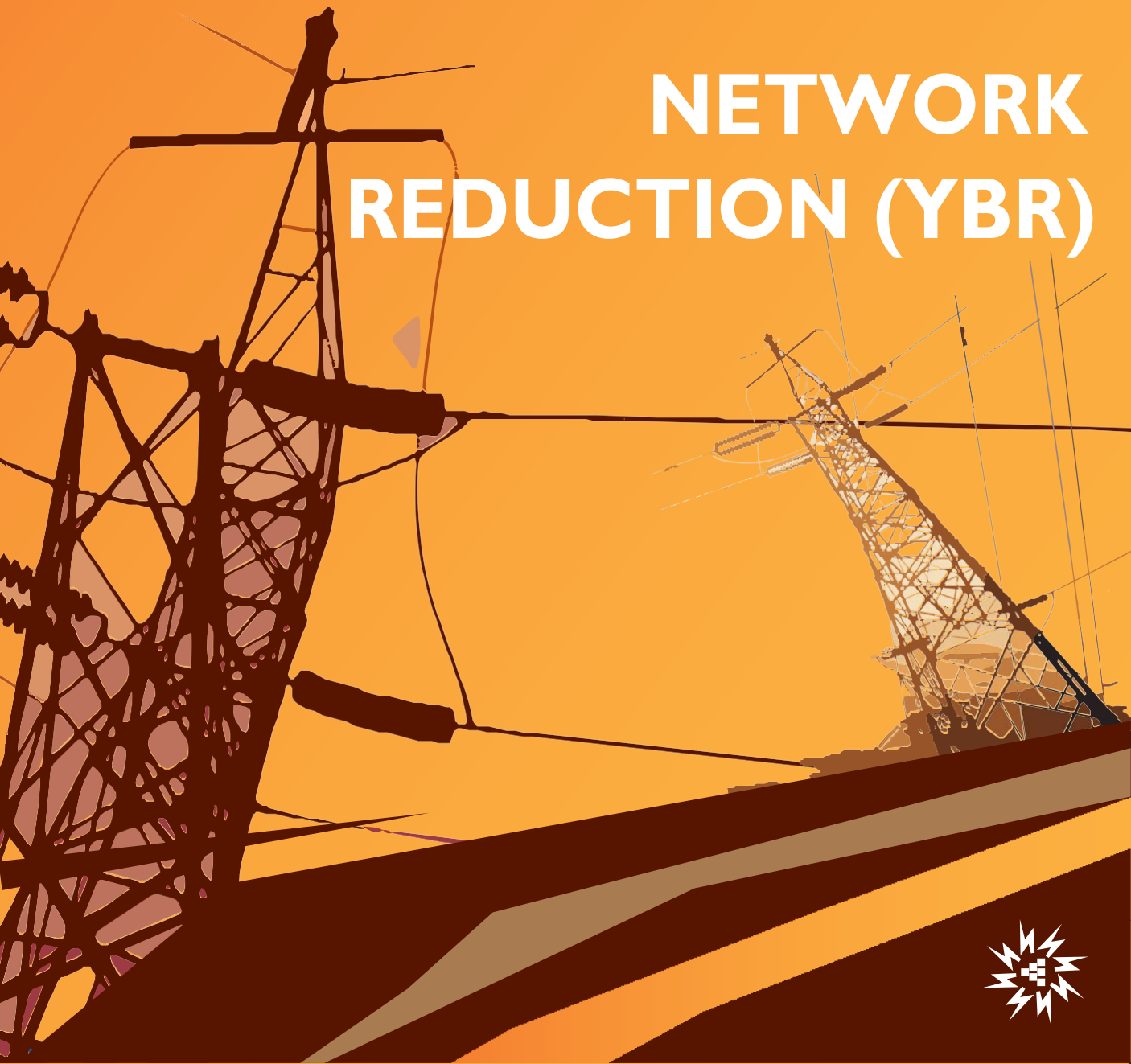
User Manual

PSCT | Protection Analytic tool

NETWORK REDUCTION (YBR)



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1. INTRODUCTION

POWERYBR is designed to provide the static and dynamic equivalents for the power system. In case of static equivalent, program determines the bus admittance matrix (Ybus) as seen from the desired nodes by eliminating the rest of the nodes. In case of dynamic equivalent, a single machine equivalent circuit is determined. The methodology is an extension of the Thevenin theorem to electromechanical circuits. It is often necessary to obtain network equivalents for proper representation in various analysis such as transient and dynamic stability analysis. In **POWERYBR** sparse storage and matrix ordering techniques are used to reduce the memory requirements. The methodology used for static equivalent, wherein all the generator buses in the system are retained consists of -

- Formation of positive sequence sparse Ybus for the given power system. In the Ybus formation, shunt elements at the buses, which are to be retained, will not be added to the corresponding diagonal elements.
- Finding the columns of the positive sequence Zbus for the nodes to be retained.
- Assembling the Zbus for the reduced system from the above columns of Zbus.
- Inverting the Zbus to find the positive sequence Ybus for the reduced system.
- Above analysis are done for negative and zero sequence networks.

In case of dynamic equivalent, the procedure involved is -

- Internal system is identified. All the buses, which are external to the area of interest, and connected directly to the internal system nodes, are identified. These are the nodes to be retained.
- An equivalent generator is considered, connected to the retained nodes in the external system.
- The single machine electromechanical circuit replaces generators in the external system.

The program input data is through an ASCII file, the format of which is described in chapter 2. In chapter 3, input and output files are given. Chapter 4 gives the case study, wherein the data file preparation for obtaining the network equivalents for sample systems are discussed along with the analysis of the results.

2. HOW TO SOLVE NETWORK REDUCTION

EXAMPLE: Network Reduction

For a typical 24 Bus System with maximum generation as slack bus. The Single Line Diagram is shown in fig-1. Element parameters are specified in the element tables.

1. Generate a Single line diagram using MiP-PSCT Power system Network Editor simultaneously Compute the Electrical parameters in p.u. on 100MVAbase.
2. Do Load Flow Analysis in Fast decoupled method, tolerance of0.001.
3. Do Ybus Network Reduction using following methods
   - **Case1: Retaining all generator buses**
     Network reduced with retaining all the buses to which the generators are connected, such as 1, 2, 3 and 4.
   - **Case2 : Retaining all Generator buses and Zone 1 buses**
     Network reduced with retaining all the buses to which the generators are connected, and buses belonging to Zone1, such as 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, and 17.
   - **Case 3: Retaining all Zone 1 buses**
     Network reduced with retaining all the Zone1 buses, such as 1, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, and 17.
   - **Case 4: Network Reduction for Dynamic Stability study.**
     Network reduced with retaining all the buses to which the generators are connected taking the option Dynamic Stability

Table 2.1: Bus Data Cable

Sl. No	Bus Name	kV rating
1	Bus1	11.000
2	Bus2	11.000
3	Bus3	11.000
4	Bus4	11.000
5	Bus5	220.000
6	Bus6	220.000
7	Bus7	220.000

8	Bus8	220.000
9	Bus9	220.000
10	Bus10	220.000
11	Bus11	220.000
12	Bus12	220.000
13	Bus13	220.000
14	Bus14	400.000
Sl. No	**Bus Name**	**kV rating**
15	Bus15	400.000
16	Bus16	220.000
17	Bus17	220.000
18	Bus18	220.000
19	Bus19	220.000
20	Bus20	220.000
21	Bus21	220.000
22	Bus22	220.000
23	Bus23	220.000
24	Bus24	220.000

Table 2.2: Transmission Line data Table

Sl. No.	From Bus	To Bus	Positive Sequence		
			Resistance R(P.U.)	Reactance X(P.U.)	Susceptance B/2(P.U.)
1	15	14	0.00430	0.04770	0.63700
2	7	11	0.02444	0.12226	0.10272
3	12	13	0.01321	0.06608	0.05552
4	13	11	0.00314	0.01570	0.05275
5	13	16	0.00578	0.02891	0.02429
6	16	11	0.00495	0.02478	0.02082
7	16	17	0.00248	0.01239	0.01041
8	5	6	0.00450	0.02251	0.30260
9	6	7	0.03716	0.18586	0.15616
10	6	13	0.05169	0.25856	0.21723
11	6	16	0.01530	0.07655	0.57882

12	6	8	0.01239	0.06195	0.20822
13	8	9	0.00363	0.01817	0.06107
14	8	10	0.00330	0.01652	0.05552
15	18	19	0.00537	0.02685	0.09022
16	19	5	0.01263	0.06319	0.21237
17	19	20	0.01131	0.05658	0.19016
18	20	24	0.01982	0.09913	0.08328
19	24	5	0.02494	0.12473	0.10480
20	22	23	0.03633	0.18173	0.15269
21	22	20	0.01734	0.08674	0.29149
22	22	21	0.00330	0.01652	0.01388

Table 2.3: Transformer data table

From Bus	To Bus	Resistance R	Reactance X	MVA Rating
Bus4	Bus15	0.001402	0.02804	475.00
Bus14	Bus11	0.00063	0.01250	475.00
Bus5	Bus1	0.000694	0.013872	704.63
Bus2	Bus18	0.003484	0.06968	156.25
Bus3	Bus22	0.002804	0.05609	237.50

Table 2.4: Generator data table

Generator	Gen1	Gen2	Gen3	Gen4
P-sch MW	563.7	125.0	190.0	380.0
P-rate MW	712	135	300	420
P-min MW	400	50	120	240
P-max MW	760	140	330	440
V-pu	1.02	1.02	1.02	1.02
Positive sequence				
R	0.00126	0.00073	0.00051	0.00026
X'd	0.03409	0.07473	0.05247	0.02623
Negative sequence				
R	0.00126	0.00073	0.00051	0.00026
X'd	0.03409	0.07479	0.05251	0.02626
Zero sequence				

R	0.00126	0.00073	0.00051	0.00026
X'd	0.03413	0.07497	0.05264	0.02632
Inertia(H)	6.917	6.917	6.917	6.917

Table 2.5: Generator Capability Curve

Point No.	P(pu)	Q-min (pu)	Q-max (pu)
1	0.0	-0.3	0.707
2	0.6	-0.2	0.6
3	0.9	-0.2	0.5
4	1.0	0.0	0.0

Table 2.6: Load Data

Bus no.	P-load Mvar	Q-load Mvar	Q-comp Mvar
6	70	30	30
7	150	40	30
9	30	10	0
10	90	50	0
11	35	15	0
12	30	10	0
13	150	60	0
16	230	60	0
17	60	25	0
19	130	100	0
20	50	35	0
21	73	48	0
23	50	30	0
24	95	50	0

Procedure to enter Bus Data

Similarly enter other bus, as per details the given in bus data table.

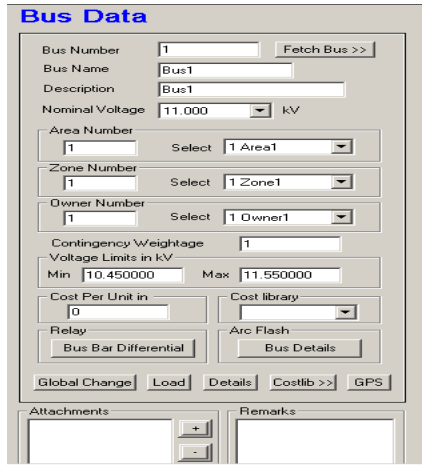


Figure 1: Bus Data

Procedure to enter Transmission line details:

Select main menu **"Libraries → Series Elements → Transmission Line"**

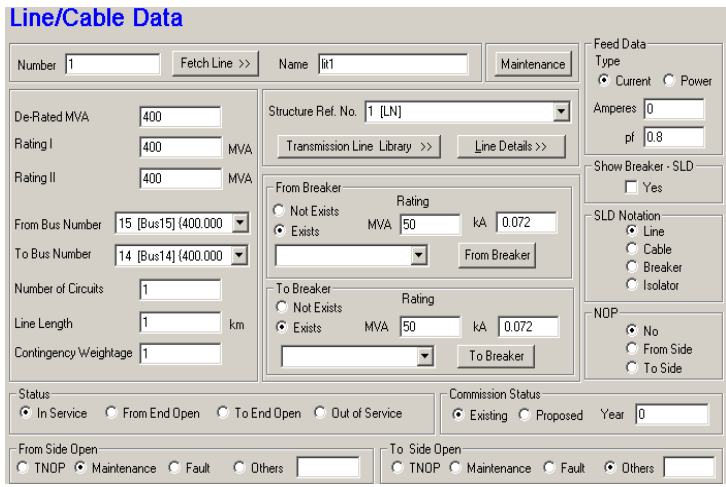


Figure 2: Line/Cable Data

Enter other **Transmission** data similarly, as per the data given in **Transmission line data table.**

Procedure to enter Element detail:
Select main menu **Libraries → Series Elements → Transmission Line →**

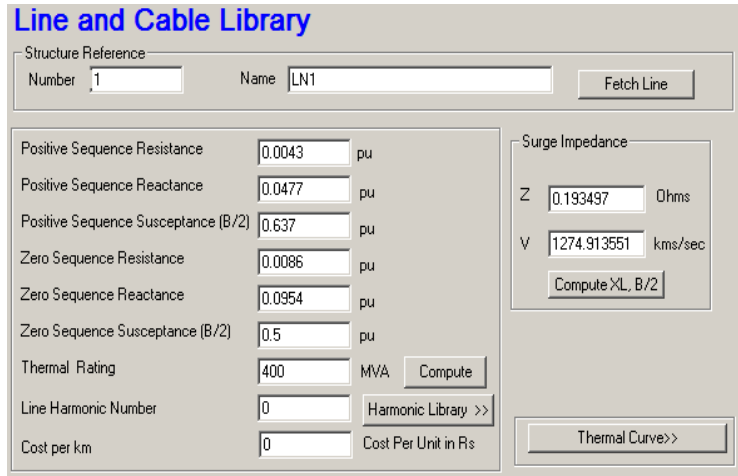


Figure 3: Line/Cable Library

Enter other **Transmission** data similarly, as per the data given in **Transmission line data table.**

Procedure to enter Element detail:

Select main menu **Elements → Series Elements →Transmission Line**

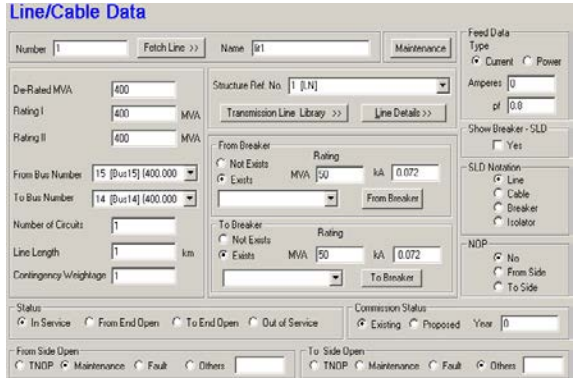


Figure 4: Line/Cable Data

Enter remaining **Transmission line data** similarly according to the following table.

Table 2.7: Transmission Line Data

Line No.	From Bus	To Bus	No. of circuits	Line Length	Structure reference no.
2	7	11	1	1	2
3	12	13	1	1	3
4	13	11	1	1	4
5	13	16	1	1	5
6	16	11	1	1	6
7	16	17	1	1	7
8	5	6	1	1	8
9	6	7	1	1	9
10	6	13	1	1	10
11	6	16	1	1	11
12	6	8	1	1	12
13	8	9	1	1	13
14	8	10	1	1	14
15	18	19	1	1	15
Line No.	**From Bus**	**To Bus**	**No. of circuits**	**Line Length**	**Structure reference no.**
16	19	5	1	1	16
17	19	20	1	1	17
18	20	24	1	1	18
19	24	5	1	1	19
20	22	23	1	1	20
21	22	20	1	1	21
22	22	21	1	1	22

Procedure to enter Transformer details

Select menu option **Libraries** → **Series Element** → **Two winding Transformer**

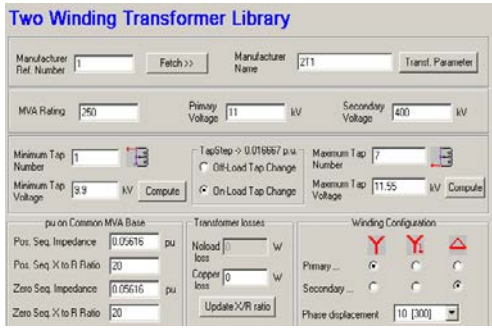


Figure 5: Two Winding Transformer Library

R and X data given in Transformer details table.
Impedance $Z = \sqrt{R^2 + X^2}$

Enter remaining **Transformer** details similarly. Data given in the following table**.**

Table 2.8: Transformer Details

Manufacturer no.	2	3	4	5
Manufacturer name	14-11	5-1	2-18	3-22
MVA rating	475.00	704.63	156.25	237.50
Impedance	0.01252	0.11112	0.06977	0.05616
X/R Ratio	19.8413	19.988	20	20.0036
Primary kV	400	220	11	11
Secondary kV	220	11	220	220
Mini Tap No	1	1	1	1
Maxi Tap No	7	13	7	7
Mini Tap kV	360	198	10.45	10.45
Maxi Tap kV	420	231	12.1	12.1
Winding configuration	Y-Y	Y-Y	Y-Y	Y-Y

2.1 Transformer Element details

Select menu option Element ➔ Series Element ➔ Two winding Transformer

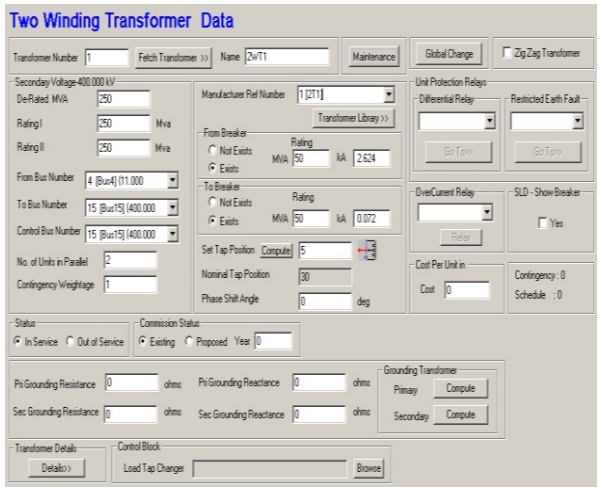


Figure 6: Transformer Element Details

Enter other **Transformer** details similarly. Details as shown in the following table**.**

Table 2.9: Transformer Details

Transformer no.	2	3	4	5
Transformer name	2T2	2T3	2T4	2T5
From Bus number	14	5	2	3
To Bus number	11	1	18	22
Control Bus number	14	5	18	22
Manufacturer ref number	2	3	4	5
De-Rated MVA	475.00	704.63	156.25	237.50
Nominal Tap	5	9	3	3

