Debre Markos University
Institute of Technology
School of Electrical and Computer Engineering
Power System II Laboratory Activities

Note: Please try to solve the given Activities using Power World Simulator, ETAP and Matlab/ Simulink/ or PSAT

Experiment #1: Solving Power Flow Problem Using Matlab/ M-File (Optional)

Procedures

1. Write the M- file Code on the Matlab script editor.
2. Solve/ Run the simulation and fix any of the problem

```
clc
clear
%Newton Raphson Method
%{
To get results in form:
- phase and magnitude ,Os=1
- Real+jImag ,Os=2
%}
Os=2;
%Number of Iteratuions:
Its=12;
%Number of Buses:
Nb=5;
%Number of Lines:
Nl=6;
%Choose delta reference;
Delta_r=2;
%{
Transmission line parameters:
Write them without j or i
1st & 2nd column for line "From-To"
From | To | R | X | Gsh | Bsh
%}
T=[1 2 0.0108 0.0640 0.01 0.1
   2 3 0 0.04 0 0
   1 4 0.0235 0.0941 0.05 2
   2 5 0.0118 0.0471 0.02 1
   3 5 0.0147 0.0588 0 0
   4 5 0.0118 0.0529 0.05 2];
%{
Generators & loads:
```

```
Start from bus 1 to Nb
Assumptions Eg~=0,|Vbus|=1
if Eg~=0 && Pd==0 (slack bus)
even if you choose Delta_r
 Eg | Pg | Sd
%}
B=[1.05 0 0
   0 0 3+2.5i
   0 0 1+0.8i
   0 0 2.5+2.5i
   1 1.8 0.8+0.8i];
% ---------DO NOT TOUCH------------
G50=0;
for ff=1:Nb
   if B(ff,1)~=0
      G50=1;
      break;
   end
end
for f=1:Nb
   if B(f,1)~=0 && B(f,2)==0
      Delta_r=f;
      break;
   end
end
if G50==1
   Y=zeros(Nb,Nb);
   k=1:Nb;
   N=0;
   for i=1:Nb
      for z=1:Nl
         for j=1:2
            if T(z,j)==k(1,i)
               M=(T(z,3)+T(z,4)*1i)^-1;
               if abs(M)==inf
                  M=0;
               end
               N=N+M+(T(z,5)+T(z,6)*1i)*0.5;
               if j/2 ~= 1
                  P=T(z,2);
                  Y(i,P)=-M;

               elseif j/2 == 1
                  P=T(z,1);
                  Y(i,P)=-M;
               end
```

```
            end
        end
    end
    Y(i,i)=N;
    N=0;
end
for Its2=1:Its
    Un=0;
    o=0;
    Delta = sym('Delta',[1 Nb]);
    Results = sym('DD',[Nb 3])*0;
    V = sym('V',[1 Nb]);
    F=sym('F',[1 Nb*2]);
    Gy=real(Y);
    By=imag(Y);
    Pd=real(B(:,3));
    Pa=Pd-B(:,2);
    Qd=imag(B(:,3));
    F(1,Delta_r)=0;
    Delta(1,Delta_r)=0;
    Results(Delta_r,1)=V(1,Delta_r);
    Results(Delta_r,3)='Zero';
    for i=1:Nb
        if B(i,1)~=0
            Results(i,1)=V(1,i);
            V(1,i)=1;
            Results(i,2)=V(1,i);
        end
    end
    for i=1:Nb
        if V(1,i)==1
            F(1,i+Nb)=0;
        end
    end
    C=0;
    for i=1:Nb
        if F(1,i)~=0
            for j=1:Nb
                C=C+V(1,i)*(Gy(i,j)*V(1,j)*cos(Delta(1,i)-Delta(1,j)));
                C=C+V(1,i)*(By(i,j)*V(1,j)*sin(Delta(1,i)-Delta(1,j)));
            end
            F(1,i)=C+Pa(i,1);
            C=0;
        end
    end
```

```
for i=1:Nb
   if F(1,Nb+i)~=0
      for j=1:Nb
         C=C+V(1,i)*(Gy(i,j)*V(1,j)*sin(Delta(1,i)-Delta(1,j)));
         C=C+V(1,i)*(-By(i,j)*V(1,j)*cos(Delta(1,i)-Delta(1,j)));
      end
      F(1,Nb+i)=C+Qd(i,1);
      C=0;
   end
end
M=F;
F=sym('0');
C1=1;
C2=1;
while(C2~=Nb*2+1)
   if M(1,C2)~=0
      F(C1,1)=M(1,C2);
      C1=C1+1;
   end
   C2=C2+1;
end
Vari=sym('0');
C1=1;
C2=1;
while(C2~=Nb+1)
   if Delta(1,C2)~=0
      Vari(C1,1)=Delta(1,C2);
      C1=C1+1;
   end
   C2=C2+1;
end
C2=1;
while(C2~=Nb+1)
   if V(1,C2)~=1
      Vari(C1,1)=V(1,C2);
      Un(C1,1)=1;
      C1=C1+1;
   end
   C2=C2+1;
end
   J=jacobian(F,Vari);
   for u=1:Its2
      Np=double(subs(J,Vari,Un));
      Un=double(Un-((Np^-1)*subs(F,Vari,Un)));
   end
```

```
H=size(Un);
H=H(1,1);
H1=size(Delta);
H1=H1(1,2);
for i=1:H
    for j=1:H1
        if Vari(i,1)==Delta(1,j)
            for o=1:Nb
                if (Results(o,3)~='Zero' && Results(o,3)==0)
                    Results(o,3)=Un(i,1);
                    if Results(o,1)==0
                        Results(o,1)=V(1,j);
                    end
                    break;
                end
            end
            break;
        end
    end
end
H=size(Un);
H=H(1,1);
H1=size(Results);
H1=H1(1,1);
for i=1:H
    for k=1:H1
        if Results(k,1)==Vari(i,1) && Results(k,2)==0
            Results(k,2)=Un(i,1);
        end
    end
end
Nub=sym('0');
Vs=sym('0');
H3=size(Results);
H3=H3(1,1);
for i=1:H3
    if Results(i,3)=='Zero'
        Results(i,3)=0;
    end
end
H3=size(Results);
H3=H3(1,1);
Vs=Results(1:H3,1);
format short
Nub=transpose(double(Results(1:H3,2:3)));
gg=Nub(2,1:H3)*(180/pi);
```

```
        if Its2~=1
          fprintf('------------------------------------------------------ \n')
        end
        fprintf('Iteration #%d',Its2)
        fprintf('      \n')
            disp(transpose(Vs));
        if Os==1
        disp(Nub(1,1:H3))
        format short
        disp(' Delta in radian :')
        disp(Nub(2,1:H3))
        disp(' Delta in degree :')
        disp(gg);
        end
        if Os==2
          for Hi=1:H3
            Nubi(1,Hi)=Nub(1,Hi)*(cos(Nub(2,Hi))+1i*sin(Nub(2,Hi)));
          end
          disp(Nubi);
        end
    end
end
if G50==0
    disp('There are no sources in the system !!');
end
% -----------The End-----------
```

