Irradiance on horizontal pane GHI value	double	0	1.0e6
4.	DHI value	double	0	1.0e6
5.	DNI value	double	0	1.0e6
6.	Ambient Temperature in degree Celsius	float	-1.0e6	1.0e6
7.	Mounting Tilt angle	float	0.0	90
8.	Mounting Azimuthal angle	float	-180	180
9.	Breaker rating MVA	double	0	1.0e6
10.	Breaker rating KV	double	0	1.0e6
11.	Date(dd/mm/yy)	int	0	1.0e6
12.	Hour	int	0	24
13.	Min	int	0	60
14.	Latitude (degree)	int	-90	90
15.	Latitude (min)	int	0	60
16.	Longitude (degree)	int	-180	180
17.	Longitude (min)	int	0	60
18.	Standard meridian (degree)	int	0	360
19.	Standard meridian (min)	int	0	60
20.	Data type	int	0	1
21.	Series Resistance(mOhms)	Double	0	1.0e6
22.	Shunt Resistance(ohms)	Double	0	1.0e6
23.	Reverse saturation current(nA)	Double	0	1.0e6
24.	Photon generated current(A)	Double	0	1.0e6
25.	Diode factor	Double	0	1
26.	Number of series cells	int	0	1.0e6
27.	Temperature coefficient of current(µA/K)	Double	0	1.0e6
28.	Band gap energy(eV)	Double	0	1.0e6
29.	PV module rating(W)	Double	0	1.0e6
30.	Efficiency of PV module(%)	Double	0	100
31.	Max. power point voltage(V)	Double	0	1.0e6
32.	Max. power point current(A)	Double	0	1.0e6
33.	Temperature coefficient. of power(%/ºC)	float	-1.0e6	1.0e6
34	Temperature coefficient of voltage(V/ºC)	float	-1.0e6	1.0e6
35.	PV module Reference number	int	1	9999
36.	Cell Temperature in degree Celsius	float	-1.0e6	1.0e6
37.	NOCT Temperature in degree Celsius	float	-1.0e6	1.0e6
38.	Alpha	int	0	1
39.	Number of module strings	int	0	99999
40.	Number of string in array	int	0	99999
41.	DC Side power rating in MW	float	0	1.0e6
42.	AC Side power rating in MVA	float	0	1.0e6
43.	AC Side voltage in kV	float	0	1.0e6
44.	Efficiency	float	0	100

45.	Number of Inverters	int	0	99999
46	Mode of operation	int	0	1
47.	Power factor	double	-1	1
48.	pf Flag	int	0	1
49.	Specified voltage in p.u.	double	0	1.0e6
50.	Minimum compensating Mvar	double	-1.0e6	1.0e6
51.	Maximum compensating Mvar	double	-1.0e6	1.0e6

Explanations to the entries given in Table 3.21 are as follows -

- Bus number is the bus number to which the Solar PV plant is connected. This number should exist in the bus data stream.

- Solar Irradiance on tilted plane is the component of the incident solar radiation which is perpendicular to the module surface.
- GHI is the global horizontal irradiance (GHI) falling onto the Earth's surface consists of the diffuse horizontal irradiance (DHI) from the sky and the direct normal irradiance (DNI) from the sun. The relation between GHI, DHI and DNI is given below:

$$GHI = DHI + DNI*\cos(\theta)$$

where **θ** is the solar zenith angle (vertically above the location is 0°, horizontal is 90°).The units for GHI, DHI and DNI is W/m^2.

- Ambient Temperature is the temperature of the surrounding atmosphere of the Solar PV plant defined in degree Celsius.

Option	Model type
0	Fixed Axis
1	One axis Tracking
2	Two axis Tracking

- Mounting Tilt angle is the tilt angle of the solar PV module for maximum energy yield expressed in degrees.

- Mounting Azimuthal angle is the compass direction from which the sunlight is coming expressed in degrees.

- Breakers are installed for the purpose of protection whose rating is to be defined in MVA and kV. Proper calculations must be done in order to select a breaker.

- Date and time of operation is to be mentioned to determine irradiance details.

- Latitude and Longitude determines the geographical location of the solar PV plant where the angle and value of irradiance is calculated which varies with geographically.

- A prime meridian is a meridian (a line of longitude) in a geographical coordinate system at which longitude is defined to be 0°.

- In PV module reference number, some pre-defined modules with rated value are available that are to be used in modelling a Solar PV plant. New modules can also be created by defining the typical values of modules. These details include Series resistance, shunt resistance, reverse saturation current, photon generated current, diode factor, number of series cells, temperature coefficient of power and voltage, energy band gap, PV module rating, efficiency, maximum power point voltage and current.

Option	Model type
0	One diode model
1	Based on name plate details

- Cell temperature is usually kept 25°C at nominal operating cell temperature condition which is at peak power operating point. In case it is to be calculated in some other case involving other than peak power its value varies.

- Number of module strings is the number of modules in a single string connected in series. These basically increase the terminal voltage of the array.

- Number of string in array consists of parallel paths in a complete array. These strings are connected in parallel and thus increase the rated current of the Solar PV array.

- DC side power rating is the power rating of the inverter on the DC side to be expressed in MW. The DC power from the Solar PV plant is fed to the DC terminal of this inverter.

- AC side power rating is the power rating of the inverter on the AC side. This is expressed in MVA since it is a source and different AC loads can be connected at this terminal.

- Efficiency of the inverter is the percentage measure of its ability to supply usable power from the power given as input to it.

- Number of inverters is the quantity we are setting up in the Solar PV plant. Its number depends upon several factors like power rating, efficiency of each inverter etc.

- There are two modes of operation. One is constant power factor mode where at a defined power factor the inverter will supply power and other one is voltage control mode where voltage is specified and proper reactive power compensation is provided in certain limits.

Option	Mode of Operation
0	Constant power factor
1	Voltage control mode

- Number The pf Flag provides the information about lag and leading of the power factor.

Option	pf Flag
0	lagging power factor
1	leading power factor

- For voltage control mode there is a specified voltage defined in p.u. Along with that there are some limit for minimum and maximum compensating Vars defined as Qmin and Qmax limits.

Stream 19 : 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. Other than normal loads, data for induction motor loads, tie line flows, which are held constant, are also provided under this stream. Data appearing under different columns of each line is given in Table 3.22.

Table 3.22 - Load Data

Col No.	Description	Type	Min	Max
1.	Load bus number	int	1	99999
2.	Real power load in MW	float	-1.0e6	1.0e6
3.	Reactive power load in Mvar	float	-1.0e6	1.0e6
4.	Compensating Mvar	float	-1.0e6	1.0e6
5.	Minimum compensating Mvar	float	-1.0e6	1.0e6
6.	Maximum compensating Mvar	float	-1.0e6	1.0e6
7.	Compensating Mvar step	float	0.0	1.0e3
8.	Load characteristic number	int	0	9999
9.	Frequency relay number	int	0	9999
10.	Shunt status	int	0	3
11.	Voltage relay number	int	0	9999

Explanations to entries given in Table 3.21 are as follows -

- Load bus number is the bus number to which the load is connected. This number should exist in the bus data stream.

- Real power and reactive power load values are the scheduled values at the scheduled frequency and nominal voltage. Nominal voltage is equal to the base voltage at the bus. Scheduled frequency is read under system specification stream. This is normally either 50 Hz or 60 Hz.

- Compensating Mvar is the fixed compensation provided at the bus. It is assumed that irrespective of the bus voltage and system frequency, compensating Mvar remains constant. If at a bus, fixed capacitor or inductor is present, it is advisable to provide the compensation data as shunt impedance/admittance at the bus.

- Compensating Mvar limits are used in reactive power optimization module of **POWERLFA**. Reactive power compensation is limited to the maximum and minimum values for violating the maximum and minimum limits respectively. Step value is the increment for the reactive power compensation. For reactive power optimization, the minimum, maximum and step values of reactive power source Mvar are specified at desired buses. The program determines the amount of compensation to be provided at the bus for the present loading and operating conditions.

- Load characteristic number is the number given in the load characteristic data to be referred for the modelling of the load at the bus. Load characteristic is detailed under "load characteristic stream".

- Unlike conventional power flow programs, in **POWERLFA** system operating frequency is also an unknown. If the frequency goes below a specified limit, part of the loads can be shed to improve the system frequency. The frequency relay number to be considered for load shedding purposes is specified. If the relay number is zero, then load shedding will not take place. The under frequency relay characteristic is detailed under "frequency relay characteristic stream".

- Load status is interpreted as -

Option	Status
0	Load does not exist.
3	Load exists.

- The voltage relay number to be considered for load shedding purposes is specified in the last column of the line.

Stream 20: Load Characteristic Data

In this stream of data, load characteristic details are given. Total number of lines of data in this stream is equal to number of load characteristics as given in specification stream. The data that appears in different columns of each line is given in Table 3.22.

Table 3.22 - Load Characteristic Data				
Col No.	**Description**	**Type**	**Min**	**Max**
1.	Load characteristic number	int	1	9999
2.	Real power - constant power factor	float	0.0	1.0
3.	Real power - constant current factor	float	0.0	1.0
4.	Real power - constant impedance factor	float	0.0	1.0
5.	Reactive power - constant power factor	float	0.0	1.0
6.	Reactive power - constant current factor	float	0.0	1.0
7.	Reactive power - constant impedance factor	float	0.0	1.0
8.	Real power - frequency factor	float	0.0	20.0
9.	Reactive power - frequency factor	float	0.0	20.0

Explanations to entries given in Table 3.22 are as follows -

- Loads are modeled as explained in load data. The Load characteristic number given here should match the one given under load data.

Loads are modelled as a constant power load or constant current load or constant impedance load or as a combination of all, including the frequency dependency. The load characteristic number determines modeling of the load. If the load characteristic number is zero, then the loads are modelled as constant power type. At any bus i, the expressions for loads are given by -

If the load characteristic number is less than or equal 50, loads are modelled as

$$P_L^i = P_{LO}^i (1 + cp_f^i \Delta f) \ (cp_p^i + cp_i^i V^i + cp_z^i V^i V^i)$$

$$Q_L^i = Q_{LO}^i (1 + cq_f^i \Delta f)(cq_p^i + cq_i^i V^i + cq_z^i V^i V^i)$$

where,

P_L^i : Actual real power load at the bus i in pu.

P_{LO}^i : Scheduled real power load at the bus i in pu.

Q_L^i : Actual reactive power load at the bus i in pu.

Q_{LO}^i : Scheduled reactive power load at the bus i in pu.

cp_f^i : Coefficients of frequency dependence for active power load.

cq_f^i : Coefficients of frequency dependence for reactive power load.

cp_p^i : Constant power fraction of the active power load at bus i.

cq_p^i : Constant power fraction of the reactive power load at bus i.

cp_i^i : Constant current fraction of the active power load at bus i.

cq_i^i : Constant current fraction of the reactive power load at bus i.

cp_z^i : Constant impedance fraction of the active power load at bus i.

cq_z^i : Constant impedance fraction of the reactive power load at bus i.

V^i : Magnitude of the voltage at bus i in pu.

If the load characteristics number is greater than 50, loads are modelled as

$$P_L^i = P_{LO}^i (1 + cp_z^i (\Delta f)^{cp_f^i})(cp_p^i (V_i)^{cp_i^i}$$
$$Q_L^i = Q_{LO}^i (1 + cq_z^i (\Delta f)^{cq_f^i})(cq_p^i (V_i)^{cq_i^i}$$

Also, if load characteristic number is less than or equal to 50

$$\sum(cp_p^i + cp_i^i + cp_z^i) = 1.0 \qquad and$$
$$\sum(cq_p^i + cq_i^i + cq_z^i) = 1.0$$

It is to be noted that, $cp_f = 2.5$, $cp_p = 0.5$, $cp_i = 0.3$, $cp_z = 0.2$, implies real power changes by 5% for 1 Hz. change in frequency, 50% of the load is constant power type, 30% of the load is constant current type and 20% of load is constant impedance type. If the voltage at a bus goes below the specified value, then the load model for that bus is switched from the given model to constant impedance model as explained in the "system specification stream".