Generator Capability Curve
Select menu option **Libraries ➔ Capability Curve**

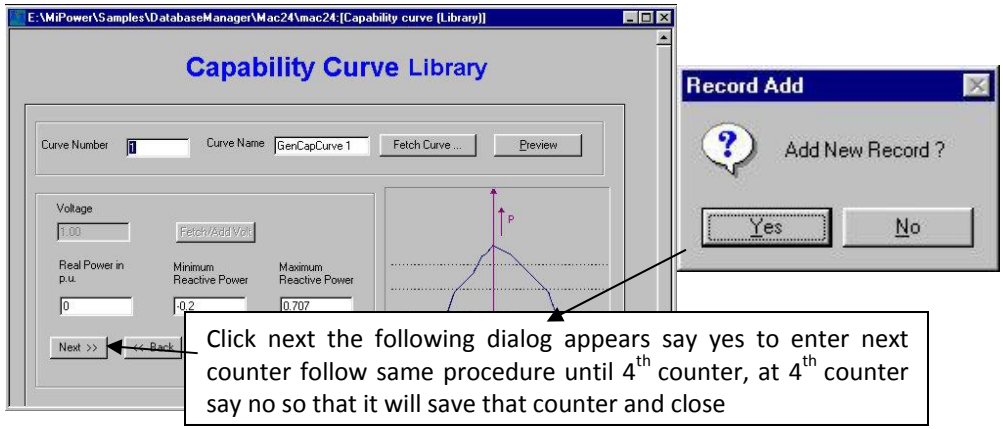


Figure 7: Capability Curve Library

Table 2.10: Generator Capability Curve Details

Point No.	P(pu)	Q-min (pu)	Q-max (pu)
2	0.6	-0.2	0.6
3	0.9	-0.2	0.5
4	1.0	0.0	0.0

Generator details

Select menu option **Libraries - ➔Shunt Elements ➔ Generator**

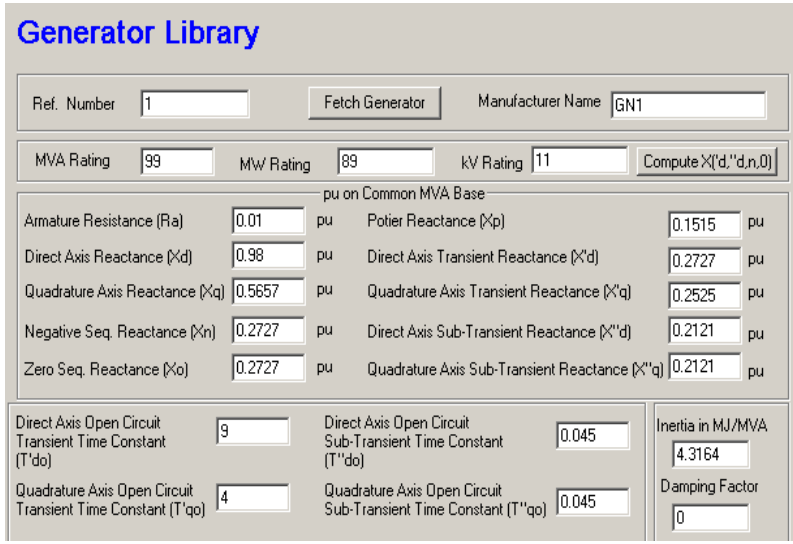


Figure 8: Generator Library

Enter other **Generator** details similarly. Data given in following table**.**

Table 2.11: Generator Details

Generator	Gen1	Gen2	Gen3	Gen4
P-sch MW	563.7	125.0	190.0	380.0
P-rate MW	712	135	300	420
P-min MW	400	50	120	240
P-max MW	760	140	330	440
V-pu	1.02	1.02	1.02	1.02
Positive sequence				
R	0.00126	0.00073	0.00051	0.00026
X'd	0.03409	0.07473	0.05247	0.02623
Negative sequence				
R	0.00126	0.00073	0.00051	0.00026
X'd	0.03409	0.07479	0.05251	0.02626
Zero sequence				
R	0.00126	0.00073	0.00051	0.00026
X'd	0.03413	0.07497	0.05264	0.02632

Inertia(H)	6.917	6.917	6.917	6.917

2.2 Generator Element details

Select menu **option Elements ➔ Shunt Elements ➔ Generator**

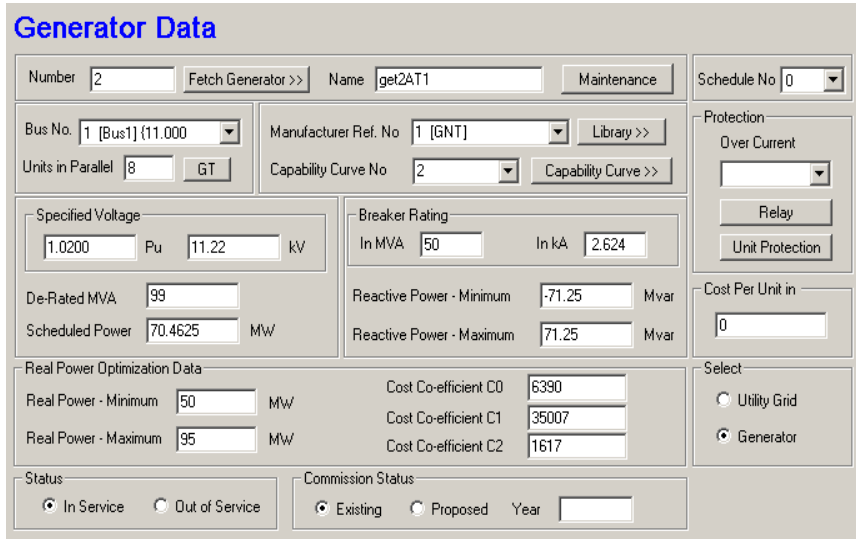


Figure 9: Generator Data

Enter remaining **Generators** similarly. Detail given in following table

Table 2.12: Generator Details

Name	GEN-2	GEN-3	GEN-4
Bus Number	2	3	4
Manufacturer Reference Number	2	3	4
Number of Generators in Parallel	1	1	1
Capability Curve Number	1	1	1
De-Rated MVA	225	225	225
Specified Voltage	11.22	11.22	11.22
Scheduled Power	125	190	380
Reactive Power Minimum	-105	-330	-330

Reactive Power Maximum	95	330	330
Breaker Rating	350	350	350

Load details

Select menu option **Elements ➔ Shunt Elements ➔ Load**

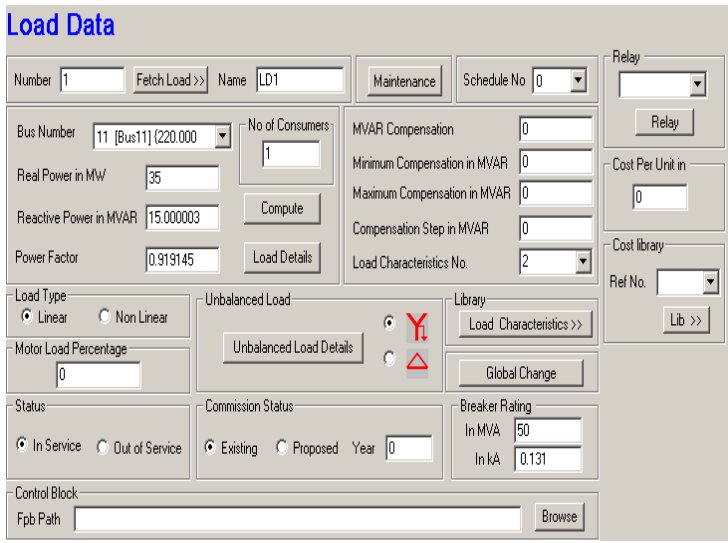


Figure 10: Load Data

Enter remaining **loads** similarly. Details given in the following table

Table 2.13: Load Details

Bus no.	P-load Mvar	Q-load Mvar	Q-comp Mvar
6	70	30	30
7	150	40	30
9	30	10	0
10	90	50	0
11	35	15	0
12	30	10	0
13	150	60	0
16	230	60	0
17	60	25	0
19	130	100	0
20	50	35	0
21	73	48	0

23	50	30	0
24	95	50	0

Solving Load Flow

Select menu option "**Solve ➔ Load Flow".**
The following form will appear.

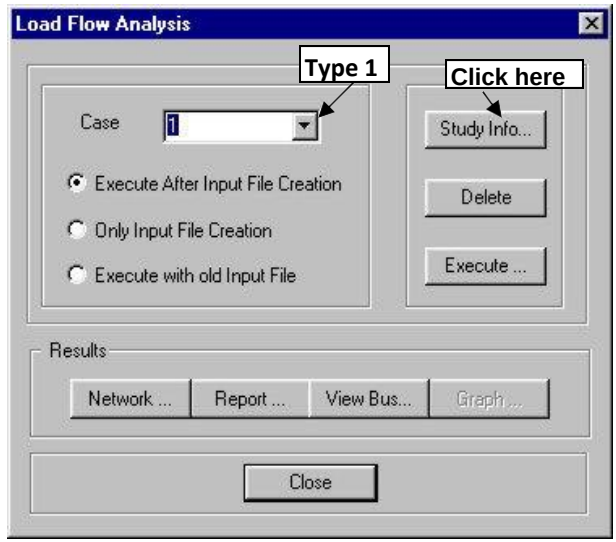


Figure 11: Load Flow Analysis

Study Information

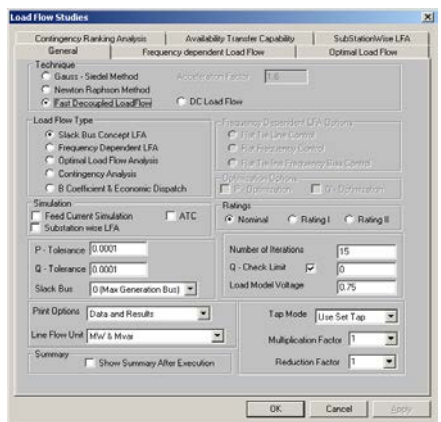


Figure 12: Load Flow Studies

Executing and Viewing the report

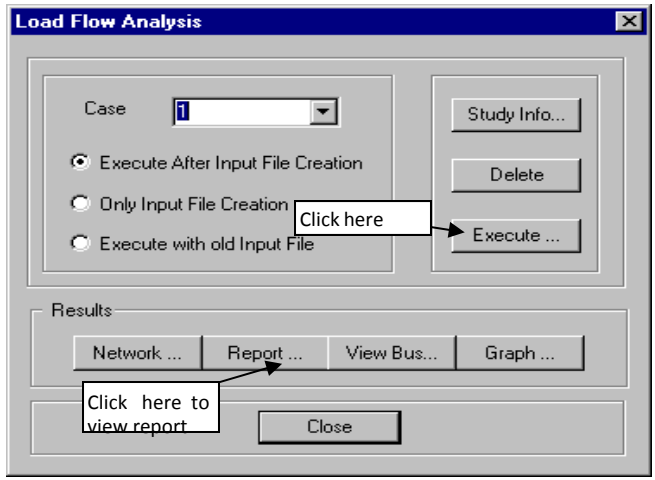


Figure 13: LFA

Report

Load flow results are given below.

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	1.0200	0.00	563.711	19.574	0.000	0.000	0.000
2	BUS2	1.0200	1.61	125.000	22.496	0.000	0.000	0.000
3	BUS3	1.0200	3.52	190.000	39.568	0.000	0.000	0.000
4	BUS4	1.0200	3.91	380.000	35.241	0.000	0.000	0.000
5	BUS5	1.0164	-4.32	0.000	0.000	0.000	0.000	0.000
6	BUS6	1.0050	-10.41	0.000	0.000	70.244	30.104	30.000
7	BUS7	0.9677	-19.85	0.000	0.000	146.636	39.103	30.000
8	BUS8	0.9756	-14.54	0.000	0.000	0.000	0.000	0.000
9	BUS9	0.9737	-14.85	0.000	0.000	29.453	9.818	0.000
10	BUS10	0.9650	-15.33	0.000	0.000	87.820	48.789	0.000
11	BUS11	0.9733	-15.09	0.000	0.000	34.351	14.722	0.000
12	BUS12	0.9568	-17.67	0.000	0.000	29.103	9.701	0.000
13	BUS13	0.9642	-16.52	0.000	0.000	146.276	58.510	0.000
14	BUS14	0.9814	-12.32	0.000	0.000	0.000	0.000	0.000
15	BUS15	1.0105	-2.00	0.000	0.000	0.000	0.000	0.000
16	BUS16	0.9638	-16.86	0.000	0.000	224.238	58.497	0.000
17	BUS17	0.9593	-17.27	0.000	0.000	58.310	24.296	0.000

```
  18     BUS18   1.0039  -3.23     0.000    0.000     0.000    0.000    0.000
  19     BUS19   0.9922  -5.08     0.000    0.000   129.295   99.458    0.000
  20     BUS20   0.9910  -5.83     0.000    0.000    49.687   34.781    0.000
  21     BUS21   0.9882  -3.03     0.000    0.000    72.398   47.604    0.000
  22     BUS22   0.9984  -2.42     0.000    0.000     0.000    0.000    0.000
  23     BUS23   0.9469  -7.40     0.000    0.000    48.171   28.903    0.000 @
  24     BUS24   0.9726  -7.97     0.000    0.000    93.194   49.050    0.000
--------------------------------------------------------------------------------
NUMBER OF BUSES EXCEEDING MINIMUM VOLTAGE LIMIT (@ mark) :    1
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 FROM       TO TO             FORWARD          LOSS            %
        NODE NAME     NODE NAME           MW     MVAR      MW     MVAR LOADING
   1  2    4     BUS4   15    BUS15  380.000   35.241   1.9630  39.2592    74.8$
   2  1   14    BUS14   11    BUS11  371.856   53.910   0.9237  18.3278    76.6#
   3  8    5     BUS5    1     BUS1 -561.589   22.848   2.1224  42.4223    69.8$
   4  1    2     BUS2   18    BUS18  125.000   22.496   0.5402  10.8041    75.5#
   5  1    3     BUS3   22    BUS22  190.000   39.568   1.0151  20.3063    76.1#
--------------------------------------------------------------------------------
! NUMBER OF TRANSFORMERS LOADED BEYOND  125%          :    0
@ NUMBER OF TRANSFORMERS LOADED BETWEEN 100% AND 125% :    0
# NUMBER OF TRANSFORMERS LOADED BETWEEN  75% AND 100% :    3
$ NUMBER OF TRANSFORMERS LOADED BETWEEN  50% AND  75% :    2
^ 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
---- -- ---- -------- ---- -------- -------- -------- -------- -------- -------
   6  1   15    BUS15   14    BUS14  378.034   -4.006   6.1755 -57.8906    93.5#
   7  1    7     BUS7   11    BUS11  -61.752    0.900   1.0242 -14.2262    55.3$
   8  1   12    BUS12   13    BUS13  -29.102   -9.699   0.1253  -9.6166    26.7^
   9  2   13    BUS13   11    BUS11 -153.297  -28.633   0.8128  -5.8370    67.4$
  10  1   13    BUS13   16    BUS16   18.655   -4.839   0.0221  -4.4042    16.7&


  11  1   16    BUS16   11    BUS11 -118.921  -13.271   0.7604  -0.0999   103.1@
  12  1   16    BUS16   17    BUS17   58.415   22.899   0.1063  -1.3940    54.9$
  13  4    5     BUS5    6     BUS6  477.840  -49.588   9.9609 -11.9946    98.5#
  14  1    6     BUS6    7     BUS7   87.746   -6.062   2.8676 -16.0514    72.9$
  15  1    6     BUS6   13    BUS13   41.800  -12.309   0.9417 -37.4225    41.5^
  16  3    6     BUS6   16    BUS16  148.596  -26.153   3.5032 -94.7018    46.2^
```

```
  17  2    6     BUS6    8     BUS8   119.493    6.806    1.8467 -31.6140    52.9$
  18  2    8     BUS8    9     BUS9    29.486   -1.617    0.0338 -11.4338    13.3&
  19  2    8     BUS8   10    BUS10    88.160   40.038    0.3407   -8.7495    43.4^
  20  2   18    BUS18   19    BUS19   124.460   11.692    0.8483 -13.7340    53.0$
  21  2   19    BUS19    5     BUS5   -27.772  -53.132    0.2321 -41.6860    25.2^
  22  2   19    BUS19   20    BUS20    22.088  -20.899    0.0566 -37.1160    12.8&
  23  1   20    BUS20   24    BUS24    38.691    3.175    0.3281 -14.4170    36.2^
  24  1   24    BUS24    5     BUS5   -54.831  -31.457    0.9149 -16.1647    54.2$
  25  1   22    BUS22   23    BUS23    49.205    5.164    1.0339 -23.7399    49.4^
  26  2   22    BUS22   20    BUS20    67.132  -32.016    0.7855 -53.7550    31.0^
  27  1   22    BUS22   21    BUS21    72.648   46.114    0.2494   -1.4903    73.1$
--------------------------------------------------------------------------------
! NUMBER OF LINES LOADED BEYOND  125%          :     0
@ NUMBER OF LINES LOADED BETWEEN 100% AND 125% :     1
# NUMBER OF LINES LOADED BETWEEN  75% AND 100% :     2
$ NUMBER OF LINES LOADED BETWEEN  50% AND  75% :     8
^ NUMBER OF LINES LOADED BETWEEN  25% AND  50% :     8
& NUMBER OF LINES LOADED BETWEEN   1% AND  25% :     3
* NUMBER OF LINES LOADED BETWEEN   0% AND   1% :     0
--------------------------------------------------------------------------------
```

To solve Y-Bus Reduction (NETWORK REDUCTION)

CASE 1 : Retaining all generator buses

24 Bus sample systems are reduced with retaining all the buses to which the generators are connected, such as buses 1,2,3 and 4. All other connections are reduced as equivalent series impedance between the retained buses and shunt admittance at the retained buses.

Select menu option
"Solve ➔ Network Reduction"
Following screen appears

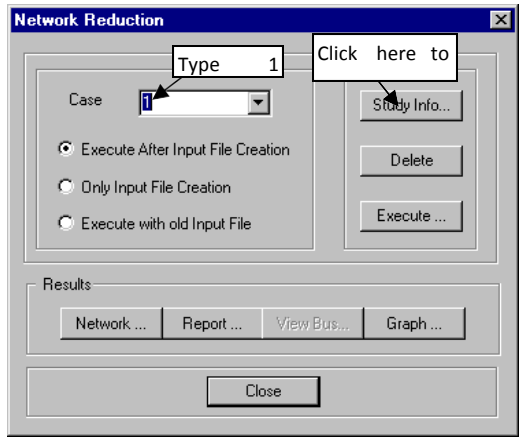


Figure 14: Network Reduction

Study Information

Following screen shows study information for **Case 1**. Similarly select buses 1, 2, 3, and 4.

