

Bapuji Educational Association (Regd)
Bapuji Institute of Engineering and Technology
Davanagere-577004

Department of Electrical and Electronics Engineering

Manual for

Power System Simulation Lab

[Semester: 7th ; Subject Code: 15EEL76]

15EEL76 Power System Simulation Laboratory

Subject Code: 15EEL76

IA Marks: 20

No. of Practical Hrs. / Week: 03

Exam Hours:

03

Total No. of Practical Hrs: 42

Exam Marks:

80

Power system simulation using MATLAB/ C or C ++ /Sci lab /octave

1. a) Formation for symmetric π configuration for Verification of $AD-BC=1$,
Determination of Efficiency and regulation.
b) Formation for symmetric T configuration for Verification of $AD-BC=1$,
Determination of Efficiency and regulation.
2. Determination of Power Angle Diagrams, Reluctance Power, Excitation, Emf and Regulation for Salient and Non-Salient Pole Synchronous Machines
3. 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.
4. Y Bus Formation for Power Systems with and without Mutual Coupling, by Singular Transformation and Inspection Method
5. Formation of Z Bus(without mutual coupling) using Z-Bus Building Algorithm.
6. Determination of Bus Currents, Bus Power and Line Flow for a Specified System Voltage (Bus) Profile.
7. Formation of Jacobian for a System not Exceeding 4 Buses (No PV Buses) in Polar Coordinates.
8. Load Flow Analysis using Gauss Siedel Method, NR Method and Fast Decoupled Method
for Both PQ and PV Buses.
9. To Determine Fault Currents and Voltages in a Single Transmission Line System With Star-Delta Transformers at a Specified Location for LG and LLG faults by simulation
10. Optimal Generation Scheduling for Thermal power plants.

Note: Questions 1-6: Simulation Experiments using MATLAB/C or C++/Scilab/Octave
Questions 7-10: Use suitable standard software package.

Program 1 a): ABCD of equivalent PI Network

```
clc
clear all
z=0.2+0.408i; y=0+3.14e-6i;
k1=input('\n Enter 1-for short line 2-for medium line 3-for long line : ');
switch k1
    case 1,
        length=40;
        Z=z*length; Y=y*length;
        A=1; B=Z; C=0; D=1;
    case 2,
        length=140;
        Z=z*length; Y=y*length;
        A=1+Y*Z/2;
        B=Z;
        C=Y*(1+Y*Z/4);
        D=A;
    case 3,
        length=300;
        zc=sqrt(z/y);
        gam=sqrt(z*y)*length;
        A=cosh(gam);
        D=A;
        B=zc*sinh(gam);
        C=1/zc*sinh(gam);
        fprintf('\n the equivalent PI circuit constants:');
        zeq=z*length*sinh(gam)/gam;
        yeq=y*length/2*tanh(gam/2)/(gam/2);
        fprintf('\n Zeq=%10.4f %+15.4fi', real(zeq), imag(zeq));
        fprintf('\n Yeq=%10.4f %+15.4fi', real(yeq), imag(yeq));
    otherwise
        disp('wrong choice of tr.line');
end
fprintf('\n A,B,C and D constants:\n');
fprintf('-----');
fprintf('\nA=%10.4f %+10.4fi',real(A), imag(A));
fprintf('\nA=%10.4f %+10.4fi',real(B), imag(B));
fprintf('\nA=%10.4f %+10.4fi',real(C), imag(C));
fprintf('\nA=%10.4f %+10.4fi',real(D), imag(D));
fprintf('\n the product AD-BC=%f', A*D-B*C);
k2=input('\n Enter 1-To read Vr, Ir and compute Vs, Is\n 2-To read Vs, Is and compute Vr, Ir : ');
switch k2,
```

```
case 1,
% vr=input('enter Vr/phase');
% ir=input('enter Ir/phase');
vrl=132+0.0i;
ir=174.96-131.22i;
vr=vrl*1e3/sqrt(3);
vs=(A*vr+B*ir);
is=C*vr+D*ir;
fprintf('\n sending end voltage/ph=%f %+fi KV', real(vs)/1e3, imag(vs)/1e3);
fprintf('\n sending end current/ph=%f %+fi AMP', real(is), imag(is));
vsl=vs*sqrt(3.0);
case 2,
% vs=input('enter Vs/phase');
% is=input('enter Is/phase');
vsl=132+0.0i;
is=174.96-131.22i;
vs=vsl*1e3/sqrt(3);
vr=(D*vs-B*is);
ir=-C*vs+D*is;
fprintf('\n Receiving end voltage/ph=%f %+fi KV', real(vr)/1e3, imag(vr)/1e3);
fprintf('\n sending end current/ph=%f %+fi AMP', real(ir), imag(ir));
vrl=vr*sqrt(3.0);
otherwise
    disp('wrong choice');
end
rec_pow=3*real(vr*conj(ir))/1e6;
send_pow=3*real(vs*conj(is))/1e6;
eff=rec_pow/send_pow*100;
reg=(abs(vs)/abs(A)-abs(vr))/abs(vr)*100;
fprintf('\n Receiving end power=%.2f MW', rec_pow);
fprintf('\n Sending end power=%.2f MW', send_pow);
fprintf('\n Efficiency=%.2f %%', eff);
fprintf('\n Voltage Regulation=%.2f%%', reg);
```

Power system simulation lab manual

O/P 1:-

Enter 1-for short line 2-for medium line 3-for long line:1

A,B,C and D constants:

A= 1.0000 +0.0000i

B= 8.0000 +16.3200i

C= 0.0000 +0.0000i

D= 1.0000 +0.0000i

the product AD-BC=1.000000

Enter 1-To read Vr,Ir and compute Vs,Is

2-To read Vs,Is and compute Vr,Ir:1

sending end voltage/ph=79.751426+1.805587i KV

sending end current/ph=174.960000-131.220000i AMP

Receiving end power=40.00 MW

Sending end power=41.15 MW

Effiency=97.21 %

Voltage regulation=4.67 %>>

O/P 2:-

Enter 1-for short line 2-for medium line 3-for long line:1

A,B,C and D constants:

A= 1.0000 +0.0000i

B= 8.0000 +16.3200i

C= 0.0000 +0.0000i

D= 1.0000 +0.0000i

the product AD-BC=1.000000

Enter 1-To read Vr,Ir and compute Vs,Is

2-To read Vs,Is and compute Vr,Ir:1

sending end voltage/ph=79.751426+1.805587i KV

sending end current/ph=174.960000-131.220000i AMP

Receiving end power=40.00 MW

Sending end power=41.15 MW

Effiency=97.21 %

Voltage regulation=4.67 %>>

Power system simulation lab manual

O/P 3:-

Enter 1-for short line 2-for medium line 3-for long line:2

A,B,C and D constants:

A= 0.9874 +0.0062i

B= 28.0000 +57.1200i

C= -0.0000 +0.0004i

D= 0.9874 +0.0062i

the product AD-BC=1.000000

Enter 1-To read Vr,Ir and compute Vs,Is

2-To read Vs,Is and compute Vr,Ir:1

sending end voltage/ph=87.647584+6.788583i KV

sending end current/ph=173.467869-95.204051i AMP

Receiving end power=40.00 MW

Sending end power=43.67 MW

Efficiency=91.59 %

Voltage regulation=16.82 %>>

O/P 4:-

Enter 1-for short line 2-for medium line 3-for long line:2

A,B,C and D constants:

A= 0.9874 +0.0062i

B= 28.0000 +57.1200i

C= -0.0000 +0.0004i

D= 0.9874 +0.0062i

the product AD-BC=1.000000

Enter 1-To read Vr,Ir and compute Vs,Is

2-To read Vs,Is and compute Vr,Ir:2

receiving end voltage/ph=62.859251-5.850527i KV

sending end current/ph=173.674054-161.787473i AMP

Receiving end power=35.59 MW

Sending end power=40.00 MW

Efficiency=88.97 %

Voltage regulation=22.25 %>>

O/P 5:-

Enter 1-for short line 2-for medium line 3-for long line:3

the equivalent PI circuit constants:

$$Z_{eq} = 57.7123 + 120.6169i$$

$$Y_{eq} = 0.0000 + 0.0005i$$

A,B,C and D constants:

 $A = 0.9428 + 0.0277i$

$$B = 57.7123 + 120.6169i$$

$$C = -0.0000 + 0.0009i$$

$$D = 0.9428 + 0.0277i$$

the product $AD-BC=1.000000$

Enter 1-To read V_r, I_r and compute V_s, I_s

2-To read V_s, I_s and compute V_r, I_r :1

sending end voltage/ph= $97.773395+15.642655i$ KV

sending end current/ph= $167.915908-48.443896i$ AMP

Receiving end power= 40.00 MW

Sending end power= 46.98 MW

Efficiency= 85.15 %

Voltage regulation= 37.75 %>>

O/P6:-

Enter 1-for short line 2-for medium line 3-for long line:3

the equivalent PI circuit constants:

$$Z_{eq} = 57.7123 + 120.6169i$$

$$Y_{eq} = 0.0000 + 0.0005i$$

A,B,C and D constants:

 $A = 0.9428 + 0.0277i$

$$B = 57.7123 + 120.6169i$$

$$C = -0.0000 + 0.0009i$$

$$D = 0.9428 + 0.0277i$$

the product $AD-BC=1.000000$

Enter 1-To read V_r, I_r and compute V_s, I_s

2-To read V_s, I_s and compute V_r, I_r :2

receiving end voltage/ph= $45.924027-11.417589i$ KV

sending end current/ph= $169.252896-189.276902i$ AMP

Receiving end power= 29.80 MW

Sending end power= 40.00 MW

Efficiency= 74.50 %

Voltage regulation= 70.75 %>

Program 1 b): ABCD of equivalent T Network

```
clc
clear all
z=0.2+0.408i; y=0+3.14e-6i;
k1=input('\n Enter 1-for short line 2-for medium line 3-for long line : ');
switch k1
    case 1,
        length=40;
        Z=z*length; Y=y*length;
        A=1; B=Z; C=0; D=1;
    case 2,
        length=140;
        Z=z*length; Y=y*length;
        A=1+Y*Z/2;
        B=Z*(1+Y*Z/4);
        C=Y;
        D=1+Y*Z/2;
    case 3,
        length=300;
        zc=sqrt(z/y);
        gam=sqrt(z*y)*length;
        A=cosh(gam);
        D=A;
        B=zc*sinh(gam);
        C=1/zc*sinh(gam);
        fprintf('\n the equivalent T circuit constants:');
        zeq=z*length/2*tanh(gam/2)/(gam/2);
        yeq=y*length*sinh(gam)/gam;
        fprintf('\n Zeq=%10.4f %+15.4fi', real(zeq), imag(zeq));
        fprintf('\n Yeq=%10.4f %+15.4fi', real(yeq), imag(yeq));
    otherwise
        disp('wrong choice of tr.line');
end
fprintf('\n A,B,C and D constants:\n');
fprintf('-----');
fprintf('\nA=%10.4f %+10.4fi',real(A), imag(A));
fprintf('\nA=%10.4f %+10.4fi',real(B), imag(B));
fprintf('\nA=%10.4f %+10.4fi',real(C), imag(C));
fprintf('\nA=%10.4f %+10.4fi',real(D), imag(D));
fprintf('\n the product AD-BC=%f', A*D-B*C);
k2=input('\n Enter 1-To read Vr, Ir and compute Vs, Is\n 2-To read Vs, Is and compute Vr, Ir :');
switch k2,
```



```
case 1,
% vr=input('enter Vr/phase');
% ir=input('enter Ir/phase');
vrl=132+0.0i;
ir=174.96-131.22i;
vr=vrl*1e3/sqrt(3);
vs=(A*vr+B*ir);
is=(C*vr+D*ir);
fprintf('\n sending end voltage/ph=%f %+fi KV', real(vs)/1e3, imag(vs)/1e3);
fprintf('\n sending end current/ph=%f %+fi AMP', real(is), imag(is));
vsl=vs*sqrt(3.0);
case 2,
% vs=input('enter Vs/phase');
% is=input('enter Is/phase');
vsl=132+0.0i;
is=174.96-131.22i;
vs=vsl*1e3/sqrt(3);
vr=(D*vs-B*is);
ir=(-C*vs+D*is);
fprintf('\n Receiving end voltage/ph=%f %+fi KV', real(vr)/1e3, imag(vr)/1e3);
fprintf('\n sending end current/ph=%f %+fi AMP', real(ir), imag(ir));
vrl=vr*sqrt(3.0);
otherwise
    disp('wrong choice');
end
rec_pow=3*real(vr*conj(ir))/1e6;
send_pow=3*real(vs*conj(is))/1e6;
eff=rec_pow/send_pow*100;
reg=(abs(vs)/abs(A)-abs(vr))/abs(vr)*100;
fprintf('\n Receiving end power=%.2f MW', rec_pow);
fprintf('\n Sending end power=%.2f MW', send_pow);
fprintf('\n Efficiency=%.2f %%', eff);
fprintf('\n Voltage Regulation=%.2f %%', reg);
```

