QMP 7.1 D/F

Channabasaveshwara Institute of Technology
(Affiliated to VTU, Belgaum & Approved by AICTE, New Delhi)
(**NAAC Accredited & ISO 9001:2015 Certified Institution)**
NH 206 (B.H. Road), Gubbi, Tumkur – 572 216. Karnataka.

Department of Electrical & Electronics Engineering

Power System Analysis-II

IPCC Lab Manual

BEE703

2026-27

Bachelor of Engineering

VII Semester

NAME: ______________________________________

USN: ____

SECTION:______________**BATCH**:_______________

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Power System Analysis-II

IPCC Lab Manual

Version 1.1

Prepared by:

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&

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OUR VISION

To create centers of excellence in education and to serve the society by enhancing the quality of life through value based professional leadership.

OUR MISSION

- To provide high quality technical and professionally relevant education in a diverse learning environment.
- To provide the values that prepare students to lead their lives with personal integrity, professional ethics and civic responsibility in a global society.
- To prepare the next generation of skilled professionals to successfully compete in the diverse global market.
- To promote a campus environment that welcomes and honors women and men of all races, creeds and cultures, values and intellectual curiosity, pursuit of knowledge and academic integrity and freedom.
- To offer a wide variety of off-campus education and training programmes to individuals and groups.
- To stimulate collaborative efforts with industry, universities, government and professional societies.
- To facilitate public understanding of technical issues and achieve excellence in the operations of the institute.

QUALITY POLICY

Our organization delights customers (students, parents and society) by providing value added quality education to meet the national and international requirements. We also provide necessary steps to train the students for placement and continue to improve our methods of education to the students through effective quality management system, quality policy and quality objectives.

DEPARTMENT VISION

To establish a centre of excellence in Electrical and Electronics Engineering education and to foster the development of technically proficient professionals in Electrical Science and related fields while instilling a strong sense of ethics to serve the society efficiently.

DEPARTMENT MISSION

M1	To provide competent human resources, and to ensure that our students receive top-notch education and mentorship, enabling them to excel in electrical and electronics engineering and allied fields.
M2	To provide quality infrastructure, and to create an environment conducive to innovative learning and research, empowering our students to explore the frontiers of Electrical Sciences and related disciplines.
M3	To foster strong collaborations with industry and research institutions, and to facilitate the exchange of knowledge and ideas, allowing our students and faculty to remain at the cutting edge of technological advancements and practical applications in the field..
M4	To emphasize social responsibility and professional ethics in our curriculum and community engagement, and to prepare our graduates to be conscientious leaders who use their expertise to benefit society, making a positive impact through their work in Electrical Sciences and allied fields..

‘Instructions to the Candidates’

1. Students should come with thorough preparation for the experiment/program to be conducted.

2. Students will not be permitted to attend the laboratory unless they bring the practical record fully completed in all respects pertaining to the experiment conducted in the previous class.

3. Come prepared to the lab with relevant theory and Logic beyond the Program you have to do it.

4. Program should be run only after showing the required writing/ calculation related to it.

5. All the calculations should be made in the observation / Manual / Work book. Specimen calculations for one set of readings have to be shown in the practical record.

6. Wherever graphs to be drawn, A-4 size graphs only should be used and the same should be firmly attached to the practical record.

7. Practical record should be neatly maintained.

8. They should obtain the signature of the staff-in-charge in the observation book after completing each experiment.

9. Theory regarding each experiment should be written in the practical record before procedure in your own words.

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

Instructions to the students'

1. Come with Formal Dress code to lab always.
2. After entering to the lab, enter the 'time in' in the movements registers immediately
3. Systems should be put on only after getting signature in the observation books for the program to be executed and handle it wisely.
4. After completing the execution of programs, shut down the systems.
5. While going out keep the chairs properly and enter the time out and put signature in the movements register.

Course objectives & outcomes

Course objectives:

- To explain formulation of network models and bus admittance matrix for solving load flow problems.
- To discuss optimal operation of generators on a bus bar and optimum generation scheduling.
- To explain symmetrical fault analysis and algorithm for short circuit studies.
- To explain formulation of bus impedance matrix for the use in short circuit studies on power systems.
- To explain numerical solution of swing equation for multi-machine stability.
- To develop admittance and impedance matrices of interconnected power systems.
- To explain the use of suitable standard software package.• To solve power flow problem for simple power systems.
- To perform fault studies for simple radial power systems.
- To study optimal generation scheduling problems for thermal power plants.

Course outcomes:

At the end of the course the student will be able to:

- Formulate network matrices and models for solving load flow problems.
- Perform steady state power flow analysis of power systems using numerical iterative techniques.
- Solve issues of economic load dispatch and unit commitment problems.
- Analyse short circuit faults in power system networks using bus impedance matrix.
- Apply Point by Point method and Runge Kutta Method to solve Swing Equation.

Power System Analysis –II

BEE703 IPCC lab Syllabus

PRACTICAL COMPONENT OF IPCC

Sl.NO	Experiments
1	To obtain Swing Curve and to Determine Critical Clearing Time, Regulation, Inertia Constant/Line Parameters /Fault Location/Clearing Time/Pre-Fault Electrical Output for a Single Machine connected to Infinite Bus through a Pair of identical Transmission Lines Under 3-Phase Fault On One of the two Lines. (Using suitable simulation package.)
2	Y-Bus Formation for Power Systems with and without Mutual Coupling, by Singular Transformation.
3	Y-Bus Formation for Power Systems without Mutual Coupling, by Inspection method
4	Formation of Z-Bus (without mutual coupling) using Z-Bus Building Algorithm.
5	Formation of Jacobian matrix in Polar Coordinates, for a System having less than 4 Buses.
6	Determination of Bus Currents, Bus Power and Line Flows, for a Specified System Voltage.
7	Load Flow Analysis using Gauss Siedal Method for the system with both PQ buses and PV Buses. By simulation
8	Load Flow Analysis using NR Method and Fast Decoupled Method for the system with both PQ buses and PV Buses. (Using suitable simulation package.)
9	Write a program to generate unit commitment schedule for a system with three units using priority listing method (priority based on least cost).
10	Optimal Generation Scheduling for Thermal power plants (Using suitable simulation package.)

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DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

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BEE703:Power System Analysis –II IPCC lab

Sl. No.	Name of the Experiment	Date			Observation Marks (Max(10)	Record Marks (Max.(05)	Signature(Student)	Signature(Faculty)
		Conduction	Repetition	Submission of Record				
01								
02								
03								
04								
05								
06								
07								
08								
09								
10								
Average								

Note: If the student fails to attend the regular lab, the experiment has to be completed in the same week. Then the observation and record will be evaluated for 50% of maximum marks

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PROGRAM:

```
clc
clear all
%program for swing curve when the fault is cleared
ps=0.9;e=1.1;v=1.0;m=0.00028; xe=0.35;xL=0.2;
%function swing2(ps,e,v,m,xe,xL)
x1=xe+xL/2;
ch=input('enter 1-for fault at the beginning of line
\n 2-for fault at the middle of line '); switch ch

case 1,
    x2=inf;
case 2,
    x2=(xe*xL+xe*xL/2+xL*xL/2)/(xL/2);
otherwise
    disp('wrong input');
end
x3=xe+xL;
dt=0.05;
%ct=ct/50; //conversion from cycles to sec
ct=input('\n enter clearing time in secs ');
     k=ct/dt;
     r=ct-floor(k)*dt;
     if(r==0)
        fprintf('FAULT IS CLEARED AT THE BEGINNING OF
AN INTERVEL');
     else
        fprintf('FAULT IS CLEARED AT THE MIDDLE  OF AN
INTERVEL');
end
     rr=180/pi;
     f=dt^2/m;
     deld=0;
     it=1;   t(it)=0;
     pm1=e*v/x1;
     del(it)=asin(ps/pm1);
     pm2=e*v/x2;
     pm3=e*v/x3;
         fprintf('\n TIME PMAX DELTA'); pm=pm1;

     pe=pm*sin(del(it));
     pa=(ps-pe);
```

Experiment :1

PROGRAMS ON SWING CURVE

AIM: To Determine i) Swing Curve ii) Critical Clearing Time For A Single M/C For Connected To Infinity Bus Through A Pair Of Identical Transmission Lines, 3-Phase Fault On One Of The Lines For Variation Of Inertia Constant/Line Parameters /Fault Location/Clearing Time/Pre-Fault Electrical Output.

The system having a single machine connected to an infinite bus has the following
data.

Pi =0.9 M= 0.016 (2.8 × 10 -4 S / electrical Degree)
e = 1.1 Transfer reactance before fault – XL = 0.2 pu
v = 1.0 – Xe = 0.35pu

Plot the swing curve for sustained fault step by step method using MATLAB. (For fault at the beginning/middle)).

AIM i) To determine the Swing curve when the fault is cleared

i) At the beginning of the Line
ii) At the middle of the line

THEORY:

Transient stability limit: The transient stability limit of a two-machine system is the maximum power that can be transmitted from one machine to the other without losing synchronism for a specified, sudden, severe, unrepeated shock.

The **load angle** or **torque angle**, denoted as δ, depends on the machine's loading; a larger load results in a larger torque angle. If a load is added to or removed from the shaft of a synchronous machine, the rotor will decelerate or accelerate, respectively, with respect to the rotating magnetic field. The rotor swings relative to the stator field. The equation that describes this relative motion of the rotor as a function of time is known as the **swing equation**.

The swing equation is given by: $M\, d^2\delta/dt^2 = Ps - Pe$

Where:

- Pe is equal to Pmsinδ
- M is the angular momentum of the rotor
- δ is the torque angle
- Ps is the power input
- Pe is the electromagnetic power output

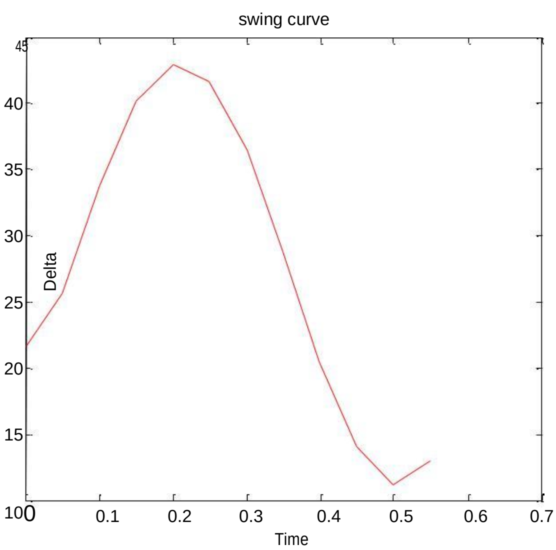
If δ increases indefinitely, it indicates instability. Conversely, if δ reaches a maximum and then starts to decrease, the system will not lose stability because the oscillations will eventually be damped out.

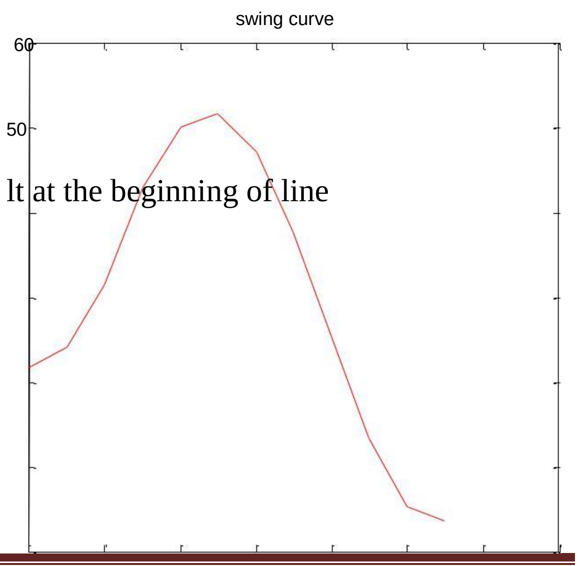
For the stability of the system, $dt/d\delta=0$

it is important to note that the system will become unstable if dt/dδ≥0 for a sufficiently long period of time.

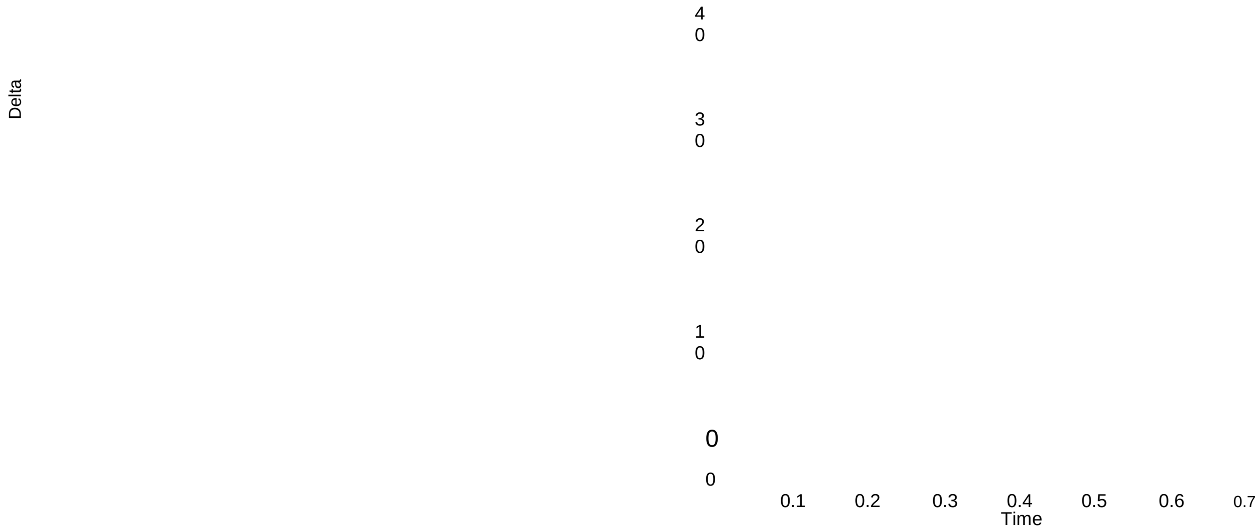
```
fprintf('\n  %5.3f  %5.2f  5.2f',t(it),pm,del(it)* rr);
     pm=pm2;

pe=pm*sin(del(it));
     pa=(ps-pe)/2;
     while(t(it)<=0.5)
         ft=f*pa/rr;
         deld=deld+ft;
         fprintf('\n  %5.3f       %5.2f
t(it),pm,del(it)* rr);
         it=it+1;
         t(it)=t(it-1)+dt;
         del(it)=del(it-1)+deld;
         pm=pm2;
         if(t(it)==ct)
                pm=(pm2+pm3)/2;
            elseif(t(it)>ct)
                pm=pm3;
            end
                pe=pm*sin(del(it));
                pa=ps-pe;
            end
plot(t,del*rr,'r');
title('swing curve');
xlabel('Time');
ylabel('Delta');
```

EXPECTED RESULT:





e lt at the beginning of line
nter1-forfau



2-for fault at the middle of line 1

enter clearing time in secs 0.05

FAULT IS CLEARED AT THE BEGINNING OF AN INTERVEL

TIME	PMAX	DELTA
0.000	2.44	21.60
0.000	0.00	21.60
0.050	1.00	25.62
0.100	2.00	33.81
0.150	2.00	40.10
0.200	2.00	42.93
0.250	2.00	41.62
0.300	2.00	36.50
0.350	2.00	28.78
0.400	2.00	20.51
0.450	2.00	14.01
0.500	2.00	11.23

enter 1-for fault at the beginning of line

2-for fault at the middle of line 2

enter clearing time in secs 0.125

FAULT IS CLEARED AT THE MIDDLE OF AN INTERVEL

TIME	PMAX	DELTA
0.000	2.44	21.60
0.000	0.88	21.60
0.050	0.88	24.17
0.100	0.88	31.56
0.150	2.00	42.88
0.200	2.00	50.07
0.250	2.00	51.61
0.300	2.00	47.19
0.350	2.00	37.70
0.400	2.00	25.33
0.450	2.00	13.35
0.500	2.00	5.29

PROGRAM:

```
clc
clear all
%swing curve for sustained fault and critical clearing
time.
%ps=mech. power input xe=xg+xt, x1=reactance before
fault x2=reactance after fault
ps=0.9;e=1.1;v=1.0;m=0.00028;xe=0.35;xLi=0.2;
%function swing(ps,e,v,m,xe,xLi) x1=xe+xLi/2;

ch=input('enter 1-for fault at the beginning \n 2-for
fault at the middle');
switch ch
    case 1
        x2=inf;
    case 2
        x2=(xe*xLi+xe*xLi/2+xLi*xLi/2)/(xLi/2);
    otherwise
        disp('wrong input');
end
dt=0.05;
rr=180/pi;
f=dt^2/m;
it=1;
t(it)=0;
deld=0;
pm1=e*v/x1;
del(it)=asin(ps/pm1);
fprintf('\n SUSTAINED FAULT');
fprintf('\n TIME PMAX DELTA');
fprintf('\n----------------');
pm=pm1;
fprintf('\n %5.3f %5.2f %5.2f',t(it),pm,del(it)*rr);
pm2=e*v/x2;
pm=pm2;
pe=pm*sin(del(it));
pa=(ps-pe)/2;
t1=0;
while(t(it)<=0.5)
    ft=f*pa/rr;
    deld=deld+ft;
    if(t1-t(it)<=0.5)
        fprintf('\n %5.3f %5.2f
%5.2f',t(it),pm,del(it)*rr);
```

AIM 2: To determine swing curve for sustained fault and critical clearing angle & time.

THEORY:

Swing curve: The solution of the swing equation provides the relationship between the rotor angle δ and time t. The plot of

δ versus t is called the **swing curve**. The swing equation does not have an analytical solution. Therefore, numerical computation techniques are used to obtain an approximate solution. Some common numerical techniques for solving the swing equation include:

- Point by point method
- Euler's method
- Euler's modified method
- Runge-Kutta method

critical clearing angle is the maximum permissible value of the rotor angle δ before a fault is cleared, at which the power system can still maintain stability. In a power system, a fault causes the electrical power output Pe) of a generator to drop below its mechanical power input (Ps). This power difference accelerates the rotor, increasing the rotor angle δ. To prevent instability, the fault must be cleared quickly. The critical clearing angle is the specific angle at which the system will eventually stabilize if the fault is removed at that instant, but will become unstable if it's cleared any later.

Critical clearing time is the maximum time a fault can persist in a power system without it losing synchronism. It's the time it takes for the rotor angle to reach the critical clearing angle. If the fault is cleared at or before this time, the system will remain stable. The relationship between the rotor angle (δ) and time (t) is described by the swing equation.

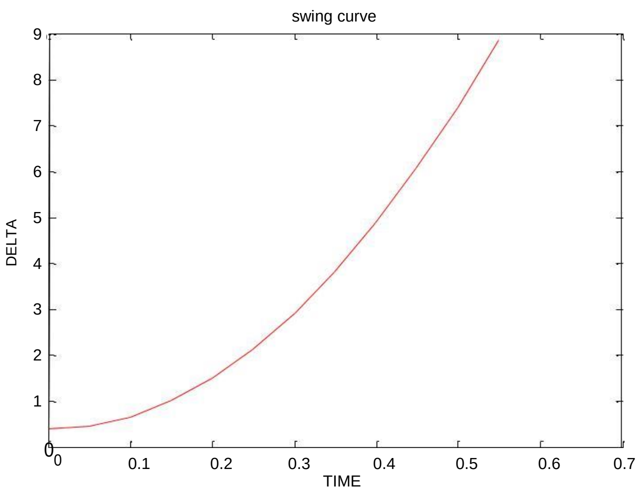
The critical clearing time is the time corresponding to the critical clearing angle on this curve. Determining this time often requires numerical methods because the swing equation has no analytical solution.

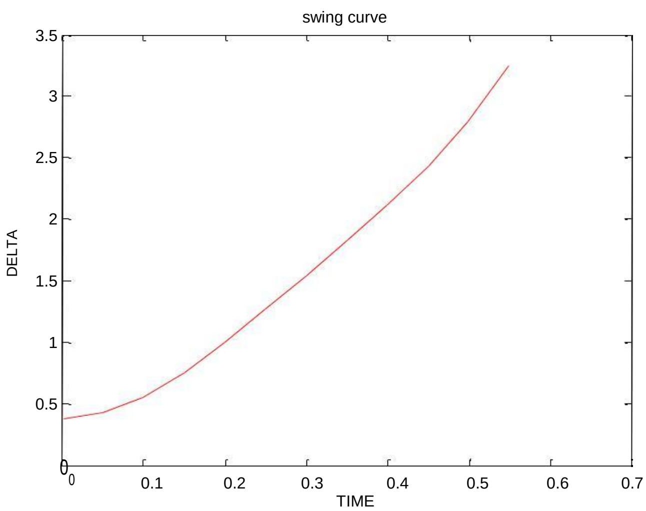
PROCEDURE:

- Enter the command window of the MATLAB.
- Create a new M – file by selecting File - New – M – File
- Type and save the program in the editor window.
- Execute the program by pressing Tools – Run.
- View the results.

```
        end
        it=it+1;
        t(it)=t(it-1)+dt;
        del(it)=del(it-1)+deld;
        pm=pm2;
        pe=pm*sin(del(it));
        pa=ps-pe;
end
x3=xe+xLi;
%x3=0.55;
pm3=e*v/x3;
delm=pi-del(1);
cdc=(ps*(delm-del(1))+pm3*cos(delm)-
pm2*cos(del(1)))/(pm3-pm2);
delc=acos(cdc);
fprintf('\n critical clearing angle-%f',delc*rr);
it=1;
while(t(it)<0.5)
        if(del(it)>=delc)
                break;
        end
        it=it+1;
end
fprintf('\n critical clearing time-%f',t(it));
plot(t,del,'r');
title('swing curve');
xlabel('TIME');
ylabel('DELTA');
```

EXPECTED RESULT:





enter 1-for fault at the beginning
2-for fault at the middle1

SUSTAINED FAULT
TIME PMAX DELTA

0.000	2.44	21.60
0.000	0.00	21.60
0.050	0.00	25.62
0.100	0.00	37.67
0.150	0.00	57.76
0.200	0.00	85.89
0.250	0.00	122.05
0.300	0.00	166.25
0.350	0.00	218.48
0.400	0.00	278.75
0.450	0.00	347.05
0.500	0.00	423.39

critical clearing angle-81.684989
critical clearing time-0.200000

enter 1-for fault at the beginning
2-for fault at the middle2

SUSTAINED FAULT
TIME PMAX DELTA

0.000	2.44	21.60
0.000	0.88	21.60
0.050	0.88	24.17
0.100	0.88	31.56
0.150	0.88	42.88
0.200	0.88	56.88
0.250	0.88	72.34
0.300	0.88	88.34
0.350	0.88	104.53
0.400	0.88	121.15
0.450	0.88	139.08
0.500	0.88	159.89

critical clearing angle-118.182332
critical clearing time-0.400000

PROGRAM:

```
%FORMATION OF Ybus USING SINGULAR TRANSFORMATION
METHOD %WITHOUT MUTUAL COUPLING:
%  p q     Z          hlcY(ADM)
 z=[5  4 0.02+0.06i  0.03i
    5  1 0.08+0.24i  0.025i
    4  1 0.06+0.18i  0.02i
    4  2 0.06+0.18i  0.02i
    4  3 0.04+0.12i  0.015i
    1  2 0.01+0.03i  0.01i
    2  3 0.08+0.24i  0.025i];
fb=z(:,1);
tb=z(:,2);
Z=z(:,3);
hlcy=z(:,4);
y=1./Z;
nbus=max(max(fb),max(tb));
Y=zeros(nbus);
nline=length(fb);
nlb=nline+nbus;
A=zeros(nlb,nbus);
for k=1:nbus
    A(k,k)=1;
end
for k=1:nline
A(nbus+k,fb(k))=1;
    A(nbus+k,tb(k))=-1;
end
sh=zeros(nbus);
for k=1:nline
    sh(fb(k))=sh(fb(k))+hlcy(k);
    sh(tb(k))=sh(tb(k))+hlcy(k);
end
ypr=zeros(nlb,nlb);
for k=1:nbus
    ypr(k,k)=sh(k);
end
for k=1:nline
    ypr(nbus+k,nbus+k)=y(k);
end
format short;
Ybus=A'*ypr*A
V(1) =1.024532-0.08729i;
V(2)=1.02394-0.931i;
V(3)=1.01825-0.1074i;
V(4)=1.0476-0.049i;
V(5)=1.06+0i;
I=Ybus*V'
```

Experiment : 2

FORMATION OF Y- BUS USING SINGULAR TRANSFORMATION METHOD WITH AND WITHOUT MUTUAL COUPLING

AIM: Y bus formation for systems, without mutual coupling, by singular transformation.