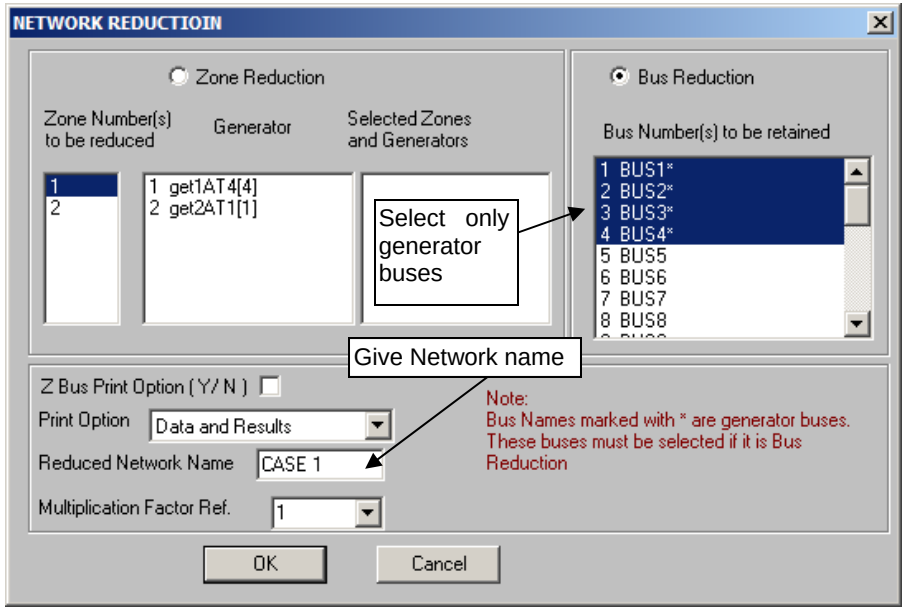


Figure 15: Network Reduction(zone Reduction & Bus reduction)

Click **OK** after entering information. **Execute** Network Reduction. Click **Report** button to view the **report**.

Network Reduction Report for case 1

```
NETWORK  REDUCTION
CASE NO :  11     CONTINGENCY  : 0  SCHEDULE NO : 0
CONTINGENCY NAME : Base Case

------------------------------------------------------------------------------
%%
TOTAL NUMBER OF BUSES          :   24    ACTUAL NUMBER OF BUSES         :   24
NUMBER OF 2 WIND. TRANSFORMERS :    5    NUMBER OF 3 WIND. TRANSFORMERS :    0
NUMBER OF TRANSMISSION LINES   :   22
NUMBER OF SERIES REACTORS      :    0    NUMBER OF SERIES CAPACITORS    :    0
NUMBER OF BUS COUPLERS         :    0
NUMBER OF SHUNT REACTORS       :    0    NUMBER OF SHUNT CAPACITORS     :    0
```

```
NUMBER OF SHUNT IMPEDANCES     :    0    NUMBER OF GENERATORS           :    4
NUMBER OF LOADS                :   14
NUMBER OF FILTERS              :    0

NUMBER OF HVDC CONVERTORS      :    0

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


NUMBER OF ZONES         :  2

PRINT OPTION            :  3 (BOTH DATA AND RESULTS PRINT)
BASE MVA                :  100.000
NOMINAL SYSTEM FREQUENCY:   50.000
PREFAULT VOLTAGE OPTION : 1 (READ FROM THE FILE)
ZONE NUMBER RETAINED    :  0
ZBUS PRINT OPTION       :  0
YBUS REDUCTION OPTION   :  1 (NETWORK REDUCTION)
--------------------------------------------------------------------------------
   4
   1     2     3     4
--------------------------------------------------------------------------------
CIRCUIT BREAKER RESISTANCE (PU)                      :   0.000000
CIRCUIT BREAKER REACTANCE  (PU)                      :   0.000100
TRANSFORMER R/X RATIO                                :   0.050000
TRANSFORMER ZERO SEQUENCE IMPEDANCE MULT FACTOR      :   0.900000

NUMBER OF TRANSMISSION VOLTAGE LEVELS                : 3
TRANSMISSION LINE VOLTAGE - KV                       :  11.000000
TRANSMISSION LINE ZERO SEQUENCE RES. MULT. FACTOR    :   0.000000
TRANSMISSION LINE ZERO SEQUENCE REA. MULT. FACTOR    :   0.000000
TRANSMISSION LINE ZERO SEQUENCE ADM. MULT. FACTOR    :   0.000000
TRANSMISSION LINE VOLTAGE - KV                       : 220.000000
TRANSMISSION  LINE  ZERO  SEQUENCE  RES.  MULT.  FACTOR  :  2.500000
TRANSMISSION  LINE  ZERO  SEQUENCE  REA.  MULT.  FACTOR  :  2.500000
TRANSMISSION  LINE  ZERO  SEQUENCE  ADM.  MULT.  FACTOR  :  0.025000
TRANSMISSION LINE VOLTAGE - KV                       : 400.000000
TRANSMISSION  LINE  ZERO  SEQUENCE  RES.  MULT.  FACTOR  :  2.500000
TRANSMISSION  LINE  ZERO  SEQUENCE  REA.  MULT.  FACTOR  :  2.500000
TRANSMISSION LINE ZERO SEQUENCE ADM. MULT. FACTOR    :   0.025000

GENERATOR NEGATIVE SEQUENCE RESISTANCE MULT. FACTOR  :    0.175000
GENERATOR NEGATIVE SEQUENCE REACTANCE  MULT. FACTOR  :    0.175000
GENERATOR ZERO SEQUENCE RESISTANCE MULT. FACTOR      :    0.037500
GENERATOR ZERO SEQUENCE REACTANCE MULT. FACTOR       :    0.037500
LOAD      NEGATIVE SEQUENCE IMPEDANCE  MULT. FACTOR  :    0.810000
LOAD      ZERO SEQUENCE IMPEDANCE  MULT. FACTOR      :    1.600000
SERIES REACTOR ZERO SEQUENCE IMPEDANCE MULT. FACTOR  :    1.000000
SHUNT  REACTOR ZERO SEQUENCE IMPEDANCE MULT. FACTOR  :    0.625000
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
```

BUS DATA

NODE	STAT	ZONE	BUS-KV	NAME	VMAG-PU	VANG-DEG	PGEN-MW	QGEN-MR
						PLOAD-MW	QLOAD-MR	QCOMP-MR
1	1	1	11.000	BUS1	0.0000	0.000	0.000	0.000
						0.000	0.000	0.000
2	1	2	11.000	BUS2	0.0000	0.000	0.000	0.000
						0.000	0.000	0.000
3	1	2	11.000	BUS3	0.0000	0.000	0.000	0.000
						0.000	0.000	0.000
4	1	1	11.000	BUS4	0.0000	0.000	0.000	0.000
						0.000	0.000	0.000
5	1	1	220.000	BUS5	0.0000	0.000	0.000	0.000
						0.000	0.000	0.000
6	1	1	220.000	BUS6	0.0000	0.000	0.000	0.000
						0.000	0.000	0.000
7	1	1	220.000	BUS7	0.0000	0.000	0.000	0.000
						0.000	0.000	0.000
8	1	1	220.000	BUS8	0.0000	0.000	0.000	0.000
						0.000	0.000	0.000
9	1	1	220.000	BUS9	0.0000	0.000	0.000	0.000
						0.000	0.000	0.000
10	1	1	220.000	BUS10	0.0000	0.000	0.000	0.000
						0.000	0.000	0.000
11	1	1	220.000	BUS11	0.0000	0.000	0.000	0.000
						0.000	0.000	0.000
12	1	1	220.000	BUS12	0.0000	0.000	0.000	0.000
						0.000	0.000	0.000
13	1	1	220.000	BUS13	0.0000	0.000	0.000	0.000
						0.000	0.000	0.000
14	1	1	400.000	BUS14	0.0000	0.000	0.000	0.000
						0.000	0.000	0.000
15	1	1	400.000	BUS15	0.0000	0.000	0.000	0.000
						0.000	0.000	0.000
16	1	1	220.000	BUS16	0.0000	0.000	0.000	0.000
						0.000	0.000	0.000
17	1	1	220.000	BUS17	0.0000	0.000	0.000	0.000
						0.000	0.000	0.000
18	1	2	220.000	BUS18	0.0000	0.000	0.000	0.000
						0.000	0.000	0.000
19	1	2	220.000	BUS19	0.0000	0.000	0.000	0.000
						0.000	0.000	0.000
20	1	2	220.000	BUS20	0.0000	0.000	0.000	0.000
						0.000	0.000	0.000
21	1	2	220.000	BUS21	0.0000	0.000	0.000	0.000
						0.000	0.000	0.000
22	1	2	220.000	BUS22	0.0000	0.000	0.000	0.000
						0.000	0.000	0.000

```
  23    1    2  220.000    BUS23   0.0000    0.000    0.000    0.000
                                              0.000    0.000    0.000
  24    1    2  220.000    BUS24   0.0000    0.000    0.000    0.000
                                              0.000    0.000    0.000
--------------------------------------------------------------------------------
TRANSFORMER DATA

STAT CKTS FROM FROM       TO TO              POSITIVE             ZERO
          NODE NAME     NODE NAME       R(P.U)  X(P.U.) R(P.U.) X(P.U.)
                                           TAP    PHASE  FB-MVA  TB-MVA
---- ---- ---- -------- ---- -------- -------- -------- ------- ------- -- --
   3    2    4     BUS4   15     BUS15  0.00140  0.02804  0.00140  0.02804
                                        1.00000    0.000      50      50  S  D
   3    1   14    BUS14   11     BUS11  0.00063  0.01250  0.00063  0.01250
                                        1.00000    0.000      50      50  G  G
   3    8    5     BUS5    1      BUS1  0.00069  0.01387  0.00069  0.01387
                                        1.00000    0.000      50      50  G  G
   3    1    2     BUS2   18     BUS18  0.00348  0.06968  0.00348  0.06968
                                        1.00000    0.000      50      50  G  G
   3    1    3     BUS3   22     BUS22  0.00280  0.05609  0.00280  0.05609
                                        1.00000    0.000      50      50  G  G

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

TRANSMISSION LINE DATA

STAT CKTS FROM FROM       TO TO
          NODE NAME     NODE NAME      RP(P.U)  XP(P.U) BP/2(PU)
                                       RZ(P.U)  XZ(P.U) BZ/2(PU)  FC-MVA TC-MVA
---- ---- ---- -------- ---- -------- -------- -------- -------- ------ ------
   3    1   15    BUS15   14     BUS14  0.00430  0.04770  0.63700
                                        0.00860  0.09540  0.50000      50     50
   3    1    7     BUS7   11     BUS11  0.02444  0.12226  0.10272
                                        0.07332  0.36677  0.07190      50     50
   3    1   12    BUS12   13     BUS13  0.01321  0.06608  0.05552
                                        0.03963  0.19825  0.03887      50     50
   3    2   13    BUS13   11     BUS11  0.00314  0.01570  0.05275
                                        0.00941  0.04714  0.03692      50     50
   3    1   13    BUS13   16     BUS16  0.00578  0.02891  0.02429
                                        0.01734  0.08674  0.01700      50     50
   3    1   16    BUS16   11     BUS11  0.00495  0.02478  0.02082
                                        0.01486  0.07434  0.01457      50     50
   3    1   16    BUS16   17     BUS17  0.00248  0.01239  0.01041
                                        0.00743  0.03717  0.00729      50     50
   3    4    5     BUS5    6      BUS6  0.00450  0.02251  0.30260
                                        0.01350  0.06753  0.21180      50     50
   3    1    6     BUS6    7      BUS7  0.03716  0.18586  0.15616
                                        0.11147  0.55759  0.10930      50     50
   3    1    6     BUS6   13     BUS13  0.05169  0.25856  0.21723
                                        0.15506  0.77567  0.15210      50     50
```

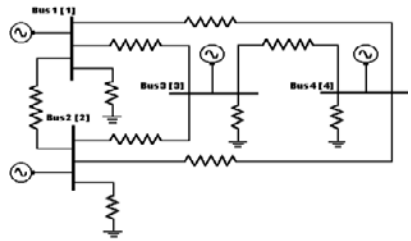
```
   3    3    6     BUS6   16     BUS16  0.01530  0.07655  0.57882
                                        0.04591  0.22964  0.40530     50     50
   3    2    6     BUS6    8      BUS8  0.01239  0.06195  0.20822
                                        0.03716  0.18586  0.14572     50     50
   3    2    8     BUS8    9      BUS9  0.00363  0.01817  0.06107
                                        0.01090  0.05452  0.04276     50     50
   3    2    8     BUS8   10     BUS10  0.00330  0.01652  0.05552
                                        0.00991  0.04956  0.03886     50     50
   3    2   18    BUS18   19     BUS19  0.00537  0.02685  0.09022
                                        0.01610  0.08054  0.06316     50     50
   3    2   19    BUS19    5      BUS5  0.01263  0.06319  0.21237
                                        0.03790  0.18958  0.14866     50     50
   3    2   19    BUS19   20     BUS20  0.01131  0.05658  0.19016
                                        0.03394  0.16975  0.13310     50     50
   3    1   20    BUS20   24     BUS24  0.01982  0.09913  0.08328
                                        0.05945  0.29738  0.05832     50     50
   3    1   24    BUS24    5      BUS5  0.02494  0.12473  0.10480
                                        0.07418  0.37420  0.07336     50     50
   3    1   22    BUS22   23     BUS23  0.03633  0.18173  0.15269
                                        0.10899  0.54520  0.10690     50     50
   3    2   22    BUS22   20     BUS20  0.01734  0.08674  0.29149
                                        0.05202  0.26021  0.20400     50     50
   3    1   22    BUS22   21     BUS21  0.00330  0.01652  0.01388
                                        0.00991  0.04956  0.00972     50     50

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

FROM FROM           POSITIVE         NEGATIVE           ZERO
NODE NAME       R(P.U)  X(P.U.)  R(P.U.)  X(P.U.)  R(P.U.)  X(P.U.) CB-MVA
---- -------- -------- -------- -------- -------- -------- -------- ------


4     BUS4  0.00050  0.02625  0.00050  0.02625  0.00050  0.02625     50

1     BUS1  0.00125  0.03409  0.00125  0.03409  0.00125  0.03409     50
   2     BUS2  0.00100  0.07470  0.00100  0.07480  0.00100  0.07480     50
   3     BUS3  0.00050  0.03735  0.00050  0.03740  0.00050  0.03740     50

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

NODE NAME
---- --------
  11    BUS11
  17    BUS17
   7     BUS7
  12    BUS12
  13    BUS13
   6     BUS6
   9     BUS9
```

```
  10    BUS10
  20    BUS20
  23    BUS23
  21    BUS21
  16    BUS16
  19    BUS19
  24    BUS24
Number of reduced buses: 4
Reduced bus array:
   1     2     3     4
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
POSITIVE SEQUENCE ADMITTANCE MATRIX ELEMENTS FOR THE GIVEN SYSTEM
--------------------------------------------------------------------------------
ROW NO COLUMN NO        REAL   IMAGINARY
------ ---------  ----------  ----------
     1         1     1.57674    -9.97533
     1         2    -0.55642     5.07156
     1         3    -0.48112     3.10001
     1         4    -0.54116     5.82485
     2         1    -0.55642     5.07156
     2         2     0.80100    -6.49955
     2         3    -0.16692     1.67456
     2         4    -0.08116     0.47480
     3         1    -0.48112     3.10001
     3         2    -0.16692     1.67456
     3         3     0.71590    -4.07908
     3         4    -0.06290     0.28943
     4         1    -0.54116     5.82485
     4         2    -0.08116     0.47480
     4         3    -0.06290     0.28943
     4         4     0.77828    -4.28315
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
NEGATIVE SEQUENCE ADMITTANCE MATRIX ELEMENTS FOR THE GIVEN SYSTEM
--------------------------------------------------------------------------------
ROW NO COLUMN NO        REAL   IMAGINARY
------ --------- ---------- ----------
     1         1     1.57674    -9.97533


     1         2    -0.55642     5.07156
     1         3    -0.48112     3.10001
     1         4    -0.54116     5.82485
     2         1    -0.55642     5.07156
     2         2     0.80100    -6.49955
     2         3    -0.16692     1.67456
     2         4    -0.08116     0.47480
     3         1    -0.48112     3.10001
     3         2    -0.16692     1.67456
     3         3     0.71590    -4.07908
```

```
     3         4    -0.06290     0.28943
     4         1    -0.54116     5.82485
     4         2    -0.08116     0.47480
     4         3    -0.06290     0.28943
     4         4     0.77828    -4.28315
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
ZERO SEQUENCE ADMITTANCE MATRIX ELEMENTS FOR THE GIVEN SYSTEM
--------------------------------------------------------------------------------
ROW NO COLUMN NO        REAL   IMAGINARY
------ ---------  ----------  ----------
     1         1     1.85798     2.79557
     1         2    -0.38654     2.97755
     1         3    -0.20996     1.32202
     1         4    -0.00000    -0.00000
     2         1    -0.38654     2.97755
     2         2     0.54724    -3.25450
     2         3    -0.12810     0.93226
     2         4    -0.00000    -0.00000
     3         1    -0.20996     1.32202
     3         2    -0.12810     0.93226
     3         3     0.35595    -1.48148
     3         4    -0.00000    -0.00000
     4         1    -0.00000    -0.00000
     4         2    -0.00000    -0.00000
     4         3    -0.00000    -0.00000
     4         4     0.00000     0.00000
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
RETAINED ZONE :    0
NUMBER OF SERIES ELEMENTS IN THE REDUCED ZONES :    6
SERIES CONNECTIONS
SLNO FROM     NAME   TO     NAME     RP       XP       BP/2 RZ       XZ       BZ/2
---- ---- -------- ---- -------- -------- -------- ---- -------- -------- ----
   1    1     BUS1    2     BUS2 0.021376 0.194833  0.0 0.042877 0.330280  0.0
   2    1     BUS1    3     BUS3 0.048886 0.314993  0.0 0.117178 0.737806  0.0
   3    1     BUS1    4     BUS4 0.015813 0.170209  0.0 0.000000 9999.000  0.0
   4    2     BUS2    3     BUS3 0.058939 0.591298  0.0 0.144667 1.052787  0.0
   5    2     BUS2    4     BUS4 0.349794 2.046351  0.0 0.000000 9999.000  0.0
   6    3     BUS3    4     BUS4 0.717003 3.299303  0.0 0.000000 9999.000  0.0
--------------------------------------------------------------------------------
NUMBER OF SHUNT ELEMENTS IN THE REDUCED ZONES :    4
SHUNT CONNECTIONS IN (G+JB) FORMAT - PU
SLNO FROM     NAME     GP       BP       GZ       BZ
---- ---- -------- -------- -------- -------- --------
   1    1     BUS1 -0.00196  4.02109  1.26147  7.09515
   2    2     BUS2 -0.00350  0.72137  0.03259  0.65530
   3    3     BUS3  0.00497  0.98491  0.01788  0.77280
   4    4     BUS4  0.09307  2.30593 -0.00000 -0.00000
--------------------------------------------------------------------------------
```

Reduced system

Retaining all generator buses



Procedure to do Case 2

CASE 2 : Retaining all generator buses and zone 1 buses

Fig 1 24Bus system is reduced with retaining all the buses to which the generators are connected, and buses belonging to Zone1, such as 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, and 17 are also retained. All connections in zone 2 are reduced as equivalent series impedance and shunt admittance.