Experiment #2: Effect of Short Circuit Faults on the Power System

The network in Figure 1 shown is the sample Power System network to be analyzed in all types of active faults.

Procedures

1. Open MATLAB/ Simulink new model and the library too.
2. From simscape>Simulink gallery>simpower, or by searching each component/ or features you can add components to the blank window.
3. connect each feature as configured in Figure 3 below.
4. By double clicking each component you have to specify its parameters as you want.
5. Finally, powergui is required as circuit solver to undertake the simulation process.
6. Simulate the network with LG, LL, LLG, LLLG faults at the load bus point.

Table 1: System given Data

No.	Component/ parameter	Set value
1	Three-Phase Source	15kV, 50Hz
2	Three-Phase Series RL Load	200kW, 50kVAr, 15kV, 50Hz
3	Three-phase Transformer	1MVA, 15/0.4kV, 50Hz

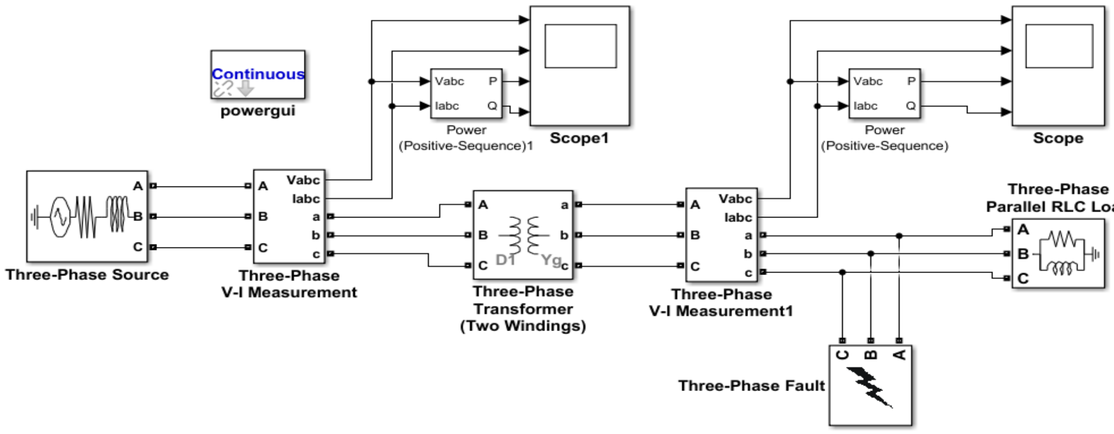


Figure 1: given power system

Questions

1. Simulate your network effectively and examine the property of the circuit?
2. Discuss on the effect of different fault types and the results you obtained?

Experiment #2: Overcurrent Relay and CB

Use the given data in the table and follow the procedures correctly!

Table 2: System given Data

No.	Component/ parameter	Set value
1	Three-Phase Source	15kV, 50Hz
2	Three-Phase Series RL Load	200MW, 50MVAR, 15kV, 50Hz

Procedures

1. Open MATLAB/ Simulink new model and the library too.
2. From simscape>Simulink gallery>simpower, or by searching each component/ or features you can add components to the blank window.
3. connect each feature as Figure 1 below.
4. By double clicking each component you have to specify its parameters as you want.
5. The relay is designed in subsystem and seen as black box, but the inner configuration is shown in Figure 2.
6. Finally, powergui is required as circuit solver to undertake the simulation process.