THEORY:

FORMATION OF Y BUS MATRIX

Bus admittance is often used in power system studies. In most of the power system studies it is required to form y- bus matrix of the system by considering certain power system parameters depending upon the type of analysis.

Y-bus may be formed by inspection method only if there is no mutual coupling between the lines. Every transmission line should be represented by - equivalent. Shunt impedances are added to diagonal element corresponding to the buses at which these are connected. The off diagonal elements are unaffected. The equivalent circuit of Tap changing transformers is included while forming Y-bus matrix.

Generalized Y-bus = Yii ……….. Yid
Ydi ……… Ydd

where, Yii = Self admittance
Ydi = Transfer admittance

The formation of the **Y-bus matrix** (also known as the admittance matrix) is a fundamental step in power system analysis, particularly for solving load flow and transient stability problems. For a system without mutual coupling between transmission lines, the Y-bus can be formed using a singular transformation method.

This method relies on the principle that the current injection at any bus is the sum of the currents flowing out from that bus into all connected branches. The process involves creating two primary matrices: the **primitive admittance matrix** (Yprim) and the **bus incidence matrix** (A). The primitive admittance matrix is a diagonal matrix where each diagonal element represents the self-admittance of a transmission line or element, and off-diagonal elements are zero since there's no mutual coupling. The bus incidence matrix, A, describes the network's topology by relating branches to buses. It is a rectangular matrix where each row corresponds to a bus and each column corresponds to a branch. The entries are typically +1 if the current flows out of a bus into a branch, -1 if it flows in, and 0 if the bus isn't connected to that branch.

The final Y-bus matrix is then calculated using the singular transformation: $Y_{bus}=A^TY_{prim}A$. This method systematically assembles the network's admittance matrix by mapping the individual branch admittances to their correct positions in the full system matrix, accounting for all interconnections and resulting in a symmetric matrix with non-zero off-diagonal elements representing the admittances between connected buses. This process is efficient and well-suited for computer-based power system analysis.

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PROCEDURE:

- Enter the command window of the MATLAB.
- Create a new M – file by selecting File - New – M – File
- Type and save the program in the editor window.
- Execute the program by pressing Tools – Run.
- View the results.

```
%FORMATION OF Ybus USING SINGULAR TRANSFORMATON METHOD
%WITH MUTUAL COUPLING & WITHOUT LINE CHARGING:
%  p   q   Z     mno  mutual(imp)
 z=[0  1  0.6i    0     0
    0  2  0.5i    1    0.1i
    2  3  0.5i    0     0
    0  1  0.4i    1     0.2i
    1  3  0.2i    0     0 ];
p=z(:,1);
q=z(:,2);
Z=z(:,3);
mno=z(:,4);
zmc=z(:,5);
nbus=max(max(p),max(q));
Y=zeros(nbus);
nline=length(p);
A=zeros(nline,nbus);
for k=1:nline,
    if(q(k)==0)
        A(k,p(k))=1;
    elseif(p(k)==0)
       A(k,q(k))=-1;
    end
    if(p(k)~=0&q(k)~=0)
        A(k,p(k))=1;
       A(k,q(k))=-1;
    end
end
zpr=zeros(nline,nline);
for k=1:nline
    zpr(k,k)=Z(k);
    if(mno(k))
zpr(k,mno(k))=zmc(k);
        zpr(mno(k),k)=zmc(k);
    end
end
ypr=inv(zpr);
format short;
Ybus=A'*ypr*A
```

EXPECTED RESULT:

FORMATION OF Ybus USING SINGULAR TRANSFORMATION METHOD WITHOUT MUTUAL COUPLING:

Ybus =

12.9167 -38.6950i	-10.0000 +30.0000i	0	-1.6667 + 5.0000i	-1.2500 + 3.7500i
-10.0000 +30.0000i	12.9167 -38.6950i	-1.2500 + 3.7500i	-1.6667 + 5.0000i	0
0	-1.2500 + 3.7500i	3.7500 -11.2100i	-2.5000 + 7.5000i	0
-1.6667 + 5.0000i	-1.6667 + 5.0000i	-2.5000 + 7.5000i	10.8333 -32.4150i	-5.0000 +15.0000i
-1.2500 + 3.7500i	0	0	-5.0000 +15.0000i	6.2500 -18.6950i

I =

-24.8742 - 7.9772i
32.7204 +11.1076i
-2.7353 - 0.6013i
-4.2194 - 1.6135i
-0.9560 - 0.6148i

FORMATION OF Ybus USING SINGULAR TRANSFORMATON METHOD WITH MUTUAL COUPLING & WITHOUT LINE CHARGING:

Ybus =

0 - 8.0208i	0 + 0.2083i	0 + 5.0000i
0 + 0.2083i	0 - 4.0833i	0 + 2.0000i
0 + 5.0000i	0 + 2.0000i	0 - 7.0000i

PROGRAM:

```
%  p q        z        hlc(ADM)    a

 z=[5  4 0.02+0.06i  0.03i     0.9
    5  1 0.08+0.24i  0.025i     1
    4  1 0.06+0.18i  0.02i      1
    4  2 0.06+0.18i  0.02i      1
    4  3 0.04+0.12i  0.015i     1
    1  2 0.01+0.03i  0.01i     0.8
    2  3 0.08+0.24i  0.025i     1   ];
%function yb(z);
fb=z(:,1);
tb=z(:,2);
Z=z(:,3);
hlc=z(:,4);
a=z(:,5);
y=1./Z;
nbus=max(max(fb),max(tb));
Y=zeros(nbus);
nline=length(fb);
for k=1:nline,
    p=fb(k);q=tb(k);
    y(k)=y(k)/a(k);
    Y(p,p)=Y(p,p)+y(k)+hlc(k)+(1-a(k))/a(k)*y(k);
    Y(q,q)=Y(q,q)+y(k)+hlc(k)+(a(k)-1)*y(k);
    Y(p,q)=Y(p,q)-y(k);
  Y(q,p)=Y(p,q);
end
Ybus=Y
```

Experiment: 3

FORMATION OF 'Y- BUS' BY INSPECTION METHOD

AIM: Y bus formation for systems, by inspection method.

PROCEDURE:

- Enter the command window of the MATLA
- Create a new M – file by selecting File - New – M – File
- Type and save the program in the editor window
- Execute the program by pressing Tools – F
- View the results.

EXPECTED RESULT:

Ybus =

18.5417 -55.5700i	-12.5000 +37.5000i	0	-1.6667 + 5.0000i	-1.2500 + 3.7500i
-12.5000 +37.5000i	12.9167 -38.6950i	-1.2500 + 3.7500i	-1.6667 + 5.0000i	0
0	-1.2500 + 3.7500i	3.7500 -11.2100i	-2.5000 + 7.5000i	0
-1.6667 + 5.0000	-1.6667 + 5.0000i	-2.500 + 7.5000i	10.8333 -32.4150i	-5.5556 -16.6667i
-1.2500 + 3.7500i	0	0	-5.5556 +16.6667i	7.4228 -22.2135i

PROGRAM:

```
%Z prim=[Element no. from   to  Value]
clc
clear all
Z= [      1 1 0 0.25
             2 2 10.1
             3 3 10.1
             4 2 00.25
             5 2 30.1];
[m n]= size(Z);
Zbus=[ ] ;%Let Zbus be a null matrix to begin with
 currentbusno=0;
for count = 1:m,
    [rows cols]=size(Zbus);
    fb=Z(count,2);
    tb=Z(count,3);
    value=Z(count,4);
    newbus=max(fb,tb);
    ref=min(fb,tb);
     % Type 1 Modification
    if newbus>currentbusno & ref==0
        Type=1
        Zbus=[Zbus zeros(rows,1)
              zeros(1,cols) value]
          currentbusno=newbus;
          continue
      end
     % Type 2 Modification
  if newbus>currentbusno & ref~=0
      Type=2
        Zbus=[Zbus Zbus(:,ref)
              Zbus(ref,:) value+Zbus(ref,ref)]
          currentbusno=newbus; continue

      end
 % Type 3 Modification
  if newbus<=currentbusno & ref==0
        Zbus=Zbus-
1/(Zbus(newbus,newbus)+value)*Zbus(:,newbus)*Zbus(newbus,:)
        continue
      end
      % Type 4 Modification
  if newbus<=currentbusno & ref~=0 Zbus=Zbus-
        1/(value+Zbus(fb,fb)+Zbus(tb,tb)-
2*Zbus(fb,tb))*((Zbus(:,fb)-Zbus(:,tb))*((Zbus(fb,:)-
Zbus(tb,:))))
        continue
      end
   end
```

Experiment :4

Z-BUS BUILDING ALGORITHM

AIM: Formation of Z-bus, using Z-bus build Algorithm without mutual.

PROCEDURE:

- Enter the command window of the MATLAB.
- Create a new M – file by selecting File - New – M – File
- Type and save the program in the editor window.
- Execute the program by pressing Tools – Run.
- View the results.

EXPECTED RESULT

Type = 1

Zbus = 0.2500

Type = 2

Zbus =

0.2500	0.2500
0.2500	0.3500

Type = 2

Zbus =

0.2500	0.2500	0.2500
0.2500	0.3500	0.2500
0.2500	0.2500	0.3500

Zbus =

0.1458	0.1042	0.1458
0.1042	0.1458	0.1042
0.1458	0.1042	0.2458

Zbus =

0.1397	0.1103	0.1250
0.1103	0.1397	0.1250
0.1250	0.1250	0.1750

PROGRAM:

```
% Formation of Jacobian
matrix clc
clear all
nb=3;
     Y=[65-45j -40+20i -25+25i; -
         40+20i 60-60i -20+40i; -
         25+25i -20+40i 45-65i];
 V = [1.0 0;1.0 0.0 ;1.0 0.0 ];
 J1 = zeros(nb-1,nb-1) ;
 J2 = zeros(nb-1,nb-1) ;
 J3 = zeros(nb-1,nb-1) ;
 J4 = zeros(nb-1,nb-1) ;


 for p = 2:nb
     Vp = V(p,1);
     delta_p = V(p,2) * pi/180;

     Ypp = abs(Y(p,p));
     theta_pp = angle(Y(p,p));

     V1 = V(1,1);
     delta_1 = V(1,2) * pi/180;
Yp1 = abs( Y(p,1) );
     theta_p1 = angle( Y(p,1));

   J1 (p-1,p-1) = Vp * V1 * Yp1 * sin( theta_p1 - delta_p + delta_1 );
   J2 (p-1,p-1) = 2*Vp*Ypp*cos(theta_pp) + V1*Yp1*cos(theta_p1 - delta_p + delta_1);
   J3 (p-1,p-1) = Vp*V1*Yp1*cos(theta_p1 - delta_p + delta_1);
   J4 (p-1,p-1) = -2*Vp*Ypp*sin(theta_pp) - Vp*Yp1*sin(theta_p1 - delta_p + delta_1);

     for q = 2:nb

          Vq = V(q,1) ;
          delta_q = V(q,2) * pi/180;

Ypq = abs ( Y(p,q) );
          theta_pq = angle( Y(p,q) );

        temp1 = -Vp * Vq * Ypq * sin( theta_pq - delta_p + delta_q) ;
        temp2 = Vq * Ypq * cos( theta_pq - delta_p + delta_q) ;
        temp3 = -Vp * Vq * Ypq * cos( theta_pq - delta_p + delta_q) ;
        temp4 = -Vp * Ypq * sin( theta_pq - delta_p + delta_q) ;

          if q ~= p
              J1(p-1,q-1) = temp1 ;
              J1(p-1,p-1) = J1(p-1,p-1) - temp1 ;

              J2(p-1,q-1) = temp2 ;
              J2(p-1,p-1) = J2(p-1,p-1) + temp2 ;
```

cont…

Experiment:5

FORMATION OF JACOBIAN MATRIX IN POLAR COORDINATES FOR THE SYSTEM HAVING LESS THAN 4 BUSES (no PV BUSES)

AIM: To form a Jacobian matrix for the system in polar coordinates for a Three-Bus system which is given.

THEORY:

The Jacobian is a matrix of partial derivatives that relates small changes in bus voltages and angles to small changes in injected real and reactive power at each bus. The power flow equations themselves, when expressed in polar coordinates, are non-linear. The Jacobian is a crucial component of the Newton-Raphson method, an iterative technique used to solve these non-linear equations. It is partitioned into four sub-matrices: J1, J2, J3, and J4. J1 contains the partial derivatives of real power with respect to bus angles ($\partial P/\partial\delta$), J2 contains partial derivatives of real power with respect to voltage magnitudes ($\partial P/\partial|V|$), J3 contains the partial derivatives of reactive power with respect to bus angles ($\partial Q/\partial\delta$), and J4 contains partial derivatives of reactive power with respect to voltage magnitudes ($\partial Q/\partial|V|$). For a system with a small number of buses, the size of this matrix is manageable and directly corresponds to the number of unknown bus angles and voltage magnitudes.

PROCEDURE:

- Enter the command window of the MATLAB.
- Create a new M – file by selecting File - New – M – File
- Type and save the program in the editor window.
- Execute the program by pressing Tools – Run.
- View the results.

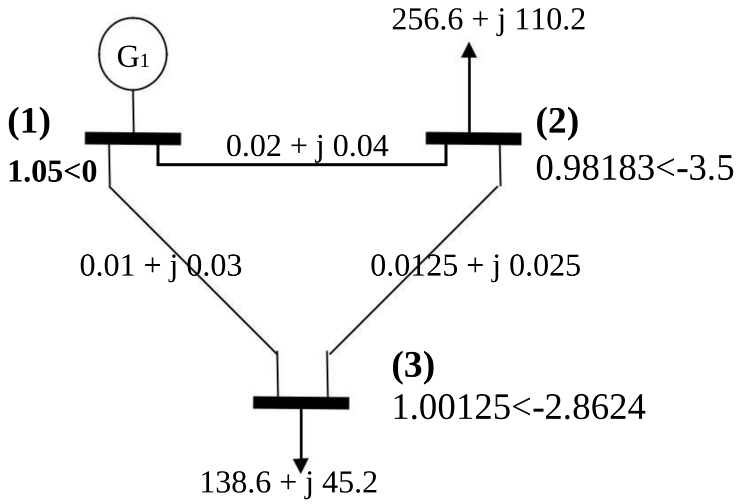
```
cont…
                J3(p-1,q-1) = temp3 ;
                J3(p-1,p-1) = J3(p-1,p-1)  - temp3 ;

                J4(p-1,q-1) = temp4 ;
                J4(p-1,p-1) = J4(p-1,p-1)  + temp4 ;

           end

      end
 end

 J = [J1 J2; J3 J4]
```

EXPECTED RESULT

J =

```
   60.0000  -40.0000   60.0000  -20.0000
  -40.0000   65.0000  -20.0000   45.0000
  -60.0000   20.0000   60.0000  -40.0000
   20.0000  -45.0000  -40.0000   65.0000
```

Case study:



Program:

```
clc;
clear;
linedata = [1    20.02         0.04  0
               1    30.01         0.03 0
               2    30.0125    0.025 0];
fr=linedata(:,1);
to=linedata(:,2);
R=linedata(:,3);
X=linedata(:,4);
B_half=linedata(:,5);
nb=max(max(fr),max(to));
nbr=length(R);

bus_data = [1     1.05         0
                 2  0.98183 -3.5
                 3  1.00125 -2.8624];
bus_no=bus_data(:,1);
volt_mag=bus_data(:,2);
angle_d=bus_data(:,3);

Z = R + j*X; %branch impedance y=
ones(nbr,1)./Z; %branch admittance
Vbus=(volt_mag.*cos(angle_d*pi/180))+ (j*volt_mag.*sin(angle_d*pi/180));
%line current
for k=1:nbr
Ifr(k)=(Vbus(fr(k))-Vbus(to(k)))*y(k)  +  (Vbus(fr(k))*j*B_half(k));
Ito(k)=(Vbus(to(k))-Vbus(fr(k)))*y(k) + (Vbus(to(k))*j*B_half(k));
end
%line flows
```

```
% S=P+jQ
for k=1:nbr
```

Experiment :6

DETERMINATION OF BUS CURRENTS, BUS POWER & LINE FLOWS FOR A SPECIFIED SYSTEM VOLTAGE (BUS) PROFILE.\

AIM: Determination of bus currents, bus power and line flow for a specified system voltage (Bus) Profile

THEORY :

The process involves these key steps:

1. **Bus Currents:** The current injected at a specific bus can be calculated using the bus admittance matrix (Ybus) and the known bus voltages (V). The formula is Ibus=Ybus Vbus. This gives the total current injected into the bus from all connected lines.
2. **Bus Power:** The complex power (S) at each bus can be determined by using the bus voltage and its corresponding current. The formula is Sbus=VbusIbus∗, where Ibus∗ is the complex conjugate of the injected bus current. This yields the real (P) and reactive (Q) power injected at each bus.
3. **Line Flows:** The power flow in each line is calculated based on the voltages at the two buses it connects. For a line between bus i and bus j, the current flowing from i to j is given by Iij=(Vi−Vj)yij, where yij is the admittance of the line. The complex power flowing from bus i into the line is then Sij=ViIij∗. The power flowing from bus j into the line is calculated similarly. The difference between the power entering and leaving the line gives the line losses.