Select menu option **Solve ➔ Network Reduction**

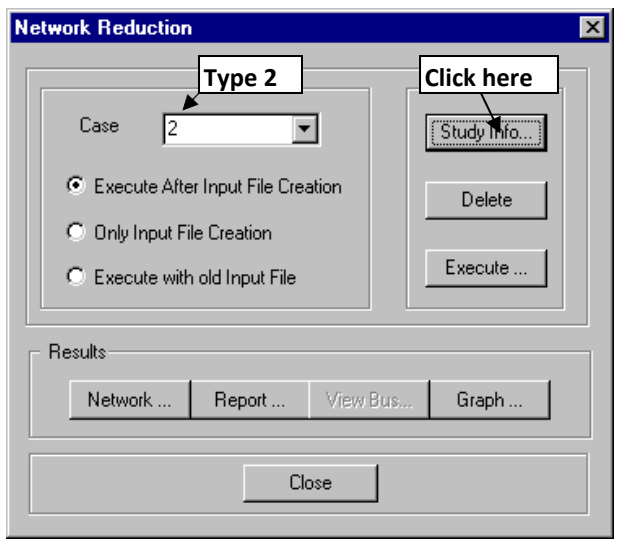


Figure 16: Network Reduction case 2

Study Information

Following study information screen will open. In that select zone 1 buses and all generator buses.

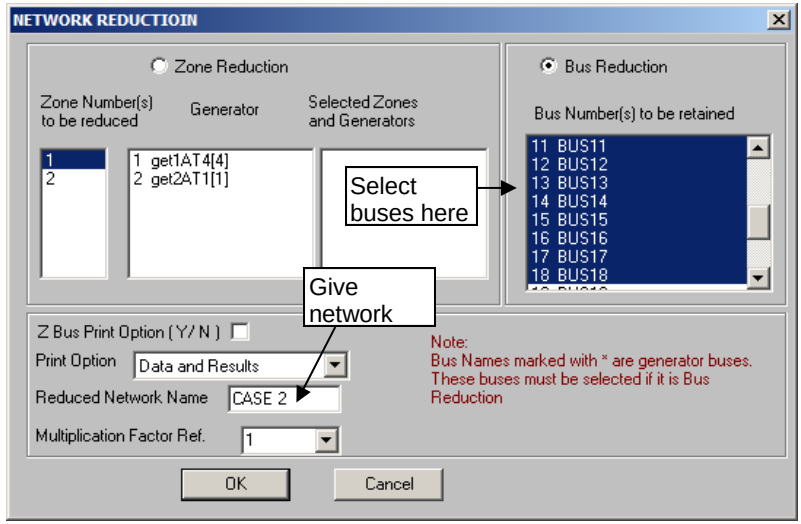


Figure 17: Study information

Executing and viewing the report

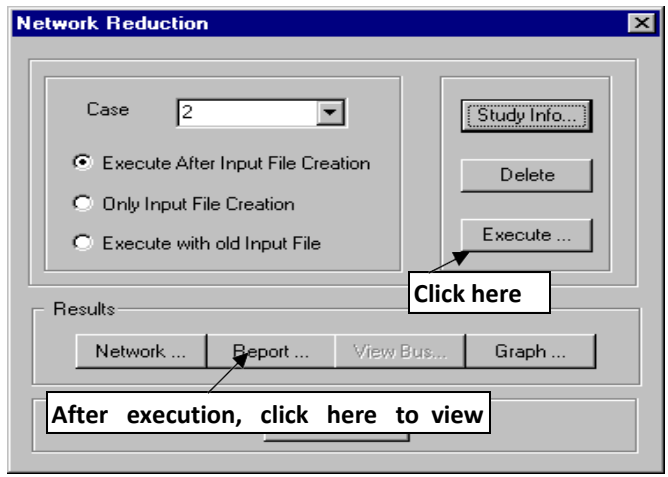


Figure 18: Executing and viewing the report

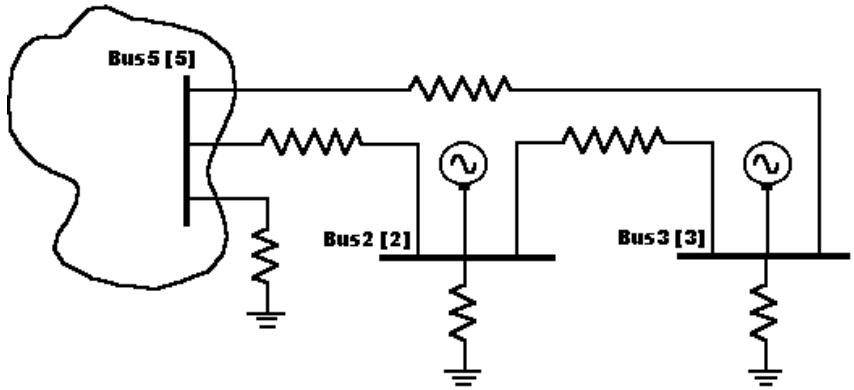
Network Reduction Report for case 2

NETWORK REDUCTION

```
CASE NO :  12     CONTINGENCY  : 0  SCHEDULE NO : 0
CONTINGENCY NAME : Base Case
------------------------------------------------------------------------------
%%
TOTAL NUMBER OF BUSES          :   24    ACTUAL NUMBER OF BUSES         :   24
NUMBER OF 2 WIND. TRANSFORMERS :    5    NUMBER OF 3 WIND. TRANSFORMERS :    0
NUMBER OF TRANSMISSION LINES   :   22
NUMBER OF SERIES REACTORS      :    0    NUMBER OF SERIES CAPACITORS    :    0
NUMBER OF BUS COUPLERS         :    0
NUMBER OF SHUNT REACTORS       :    0    NUMBER OF SHUNT CAPACITORS     :    0
NUMBER OF SHUNT IMPEDANCES     :    0    NUMBER OF GENERATORS           :    4
NUMBER OF LOADS                :   14
NUMBER OF FILTERS              :    0

NUMBER OF HVDC CONVERTORS      :    0

------------------------------------------------------------------------------
NUMBER OF ZONES         :  2
PRINT OPTION            :  3 (BOTH DATA AND RESULTS PRINT)
BASE MVA                :  100.000
NOMINAL SYSTEM FREQUENCY:   50.000
PREFAULT VOLTAGE OPTION : 1 (READ FROM THE FILE)
ZONE NUMBER RETAINED    :  0
ZBUS PRINT OPTION       :  0
YBUS REDUCTION OPTION   :  1 (NETWORK REDUCTION)
------------------------------------------------------------------------------
  17
   1     2     3     4     5     6     7     8     9    10
  11    12    13    14    15    16    17
------------------------------------------------------------------------------
CIRCUIT BREAKER RESISTANCE (PU)                     :   0.000000
CIRCUIT BREAKER REACTANCE  (PU)                     :   0.000100
TRANSFORMER R/X RATIO                               :   0.050000
TRANSFORMER ZERO SEQUENCE IMPEDANCE MULT FACTOR     :   0.900000

NUMBER OF TRANSMISSION VOLTAGE LEVELS               : 3
TRANSMISSION LINE VOLTAGE - KV                      :  11.000000
TRANSMISSION  LINE  ZERO  SEQUENCE  RES.  MULT.  FACTOR  :  0.000000
TRANSMISSION  LINE  ZERO  SEQUENCE  REA.  MULT.  FACTOR  :  0.000000
TRANSMISSION  LINE  ZERO  SEQUENCE  ADM.  MULT.  FACTOR  :  0.000000
TRANSMISSION LINE VOLTAGE - KV                      : 220.000000
TRANSMISSION  LINE  ZERO  SEQUENCE  RES.  MULT.  FACTOR  :  2.500000
TRANSMISSION  LINE  ZERO  SEQUENCE  REA.  MULT.  FACTOR  :  2.500000
TRANSMISSION  LINE  ZERO  SEQUENCE  ADM.  MULT.  FACTOR  :  0.025000
TRANSMISSION LINE VOLTAGE - KV                      : 400.000000
TRANSMISSION LINE ZERO SEQUENCE RES. MULT. FACTOR    :   2.500000
```

```
TRANSMISSION LINE ZERO SEQUENCE REA. MULT. FACTOR    :    2.500000
TRANSMISSION LINE ZERO SEQUENCE ADM. MULT. FACTOR    :    0.025000
GENERATOR NEGATIVE SEQUENCE RESISTANCE MULT. FACTOR  :    0.175000
GENERATOR NEGATIVE SEQUENCE REACTANCE  MULT. FACTOR  :    0.175000
GENERATOR ZERO SEQUENCE RESISTANCE MULT. FACTOR      :    0.037500
GENERATOR ZERO SEQUENCE REACTANCE MULT. FACTOR       :    0.037500
LOAD      NEGATIVE SEQUENCE IMPEDANCE  MULT. FACTOR  :    0.810000
LOAD      ZERO SEQUENCE IMPEDANCE  MULT. FACTOR      :    1.600000
SERIES REACTOR ZERO SEQUENCE IMPEDANCE MULT. FACTOR  :    1.000000
SHUNT  REACTOR ZERO SEQUENCE IMPEDANCE MULT. FACTOR  :    0.625000
-------------------------------------------------------------------
Number of reduced buses : 17
Reduced bus array :
   1     2     3     4     5     6     7     8     9    10
  11    12    13    14    15    16    17
-------------------------------------------------------------------------------
RETAINED ZONE :    0
NUMBER OF SERIES ELEMENTS IN THE REDUCED ZONES :    3
SERIES CONNECTIONS
SLNO FROM     NAME   TO     NAME      RP       XP       BP/2 RZ       XZ       BZ/2
---- ---- -------- ---- -------- -------- -------- ---- -------- -------- ----
   1    2     BUS2    3     BUS3 0.052959 0.698685  0.0 0.144805 1.117180  0.0
   2    2     BUS2    5     BUS5 0.021307 0.167338  0.0 0.053638 0.341475  0.0
   3    3     BUS3    5     BUS5 0.046777 0.270327  0.0 0.142020 0.762220  0.0
-------------------------------------------------------------------------------
NUMBER OF SHUNT ELEMENTS IN THE REDUCED ZONES :    3
SHUNT CONNECTIONS IN (G+JB) FORMAT - PU
SLNO FROM     NAME     GP       BP       GZ       BZ
---- ---- -------- -------- -------- -------- --------
   1    2     BUS2  0.02202  0.39125  0.01230  0.36643
   2    3     BUS3  0.02972  0.78283  0.01249  0.64382
   3    5     BUS5 -0.03960  1.19377 -0.01182  0.66770
-------------------------------------------------------------------------------
```

Reduced network retaining all generator buses and zone 1 buses is shown below.



Case 3 : Retaining all zone 1 buses

24 Bus Typical System Network reduced with retaining all the Zone1 buses, such as 1, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, and 17.

Select menu option **Solve ➔Network Reduction**

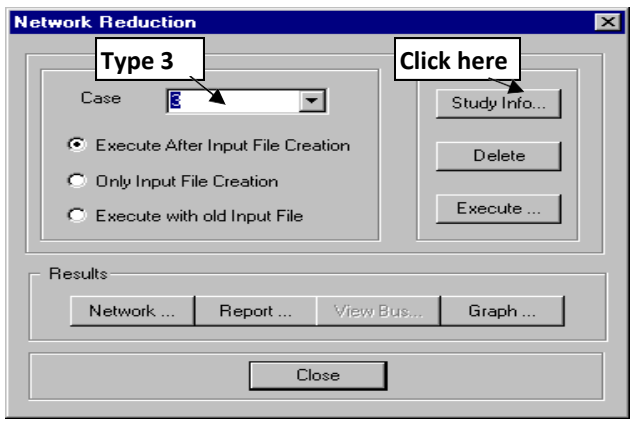


Figure 19: Type 3 network Reduction

Study Information

Following study information screen will open.

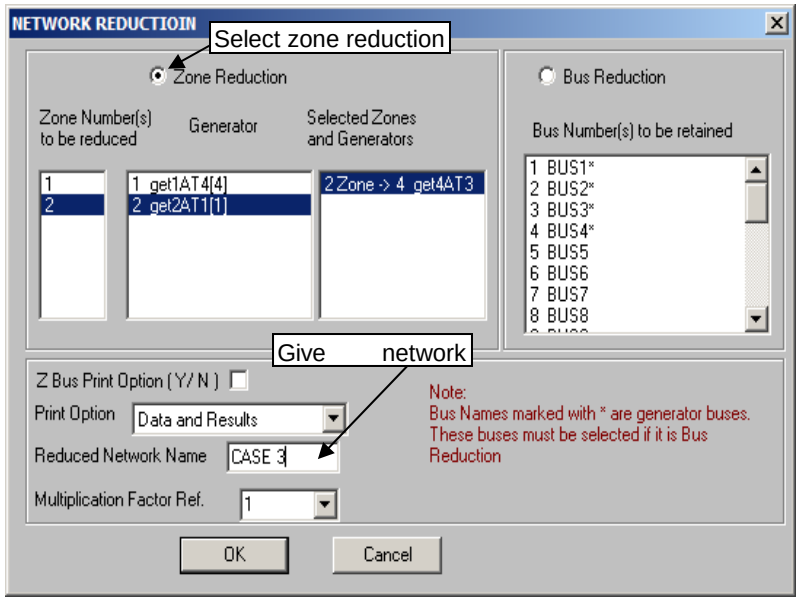


Figure 20: Select zone reduction

Executing and Viewing the Report

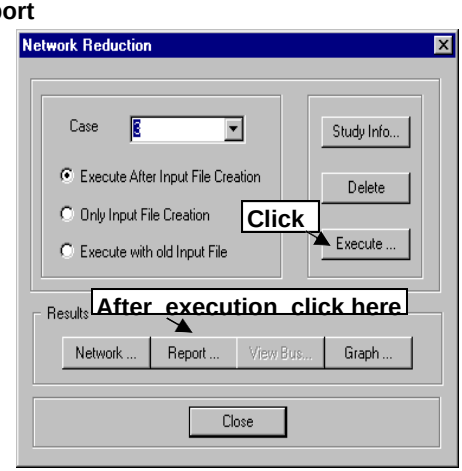


Figure 21: Executing and Viewing the Report

Network Reduction Report for Case 3 :

NETWORK REDUCTION
CASE NO : 13 CONTINGENCY : 0 SCHEDULE NO : 0
CONTINGENCY NAME : Base Case

```
--------------------------------------------------------------------------------
%%
TOTAL NUMBER OF BUSES          :   24    ACTUAL NUMBER OF BUSES         :   24
NUMBER OF 2 WIND. TRANSFORMERS :    5    NUMBER OF 3 WIND. TRANSFORMERS :    0
NUMBER OF TRANSMISSION LINES   :   22
NUMBER OF SERIES REACTORS      :    0    NUMBER OF SERIES CAPACITORS    :    0
NUMBER OF BUS COUPLERS         :    0
NUMBER OF SHUNT REACTORS       :    0    NUMBER OF SHUNT CAPACITORS     :    0
NUMBER OF SHUNT IMPEDANCES     :    0    NUMBER OF GENERATORS           :    4
NUMBER OF LOADS                :   14
NUMBER OF FILTERS              :    0

NUMBER OF HVDC CONVERTORS      :    0

--------------------------------------------------------------------------------
NUMBER OF ZONES         :  2
PRINT OPTION            :  3 (BOTH DATA AND RESULTS PRINT)
BASE MVA                :  100.000
NOMINAL SYSTEM FREQUENCY:   50.000
PREFAULT VOLTAGE OPTION : 1 (READ FROM THE FILE)
ZONE NUMBER RETAINED    :  1
ZBUS PRINT OPTION       :  0


YBUS REDUCTION OPTION   :  1 (NETWORK REDUCTION)
--------------------------------------------------------------------------------
NUMBER OF GENERATORS IN THE EXTERNAL SYSTEM   :    2
RETAINED GENERATOR BUS IN THE EXTERNAL SYSTEM :    3

--------------------------------------------------------------------------------
CIRCUIT BREAKER RESISTANCE (PU)                       :   0.000000
CIRCUIT BREAKER REACTANCE  (PU)                       :   0.000100
TRANSFORMER R/X RATIO                                 :   0.050000
TRANSFORMER ZERO SEQUENCE IMPEDANCE MULT FACTOR       :   0.900000

NUMBER OF TRANSMISSION VOLTAGE LEVELS                 : 3
TRANSMISSION LINE VOLTAGE - KV                        :  11.000000
TRANSMISSION LINE ZERO SEQUENCE RES. MULT. FACTOR     :   0.000000
TRANSMISSION LINE ZERO SEQUENCE REA. MULT. FACTOR     :   0.000000
TRANSMISSION LINE ZERO SEQUENCE ADM. MULT. FACTOR     :   0.000000
TRANSMISSION LINE VOLTAGE - KV                        : 220.000000
TRANSMISSION  LINE  ZERO  SEQUENCE  RES.  MULT.  FACTOR  :  2.500000
TRANSMISSION  LINE  ZERO  SEQUENCE  REA.  MULT.  FACTOR  :  2.500000
TRANSMISSION LINE ZERO SEQUENCE ADM. MULT. FACTOR     :   0.025000
```

```
TRANSMISSION LINE VOLTAGE - KV                          :  400.000000
TRANSMISSION LINE ZERO SEQUENCE RES. MULT. FACTOR       :    2.500000
TRANSMISSION LINE ZERO SEQUENCE REA. MULT. FACTOR       :    2.500000
TRANSMISSION LINE ZERO SEQUENCE ADM. MULT. FACTOR       :    0.025000

GENERATOR NEGATIVE SEQUENCE RESISTANCE MULT. FACTOR  :    0.175000
GENERATOR NEGATIVE SEQUENCE REACTANCE  MULT. FACTOR  :    0.175000
GENERATOR ZERO SEQUENCE RESISTANCE MULT. FACTOR      :   0.037500
GENERATOR ZERO SEQUENCE REACTANCE MULT. FACTOR       :    0.037500
LOAD      NEGATIVE SEQUENCE IMPEDANCE  MULT. FACTOR  :    0.810000
LOAD      ZERO SEQUENCE IMPEDANCE  MULT. FACTOR      :    1.600000
SERIES REACTOR ZERO SEQUENCE IMPEDANCE MULT. FACTOR  :    1.000000
SHUNT  REACTOR ZERO SEQUENCE IMPEDANCE MULT. FACTOR  :    0.625000
------------------------------------------------------------------------------
------------------------------------------------------------------------------
BUS DATA
NODE  STAT  ZONE BUS-KV   NAME     VMAG-PU  VANG-DEG  PGEN-MW  QGEN-MR
                                             PLOAD-MW QLOAD-MR QCOMP-MR
---- ---- ---- -------- -------- -------- -------- -------- --------
   1    1    1   11.000      BUS1   1.0200    0.000  563.710   19.590
                                               0.000    0.000    0.000
   2    1    2   11.000      BUS2   1.0200    1.609  125.000   22.500
                                               0.000    0.000    0.000
   3    1    2   11.000      BUS3   1.0200    3.521  190.000   39.570
                                               0.000    0.000    0.000
   4    1    1   11.000      BUS4   1.0200    3.906  380.000   35.270
                                               0.000    0.000    0.000
   5    1    1  220.000      BUS5   1.0164   -4.319    0.000    0.000
                                               0.000    0.000    0.000
   6    1    1  220.000      BUS6   1.0050  -10.410    0.000    0.000
                                              70.240   30.100   30.000
   7    1    1  220.000      BUS7   0.9676  -19.848    0.000    0.000
                                             146.630   39.100   30.000
   8    1    1  220.000      BUS8   0.9756  -14.538    0.000    0.000
                                               0.000    0.000    0.000
   9    1    1  220.000      BUS9   0.9737  -14.852    0.000    0.000
                                              29.450    9.820    0.000


  10    1    1  220.000     BUS10   0.9650  -15.333    0.000    0.000
                                              87.820   48.790    0.000
  11    1    1  220.000     BUS11   0.9733  -15.094    0.000    0.000
                                              34.350   14.720    0.000
  12    1    1  220.000     BUS12   0.9567  -17.674    0.000    0.000
                                              29.100    9.700    0.000
  13    1    1  220.000     BUS13   0.9641  -16.518    0.000    0.000
                                             146.270   58.510    0.000
  14    1    1  400.000     BUS14   0.9814  -12.324    0.000    0.000
                                               0.000    0.000    0.000
  15    1    1  400.000     BUS15   1.0104   -2.002    0.000    0.000
                                               0.000    0.000    0.000
```