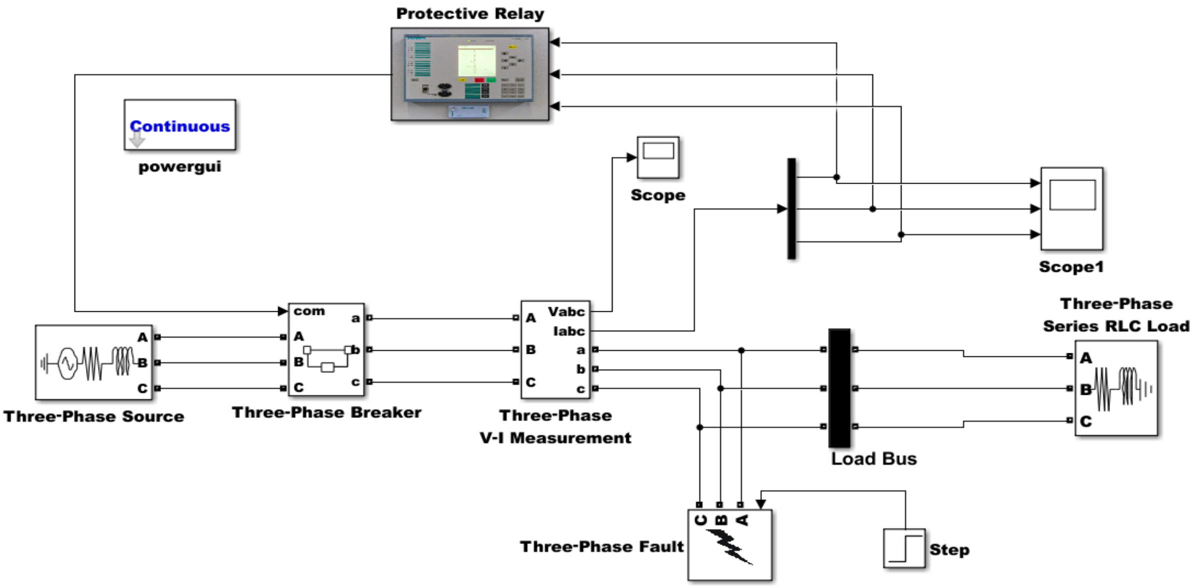


Figure 2: General schematic diagram of the system

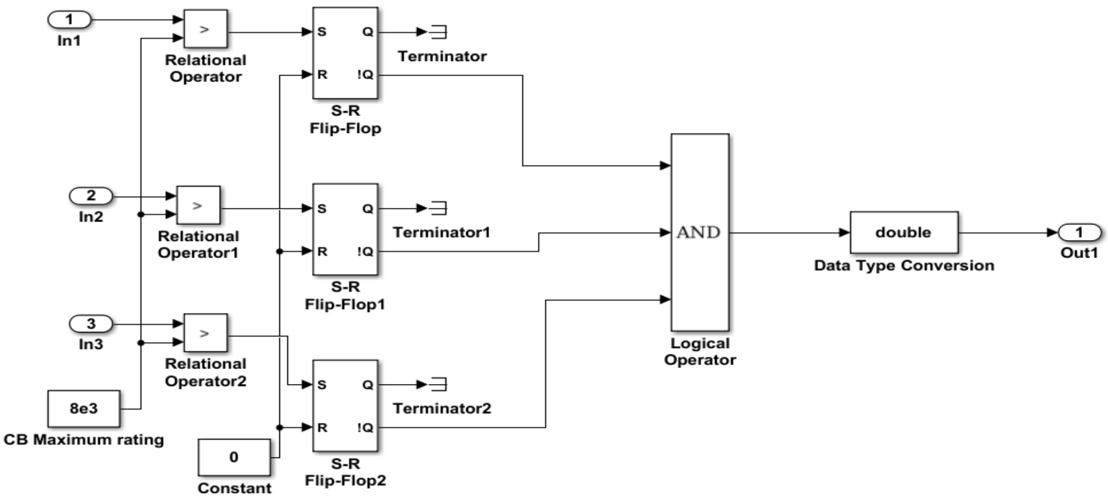


Figure 3: Relay Simulink model

Questions

1) Simulate your network effectively and examine the property of the circuit?
2) Discuss on the voltage and current simulation results you obtained?

Experiment 4: Short Circuit Analysis

1. The one-line diagram of a simple power system is given in the Figure below. The neutral of each generator is grounded through a current limiting reactor of 0.25/3 pu on a 100MVA base, and T1 is Y-Y connected with both solidly grounded and T2 is connected as Δ-Y with Y solidly grounded. The system data expressed in pu on a common 100MVA base is tabulated below. The generators are running on no-load at their rated voltage and frequency with their emfs in phase.

Determine the fault current for the following faults:

a) A balanced three phase fault at bus 3 through a fault impedance $Z_f = j0.1$ pu
b) A L-G fault at bus 3 through a fault impedance $Z_f = j0.1$ pu
c) A L-L fault at bus 3 through a fault impedance $Z_f = j0.1$ pu

d) A DLG at bus 3 through a fault impedance $Z_f = j0.1$ pu

Simulate the given system in case of short circuit and transient analysis using ETAP power station to validate your calculations?

Table 4: System Data

Item	Voltage (KV)	X^1	X^2	X^0
G1	20	0.15	0.15	0.05
G2	20	0.15	0.15	0.05
T1	20/220	0.1	0.1	0.1
T2	20/220	0.1	0.1	0.1
L12	220	0.125	0.125	0.3
L13	220	0.15	0.15	0.35
L32	220	0.25	0.25	0.7125