PROCEDURE:

- Enter the command window of the MATLAB.
- Create a new M – file by selecting File - New – M – File
- Type and save the program in the editor window.
- Execute the program by pressing Tools – Run.
- View the results.

```
Sfr(k)=Vbus(fr(k))*Ifr(k)';
Sto(k)=Vbus(to(k))*Ito(k)';
end
%line losses
for k=1:nbr
SL(k)=Sfr(k)+Sto(k);
end
%bus power
Sbus=zeros(nb,1);
for n=1:nb
    for k=1:nbr
            if fr(k)==n
                Sbus(n)=Sbus(n)+Sfr(k);
            elseif to(k)==n
                    Sbus(n)=Sbus(n)+Sto(k);
            end
    end
end
%Bus current
%P+jQ=V*I'
Ibus=(Sbus./Vbus)';
fprintf('       OUTPUT DATA \n');
 fprintf('------------------------------\n');
 fprintf('      Line Currents\n');
 fprintf('------------------------------\n');
    for k=1:nbr
        fprintf(' I%d%d= %4.3f (+) %4.3f  \n',fr(k),to(k),real(Ifr(k)),imag(Ifr(k)));
        fprintf(' I%d%d= %4.3f (+) %4.3f \n', to(k),fr(k),real(Ito(k)),imag(Ito(k)));
    end
 fprintf('------------------------------\n');

 fprintf('      Line Flows\n')
 fprintf('------------------------------\n');
    for k=1:nbr
        fprintf(' S%d%d= %4.3f (+) %4.3f  \n',fr(k),to(k),real(Sfr(k)),imag(Sfr(k)));
        fprintf(' S%d%d= %4.3f (+) %4.3f \n', to(k),fr(k),real(Sto(k)),imag(Sto(k)));
    end
 fprintf('------------------------------\n');
 fprintf('      Line Losses\n')
 fprintf('------------------------------\n');
    for k=1:nbr
        fprintf(' SL%d%d= %4.3f (+) %4.3f  \n',fr(k),to(k),real(SL(k)),imag(SL(k)));
    end
    fprintf('------------------------------\n');
 fprintf('      Bus Power\n')
 fprintf('------------------------------\n');
    for k=1:nb
        fprintf(' P%d= %4.3f (+) %4.3f \n',k,real(Sbus(k)),imag(Sbus(k)));
    end
```

```
    fprintf('      Bus Current\n')
 fprintf('------------------------------\n');
       for k=1:nb
  fprintf(' I%d= %4.3f (+) %4.3f  \n',k,real(Ibus(k)),imag(Ibus(k)));
    end
       fprintf('----------------------  \n');
```

EXPECTED RESULT:

```
  OUTPUT DATA
------------------------------
      Line Currents
------------------------------
 I12= 1.899 (+) -0.801
 I21= -1.899 (+) 0.801
 I13= 2.000 (+) -1.000
 I31= -2.000 (+) 1.000
 I23= -0.638 (+) 0.481
 I32= 0.638 (+) -0.481
------------------------------
      Line Flows
------------------------------
 S12= 1.994 (+) 0.841
 S21= -1.909 (+) -0.671
 S13= 2.100 (+) 1.050
 S31= -2.050 (+) -0.900
 S23= -0.654 (+) -0.433
 S32= 0.662 (+) 0.449
------------------------------
      Line Losses
------------------------------
 SL12= 0.085 (+) 0.170
 SL13= 0.050 (+) 0.150
 SL23= 0.008 (+) 0.016
------------------------------
      Bus Power
------------------------------
 P1= 4.094 (+) 1.891
 P2= -2.563 (+) -1.104
 P3= -1.388 (+) -0.451
      Bus Current
------------------------------
 I1= 3.899 (+) -1.801
 I2= -2.537 (+) 1.282
 I3= -1.362 (+) 0.519
------------------------------
```

PROGRAM:

```
clc
clear all
% enter Y-bus of the system
Y=[3-12i -2+8i        -1+4i          0
  -2+8i  3.66-14.664i -0.666+2.664i -1+4i
  -1+4i  -0.666+2.664i 3.66-14.664i  -2+8i
  0      -1+4i        -2+8i          3-12i];
%enter no. of buses, slack bus no, no.of pq buses, no of pv buses
nbus=4;
sbno=1;
npq=2;
npv=1;
% assume bus no 1 as slack bus, next npq buses as pq buses and the
remaining as pv buses
%enter slack bus voltage
v(1)=1.06+0i;
%assume voltages at all other buses as 1+j0
v(2)=1;v(3)=1;v(4)=1;
%enter p & q at all pq buses P(2)=-
 0.5;P(3)=-0.4;Q(2)=-0.2;Q(3)=-0.3;
 %enter p ,vsp and q limits at pv buses
 P(4)=0.3;
 vsp(4)=1.04;Qmin(4)=0.1;Qmax(4)=1.0;
 %enter accuracy of convergence
 acc=0.001;
for it=1:5
%to find voltages at pq buses
    for p=2:npq+1,
        v1(p)=v(p); pq=(P(p)-
        Q(p)*i)/conj(v(p)); ypq=0;

 for q=1:nbus
if(p==q) continue;
           end
           ypq=ypq+Y(p,q)*v(q)
           ;
        end v(p)=(pq-
      ypq)/Y(p,p);
    end
%to find voltages at pv buses
    for p=npq+2:nbus,
        v1(p)=v(p);
```

```
        s=0;
        for q=1:nbus,
            if(p~=q)
                s=s+Y(p,q)*v(q);
            else
                vp=v(q);
```

Experiment : 7

GAUSS-SEIDEL METHOD

AIM: To perform load flow analysis using Gauss- Seidel method (only pq bus)

THEORY :

The **Gauss-Seidel method** is an iterative numerical algorithm used to solve non-linear power flow equations. For a system containing both **PQ (load)** and **PV (generator)** buses, the method treats each bus type differently. Initially, a flat voltage profile is assumed, typically with all unknown voltages set to 1.0∠0∘ per unit. The voltage at each bus is then updated sequentially using the most recently calculated voltage values of the other buses. For a **PQ bus**, the voltage magnitude and angle are both unknown, and its voltage is updated using the specified real (P) and reactive (Q) power values. For a **PV bus**, where the voltage magnitude (|V|) and real power (P) are specified, the reactive power (Q) is first calculated. This calculated Q is then checked against the generator's reactive power limits. If the limits are violated, the bus is temporarily treated as a PQ bus for that iteration. The voltage angle is then updated while the magnitude is held constant at its specified value. This iterative process continues for all buses until the change in voltage magnitudes and angles between successive iterations is within a predefined tolerance, indicating that a solution has been reached.

PROCEDURE:

- Enter the command window of the MATLAB.
- Create a new M – file by selecting File - New – M – File
- Type and save the program in the editor window.
- Execute the program by pressing Tools – Run.
- View the results.

```
                ang=angle(v(q));
                v(q)=complex(vsp(q)*cos(ang),vsp(q)*sin(ang));
                s=s+Y(p,q)*v(q);
            end
        end
        Qc(p)=-1*imag(conj(v(p))*s);
        if(Qc(p)>=Qmin(p)& Qc(p)<=Qmax(p))
             pq=(P(p)-Qc(p)*i)/conj(v(p));
            ypq=0;
            for q=1:nbus
                if(p==q) continue;
                end
                ypq=ypq+Y(p,q)*v(q);
            end
            v(p)=(pq-ypq)/Y(p,p);
            ang=angle(v(p));
            v(p)=complex(vsp(p)*cos(ang),vsp(p)*sin(ang));
 else
            if(Qc(p)<Qmin(p))
                Q(p)=Qmin(p);
            else
                Q(p)=Qmax(p);
            end
            pq=(P(p)-Q(p)*i)/conj(vp);
            ypq=0;
            for q=1:nbus
                if(p==q) continue;
                end
                ypq=ypq+Y(p,q)*v(q);
            end
            v(p)=(pq-ypq)/Y(p,p);
        end
    end
    %to find the votages at all buses and Q at pv busses
    fprintf('\nThe votages at all buses and Q at pv busses after
iteration no %d',it);
    for p=1:npq+1
    fprintf('\nV(%d)=%.4f
at%.2fdeg',p,abs(v(p)),angle(v(p))*180/pi);
    end
    for p=npq+2:nbus
    fprintf('\nV(%d)=%.4f at%.2fdeg
```

```
Q(%d)=%+.3f\n',p,abs(v(p)),angle(v(p))*180/pi,p,Qc(p));
    end
    %to check for convergence
    for p=2:nbus
        diff(p)=abs(v(p)-v1(p));
    end
    err=max(diff);
    if(err<=acc)
        break;
    end
end
```

EXPECTED RESULT:

The votages at all buses and Q at pv busses after iteration no 1

V(1)=1.0600 at0.00deg

V(2)=1.0124 at-1.61deg

V(3)=0.9933 at-1.48deg

V(4)=1.0400 at-0.66deg Q(4)=+0.425

The votages at all buses and Q at pv busses after iteration no 2

V(1)=1.0600 at0.00deg

V(2)=1.0217 at-1.99deg

V(3)=1.0162 at-1.86deg

V(4)=1.0400 at-0.85deg Q(4)=+0.208

The votages at all buses and Q at pv busses after iteration no 3

V(1)=1.0600 at0.00deg

V(2)=1.0259 at-2.09deg

V(3)=1.0175 at-1.94deg

V(4)=1.0400 at-0.91deg Q(4)=+0.185

The votages at all buses and Q at pv busses after iteration no 4

V(1)=1.0600 at0.00deg

V(2)=1.0261 at-2.11deg

V(3)=1.0175 at-1.98deg

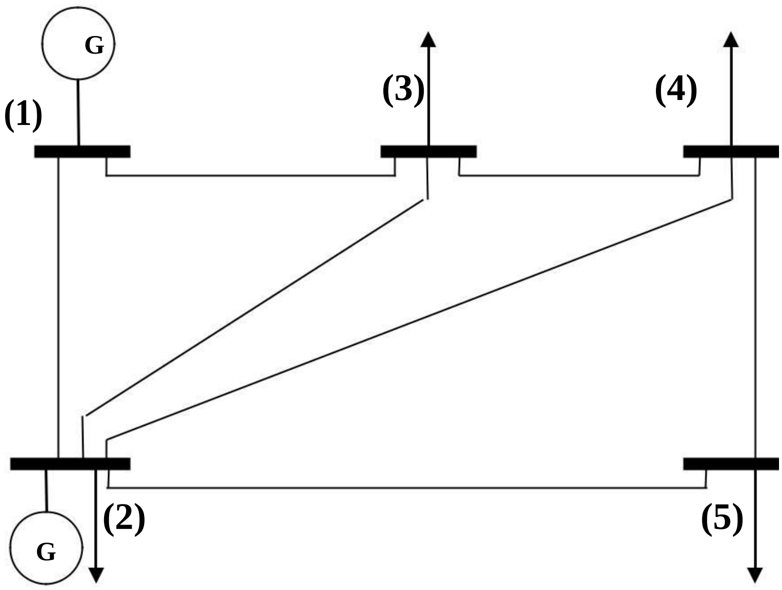
V(4)=1.0400 at-0.95deg Q(4)=+0.185

Power System Analysis-II Simulation using MiPower™

Experiment 8:

LOAD FLOW STUDIES FOR A GIVEN POWER SYSTEM USING SOFTWARE PACKAGE

Figure below shows a single line diagram of a 5bus system with 2 generating units, 7 lines. Per unit transmission line series impedances and shunt susceptances are given on 100MVA Base, real power generation, real & reactive power loads in MW and MVAR are given in the accompanying table with bus1 as slack, obtain a load flow solution with Y-bus using Gauss-Siedel method and Newton Raphson method. Take acceleration factors as 1.4 and tolerances of 0.0001 and 0.0001 per unit for the real and imaginary components of voltage and 0.01 per unit tolerance for the change in the real and reactive bus powers**.**



IMPEDANCES AND LINE CHARGING ADMITTANCES FOR THE SYSTEM

Table: 1.1		
Bus cone From-To	**Impedance R+jX**	**Line Charging B/2**
1-2	0.02+j0.06	j 0.030
1-3	0.08+j0.24	j 0.025
2-3	0.06+j0.18	j 0.020
2-4	0.06+j0.18	j 0.020
2-5	0.04+j0.12	j 0.015
3-4	0.01+j0.03	j 0.010
4-5	0.08+j0.24	j 0.025

GENERATION, LOADS AND BUS VOLTAGES FOR THE SYSTEM

Table: 1.2

Bus No	Bus Voltage	Generation MW	Generation MVAR	Load MW	Load MVAR
1	1.06+j0.0	0	0	0	0
2	1.00+j0.0	40	30	20	10
3	1.00+j0.0	0	0	45	15
4	1.00+j0.0	0	0	40	5
5	1.00+j0.0	0	0	60	10

General procedure for using Mi-Power software

1. Double click on the **MiPower** icon present in the desktop.
2. Click ok and click on **MiPower** button, then select super user than click **ok**.
3. A blue screen MiPower window will appear, then double click on the power system editor to get MiGui window.

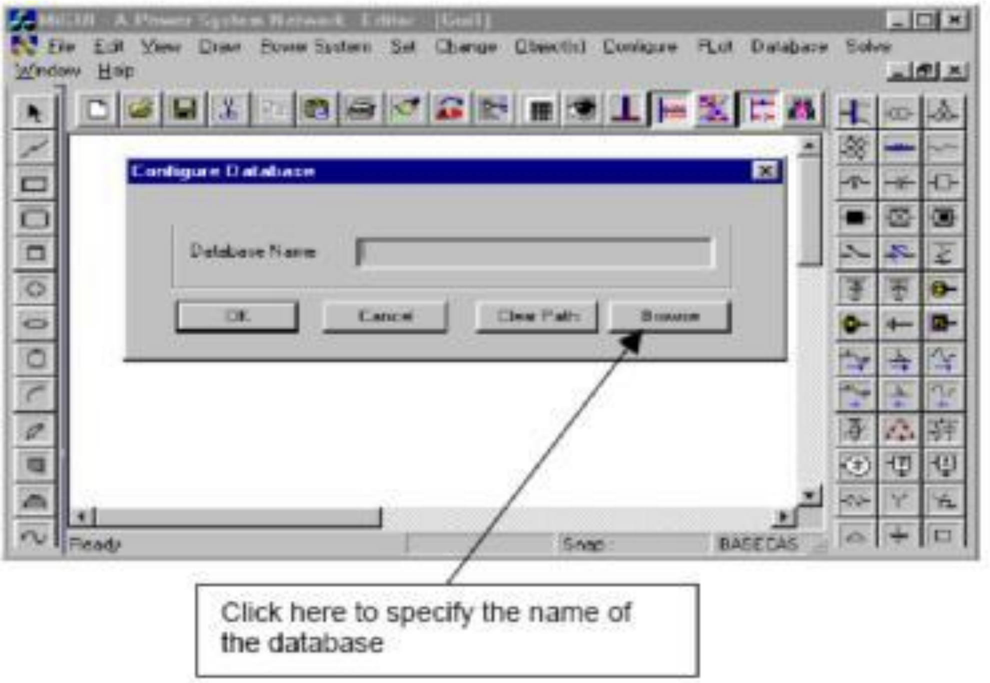
   Load flow studies

   1. Select menu option **Database** ⇒ **Configure.** Configure Database **dialog** is popped, Click **Browse** button.
   2. **Open** dialog box is popped up, then browse the desired directory and specify the name of the database (file name).
   3. Create the Bus-bar structure as given in the single line diagram.
      Note: since the voltages are mentioned in the PU, any KV can be assumed. So the base voltage is chosen as 220 KV
   4. After creating the Buses draw the transmission line according to the single line diagram given.
   5. Place the generator and enter it's ratings on the respective Bus number mentioned in the single line diagram.
   6. Similarly as generator place the load and its data.
   7. Go to solve menu in that select load flow analysis, select case (as no 1), select study info..
   8. Load flow studies window will appear in that select gauss seidel method (, then enter the accretion factor 1.4 or 1.6, then mention slack bus as Bus no 1, finally select print option as detailed results with data then press ok.
   9. Click on execute button, then click on the report. Select standard finally click on OK.

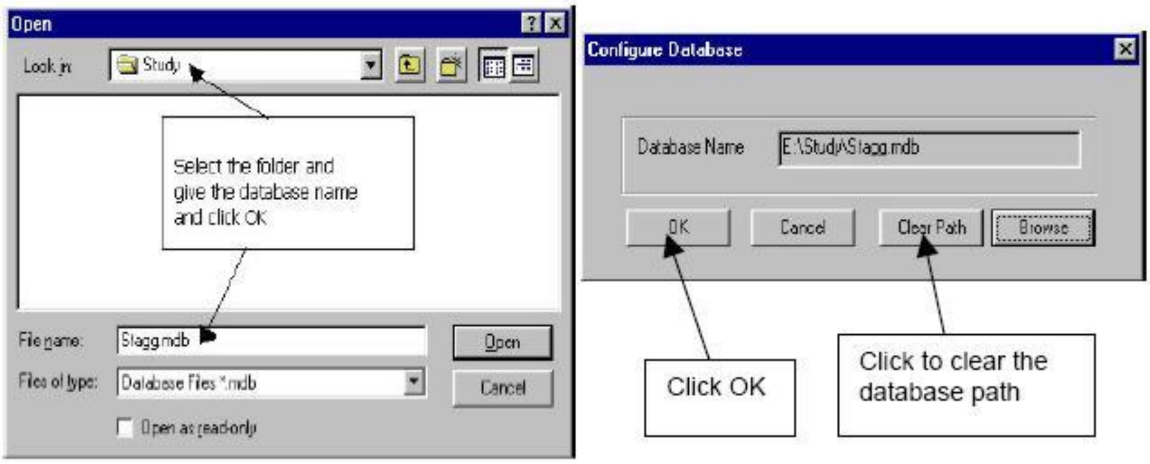
Procedure to enter the data for performing studies using MiPower

MiPower - Database Configuration

Open Power System Network Editor. Select menu option **Database** ⇒ **Configure.** Configure Database **dialog** is popped up as shown below. Click **Browse** button.

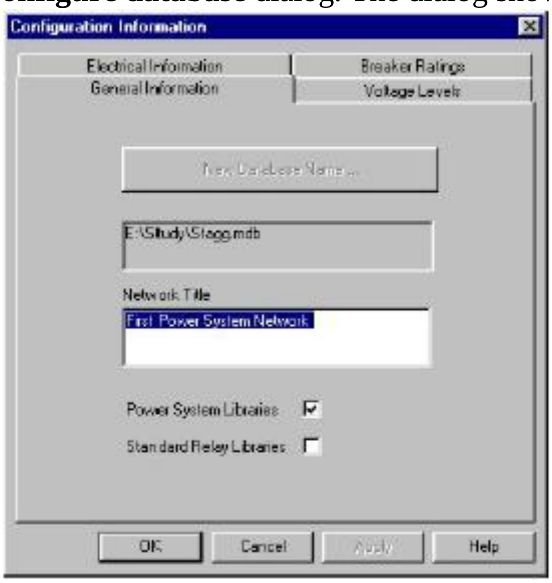


Open dialog box is popped up as shown below, where you are going to browse the desired directory and specify the name of the database to be associated with the single line diagram. Click **Open** button after entering the hired database name. **Configure Database** dialog will appear with path chosen.

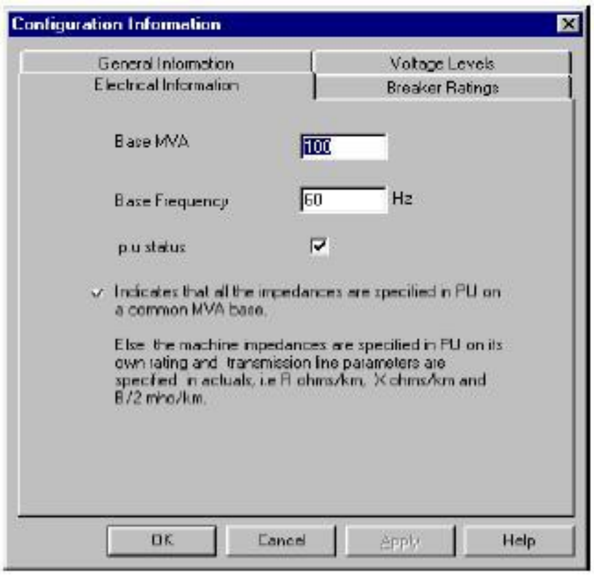


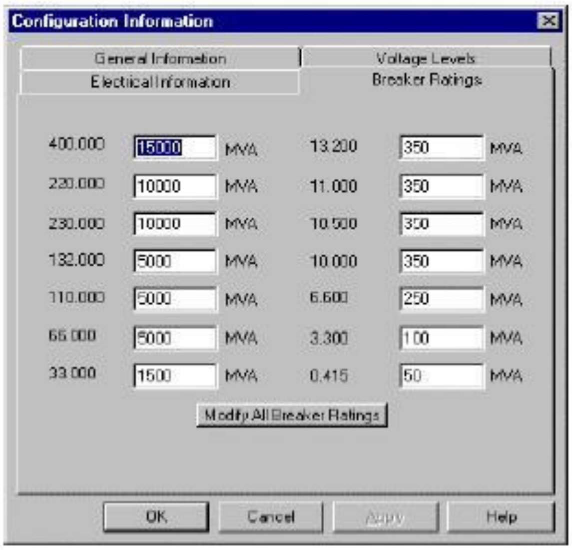
Note: Do not work in the MiPower directory.

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



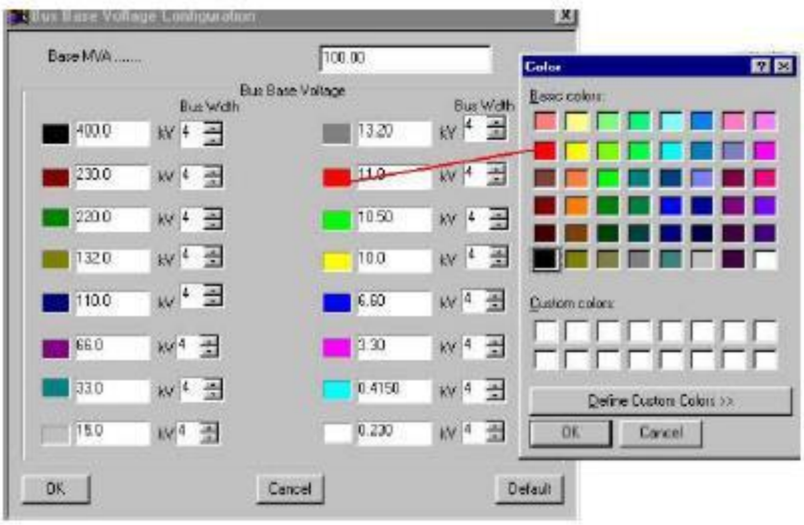
Uncheck the Power System Libraries and Standard Relay Libraries. For this example these standard libraries are not needed, because all the data is given on pu for power system libraries (like transformer, line\cable, generator), and relay libraries are required only for relay co-ordinate studies. If Libraries are selected, standard libraries will be loaded along with the database. Click **Electrical Information** tab. Since the impedances are given on 100 MVA base, check the pu status. Enter the Base and Base frequency as shown below. Click on Breaker Ratings button to give breaker ratings. Click **OK** to create the database to return to Network Editor.





Bus Base Voltage Configuration

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

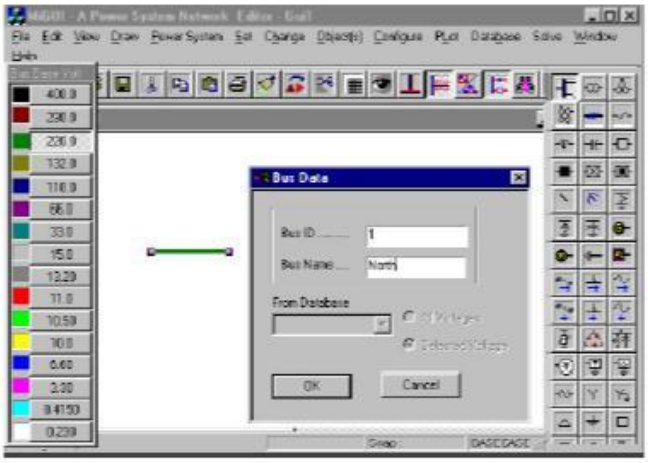


Procedure to Draw First Element - Bus

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

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

East.

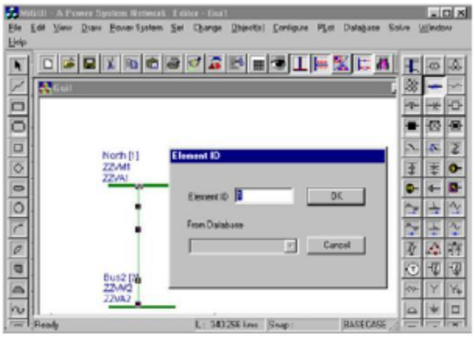


After entering data click **Save** which invokes **Network Editor**. Follow the same procedure for remaining buses. Following table gives the data for other buses.