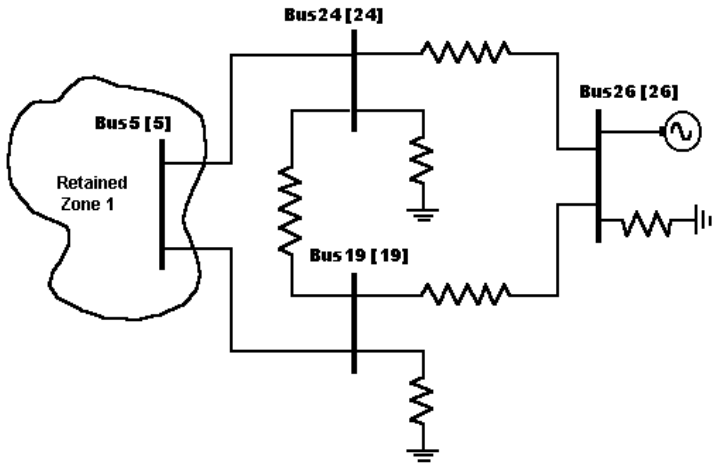
```
  16    1    1  220.000    BUS16    0.9638   -16.860    0.000    0.000
                                              224.240   58.500    0.000
  17    1    1  220.000    BUS17    0.9593   -17.271    0.000    0.000
                                               58.310   24.300    0.000
  18    1    2  220.000    BUS18    1.0039    -3.226    0.000    0.000
                                                0.000    0.000    0.000
  19    1    2  220.000    BUS19    0.9922    -5.084    0.000    0.000
                                              129.290   99.460    0.000
  20    1    2  220.000    BUS20    0.9910    -5.827    0.000    0.000
                                               49.690   34.780    0.000
  21    1    2  220.000    BUS21    0.9882    -3.029    0.000    0.000
                                               72.400   47.600    0.000
  22    1    2  220.000    BUS22    0.9984    -2.423    0.000    0.000
                                                0.000    0.000    0.000
  23    1    2  220.000    BUS23    0.9470    -7.400    0.000    0.000
                                               48.170   28.900    0.000
  24    1    2  220.000    BUS24    0.9726    -7.973    0.000    0.000
                                               93.190   49.050    0.000
--------------------------------------------------------------------------------
TRANSFORMER DATA

STAT CKTS FROM FROM       TO TO              POSITIVE              ZERO
          NODE NAME     NODE NAME       R(P.U)  X(P.U.) R(P.U.) X(P.U.)
                                           TAP     PHASE  FB-MVA  TB-MVA
---- ---- ---- -------- ---- -------- -------- -------- ------- ------- -- --
   3    2    4     BUS4   15     BUS15  0.00140  0.02804  0.00140  0.02804
                                        1.00000    0.000      50      50  S  D
   3    1   14    BUS14   11     BUS11  0.00063  0.01250  0.00063  0.01250
                                        1.00000    0.000      50      50  G  G
   3    8    5     BUS5    1      BUS1  0.00069  0.01387  0.00069  0.01387
                                        1.00000    0.000      50      50  G  G
   3    1    2     BUS2   18     BUS18  0.00348  0.06968  0.00348  0.06968
                                        1.00000    0.000      50      50  G  G
   3    1    3     BUS3   22     BUS22  0.00280  0.05609  0.00280  0.05609
                                        1.00000    0.000      50      50  G  G

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

STAT CKTS FROM FROM       TO TO
          NODE NAME     NODE NAME       RP(P.U)  XP(P.U) BP/2(PU)
                                        RZ(P.U)  XZ(P.U) BZ/2(PU) FC-MVA TC-MVA
---- ---- ---- -------- ---- -------- -------- -------- -------- ------ ------
   3    1   15    BUS15   14     BUS14  0.00430  0.04770  0.63700
                                        0.00860  0.09540  0.50000     50     50


   3    1    7     BUS7   11     BUS11  0.02444  0.12226  0.10272
                                        0.07332  0.36677  0.07190     50     50
   3    1   12    BUS12   13     BUS13  0.01321  0.06608  0.05552
                                        0.03963  0.19825  0.03887     50     50
```

```
   3    2   13    BUS13   11    BUS11   0.00314  0.01570  0.05275
                                        0.00941  0.04714  0.03692     50     50
   3    1   13    BUS13   16    BUS16   0.00578  0.02891  0.02429
                                        0.01734  0.08674  0.01700     50     50
   3    1   16    BUS16   11    BUS11   0.00495  0.02478  0.02082
                                        0.01486  0.07434  0.01457     50     50
   3    1   16    BUS16   17    BUS17   0.00248  0.01239  0.01041
                                        0.00743  0.03717  0.00729     50     50
   3    4    5     BUS5    6     BUS6   0.00450  0.02251  0.30260
                                        0.01350  0.06753  0.21180     50     50
   3    1    6     BUS6    7     BUS7   0.03716  0.18586  0.15616
                                        0.11147  0.55759  0.10930     50     50
   3    1    6     BUS6   13    BUS13   0.05169  0.25856  0.21723
                                       0.15506  0.77567  0.15210     50     50
   3    3    6     BUS6   16    BUS16   0.01530  0.07655  0.57882
                                        0.04591  0.22964  0.40530     50     50
   3    2    6     BUS6    8     BUS8   0.01239  0.06195  0.20822
                                        0.03716  0.18586  0.14572     50     50
   3    2    8     BUS8    9     BUS9   0.00363  0.01817  0.06107
                                        0.01090  0.05452  0.04276     50     50
   3    2    8     BUS8   10    BUS10   0.00330  0.01652  0.05552
                                        0.00991  0.04956  0.03886     50     50
   3    2   18    BUS18   19    BUS19   0.00537  0.02685  0.09022
                                        0.01610  0.08054  0.06316     50     50
   3    2   19    BUS19    5     BUS5   0.01263  0.06319  0.21237
                                        0.03790  0.18958  0.14866     50     50
   3    2   19    BUS19   20    BUS20   0.01131  0.05658  0.19016
                                        0.03394  0.16975  0.13310     50     50
   3    1   20    BUS20   24    BUS24   0.01982  0.09913  0.08328
                                        0.05945  0.29738  0.05832     50     50
   3    1   24    BUS24    5     BUS5   0.02494  0.12473  0.10480
                                        0.07418  0.37420  0.07336     50     50
   3    1   22    BUS22   23    BUS23   0.03633  0.18173  0.15269
                                        0.10899  0.54520  0.10690     50     50
   3    2   22    BUS22   20    BUS20   0.01734  0.08674  0.29149
                                        0.05202  0.26021  0.20400     50     50
   3    1   22    BUS22   21    BUS21   0.00330  0.01652  0.01388
                                        0.00991  0.04956  0.00972     50     50

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

FROM FROM           POSITIVE          NEGATIVE           ZERO
NODE NAME       R(P.U)  X(P.U.)  R(P.U.)  X(P.U.)  R(P.U.)  X(P.U.) CB-MVA
---- -------- -------- -------- -------- -------- -------- -------- ------
   4     BUS4  0.00050  0.02625  0.00050  0.02625  0.00050  0.02625     50
   1     BUS1  0.00125  0.03409  0.00125  0.03409  0.00125  0.03409     50
   2     BUS2  0.00100  0.07470  0.00100  0.07480  0.00100  0.07480     50
   3     BUS3  0.00050  0.03735  0.00050  0.03740  0.00050  0.03740     50

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

LOAD DATA

```
NODE NAME
---- --------
  11    BUS11
  17    BUS17
   7     BUS7
  12    BUS12
  13    BUS13
   6     BUS6
   9     BUS9
  10    BUS10
  20    BUS20
  23    BUS23
  21    BUS21
  16    BUS16
  19    BUS19
  24    BUS24
--------------------------------------------------------------------------------

EXTERNAL GENERATOR DATA
SLNO BUSNO NAME     INERTIA-H-PU
---- ----- -------- ------------
   1     2     BUS2       11.413
   2     3     BUS3       11.413
Number of reduced buses : 4
Reduced bus array :
  26    25    19    24
--------------------------------------------------------------------------------
RETAINED ZONE:    1
NUMBER OF SERIES ELEMENTS IN THE REDUCED ZONES:    3
SERIES CONNECTIONS
SLNO FROM   NAME     TO    NAME     RP        XP      BP/2         RZ           XZ
BZ/2
---- ---- ------- ----- -------- -------- -------- -------   ----------- -------
---- ------
   1    26        GEN3     19      BUS19  0.005764  0.110167   0.0        0.035423
0.769343  0.0
   2    26        GEN3     24      BUS24  0.032432  0.587300   0.0        0.062020
1.347783  0.0
   3    19      BUS19     24      BUS24  0.035152  0.187472   0.0        0.099468
0.620119  0.0
--------------------------------------------------------------------------------
---
NUMBER OF SHUNT ELEMENTS IN THE REDUCED ZONES :    3
SHUNT CONNECTIONS IN (G+JB) FORMAT - PU
SLNO FROM    NAME     GP        BP        GZ        BZ
---- ---- -------- -------- -------- -------- --------
   1   19    BUS19  1.90970 -0.24798  2.10356 -5.24444
   2   24    BUS24  1.31295 -0.34366  1.20133 -0.48369
   3   26     GEN3  0.82939 -0.61373  0.91642 -0.43791
```

```
--------------------------------------------------------------------------------
EQUIVALENT GENERATOR INERTIA CONSTANT - PU :    22.82422
EQUIVALENT GENERATOR REAL POWER       - MW :   315.55176
EQUIVALENT GENERATOR REACTIVE POWER - MVAR :    86.34813
EQUIVALENT GENERATOR TERMINAL VOLTAGE MAG  :     1.00000


EQUIVALENT GENERATOR TERMINAL VOLTAGE ANG-D:     6.99663
EQUIVALENT GENERATOR RESISTANCE  PU        :     0.00000
EQUIVALENT GENERATOR REACTANCE   PU        :    0.00001
 --------------------------------------------------------------------------------
```



Reduced system for case 3: Retaining all Zone 1 buses

3. INPUT FORMAT

Input data to **POWERYBR** is through an ASCII file. The file name is "**YBRIN**". Results are written to files " **YBROUT**" and "**YBRTOETC**". Significance and contents of these files are explained in chapter 3.

The input data is read in free format. Input data is divided into different heads called streams for explanation purposes. `*int*' is used to indicate that the data type is an integer. `*float*' is used to reference the floating point (real) variable. Character streams (string) are indicated by `*char*' type.

In order to reduce the effort in preparing the data, input format for **POWERYBR** is retained almost same as that required for short circuit study. Hence the document on Short Circuit Study module (Chapter two, Short Circuit Study data preparation for **POWERSCS**) can be referred for further details. Only those changes in the input data format from the input data format of **POWRESCS** are explained in this section. The changes are only in stream 2, i.e., System Specification. In stream 2 -

- Line 1 which describes the system size definition remains unaltered.
- Program control options given in line 2 and 3 differ in " **YBRIN**".

In table 2.1, the data appearing in different columns of line 2 are given.

Table 3.1: System Specification - Line 2 : Control Option

Col. No	Description	Type	Min	Max
1.	Number of zones	int	0	20
2.	Print option	int	0	4
3.	Base MVA	float	0.1	10000.0
4.	Nominal system frequency	float	0.1	100.0
5.	Initial voltage option	int	0	1
6.	Zone number buses retained	int	0	20
7.	Z bus print option	int	0	1
8.	Y bus reduction option	int	0	1

Explanation to entries given in table 2.1, are as follows

In power system, the equipments are owned by different utilities, and in a same utility, equipments belong to different zones. Hence each bus is associated with a number called zone. All the equipments (shunt elements) connected to the bus are attributed to the zone of the bus. In case of series elements, the line belongs to the zone of the from bus (sending bus). Number of zones in the given power system are given in column 1.

- Print option in table 2.1 is interpreted as -
  - 0 : No printing of data or results.
  - 1 : Data printing only.
  - 2 : Results printing only.
  - 3 : Both data and results printing.
  - 4 : Detailed printing of data and results.

- Network parameter (resistance, reactance etc.,) data to **POWERYBR** is in pu on a common MVA base. The common MVA base is provided in column 3 of table 2.1.

- Initial voltage option is interpreted as -
  - 0 : Initial voltage of 1.0 pu is assumed at all the buses.
  - 1 : Initial voltage is read from the file.

For preparing the data file subsequently used for load flow analysis, dynamic stability study and transient stability study ("LFAIN" file of POWERLFA, "**DYSIN**" file of **POWERDYS** and "**TRSOUT**" file of **POWERTRS**) initial voltage option should be always 1. Data for initial voltage and operating condition of the system are given in bus data stream. Column 6 entry is interpreted based on the YBUS reduction option as given in column 8.

- If the YBUS reduction option is 1, then this entry gives the number of buses in the retained system. In the practical power system, buses are grouped to form different zones/areas. If the zone number in column 6 is other than zero, and the YBUS reduction option is 1, then the corresponding zone is retained. This implies, the network elements internal to the system and also the tie line connections are retained. If the zone number is zero (0), then the nodes specified in the subsequent stream are retained.

- Zbus option is interpreted as -
  - 0 : No print of Zbus for the reduced system.
  - 1 : Zbus for the reduced system is printed.

- YBUS reduction option given in column 8 is interpreted as -
  - 0 : YBUS reduction option for dynamic stability study.

  - 1 : YBUS reduction option for static and dynamic equivalents.

- Line 3 of stream 2 is interpreted as -
  - If the YBUS reduction option is 0, bus numbers to be retained are given (int filed separated by blanks).

  - If the YBUS reduction option is 1, and the retained zone number field is zero (0), then the first entry gives the number of buses retained in the original system (int field). Subsequently, bus numbers to be retained are given (int field separated by blanks).

  - If the YBUS reduction option is 1, and the retained zone number field is other than zero (0), two values (int fields) are read. First value indicates the number of generators in the external system. Second field indicates the generator bus number in the external system to be considered as reference. If there are no generators in the external system, then both the values are entered as zero (0).

- Line 4 in "**SCSIN**" which gives the fault impedance data is not present in "**YBRIN**".

- Line 5, which gives the multiplication factors, remains unaltered in "**YBRIN**".

- Line 6, which gives the travelling shunt fault, is not present in "**YBRIN**".

If the YBUS reduction option is 1, i.e., equivalent generator is considered, for each retained generator bus, bus number and the corresponding inertia constant in pu on a common base are given as the last stream.

4. INPUT/OUTPUT FILES

Table 3.1 gives names of different input and output files used by **POWERYBR**.

Table 4.1: Input and Output Files of POWERYBR

Sl. No.	File Name	Mode	Description
1.	"**YBRIN**"	input	Program input file
2.	"**YBROUT**"	output	Program output (general report) file
3.	**"YBRTOETC**"	output	File in pre-defined format used by other programs.

"**YBROUT**" file contains -

- Input data to the program, in the order the data is read.
- New order for the buses, if the report option is 4.
- Ybus element values for the system, if the report option is 4.
- Zbus element values if the report option is 4.
- Zbus of the reduced system if the Zbus option is 1.
- Positive, negative and zero sequence bus admittance matrix elements in rectangular form.
- Additional series and shunt connections data, arising because of the network reduction.

"**YBRTOETC**" file contains -

- If the YBUS reduction option is 0 -
  - Number of buses in the reduced system (one int field).

  For each elements of positive sequence Ybus -
    - row number (int field),
    - column number (int field),
    - real value (float field),
    - imaginary value (float filed),

in the row wise and column wise.
- Negative sequence and Zero sequence Ybus elements in the above order.

- If the YBUS reduction option is 1 -
  - Zone number retained (int field).
  - Number of additional series elements due to network reduction (int field).
  - For each series element, from node and to node numbers (int fields), positive sequence resistance, reactance and susceptance (b/2), and zero sequence resistance, reactance and susceptance (b/2) in pu on the given base (6 float fields).
  - Number of shunt elements, arising because of the network reduction (int field).
  - For each shunt element, from node number (int field), positive sequence conductance and susceptance (G+jB), and zero sequence conductance and susceptance in pu on the given base (4 float fields).
  - Number of generators retained in the external system (int field). If this value is zero, subsequent entries will not be present.
  - For each retained generator, generator bus number (int field), equivalent inertia H in pu on a common base, real power generation in MW, reactive power generation in Mvar, bus voltage in pu, bus angle in degrees,
  - Equivalent generator resistance and reactance in pu on a common base (totally 7 float fields). While reducing the network, generator internal buses are considered. Hence the resistance value is 0.0, and the reactance value is negligible.

Contents of YBRTOETC file can be made use of by other programs.

The file names in table 3.1 are the default, when no arguments (parameters) are passed to **POWERYB**.

Error Messages

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

Error Number Error Message Error Description

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

The errors identified by the program are -

- **[Error no 0]** Parameter passing error : If there is an error in passing parameters to the program, then an error is reported. In the description, the missing parameter is named.

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

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

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

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

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

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

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

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

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

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

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

For example the input file is - **ybrin** and **ybrout** is output (report) file, then if input file is not found in the current working directory, or error while opening the file, or insufficient data being present in the data file, or the bus number given for any element is not mentioned in the bus data stream, the message generated will be as follows.

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 24-bus system is considered as an example to test **POWERYBR** single line diagram of a sample 24-node system in figure 5.1. Four different cases are considered to show the capability of **POWERYBR**.

The different cases are as follows:

- **Case 1** : Reduced system with only generator buses being retained.
- **Case 2** : Reduced system with retaining generator buses and buses belonging to Zone 1 only.
- **Case 3** : Reduced system with retaining buses belongs to Zone 1 only.
- **Case 4** : Reduced system for dynamic stability.

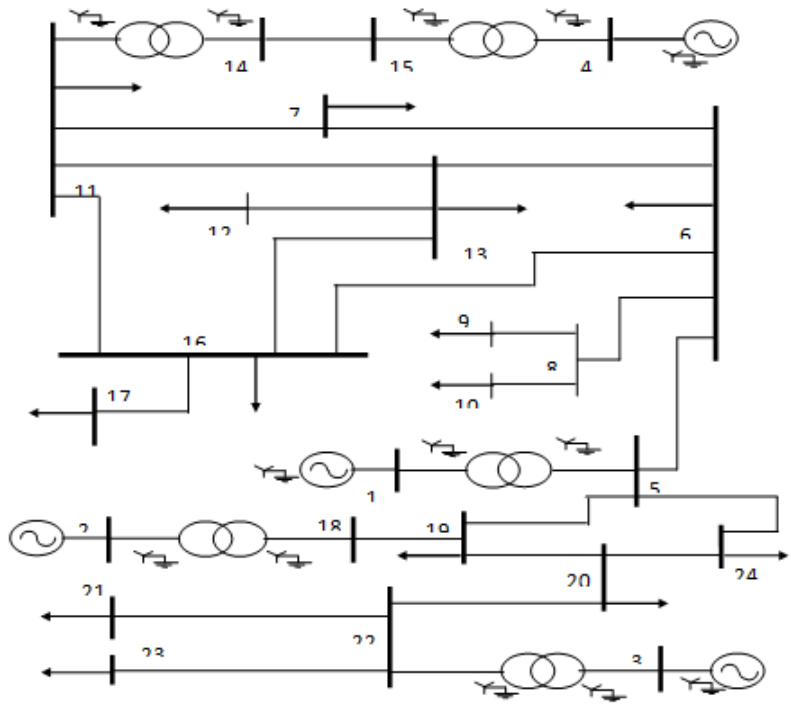


Figure 22: Sample 24 node System

5.1 Case 1: Retaining all generator buses

In this case, the sample system shown in figure 5.1 is reduced all the buses to which the generators are connected, such as equivalent series impedances between the retained buses and shunt admittances at the retained buses. The detailed listing of "YBRIN" and "YBROUT" files is given in Reportd 5.1 and 5.2 respectively. The single line diagram of the reduced system is shown in figure 5.2

" YBRIN" File Listing for Case 1.