- Sum of constant power coefficient, constant current coefficient and constant impedance coefficient is always unity for load characteristic number less than or equal to 50. But specifying the values such that the sum is less than unity is a feature by which the specified load is multiplied by a smaller factor, which can be treated as light load condition. Hence if all the loads are of constant power type, then by specifying the relay characteristic number for all the loads as one for which the constant power factor is 0.9, the loads are curtailed by 10 percent.

- Frequency factor of 2.5 implies the load changes by 5 percent for 1 Hz. change in frequency.

Stream 21 : Frequency Relay Characteristic Data

In this stream of data, frequency relay characteristic details are given. Total number of lines of data in this stream is equal to number of relay characteristics as given in specification stream. The data that appears in different columns of each line is given in Table 3.23.

Table 3.23 – Frequency Relay Characteristic Data

Col No.	Description	Type	Min	Max
1.	Frequency relay characteristic number	int	1	9999
2.	Frequency setting 1 in Hz.	float	0.0	100.0
3.	Load shedding factor 1	float	0.0	1.0
4.	Frequency setting 2 in Hz.	float	0.0	100.0
5.	Load shedding factor 2	float	0.0	1.0
6.	Frequency setting 3 in Hz.	float	0.0	100.0
7.	Load shedding factor 3	float	0.0	1.0

Explanations to entries given in Table 3.23 are as follows -

- The frequency relay number given here should match the one given under load data.
- The relays are modelled to have 3 frequency settings. If the frequency goes below the setting 3, load is curtailed by the amount given by factor 3. Thus if the specified load is 100 MW, frequency setting 3 is 47 Hz., and the load shedding factor is 0.5, then if the system frequency goes below 47 Hz., the actual load considered is 50 MW. Same explanation holds good for other two settings also.

- Load shedding factor is the amount of load to be shed from the specified value. At the end of each load flow iteration systems' new frequency is computed and relay logic are introduced to determine the load shedding. A proper co-ordination of relays is required in terms of frequency settings to avoid the shedding of loads at all the places simultaneously.
- It is assumed that frequency-setting 3 is less than frequency setting 2 and frequency setting 2 is less than frequency setting 1.

Stream 22 : Generator Capability Curve Data

In this stream of data, generator capability curve details are given. For each capability curve, the data given are –

- Curve number.
- Number of curve points.
- Real power in pu, corresponding minimum and maximum reactive powers in pu on its own rating for each data point.

Curve number is the generator capability curve number referred by the generator under "generator data stream". Minimum number of curve points required is two. Maximum number of curve points should not exceed ten. For a generator MVA rating 265, figure 3.15 shows a sample generator capability curve for minimum and maximum reactive power limits as shown in the Table 3.23.

Table 3.23: Generator Capability Curve

Real Power in MW	Reactive Power in Mvar	
	Min.	Max.
0	-100	200
50	-100	175
100	-100	150
150	-75	125
200	-50	100
250	-25	50
265	0	0
Only Values need to be entered		

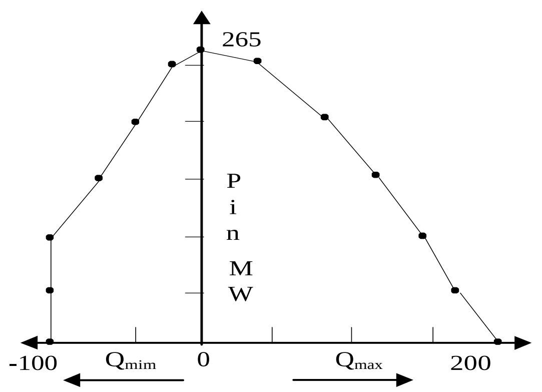


Figure 3.16: A sample generator capability curve

Then the capability curve for curve number 5 say is given as follows.

Table 3.24: Generator Capability Curve		
5		
7		
MW	**(Mvar) min**	**(Mvar) max**
0.000	-0.377	0.755
0.189	-0.377	0.660
0.377	-0.377	0.566
0.566	-0.283	0.472
0.755	-0.189	0.377
0.943	-0.094	0.189
1.000	0.000	0.000
Only values need to be entered		

The advantage obtained using this technique is that generators with different ratings can refer to same capability curve, if the curve shape in pu scale is same for all the generators. It is assumed that the MW values in pu are given in the increasing order.

Stream 23 : Generator Regulation Dependent Characteristic Data

In this stream of data, generator regulation characteristic details are given. Data given under this stream is used in frequency dependent load flow and real power optimisation i.e., economic load dispatch. 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 3.25.

Table 3.25 - Generator Regulation Characteristic Data

Col No.	Description	Type	Min	Max
1.	Generator bus number	int	1	99999
2.	Real power rating in MW	float	0.0	1.0e6
3.	Minimum real power in MW	float	-1.0e6	1.0e6
4.	Maximum real power in MW	float	-1.0e6	1.0e6
5.	Percentage droop on own rating	float	1.0	100.0
6.	Participation factor	float	0.0	1.0
7.	Bias setting	float	-1.0e2	1.0e2
8.	Cost coefficient C_0 in Rs.	float	0.0	1.0e6
9.	Cost coefficient C_1 in Rs/MW.	float	0.0	1.0e2
10.	Cost coefficient C_2 in Rs/MW^2.	float	0.0	1.0e2

Explanations to entries given in Table 3.25 are as follows -

- Generator bus number is the bus number to which the generator is connected.

- Generator real power rating in MW is used to convert the percentage droop to a common base.
- If the generator real power computed is outside the minimum and maximum limits, it is limited to the limiting values.
- Percentage droop on own rating is usually 4 to 5. If the percentage droop is greater than 99.0, then the droop characteristic for the generator is not considered. In that case participation factor is applicable. Percentage droop is converted to the common base internally.
- Participation factor is applicable only if flat frequency control is selected. In this case, generators with participation factor other than zero are considered as tie lines. Total area inter change error is distributed among these generators depending on the participation factor. Sum of participation factors of all the generators treated, as tie lines should be unity. When tie line interchange schedule is specified, the generators whose participation factor is other than zero participate in the secondary control.
- Bias setting field should be zero.
- Generator cost curve is given by

$$G_{Rs} = C_0 + C_1 P + C_2 P^2$$

Where,

G_{Rs} : Generation cost in Rupees at generation of P MW.
C_0 : Constant cost in Rs., irrespective of generation (capital cost).
C_1 : Cost in Rs/MW which is proportional to MW generation.
C_2 : Cost in Rs/MW^2 which is proportional to square of MW generation.

Stream 24 : Filter Data

In this stream of data filter details are given. For each filter, the bus number to which the filter is connected and the number 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 3.26.

Table 3.26 - 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

Explanations to entries in the Table 3.26 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 -

Element Type	Element name & value
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 load flow application, 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. Frequency variation on filter admittance is not considered since the frequency deviation from the scheduled frequency is small.
- If a filter at bus say 8, consists of resistor, inductor and capacitor connected as shown in Figure 3.16, then the data appearing for the filter is as follows:

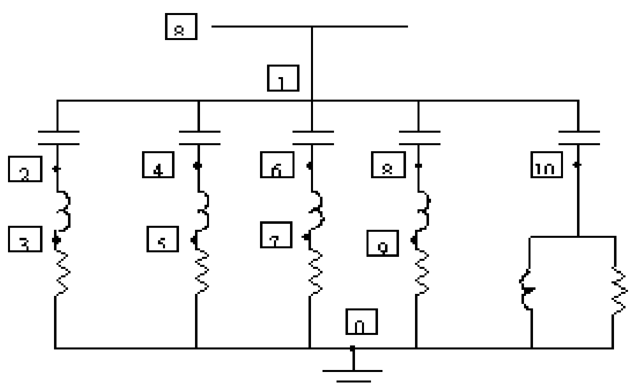


Figure 3.17: Example of a Filter Data

Table 3.27 - Filter Data				
Bus = 8		**Filter Branch Elements = 15**		
Branch	From node	To node	Branch element type	Active Value
1	1	2	3	000.417e-6
2	2	3	2	000.974
3	3	0	1	037.000
4	1	4	3	000.417e-6
5	4	5	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	452.00
Only values need to be entered				

Stream 25 : Tie-line Schedule Data

In this stream, schedules for tie line interchange are given. Total number of lines in this stream is equal to number of tie line schedules as given under system specification stream. Data appearing under different columns of each line is given in Table 3.28.

Table 3.28 - Tie Line Schedule Data				
Col No.	**Description**	**Type**	**Min**	**Max**
1.	Control zone (area) number	int	1	20
2.	Net tie-line schedule MW	float	-1.0e6	1.0e6
3.	Net tie-line interchange error tolerance in MW	float	0.1	100.0

Explanation to entries in the Table 3.28 is as follows -

- In an interconnected system, for load changes in the internal area, generators in that area should act to control the frequency and tie line interchange. Zone/area number is the number from which the net tie-line interchange to other areas is specified. This number should correspond to one of the zone number, as specified under bus data stream.
- Net tie-line schedule is the scheduled total real power exchange from the above area to all other areas. This schedule is given in MW. The schedule is positive if the above area is exporting power to other areas and it is negative, if the above area is importing power from other areas. If the net tie-line interchange deviates from the schedule, generators participating in the secondary control act to bring the net tie line interchange to the scheduled value.

- Error tolerance is used to terminate the iterative technique of controlling the tie -line interchange.

Stream 26 : HVDC Converter Data

In this stream of data, HVDC converter details are given. The schematic diagram of a 12 pulse converter station and its equivalent representation are given in figures 3.17 and 3.18 respectively. Total number of lines of data in this stream is equal to number of HVDC converters as given in specification stream. The data that appears in different columns of each line is given in Table 3.29.

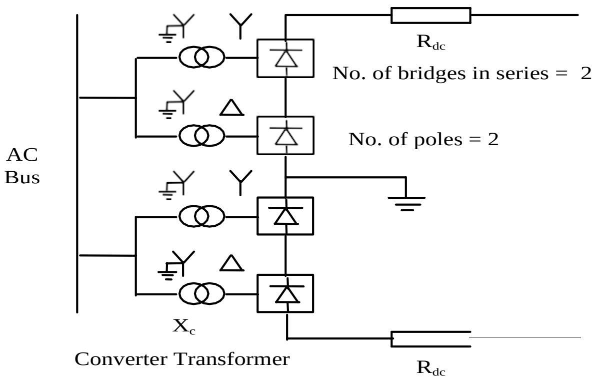


Figure 3.18: Schematic of 12 pulse bipolar converter station

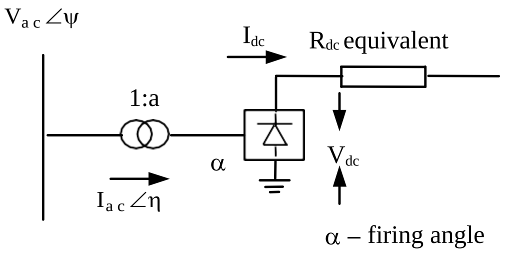


Figure 3.19: Equivalent Representation

Table 3.29 - HVDC Convertor Data				
Col No.	**Description**	**Type**	**Min**	**Max**
1.	Convertor number	int	1	20
2.	AC bus number	int	1	99999
3.	Converter transformer X in pu	float	1.0e-5	1.0e2
4.	Control Type	int	1	3
5.	Specified control value	float	0.5	1.5
6.	Control angle in degree	float	0.01	89.0
7.	Minimum convertor transformer tap	float	0.5	1.5
8.	Maximum convertor transformer tap	float	0.5	1.5
9.	Step for convertor transformer tap	float	0.0	0.1
10.	Number of bridges in series	int	1	10
11.	Number of poles	int	1	2
12.	Convertor transformer secondary kV	float	0.1	1.0e4
13.	Convertor transformer MVA rating	float	0.1	1.0e4

Explanations to entries given in Table 3.29 are as follows -

- Convertor number is the serial number of the convertor, which is also the dc bus number.
- AC bus number is the bus number to which the converter is connected. This number should exist in the "bus data stream".
- Converter transformer reactance is in pu on transformer MVA rating. Commutation resistance R_c is related to the transformer reactance X_c by the expression -

$$R_c = \frac{3X_c}{\pi}$$

- Control tag is interpreted as -

Option	Control tag
1	Constant voltage control
2	Constant current control
3	Constant power control.