Power system simulation lab manual

O/P 1:-

enter 1-for short line 2-medium line 3-for long line:1

A,B,C and D constants:

A= 1.0000 +0.0000i

B= 8.0000 +16.3200i

C= 0.0000 +0.0000i

D= 1.0000 +0.0000i

the product AD-BC=1.000000

enter 1 to read Vr,Ir and compute Vs,Is

2 to read Vs,Is and compute Vr,Ir: 1

sending end voltage/ph=79.751426+1.805587iKV

sending end current/ph=174.960000-131.220000iAMP

receiving end power=40.00MW

sending end power=41.15MW

efficiency=97.21%

voltage regulation= 4.67%>>

O/P2:-

enter 1-for short line 2-medium line 3-for long line:1

A,B,C and D constants:

A= 1.0000 +0.0000i

B= 8.0000 +16.3200i

C= 0.0000 +0.0000i

D= 1.0000 +0.0000i

the product AD-BC=1.000000

enter 1 to read Vr,Ir and compute Vs,Is

2 to read Vs,Is and compute Vr,Ir:2

receiving end voltage/ph=72.669045-1.805587iKV

sending end current/ph=174.960000-131.220000iAMP

receiving end power=38.85MW

sending end power=40.00MW

efficiency=97.13%

voltage regulation= 4.84%>>

Power system simulation lab manual

O/P 3:-

enter 1-for short line 2-medium line 3-for long line:2

A,B,C and D constants:

A= 0.9874 +0.0062i

B= 27.6485 +56.8476i

C= 0.0000 +0.0004i

D= 0.9874 +0.0062i

the product AD-BC=1.000000

enter 1 to read Vr,Ir and compute Vs,Is

2 to read Vs,Is and compute Vr,Ir:1

sending end voltage/ph=87.550333+6.787052iKV

sending end current/ph=173.570962-94.993743iAMP

receiving end power=40.00MW

sending end power=43.65MW

efficiency=91.63%

voltage regulation= 16.69%>>

O/P 4:-

enter 1-for short line 2-medium line 3-for long line:2

A,B,C and D constants:

A= 0.9874 +0.0062i

B= 27.6485 +56.8476i

C= 0.0000 +0.0004i

D= 0.9874 +0.0062i

the product AD-BC=1.000000

enter 1 to read Vr,Ir and compute Vs,Is

2 to read Vs,Is and compute Vr,Ir:2

receiving end voltage/ph=62.956502-5.848995iKV

sending end current/ph=173.570962-161.997782iAMP

receiving end power=35.62MW

sending end power=40.00MW

efficiency=89.06%

voltage regulation= 22.06%>

O/P 5:-

enter 1-for short line 2-medium line 3-for long line:3

the equivalent T circuit constants:

$$Z_{eq} = 122.3432 + 246.5944i$$

$$Y_{eq} = -0.0000 + 0.0009i$$

A,B,C and D constants:

$$A = 0.9428 + 0.0277i$$

$$B = 57.7123 + 120.6169i$$

$$C = -0.0000 + 0.0009i$$

$$D = 0.9428 + 0.0277i$$

the product AD-BC=1.000000

enter 1 to read V_r, I_r and compute V_s, I_s

2 to read V_s, I_s and compute V_r, I_r : 1

sending end voltage/ph=97.773395+15.642655iKV

sending end current/ph=167.915908-48.443896iAMP

receiving end power=40.00MW

sending end power=46.98MW

efficiency=85.15%

voltage regulation= 37.75%>>

O/P 6:-

enter 1-for short line 2-medium line 3-for long line:3

the equivalent T circuit constants:

$$Z_{eq} = 122.3432 + 246.5944i$$

$$Y_{eq} = -0.0000 + 0.0009i$$

A,B,C and D constants:

$$A = 0.9428 + 0.0277i$$

$$B = 57.7123 + 120.6169i$$

$$C = -0.0000 + 0.0009i$$

$$D = 0.9428 + 0.0277i$$

the product AD-BC=1.000000

enter 1 to read V_r, I_r and compute V_s, I_s

2 to read V_s, I_s and compute V_r, I_r :2

receiving end voltage/ph=45.924027-11.417589iKV

sending end current/ph=169.252896-189.276902iAMP

receiving end power=29.80MW

sending end power=40.00MW

efficiency=74.50%

voltage regulation= 70.75%>>

Power system simulation lab manual

PROGRAM 2 a): Power angle characteristics of Salient pole rotor syn. m/c

```
clc
clear all
%Xd=1.2;xq=0.8;ra=0.025; v=1.0; p=0.6; pf=0.8;
xd=input('Enter direct axis reactance per phase in pu\n');
xq=input('Enter quadrature axis reactance per phase in pu\n');
ra=input('Enter the armature resistance per phase in pu\n');
v=input('Enter the terminal voltage of the generator in pu\n');
p=input('Enter the power output of the generator in pu\n');
pf=input('Enter power factor\n');
pfsign=input('Enter -1 for lagging power factor & 1 for leading power factor');
iamag=p/(v*pf);
theta=acos(pf)*pfsign;
realia=iamag*cos(theta);
imagia=iamag*sin(theta);
ia=complex(realia, imagia);
efdash=v+(ia*ra)+(ia*j*xq);
delta=angle(efdash);
si=delta-theta;
id=iamag*sin(si);
iq=iamag*cos(si);
ef=abs(efdash)+id*(xd-xq);
p1=ef*abs(v)/xd;
p2=abs(v)^2*(xd-xq)/(2*xd*xq);
del=0:0.01:pi;
pext=p1*sin(del);
prlc=p2*sin(2*del);
pe=pext+prlc;
[pmax,k]=max(pe);
plot(del*180/pi,pext,'r');
hold on
plot(del*180/pi,prlc,'m');
plot(del*180/pi,pe,'b');
legend('excitation power','reluctance power', 'salient power');
title('power angle characteristics salient pole syn. m/c');
```

Power system simulation lab manual

```
xlabel('delta in deg');
ylabel('power in pu');
% line(del*180/pi,0); del=0:0.01:del(k); line(del*180/pi,pmax);
% y=0:0.01:pmax; line(pi/2*(180/pi),y); text(75,1.05*pmax,'p_{max}');
% text(del(k)*180/pi,-0.1,'del_{max}');
reg=(abs(ef)-abs(v))/abs(v)*100;
fprintf('\n the excitation voltage=%f p.u',abs(ef));
fprintf('\n the maximum power=%f p.u and the corresponding angle=%f
degrees',pmax,del(k)*180/pi);
fprintf('\n the voltage regulation=%f%%',reg);
fprintf('\n reluctance power=%f pu',p2);
```