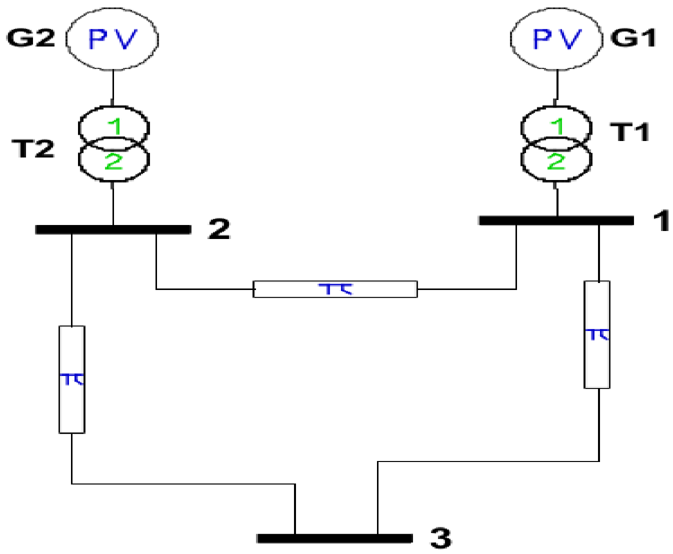
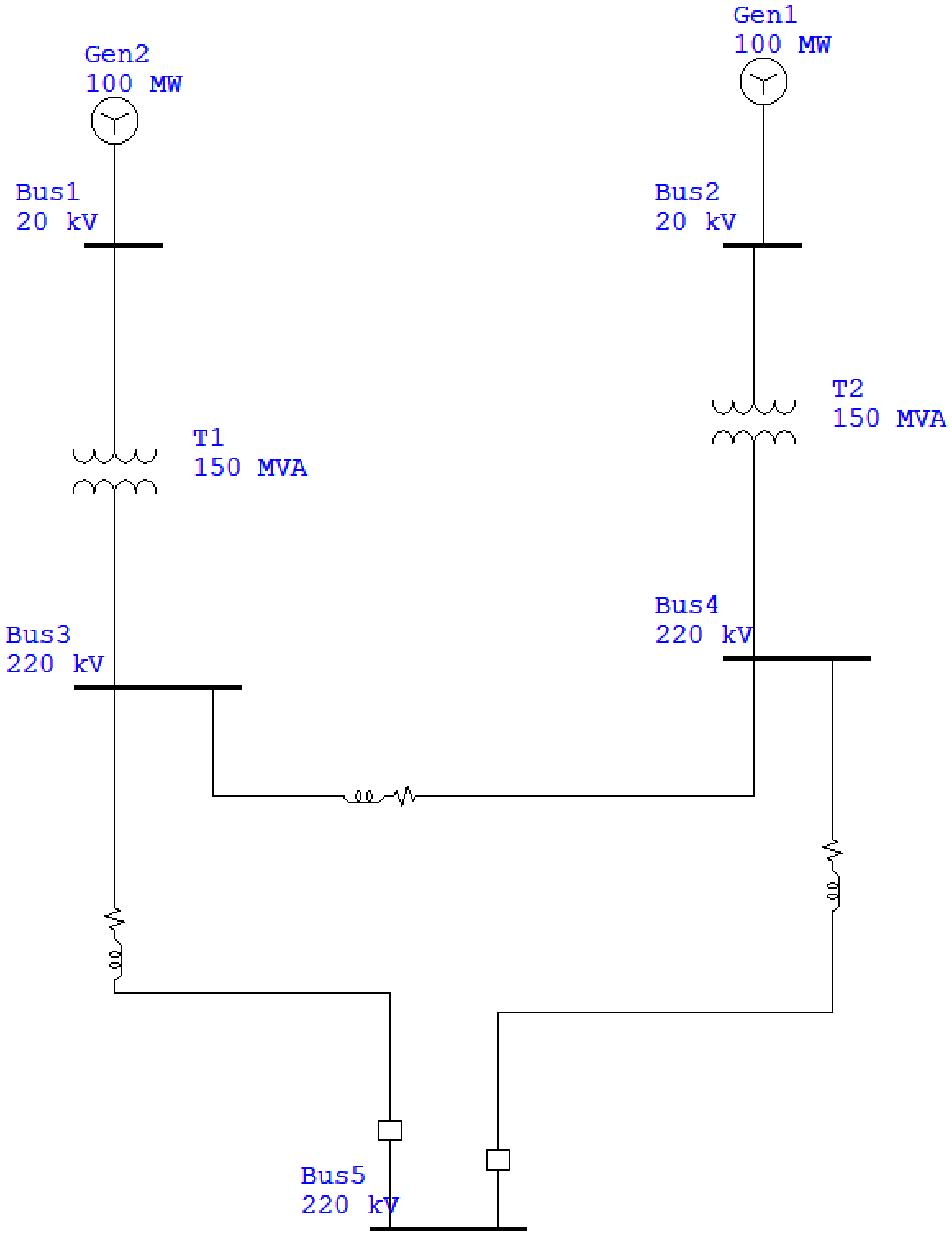
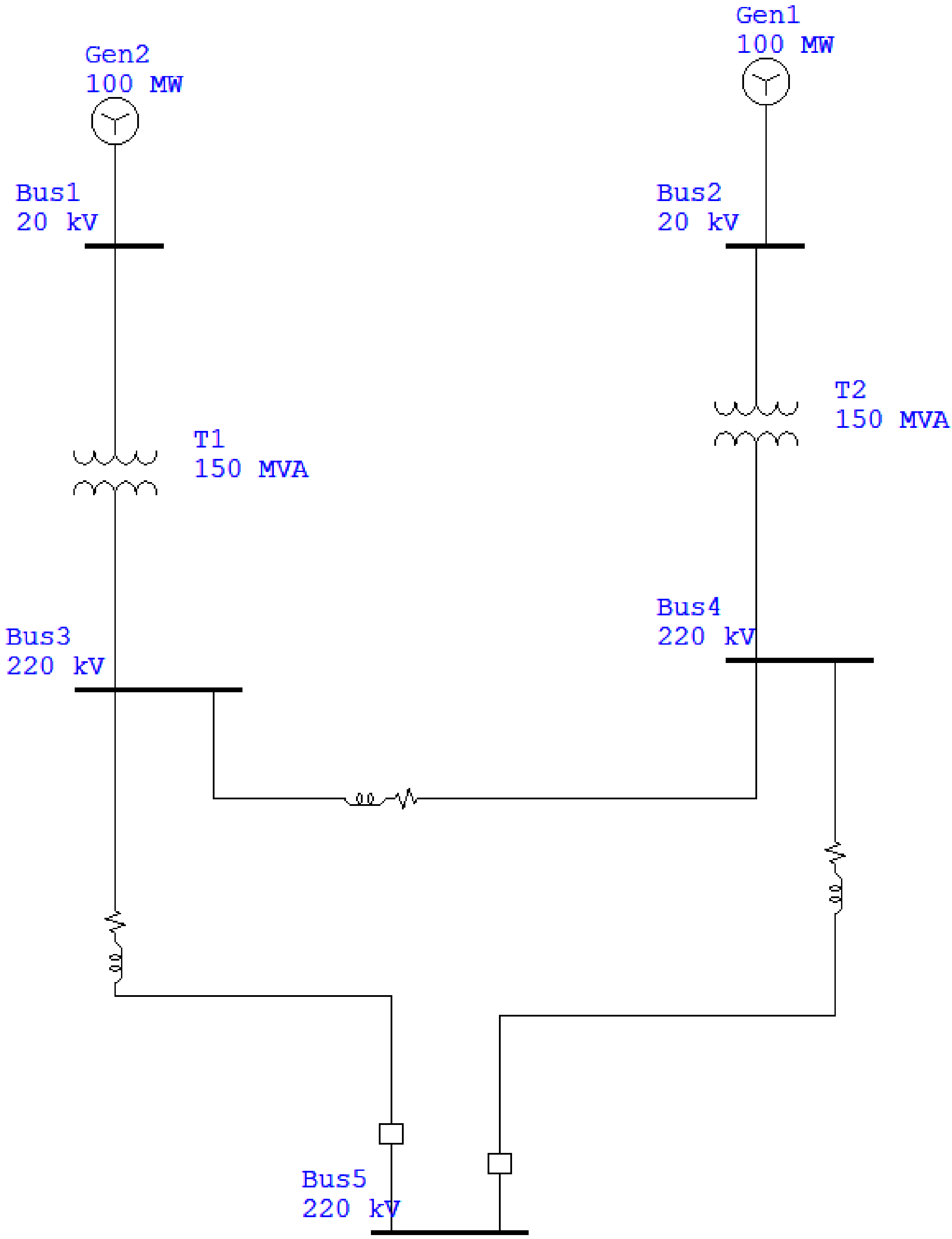


Figure 4: One Line Diagram of 3-Bus System


Gen2
100 MW
Gen1
100 MW
Bus1
20 kV
Bus2
20 kV
T1
150 MVA
T2
150 MVA
Bus3
220 kV
Bus4
220 kV
Bus5
220 kV



Questions

1) Simulate the network as proposed by the above questions and apply the sub-transient, transient and steady state fault options?
2) Discuss on the voltage and fault current simulation results you obtained?