In a two-terminal or multi-terminal convertor group, at least one convertor in the group should have control tag as 1.

- Specified control value depends on the type of convertor control. It is interpreted as -
  - Specified voltage in kV for voltage control
  - Specified current in Amperes for current control
  - Specified power in MW for power control.

Specified current and power are positive for convertor and negative for inverter.

If the system is bipolar ($\pm V_{dc}$), give specified voltage as $2*V_{dc}$.

If dc link resistance data (R_c) is provided on bipolar mode, give dc link resistance value as $R_c/2$.

- Control angle in degrees is the firing angle α for convertor and the extinction angle (η = 180.0 - α -μ) for the inverter. μ is the overlap angle. In steady state load flow for HVDC system, the control angle is held constant at the specified value and the transformer tap is determined for the scheduled voltage, current and power. Minimum firing angle ranges from 5 degrees to 7 degrees. Minimum extinction angle ranges from 15 degrees to 20 degrees.
- Transformer tap ranges are used to determine the transformer tap setting for the given firing angle and specified control. Convertor transformer tap positions have wide range of control compared to conventional power transform er tap settings. If the transformer tap hits the limit, then the scheduled voltage at the voltage controlled convertor is modified to keep the transformer tap position within the limits. The tap range is normally in between 0.9 and 1.1. If the specified transformer maximum tap is equal to the minimum tap, then control angle is computed for the given tap position and control type.

- In ac system, the base quantities are –

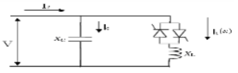
P_{ac} base = 3 phase power
V_{ac} base = line to line rms value

$$I_{ac} base = \frac{P_{ac} base}{\sqrt{3} V_{ac} base}$$

- In dc system, the base quantities are -

P_{dc} base = P_{ac} base

V_{dc} base = $K_b V_{ac}$ base.



$$I_{dc} base = \frac{3\sqrt{2}}{\pi} I_{ac} base$$

n_b number of series connected bridges in a HVDC terminal.

- The dc voltage and power at the convertor are given by **-**

$V_{dc} = a\, V_{ac}\, \cos\alpha - R_c\, I_{dc}$

$P_{dc} = V_{dc}\, I_{dc}$

where,
a: transformer tap setting
α : firing angle.
Neglecting the losses in the convertor and its transformer, the equation for power factor angle **(φ - η)** is given by

$$V_{dc} = a\, V_{ac} \cos(\varphi - \eta)$$

Expression for reactive power flowing from the AC bus into the convertor terminal is given by
$Q_{dc} = P_{dc} \tan(\varphi - \eta)$

Where, φ : AC voltage angle and η : AC current angle.

Stream 27 : DC Link Data

In this stream of data, DC link details are given. Total number of lines of data in this stream is equal to number of DC links as given in specification stream. The data that appears in different columns of each line is given in Table 3.30.

Table 3.30 - DC Link Data

Col No.	Description	Type	Min	Max
1.	From convertor number	int	1	20
2.	To convertor number	int	1	20
3.	DC link resistance in ohms	float	1.0e-5	1.0e2

Explanations to entries given in Table 3.30 are as follows –

- From converter number is the converter number to which one end of dc link is connected. This number should exist in the convertor data stream.
- To converter number is the convertor number to which the other end of dc link is connected. This number should exist in the convertor data stream.
- DC link resistance is in ohms for one pole. For bipolar operation, equivalent resistance is computed internally.

Stream 28 : SVC/STATCOM

SVC: The Static Var Compensator (SVC) is used to control the bus voltage. It controls the bus voltage profile by injecting or drawing reactive power from the system. The basic circuit of SVC is shown in figure 3.19. It contains a fixed capacitor and variable inductor connected in parallel. By varying the inductive reactance the current drawn or injected by the SVC is controlled.

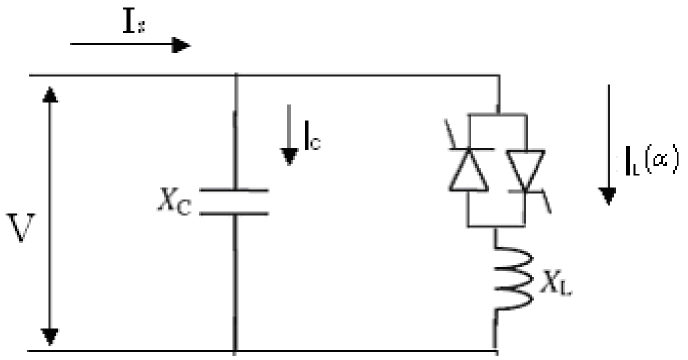


Figure 3.20 : SVC Equivalent Representation

STATCOM: The Static Compensator (STATCOM) is also used to control the bus voltage. The basic equivalent circuit of STATCOM is shown in figure 3.20. It contains a DC source connected to AC system through voltage source converter. The converter acts as an inverter or rectifier. STATCOM injects reactive power into connected bus when acting as an inverter and absorbs when acting as a rectifier.

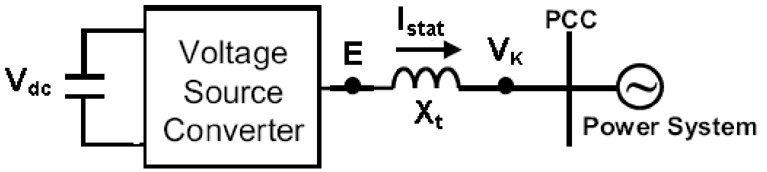


Figure 3.21 : STATCOM Equivalent Representation

Table 3.31 – SVC/STATCOM Data				
Col No.	**Description**	**Type**	**Min**	**Max**
1.	Bus Number	int	1	99999
2.	Shunt FACTS Device Type	int	1	2
3.	Reference Voltage (pu)	float	0.95	1.05
4.	Slope (pu)	float	0	0.2
5.	Inductive Maximum (MVar)	float	0	999
6.	Capacitive Maximum (MVar)	float	0	999
7.	Tolerance (pu)	float	1.0e-4	1.0

Explanations to entries given in Table 3.31 are as follows –

- Bus Number field is used to specify the bus number to which the shunt FACTS device is connected.
- Shunt FACTS device type is interpreted as -

Option	Device Type
1	SVC
2	STACOM

- Reference Voltage corresponds to the value of voltage in p.u. at which the bus voltage is to be maintained.
- The slope reactance of the SVC characteristic is normally selected to be more than system thevinen’s reactance.
- The maximum Inductive Mvar corresponds to the reactive power that can be drawn by SFD at its rated voltage.
- The maximum Capacitive Mvar corresponds to the reactive power that can be injected by SFD at its rated voltage.
- SFD tolerance is the voltage difference in PU of SFD bus compared to previous iteration.

Stream 29: Wind Turbine Curves Data

In this stream of data, wind turbine related curves details are given. For each curve, the data given are -

1. Curve number.
2. Curve type.
3. Number of curve points.
4. Real power in pu, corresponding minimum and maximum reactive powers in pu on its own rating for each data point.

Curve number is the generator capability curve number referred by the generator under "generator data stream". Minimum number of curve points required is two. Maximum number of curve points should not exceed ten. For a generator MVA rating 265, figure 3.8 shows a sample generator capability curve for minimum and maximum reactive power limits as shown in the Table 3.17.

In this stream, Wind Turbine related curves library is printed. Basically there are five types of curves. They are

1. Power curve represented in formula 1 format.
2. Power curve represented in formula 2 format.
3. Power curve represented in curve data format.
4. Operating mechanical power(p.u.) Vs operating rotor speed (p.u.)
5. Operating wind speed(m/s) Vs operating rotor speed(p.u.)

Curve type 1-3 will represent for power curve. Curve type 4 represent for operating mechanical power Vs operating rotor speed and curve type 5 for operating wind speed vs operating rotor speed. The format for the curve type 3-5 is same but for curve type 1 and 2 are different. Various streams present for each type of curve are listed in tables for each curve type separately.

Data streams for curve type 1 are given in Table 3.32.

Table 3.32 – Curve data for curve type 1

Col No.	Description	Type	Min	Max
1	C0	Double	-1.0e6	1.0e6
2	C1	Double	-1.0e6	1.0e6
3	C2	Double	-1.0e6	1.0e6
4	C3	Double	-1.0e6	1.0e6
5	C4	Double	-1.0e6	1.0e6
6	C5	Double	-1.0e6	1.0e6
7	a	Double	-1.0e6	1.0e6
8	b	Double	-1.0e6	1.0e6
9	c	Double	-1.0e6	1.0e6
10	d	Double	-1.0e6	1.0e6
11	a0	Double	-1.0e6	1.0e6
12	a1	Double	-1.0e6	1.0e6

The generalized formula for curve type 1 is as below:

$$C_p = C_0\left\{\frac{C_1}{\lambda_?} + C_2\lambda_? + C_3 ?^{?} + C_4 ?^{?} + C_5\right\} e^{\left(? \lambda_i + \frac{?}{\lambda_i}\right)}$$

$$\lambda_? = \frac{1}{\frac{1}{\quad} \qquad \frac{a_1}{\quad}}$$

Where C_p is the coefficient of power λ is tip speed ratio β is pitch angle

$\lambda + a_0$� − �$^{3} + 1$

All other coefficients in the equation are constant values and to be entered by the user.

Data streams for curve type 2 are given in Table 3.33.

Table 3.33 – Curve data for curve type 2				
Col No.	**Description**	**Type**	**Min**	**Max**
1	α_{00}	Double	-1.0e6	1.0e6
2	α_{01}	Double	-1.0e6	1.0e6
3	α_{02}	Double	-1.0e6	1.0e6
4	α_{03}	Double	-1.0e6	1.0e6
5	α_{04}	Double	-1.0e6	1.0e6
6	α_{10}	Double	-1.0e6	1.0e6
7	α_{11}	Double	-1.0e6	1.0e6
8	α_{12}	Double	-1.0e6	1.0e6
9	α_{13}	Double	-1.0e6	1.0e6
10	α_{14}	Double	-1.0e6	1.0e6
11	α_{20}	Double	-1.0e6	1.0e6
12	α_{21}	Double	-1.0e6	1.0e6
13	α_{22}	Double	-1.0e6	1.0e6
14	α_{23}	Double	-1.0e6	1.0e6
15	α_{24}	Double	-1.0e6	1.0e6
16	α_{30}	Double	-1.0e6	1.0e6
17	α_{31}	Double	-1.0e6	1.0e6
18	α_{32}	Double	-1.0e6	1.0e6
19	α_{33}	Double	-1.0e6	1.0e6
20	α_{34}	Double	-1.0e6	1.0e6
21	α_{40}	Double	-1.0e6	1.0e6
22	α_{41}	Double	-1.0e6	1.0e6
23	α_{42}	Double	-1.0e6	1.0e6
24	α_{43}	Double	-1.0e6	1.0e6
25	α_{44}	Double	-1.0e6	1.0e6

The generalized formula for curve type 2 is as below:

$$P = \sum_{i=0}^{4}\sum_{j=0}^{4}(\alpha_{ij}\beta^{i}\lambda^{j})$$

Where P_w is mechanical power generation

αij coefficients for i = 0 to 4 and j = 0 to 4 need to be given in the input data

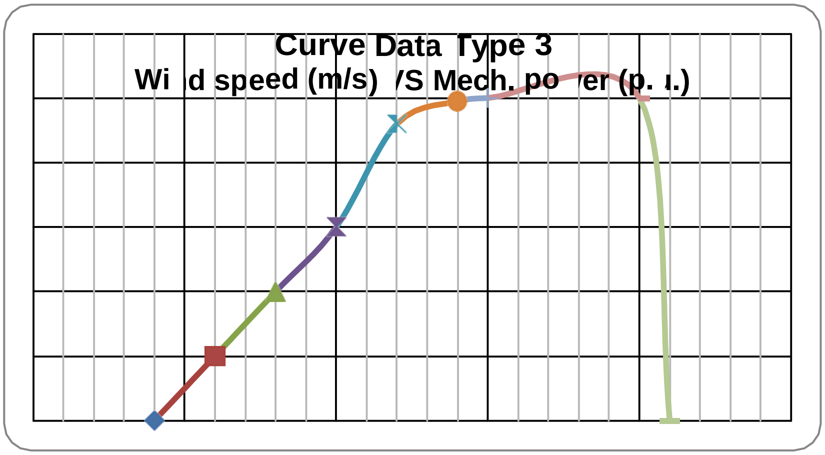
β is the pitch angle

λ is the tip speed ratio

Sample Data streams for curve type 3 are given in Table 3.34.