Power system simulation lab manual

O/P 1:-

Enter direct axis reactance per phase in pu

1.2

Enter quadrature axis reactance per phase in pu

0.8

Enter the armature resistance per phase in pu

0.025

Enter the terminal voltage of the generator in pu

1

Enter the power output of the generator in pu

0.6

Enter power factor

0.8

Enter -1 for lagging power factor & 1 for leading power factor-1

the excitation voltage=1.700518 pu

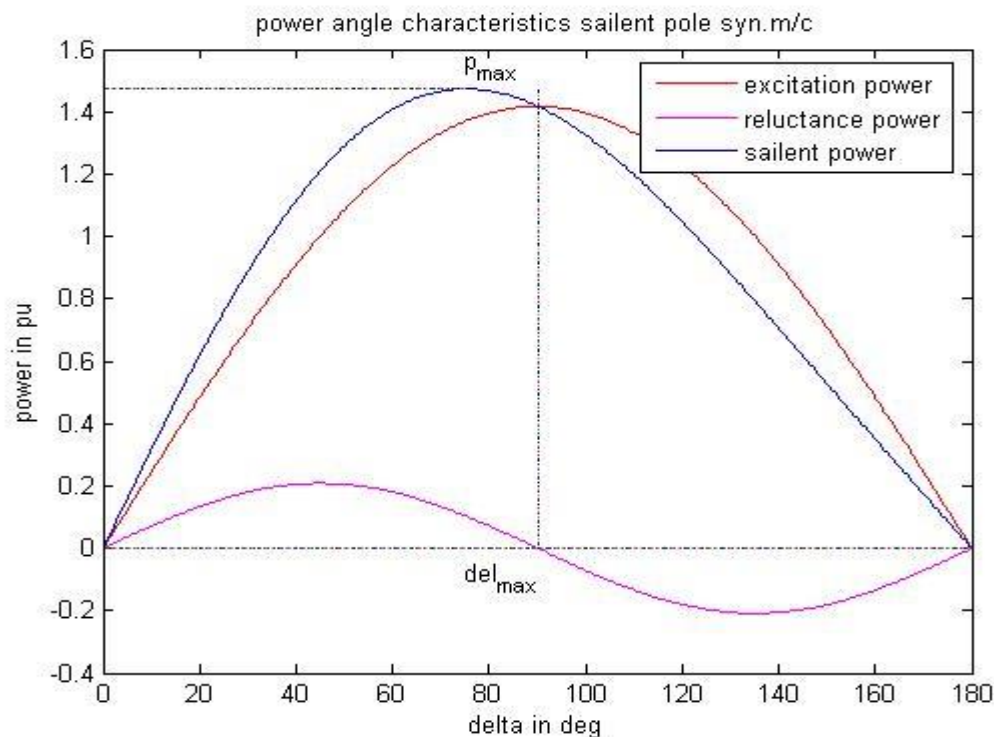
the max power =1.472984 pu and the corresponding angle=75.057471 degrees

the voltage regulation=70.051849%

reluctance power=0.208333pu>>

ibus =

3.9000 - 1.8000i 1.2600 - 0.3200i 1.3600 - 0.5200i



Power system simulation lab manual

O/P 2:-

Enter direct axis reactance per phase in pu

1.2

Enter quadrature axis reactance per phase in pu

0.8

Enter the armature resistance per phase in pu

0.025

Enter the terminal voltage of the generator in pu

1

Enter the power output of the generator in pu

0.6

Enter power factor

0.8

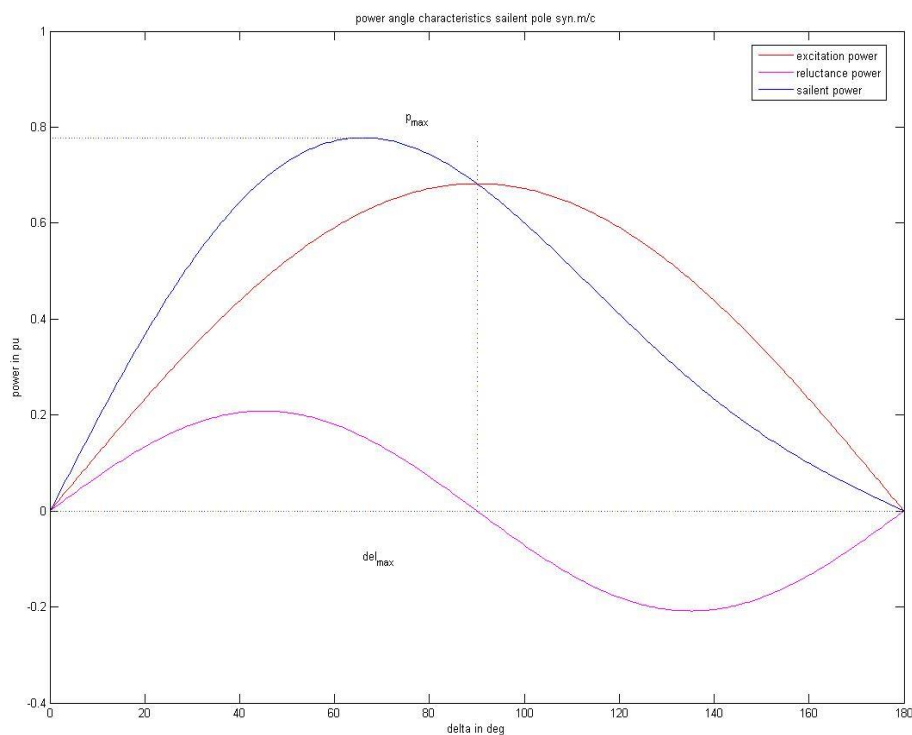
Enter -1 for lagging power factor & 1 for leading power factor