Bus Number	Bus Name	Nominal Voltage(kV)
2	South	220
3	Lake	220
4	Main	220
5	Elm	220

Note: Since the voltages are mentioned in pu, any kV can be assumed. So the base voltage is chosen as 220 kV.

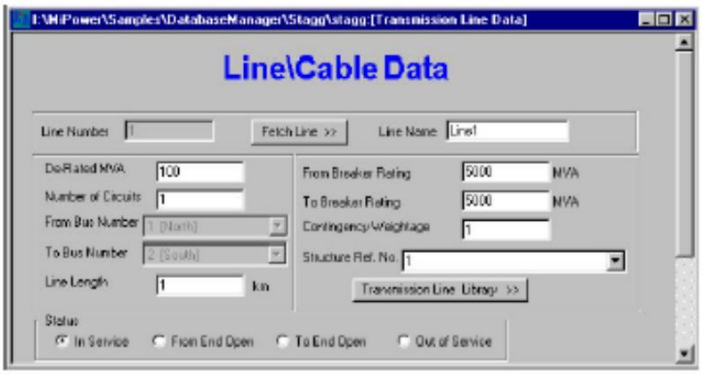
Procedure to Draw Transmission Line



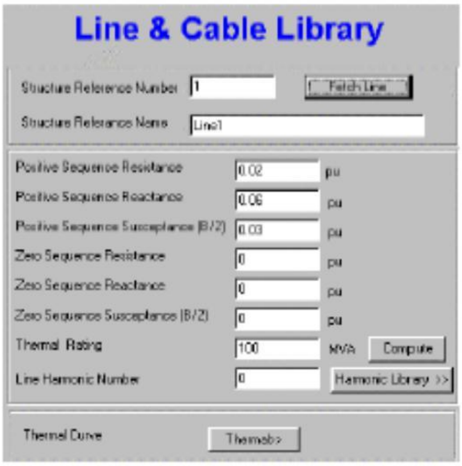
Click on **Transmission Line** icon provided on power system tool bar. To draw the line click in between two buses and to connect to the from bus double clicking LMB (Left Mouse Button) on the **From Bus** and join it to another bus by double clicking the mouse button on the **To Bus**. **Element ID**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

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

Enter **Structure Ref No.as 1** and click on **Transmission Line Library >>** button.



Line & Cable Library form will appear. Enter Transmission line library data in the form as shown below for Line1-2.



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

Transmission Line Element Data

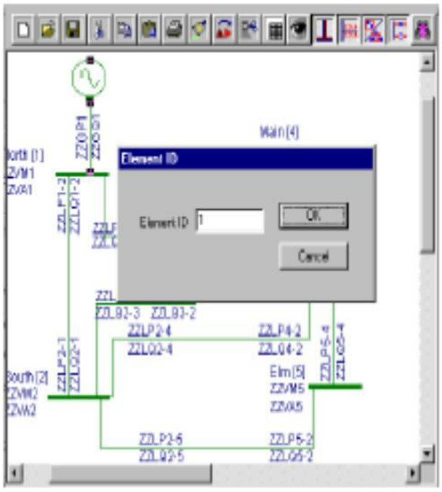
Line No	From Bus	To Bus	No. Of circuits	Structure Ref. No.
2	1	3	1	2
3	2	3	1	3
4	2	4	1	3
5	2	5	1	4
6	3	4	1	5
7	4	5	1	2

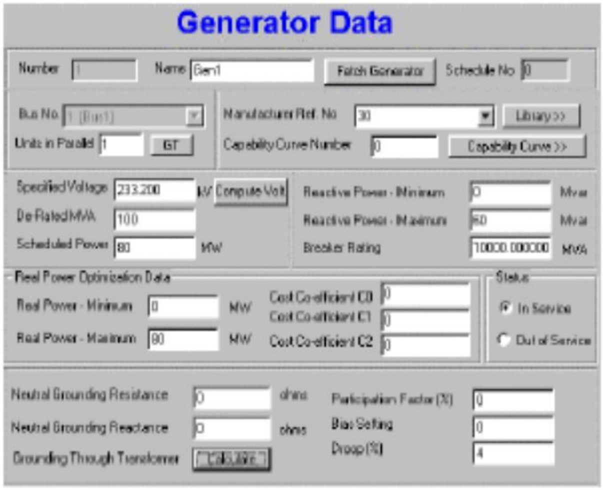
Transmission Line Library Data

Structure Ref No	Structure Ref Name	Resistance	Reactance	Line charging B/2	Thermal Rating
1	Line 1-2	0.02	0.06	0.03	100
2	Line1-3 & 4-5	0.08	0.24	0.025	100
3	Line2-3 & 2-4	0.06	0.18	0.02	100
4	Line2-5	0.04	0.12	0.015	100
5	Line3-4	0.01	0.03	0.01	100

Procedure to Draw Generator

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





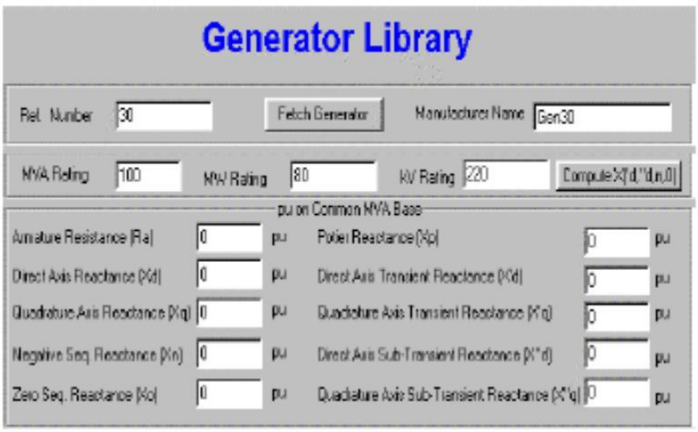
Since the specified voltage is given as 1.06 pu, click the **Compute Volt** button and give 1.06 value. Voltage will be calculated and appear in the specified voltage field.

Since generator at bus 1 is mention as slack bus, only specified voltage will have importance.

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

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

Enter Manufacturer Ref. No.as 1 and click on **Generator Library** button. Generator library form will appear.



After entering data **Save** and close. In **Generator Data** form click **Save**. **Network Editor** screen will be invoked. Similarly connect generator 2 at bus 2. Enter its details as given in the following table.

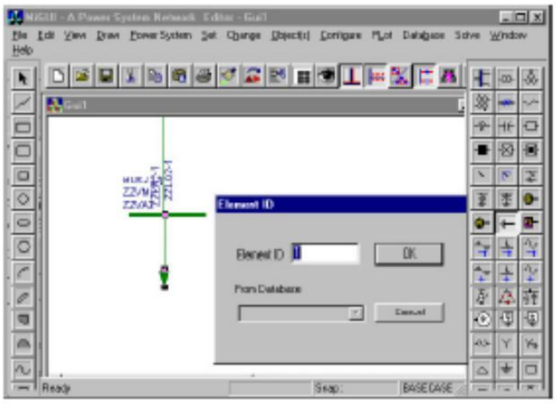
Generator 2 Element Data	
Manufacturer Ref.No	2
No. of Units parallel	1
Specified voltage	220
Derated MVA	50
Scheduled Power	40
Real Power Min.	0
Real Power Max.	40
Reactive Power Min	30
Reactive Power Max	30

Note: *Since in the data at bus 2, it is mentioned the Q generation as 30 MVAR. It means that generator has to generate 30 MVAR compulsorily. So mention Q min and Q max data as same (30) for this particular case. Thus bus has become PQ bus.*

Generator 2 Library Data	
MVA Rating	50
MW rating	40
kV rating	220
Manufacturer Name	Gen2

Procedure To Enter Load Data

Click on **Load** icon provided on power system tool bar. Connect load 1 at BUS2 by clicking the LMB on Bus 2. **Element ID** dialog will appear. Give ID No as 1 and say OK. **Load Data** form will appear. Enter load details as shown below. Then click **Save** button, which invokes Network Editor.



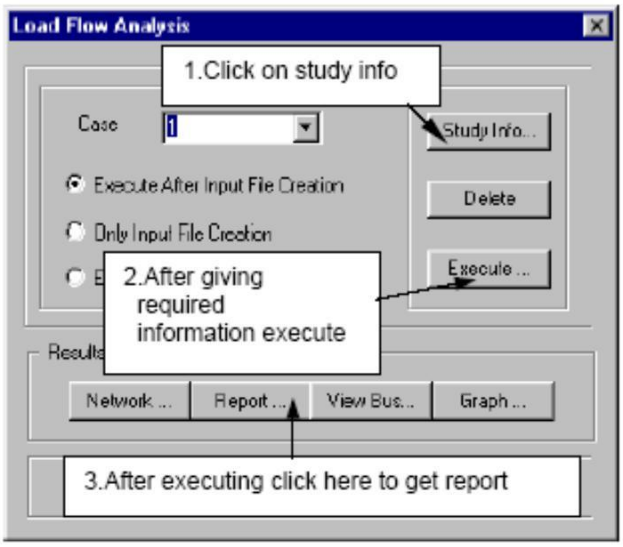
Connect other loads to buses 3, 4 and 5. Enter other load details as given in the following table.

Load Details			
Load No	Bus No	MW	MVAR
2	5	60	10
3	3	45	15
4	4	40	5

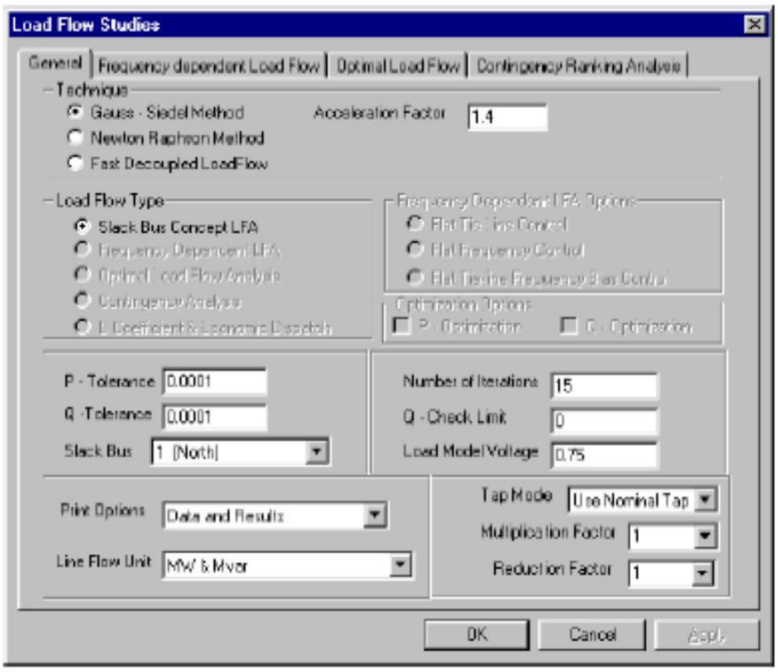
Solve Load Flow Analysis

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

When **Study Info** button is clicked, following dialog will open. Select Gauss-Siedel Method and enter acceleration factor as 1.4 and P-Tolerance and Q-Tolerance as 0.0001. Click OK.



When **Study Info** button is clicked, following dialog will open. Select Gauss-Siedel Method and enter acceleration factor as 1.4 and P-Tolerance and Q-Tolerance as 0.0001. Click OK.



Execute load flow analysis and click on **Report** in load flow analysis dialog to view report. Repeat the procedure with P and Q tolerances as 0.01 for Newton Raphson Method.

Report

```
-------------------------------------------------------------------------------
Date and Time : Fri Jan 12 16:52:27 2001
-------------------------------------------------------------------------------
       LOAD FLOW BY GAUSS-SIEDEL METHOD
CASE NO :  1     CONTINGENCY  : 0   SCHEDULE NO : 0
CONTINGENCY NAME : Base Case

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

```
-------------------------------------------------------------------------------
LARGEST BUS NUMBER USED        :    5    ACTUAL NUMBER OF BUSES          :    5
NUMBER OF 2 WIND. TRANSFORMERS :    0    NUMBER OF 3 WIND. TRANSFORMERS :    0
NUMBER OF TRANSMISSION LINES   :    7
NUMBER OF SERIES REACTORS      :    0    NUMBER OF SERIES CAPACITORS    :    0
NUMBER OF CIRCUIT BREAKERS     :    0
NUMBER OF SHUNT REACTORS       :    0    NUMBER OF SHUNT CAPACITORS     :    0
NUMBER OF SHUNT IMPEDANCES     :    0
NUMBER OF GENERATORS           :    2    NUMBER OF LOADS                :    4
NUMBER OF LOAD CHARACTERISTICS :    0    NUMBER OF UNDER FREQUENCY RELAY:    0
NUMBER OF GEN CAPABILITY CURVES:    0    NUMBER OF FILTERS              :    0
NUMBER OF TIE LINE SCHEDULES   :    0
NUMBER OF CONVERTORS           :    0    NUMBER OF DC LINKS             :    0

-------------------------------------------------------------------------------
LOAD FLOW WITH GAUSS-SEIDEL METHOD                 :    5
NUMBER OF ZONES                                    :    1
PRINT OPTION                                       :    3 - BOTH DATA AND RESULTS PRINT
PLOT OPTION                                        :    1 - PLOTTING WITH PU VOLTAGE
NO FREQUENCY DEPENDENT LOAD FLOW, CONTROL OPTION:       0
BASE MVA                                           : 100.000000
NOMINAL SYSTEM FREQUENCY (Hzs)                     : 60.000000
FREQUENCY DEVIATION (Hzs)                          : 0.000000
FLOWS IN MW AND MVAR, OPTION                       : 0
SLACK BUS                                          :    1
TRANSFORMER TAP CONTROL OPTION                     :    0
Q CHECKING LIMIT  (ENABLED)                        :    0
REAL POWER TOLERANCE (PU)                          :  0.00010
REACTIVE POWER TOLERANCE (PU)                      :  0.00010
MAXIMUM NUMBER OF ITERATIONS                       :   15
BUS VOLTAGE BELOW WHICH LOAD MODEL IS CHANGED      :  0.75000
CIRCUIT BREAKER RESISTANCE  (PU)                   :  0.00000
CIRCUIT BREAKER REACTANCE   (PU)                   :  0.00010
TRANSFORMER R/X RATIO                              :  0.05000
-------------------------------------------------------------------------------
-------------------------------------------------------------------------------
ANNUAL PERCENTAGE INTEREST CHARGES                 : 15.000
ANNUAL PERCENT OPERATION & MAINTENANCE CHARGES     :  4.000
LIFE OF EQUIPMENT IN YEARS                         : 20.000
ENERGY UNIT CHARGE (KWHOUR) IN RUPEES              :  2.500
LOSS LOAD FACTOR                                   :  0.300
COST PER MVAR IN LAKHS OF RUPEES                   :  5.000
-------------------------------------------------------------------------------
ZONE WISE MULTIPLICATION FACTORS
ZONE   P LOAD   Q LOAD    P GEN    Q GEN SH REACT   SH CAP
---- -------- -------- -------- -------- -------- --------
   0    1.000    1.000    1.000    1.000    1.000    1.000
   1    1.000    1.000    1.000    1.000    1.000    1.000
-------------------------------------------------------------------------------
BUS DATA

BUS NO. STATUS ZONE   BUS KV  VMIN-PU  VMAX-PU     NAME
------- ------ ---- -------- -------- -------- --------
      1      1    1  220.000    0.950    1.050    North
      2      1    1  220.000    0.950    1.050    South
      3      1    1  220.000    0.950    1.050     Lake
      4      1    1  220.000    0.950    1.050     Main
      5      1    1  220.000    0.950    1.050      Elm

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

TRANSMISSION LINE DATA

STA	CKT	FROM NODE	FROM NAME*	TO NODE	TO NAME*	LINE PARAMETER R(P.U)	X(P.U.)	B/2(P.U.)	RATING MVA	KMS
3	1	1	North	2	South	0.02000	0.06000	0.03000	100	1.0
3	1	1	North	3	Lake	0.08000	0.24000	0.02500	100	1.0
3	1	4	Main	5	Elm	0.08000	0.24000	0.02500	100	1.0
3	1	2	South	3	Lake	0.06000	0.18000	0.02000	100	1.0
3	1	2	South	4	Main	0.06000	0.18000	0.02000	100	1.0
3	1	2	South	5	Elm	0.04000	0.12000	0.01500	100	1.0
3	1	3	Lake	4	Main	0.01000	0.03000	0.01000	100	1.0

TOTAL LINE CHARGING SUSCEPTANCE : 0.29000
TOTAL LINE CHARGING MVAR AT 1 PU VOLTAGE : 29.000

TOTAL CAPACITIVE SUSCEPTANCE : 0.00000 pu - 0.000 MVAR
TOTAL INDUCTIVE SUSCEPTANCE : 0.00000 pu - 0.000 MVAR

GENERATOR DATA

SL.NO*	FROM NODE	FROM NAME*	REAL POWER(MW)	Q-MIN MVAR	Q-MAX MVAR	V-SPEC P.U.	CAP. CURV	MVA RATING	STAT
1	1	North	80.0000	0.0000	60.0000	1.0600	0	100.00	3
2	2	South	40.0000	30.0000	30.0000	1.0000	0	50.00	3

LOAD DATA

SLNO *	FROM NODE	FROM NAME*	REAL MW	REACTIVE MVAR	COMP MVAR	COMPENSATING MVAR VALUE MIN	MAX	STEP	CHAR NO STAT	F/V NO
1	2	South	20.000	10.000	0.000	0.000	0.000	0.000	0	0
									3	0
2	5	Elm	60.000	10.000	0.000	0.000	0.000	0.000	0	0
									3	0
3	3	Lake	45.000	15.000	0.000	0.000	0.000	0.000	0	0
									3	0
4	4	Main	40.000	5.000	0.000	0.000	0.000	0.000	0	0
									3	0

TOTAL SPECIFIED MW GENERATION : 120.00000
TOTAL MIN MVAR LIMIT OF GENERATOR : 30.00000
TOTAL MAX MVAR LIMIT OF GENERATOR : 90.00000
TOTAL SPECIFIED MW LOAD : 165.00000 reduced 165.00000
TOTAL SPECIFIED MVAR LOAD : 40.00000 reduced 40.00000
TOTAL SPECIFIED MVAR COMPENSATION : 0.00000 reduced 0.00000

GENERATOR DATA FOR FREQUENCY DEPENDENT LOAD FLOW

SLNO*	FROM NODE	FROM NAME*	P-RATE MW	P-MIN MW	P-MAX MW	%DROOP C0	PARTICI FACTOR C1	BIAS SETTING C2
1	1	North	80.000	0.0000	80.0000	4.0000	0.0000	0.0000
						0.0000	0.0000	0.0000
2	2	South	40.000	0.0000	40.0000	4.0000	0.0000	0.0000
						0.0000	0.0000	0.0000

Acceleration factor : 1.40

Iteration count = 1 Error = 0.052537 Bus = 2

Iteration count = 2 Error = 0.015724 Bus = 5

Iteration count = 3 Error = 0.007669 Bus = 5

Iteration count = 4 Error = 0.002768 Bus = 2

Iteration count = 5 Error = 0.002594 Bus = 5

Iteration count = 6 Error = 0.001050 Bus = 4

Iteration count = 7 Error = 0.000867 Bus = 3

Iteration count = 8 Error = 0.000394 Bus = 2

Iteration count = 9 Error = 0.000217 Bus = 3

```
--------------------------------------------------------------------------------
Zone wise distribution
Description        Zone # 1
---------------- ----------
MW generation      169.5343

MVAR generation     22.5314

MW load            165.0000

MVAR load           40.0000

MVAR compensation    0.0000

MW loss              4.5846

MVAR loss          -17.4293

MVAR - inductive     0.0000

MVAR - capacitive    0.0000
--------------------------------------------------------------------------------
Zone wise export(+ve)/import(-ve)
Zone #   1 MW & MVAR
------ --------- --------
     1       -----

--------------------------------------------------------------------------------
Date and Time : Fri Jan 12 16:52:28 2001
--------------------------------------------------------------------------------
```

Exercise Problems:

1. Using the available software package conduct load flow analysis for the given power system using Gauss-Siedel / Newton-Raphson / Fast decoupled load flow method. Determine
   (a) Voltage at all buses
   (b) Line flows
   (c) Line losses and
   (d) Slack bus power.

   Also draw the necessary flow chart (general flow chart)

2. Using the available software package conduct load flow analysis for the given power system using Gauss-Siedel / Newton-Raphson / Fast decoupled load flow method. Determine
   (a) Voltage at all buses
   (b) Line flows
   (c) Line losses and
   (d) Slack bus power.

   Also draw the necessary flow chart (general flow chart), Compare the results with the results obtained when (i) a line is removed (ii) a load is removed.

Refer below question for Q.(1) & Q(2)

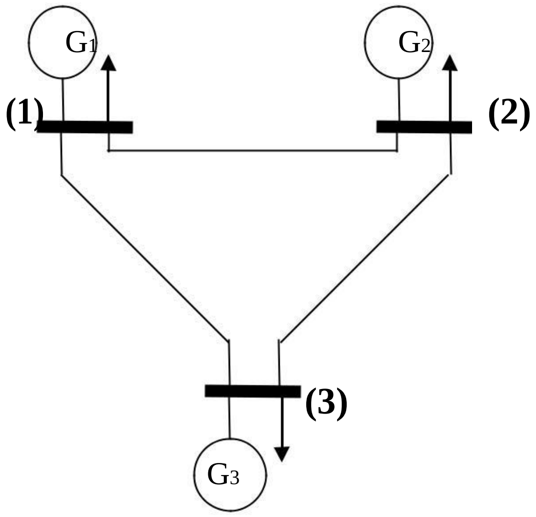
Consider the 3 bus system of figure each of the line has a series impedence of (0.02 + j0.08) p.u. & a total shunt admittance of j 0.02 p.u. The specified quantities at the buses are tabulated below on 100 MVA base.