```
NETWORK  REDUCTION
CASE NO :  1     CONTINGENCY  : 0    SCHEDULE NO : 0

% Common System Specifications
  24    24     5     0    22     0     0     0     0     0   0
   4    14     0     0

% Control Options
% 1. No of Areas   2. YBUS print Option
% 3. BaseMVA       4. Nominal Freq   5. PreFaultOpt
   2     3     100.000000   50.0000 1

% 6. ZoneNo Retained   7. ZBUS Print Option
% 8. YBUS Reduction Option
   0   3  1

% Retained Buses
   4
   1    2    3    4

% CBResistance CBReactance Trans R/X
 0.000000   0.000100   0.050000

% Multiplication Factors
% 1. Transformer Zero Seq Impedance Factor
% 2. No Of Voltage Levels
%      i. Transmission Line Voltage
%     ii. Transmission Line Zero Seq Res Mult Factor
%    iii. Transmission Line Zero Seq Rea Mult Factor
%     iv. Transmission Line Zero Seq Adm Mult Factor
% 3. Generator Negative Seq Resistance Mult Fact
% 4. Generator Negative Seq Reactance Mult Fact
% 5. Generator Zero Seq Resistance Mult Fact
% 6. Generator Zero Seq Reactance Mult Fact
% 7. Load Negative Seq Imp Mult Fact
% 8. Load Zero Seq Imp Mult Fact
% 9. Series Reactor Zero Seq Imp Mult Fact
%10. Shunt Reactor Zero Seq Imp Mult Fact
```

```
 0.90000   3
  11.0000      2.5000      2.5000     0.0250
 220.0000      2.5000      2.5000     0.0250

 400.0000      2.5000      2.5000     0.0250
   0.1750      0.1750      0.0375      0.0375
   0.8100      1.6000      1.0000      0.6250
% Bus Data
% BusId  AreaNo    BaseVolt   BusName   VMag        VAng
%        PGen(mw)  QGen(mvar) PLoad(mw) QLoad(mvar) QComp(mvar)
   1 1  1  11.000     BUS1  1.02000  0.00000
        563.70    19.58     0.00     0.00   0.00
   2 1  2  11.000     BUS2  1.02000  1.60957
        125.00    22.50     0.00     0.00   0.00
   3 1  2  11.000     BUS3  1.02000  3.52133
        190.00    39.57     0.00     0.00   0.00
   4 1  1  11.000     BUS4  1.02000  3.90614
        380.00    35.27     0.00     0.00   0.00
   5 1  1 220.000     BUS5  1.01639 -4.31840
          0.00     0.00     0.00     0.00   0.00
   6 1  1 220.000     BUS6  1.00496 -10.40950
          0.00     0.00    70.24    30.10  30.00
   7 1  1 220.000     BUS7  0.96764 -19.84798
          0.00     0.00   146.63    39.10  30.00
   8 1  1 220.000     BUS8  0.97560 -14.53740
          0.00     0.00     0.00     0.00   0.00

 9 1  1 220.000     BUS9  0.97373 -14.85133
          0.00     0.00    29.45     9.82   0.00
  10 1  1 220.000    BUS10  0.96503 -15.33271
          0.00     0.00    87.82    48.79   0.00
  11 1  1 220.000    BUS11  0.97330 -15.09323
          0.00     0.00    34.35    14.72   0.00
  12 1  1 220.000    BUS12  0.95674 -17.67398
          0.00     0.00    29.10     9.70   0.00
  13 1  1 220.000    BUS13  0.96415 -16.51734
          0.00     0.00   146.27    58.51   0.00
  14 1  1 400.000    BUS14  0.98142 -12.32362
          0.00     0.00     0.00     0.00   0.00
  15 1  1 400.000    BUS15  1.01044 -2.00128
          0.00     0.00     0.00     0.00   0.00
  16 1  1 220.000    BUS16  0.96382 -16.85907
          0.00     0.00   224.24    58.50   0.00
  17 1  1 220.000    BUS17  0.95927 -17.27090
          0.00     0.00    58.31    24.30   0.00
  18 1  2 220.000    BUS18  1.00393 -3.22595
          0.00     0.00     0.00     0.00   0.00
  19 1  2 220.000    BUS19  0.99224 -5.08417
          0.00     0.00   129.29    99.46   0.00
  20 1  2 220.000    BUS20  0.99105 -5.82668
          0.00     0.00    49.69    34.78   0.00
```

```
  21 1  2 220.000    BUS21  0.98818 -3.02889
         0.00     0.00    72.40    47.60   0.00
  22 1  2 220.000    BUS22  0.99839 -2.42293
         0.00     0.00     0.00     0.00   0.00
  23 1  2 220.000    BUS23  0.94695 -7.39961
         0.00     0.00    48.17    28.90   0.00
  24 1  2 220.000    BUS24  0.97263 -7.97324
         0.00     0.00    93.19    49.05   0.00


% Two Winding Transformer Data
% 1. Status  2. NoOfCkts  3. FromBus 4. ToBus   5. +ve R
% 6. +ve X   7. Zero R    8. Zero X  9. NomTap 10. PhaseShift
%11. FromBreaker MVARat  12. ToBreaker MVARat
%13. FromWindConn        14. ToWindConn
3    2       4    15   1.402248e-003 2.804497e-002 1.402248e-003  2.804497e-002
1.00000  0.00000    50.0000   50.0000 G G
3    1      14    11   6.302072e-004 1.250413e-002 6.302081e-004  1.250413e-002
1.00000  0.00000    50.0000   50.0000 G G
3    8       5     1   6.940489e-004 1.387265e-002 6.940485e-004  1.387265e-002
1.00000  0.00000    50.0000   50.0000 G G
3    1       2    18   3.484147e-003 6.968295e-002 3.484147e-003  6.968295e-002
1.00000  0.00000    50.0000   50.0000 G G
3    1       3    22   2.803993e-003 5.608996e-002 2.803993e-003  5.608996e-002
1.00000  0.00000    50.0000   50.0000 G G

% Three Winding Transformer
% Transmission Line
% 1.Status  2.NoOfCkts  3.FromBus  4.ToBus  5.+veR  6.+veX  7.+veB/2
% 8.ZeroR   9.ZeroX    10.ZeroB/2
%11.FromCBMVARating    12.ToCBMVARating
3  1     15    14 4.300000e-003 4.770000e-002 6.370000e-001    0.00860   0.09540
0.50000   50.000   50.000
3  1      7    11  2.444000e-002 1.222600e-001 1.027200e-001    0.07332   0.36677
0.07190   50.000   50.000
3  1     12    13 1.321000e-002 6.608000e-002 5.552000e-002    0.03963   0.19825
0.03887   50.000   50.000
3  2     13    11 3.140000e-003 1.570000e-002 5.275000e-002    0.00941   0.04714
0.03692   50.000   50.000
3  1     13    16 5.780000e-003 2.891000e-002 2.429000e-002    0.01734   0.08674
0.01700   50.000   50.000
3  1     16    11 4.950000e-003 2.478000e-002 2.082000e-002    0.01486   0.07434
0.01457   50.000   50.000
3  1     16    17 2.480000e-003 1.239000e-002 1.041000e-002    0.00743   0.03717
0.00729   50.000   50.000
3  4      5     6  4.500000e-003 2.251000e-002 3.026000e-001    0.01350   0.06753
0.21180   50.000   50.000
3  1      6     7  3.716000e-002 1.858600e-001 1.561600e-001    0.11147   0.55759
0.10930   50.000   50.000
3  1      6    13  5.169000e-002 2.585600e-001 2.172300e-001    0.15506   0.77567
0.15210   50.000   50.000
```

```
3   3      6    16  1.530000e-002 7.655000e-002 5.788200e-001    0.04591   0.22964
0.40530   50.000   50.000
3   2      6     8  1.239000e-002 6.195000e-002 2.082200e-001    0.03716   0.18586
0.14572   50.000   50.000
3   2      8     9  3.630000e-003 1.817000e-002 6.107000e-002    0.01090   0.05452
0.04276   50.000   50.000
3   2      8    10  3.300000e-003 1.652000e-002 5.552000e-002    0.00991   0.04956
0.03886   50.000   50.000
3   2     18    19 5.370000e-003 2.685000e-002 9.022000e-002    0.01610   0.08054
0.06316   50.000   50.000
3   2     19     5  1.263000e-002 6.319000e-002 2.123700e-001    0.03790   0.18958
0.14866   50.000   50.000
3   2     19    20 1.131000e-002 5.658000e-002 1.901600e-001    0.03394   0.16975
0.13310   50.000   50.000
3   1     20    24 1.982000e-002 9.913000e-002 8.328000e-002    0.05945   0.29738
0.05832   50.000   50.000
3   1     24     5  2.494000e-002 1.247300e-001 1.048000e-001    0.07418   0.37420
0.07336   50.000   50.000
3   1     22    23 3.633000e-002 1.817300e-001 1.526900e-001    0.10899   0.54520
0.10690   50.000   50.000
3   2     22    20 1.734000e-002 8.674000e-002 2.914900e-001    0.05202   0.26021
0.20400   50.000   50.000
3   1     22    21 3.300000e-003 1.652000e-002 1.388000e-002    0.00991   0.04956
0.00972   50.000   50.000

% Generator Data
% 1.BusNo 2.+ve R  3.+veX  4.-veR  5.-veX  6.ZeroR  7.ZeroX
% 8.CBMVA
   4   5.000000e-004 2.625000e-002   5.000000e-004 2.625000e-002   5.000000e-004
2.625000e-002   50.000
   1   1.250000e-003 3.408750e-002   1.250000e-003 3.408750e-002   1.250000e-003
3.408750e-002   50.000
   2   1.000000e-003 7.470000e-002   1.000000e-003 7.480000e-002   1.000000e-003
7.480000e-002   50.000
   3   5.000000e-004 3.735000e-002   5.000000e-004 3.740000e-002   5.000000e-004
3.740000e-002   50.000

% Load Data
% LoadBus
  11
  17
   7
  12
  13
   6
   9
  10
  20
  23
  21
  16
```

```
  19
  24
```

Report 5.2: " YBROUT " File Listing for Case 1.

```
--------------------------------------------------------------------------------
Date and Time : Wed Dec 16 10:43:41 1998
--------------------------------------------------------------------------------
                                NETWORK  REDUCTION

             CASE NO :  1     CONTINGENCY  : 0    SCHEDULE NO : 0

--------------------------------------------------------------------------------
TOTAL NUMBER OF BUSES          :   24    ACTUAL NUMBER OF BUSES        :   24
NUMBER OF 2 WIND. TRANSFORMERS :    5   NUMBER OF 3 WIND. TRANSFORMERS :    0
NUMBER OF TRANSMISSION LINES   :   22
NUMBER OF SERIES REACTORS      :    0   NUMBER OF SERIES CAPACITORS    :    0
NUMBER OF BUS COUPLERS         :    0
NUMBER OF SHUNT REACTORS       :    0   NUMBER OF SHUNT CAPACITORS     :    0
NUMBER OF SHUNT IMPEDANCES     :   0    NUMBER OF GENERATORS           :    4
NUMBER OF LOADS                :   14
NUMBER OF FILTERS              :    0
NUMBER OF HVDC CONVERTORS      :    0

--------------------------------------------------------------------------------
NUMBER OF ZONES         :  2
PRINT OPTION            :  3 (BOTH DATA AND RESULTS PRINT)
BASE MVA                :  100.000
NOMINAL SYSTEM FREQUENCY:   50.000
PREFAULT VOLTAGE OPTION : 1 (READ FROM THE FILE)
ZONE NUMBER RETAINED    :  0
ZBUS PRINT OPTION       :  0
YBUS REDUCTION OPTION   :  1 (NETWORK REDUCTION)
--------------------------------------------------------------------------------
   4
   1     2     3     4
--------------------------------------------------------------------------------
CIRCUIT BREAKER RESISTANCE (PU)                      :   0.000000
CIRCUIT BREAKER REACTANCE  (PU)                      :   0.000100
TRANSFORMER R/X RATIO                                :   0.050000
TRANSFORMER ZERO SEQUENCE IMPEDANCE MULT FACTOR      :   0.900000

NUMBER OF TRANSMISSION VOLTAGE LEVELS                : 3
TRANSMISSION LINE VOLTAGE - KV                       :  11.000000
TRANSMISSION  LINE  ZERO  SEQUENCE  RES.  MULT.  FACTOR  :  2.500000
TRANSMISSION  LINE  ZERO  SEQUENCE  REA.  MULT.  FACTOR  :  2.500000
TRANSMISSION  LINE  ZERO  SEQUENCE  ADM.  MULT.  FACTOR  :  0.025000
TRANSMISSION LINE VOLTAGE - KV                       : 220.000000
TRANSMISSION  LINE  ZERO  SEQUENCE  RES.  MULT.  FACTOR  :  2.500000
TRANSMISSION LINE ZERO SEQUENCE REA. MULT. FACTOR    :   2.500000
```

```
TRANSMISSION LINE ZERO SEQUENCE ADM. MULT. FACTOR    :    0.025000
TRANSMISSION LINE VOLTAGE - KV                       :  400.000000
TRANSMISSION LINE ZERO SEQUENCE RES. MULT. FACTOR    :    2.500000
TRANSMISSION LINE ZERO SEQUENCE REA. MULT. FACTOR    :    2.500000
TRANSMISSION LINE ZERO SEQUENCE ADM. MULT. FACTOR    :    0.025000

GENERATOR NEGATIVE SEQUENCE RESISTANCE MULT. FACTOR  :    0.175000
GENERATOR NEGATIVE SEQUENCE REACTANCE  MULT. FACTOR  :    0.175000
GENERATOR ZERO SEQUENCE RESISTANCE MULT. FACTOR      :    0.037500
GENERATOR ZERO SEQUENCE REACTANCE MULT. FACTOR       :    0.037500
LOAD      NEGATIVE SEQUENCE IMPEDANCE  MULT. FACTOR  :    0.810000
LOAD      ZERO SEQUENCE IMPEDANCE  MULT. FACTOR      :    1.600000
SERIES REACTOR ZERO SEQUENCE IMPEDANCE MULT. FACTOR  :    1.000000
SHUNT  REACTOR ZERO SEQUENCE IMPEDANCE MULT. FACTOR  :    0.625000
------------------------------------------------------------------------------
------------------------------------------------------------------------------
BUS DATA
NODE STAT ZONE BUS-KV   NAME     VMAG-PU  VANG-DEG  PGEN-MW  QGEN-MR
                                           PLOAD-MW QLOAD-MR QCOMP-MR
---- ---- ---- -------- -------- -------- -------- -------- --------
   1    1    1   11.000      BUS1   1.0200    0.000  563.700   19.580
                                              0.000    0.000    0.000
   2    1    2   11.000      BUS2   1.0200    1.610  125.000   22.500
                                              0.000    0.000    0.000
   3    1    2   11.000      BUS3   1.0200    3.521  190.000   39.570
                                              0.000    0.000    0.000
   4    1    1   11.000      BUS4   1.0200    3.906  380.000   35.270
                                              0.000    0.000    0.000
   5    1    1  220.000      BUS5   1.0164   -4.318    0.000    0.000
                                              0.000    0.000    0.000
   6    1    1  220.000      BUS6   1.0050  -10.410    0.000    0.000
                                             70.240   30.100   30.000
   7    1    1  220.000      BUS7   0.9676  -19.848    0.000    0.000
                                            146.630   39.100   30.000
   8    1    1  220.000      BUS8   0.9756  -14.537    0.000    0.000
                                              0.000    0.000    0.000
   9    1    1  220.000      BUS9   0.9737  -14.851    0.000    0.000
                                             29.450    9.820    0.000
  10    1    1  220.000     BUS10   0.9650  -15.333    0.000    0.000
                                             87.820   48.790    0.000
  11    1    1  220.000     BUS11   0.9733  -15.093    0.000    0.000
                                             34.350   14.720    0.000
  12    1    1  220.000     BUS12   0.9567  -17.674    0.000    0.000
                                             29.100    9.700    0.000
  13    1    1  220.000     BUS13   0.9642  -16.517    0.000    0.000
                                            146.270   58.510    0.000
  14    1    1  400.000     BUS14   0.9814  -12.324    0.000    0.000
                                              0.000    0.000    0.000
  15    1    1  400.000     BUS15   1.0104   -2.001    0.000    0.000
                                              0.000    0.000    0.000
  16    1    1  220.000     BUS16   0.9638  -16.859    0.000    0.000
```