Experiment 5: Power Flow Simulation Using PSAT MATLAB Toolbox

Procedures: Follow the procedures to carefully!

1. Firstly, it is must to include the PSAT toolbox to the matlab directory. So, download latest PSAT version, and copy and paste the folder to your disk: C>MMATLAB>R2016b>toolbox.
2. Open Matlab and and click the set path from the task bar and click the option Add Folder.
3. Then add the PSAT folder that you have already have from matlab toolbox in disk C.

4. After added and saved to the matlab close the popup set path window.
5. Now open the PSAT by writing '*psat*' on the matlab command window.
6. PSAT getting started….., and open the psat Simulink library>create as Simulink default or blank model.
7. Now using the two windows side by side, you can draw any power system to manipulate any type of power flow.
8. After setting and specifying each component, you have to save the model as '.mdl' where ever you want by forming a folder before.
9. Then open the data file from that you saved to run the power flow.
10. Optimize the parameters of each component if any error avail.
11. Report the output from 'Static Report' on the PSAT top option
12. ENJOY!

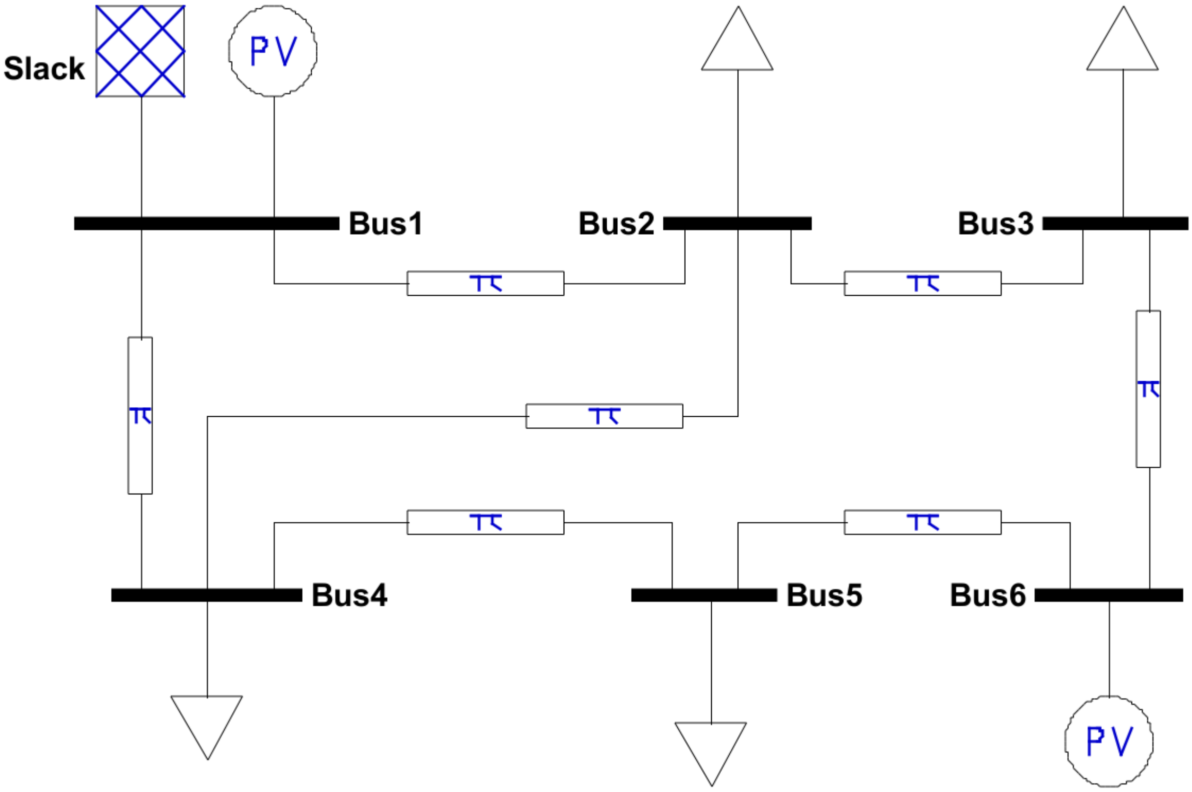


Figure 5: IEEE 6-Bus Power System

Table 5: Bus Data

		Generation		Load	
Bus Code	Assumed Bus Voltage	P_g (p.u)	Q_g (p.u)	P_L (p.u)	Q_L (p.u)
1	1.05+j0.00	…	…	0	0
2	1.00+j0.00	0	0	0.5	0.3
3	1.00+j0.00	0	0	0.3	0.16
4	1.00+j0.00	0	0	0.8	0.6
5	1.00+j0.00	0	0	0	0
6	1.04+j0.00	0.5	…	0.4	0.2

Table 6: Line Data

Line #	Bus to bus	Series Z (pu)
1	1-2	0.01+j0.1
2	1-4	0.08+j0.37
3	2-3	0.05+j0.8
4	2-4	0.01+j0.1
5	3-6	0.02+j0.4
6	4-5	0.03+j0.3
7	5-6	0.06+j0.7

Questions

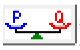
1) Simulate the power flow and see all the parameters numerically and in bar graph, and lastly report the whole system statistics?
2) Discuss on the all simulation results you obtained?

ETAP PowerStation Based Power System Analysis

1. Power Flow Analysis

Simulate the power flow of the given network using ETAP PowerStation Software based on its default power flow solver (Newton Raphson LF Method).