Table 3.34 – Curve data for curve type 3		
Col No.	**Wind Speed (m/s)**	**Mechanical Power Generation (p.u.)**
1	4	0
2	6	0.2
3	8	0.4
4	10	0.6
5	12	0.92
6	14	0.99
7	15	1.0
8	20	1.0
9	21	0.0

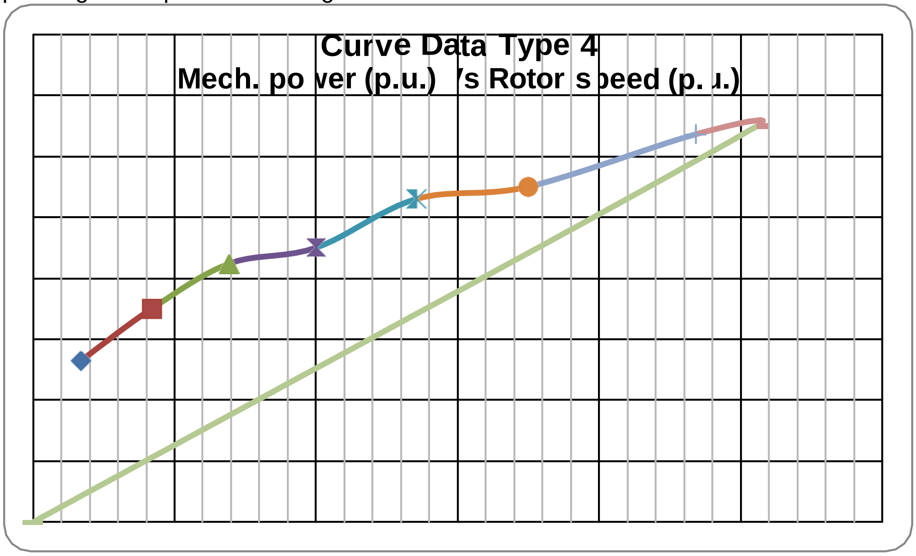
The maximum allowed number of points is 20. A typical power curve diagram is shown below.



Sample Data streams for curve type 4 are given in Table 3.35.

Table 3.35 – Curve data for curve type 4		
Col No.	**Operating Mechanical Power Generation (p.u.)**	**Operating Rotor Speed (p.u.)**
1	0.0678	0.53
2	0.1678	0.7
3	0.2775	0.848
4	0.4	0.9
5	0.5421	1.06
6	0.7	1.1
7	0.9367	1.272
8	1.0238	1.3

The maximum allowed number of points is 20. A typical operating mechanical power generation Vs Operating rotor speed curve diagram is shown below.

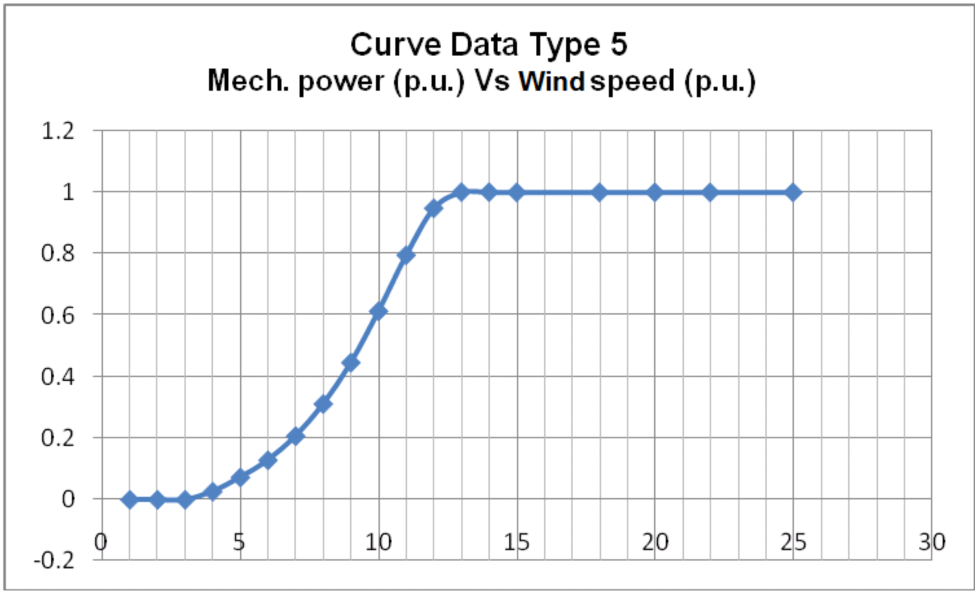


Sample Data streams for curve type 5 are given in Table 3.36.

Table 3.36 – Curve data for curve type 5

Col No.	Operating Wind Speed (m/s)	Mechanical Power Generation (p.u.)
1	1	0
2	2	0
3	3	0
4	4	0.026403
5	5	0.072607
6	6	0.128383
7	7	0.206931
8	8	0.311551
9	9	0.445875
10	10	0.613201
11	11	0.79538
12	12	0.948185
13	13	1.00066
14	14	1.00066
15	15	1
16	18	1
17	20	1
18	22	1
19	25	1

The maximum allowed number of points is 20. A typical operating mechanical power generation Vs Operating wind speed curve diagram is shown below.



Stream 30 : Contingency Specification

In control Option, if the load flow option is 4 (Contingency Analysis), then these data has to be given in the data file. This consists of a single line of data. 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. Table 3.37 gives the data appearing under different columns of a line.

Table 3.37 : Contingency Specification

Col No.	Description	Type	Min	Max
1.	Number of weightage specified buses	int	1	2000
2.	Number of weightage specified lines	int	1	10000
3.	Number of contingency cases	int	1	100

Explanations for the entries in Table 3.37 are -

- Number of weightage specified buses are the total number of buses at which the user has provided a weightage factor for bus voltage deviation from its specified voltage magnitude. For the other buses unity weightage is considered.

- Number of weightage specified lines are the total number of series elements for which weightage factor is given. For other series elements unity weightage is considered.
- Number of contingency cases is the total number of contingencies considered for the analysis. For examples outage of series elements.

Stream 31 : Bus Weightages

This consists of a single line of data, which specifies the weightage provided for the bus voltage deviation. Data types/specifications are separated by blanks. Total number of lines in this stream is equal to number of weightage specified buses as given under contingency specification stream. Table 3.38 gives the data appearing under different columns of a line.

Table 3.38: Bus Weightage Details

Col No.	Description	Type	Min	Max
1.	Bus number	int	1	99999
2.	Weightage factor	float	0.0	1000.0

The voltage performance index **PIV** is computed as -

$$PIV = \sum_{i=1}^{nb} W_i \left[\frac{|V_i|_{new} - |V_i|_{spec}}{\Delta V_{imax}} \right]^2$$

Where,

n_b : Number of buses
Wi : Weightage factor for bus ***i***
|V i| new : Post outage voltage magnitude at bus ***i***
|V i| spec : Specified voltage magnitude at bus ***i*** (1.0 pu)
Vi max : Maximum allowable voltage change, which is computed as the difference between maximum voltage and specified voltage, if the voltage magnitude is greater than the specified voltage and difference between minimum voltage and specified voltage, if the voltage magnitude is less than the specified voltage. The significance of the weightage is to give lower ranking (higher severity) for poor voltage at specific buses.

Stream 32: Line Weightages

This consists of a single line of data, which specifies the weightage provided for the series elements. Data types/specifications are separated by blanks. Total number of lines under this stream is equal to number of weightage specified data lines as given in the specification stream. Table 3.39 gives the data appearing under different columns of a line.

Table 3.39: Line Weightage Details

Col No.	Description	Type	Min	Max
1.	Line number	int	1	10000
2.	Weightage factor	float	0.0	1000.0

Explanations for the entries in Table 3.39 are -

- The serial number of the line in the input data for the series elements for which weightage factor is given. The serial number is counted beginning from the two winding transformer and ending at series reactor/capacitor.
- The overload performance index is evaluated as -

$$PIP = W \sum_{i=1}^{nl} {}_i \left[\frac{P_{inew}}{P^{i}_{limit}} \right]^2$$

where,
n_l : Total number of series equipments
W_i: Weightage factor for series element ***i***
P_{inew} : New real power flow in the line
P_{ilimit} : Real power flow limit of the line.
The contingency can be ranked depending on the importance of a line. If it is desired not to overload a particular line, then that line weightage is assigned a high value.

Stream 33 : Contingency Element Details

This stream consists of equipments to be considered for outage. Data types/specifications are separated by blanks. Total number of lines under this stream is equal to number of contingency as given in the contingency specification stream. The data appearing in different columns of a line are given in Table 3.40.

Table 3.40: Contingency element details

Col No.	Description	Type	Min	Max
1.	Line number	int	1	10000
2.	Element type	int	1	4
3.	Contingency Number	int	1	1000

Explanations for the entries in the Table 3.40 are -

- Line number is number at which the contingency is created by he removal of contingency elements.
  - ♦ For series elements, it is the series element number at which the contingency is created.
  - ♦ For shunt reactor/capacitor, it is the shunt element number at which contingency is created.
  - ♦ For generators, it is the serial number of the generator selected for contingency.
  - ♦ For load, it is the serial number of the load at which contingency is created.
- Element type is the type of the element at which contingency is created. Element type can be interpreted as -

  1: Series elements
  2: Shunt reactor/capacitor
  3: Generator
  4: Load

- Contingency number indicates the order of contingency cases. Unique contingency number for different contingency elements indicates different contingency cases. Specifying same contingency number for more than one contingency element can perform multiple contingency analysis.

Stream 34: Acceleration Factor

In this stream, acceleration factor for Gauss-Seidel method of load flow is read. The value should be given, if the load flow option in Table 3.2 is 5. Typical value is 1.6.

Stream 35: Slack Bus Angle

Slack bus angle is considered as 0.0

Stream 36: Feed Current Element Details

This stream consists of lines to be considered as feed. Data types/specifications are separated by blanks. Total number of lines under this stream is equal to number of feeds as given in the feed current specification stream. The data appearing in different columns of a line are given in Table 3.41.