Bus No.	Real Load Demand P_D	Reactive Load Demand Q_D	Real Power Generation P_G	Reactive Power Generation Q_G	Voltage Specification
1	2.0	1.0	Unspesified	Unspesified	$V_1 = (1.04 + j\,0)$ (Slack Bus)
2	0.0	0.0	0.5	1.0	Unspesified (PQ Bus)
3	0.5	0.6	0.0	Q_{G3} = ?	$V_3 = 1.04$ (PV Bus)

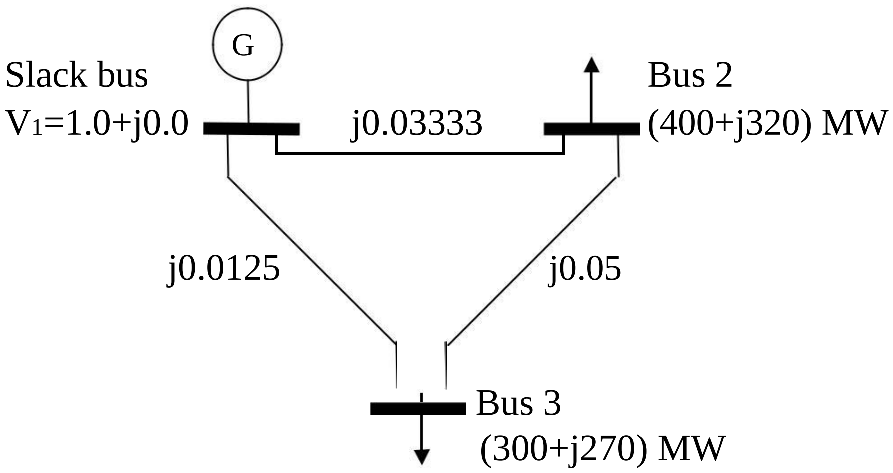
Controllable reactive power source is available at bus 3 with the constraint

$0 \le Q_{G3} \le 1.5$ p.u.

Find the load flow solution using N R method. Use a tolerance of 0.01 for power mismatch.



3. Figure shows the one line diagram of a simple three bus system with generation at bus 1, the voltage at bus 1 is $V_1 = 1.0\angle 0^0$ pu. The scheduled loads on buses 2 and 3 are marked on diagram. Line impedances are marked in pu on a 100MVA base. For the purpose of hand calculations line resistances and line charging susceptances are neglected. Using Gauss-Seidel method and initial estimates of $V_2 = 1.0\angle 0^0$ pu & $V_3 = 1.0\angle 0^0$ pu. Conduct load flow analysis.



Experiment: 9

UNIT COMMITMENT SCHEDULE FOR A SYSTEM WITH THREE UNITS USING PRIORITY LISTING METHOD

AIM: To Generate Unit Commitment Schedule For A System With Three Units Using Priority Listing Method

THEORY:

The **Priority List Method** is a simple, heuristic approach for solving the **Unit Commitment (UC)** problem in a power system. The goal of UC is to determine the on/off status of generating units over a specific period to meet the forecasted load at the lowest possible cost, subject to various operational constraints.

In this method, generating units are ranked in a fixed order of their economic efficiency, typically based on their average production cost. The unit with the lowest average production cost is given the highest priority. When a unit commitment schedule is being created for a system with three units, the method simply involves committing the units one by one in this priority order until the total capacity of the committed units is sufficient to cover the required load. No complex optimization is performed. This method is computationally fast and easy to implement, but it does not guarantee the most optimal or least-cost solution because it doesn't account for start-up costs, minimum up/down times, or other system constraints in a comprehensive way.

PROGRAM

```
% Unit Commitment-Priority List Method

clc;
clear;

%input data

unit=[1 2 3];
Min_MW=[100 50 150];
Max_MW=[400 300 500];
a=[0.006 0.01 0.008];
b=[7 8 6];
c=[600 500 500];
ki=[1.1 1.2 1];
Pg1=Max_MW(1);
Pg2=Max_MW(2);
Pg3=Max_MW(3);
H1=a(1)*Pg1^2+b(1)*Pg1+c(1)
H2=a(2)*Pg2^2+b(2)*Pg2+c(2)
H3=a(3)*Pg3^2+b(3)*Pg3+c(3)

% To calculate Full Load Average Production Cost

FLAPC1=ki(1)*H1/Pg1
FLAPC2=ki(2)*H2/Pg2
FLAPC3=ki(3)*H3/Pg3
```

```
% Ascending order of Full Load Average Production Cost

x=[FLAPC1 FLAPC2 FLAPC3];
y=sort(x);
[tf_member,loc]=ismember(y,x);

% Priority List

priority_list=zeros(3,4);
fori=1:1:3
priority_list(i,1)=unit(loc(i));
priority_list(i,2)=x(loc(i));
priority_list(i,3)=Min_MW(loc(i));
priority_list(i,4)=Max_MW(loc(i));
end

fprintf('    Unit     FLAPC    Min(MW)   Max(MW)')

priority_list

% Minimum and Maximum MW consumption from combination

prior_min312=0;
prior_max312=0;
fori=1:1:3
   prior_min312=prior_min312+priority_list(i,3);
   prior_max312=prior_max312+priority_list(i,4);
end
Min_MW312=prior_min312;
Max_MW312=prior_max312;

prior_min31=0;
prior_max31=0;
fori=1:1:2
   prior_min31=prior_min31+priority_list(i,3);
   prior_max31=prior_max31+priority_list(i,4);
end
Min_MW31=prior_min31;
Max_MW31=prior_max31;

Min_MW3=priority_list(1,3);
Max_MW3=priority_list(1,4);

% Unit Combination

combination=zeros(3,3);
unit_combination=[312 31 3];
CMin_MW=[Min_MW312 Min_MW31 Min_MW3];
CMax_MW=[Max_MW312 Max_MW31 Max_MW3];

fori=1:1:3
   combination(i,1)=unit_combination(i);
   combination(i,2)=CMin_MW(i);
```

```
    combination(i,3)=CMax_MW(i);
end

fprintf('       Unit      Min MW from    Max MW from \n')
fprintf('    Combination  CombinationCombination \n')
combination

fprintf('If power demand is more than or equal to 900MW,turn on units 3,1,2\n');
fprintf('If power demand is more than or equal to 500MW,turn on units 3 & 1\n');
fprintf('If power demand is less than 500MW,turn on unit 3\n');
```

EXPECTED OUTPUT:

```
FLAPC1 =    11.9900
FLAPC2 =     15.2000
FLAPC3 =    11
                  Unit     FLAPC    Min(MW)   Max(MW)
priority_list =

    3.0000   11.0000 150.0000 500.0000
    1.0000   11.9900 100.0000 400.0000
    2.0000   15.2000   50.0000 300.0000

 Unit         Min MW from    Max MW from
 combination =

       312       300       1200
        31       250        900
         3       150        500

If power demand is more than or equal to 900MW,turn on units 3,1,2
If power demand is more than or equal to 500MW,turn on units 3 & 1
If power demand is less than 500MW,turn on unit 3
```

Experiment: 10

OPTIMAL GENERATOR SCHEDULING FOR THERMAL POWER PLANTS USING SOFTWARE PACKAGE

How to solve Economic dispatch using B-coefficient method.

Problem:
Cost equation and loss co-efficient of different units in a plant are given. Determine economic generation for a total load demand of 240 MW.

Unit No	Cost of fuel input in RS/hr
1	$C1=0.05P_1^2 + 20 P_1 + 800$ $0<= P_1 < = 100$
2	$C2=0.06P_2^2 + 15 P_2 + 1000$ $0<= P_2 < = 100$
3	$C2=0.07P_3^2 + 18 P_3 + 900$ $0 < = P_3 < = 100$

Loss Co-efficient:
$B_{11}=0.0005$; $B_{12}=0.00005$; $B_{13}=0.0002$;
$B_{22}=0.0004$; $B_{23}=0.00018$; $B_{33}=0.0005$;
$B_{21}= B_{12}$; $B_{23}= B_{32}$; $B_{13}= B_{31}$;

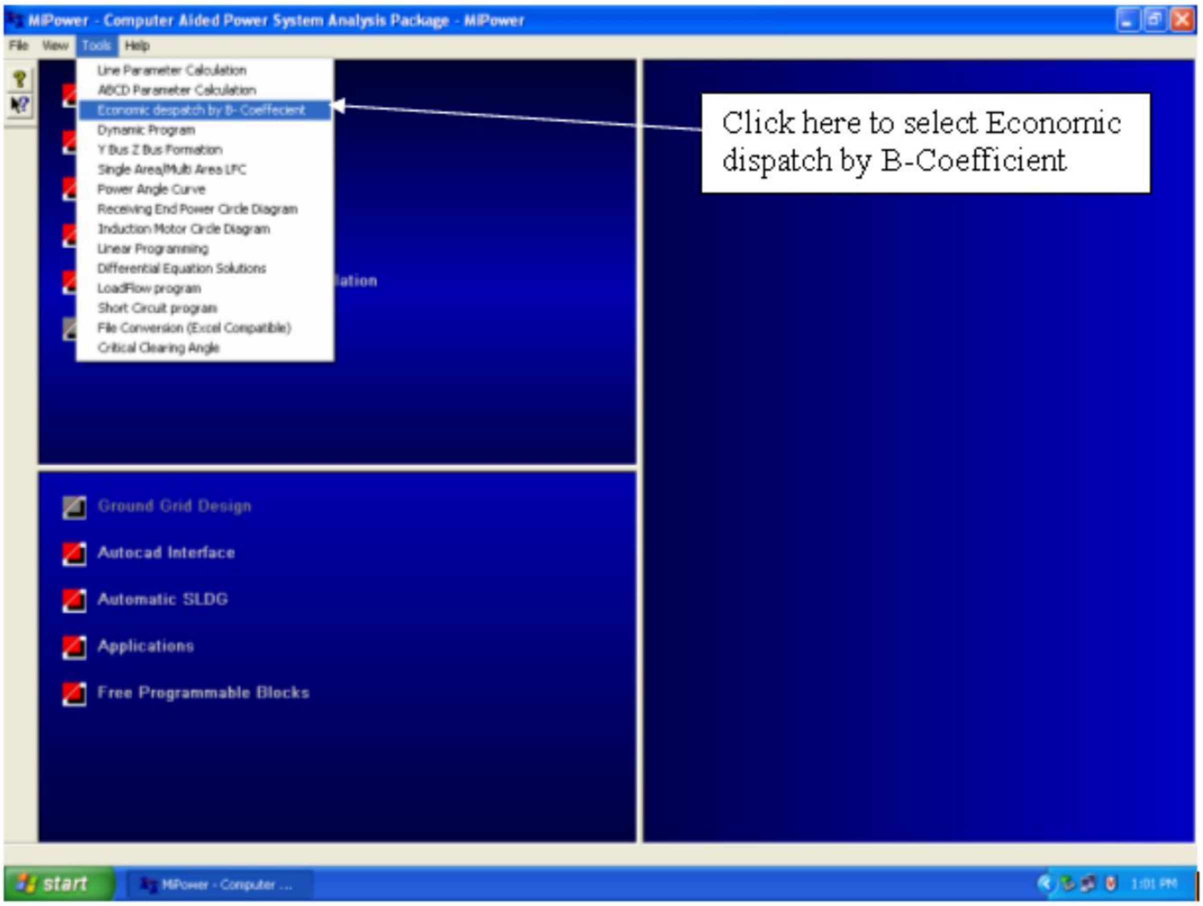
1. To solve Economic Despatch by using **MiPower** Package, invoke "**MiPower Tools**" in the MiPower main screen and select " *Economic dispatch by B-Coefficient* ".

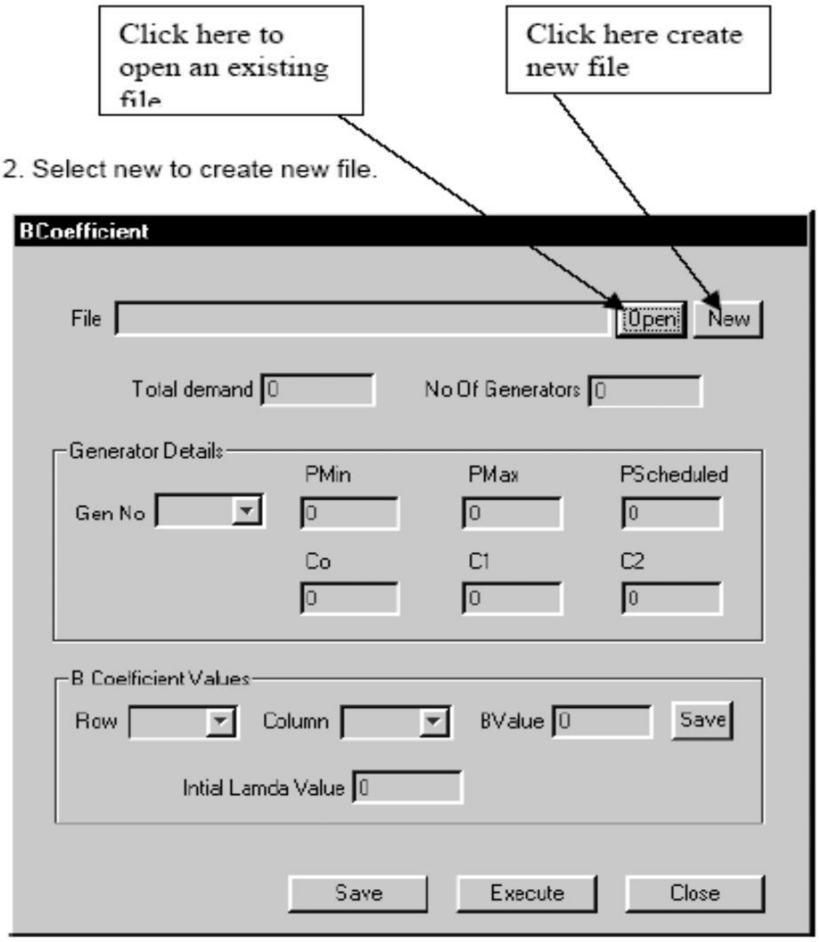
General procedure for using Mi-Power software

Economic dispatch

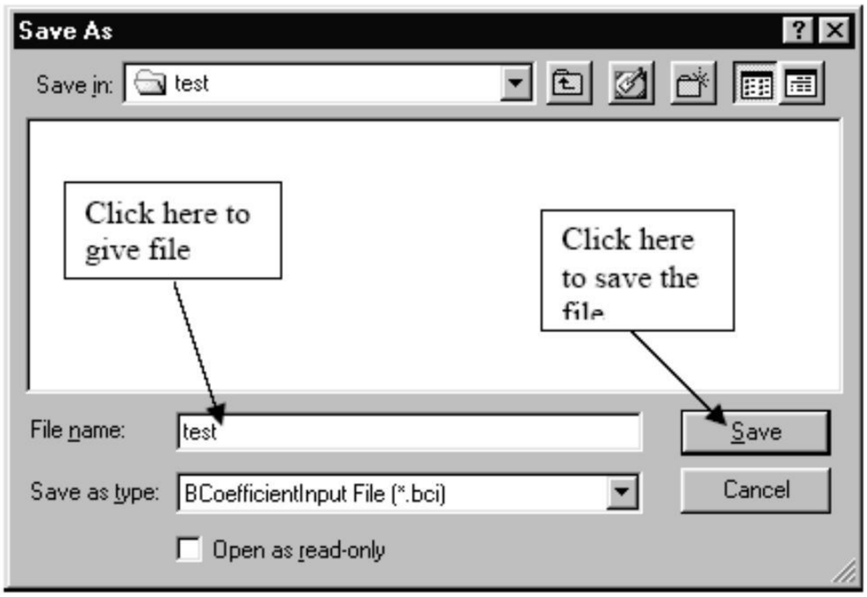
1. Double click on the **MiPower** icon present in the desktop.
2. Click ok and click on **MiPower** button, then select super user than click **ok**.
3. Click on tools menu and select economic dispatch by B-coefficient.
4. Click on new button create a new file, and save it.
5. Enter the value of load demand, number of generators and B-Coefficient and save.
6. Enter initial lamda value as 5.
7. Click on save and then execute.

Note: B-coefficient $B_{00}= B_{01}= B_{10}= B_{02}= B_{20}= B_{30}= B_{03}=0$

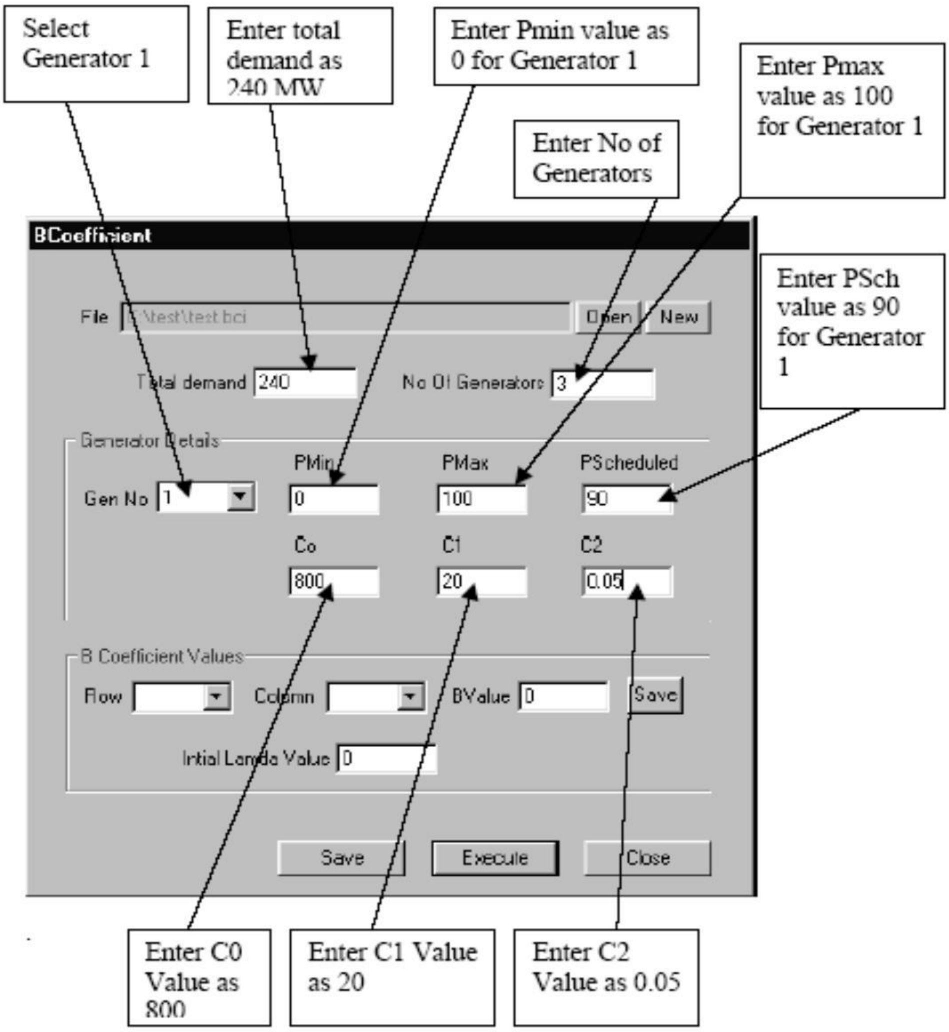

MiPower - Computer Aided Power System Analysis Package - MiPower
File View Tools Help
Line Parameter Calculation
ABCD Parameter Calculation
Economic despatch by B- Coeffecient
Dynamic Program
Y Bus Z Bus Formation
Single Area/Multi Area LFC
Power Angle Curve
Receiving End Power Circle Diagram
Induction Motor Circle Diagram
Linear Programming
Differential Equation Solutions
LoadFlow program
Short Circuit program
File Conversion (Excel Compatible)
Critical Clearing Angle
Click here to select Economic dispatch by B-Coefficient
Ground Grid Design
Autocad Interface
Automatic SLDG
Applications
Free Programmable Blocks
start


Click here to open an existing file
Click here create new file
2. Select new to create new file.
BCoefficient
File
Open
New
Total demand
No Of Generators
Generator Details
Gen No
PMin
PMax
PScheduled
Co
C1
C2
B Coefficient Values
Row
Column
BValue
Save
Intial Lamda Value
Save
Execute
Close

3. Select location to save the file and give the file name.



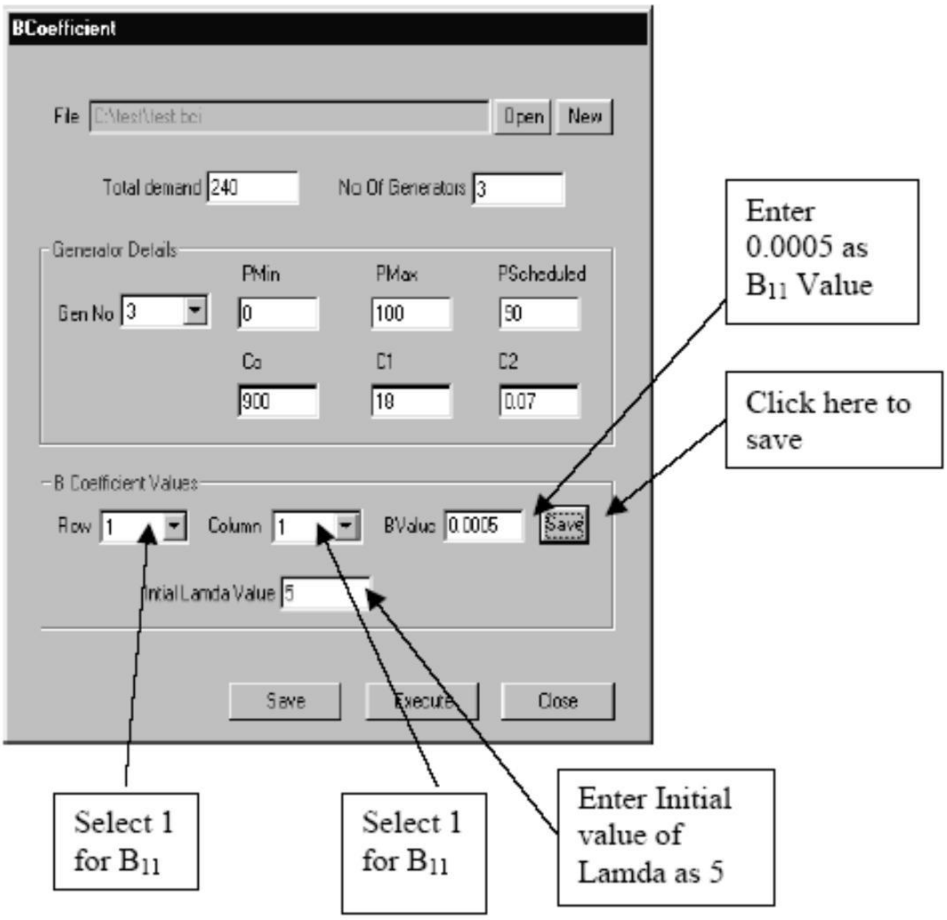
4. Enter the values of total demand as 240 MW and No of generators as 3. Select Generator number as 1 in generator details and enter corresponding values of Pmin, Pmax, Pscheduled and Corresponding C_0, C1, C2 values.