Procedures

1. Open new project window from file
2. On the new window blank space and materials on the right edge will appear so that you can drag whatever you want
3. After placing and setting all features you can connect each other accordingly.
4. Then, by double clicking a device/ feature, you can set the parameters that you have allotted in a case.
5. But for beginners it highly recommended that to fill all the parameters (especially the impedance) of generators, transformers and lines is setting typical data on its popup window and press OK.
6. For lines follow and fill all wrap options of the top task bar reasonably! Refer Power System I Course contents (like line parameters and mechanical design of transmission lines)
7. The click the Load Flow Analysis Icon from the top task bar.
8. Now click the  icon to run the load flow.
9. Finally, you can gather the simulation result in PDF by clicking the report manager on the right edge of the window by letting a file name to your results.
10. If you're interested to have the complete report, plz click complete and press OK.
11. ENJOY IT!
12. ***Note:-*** You have to allow one swing bus all the time!

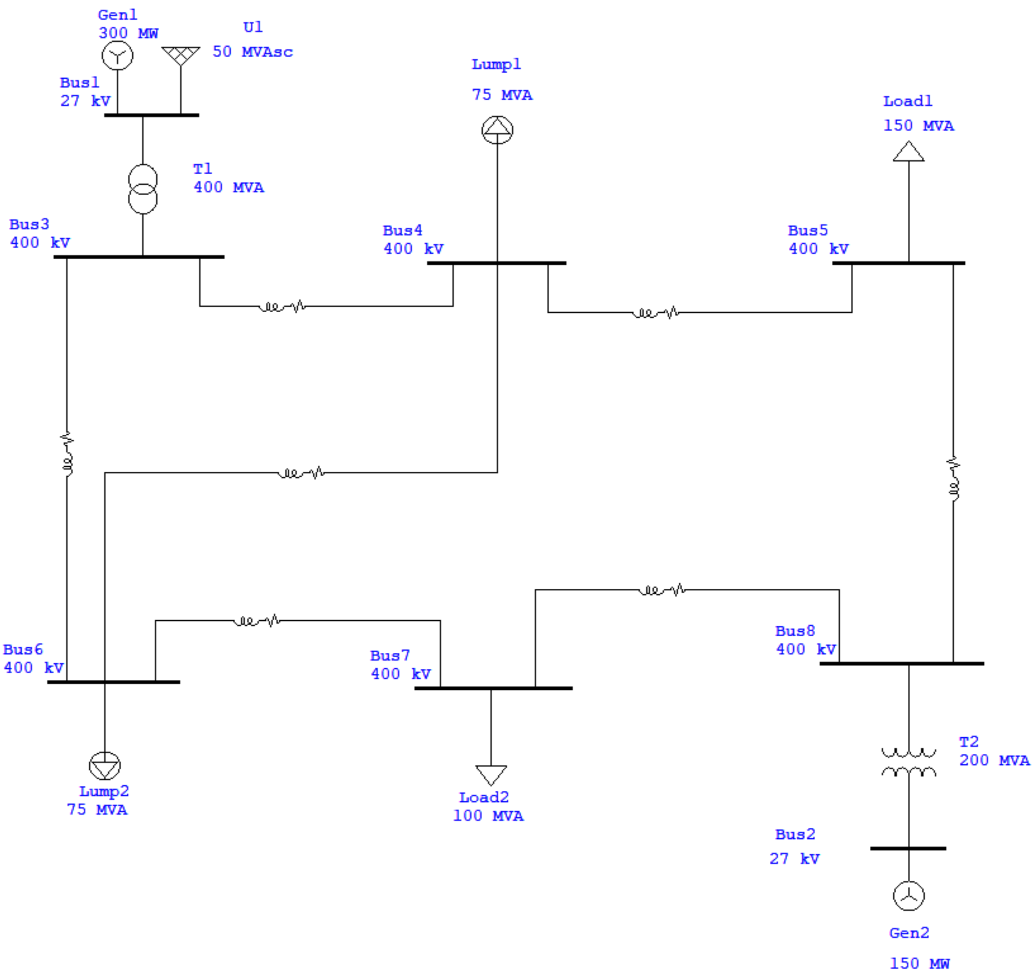


Figure 1: IEEE 6-Bus system

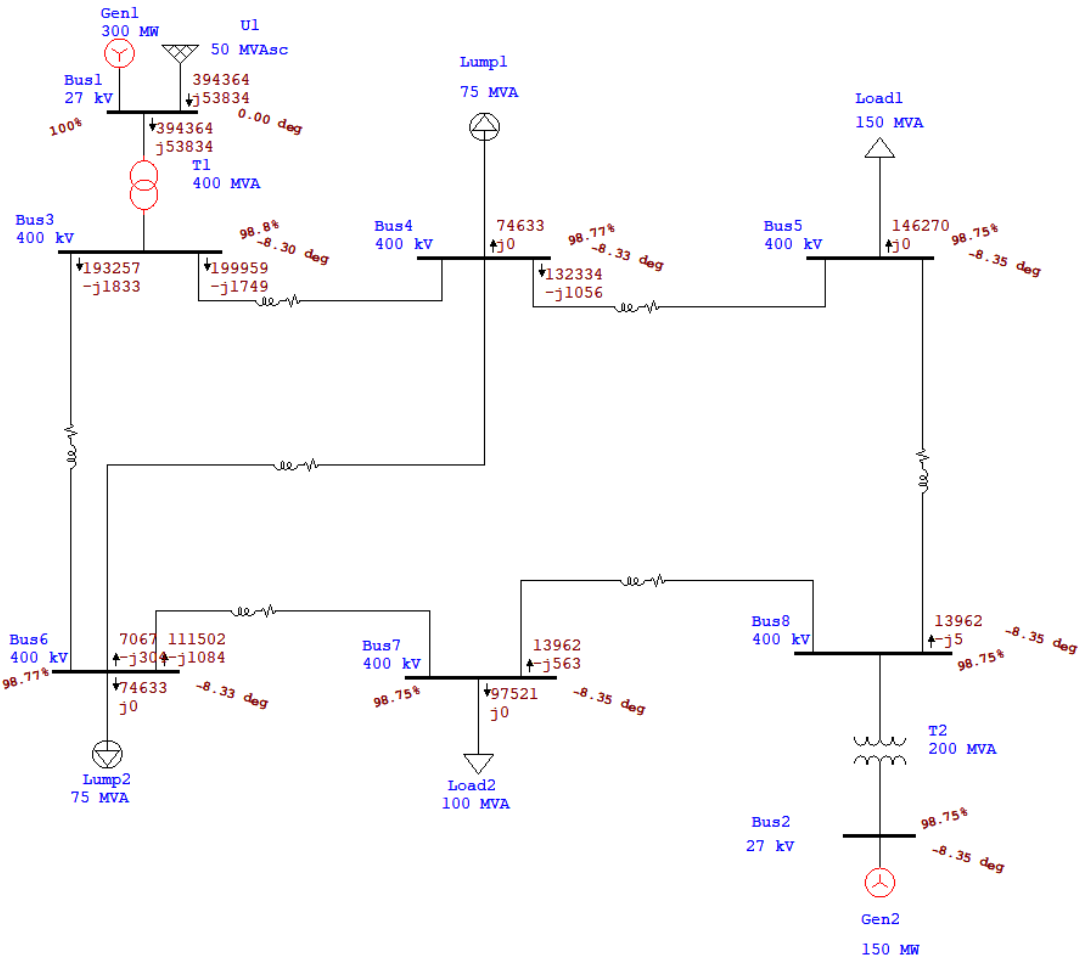


Figure 2: Simulation of IEEE 6-Bus System

Questions

Tabulate PF results and write interpretations of the proposed data that you have from the complete report.

2. Short Circuit Analysis

For the given network, simulate all types of shunt faults at bus 5 and see the effect of each fault type and severity?

Procedures

1. Open new project window from file