the excitation voltage = 0.818750 pu

the max power = 0.778126 pu and the corresponding angle = 65.890146 degrees

the voltage regulation = -18.125000%

reluctance power = 0.208333 pu >>



PROGRAM 2 b): Power angle characteristics of Non salient pole rotor synchronous machine

```
clc
clear all
%Xdd=0.3;ra=0.0; v=1.0; p=0.9; pf=0.8;
fprintf('generator is modelled by a voltage source behind a reactance\n');
xdd=input('Enter generator reactance per phase in pu\n');
ra=input('Enter the armature resistance per phase in pu\n');
v=input('Enter the terminal voltage of the generator in pu\n');
p=input('Enter the power output of the generator in pu\n');
pf=input('Enter power factor\n');
pfsign=input('Enter -1 for lagging power factor & 1 for leading power factor');

iamag=p/(v*pf);
theta=acos(pf)*pfsign;
realia=iamag*cos(theta);
imagia=iamag*sin(theta);
ia=complex(realia, imagia);
ef=v+ia*(ra+j*xdd);
pmax=abs(ef)*abs(v)/xdd;
del=0:0.01:pi;
plot(del*180/pi,pmax*sin(del),'r');

title('power angle characteristics cylindrical rotor syn m/c');

xlabel('Delta in deg');
ylabel('Power in pu');
del=0:0.01:pi/2;
legend('pmax*sin(del)');
% line(del*180/pi,pmax);
% y=0:0.01:pmax; line(pi/2*(180/pi),y);
% text(-10,1.02*pmax,'p_{max}');
% text(pi/2*(180/pi),0.2,'del_{max}');
reg=(abs(ef)-abs(v))/abs(v)*100;
fprintf('\n the voltage regulation=%f %%\n',reg);
fprintf('the maximum power=%f pu',pmax);
```

Power system simulation lab manual

O/P 1:-

generator is modelled by a voltage source behind a reactance

enter generator reactance per phase in pu

0.3

enter the armature resistance per phase in pu

0.0

enter the terminal voltage of the generator per phase in pu

1.0

enter the power output of the generator in pu

0.9

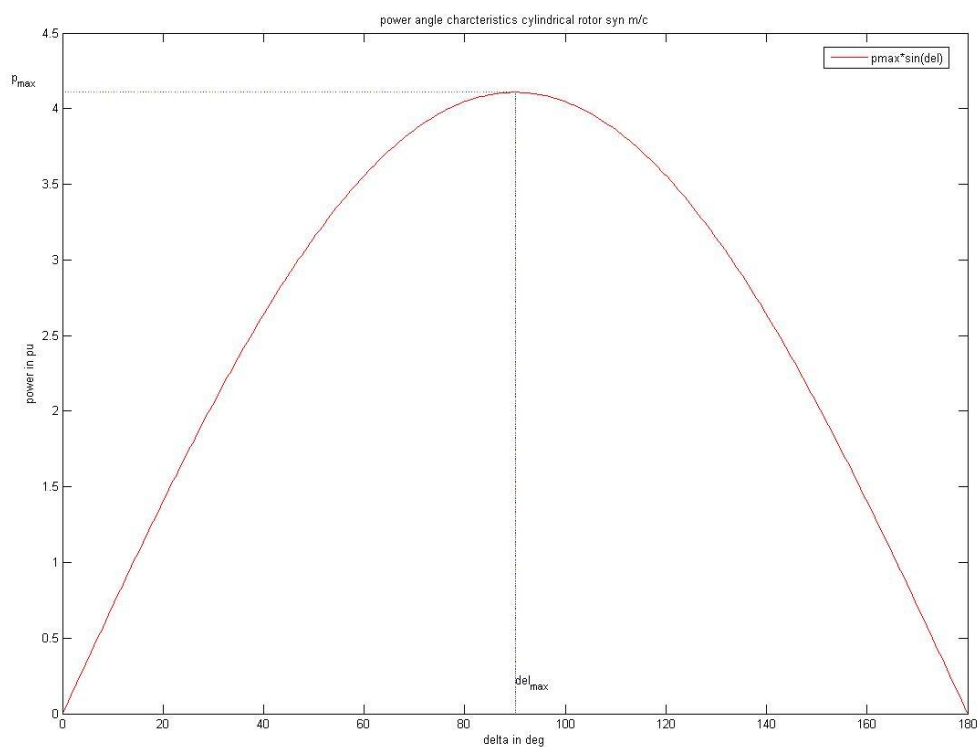
enter the power factor

0.8

enter -1 for lagging power factor & 1 for leading power factor-1the maximum power=2.806552 pu