Table 3.41: Feed current element details				
Col No.	**Description**	**Type**	**Min**	**Max**
1.	Line number	int	1	10000
2.	Feed type	int	1	2
3.	Source current (or) real power	float	0.1	10000
4.	Source power factor (or) reactive power	float	0.1	10000

Explanations for the entries in the Table 3.41 are -

- Line number is number at which the source is created by the injection of current or power.
- Feed type is the type of the injection created. Feed type can be interpreted as -
    1. Power
    2. Current

- Source current / real power is the current/ power that is getting injected at that particular feed.
- Source power factor/ reactive power are the power factor of the current that is getting injected or the amount of reactive power that is getting injected.

Stream 37: Sub Station wise Details

In this method substation wise load flow analysis can be carried out. The required entries for carrying out substation wise power flow are given in Table 3.42.

Table 3.42: Sub Station wise power flow details				
Col No.	**Description**	**Type**	**Min**	**Max**
1.	Number of sub stations selected	int	1	10000
2.	Substation (bus) numbers	int	1	10000

Explanations for the entries in the Table 3.42 are -

- First entry consists of number of substations (buses) selected. Data types/specifications are separated by blanks.

- In second entry, the total number of lines under this is equal to the number of sub stations selected.

Stream 38: Available Transfer Capability Details

In the recent bid to open up access to electric power transmission networks in order to foster generation competition and customer choice, the Available Transfer Capability (ATC) information be made available on a publicly accessible Load dispatch centre web pages.

ATC is defined as a measure of the transfer capability, or available room in the physical transmission network, for transfers of power for further commercial activity, over and above already committed uses. According to the NERC definition, ATC is determined as a function of increases in power transfers between different systems through prescribed interfaces. As the transfers increase, the flows in transmission lines increase. The Total Transfer Capability (TTC) is the largest flow in the selected interface for which there are no thermal overloads, voltage limit violations, voltage collapse and/or any other system security problems such as transient stability. The TTC minus the base case flow and appropriate transmission margin is the ATC for the selected interface. The need for transmission margin and the definition of its components: transmission reliability margin (TRM) and capacity benefit margin (CBM) is well documented in the literature.

In this stream various factors read by the **POWERLFA** for the computation of ATC are given. In Table 3.43 data appearing under different columns are described.

Table 3.43: ATC details

Col No.	Description	Type	Min	Max
1.	Type	int	0	1
2.	Source	int	1	10000
3.	Sink	int	1	10000
4.	Capacity Benefit Margin (CBM)	int	0	1
5.	Load type	int	0	1
6.	Print option	int	0	1
7.	No. of contingencies	int	-1	10000
8.	Contingency elements	int	1	10000
9.	Generation increment option	int	1	2
10.	Loads incremented	int	1	2
11.	Loads increment option	int	0	1
12.	No. of loads incremented	int	1	10000
13.	Load bus numbers	int	1	10000
14.	Load increased percentage	float	0.1	1000

- Type field specifies whether ATC is to be calculated between two Areas (0) or two Buses (1).
- Source field gives the source bus/Area number.

- Sink field gives the sink bus/Area number.
- Capacity Benefit Margin field is used to specify whether CBM is to be considered or not while calculating ATC between two areas. It has no significance when ATC is calculated between two buses.
- CBM is interpreted as -

Option	Description
0	CBM is not to be computed
1	CBM is be computed

- Load type field specifies whether load increment in sink is either constant power factor type (Option is 0) or constant reactive power type (Option is 1).
- Print Option field is used to specify whether detailed report (Option is 1) or customized report (Option is 0) is to be printed in output report file.
- No. of Contingencies field is used to specify how many contingencies are considered while calculating ATC.
- No. of Contingencies is interpreted as -

Option	Description
-1	All elements contingency is considered
0	No contingency is considered
+ve number >1	specified number of contingencies is considered

- Contingency elements stream gives the contingencies that to be considered while calculating ATC. Total number of lines under this stream is equal to the number of contingencies that are selected.
- Increment type field is used to specify whether increase in generation is to be equal at all generators in source area (Option is 1) or depends on their ratings and loading conditions (Option is 2).
- Load increment percentage field specifies whether loads in the sink area are incremented at equal percentage or unequal percentage.
- Load increment percentage is interpreted as -

Option	Description
1	Loads are incremented by equal percentage
2	Loads are incremented at unequal percentage.

- Load Increment option field specifies whether all loads in sink area are incremented or only selected loads are incremented.
- Load increment option is interpreted as -

Option	Description
0	Loads at all buses in sink area are incremented
1	Loads at specified buses in sink area are incremented

- No. of Loads Incremented field is filled based on the following condition-
    - If load increment percentage option is 2 or load increment percentage option is 1 and load increment option is 1, this field gives the number of loads selected for increment.
- Load bus numbers field is filled based on the following condition-
    - This stream consists of the selected bus numbers for loads to be incremented if load increment percentage option is 2 or load increment percentage option is 1 and load increment option is 1.
- Load increased Percentage field is filled based on the following condition-
    - This stream gives the percentage of load that need to be incremented at the specified bus numbers in the load bus numbers if load increment percentage option is 2.

4. INPUT/OUTPUT FILES

Table 4.1 gives extensions of different input and output files of **POWERLFA** by default. About input file name it has been explained in Chapter 3.

Table 4.1 - Input and Output Files of POWERLFA

Sl. No.	File Extension	Mode	Description
1.	**.dat*X***	input	Program input file
2.	**.out*X***	output	Program output (general report) file
3.	.**plt*X***	output	Plot file compatible to graphic utility
4.	**.etc*X***	output	File which completely describes the operating state of the system, which can be used by other programs.
5.	**.barX**	output	File for zone wise generation and load display, compatible to graphic utility
6	**.ACD & .NT0**	Output	This file has the information regarding the line flows, Bus Voltages etc. This is used to get the load flow results on the network with “ZZ” code.

".datX" file contains - The user defined input data.

".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.
- Y_{bus} element values for the system, if the report option is 4.
- Number of islands in the system, and the slack bus considered at each island.
- Iteration number, maximum real and reactive powers mismatches and the corresponding bus numbers at the end of each iteration.
- New transformer tap settings.
- Reactive power allocation at the buses.
- Generation schedules.
- Voltage magnitude and angle at the end of each iteration, if the report option is 4.
- Bus details from the study, which includes voltage magnitude, voltage angle, generation and load.
- Line flow details from the study, which includes real power flow and loss.
- Shunt injections at buses.
- HVDC convertor power and tap details.
- DC link power flow and losses.
- Flows due to FACTS devices.
- System frequency at each island and total tie line power interchange error.
- Summary of generation, load and losses in the system.
- Area wise generation, load and losses.
- Import/Export from one area to another area.
- Available Transfer Capability flows.

"**.pltX**" file contains -

- **For Buses :** Bus number, bus voltage magnitude in pu and bus voltage angle in degrees
(3 fields) all separated by blanks.
- **For Series Elements:** Series element number, forward real and reactive power flow, reverse real and reactive power flow, percentage loading on the line and transformer tap setting (7 fields) all separated by blanks. Flow convention is positive for the flow away from the bus and negative for flow in to the bus.
- **For Shunt Reactors and Capacitors:** Bus number, real power injection, reactive power injection, a dummy value (4 fields) all separated by blanks. Flow Convention is negative for power injected to the bus and vice versa.
- **For Generators:** Generator bus number, real power generation, reactive power generation, a dummy value (4 fields) all separated by blanks. Flow Convention is negative for power injected to the bus and vice versa.
- **For Loads:** Load bus number, real power load, reactive power load, Mvar compensation (4 fields) all separated by blanks. Positive convention is used for power flowing away from the bus.

- **For HVDC Converters:** Converter AC bus number, DC voltage, real power, reactive power, transformer tap (5 fields) all separated by blanks.
- **For DC Links:** DC link number, current in pu and POWER in MW from the sending end to the receiving end.
- Flows due to FACTS devices.

"**.etcX**" file contains

* 3 lines of system description as given in " **.datX** " file.
* System specification fields as given in " **.datX** " file.
* Total number of islands in the system and number of valid islands, i.e., islands having at least one generator bus (2 fields) separated by blanks.
* For valid islands : Slack bus number for the island and frequency for the island.
* For each bus : bus number, island number, voltage magnitude in pu., voltage angle in degree., real power generation in MW (+ve for injection in to the bus), reactive power generation in Mvar, real power load in MW, reactive power load in Mvar, compensation in MVAR(fixed) i.e., 9 fields all separated by blanks.
* For transformers : Transformer serial number, from bus number, to bus number and transformer tap (4 fields) all separated by blanks.
* For convertors : Convertor serial number, convertor ac bus number, dc voltage, real power in MW, reactive power in Mvar, control angle in degrees and transformer tap setting (7 fields) all separated by blanks.
* For each series element : Impedance seen by the relay at from node and to node in (**R+jX**) format in pu. i.e., **V/I** in per unit where in **V** is the complex node voltage in pu and **I** is the complex current in the series element, flowing away from the node.
* Flows due to FACTS devices.

Error Messages

If any error is traced by the program while execution, 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.

[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 is 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 reason 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 the user has not provided data and end of file is reached, then the error message is written in the report file.

Error [3]: Too Less Parameters to Read: Insufficient data provided for Stream No (-) 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 is written in the report file.

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 execution and analysis of results of **POWERLFA**. The single line diagram of the sample network considered is given in figure 5.1. Tables 5.1 gives "**.datX"** the input data file and Table 5.2 gives "**.outX"** the output results file respectively. To view the load flow 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 display code, select plot - load flow results in the menu. This will pop up a window where user has to give the *.nt0 file generated by the same load flow case. Then the pu or kV voltage can be plotted with different flow options. The result looks as shown in figure 5.2