2. On the new window blank space and materials on the right edge will appear so that you can drag whatever you want
3. After placing and setting all features you can connect each other accordingly.
4. Then, by double clicking a device/ feature, you can set the parameters that you have allotted in a case.
5. But for beginners it highly recommended that to fill all the parameters (especially the impedance) of generators, transformers and lines is setting typical data on its popup window and press OK.
6. For lines follow and fill all wrap options of the top task bar reasonably! Refer Power System I Course contents (like line parameters and mechanical design of transmission lines)
7. The click the Short circuit Analysis Icon from the top task bar.

8. Now you can simulate the sub-transient, transient and steady state conditions off all fault types by clicking  ,  and  icons respectively and you can also select fault type from display options on the right edge of your window.
9. Finally, you can gather the simulation result in PDF by clicking the report manager on the right edge of the window by letting a file name to your results.
10. If you're interested to have the complete report, plz click complete and press OK.
11. ENJOY IT!

Note:- You have to allow one swing bus all the time!

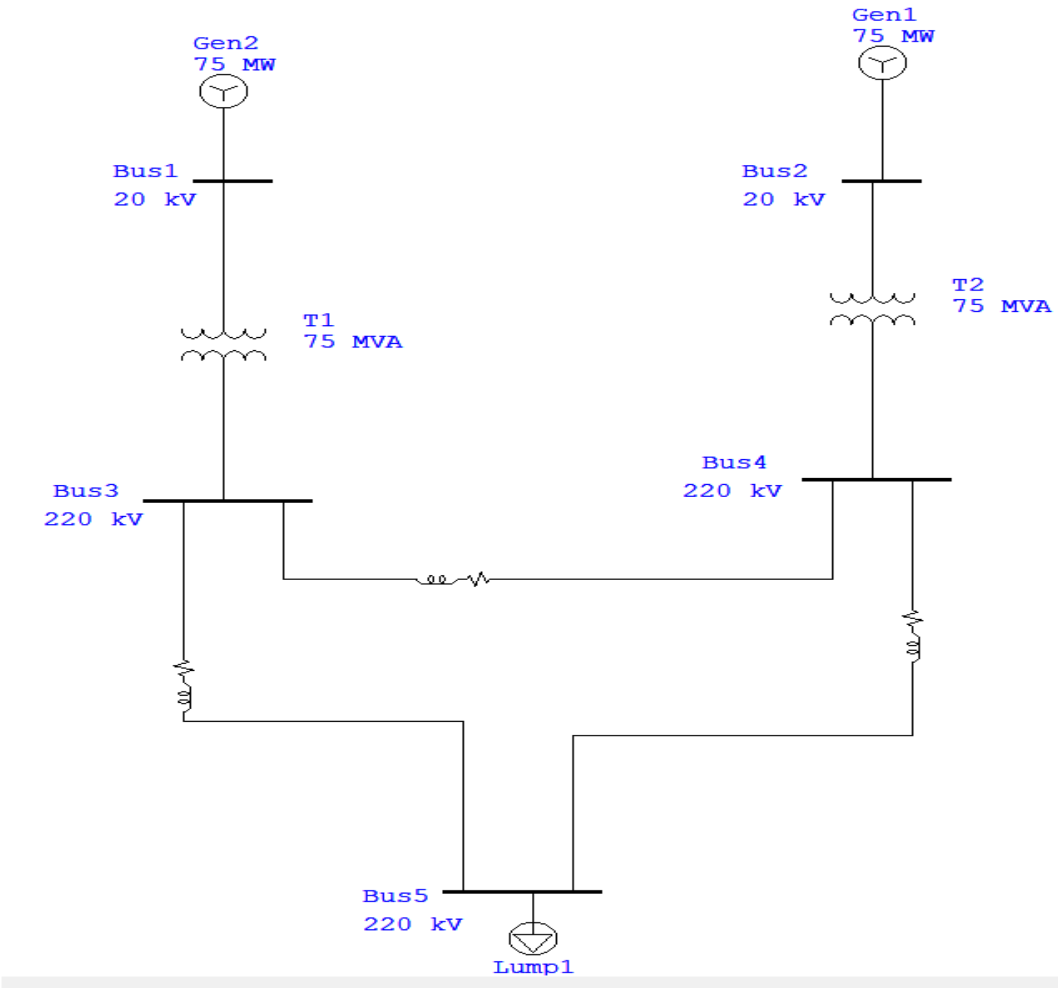


Figure 7: 5-Bus test system

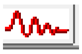
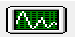
Questions

1) Simulate the network as proposed by the above questions and apply the sub-transient, transient and steady state fault options?
2) Discuss on the voltage and fault current simulation results you obtained?