Similarly enter the values of P_{min}, P_{max} and P_{sch}, and C_0, $C_1$and C_2 values for other two generators as

Generator Number	P_{min}	P_{max}	P_{sch}	C_0	C_1	C2
2	0	100	90	1000	15	0.06
3	0	100	90	900	18	0.07

5. Enter initial value of Lamda as 5 .Enter the values of B11 as 0.0005 and save the value.

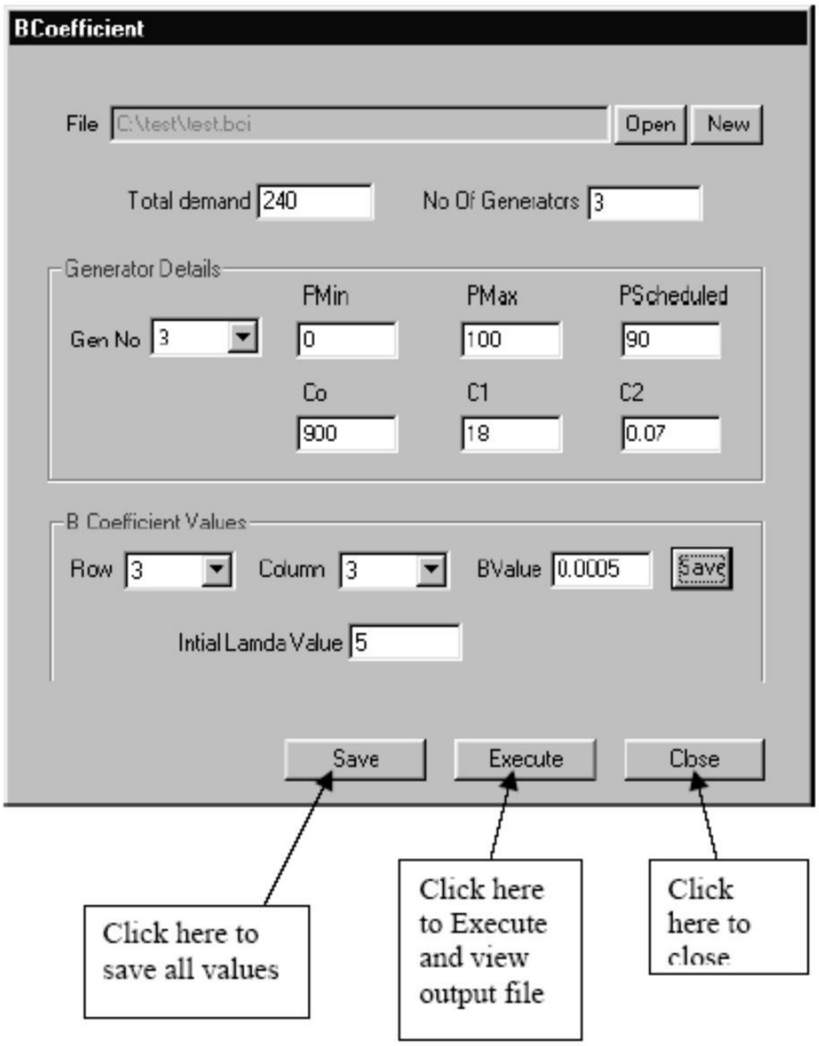


Similarly enter the values of B_{12} to B_{31} as

Variable	Value
B_{12}	0.00005
B_{13}	0.0002
B_{21}	0.00005
B_{22}	0.0004
B_{23}	0.00018
B_{31}	0.0002
B_{32}	0.00018
B_{33}	0.0005

And save the values.

6.Click on save button to save all values. Now click on execute to run economic dispatch study.



7. A part of the output file is as shown.

ECOMAMIC DESPATCH USING B-COEFFICENT MATRIX AND PENALTY FACTOR

Values of B-Coeff Matrix are

0.0005000 0.0000500 0.0002000
0.0000500 0.0004000 0.0001800
0.0002000 0.0001800 0.0005000

Scheduled Generations are

Genp 90.000000 MW
Genp 90.000000 MW
Genp 90.000000 MW

---

total_loss 18.306000 MW

Initial Cost of generation at bus 1 = 3005.000006 Rs for 90.000000 MW
Initial Cost of generation at bus 2 = 2835.999989 Rs for 90.000000 MW
Initial Cost of generation at bus 3 = 3087.000002 Rs for 90.000000 MW

Iter count 39 Lambda 32.339989 Total gen 255.925873 Total loss 15.978104
Total load 240.000000 Delta power -0.052231

Initial Total generation cost 8928.000000 Rs
Final Cost of generation at Generator 1 = 2807.234673 Rs for 83.098381 MW
Final Cost of generation at Generator 2 = 3099.999987 Rs for 100.000000 MW
Final Cost of generation at Generator 3 = 2582.163687 Rs for 72.827484 MW

Final Total generation cost is Rs 8489.398438

Cost Coefficient C0

This field specifies the constant cost coefficient C0 in rupees for the generator. This cost is independent of generation.

Generation Cost = Co + C1 MW + C2 (MW)(MW) Rs / hour

Co = Fixed cost (Capital Cost) in Rs/hour, which includes plant installation cost, fuel cost in controllable generator units, generating costs in base loaded units

C1 = Cost in Rs / MW / hour

C2 = Cost in Rs / (MW) (MW) / hour

Exercise Problems:

1. **Data given:**

Total No. of Generators : 2
Total Demand : 100MW

GENERATOR RATINGS:

GENERATOR 1: Pscheduled = 70 MW ; Pmin= 0.0MW; Pmax= 100MW

$C_0 = 50$; $C_1 = 16$; $C_2 = 0.015$

$C_{g1} = 50 + 16 P_1 + 0.015 P_1^2$ Rs / hr

GENERATOR 2: Pscheduled = 70 MW; Pmin= 0.0MW; Pmax= 100MW

$C_0 = 30$; $C_1 = 12$; $C_2 = 0.025$

$C_{g1} = 30 + 12 P_1 + 0.025 P_1^2$ Rs / hr

Loss (or B) Co- efficients :

$B_{11} = 0.005$; $B_{12} = B_{21} = 0.0012$; $B_{22} = 0.002$

2. Given the cost equation and loss Co-efficient of different units in a plant determine economic generation using the available software package for a total load demand of _____ MW (typically 150 MW for 2 units and 250 MW for 3 Units) neglecting transmission losses.

3. Given the cost equation and loss Co-efficient of different units in a plant determine penalty factor, economic generation and total transmission loss using the available software package for a total load demand of _____ MW (typically 150 MW for 2 units and 250 MW for 3 Units) .

Refer below questions for Q(2) & Q(3)

A)

Unit No.	Cost of Fuel input in Rs./ hr.
1	$C_1 = 800 + 20\ P_1 + 0.05\ P_1^2 \qquad 0 \le P_1 \le 100$
2	$C_2 = 1000 + 15\ P_2 + 0.06\ P_2^2 \qquad 0 \le P_2 \le 100$
3	$C_3 = 900 + 18\ P_3 + 0.07\ P_3^2 \qquad 0 \le P_3 \le 100$

Loss (or B) Co- efficients :

$B_{11} = 0.0005$ $B_{12} = 0.00005$ $B_{13} = 0.0002$

$B_{22} = 0.0004$ $B_{23} = 0.00018$ $B_{33} = 0.0005$

$B_{21} = B_{12}$ $B_{32} = B_{23}$ $B_{13} = B_{31}$

B)

Unit No.	Cost of Fuel input in Rs./ hr.
1	$C_1 = 50 + 16\ P_1 + 0.015\ P_1^2 \qquad 0 \le P_1 \le 100$
2	$C_2 = 30 + 12\ P_2 + 0.025\ P_2^2 \qquad 0 \le P_2 \le 100$

Loss (or B) Co- efficients :

$B_{11} = 0.005$ $B_{12} = B_{21} = -0.0012$ $B_{22} = 0.002$

REFERENCES

1. Modern Power System Analysis, D P Kothari, I J Nagrath, McGraw Hill, 4th Edition, 2011.
2. Computer Methods in Power Systems Analysis, Glenn W. Stagg, Ahmed H Ei- Abiad, Scientific International, Pvt. Ltd, 1stEdition, 2019.
3. Power Generation Operation and Control, AllenJ Wood etal, Wiley, 2nd Edition, 2016.
4. Computer Techniques in Power System Analysis, M.A. Pai,McGraw Hill, 2ndEdition, 2012.
5. Power System Analysis, Hadi Saadat, McGraw Hill, 2nd Edition, 2002.

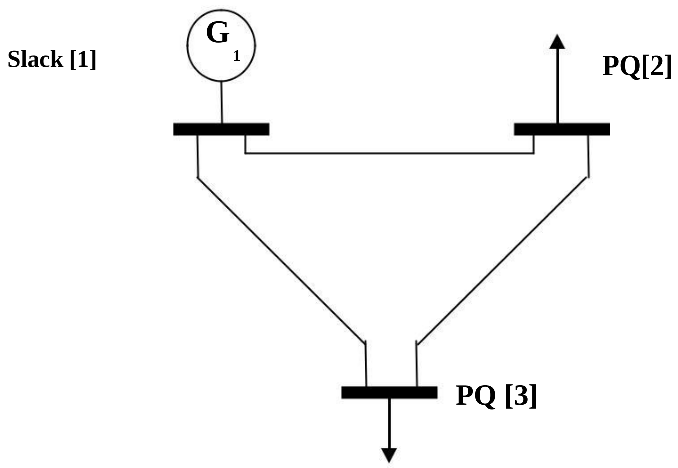
Viva Questions

1. What is Single line diagram?
2. What are the components of Power system?
3. What is a bus?
4. What is bus admittance matrix?
5. What is bus impedance matrix?
6. What is load flow study?
7. What are the information that obtained from a load flow study?
8. What is the need for load flow study?
9. What are quantities that are associated with each bus in a system?
10. What are the different types of buses in a power system?
11. Define Voltage controlled bus.
12. What is PQ-bus?
13. What is Swing (or Slack) bus?
14. What is the need for Slack bus?
15. What are the iterative methods mainly used for the solution of load flow problems?
16. Why do we go for iterative methods to solve load flow problems?
17. What do you mean by flat voltage start?
18. When the generator bus is treated as load bus?
19. What will be the reactive power and bus voltage when the generator bus is treated as load bus?
20. What are the advantages and disadvantages of Gauss-Seidel method?
21. How approximation is performed in Newton-Raphson method?
22. What is Jacobian matrix?
23. What are the advantages and disadvantages of Newton-Raphson method?
24. What is the need for voltage control in a Power system?
25. What is the reason for changes in bus voltage?
26. What is infinite bus?
27. How the reactive power of a generator is controlled?
28. What is the draw back in series connected capacitor?
29. What is synchronous capacitor?
30. What is tap changing transformer? How Voltage control is achieved in it?
31. What is regulating transformer?
32. What is Booster transformer?
33. What is off-nominal transformer ratio?
34. What is meant by a fault?
35. Why fault occurs in a power system?
36. How the faults are classified?
37. List the various types of Shunt and Series faults.
38. List the Symmetrical and unsymmetrical faults.
39. Name any two methods of reducing short-circuit current.
40. Name the main difference in representation of power system for load flow and short circuit studies.
41. Write the relative frequency of occurrence of various types of faults.
42. What is meant by fault calculation?
43. What is the need for short circuit studies or fault analysis?
44. What is the reason for transients during short circuits?
45. What is meant by doubling effect?
46. Define DC off-set current.
47. What is synchronous reactance?

48. Define sub transient reactance?
49. Define transient reactance?
50. What is the significance of sub transient reactance in short circuit studies?
51. What is the significance of transient reactance in short circuit studies?
52. Why the armature current decreases when the flux diminishes?
53. Give one application of sub transient reactance.
54. Name the fault in which positive, negative and zero sequence component currents are equal.
55. Name the fault in which positive and negative sequence component currents are together is equal and zero sequence current in magnitude
56. Define negative sequence impedance.
57. Name the faults which do not have zero sequence current flowing.
58. Name the faults involving ground.
59. Define positive sequence impedance
60. In what type of fault the positive sequence component of current is equal in magnitude but opposite in phase to negative sequence components of current?
61. In which fault negative and zero sequence currents are absent?
62. Define stability.
63. Define steady state stability.
64. Define transient stability.
65. What is steady state stability limit?
66. What is transient stability limit?
67. How stability studies are classified? What are they?
68. Define synchronizing coefficient.
69. Define swing curve.
70. What is the use of swing curve?
71. Define power angle.
72. For the swing equation M d2δ/dt2 = Pa, What will be the value of Pa during steady state operation?
73. Name the two ways by which transient stability study can be made in a system where one machine is swinging with respect to an infinite bus.
74. Define critical clearing time and critical clearing angle.
75. List the methods of improving the transient stability limit of a power system.
76. State equal area criterion.
77. Define efficiency of lines.
78. Define regulation of lines.
79. In Which method, for a long transmission line, for a particular receiving end voltage, when sending end voltage is calculated, it is more than the actual value.
80. What will be the power factor of the load if, in a short transmission line, resistance and inductive reactance are found to be equal and regulation appears to be zero.
81. In which of the models of Transmission lines, is the full charging current assumed to flow over half the length of the line only?
82. What is infinite line?
83. What is Short Transmission line?
84. What is Medium Transmission line?
85. What is Long Transmission line?

QUESTION BANK

1. Formation of Jacobian for a system not exceeding 4 buses * (no PV buses) in polar. A Three-Bus system is given below. The system parameters are given in the Table A and the load and generation data in Table B . Line impedances are marked in per unit on a 100MVA Base, and line charging susceptances are neglected. Taking bus 1 as Slack bus. Obtain the load



Bus No	Bus Voltage	Generation		Load	
		MW	Mvar	MW	Mvar
1	1.05+j0.0	--	--	0	0
2	--	0	0	50	20
3	--	0	0	60	25

Bus Code (i-k)	Impedance (p.u) Z_{ik}	Line charging Admittance (p.u) Y_i
1-2	0.08+j0.24	0
1-3	0.02+j0.06	0
2-3	0.06+j0.18	0

2. Figure below shows a single line diagram of a 5bus system with 2 generating units, 7 lines. Per unit transmission line series impedances and shunt susceptances are given on 100MVA Base, real power generation, real & reactive power loads in MW and MVAR are given in the accompanying table with bus1 as slack, obtain a load flow solution with Y-bus using Gauss-Siedel method and Newton Rapson method. Take acceleration factors as 1.4 and tolerances of 0.0001 and 0.0001 per unit for the real and imaginary components of voltage and 0.01 per unit tolerance for the change in the real and reactive bus powers.

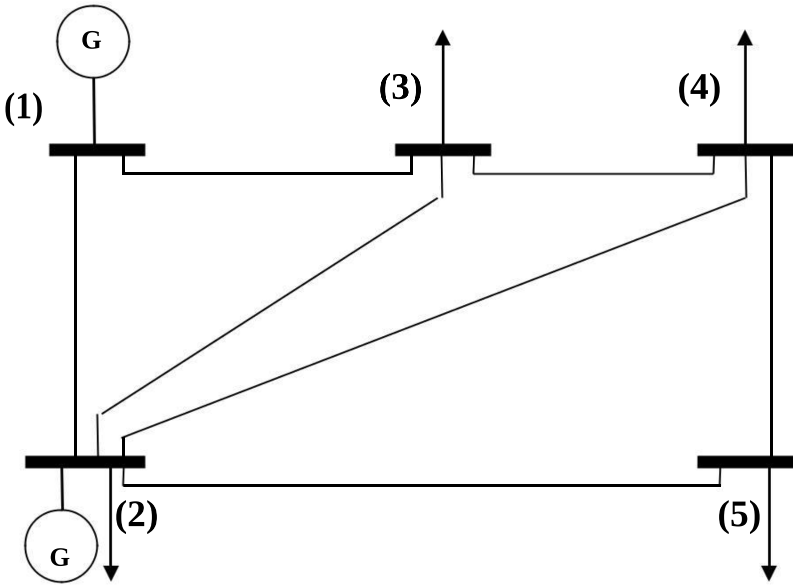


Table: 1.1		
Bus code From-To	Impedance R+jX	Line Charging B/2
1-2	0.02+j0.06	j 0.030
1-3	0.08+j0.24	j 0.025
2-3	0.06+j0.18	j 0.020
2-4	0.06+j0.18	j 0.020
2-5	0.04+j0.12	j 0.015
3-4	0.01+j0.03	j 0.010
4-5	0.08+j0.24	j 0.025

Table: 1.2					
Bus No	Bus Voltage	Generation MW	Generation MVAR	Load MW	LoadMVAR
1	1.00+j0.0	0	0	0	0
2	1.00+j0.0	40	30	20	10
3	1.00+j0.0	0	0	45	15
4	1.00+j0.0	0	0	40	5
5	1.00+j0.0	0	0	60	10

3. Determine the power angle curve and obtain the Graph for the given detail
   - Terminal Voltage = 1 p.u
   - Terminal Angle = 17.455 degree
   - Infinite bus voltage = 1 p.u
   - Xe = 0.2 p.u
   - X1 = 0.3

4. Cost equation & loss co-efficients of different units in a plant are given. Determine economic Generation for a total load demand of 240MW.

$C_1 = 0.05 P_1^2+20P_1+800 \qquad 0<=P_1<=100$

$C_2 = 0.06P_2^2+15P_2+1000 \qquad 0<=P_2<=100$

$C_3 = 0.07P_3^2+18P_3+900 \qquad 0<=P_3<=100$

Loss co-efficients:

$B_{11}=0.0005; \quad B_{12}=0.00005; \quad B_{13}=0.0002;$

$B_{22}=0.0004; \quad B_{23}=0.00018; \quad B_{33}=0.0005;$

$B_{21}=B_{12}; \quad B_{23}=B_{32}; \quad B_{13}=B_{31}$

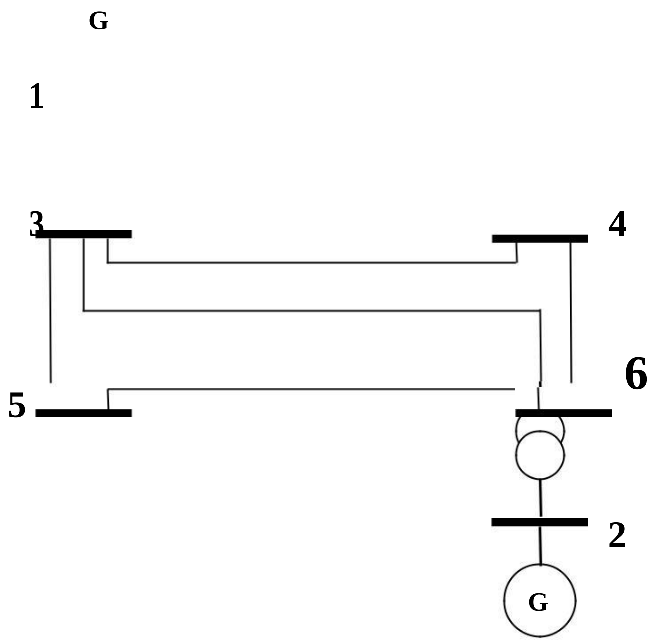
5. Write a program to find ABCD parameters for short line. Calculate Vr& Ir for the given Vs and Is or Calculate Vs& Is for the given Vr and Ir.
   Z=0.2+0.408i; Y=0+3.14e-6i.Vs=132 Is=174.96- 131.22i

6. Write a program to find ABCD parameters for long line network Calculate Vr & Ir for the given Vs and Is or Calculate Vs& Is for the given Vr and Ir.
   Z=0.2+0.408i; Y=0+3.14e-6i. Vs=132 Is=174.96-131.22i

7. Write a program to find ABCD parameters for medium line PI network Calculate Vr & Ir for the given Vs and Is or Calculate Vs& Is for the given Vr and Ir.
   Z= 2+0.408i; Y=0+3.14e-6i. Vs=132 Is=174.96- 131.22i

8. Write a program to find ABCD parameters for medium line T network Calculate Vr & Ir for the given Vs and Is or Calculate Vs& Is for the given Vr and Ir.
   Z= 2+0.408i; Y=0+3.14e-6i. Vs=132 Is=174.96- 131.22i

9. Figure shown below represents the single line diagram of 6-bus system with two identical Generating units, five lines and two transformers per unit transmission line series impedances and shunt susceptances are given on 100MVA base, generator's transient impedance and Transformer leakage reactances are given in accompanying table.



If a 3-phase to ground fault occurs at bus5, find the fault MVA. The data is given below.

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

Generator details:

G1=G2=100MVA, 11KV with X'd=10%
Transformer details:
T1=T2= 11/110KV, 100MVA, leakage reactance= X = 5%
All impedances are on 100MVA base

10. Write a program to form Y-bus using singular transformation method without mutual Coupling.

```
       p   q        Z          hlc Y(ADM)
   Z= [ 5   4   0.02+0.06i        0.03i
        5   1    0.08+0.24i       0.025i
        4   1   0.06+0.18i         0.02i
        4   2   0.06+0.18i         0.02i
        4   3   0.04+0.12i         0.015i
        1   2   0.01+0.03i         0.01i
        2   3   0.08+0.24i        0.025i ]
```

11. Write a program to form Y-bus using singular transformation method with mutual coupling.

```
        p qZ  mno  mutual
      Z= [ 0 1   0.6i     0     0
           0   2  0.5i      1  0.1i
           2   3  0.5i      0      0
           0   1  0.4i      1   0.2i
           1   3  0.2i      0     0];
```

12. Write a program to form Y-bus using Inspection method

```
       p q        Z            hlc  Y(ADM)
   Z= [ 5   4  0.02+0.06i 0.03i      0.9
        5   1 0.08+0.24i  0.025i     1
        4   1 0.06+0.18i  0.02i      1
        4   2 0.06+0.18i  0.02i      1
        4   3 0.04+0.12i  0.015i     1
        1   2 0.01+0.03i  0.01i      0.8
        2   3 0.08+0.24i  0.025i      1]
```

13. Write a program to obtain swing curve when the fault is cleared Ps=0.9,e=1,v=1,m=0.00028,xe=0.35,xl=0.2

14. Write a program to obtain swing curve for the sustained fault Ps=0.9,e=1,v=1,m=0.00028,xe=0.35,xl=0.3

15. Write a program for Determination of bus currents, bus power &line flows for a specified system voltage (bus) profile.