Table 5.1: Input File- "1Glove0l.dat0"

```
LOAD FLOW ANALYSIS
CASE NO :  1     CONTINGENCY  : 0  SCHEDULE NO : 0
CONTINGENCY  NAME :  BaseCase         RATING  CONSIDERED :  NOMINAL
VERSION   8.1
%% First Power System Network
% System Specifications

% 1.MaxBusID      2.TotalBuses     3.Total2Wdg        4.Total3Wdg        5.TotalLines
% 6.TotalSeReac   7.TotalSeCap     8.TotalBusCoupler  9.TotalShRea      10.TotalShCap
%11.TotalMotor       12.TotalGen+WindGen    13.TotalLoad       14.TotalLdChar
        15.TotalFreqRelay
%16.TotalGenCap    17.TotalFilter   18.TotalTieLines     19.TotalHVDC
        20.TotalDCLinks
%21 TotalSFD 22: FeedCurrent 23. Total TCSC 24. Total SPS 25. Total  UPFC
%26.TotalDetailedWndGen   27.No.ofWTCurves  28.No.ofDetailedCurves

  11    11     4     0     8     0     0     0     0     2     0
   4     2     0     0     0     0     0     2     1    1  0

    0    0    0    0    0    0
%Common Control Options

% 1.LFAOption                      (0-Only Slack Bus Concept          <FDLF>)
%                                  (1- Reactive Power Optimization    <FDLF>)
%                                  (2-Real Power Optimization                 <FDLF>)
%                                  (3-Real and Reactive  Power Optimization    <FDLF>)
%                                  (4-Contingency Analysis                    <FDLF>)
%                                  (5-Only Slack Bus Concept          <Gauss-Siedel  Method>)
%                                  (6-Only Slack Bus Concept          <NR Method>)
%                                  (66-DC Power  Flow)
%                                  (700-Substation wise  Load Flow    <FDLF>)
%                                  (705-Substation wise  Load Flow    <Gauss-Siedel  Method>)
%                                  (706-Substation wise  Load Flow    <NR Method>)

% 2.Number Of Zones 3.Print Option(0/1-Only Data/2-Only Output/3-Detailed/4-Impedance/5-
BusWise Flow)
% 4.Plot Option (0/1)     5.Frequency Dependent LFA  (0/1-FTC/2-FFC/3-Bias)
% 6.Base MVA                       7.Nominal Frequency         8.Frequency Deviation
%16.Flow Type Option (0/1/2/3/4)    17.Slack Bus ID (0-Program  search/Specific)
%18.Tap Change Option (0/1)  19.ATC(0/1)

   0    1  3  1  0      900.000000  60.00  0.00  0     0    0     0
% 1.Q-Checking Limit  (iteration no)        2.P-Tolerance     3.Q-Tolerance
% 4.Maximum Iterations    5.Load Model Voltage (pu) 6.CB Resistance  7.CB  Reactance
% 8.Transformer R/X ratio
    4  1.00000e-003  1.00000e-003  100  0.750  0.00000e+000 1.00000e-004   0.050


%Cost Factors
% 1. Interest Charges  2.  Operational Charges   3. Life of Equipment  (yrs)
% 4. Energy Charges       5. Loss Load Factor        6. Cost per Mvar(in Lakhs)  7. Currency
15.00000   4.00000  20.00000   2.50000   0.30000   5.00000 Rs
```

```
%Zonal Multiplication Factors
% 1.Zone  Numbers   2.PLoad    3.QLoad     4.PGen       5.QGen          6.ShRea       7.ShCap
                            8 Compensation
   0   1.0000   1.0000   1.0000   1.0000   1.0000   1.0000  1.0000
   1   1.0000   1.0000   1.0000   1.0000   1.0000   1.0000  1.0000



%Bus Data
%Bus ID  AreaNo ZoneNo     BasekV   MinVolt(pu)      MaxVolt(pu)      BusName

1     1     1   20.000  0.950  1.050       Bus1
2     1     1   20.000  0.950  1.050       Bus2
3     1     1   20.000  0.950  1.050       Bus3
4     1     1   20.000  0.950  1.050       Bus4
5     1     1  230.000  0.950  1.050       Bus5
6     1     1  230.000  0.950  1.050       Bus6
7     1     1  230.000  0.950  1.050       Bus7
8     1     1  230.000  0.950  1.050       Bus8
9     1     1  230.000  0.950  1.050       Bus9
10    1     1  230.000  0.950  1.050      Bus10
11    1     1  230.000  0.950  1.050      Bus11



%Two Winding Transformers
%Status  NoOfUnits        FromBus   ToBus            R     X     NominalTap       MVA
%Control MinTap           MaxTap    TapStep PhaseShift
3   1     5     1  1.50015e-005  1.50000e-001   1.00000  900.000000
                3   0.85000   1.05000   0.01250      0.00
3   1     6     2  1.50015e-005  1.50000e-001   1.00000  900.000000
               11   0.85000   1.05000   0.01250      0.00
3   1    11     3  1.50015e-005  1.50000e-001   1.00000  900.000000
                2   0.85000   1.05000   0.01250      0.00
3   1    10     4  1.50015e-005  1.50000e-001   1.00000  900.000000
                3   0.85000   1.05000   0.01250      0.00



%Transmission Line
%Status  NoOfCkts FromBus   ToBus            R     X     B/2     MVA   kMs
3   1      5     6  2.25000e-002  2.25000e-001  2.430000e-003 900.0000   2.50e+001
3   1      6     7  9.00000e-003  9.00000e-002  9.720000e-004 900.0000   1.00e+001
3   1      7     8  9.90000e-002  9.90000e-001  1.069000e-002 900.0000   1.10e+002
3   1      7     8  9.90000e-002  9.90000e-001  1.069000e-002 900.0000   1.10e+002
3   1      8     9  9.90000e-002  9.90000e-001  1.069000e-002 900.0000   1.10e+002
3   1      8     9  9.90000e-002  9.90000e-001  1.069000e-002 900.0000   1.10e+002
3   1      9    10  9.00000e-003  9.00000e-002  9.720000e-004 900.0000   1.00e+001
3   1     10    11  2.25000e-002  2.25000e-001  2.430000e-003 900.0000   2.50e+001



%Shunt Capacitor
%Bus/LineNo      G           B    Status           Location(0-Bus/1-Line/2-Line)
   7  0.00000e+000  3.60000e-001  3   0
   9  0.00000e+000  5.27000e-001  3   0
```

```
%Generator Data
%Bus     SchMW    MinMvar  MaxMvar          SpecVoltage(pu)   CapCurveNo        MVA      Status
Type
   1   700.000  -185.000   185.000   1.03000     0   900.000 3   1
   2   700.000  -235.000   235.000   1.01000     0   900.000 3   1
   3   719.000     0.000   176.000   1.03000     0   900.000 3   1
   4   700.000  -202.000   202.000   1.01000     0   900.000 3   1

% LOAD DATA
%FromBus  LoadMW  LoadMvar CompMVAR  MinCompMVAR  MaxCompMVAR  CompStep
%                  LoadCharRefNo FreqRelayId Status   VoltRelayId

   7   9.670000e+002 1.000000e+002 0.000000e+000   0.000000e+000 0.000000e+000  0.000000e+000
0    0  3     0
   9   1.767000e+003 1.000000e+002 0.000000e+000   0.000000e+000 0.000000e+000  0.000000e+000
0    0  3     0


%GENERATOR FREQUENCY  CHARACTERISTICS
%FromBus Rating MinRat  MaxRat  %Droop  PartFactor   BiasSet
%                                   C0       C1       C2
   1    700.000      0.000    700.000    4.00  0.0000     0.000
                           0.0000e+000   0.0000e+000   0.0000e+000
   2    700.000      0.000    700.000    4.00  0.0000     0.000
                           0.0000e+000   0.0000e+000   0.0000e+000
   3    719.000      0.000    719.000    4.00  0.0000     0.000
                           0.0000e+000   0.0000e+000   0.0000e+000
   4    700.000      0.000    700.000    4.00  0.0000     0.000
                           0.0000e+000   0.0000e+000   0.0000e+000
%CONVERTER DATA
%CONV   AC   XC  CTRL  CTRL  CTRL
%BUSNo. NUM  PU  TYPE  VALUE  ANGLE

%  TAP    TAP   TAP  Nb   Np           Tfr   Tfr
%  MIN.   MAX   STEP     (mono/bipole)   kV    MVA

   1     7   0.18000  3  200.000    0.00
0.9565  1.1304  0.0092  1  1    56.0000   235.0000
   2     9   0.18000  1  56.000    0.00
0.8478  1.1304  0.0149  1  1    56.0000   235.0000

%DC LINK DATA
%From    To      R-DC
%ConvNo  ConvNo  Ohms

   1      2   1.500000
%  Shunt Fact Device Data
% 1. Bus No 2. Fact Device Type 3. Voltage Reference 4. Slope 5 Inductive Max 6 Capacitive
Max 7 Tolerance
8 1 1.000000 0.100000 21859.50 21859.50 0.001000  0


%Slack Bus Angle
 0.00
```

Table 5.2: Output File "1Glove0l.out0"

```
-------------------------------------------------------------------------------
Date and Time : Thu Dec 19 14:56:23  2013
--------------------------------------------------------------------------
        ----- LOAD FLOW ANALYSIS
CASE NO :  1     CONTINGENCY  : 0  SCHEDULE NO :  0
CONTINGENCY NAME : BaseCase        RATING CONSIDERED :  NOMINAL

--------------------------------------------------------------------------
----- VERSION NUMBER :  8.1
%% First Power System Network
LARGEST BUS NUMBER USED        :   11    ACTUAL NUMBER OF BUSES         :   11
NUMBER OF 2 WIND. TRANSFORMERS :    4    NUMBER OF 3 WIND. TRANSFORMERS :    0
NUMBER OF TRANSMISSION LINES   :    8    NUMBER OF SERIES REACTORS      :    0
NUMBER OF SERIES CAPACITORS    :    0    NUMBER OF CIRCUIT BREAKERS     :    0
NUMBER OF SHUNT REACTORS       :    0    NUMBER OF SHUNT CAPACITORS     :    2
NUMBER OF SHUNT IMPEDANCES     :    0    NUMBER OF GENERATORS           :    4
NUMBER OF LOADS                :    2    NUMBER OF LOAD CHARACTERISTICS :    0
NUMBER OF UNDER FREQUENCY  RELAY:   0    NUMBER OF GEN CAPABILITY CURVES:    0
NUMBER OF FILTERS              :    0    NUMBER OF TIE LINE SCHEDULES   :    0
NUMBER OF CONVERTORS           :    2    NUMBER OF DC LINKS             :    1
NUMBER OF SHUNT CONNECTED FACTS:    1    POWER FORCED LINES             :    0

NUMBER OF TCSC CONNECTED       :    0
NUMBER OF SPS CONNECTED        :    0
NUMBER OF UPFC CONNECTED       :    0

NUMBER OF WIND GENERATORS      :    0    NUMBER OF WTG CURVES           :    0
NUMBER OF WTG DETAILED CURVES  :    0

--------------------------------------------------------------------------
----- LOAD FLOW - FAST  DE-COUPLED TECHNIQUE     :    0
NUMBER OF ZONES                                  :    1
PRINT OPTION                                     :    3 - BOTH DATA AND RESULTS  PRINT
PLOT OPTION                                      :    1 - PLOTTING WITH  PU
VOLTAGE NO FREQUENCY DEPENDENT LOAD FLOW,  CONTROL OPTION: 0
BASE MVA                                         : 900.000000
NOMINAL SYSTEM  FREQUENCY (Hz)                  : 60.000000
FREQUENCY DEVIATION (Hz)                        : 0.000000
FLOWS IN MW AND  MVAR, OPTION                    : 0
SLACK BUS                                        :    0 (MAX GENERATION BUS)
TRANSFORMER TAP CONTROL OPTION                   :    0
Q CHECKING LIMIT  (ENABLED)                      :    4
REAL POWER TOLERANCE (PU)                        :  0.00100
REACTIVE POWER TOLERANCE (PU)                    :  0.00100
MAXIMUM NUMBER  OF ITERATIONS                    :  100
BUS VOLTAGE BELOW WHICH LOAD MODEL  IS CHANGED   :  0.75000
CIRCUIT BREAKER RESISTANCE   (PU)                :  0.00000
CIRCUIT BREAKER REACTANCE    (PU)                :  0.00010
TRANSFORMER R/X RATIO                            :  0.05000
------------------------------------------------------------------------------
ANNUAL PERCENTAGE  INTEREST CHARGES              :  15.000
ANNUAL PERCENT OPERATION & MAINTENANCE CHARGES   :   4.000
LIFE OF EQUIPMENT  IN YEARS                      :  20.000
ENERGY UNIT  CHARGE (KWHOUR)                     :   2.500 Rs
LOSS LOAD FACTOR                                 :   0.300
```

COST PER MVAR IN LAKHS : 5.000 Rs

ZONE WISE MULTIPLICATION FACTORS

ZONE	P LOAD	Q LOAD	P GEN	Q GEN	SH REACT	SH CAP	C LOAD
0	1.000	1.000	1.000	1.000	1.000	1.000	1.000
1	1.000	1.000	1.000	1.000	1.000	1.000	1.000

BUS DATA

BUS NO.	AREA	ZONE	BUS KV	VMIN-PU	VMAX-PU	NAME
1	1	1	20.000	0.950	1.050	Bus1
2	1	1	20.000	0.950	1.050	Bus2
3	1	1	20.000	0.950	1.050	Bus3
4	1	1	20.000	0.950	1.050	Bus4
5	1	1	230.000	0.950	1.050	Bus5
6	1	1	230.000	0.950	1.050	Bus6
7	1	1	230.000	0.950	1.050	Bus7
8	1	1	230.000	0.950	1.050	Bus8
9	1	1	230.000	0.950	1.050	Bus9
10	1	1	230.000	0.950	1.050	Bus10
11	1	1	230.000	0.950	1.050	Bus11