the voltage regulation=23.243915%

the maximum power=4.108130 pu>>



Power system simulation lab manual

O/P 2:-

generator is modelled by a voltage source behind a reactance

enter generator reactance per phase in pu

0.3

enter the armature resistance per phase in pu

0.0

enter the terminal voltage of the generator per phase in pu

1.0

enter the power output of the generator in pu

0.9

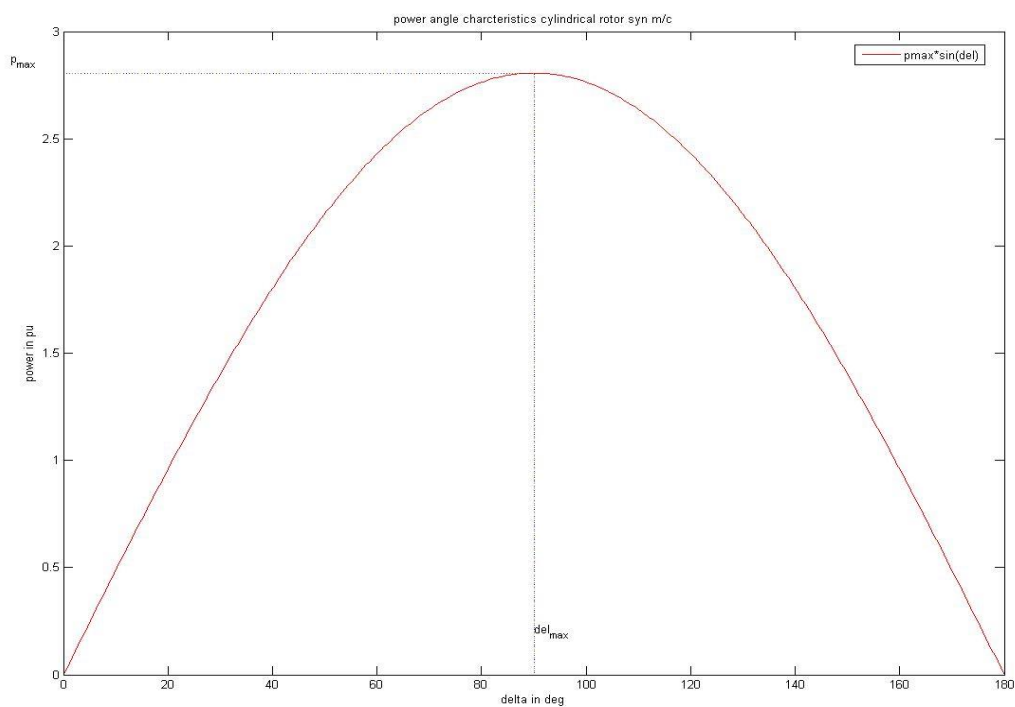
enter the power factor

0.8

enter -1 for lagging power factor & 1 for leading power factor

the voltage regulation=-15.803429%

the maximum power=2.806552 pu>>



Power system simulation lab manual

PROGRAM 3(a): To determine i) swing curve ii) critical clearing time for a single machine connected to infinite bus through a pair of identical transmission lines, for a 3 ϕ sustained fault on one of the lines.

```
% ps=mechanical power input.
% x2=reactance after fault
clc
clear all
ps=0.9;e=1.1;v=1;m=0.00028;xe=0.35;x1=0.2;
% m in electrical degrees
x1=xe+x1/2;
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*x1+xe*x1/2+x1*x1/2)/(x1/2);
    otherwise
        disp('wrong input');
end
dt=0.05;
it=1; % it is the iteration count
t(it)=0;
deld=0;
pm1=e*v/x1;
del(it)=asin(ps/pm1);
pm2=e*v/x2;
pm=pm2;
pe=pm2*sin(del(it));
pa=(ps-pe)/2;
fprintf('\n sustained fault');
fprintf('\n-----');
fprintf('\n time      pmax      delta');
fprintf('\n-----');
while(t(it)<=1.0)
    deld=deld+(pa*(dt^2/m));
    it=it+1;
    t(it)=t(it-1)+dt;
```

Power system simulation lab manual

```
del(it)=del(it-1)+deld*(pi/180); % deld is converted to radian and added.
    fprintf('\n %5.3f    %5.2f    %5.2f',t(it),pm,del(it)*(180/pi));
    pm=pm2;
    pe=pm*sin(del(it));
    pa=ps-pe;
end

plot(t,del*(180/pi),'r')
title('Swing curve')
xlabel('time in seconds')
ylabel('\delta in degrees')
x3=xe+x1; % 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);
D=delc*(180/pi);
fprintf('\n critical clearing angle %f',D);
it=1;
while(t(it)<1)
    if(del(it)>=delc)
        break;
    end
    it=it+1;
end
fprintf('critical clearing time=%f sec\n',t(it));
```

Power system simulation lab manual

O/P 1:-

enter 1 for fault at the beginning

2-for fault at the middle:1

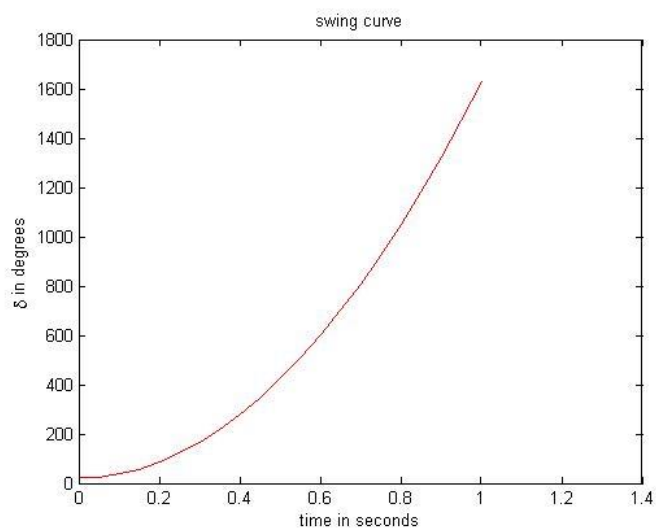
sustained fault

| time | pmax | delta |
|------|------|-------|
|------|------|-------|

| | | |
|-------|------|---------|
| 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 |
| 0.550 | 0.00 | 507.76 |
| 0.600 | 0.00 | 600.17 |
| 0.650 | 0.00 | 700.62 |
| 0.700 | 0.00 | 809.10 |
| 0.750 | 0.00 | 925.62 |
| 0.800 | 0.00 | 1050.17 |
| 0.850 | 0.00 | 1182.76 |
| 0.900 | 0.00 | 1323.39 |
| 0.950 | 0.00 | 1472.05 |
| 1.000 | 0.00 | 1628.75 |

critical clearing angle 81.684989critical clearing time=0.200000 sec

>>



Power system simulation lab manual

O/P 2:-

enter 1 for fault at the beginning

2-for fault at the middle:2

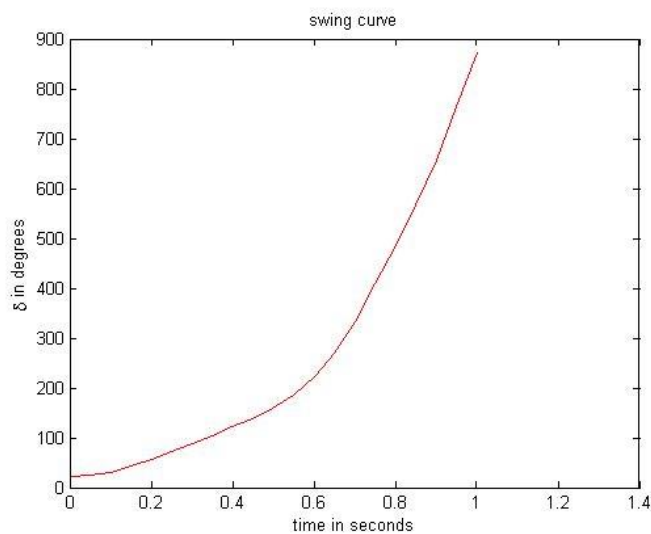
sustained fault

time pmax delta

| | | |
|-------|------|--------|
| 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 |
| 0.550 | 0.88 | 186.05 |
| 0.600 | 0.88 | 221.06 |
| 0.650 | 0.88 | 269.28 |
| 0.700 | 0.88 | 333.38 |
| 0.750 | 0.88 | 409.04 |
| 0.800 | 0.88 | 486.81 |
| 0.850 | 0.88 | 566.32 |
| 0.900 | 0.88 | 657.34 |
| 0.950 | 0.88 | 763.39 |
| 1.000 | 0.88 | 872.07 |

critical clearing angle 118.182332critical clearing time=0.400000 sec

>>



PROGRAM 3 (b): Program to obtain swing curve when the fault is cleared using MATLAB.

```
% check the output for case 1- time=0.05 & 0.125secs and
for case 2-time=0.5secs and 0.2secs
clear all
clc
ps=0.9;e=1.1; v=1.0; m=0.00028; xe=0.35;xl=0.2;
x1=xe+xl/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*xl+xe*xl/2+xl*xl/2)/(xl/2);
otherwise
    disp('wrong input');
end
x3=xe+xl;
dt=0.05;
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 interval');
else
    fprintf('fault is cleared at the middle of an interval');
end
deld=0;
it=1;
t(it)=0;
pmax1=e*v/x1;
del(it)=asin(ps/pmax1);
pmax2=e*v/x2;
pmax3=e*v/x3;
pm=pmax2;
pe=pm*sin(del(it));
pa=(ps-pe)/2;
fprintf('\n
while(t(it)<=1.05)
    deld=deld+(pa*(dt^2/m)); % deld is calculated in degrees.
    fprintf('\n %5.2f, %5.2f, %5.2f ',t(it),pm,del(it)*(180/pi));
    it=it+1;
    t(it)=t(it-1)+dt;
```