<u>INPUT Data:</u>

```
Line data= [3        3
            1    2        0.02        0.04    0
            1    3        0.01        0.03    0
            2    3      0.0125      0.025   0]
Bus data= [1      1.05        0
             2     0.98183   -3.5
             3   1.00125  -2.8624]
```

16. Write a program to perform load flow analysis using Gauss siedel method.

```
Y = [3-12i    -2+8i            -1+4i            0
     -2+8i    3.66-14.664i     -0.666+2.664i    -1+4i
     -1+4i    -0.666+2.664i    3.66-14.664i     -2+8i
      0       -1+4i            -2+8i            3-12i]
```

17. Write program for the formation of Zbus using Zbus building algorithm Z= [1 1 0 0.25

```
2 2 1 0.1
3 3 1 0.1
4 2 0 0.25
5 2 3 0.1];
```

ADDITIONAL PROGRAMS

1. Fault Studies For A Given Power System Using Software Package

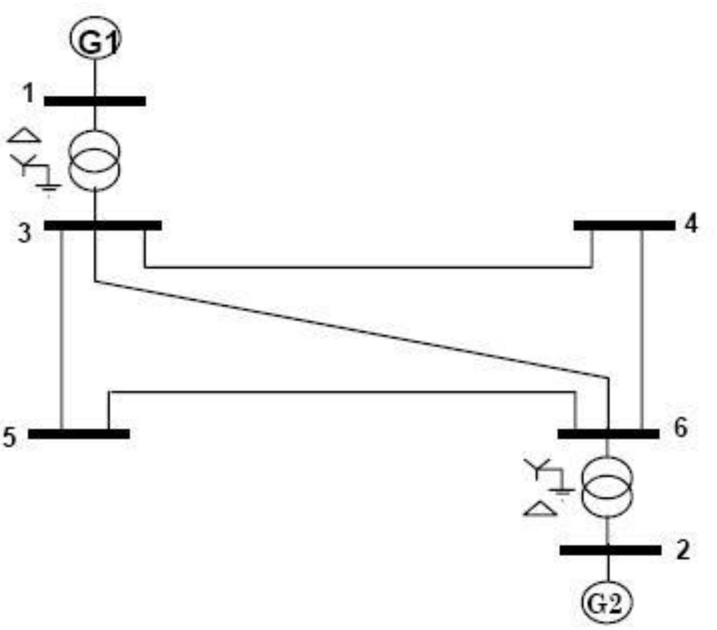


Figure shows a single line diagram of a 6-bus system with two identical generating units, five lines and two transformers. Per-unit transmission line series impedances and shunt susceptances are given on 100 MVA base, generator's transient impedance and transformer leakage reactances are given in the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

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

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

Generator details:

$G_1 = G_2$ = 100MVA, 11KV with X'_d =10%

Transformer details:

$T_1 = T_2$ = 11/110KV , 100MVA, leakage reactance = X = 5%

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

<u>**Mi Power Data Interpretation:**</u>

SOLUTION:

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

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

General procedure for using Mi-Power software

1. Double click on the **MiPower** icon present in the desktop.
2. Click ok and click on **MiPower** button, then select super user than click **ok**.
3. A blue screen MiPower window will appear, then double click on the power system editor to get MiGui window

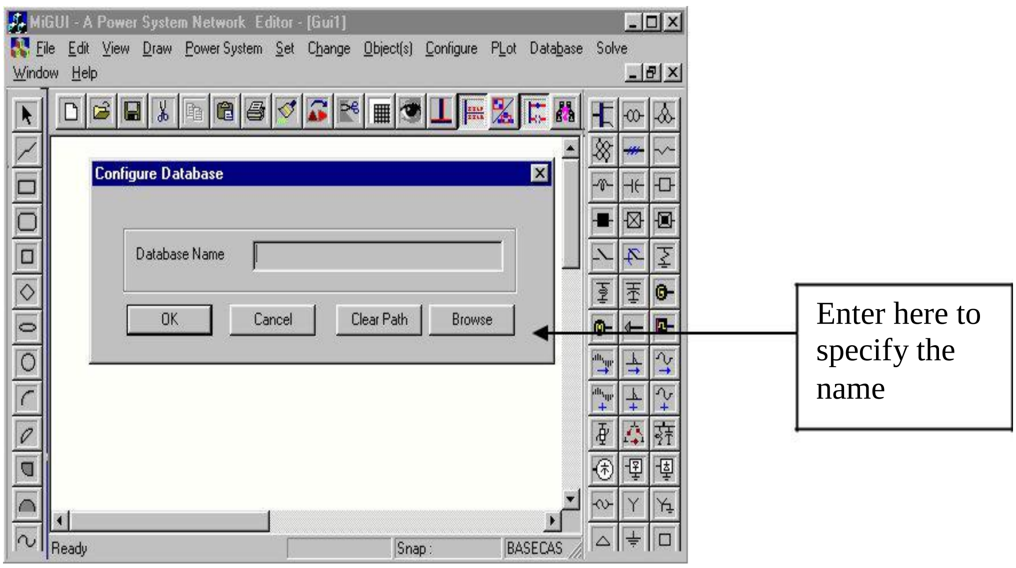
Short Circuit Analysis

1. Select menu option **Database** ⇒ **Configure.** Configure Database **dialog** is popped, Click **Browse** button.
2. **Open** dialog box is popped up, then browse the desired directory and specify the name of the database (file name).
3. Create the Bus-bar structure as given in the single line diagram.
4. After creating the Buses draw the transmission line according to the single line diagram given.
5. Place the generator and transformer; enter its ratings on the respective Bus number mentioned in the single line diagram.
6. Similarly as generator place the load and its data.
7. Go to solve menu in that select Short Circuit analysis, select case (as no 1), select study info..
8. In short circuit data select: 3 phase to ground fault, then in option select 'select buses' in that select which bus fault has to be created
9. Click on execute button and then click on the report. Select standard finally click on OK.

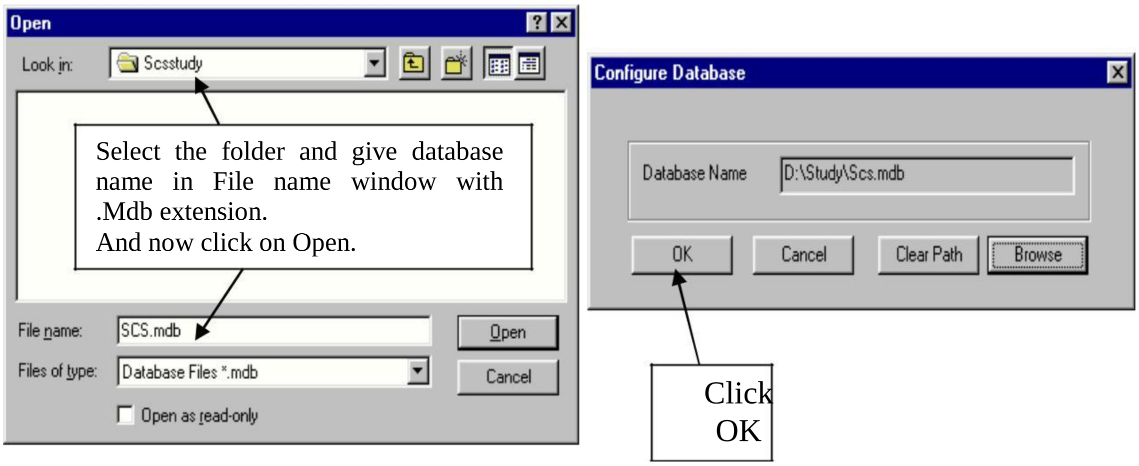
Procedure to enter the data for performing studies using Mi Power

Mi Power - Database Configuration

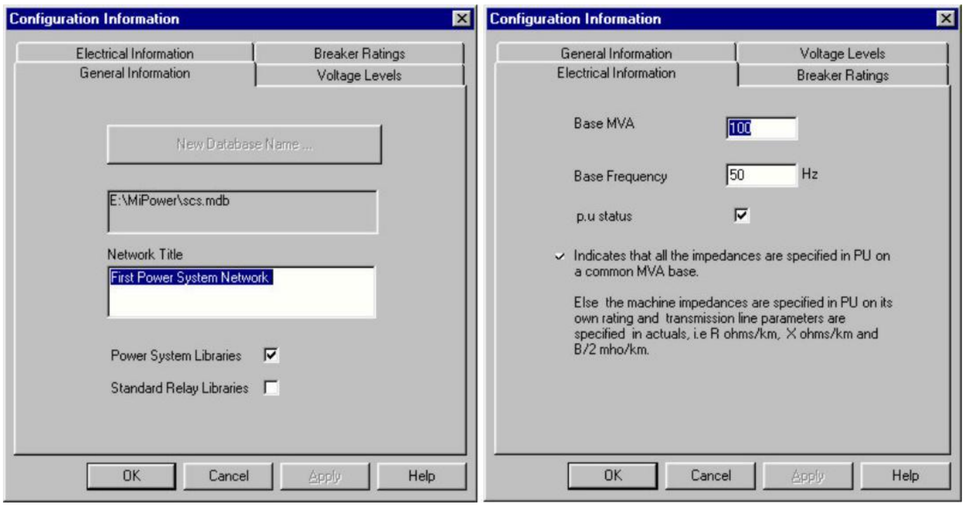
Open Power System Network Editor. Select menu option **Database→Configure**. Configure Database dialog is popped up. Click **Browse** button.



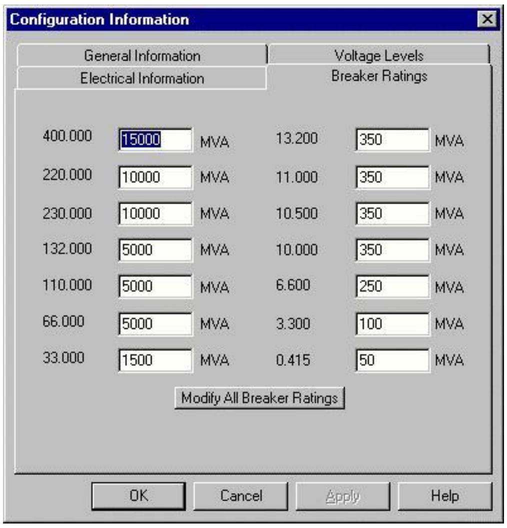
Open dialog box is popped up as shown below, where you are going to browse the desired directory and specify the name of the database to be associated with the single line diagram. Click **Open** button after entering the desired database name. **Configure Database** dialog will appear with path chosen.



Click on **OK** button in the **Configure database** dialog, the following dialog appears.



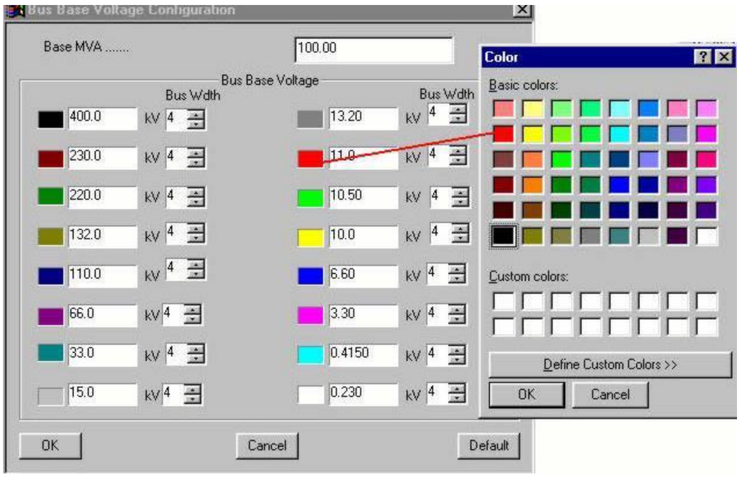
Uncheck the Power System Libraries and Standard Relay Libraries. For this example these standard libraries are not needed, because all the data is given on p u for power system libraries (like transformer, line\cable, generator), and relay libraries are required only for relay co-ordination studies. If Libraries are selected, standard libraries will be loaded along with the database. Click electrical **information** tab.



Since the impedances are given on 100 MVA base, check the pu status. Enter the Base MVA and Base frequency as shown below. Click **Breaker Ratings** tab. If the data is furnished, modify the breaker ratings for required voltage levels. Otherwise accept the default values. Click **OK** button to create the database to return to Network Editor.

Bus Base Voltage Configuration

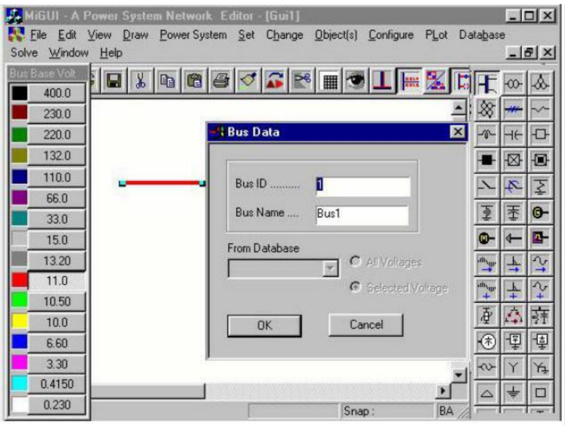
In the network editor, configure the base voltages for the single line diagram. Select menu option **Configure Base voltage.** Dialog shown below appears. If necessary change the **Base-voltages, color, Bus width** and click **OK.**

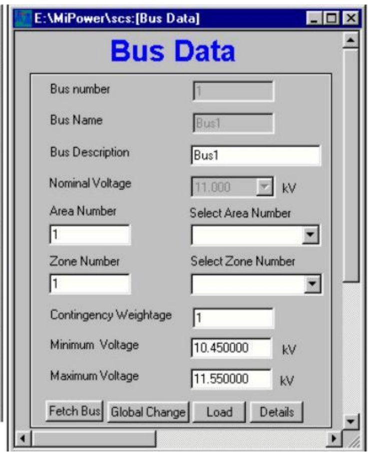


Procedure to Draw First Element - Bus

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

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



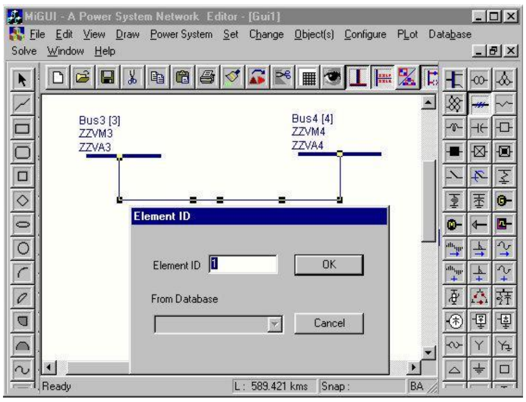


After entering data click save, which invokes Network Editor. Follow the same procedure for remaining buses. Following table gives the data for other buses.

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

Procedure to Draw Transmission Line

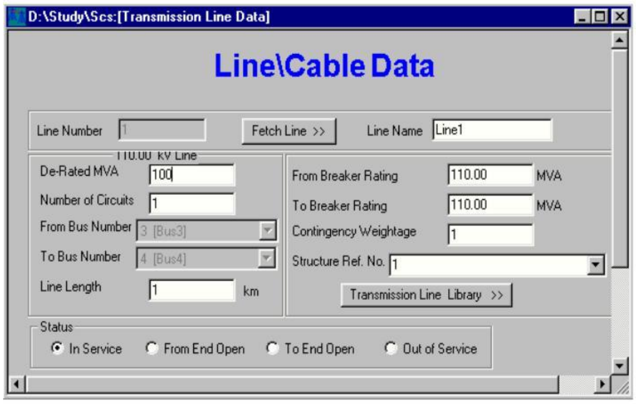
Click on **Transmission Line** icon provided on power system tool bar. To draw the line click in between two buses and to connect to the from bus, double click LMB (Left Mouse Button) on the **From Bus** and join it to another bus by double clicking the mouse button on the **To Bus** .**Element ID**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

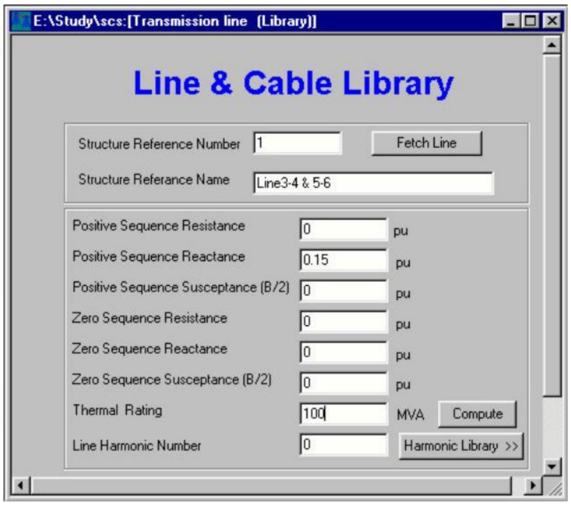


Enter **Element ID** number and click OK. Database manager with corresponding **Line\Cable Data** form will be open. Enter the details of that line as shown below.

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

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



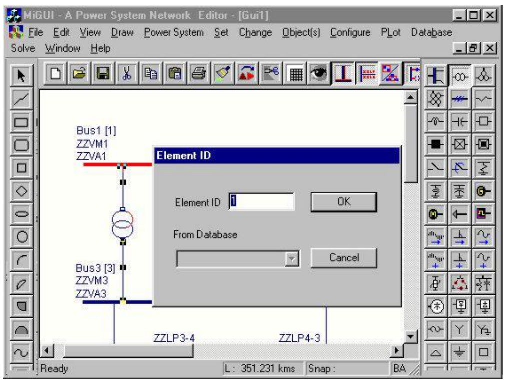


Transmission Line Element Data					
Line Number	1	2	3	4	5
Line Name	Line3-4	Line3-5	Line3-6	Line4-6	Line5-6
De-Rated MVA	100	100	100	100	100
No. Of Circuits	1	1	1	1	1
From Bus No.	3	3	3	4	5
To Bus No.	4	5	6	6	6
Line Length	1	1	1	1	1
From Breaker Rating	5000	5000	5000	5000	5000
To Breaker Rating	5000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

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

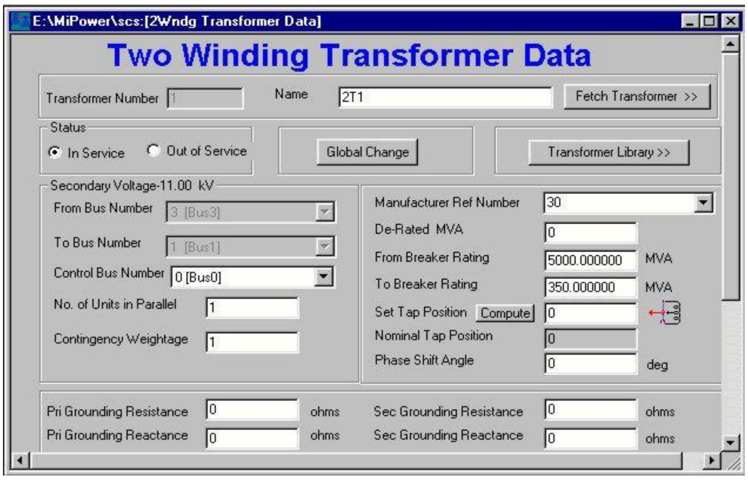
Procedure to Draw Transformer

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

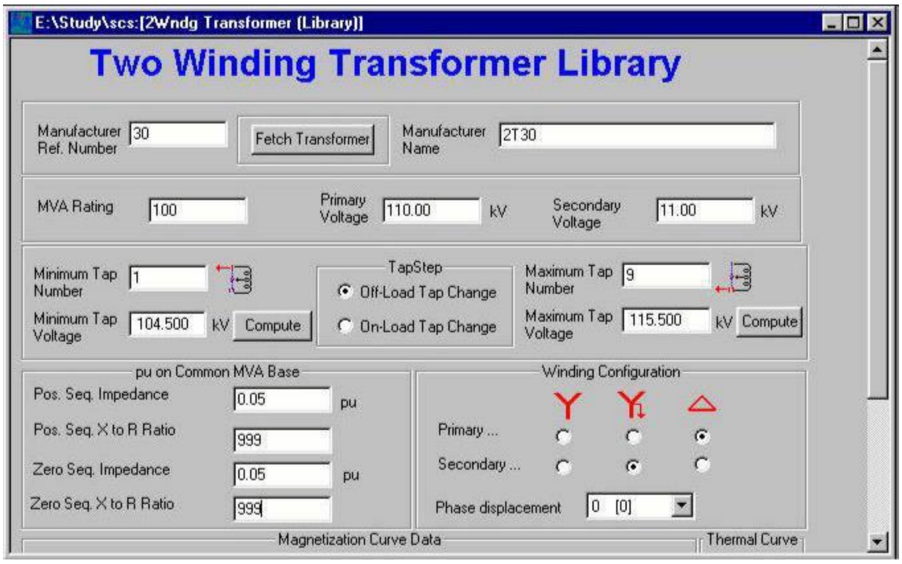


Transformer Element Data form will be open. Enter the **Manufacturer Ref. Number as 30.** Enter transformer data in the form as shown below. Click on **Transformer Library** >>button.