TRANSFORMER DATA

STATUS	CKT	FROM NODE	FROM NAME*	TO NODE	TO NAME*	IMPEDANCE R(P.U)	IMPEDANCE X(P.U.)	NOMINAL TAP	RATING MVA
	CTR					MINTAP	MAXTAP	TAPSTEP	SHIFT-DE
3	1	5	Bus5	1	Bus1	0.00002	0.15000	1.00000	900.00
	3					0.85000	1.05000	0.01250	0.000
3	1	6	Bus6	2	Bus2	0.00002	0.15000	1.00000	900.00
	11					0.85000	1.05000	0.01250	0.000
3	1	11	Bus11	3	Bus3	0.00002	0.15000	1.00000	900.00
	2					0.85000	1.05000	0.01250	0.000
3	1	10	Bus10	4	Bus4	0.00002	0.15000	1.00000	900.00
	3					0.85000	1.05000	0.01250	0.000

TRANSMISSION LINE DATA

STA	CKT	FROM NODE	FROM NAME*	TO NODE	TO NAME*	LINE PARAMETER R(P.U)	LINE PARAMETER X(P.U.)	LINE PARAMETER B/2(P.U.)	RATING MVA	KMS
3	1	5	Bus5	6	Bus6	0.02250	0.22500	0.00243	900	25.0
3	1	6	Bus6	7	Bus7	0.00900	0.09000	0.00097	900	10.0
3	1	7	Bus7	8	Bus8	0.09900	0.99000	0.01069	900	110.0
3	1	7	Bus7	8	Bus8	0.09900	0.99000	0.01069	900	110.0
3	1	8	Bus8	9	Bus9	0.09900	0.99000	0.01069	900	110.0
3	1	8	Bus8	9	Bus9	0.09900	0.99000	0.01069	900	110.0
3	1	9	Bus9	10	Bus10	0.00900	0.09000	0.00097	900	10.0
3	1	10	Bus10	11	Bus11	0.02250	0.22500	0.00243	900	25.0

TOTAL LINE CHARGING SUSCEPTANCE : 0.09913

TOTAL LINE CHARGING MVAR AT 1 PU VOLTAGE : 89.215

```
SHUNT CONNECTION (ADMITTANCE)  DATA

MVAR* : +ve => Capacitive and -ve =>  Inductive
FROM      FROM        ADMITTANCE  IN P.U    MVAR*  STATUS  LOCATION
NODE/LINE NAME*       G(P.U)    B(P.U.)            0/3    0/1/2
--------- --------  --------- --------- -------- ------ --------
        7     Bus7    0.00000   0.36000  324.000      3        0
        9     Bus9    0.00000   0.52700  474.300      3        0
-------------------------------------------------------------------------------
TOTAL CAPACITIVE SUSCEPTANCE          :    0.88700 pu -  798.300  MVAR
TOTAL INDUCTIVE SUSCEPTANCE           :    0.00000 pu -    0.000  MVAR

-------------------------------------------------------------------------------
GENERATOR DATA

SL.NO* FROM FROM          REAL     Q-MIN     Q-MAX    V-SPEC CAP.     MVA STAT
       NODE NAME*    POWER(MW)      MVAR     MVAR       P.U. CURV  RATING
------ ---- -------- --------- --------- --------- --------- ---- ------- ----
    1    1     Bus1  700.0000 -185.0000  185.0000    1.0300    0  900.00    3
    2    2     Bus2  700.0000 -235.0000  235.0000    1.0100    0  900.00    3
    3    3     Bus3  719.0000    0.0000  176.0000    1.0300    0  900.00    3
    4    4     Bus4  700.0000 -202.0000  202.0000    1.0100    0  900.00    3

-------------------------------------------------------------------------------

LOAD DATA

SLNO FROM FROM         REAL REACTIVE     COMP COMPENSATING MVAR VALUE CHAR   F/V
*    NODE NAME*          MW     MVAR     MVAR     MIN      MAX    STEP   NO   NO
                                                                       STAT
---- ---- -------- -------- -------- -------- ------- ------- ------- ----   ----
   1    7     Bus7  967.000  100.000    0.000   0.000   0.000   0.000    0     0
                                                                         3     0
   2    9     Bus9 1767.000  100.000    0.000   0.000   0.000   0.000    0     0
                                                                         3     0
-------------------------------------------------------------------------------
TOTAL SPECIFIED MW GENERATION       : 2819.00000
TOTAL MIN MVAR LIMIT OF GENERATOR   : -622.00000
TOTAL MAX MVAR LIMIT OF GENERATOR   :  798.00000
TOTAL SPECIFIED MW LOAD             : 2734.00000 changed to 2734.00000
TOTAL SPECIFIED MVAR LOAD           :  200.00000 changed to  200.00000
TOTAL SPECIFIED MVAR COMPENSATION   :    0.00000 changed to     0.00000
-------------------------------------------------------------------------------
TOTAL (Including out of service  units)
TOTAL  SPECIFIED  MW  GENERATION      :  2819.00000
TOTAL  MIN  MVAR  LIMIT  OF  GENERATOR :  -622.00000
TOTAL MAX MVAR LIMIT OF GENERATOR   :   798.00000
TOTAL SPECIFIED MW LOAD             : 2734.00000 changed  to 2734.00000
TOTAL SPECIFIED MVAR LOAD           :  200.00000 changed to   200.00000
TOTAL SPECIFIED MVAR COMPENSATION   :    0.00000 changed to     0.00000
-------------------------------------------------------------------------------

-------------------------------------------------------------------------------
GENERATOR DATA FOR FREQUENCY DEPENDENT LOAD  FLOW

SLNO*  FROM FROM        P-RATE     P-MIN     P-MAX   %DROOP   PARTICI      BIAS
       NODE NAME*           MW        MW        MW              FACTOR   SETTING
                                                         C0        C1        C2
```

```
------ ---- -------- -------- --------- --------- --------- ---------   ---------
     1    1      Bus1  700.000    0.0000  700.0000    4.0000    0.0000    0.0000
                                                      0.0000    0.0000    0.0000
     2    2      Bus2  700.000    0.0000  700.0000    4.0000    0.0000    0.0000
                                                      0.0000    0.0000    0.0000
     3    3      Bus3  719.000    0.0000  719.0000    4.0000    0.0000    0.0000
                                                      0.0000    0.0000    0.0000
     4    4      Bus4  700.000    0.0000  700.0000    4.0000    0.0000    0.0000
                                                     0.0000    0.0000    0.0000

------------------------------------------------------------------------------
CONVERTOR DATA FOR AC-DC LOAD  FLOW

SLNO CONV AC    AC BUS       XC  CTRL CONTROL CONTROL   TAP  TAP   TAP
*    NUMB NUMB NAME*        P.U. TYPE   VALUE   ANGLE  MIN  MAX  STEP
                             Nb    Np    TrKV   TrMVA
---- ---- ---- -------- ------- ---- ------- ------- ---- ----  -----
   1    1    7      Bus7 0.18000    3 200.000   0.000 0.96 1.13 0.009
                               1    1 56.00000 235.00000
   2    2    9      Bus9 0.18000    1  56.000   0.000 0.85 1.13 0.015
                               1    1 56.00000 235.00000

------------------------------------------------------------------------------
DCLINK DATA FOR AC-DC LOAD FLOW

SLNO FROM FROM      TO   TO          R-DC
*    NUMB NAME*    NUMB NAME*        OHMS
---- ---- -------- ---- -------- -------
   1    1     Bus7    2     Bus9 1.50000
------------------------------------------------------------------------------

SHUNT FACTS DEVICES DATA

BUS NO. BUS_NAME FACTS_TYPE V-REF     SLOPE    IND_MAXIMUM CAP_MAXIMUM TOLERANCE  STATUS
------- -------- ---------- --------- -------- ----------- ----------- --------- ------
      8     Bus8 1-     SVC     1.000    0.100     218.504     218.504    0.0010      0
------------------------------------------------------------------------------
------------------------------------------------------------------------------
Slack bus angle (degrees) :   0.00
------------------------------------------------------------------------------
TOTAL NUMBER OF ISLANDS IN THE  GIVEN SYSTEM          :    1
TOTAL NUMBER OF ISLANDS HAVING ATLEAST ONE  GENERATOR :    1
SLACK BUSES CONSIDERED FOR THE STUDY
ISLAND NO. SLACK BUS NAME     SPECIFIED MW
---------- --------- --------  ------------
         1         3     Bus3      719.000

------------------------------------------------------------------------------

ITERATION    MAX P BUS     MAX P    MAX Q BUS     MAX Q
    COUNT       NUMBER  PER UNIT       NUMBER  PER UNIT
---------    ---------  --------    ---------  --------
        1            9     1.759            5     0.169
        2            7     0.046            7     0.013
        3            7     0.008            7     0.002
        4            9     0.002            9     0.000
        5            9     0.000            7     0.000
Number of p iterations :   4 and Number of q iterations :   4
```

```
        6          9     0.001          7     0.004
        7          9     0.002          9     0.001
        8          9     0.000          9     0.001
Number of p iterations :   5 and Number of q iterations :   5
        9          9     0.000          9     0.002
       10          9     0.002          9     0.000
       11          9     0.000          9     0.000
Number of p iterations :   6 and Number of q iterations :   6
       12          9     0.000          9     0.001
Number of p iterations :   6 and Number of q iterations :   6
       13          9     0.000          9     0.001
Number of p iterations :   6 and Number of q iterations :   6
       14          9     0.000          9     0.001
Number of p iterations :   6 and Number of q iterations :   6
       15          9     0.000          9     0.001
Number of p iterations :   6 and Number of q iterations :   6
       16          9     0.000          9     0.001
Number of p iterations :   6 and Number of q iterations :   6
       17          9     0.000          9     0.001
Number of p iterations :   6 and Number of q iterations :   6
----------------------------------------------------------------------------
----- BUS VOLTAGES AND POWERS
```

NODE NO.	FROM NAME	V-MAG P.U.	ANGLE DEGREE	MW GEN	MVAR GEN	MW LOAD	MVAR LOAD	MVAR COMP
1	Bus1	1.0300	12.72	700.000	152.110	0.000	0.000	0.000
2	Bus2	1.0100	3.04	700.000	155.314	0.000	0.000	0.000
3	Bus3	1.0300	0.00	717.417	129.190	0.000	0.000	0.000
4	Bus4	1.0100	-10.02	700.000	90.244	0.000	0.000	0.000
5	Bus5	1.0117	6.29	0.000	0.000	0.000	0.000	0.000
6	Bus6	0.9911	-3.65	0.000	0.000	0.000	0.000	0.000
7	Bus7	0.9844	-11.81	0.000	0.000	967.000	100.000	0.000
8	Bus8	0.9986	-18.39	0.000	0.000	0.000	0.000	0.000
9	Bus9	1.0043	-24.71	0.000	0.000	1767.000	100.000	0.000
10	Bus10	1.0018	-16.65	0.000	0.000	0.000	0.000	0.000
11	Bus11	1.0157	-6.56	0.000	0.000	0.000	0.000	0.000

```
----------------------------------------------------------------------------
----- NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@  mark) :  0
NUMBER OF BUSES EXCEEDING MAXIMUM VOLTAGE LIMIT (#  mark) :    0
NUMBER OF GENERATORS EXCEEDING MINIMUM Q LIMIT (<  mark)  :    0
NUMBER OF GENERATORS EXCEEDING MAXIMUM Q LIMIT (>  mark)  :    0

---------------------------------------------------------------------------------
TRANSFORMER FLOWS AND TRANSFORMER  LOSSES
```