Power system simulation lab manual

```
del(it)=del(it-1)+deld*(pi/180); % deld is converted into radians and then added.
if(r==0)
    if(t(it)<ct)

        pm=pmax2;
    else
        if (t(it)==ct)
            pm=(pmax2+pmax3)/2;
        else
            pm=pmax3;
        end
    end
end
if (r~=0)
    if (t(it)<ct)
        pm=pmax2;
    else
        pm=pmax3;
    end
end
pe=pm*sin(del(it));
pa=ps-pe;
end
plot(t,del*(180/pi),'r');
title('Swing curve');
xlabel('time in seconds');
ylabel('delta in degrees');
pr=0;
for k=2:it
    if (del(k)<del(k-1))
        pr=1;
        break
    end
end

if (pr)
    text(0.5,1.0,'system is stable');
else
    text(0.5,1.0, 'system is unstable');
end
end
```

Power system simulation lab manual

O/P 1:-

enter 1 for fault at the beginning

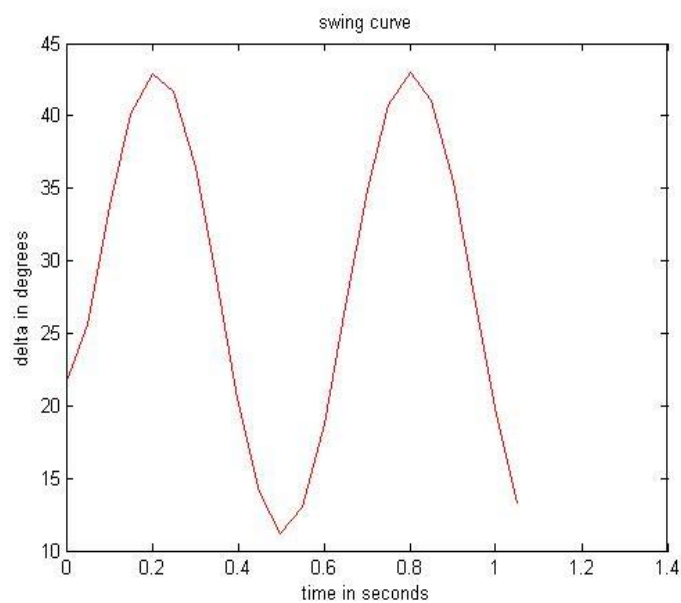
2-for fault at the middle:1

enter clearing time in sec:0.05

fault is cleared at the beginning of an interval

| TIME | PMAX | DELTA |
|-------|-------|---------|
| 0.00, | 0.00, | 21.60 |
| 0.05, | 1.00, | 25.62 |
| 0.10, | 2.00, | 33.81 |
| 0.15, | 2.00, | 40.10 |
| 0.20, | 2.00, | 42.93 |
| 0.25, | 2.00, | 41.62 |
| 0.30, | 2.00, | 36.50 |
| 0.35, | 2.00, | 28.78 |
| 0.40, | 2.00, | 20.51 |
| 0.45, | 2.00, | 14.01 |
| 0.50, | 2.00, | 11.23 |
| 0.55, | 2.00, | 13.00 |
| 0.60, | 2.00, | 18.80 |
| 0.65, | 2.00, | 26.87 |
| 0.70, | 2.00, | 34.91 |
| 0.75, | 2.00, | 40.77 |
| 0.80, | 2.00, | 43.00 |
| 0.85, | 2.00, | 41.09 |
| 0.90, | 2.00, | 35.47 |
| 0.95, | 2.00, | 27.54 |
| 1.00, | 2.00, | 19.38>> |

critical clearing angle 81.684989critical clearing time=0.200000 sec



Power system simulation lab manual

O/P 2:-

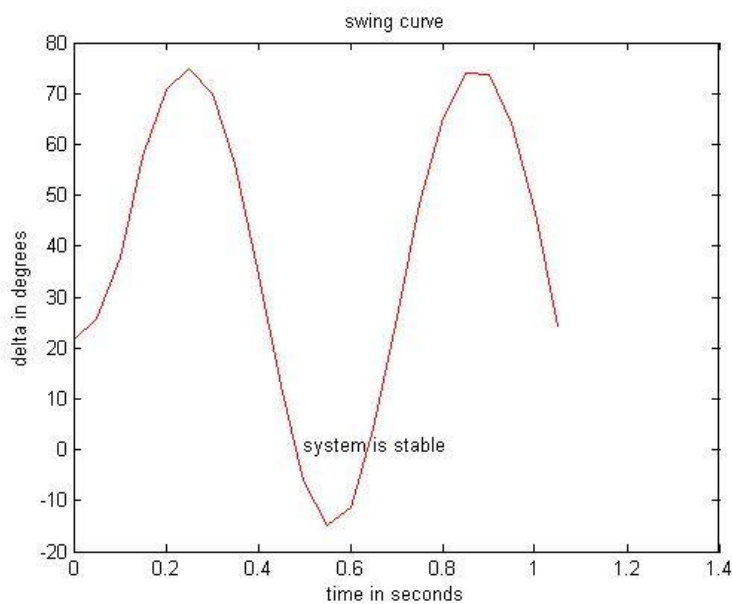
enter 1 for fault at the beginning

2-for fault at the middle:1

enter clearing time in sec:0.125

fault is cleared at the middle of an interval

| TIME | PMAX | DELTA |
|-------|-------|---------|
| 0.00, | 0.00, | 21.60 |
| 0.05, | 0.00, | 25.62 |
| 0.10, | 0.00, | 37.67 |
| 0.15, | 2.00, | 57.76 |
| 0.20, | 2.00, | 70.78 |
| 0.25, | 2.00, | 74.98 |
| 0.30, | 2.00, | 69.96 |
| 0.35, | 2.00, | 56.20 |
| 0.40, | 2.00, | 35.64 |
| 0.45, | 2.00, | 12.71 |
| 0.50, | 2.00, | -6.11 |
| 0.55, | 2.00, | -15.00 |
| 0.60, | 2.00, | -11.23 |
| 0.65, | 2.00, | 4.05 |
| 0.70, | 2.00, | 26.11 |
| 0.75, | 2.00, | 48.35 |
| 0.80, | 2.00, | 65.27 |
| 0.85, | 2.00, | 74.02 |
| 0.90, | 2.00, | 73.63 |
| 0.95, | 2.00, | 64.14 |
| 1.00, | 2.00, | 46.62>> |