```
                                                  224.240    58.500    0.000
  17    1    1  220.000    BUS17    0.9593    -17.271     0.000     0.000
                                                   58.310    24.300    0.000
  18    1    2  220.000    BUS18    1.0039     -3.226     0.000     0.000
                                                    0.000     0.000    0.000
  19    1    2  220.000    BUS19    0.9922     -5.084     0.000     0.000
                                                  129.290    99.460    0.000
  20    1    2  220.000    BUS20    0.9911     -5.827     0.000     0.000
                                                   49.690    34.780    0.000
  21    1    2  220.000    BUS21    0.9882     -3.029     0.000     0.000
                                                   72.400    47.600    0.000
  22    1    2  220.000    BUS22    0.9984     -2.423     0.000     0.000
                                                    0.000     0.000    0.000
  23    1    2  220.000    BUS23    0.9470     -7.400     0.000     0.000
                                                   48.170    28.900    0.000
  24    1    2  220.000    BUS24    0.9726     -7.973     0.000     0.000
                                                   93.190    49.050    0.000
--------------------------------------------------------------------------------
TRANSFORMER DATA

STAT CKTS FROM FROM       TO TO              POSITIVE              ZERO
          NODE NAME     NODE NAME       R(P.U) X(P.U.)  R(P.U.) X(P.U.)
                                           TAP    PHASE  FB-MVA  TB-MVA
---- ---- ---- -------- ---- -------- -------- -------- ------- ------- -- --
   3    2    4     BUS4   15    BUS15  0.00140  0.02804  0.00140  0.02804
                                       1.00000    0.000      50      50  G  G
   3    1   14    BUS14   11    BUS11  0.00063  0.01250  0.00063  0.01250
                                       1.00000    0.000      50      50  G  G
   3    8    5     BUS5    1     BUS1  0.00069  0.01387  0.00069  0.01387
                                       1.00000    0.000      50      50  G  G
   3    1    2     BUS2   18    BUS18  0.00348  0.06968  0.00348  0.06968
                                       1.00000    0.000      50      50  G  G
   3    1    3     BUS3   22    BUS22  0.00280  0.05609  0.00280  0.05609
                                       1.00000    0.000      50      50  G  G
TRANSMISSION LINE DATA

STAT CKTS FROM FROM       TO TO
          NODE NAME     NODE NAME       RP(P.U)  XP(P.U) BP/2(PU)
                                        RZ(P.U)  XZ(P.U) BZ/2(PU) FC-MVA TC-MVA
---- ---- ---- -------- ---- -------- -------- -------- -------- ------ -----
   3    1   15    BUS15   14    BUS14  0.00430  0.04770  0.63700
                                       0.00860  0.09540  0.50000     50     50
   3    1    7     BUS7   11    BUS11  0.02444  0.12226  0.10272
                                       0.07332  0.36677  0.07190     50     50
   3    1   12    BUS12   13    BUS13  0.01321  0.06608  0.05552
                                       0.03963  0.19825  0.03887     50     50
   3    2   13    BUS13   11    BUS11  0.00314  0.01570  0.05275
                                       0.00941  0.04714  0.03692     50     50
   3    1   13    BUS13   16    BUS16  0.00578  0.02891  0.02429
                                       0.01734  0.08674  0.01700     50     50
   3    1   16    BUS16   11    BUS11  0.00495  0.02478  0.02082
```

						0.01486	0.07434	0.01457	50	50
3	1	16	BUS16	17	BUS17	0.00248	0.01239	0.01041		
						0.00743	0.03717	0.00729	50	50
3	4	5	BUS5	6	BUS6	0.00450	0.02251	0.30260		
						0.01350	0.06753	0.21180	50	50
3	1	6	BUS6	7	BUS7	0.03716	0.18586	0.15616		
						0.11147	0.55759	0.10930	50	50
3	1	6	BUS6	13	BUS13	0.05169	0.25856	0.21723		
						0.15506	0.77567	0.15210	50	50
3	3	6	BUS6	16	BUS16	0.01530	0.07655	0.57882		
						0.04591	0.22964	0.40530	50	50
3	2	6	BUS6	8	BUS8	0.01239	0.06195	0.20822		
						0.03716	0.18586	0.14572	50	50
3	2	8	BUS8	9	BUS9	0.00363	0.01817	0.06107		
						0.01090	0.05452	0.04276	50	50
3	2	8	BUS8	10	BUS10	0.00330	0.01652	0.05552		
						0.00991	0.04956	0.03886	50	50
3	2	18	BUS18	19	BUS19	0.00537	0.02685	0.09022		
						0.01610	0.08054	0.06316	50	50
3	2	19	BUS19	5	BUS5	0.01263	0.06319	0.21237		
						0.03790	0.18958	0.14866	50	50
3	2	19	BUS19	20	BUS20	0.01131	0.05658	0.19016		
						0.03394	0.16975	0.13310	50	50
3	1	20	BUS20	24	BUS24	0.01982	0.09913	0.08328		
						0.05945	0.29738	0.05832	50	50
3	1	24	BUS24	5	BUS5	0.02494	0.12473	0.10480		
						0.07418	0.37420	0.07336	50	50
3	1	22	BUS22	23	BUS23	0.03633	0.18173	0.15269		
						0.10899	0.54520	0.10690	50	50
3	2	22	BUS22	20	BUS20	0.01734	0.08674	0.29149		
						0.05202	0.26021	0.20400	50	50
3	1	22	BUS22	21	BUS21	0.00330	0.01652	0.01388		
						0.00991	0.04956	0.00972	50	50

GENERATOR DATA

FROM NODE	FROM NAME	POSITIVE R(P.U)	POSITIVE X(P.U.)	NEGATIVE R(P.U.)	NEGATIVE X(P.U.)	ZERO R(P.U.)	ZERO X(P.U.)	CB-MVA
4	BUS4	0.00050	0.02625	0.00050	0.02625	0.00050	0.02625	50
1	BUS1	0.00125	0.03409	0.00125	0.03409	0.00125	0.03409	50
2	BUS2	0.00100	0.07470	0.00100	0.07480	0.00100	0.07480	50
3	BUS3	0.00050	0.03735	0.00050	0.03740	0.00050	0.03740	50

LOAD DATA

NODE	NAME
11	BUS11
17	BUS17
7	BUS7
12	BUS12
13	BUS13
6	BUS6
9	BUS9
10	BUS10
20	BUS20
23	BUS23
21	BUS21
16	BUS16
19	BUS19
24	BUS24

Number of reduced buses : 4
Reduced bus array :
1 2 3 4

POSITIVE SEQUENCE ADMITTANCE MATRIX ELEMENTS FOR THE GIVEN SYSTEM

ROW NO	COLUMN NO	REAL	IMAGINARY
1	1	4.84122	-12.15417
1	2	-0.00502	4.64545
1	3	0.05451	2.69446
1	4	1.13690	4.56290
2	1	-0.00502	4.64545
2	2	1.01332	-6.70635
2	3	0.04604	1.48618
2	4	0.08059	0.35653
3	1	0.05451	2.69446
3	2	0.04604	1.48618
3	3	1.46098	-4.75623
3	4	0.05115	0.20579

```
     4         1    1.13690    4.56290
     4         2    0.08059    0.35653
     4         3    0.05115    0.20579
     4         4    2.05991   -5.37231
-------------------------------------------------------------------------------


NEGATIVE SEQUENCE ADMITTANCE MATRIX ELEMENTS FOR THE GIVEN SYSTEM
-------------------------------------------------------------------------------
ROW NO COLUMN NO       REAL   IMAGINARY
------ --------- ----------  ----------
     1         1    4.84122  -12.15417
     1         2   -0.00502    4.64545
     1         3    0.05451    2.69446
     1         4    1.13690    4.56290
     2         1   -0.00502    4.64545
     2         2    1.01332   -6.70635
     2         3    0.04604    1.48618
     2         4    0.08059    0.35653
     3         1    0.05451    2.69446
     3         2    0.04604    1.48618
     3         3    1.46098   -4.75623
     3         4    0.05115    0.20579
     4         1    1.13690    4.56290
     4         2    0.08059    0.35653
     4         3    0.05115    0.20579
     4         4    2.05991   -5.37231
-------------------------------------------------------------------------------
ZERO SEQUENCE ADMITTANCE MATRIX ELEMENTS FOR THE GIVEN SYSTEM
-------------------------------------------------------------------------------
ROW NO COLUMN NO       REAL   IMAGINARY
------ --------- ----------  ----------
     1         1    3.12541   -6.30191
     1         2   -0.00604    2.31144
     1         3    0.08009    0.91596
     1         4    0.88516    1.65941
     2         1   -0.00604    2.31144
     2         2    0.85075   -3.58946
     2         3    0.05142    0.74282
     2         4    0.03145    0.05832
     3         1    0.08009    0.91596
     3         2    0.05142    0.74282
     3         3    1.27050   -2.37628
     3         4    0.01454    0.02198
     4         1    0.88516    1.65941
     4         2    0.03145    0.05832
     4         3    0.01454    0.02198
     4         4    1.84500   -3.08517
-------------------------------------------------------------------------------
RETAINED ZONE :    0
```

```
NUMBER OF SERIES ELEMENTS IN THE REDUCED ZONES :    6
SERIES CONNECTIONS
SLNO FROM     NAME   TO     NAME    RP      XP        BP/2 RZ       XZ      BZ/2
---- ---- -------- ---- -------- -------- --------- ---- -------- -------- ---
 1    1      BUS1    2      BUS2  0.000233 0.215264   0.0  0.001131 0.432628  0.0
2    1   BUS1    3    BUS3 -0.007506 0.370980  0.0 -0.094733 1.083469  0.0
 3    1  BUS1    4     BUS4 -0.051414 0.206348  0.0 -0.250246 0.469137  0.0
   4   2   BUS2    3     BUS3 -0.020825 0.672222  0.0 -0.092744 1.339802  0.0
   5   2   BUS2    4     BUS4 -0.603154 2.668483  0.0 -7.163429 13.282542 0.0
   6   3   BUS3    4     BUS4 -1.137457 4.576533  0.0 -20.93122 31.641287 0.0
-------------------------------------------------------------------------------
NUMBER OF SHUNT ELEMENTS IN THE REDUCED ZONES :    4
SHUNT CONNECTIONS IN (G+JB) FORMAT - PU
SLNO FROM     NAME     GP       BP       GZ       BZ
---- ---- -------- -------- -------- -------- --------
   1    1     BUS1  6.02761 -0.25136  4.08461 -1.41509
   2    2     BUS2  1.13492 -0.21819  0.92758 -0.47688
   3    3     BUS3  1.61269 -0.36980  1.41655 -0.69552
   4    4     BUS4  3.32855 -0.24709  2.77616 -1.34544
-------------------------------------------------------------------------------
Date and Time : Wed Dec 16 10:43:41 1998
-------------------------------------------------------------------------------
```

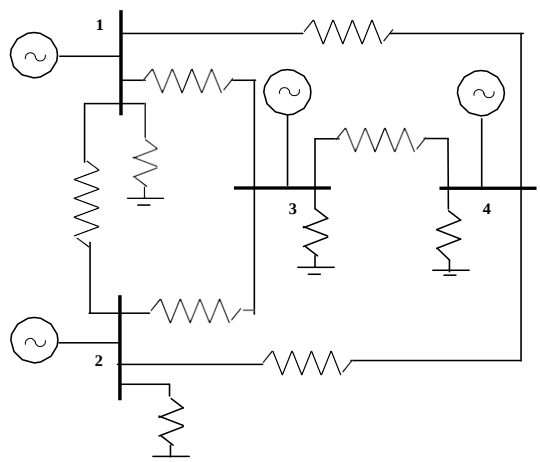


Figure 23: Reduced System for case 1

5.2 Case 2: Retaining all generator buses and zone 1 buses

In this case, the sample system shown in Report 5.1 is reduced with retaining all the buses to which the generators are connected, such as buses 1,2, 3 and 4. The buses which are belonging to zone 1, such as buses 5, 6, 7, 8, 9,10, 11,12,13,14,15,16 and 17 are also retained. All connections in zone 2 are reduced as equivalent series impedances and shunt admittances. Only a portion of file specification is shown in Report 5.3 and 5.4 for "YBRIN" and "YBROUT" respectively. The single line diagram of the reduced network is shown in Report 5.3

Report 5.3: " YBRIN " File Listing for Case 2.

```
NETWORK REDUCTION
CASE NO : 2  CONTINGENCY  : 0    SCHEDULE NO : 0

% Common System Specifications
  24    24     5     0    22     0     0     0     0     0   0
   4    14     0     0


% Control Options
% 1. No of Areas   2. YBUS print Option
% 3. BaseMVA       4. Nominal Freq   5. PreFaultOpt
   2     3     100.000000   50.0000 1

% 6. ZoneNo Retained   7. ZBUS Print Option
% 8. YBUS Reduction Option
   0   3  1

% Retained Buses
  17
1   2   3   4   5    6    7    8    9   10   11   12   13   14   15   16   17


% CBResistance CBReactance Trans R/X
 0.000000   0.000100   0.050000

% Multiplication Factors
% 1. Transformer Zero Seq Impedance Factor
% 2. No Of Voltage Levels
%      i. Transmission Line Voltage
%     ii. Transmission Line Zero Seq Res Mult Factor
%    iii. Transmission Line Zero Seq Rea Mult Factor
%     iv. Transmission Line Zero Seq Adm Mult Factor
% 3. Generator Negative Seq Resistance Mult Fact
% 4. Generator Negative Seq Reactance Mult Fact
% 5. Generator Zero Seq Resistance Mult Fact
```

```
% 6. Generator Zero Seq Reactance Mult Fact
% 7. Load Negative Seq Imp Mult Fact
% 8. Load Zero Seq Imp Mult Fact
% 9. Series Reactor Zero Seq Imp Mult Fact
%10. Shunt Reactor Zero Seq Imp Mult Fact
 0.90000   3
  11.0000      2.5000      2.5000     0.0250
 220.0000      2.5000      2.5000     0.0250
 400.0000      2.5000      2.5000     0.0250
   0.1750      0.1750      0.0375      0.0375
   0.8100      1.6000      1.0000      0.6250
% Bus Data  not given
```

Report 5.4: "YBROUT " File Listing for Case 2

```
--------------------------------------------------------------------------------
Date and Time: Wed Dec 16 10:50:19 1998
--------------------------------------------------------------------------------
                                NETWORK  REDUCTION
             CASE NO :  2     CONTINGENCY  : 0    SCHEDULE NO : 0
--------------------------------------------------------------------------------
TOTAL NUMBER OF BUSES          :   24    ACTUAL NUMBER OF BUSES        :   24
NUMBER OF 2 WIND. TRANSFORMERS :    5   NUMBER OF 3 WIND. TRANSFORMERS :    0
NUMBER OF TRANSMISSION LINES   :   22
NUMBER OF SERIES REACTORS      :    0   NUMBER OF SERIES CAPACITORS    :    0
NUMBER OF BUS COUPLERS         :    0
NUMBER OF SHUNT REACTORS       :    0   NUMBER OF SHUNT CAPACITORS     :    0
NUMBER OF SHUNT IMPEDANCES     :    0    NUMBER OF GENERATORS          :    4
NUMBER OF LOADS                :   14
NUMBER OF FILTERS              :    0

NUMBER OF HVDC CONVERTORS      :    0

--------------------------------------------------------------------------------
NUMBER OF ZONES         :  2
PRINT OPTION            :  3 (BOTH DATA AND RESULTS PRINT)
BASE MVA                :  100.000
NOMINAL SYSTEM FREQUENCY:   50.000
PREFAULT VOLTAGE OPTION : 1 (READ FROM THE FILE)
ZONE NUMBER RETAINED    :  0
ZBUS PRINT OPTION       :  3
YBUS REDUCTION OPTION   :  1 (NETWORK REDUCTION)
--------------------------------------------------------------------------------
  17
   1     2     3     4     5     6     7     8     9    10
  11    12    13    14    15    16    17
--------------------------------------------------------------------------------
CIRCUIT BREAKER RESISTANCE (PU)                    :   0.000000
CIRCUIT BREAKER REACTANCE  (PU)                    :   0.000100
TRANSFORMER R/X RATIO                              :   0.050000
TRANSFORMER ZERO SEQUENCE IMPEDANCE MULT FACTOR    :   0.900000
```

```
NUMBER OF TRANSMISSION VOLTAGE LEVELS                : 3
TRANSMISSION LINE VOLTAGE - KV                       :  11.000000
TRANSMISSION  LINE  ZERO  SEQUENCE  RES.  MULT.  FACTOR  :  2.500000
TRANSMISSION  LINE  ZERO  SEQUENCE  REA.  MULT.  FACTOR  :  2.500000
TRANSMISSION  LINE  ZERO  SEQUENCE  ADM.  MULT.  FACTOR  :  0.025000
TRANSMISSION LINE VOLTAGE - KV                       : 220.000000
TRANSMISSION  LINE  ZERO  SEQUENCE  RES.  MULT.  FACTOR  :  2.500000
TRANSMISSION  LINE  ZERO  SEQUENCE  REA.  MULT.  FACTOR  :  2.500000
TRANSMISSION  LINE  ZERO  SEQUENCE  ADM.  MULT.  FACTOR  :  0.025000
TRANSMISSION LINE VOLTAGE - KV                       : 400.000000
TRANSMISSION  LINE  ZERO  SEQUENCE  RES.  MULT.  FACTOR  :  2.500000
TRANSMISSION  LINE  ZERO  SEQUENCE  REA.  MULT.  FACTOR  :  2.500000
TRANSMISSION LINE ZERO SEQUENCE ADM. MULT. FACTOR    :   0.025000

GENERATOR NEGATIVE SEQUENCE RESISTANCE MULT. FACTOR  :    0.175000
GENERATOR NEGATIVE SEQUENCE REACTANCE  MULT. FACTOR  :    0.175000
GENERATOR ZERO SEQUENCE RESISTANCE MULT. FACTOR      :    0.037500
GENERATOR ZERO SEQUENCE REACTANCE MULT. FACTOR      :   0.037500
LOAD      NEGATIVE SEQUENCE IMPEDANCE  MULT. FACTOR  :    0.810000
LOAD      ZERO SEQUENCE IMPEDANCE  MULT. FACTOR      :    1.600000
SERIES REACTOR ZERO SEQUENCE IMPEDANCE MULT. FACTOR  :    1.000000
SHUNT  REACTOR ZERO SEQUENCE IMPEDANCE MULT. FACTOR  :    0.625000
------------------------------------------------------------------------------
%%below results not given

%% above results not given
Number of reduced buses: 17
Reduced bus array:
   1     2     3     4     5     6     7     8     9    10
  11    12    13    14    15    16    17
------------------------------------------------------------------------------
------------------------------------------------------------------------------
RETAINED ZONE :    0
NUMBER OF SERIES ELEMENTS IN THE REDUCED ZONES :    3
SERIES CONNECTIONS
SLNO FROM      NAME    TO      NAME      RP         XP         BP/2 RZ         XZ
BZ/2
---- ---- -------- ---- -------- -------- -------- ---- -------- -------- ---
   1     2      BUS2     3      BUS3 -0.028424 0.782242   0.0 -0.095517 1.400827
0.0
   2    2     BUS2    5     BUS5 0.012834 0.178231  0.0 0.017896 0.393823  0.0
   3    3     BUS3    5     BUS5 0.015571 0.307624  0.0 -0.044008 0.990090  0.0
------------------------------------------------------------------------------
NUMBER OF SHUNT ELEMENTS IN THE REDUCED ZONES :    3
SHUNT CONNECTIONS IN (G+JB) FORMAT - PU
SLNO FROM     NAME     GP       BP       GZ       BZ
---- ---- -------- -------- -------- -------- --------
   1    2     BUS2  0.66607 -0.20891  0.78390 -0.42636
   2    3     BUS3  1.34087 -0.35863  1.36143 -0.67038
   3    5     BUS5  1.83134 -0.16570  1.21497 -0.42648
```