SLNO	CS	FROM NODE	FROM NAME	TO NODE	TO NAME	FORWARD MW	FORWARD MVAR	LOSS MW	LOSS MVAR	% LOADING
1	1	5	Bus5	1	Bus1	-699.992	-71.497	0.0081	80.6135	77.3#
2	1	6	Bus6	2	Bus2	-699.994	-71.315	0.0084	83.9993	78.9#
3	1	11	Bus11	3	Bus3	-717.409	-45.711	0.0083	83.4790	78.6#
4	1	10	Bus10	4	Bus4	-699.993	-8.856	0.0081	81.3883	77.6#

```
---------------------------------------------------------------------------------
! NUMBER OF TRANSFORMERS LOADED  BEYOND  125%          :    0
@ NUMBER OF TRANSFORMERS LOADED BETWEEN 100% AND  125% :    0
# NUMBER OF TRANSFORMERS LOADED BETWEEN  75% AND  100% :    4
$ NUMBER OF TRANSFORMERS LOADED  BETWEEN  50% AND  75% :    0
^ NUMBER OF TRANSFORMERS LOADED  BETWEEN  25% AND  50% :    0
```

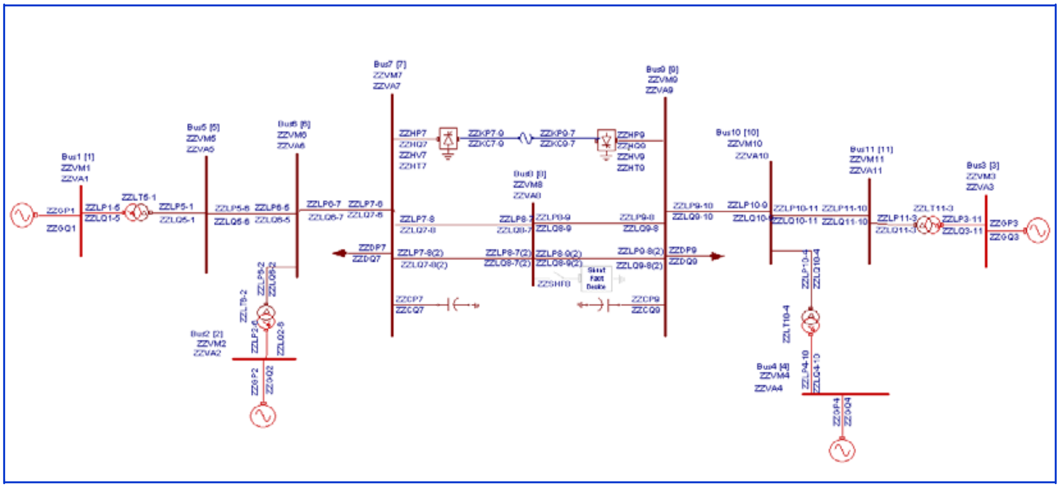
```
& NUMBER OF TRANSFORMERS LOADED  BETWEEN    1% AND  25% :     0
* NUMBER OF TRANSFORMERS LOADED  BETWEEN    0% AND   1% :     0

-------------------------------------------------------------------------------
LINE FLOWS AND LINE LOSSES

SLNO CS FROM FROM       TO TO               FORWARD            LOSS          %
        NODE NAME     NODE NAME           MW     MVAR        MW     MVAR LOADING
---- -- ---- -------- ---- -------- -------- -------- -------- --------   -------
   5  1    5     Bus5    6     Bus6  699.996   71.474  12.1000 116.6134    77.3#
   6  1    6     Bus6    7     Bus7 1387.901   26.073  19.6171 194.4638   155.6!
   7  1    7     Bus7    8     Bus8  100.627  -26.227   1.1819  -7.0968    11.7&
   8  1    7     Bus7    8     Bus8  100.627  -26.227   1.1819  -7.0968    11.7&
   9  1    8     Bus8    9     Bus9   99.442  -19.143   1.1009  -8.2875    11.3&
  10  1    8     Bus8    9     Bus9   99.442  -19.143   1.1009  -8.2875    11.3&
  11  1    9     Bus9   10    Bus10 -1385.16  261.971  19.7098 195.3378   156.0!
  12  1   10    Bus10   11    Bus11 -704.898   75.226  12.5273 120.8215    78.6#
-------------------------------------------------------------------------------
! NUMBER OF LINES LOADED  BEYOND  125%          :     2
@ NUMBER OF LINES LOADED BETWEEN 100% AND 125%  :     0
# NUMBER OF LINES LOADED BETWEEN  75% AND 100%  :     2
$ NUMBER OF LINES LOADED  BETWEEN   50% AND   75% :     0
^ NUMBER OF LINES LOADED  BETWEEN   25% AND   50% :     0
& NUMBER OF LINES LOADED  BETWEEN    1% AND   25% :     4
* NUMBER OF LINES LOADED  BETWEEN    0% AND    1% :     0

-------------------------------------------------------------------------------
SHUNT CAPACITOR AND REACTOR  INJECTION

NODE     FROM       V-MAG  ANGLE         MW     MVAR
NO.      NAME        P.U. DEGREE        GEN      GEN
-------- --------  ------ ------  -------- --------
       7     Bus7   0.984 -11.81     0.000  313.948
       9     Bus9   1.004 -24.71    -0.000  478.341

-------------------------------------------------------------------------------
CONVERTOR OUTPUT FOR AC-DC LOADFLOW

CONV AC        AC BUS        V-DC      P-DC      Q-DC      I-DC  CONTROL      TAP
NUMB NUMB      NAME            KV        MW      MVAR      AMPS    ANGLE  SETTING
---- -------- -------- -------- -------- -------- -------- --------   --------
   1        7     Bus7   64.042  200.000    97.205  3122.941     0.000   0.9565
   2        9     Bus9   59.358 -185.371    93.777 -3122.941     0.000   0.8759

-------------------------------------------------------------------------------
DCLINK RESULT FOR AC-DC LOADFLOW

SLNO FROM     FROM     TO   TO          I-LINK  P-LINK  P-LOSS
     NUMB     NAME     NUMB NAME          AMPS      MW      MW
---- -------- -------- ---- -------- ------- ------- -------
   1        1     Bus7    2     Bus9 3122.938   200.0  14.629
-------------------------------------------------------------------------------

-------------------------------------------------------------------------------
SHUNT FACTS DEVICES OUTPUT
-ve: Inductive, +ve:  Capacitive

BUSNO BUS NAME REF-VOLTAGE BUS-VOLTAGE COMPENSATION  CURRENT  OUTPUT-B   DEVICE
```

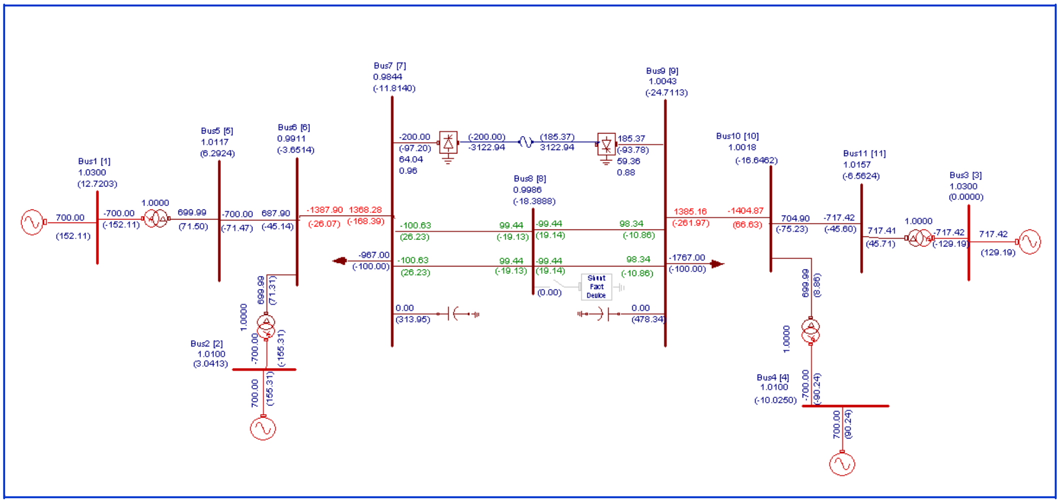
```
              PU          PU          MVAR          AMPERE pu-SYSTEM
----- -------- ----------- ----------- ------------ -------- --------- ---
    ----  8         Bus8        1.0000        0.9986   0.000     0.000
          0.000 SVC
-------------------------------------------------------------------------------
--------------------------------------------------------------------------
----- BUSES BETWEEN WHICH ANGLE DIFFERENCE IS > 30 degrees ARE:  ZERO
--------------------------------------------------------------------------
----- ISLAND FREQUENCY SLACK-BUS        CONVERGED(1)
------ --------- ---------- -------
     ----- 1  60.00000     3
                           1

-------------------------------------------------------------------------------
Summary of results
TOTAL REAL POWER  GENERATION (CONVENTIONAL)   :   2817.417 MW
TOTAL REAL POWER  INJECT,-ve L                :      0.000 MW
TOTAL REACT. POWER GENERATION (CONVENTIONAL)  :    526.858 MVAR
GENERATION pf                                 :      0.983

TOTAL REAL POWER  GENERATION (WIND)           :      0.000 MW
TOTAL REACT. POWER  GENERATION (WIND)         :      0.000 MVAR
TOTAL REAL POWER  GENERATION (SOLAR)          :      0.000 MW
TOTAL REACT. POWER  GENERATION (SOLAR)        :      0.000 MVAR
TOTAL SHUNT  REACTOR INJECTION                :     -0.000 MW
TOTAL SHUNT  REACTOR INJECTION                :     -0.000 MVAR

TOTAL  SHUNT  CAPACIT.INJECTION               :      0.000 MW
TOTAL  SHUNT  CAPACIT.INJECTION               :    792.289 MVAR

TOTAL TCSC  REACTIVE DRAWL                    :      0.000 MVAR

TOTAL SPS  REACTIVE DRAWL                     :      0.000 MVAR

TOTAL UPFC  FACTS.  INJECTION                 :    -0.0000 MVAR

TOTAL  SHUNT  FACTS.INJECTION                 :      0.000 MVAR
TOTAL  SHUNT  FACTS.DRAWAL                    :      0.000 MVAR

TOTAL REAL  POWER LOAD                        :   2734.000 MW
TOTAL REAL POWER DRAWAL  -ve g                :      0.000 MW
TOTAL REACTIVE  POWER LOAD                    :    200.000 MVAR
LOAD pf                                       :      0.997
TOTAL COMPENSATION  AT LOADS                  :      0.000 MVAR
TOTAL HVDC  REACTIVE POWER                    :    190.982 MVAR
TOTAL REAL POWER  LOSS (AC+DC)                :  83.181941 MW ( 68.552828+ 14.629113)
PERCENTAGE REAL   LOSS (AC+DC)                :      2.952
TOTAL REACTIVE POWER  LOSS                    : 925.948036 MVAR

-------------------------------------------------------------------------------
Zone wise
distribution
Description
                   Zo
ne # 1
---------------- ----------
MW generation      2817.4172

MVAR generation     526.8579
```

```
MW wind. gen.         0.0000

MVAR wind. gen.       0.0000
```

```
MW solar. gen.         0.0000

MVAR solar. gen.       0.0000

MW load            2734.0000
MVAR load           200.0000

MVAR compensation     0.0000

MW loss              83.1819

MVAR loss           925.9480

MVAR - inductive      0.0000

MVAR - capacitive   792.2889

-------------------------------------------------------------------------------
Zone wise export(+ve)/import(-ve)
Zone #   1 MW & MVAR
------ -------- --------
     1       -----

Area wise distribution
Description         Area # 1
---------------- ----------
MW generation      2817.4172

MVAR generation     526.8579

MW wind gen.          0.0000

MVAR wind gen.        0.0000

MW solar gen.         0.0000

MVAR solar gen.       0.0000

MW load            2734.0000

MVAR load           200.0000

MVAR compensation     0.0000

MW loss              83.1819

MVAR loss           925.9480

MVAR - inductive      0.0000

MVAR - capacitive   792.2889

-------------------------------------------------------------------------------
```

```
Date and Time : Thu Dec 19 14:56:23  2013
-------------------------------------------------------------------------------
```





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