3. Transient Stability Analysis

Procedures

1. Open new project window from file
2. On the new window blank space and materials on the right edge will appear so that you can drag whatever you want
3. After placing and setting all features you can connect each other accordingly.
4. Then, by double clicking a device/ feature, you can set the parameters that you have allotted in a case.

5. But for beginners it highly recommended that to fill all the parameters (especially the impedance) of generators, transformers and lines is setting typical data on its popup window and press OK.
6. For lines follow and fill all wrap options of the top task bar reasonably! Refer Power System I Course contents (like line parameters and mechanical design of transmission lines)
7. The click the  Transient Stability Analysis Icon from the top task bar.
8. Now click the  icon to run the transient issues.
9. Then click the plot dialogue  icon to plot your cases.
10. Finally, you can gather the simulation result in PDF by clicking the report manager on the right edge of the window by letting a file name to your results.
11. If you're interested to have the complete report, plz click complete and press OK.
12. ENJOY IT!

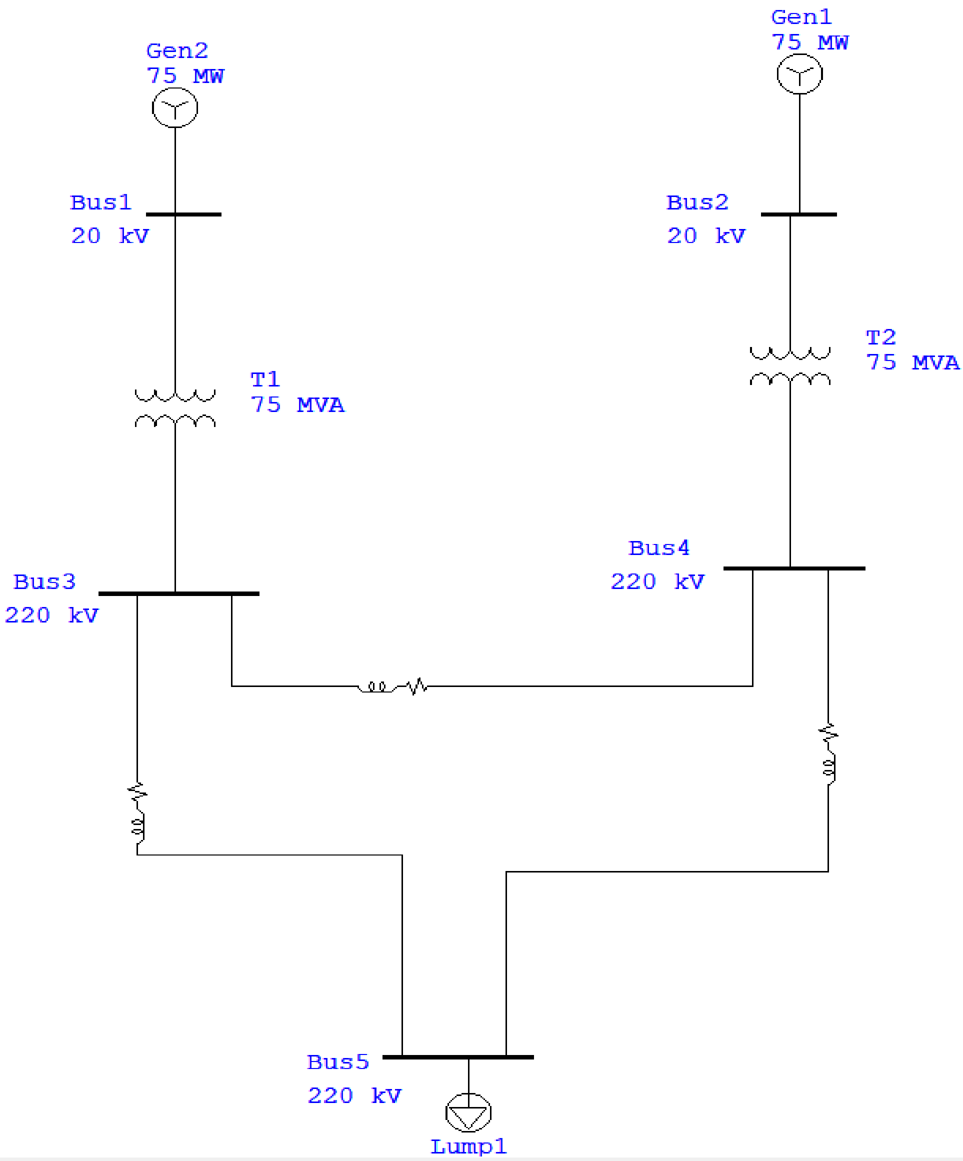


Figure 1: 5-Bus system model

Questions

If the three-phase fault is occurred at transmission line 2 (bus 4 to bus 5) at t=20sec and is supposed to be cleared at t=20.5sec and if the simulation time is 100sec. plot the following parameters at G2 after the system has been regained its stability?

a) G2 relative power angle, delta
b) G2 speed
c) G2 mechanical power
d) G2 electrical power, Pe
e) G2 reactive power, Qe

Now discuss about each of the plotted graphs with respect to transient stability analysis concepts?

Tips About Report Contents and Evaluation

I. ***Power Flow***
- IEEE 5-Bus Test System Using Matlab Newton Raphson Coding (Optional)
- IEEE 6-bus system Using Matlab/PSAT (Mandatory!)
- IEEE 6-bus system Using ETAP PowerStation (Optional)

II. ***Fault Analysis***
- All fault type analysis using Matlab/Simulink (Mandatory!)
- Relay in conjunction with CB based Fault protection using Matlab/Simulink (Mandatory!)
- IEEE 5-Bus Test System Using ETAP PowerStation (Optional)

III. ***Transient Stability Analysis***
- 5-Bus Test System Transient Stability Analysis Using ETAP PowerStation (Mandatory!)

Evaluation Process

a) Report Documentation (group assessment) 20%
b) PowerPoint quality (group assessment) 10%
c) Presentation and reaction to Queries (ind. assessment) 10%

Note:- Every group member should take responsibilities of preparing report, presentation and reply for questions!