```
--------------------------------------------------------------------------------
Date and Time : Wed Dec 16 10:50:19 1998
--------------------------------------------------------------------------------
```

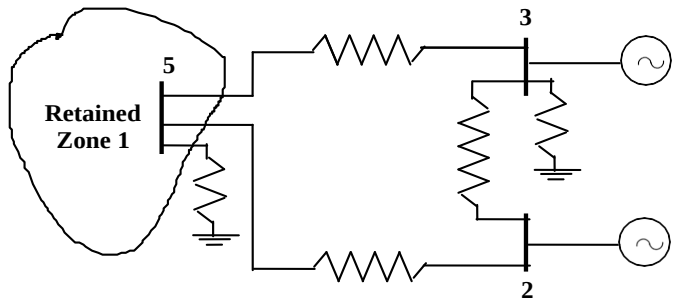


Figure 24: Reduced network retaining all generator buses and zone 1

5.3 Case 3: Retaining all zone 1 buses

In this case, the sample system shown in figure 5.1 is reduced with retaining only the buses which are belonging to zone 1, such as buses 1, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16 and 17. The generators at buses 2 and 3 belongs to zone 2 are reduced as an equivalent generator at a retained generator bus 3 in the external system. All connections in zone 2 are reduced as equivalent series impedances and shunt admittances. Only a portion of file specification are shown in Report 5.5 and 5.6 for "**YBRIN** " and "**YBROUT**" respectively. The single line diagram of the reduced network is shown in Report 4.4.

Report 5.5: "YBRIN" File Listing for Case 3

```
       NETWORK  REDUCTION
CASE NO :  3     CONTINGENCY  : 0    SCHEDULE NO : 0

% Common System Specifications
  24    24     5     0    22     0     0     0     0     0   0
   4    14     0     0

% Control Options
```

```
% 1. No of Areas   2. YBUS print Option
% 3. BaseMVA       4. Nominal Freq   5. PreFaultOpt
   2     3     100.000000   50.0000 1

% 6. ZoneNo Retained   7. ZBUS Print Option
% 8. YBUS Reduction Option
   1   3  1

% External System
% No of Generators in External System
% Reference Bus in External System
 2     3

% CBResistance CBReactance Trans R/X
 0.000000   0.000100   0.050000

% Multiplication Factors
% 1. Transformer Zero Seq Impedance Factor
% 2. No Of Voltage Levels
%      i. Transmission Line Voltage
%     ii. Transmission Line Zero Seq Res Mult Factor
%    iii. Transmission Line Zero Seq Rea Mult Factor
%     iv. Transmission Line Zero Seq Adm Mult Factor
% 3. Generator Negative Seq Resistance Mult Fact
% 4. Generator Negative Seq Reactance Mult Fact
% 5. Generator Zero Seq Resistance Mult Fact
% 6. Generator Zero Seq Reactance Mult Fact
% 7. Load Negative Seq Imp Mult Fact
% 8. Load Zero Seq Imp Mult Fact
% 9. Series Reactor Zero Seq Imp Mult Fact
%10. Shunt Reactor Zero Seq Imp Mult Fact
 0.90000   3
   11.0000       2.5000       2.5000      0.0250
  220.0000       2.5000       2.5000      0.0250
  400.0000       2.5000       2.5000      0.0250
    0.1750       0.1750       0.0375      0.0375
    0.8100       1.6000       1.0000      0.6250
%% Below data not given
%% above data not given

% External Machine Data
% BusNo   Inertia
   2     11.413
   3     11.413
```

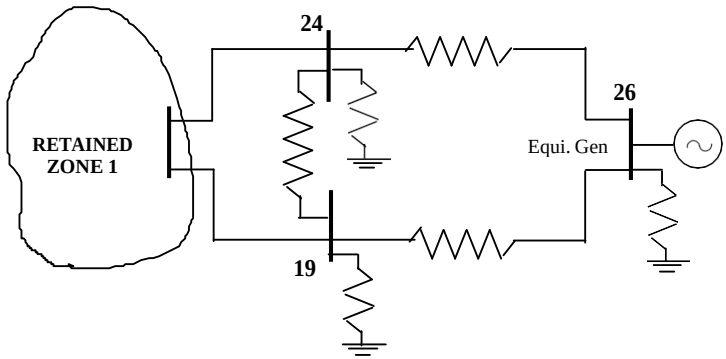
Report 5.6: "YBROUT" File Listing for Case 3

```
--------------------------------------------------------------------------------
Date and Time: Wed Dec 16 11:11:34 1998
--------------------------------------------------------------------------------
```

```
                                NETWORK  REDUCTION
              CASE NO:  13     CONTINGENCY : 0    SCHEDULE NO : 0
-------------------------------------------------------------------------------
TOTAL NUMBER OF BUSES          :   24    ACTUAL NUMBER OF BUSES        :   24
NUMBER OF 2 WIND. TRANSFORMERS :    5   NUMBER OF 3 WIND. TRANSFORMERS :    0
NUMBER OF TRANSMISSION LINES   :   22
NUMBER OF SERIES REACTORS      :    0   NUMBER OF SERIES CAPACITORS    :    0
NUMBER OF BUS COUPLERS         :    0
NUMBER OF SHUNT REACTORS       :    0   NUMBER OF SHUNT CAPACITORS     :    0
NUMBER OF SHUNT IMPEDANCES     :    0    NUMBER OF GENERATORS          :    4
NUMBER OF LOADS                :   14
NUMBER OF FILTERS              :    0

NUMBER OF HVDC CONVERTORS      :    0

-------------------------------------------------------------------------------
NUMBER OF ZONES         :  2
PRINT OPTION            :  3 (BOTH DATA AND RESULTS PRINT)
BASE MVA                :  100.000
NOMINAL SYSTEM FREQUENCY:   50.000
PREFAULT VOLTAGE OPTION : 1 (READ FROM THE FILE)
ZONE NUMBER RETAINED    :  1
ZBUS PRINT OPTION       :  3
YBUS REDUCTION OPTION   :  1 (NETWORK REDUCTION)
-------------------------------------------------------------------------------
NUMBER OF GENERATORS IN THE EXTERNAL SYSTEM   :    2
RETAINED GENERATOR BUS IN THE EXTERNAL SYSTEM :    3

-------------------------------------------------------------------------------
CIRCUIT BREAKER RESISTANCE (PU)                      :   0.000000
CIRCUIT BREAKER REACTANCE  (PU)                      :   0.000100
TRANSFORMER R/X RATIO                                :   0.050000
TRANSFORMER ZERO SEQUENCE IMPEDANCE MULT FACTOR      :   0.900000

NUMBER OF TRANSMISSION VOLTAGE LEVELS                : 3
TRANSMISSION LINE VOLTAGE - KV                       :  11.000000
TRANSMISSION  LINE  ZERO  SEQUENCE  RES.  MULT.  FACTOR  :  2.500000
TRANSMISSION  LINE  ZERO  SEQUENCE  REA.  MULT.  FACTOR  :  2.500000
TRANSMISSION  LINE  ZERO  SEQUENCE  ADM.  MULT.  FACTOR  :  0.025000
TRANSMISSION LINE VOLTAGE - KV                       : 220.000000
TRANSMISSION  LINE  ZERO  SEQUENCE  RES.  MULT.  FACTOR  :  2.500000
TRANSMISSION  LINE  ZERO  SEQUENCE  REA.  MULT.  FACTOR  :  2.500000
TRANSMISSION  LINE  ZERO  SEQUENCE  ADM.  MULT.  FACTOR  :  0.025000
TRANSMISSION LINE VOLTAGE - KV                       : 400.000000
TRANSMISSION  LINE  ZERO  SEQUENCE  RES.  MULT.  FACTOR  :  2.500000
TRANSMISSION  LINE  ZERO  SEQUENCE  REA.  MULT.  FACTOR  :  2.500000
TRANSMISSION LINE ZERO SEQUENCE ADM. MULT. FACTOR    :   0.025000

GENERATOR  NEGATIVE  SEQUENCE  RESISTANCE  MULT.  FACTOR  :  0.175000
GENERATOR  NEGATIVE  SEQUENCE  REACTANCE  MULT.  FACTOR  :  0.175000
GENERATOR ZERO SEQUENCE RESISTANCE MULT. FACTOR      :   0.037500
```

```
GENERATOR ZERO SEQUENCE REACTANCE MULT. FACTOR       :    0.037500
LOAD      NEGATIVE SEQUENCE IMPEDANCE  MULT. FACTOR  :    0.810000
LOAD      ZERO SEQUENCE IMPEDANCE  MULT. FACTOR      :    1.600000
SERIES REACTOR ZERO SEQUENCE IMPEDANCE MULT. FACTOR  :   1.000000
SHUNT  REACTOR ZERO SEQUENCE IMPEDANCE MULT. FACTOR  :   0.625000
--------------------------------------------------------------------------------
--------------------------------------------------------------------------------
%%Below results not given
%% above results not given
--------------------------------------------------------------------------------
EXTERNAL GENERATOR DATA
SLNO BUSNO NAME     INERTIA-H-PU
---- ----- -------- ------------
   1     2     BUS2       11.413
   2     3     BUS3       11.413
Number of reduced buses : 4
Reduced bus array :
  26    25    19    24
--------------------------------------------------------------------------------
%% below results not given
%% above results not given
--------------------------------------------------------------------------------
---
RETAINED ZONE :    1
NUMBER OF SERIES ELEMENTS IN THE REDUCED ZONES :    3
SERIES CONNECTIONS
SLNO FROM   NAME     TO    NAME     RP        XP      BP/2         RZ           XZ
BZ/2
---- ---- ------- ----- -------- -------- -------- -------  ----------- -----
   1    26        GEN3     19      BUS19  0.005764  0.110167   0.0        0.035423
0.769343  0.0
   2    26        GEN3     24      BUS24  0.032432  0.587300   0.0        0.062020
1.347784  0.0
   3    19       BUS19     24      BUS24  0.035152  0.187473   0.0        0.099468
0.620119  0.0
--------------------------------------------------------------------------------

NUMBER OF SHUNT ELEMENTS IN THE REDUCED ZONES :    3
SHUNT CONNECTIONS IN (G+JB) FORMAT - PU
SLNO FROM    NAME     GP       BP       GZ       BZ
---- ---- -------- -------- -------- -------- --------
   1   19    BUS19  1.90970 -0.24798  2.10356 -5.24444
   2   24    BUS24  1.31295 -0.34366  1.20133 -0.48369
   3   26     GEN3  0.82938 -0.61373  0.91641 -0.43791
--------------------------------------------------------
EQUIVALENT GENERATOR INERTIA CONSTANT - PU :   22.82422
EQUIVALENT GENERATOR REAL POWER       - MW :  315.55257
EQUIVALENT GENERATOR REACTIVE POWER - MVAR :   86.34824
EQUIVALENT GENERATOR TERMINAL VOLTAGE MAG  :    1.00000
EQUIVALENT GENERATOR TERMINAL VOLTAGE ANG-D:    6.99686
EQUIVALENT GENERATOR RESISTANCE  PU        :    0.00000
```

```
EQUIVALENT GENERATOR REACTANCE   PU        :    0.00001
--------------------------------------------------------------------------------
Date and Time : Wed Dec 16 11:11:34 1998
--------------------------------------------------------------------------------
```



Report 5.7: "YBRIN" File Listing for Case 4.

```
NETWORK  REDUCTION  for DYNAMIC STABILITY
CASE NO :  4     CONTINGENCY  : 0    SCHEDULE NO : 0

% Common System Specifications
  24    24     5     0    22     0     0     0     0     0   0
   4    14     0     0

% Control Options
% 1. No of Areas   2. YBUS print Option
% 3. BaseMVA       4. Nominal Freq   5. PreFaultOpt
   2     3     100.000000   50.0000 1

% 6. No of Retained Gen Buses  7. ZBUS Print Option
% 8. YBUS Reduction Option
   4  1  0

% Retained Buses
   1    2    3  4


% CBResistance CBReactance Trans R/X
 0.000000   0.000100   0.050000

% Multiplication Factors
% 1. Transformer Zero Seq Impedance Factor
```

```
% 2. No Of Voltage Levels
%      i. Transmission Line Voltage
%     ii. Transmission Line Zero Seq Res Mult Factor
%    iii. Transmission Line Zero Seq Rea Mult Factor
%     iv. Transmission Line Zero Seq Adm Mult Factor
% 3. Generator Negative Seq Resistance Mult Fact
% 4. Generator Negative Seq Reactance Mult Fact
% 5. Generator Zero Seq Resistance Mult Fact
% 6. Generator Zero Seq Reactance Mult Fact
% 7. Load Negative Seq Imp Mult Fact
% 8. Load Zero Seq Imp Mult Fact
% 9. Series Reactor Zero Seq Imp Mult Fact
%10. Shunt Reactor Zero Seq Imp Mult Fact
 0.90000   3
   11.0000      2.5000      2.5000     0.0250
  220.0000      2.5000      2.5000     0.0250
  400.0000      2.5000      2.5000     0.0250
    0.1750      0.1750      0.0375      0.0375
    0.8100      1.6000      1.0000      0.6250
%% remaining data not given
```

Report 5.8: "YBROUT" File Listing for Case 4.

```
------------------------------------------------------------------
-----------------------------------------------------
Date and Time : Wed Dec 16 12:50:34 1998
-------------------------------------------------------------------------
       NETWORK  REDUCTION  for DYNAMIC STABILITY
CASE NO :  14     CONTINGENCY  : 0    SCHEDULE NO : 0


-------------------------------------------------------------------------
TOTAL NUMBER OF BUSES          :   24    ACTUAL NUMBER OF BUSES        :   24
NUMBER OF 2 WIND. TRANSFORMERS :    5   NUMBER OF 3 WIND. TRANSFORMERS :    0
NUMBER OF TRANSMISSION LINES   :   22
NUMBER OF SERIES REACTORS      :    0   NUMBER OF SERIES CAPACITORS    :    0
NUMBER OF BUS COUPLERS         :    0
NUMBER OF SHUNT REACTORS       :    0   NUMBER OF SHUNT CAPACITORS     :    0
NUMBER OF SHUNT IMPEDANCES     :    0    NUMBER OF GENERATORS          :    4
NUMBER OF LOADS                :   14
NUMBER OF FILTERS              :    0

NUMBER OF HVDC CONVERTORS      :    0

-------------------------------------------------------------------------
NUMBER OF ZONES         :  2
PRINT OPTION            :  3 (BOTH DATA AND RESULTS PRINT)
BASE MVA                :  100.000
NOMINAL SYSTEM FREQUENCY:   50.000
PREFAULT VOLTAGE OPTION : 1 (READ FROM THE FILE)
TOTAL BUSES IN THE REDUCED SYSTEM :  4
ZBUS PRINT OPTION       :  0
```

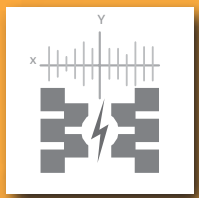
```
YBUS REDUCTION OPTION   :  0 (DYNAMIC STABILITY STUDY)
--------------------------------------------------------------------------------
BUSES :    1     2     3     4
--------------------------------------------------------------------------------
%% below results not shown
.............
.......
%% above results not shown
Number of reduced buses : 4
Reduced bus array :
   1     2     3     4
--------------------------------------------------------------------------------
POSITIVE SEQUENCE ADMITTANCE MATRIX ELEMENTS FOR THE GIVEN SYSTEM
--------------------------------------------------------------------------------
ROW NO COLUMN NO        REAL   IMAGINARY
------ ---------  ----------  ----------
     1         1    4.84122   -12.15417
     1         2   -0.00502     4.64545
     1         3    0.05451     2.69446
     1         4    1.13690     4.56290
     2         1   -0.00502     4.64545
     2         2    1.01332    -6.70635
     2         3    0.04604     1.48618
     2         4    0.08059     0.35653
     3         1    0.05451     2.69446
     3         2    0.04604     1.48618
     3         3    1.46098    -4.75623
     3         4    0.05115     0.20579
     4         1    1.13690     4.56290
     4         2    0.08059     0.35653
     4         3    0.05115     0.20579
     4         4    2.05991    -5.37231
--------------------------------------------------------------------------------
NEGATIVE SEQUENCE ADMITTANCE MATRIX ELEMENTS FOR THE GIVEN SYSTEM
--------------------------------------------------------------------------------
ROW NO COLUMN NO        REAL   IMAGINARY
------ --------- ---------- ----------
     1         1    4.84122   -12.15417
     1         2   -0.00502     4.64545
     1         3    0.05451     2.69446
     1         4    1.13690     4.56290
     2         1   -0.00502     4.64545
     2         2    1.01332    -6.70635
     2         3    0.04604     1.48618
     2         4    0.08059     0.35653
     3         1    0.05451     2.69446
     3         2    0.04604     1.48618
     3         3    1.46098    -4.75623
     3         4    0.05115     0.20579
     4         1    1.13690     4.56290
     4         2    0.08059     0.35653
```

```
     4         3    0.05115    0.20579
     4         4    2.05991   -5.37231
-------------------------------------------------------------------------------
ZERO SEQUENCE ADMITTANCE MATRIX ELEMENTS FOR THE GIVEN SYSTEM
-------------------------------------------------------------------------------
ROW NO COLUMN NO       REAL  IMAGINARY
------ --------- ----------  ----------
     1         1   3.12541   -6.30191
     1         2  -0.00604    2.31144
     1         3   0.08009    0.91596
     1         4   0.88516    1.65941
     2         1  -0.00604    2.31144
     2         2   0.85075   -3.58946
     2         3   0.05142    0.74282
     2         4   0.03145    0.05832
     3         1   0.08009    0.91596
     3         2   0.05142    0.74282
     3         3   1.27050   -2.37628
     3         4   0.01454    0.02198
     4         1   0.88516    1.65941
     4         2   0.03145    0.05832
     4         3   0.01454    0.02198
     4         4   1.84500   -3.08517
-------------------------------------------------------------------------------
Date and Time: Wed Dec 16 12:50:34 1998
-------------------------------------------------------------------------------
```

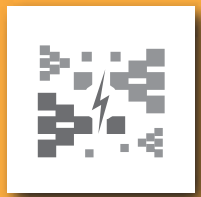
Protection Suite

PSCT | *Protection Analytic tool*

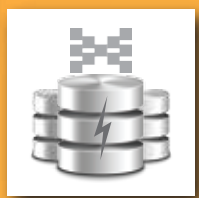
Power System Network Editor



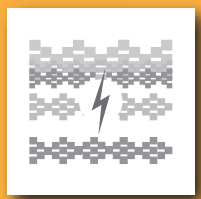
Graph Utility



Free Programmable Block



Database Manager



COMTRADE Viewer

LPC/CPC

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