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



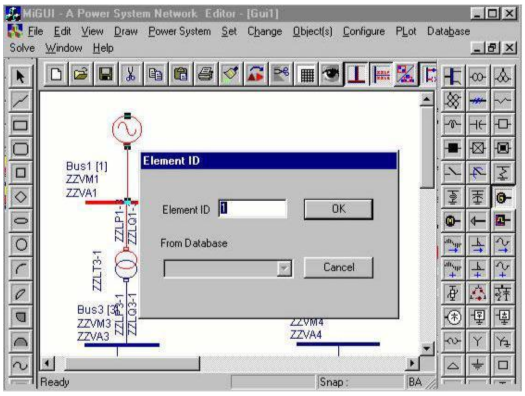
Transformer element data form will appear. Click **Save** button, which invokes network editor. In the similar way enter other transformer details.



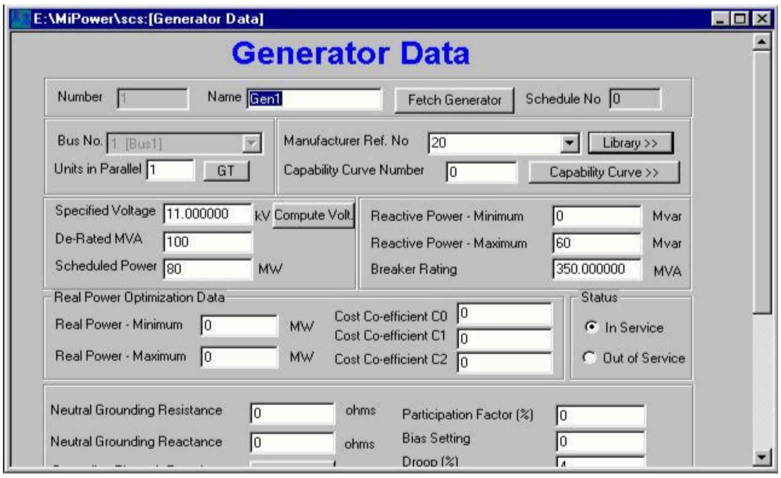
2^{nd} Transformer details	
Transformer Number	2
Transformer Name	2T2
From Bus Number	6
To Bus Number	2
Control Bus Number	2
Number of Units in Parallel	1
Manufacturer ref. Number	30
De Rated MVA	100
From Breaker Rating	5000
To Breaker Rating	350
Nominal Tap Position	5

Procedure to Draw Generator

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

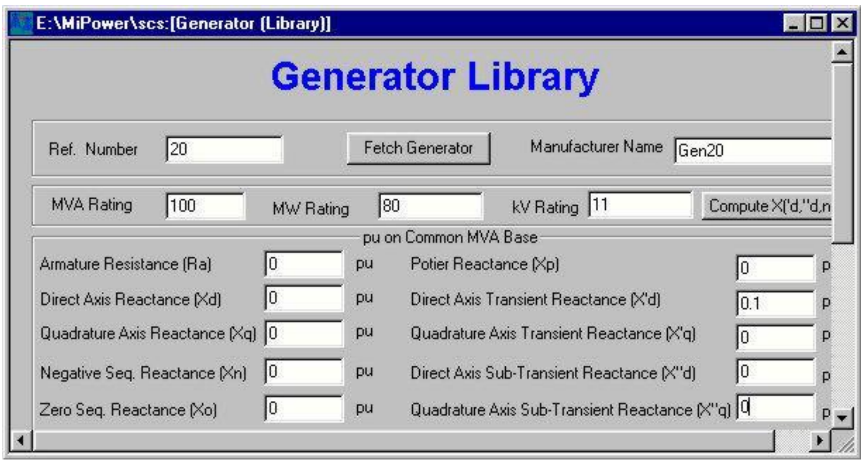


Generator Data form will be opened. Enter the **Manufacturer Ref. Number** as **20.** Enter Generator data in the form as shown below.



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

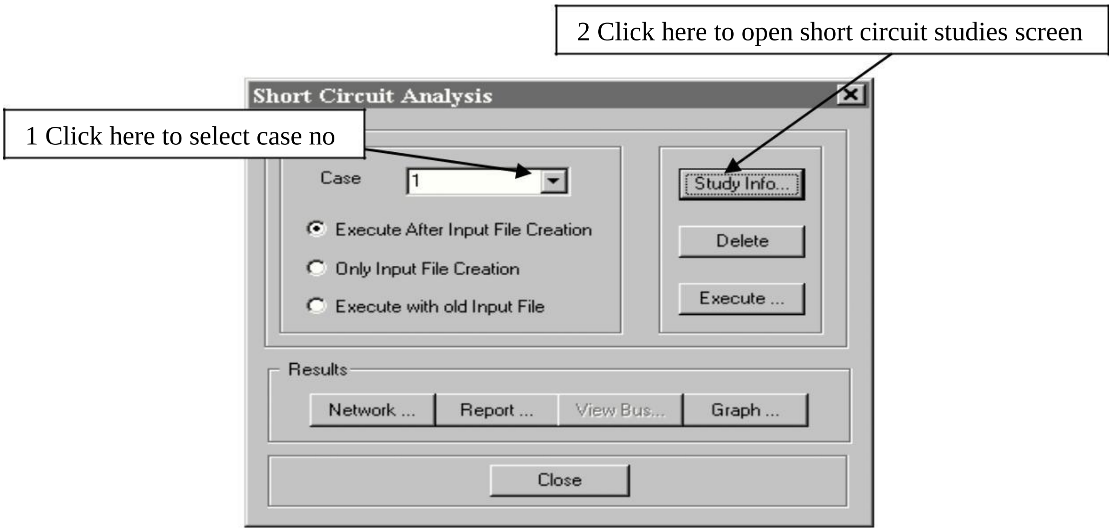
Save and **Close** the library screen. Generator data screen will be reopened. Click **Save** button, which invokes Network Editor. Connect another generator to Bus 2. Enter its details as given in the following table.



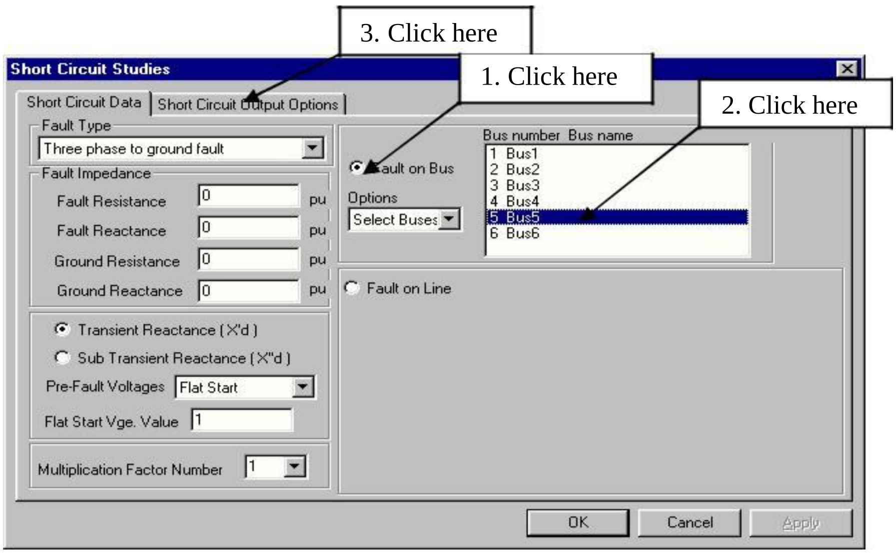
2^{nd} Generator details	
Name	GEN-2
Bus Number	2
Manufacturer Ref. Number	20
Number of Generators in Parallel	1
Capability Curve Number	0
De-Rated MVA	100
Specified Voltage	11
Scheduled Power	20
Reactive Power Minimum	0
Reactive Power Maximum	60
Breaker Rating	350
Type of Modeling	Infinite

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

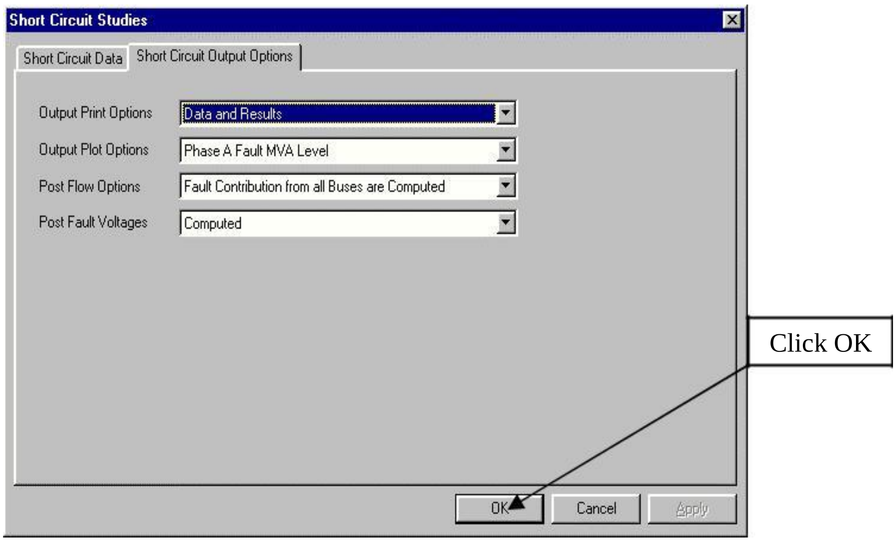
TO solve short circuit studies choose menu option **Solve →Short Circuit Analysis** or click on **SCS** button on the toolbar on the right side of the screen. Short circuit analysis screen appears.



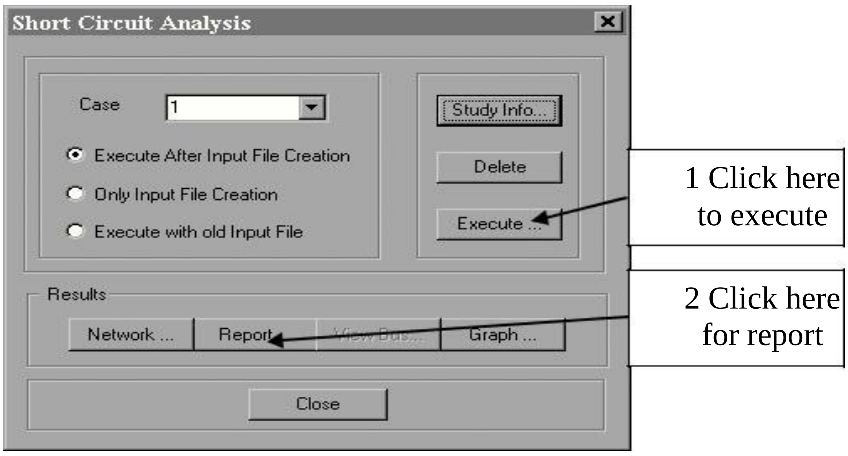
Study Information.



In **Short Circuit Output Options** select the following.



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



Part of the Report is shown below

```
FAULT AT BUS NUMBER      5 : NAME     Bus5
      CURRENT (AMPS/DEGREE)                        FAULT MVA
 SEQUENCE (1,2,0)    PHASE (A,B,C)      SEQUENCE (1,2,0)     PHASE (A,B,C)
MAGNITUDE   ANGLE  MAGNITUDE   ANGLE        MAGNITUDE          MAGNITUDE
--------- -------  --------- -------        ---------          ---------
     3870  -90.00       3870  -90.00              737                737
        0  -90.00       3870  150.00                0                737
        0  -90.00       3870   30.00                0                737
R/X RATIO OF THE SHORT CIRCUIT PATH        :   0.0000
PEAK ASYMMETRICAL SHORT-CIRCUIT CURRENT :    10947 AMPS
PASCC = k x sqrt(2) x If , k =    2.0000
-------------------------------------------------------------------------------
```

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

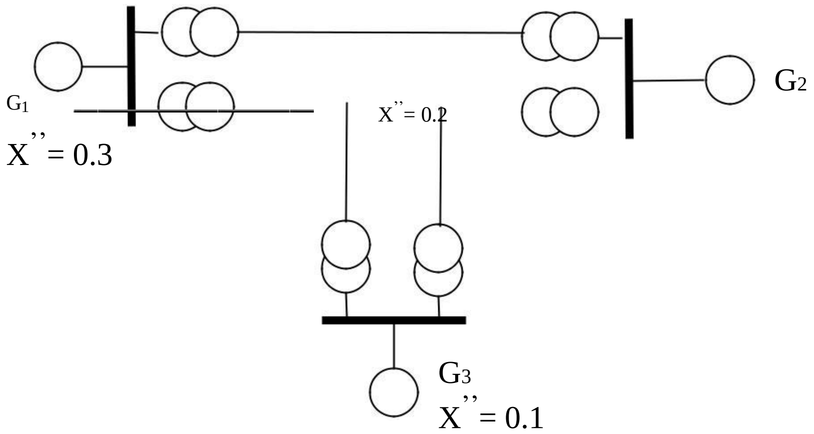
Exercise problems:

1. Using the available software package determine (a) fault current (b) post fault voltages at all buses (c) fault MVA , when a line to ground fault with / with out Zf = ___ occurring at _____ bus for a given test system.(Assume pre fault voltages at all buses to be 1 pu) compare the results with the symmetrical fault.

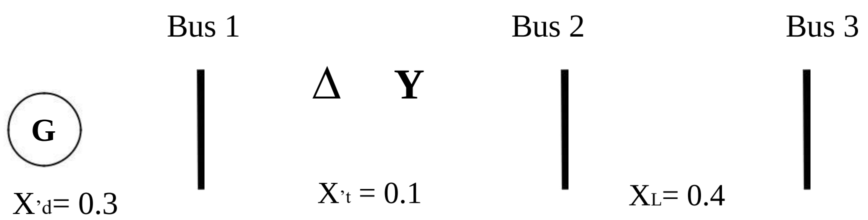
2. Using the available software package determine (a) fault current (b) post fault voltages at all buses (c) fault MVA , when a line to line & ground fault with / with out Zf = ___ occurring at _____ bus for a given test system.(Assume pre fault voltages at all buses to be 1 pu) compare the results with the symmetrical fault.

Refer below question for Q.(1) & Q(2)

Reactance of all transformers and transmission lines	= 0.1 pu
Zero sequence reactance of transmission line	= 0.25 pu
Negative sequence reactance of generator	= Subtransient reactace
Zero sequence reactance of generator	= 0.1 pu

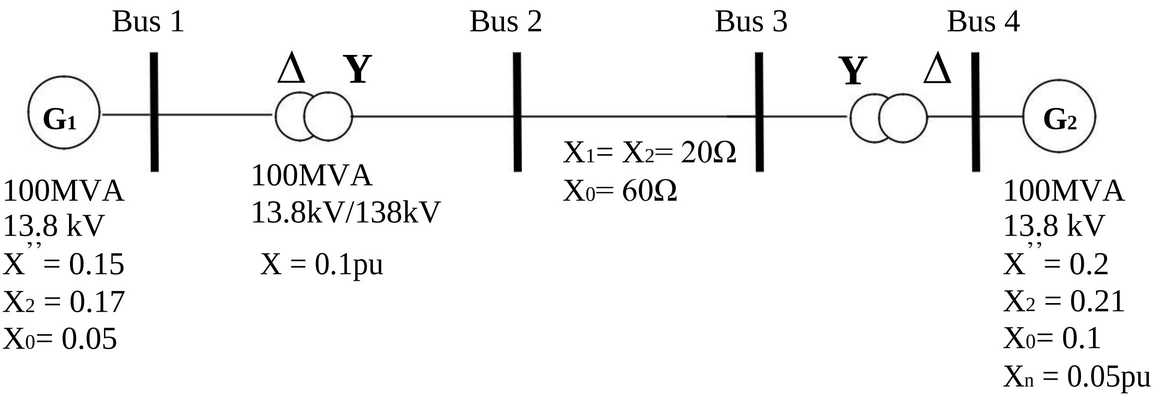


3. For the given circuit, find the fault currents, voltages for the following type of faults at Bus3.
1. Single Line to Ground Fault
2. Line to Line Fault
3. Double line to Ground Fault
For the transmission line assume $X_1 = X_1$, $X_0 = 2.5 X_L$

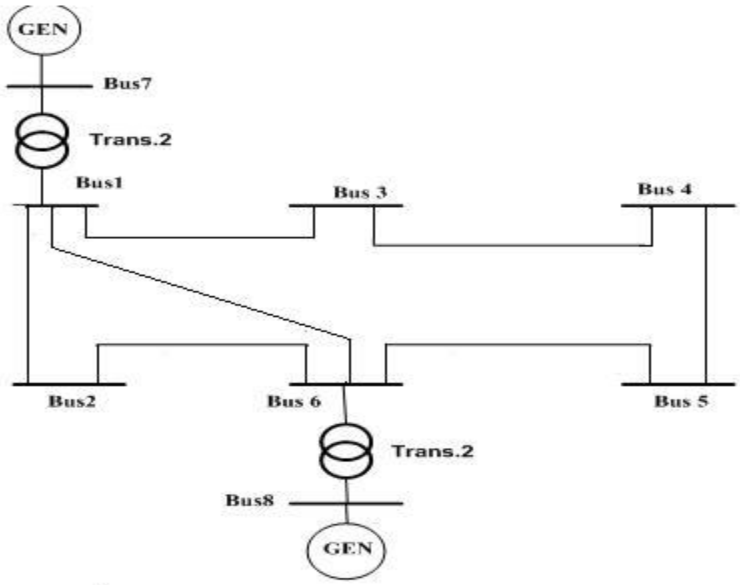


4. For the given circuit, find the fault currents, voltages for the following type of faults at Specified location.

1. Single Line to Ground Fault
2. Double line to Ground Fault
3. Line to Line Fault



5. Figure shown below represents the single line diagram of 8-bus system with two identical Generating units, seven lines and two transformers per unit transmission line series impedances and shunt susceptances are given on 500MVA base, generator's transient impedance and Transformer leakage reactances are given in accompanying table



If a 1-phase to ground fault occurs at bus5, find the fault MVA. The data is given below.

Bus-code	Impedance	Line Charging
p-q	Zpq	Y'pq/2
1-2	0.005+j0.0563	0.079
1-3	0.0057+j0.0714	0
1-6	0.005+j0.045	0
3-4	0.0045+j0.0409	0.179
4-5	0.0044+j0.05	0.153

5-6	0.004+j0.05	0.0745
2-6	0.005+j0.05	0

Generator details:

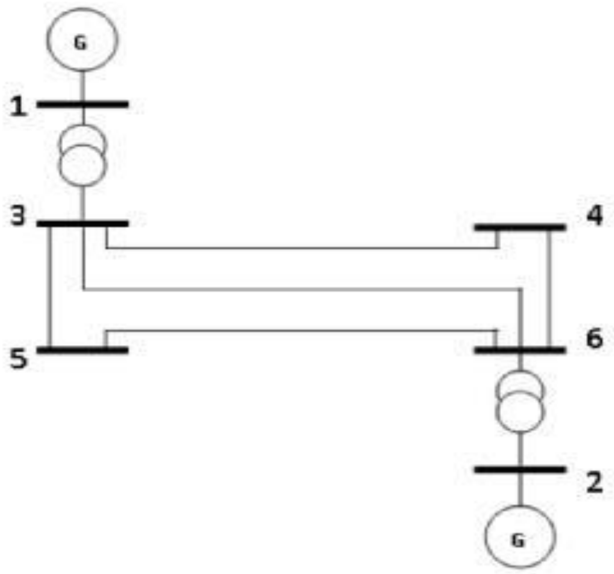
G1=G2=500MVA, 33KV with X'd=10%

Transformer details:

T1=T2= 33/330KV, 500MVA, leakage reactance= X = 5%

All impedances are on 500MVA base

6. Figure shown below represents the single line diagram of 6-bus system with two identical Generating units, five lines and two transformers per unit transmission line series impedances and shunt susceptances are given on 100MVA base, generator's transient impedance and Transformer leakage reactances are given in accompanying table.



If a 3-phase occurs at bus4, find the fault MVA. The data is given below.

Generator details:

G1=G2=100MVA, 11KV with X'd=25%

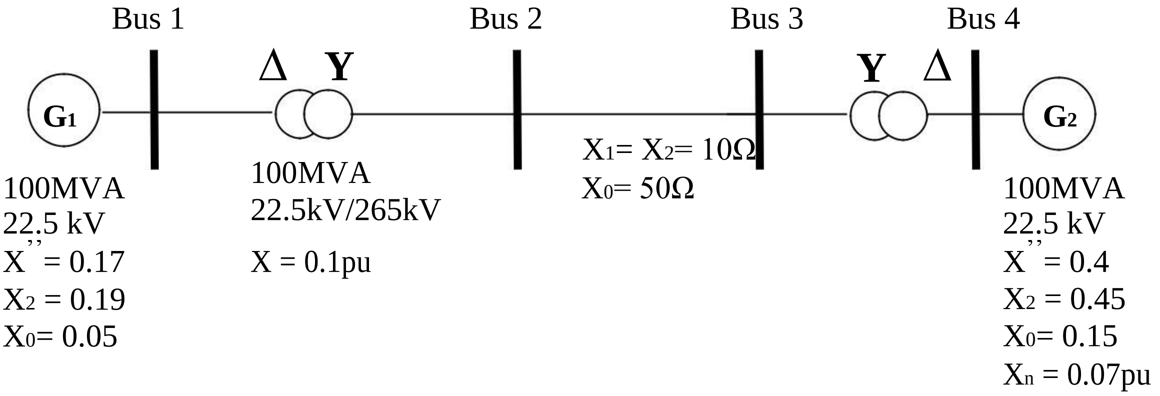
Transformer details:

T1=T2= 11/110KV, 100MVA, leakage reactance= X = 20%

All impedances are on 100MVA base

7.For the given circuit, find the fault currents, voltages for the following type of faults at Specified location.

Single Line to Ground Fault
Double line to Ground Fault
Line to Line Fault
Double line fault



8.Write a program to form Y-bus using Inspection method

	p	q	Z	hlc	Y(ADM)
Z= [	5	4	0.01+0.05i	0.02i	0.8
	5	1	0.08+0.24i	0.025i	1
	4	1	0.06+0.15i	0.03i	1
	4	2	0.02+0.18i	0.03i	1
	4	3	0.05+0.14i	0.013i	1
	1	2	0.03+0.03i	0.02i	0.9
	2	3	0.09+0.24i	0.025i	1]

9.Write a program to obtain swing curve when the fault is cleared

Ps=0.8,e=1,v=1,m=0.00058,xe=0.25,xl=0.1