Power system simulation lab manual

O/P 3:-

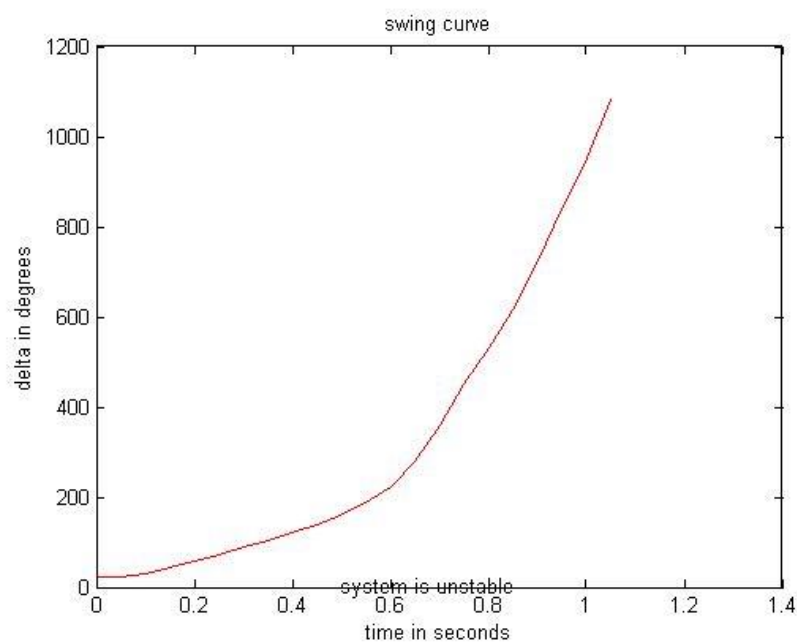
enter 1 for fault at the beginning

2-for fault at the middle:2

enter clearing time in sec:0.5

fault is cleared at the beginning of an interval

| TIME | PMAX | DELTA |
|-------|-------|----------|
| 0.00, | 0.88, | 21.60 |
| 0.05, | 0.88, | 24.17 |
| 0.10, | 0.88, | 31.56 |
| 0.15, | 0.88, | 42.88 |
| 0.20, | 0.88, | 56.88 |
| 0.25, | 0.88, | 72.34 |
| 0.30, | 0.88, | 88.34 |
| 0.35, | 0.88, | 104.53 |
| 0.40, | 0.88, | 121.15 |
| 0.45, | 0.88, | 139.08 |
| 0.50, | 0.88, | 159.89 |
| 0.55, | 2.00, | 186.05 |
| 0.60, | 2.00, | 222.12 |
| 0.65, | 2.00, | 278.20 |
| 0.70, | 2.00, | 359.99 |
| 0.75, | 2.00, | 449.82 |
| 0.80, | 2.00, | 529.83 |
| 0.85, | 2.00, | 614.72 |
| 0.90, | 2.00, | 724.88 |
| 0.95, | 2.00, | 841.55 |
| 1.00, | 2.00, | 951.04>> |



Power system simulation lab manual

O/P 4:-

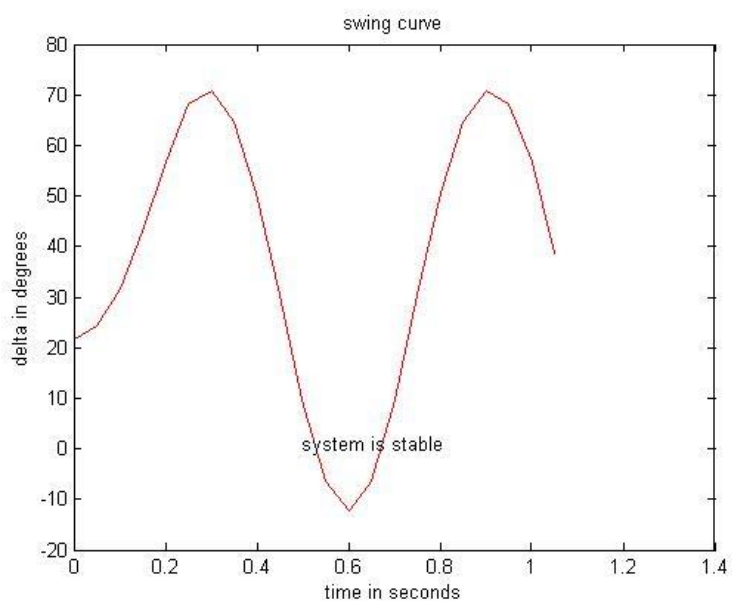
enter 1 for fault at the beginning

2-for fault at the middle:2

enter clearing time in sec:0.2

fault is cleared at the beginning of an interval

| TIME | PMAX | DELTA |
|-------|-------|---------|
| 0.00, | 0.88, | 21.60 |
| 0.05, | 0.88, | 24.17 |
| 0.10, | 0.88, | 31.56 |
| 0.15, | 0.88, | 42.88 |
| 0.20, | 1.44, | 56.88 |
| 0.25, | 2.00, | 68.15 |
| 0.30, | 2.00, | 70.88 |
| 0.35, | 2.00, | 64.77 |
| 0.40, | 2.00, | 50.55 |
| 0.45, | 2.00, | 30.57 |
| 0.50, | 2.00, | 9.55 |
| 0.55, | 2.00, | -6.40 |
| 0.60, | 2.00, | -12.33 |
| 0.65, | 2.00, | -6.40 |
| 0.70, | 2.00, | 9.55 |
| 0.75, | 2.00, | 30.57 |
| 0.80, | 2.00, | 50.55 |
| 0.85, | 2.00, | 64.77 |
| 0.90, | 2.00, | 70.88 |
| 0.95, | 2.00, | 68.15 |
| 1.00, | 2.00, | 56.88>> |



PROGRAM 4 a): Formation of Y-bus without line charging-Inspection method

```
clc
data1=[ 1 2 0.3 0.4;           % creating input file
        1 3 0.2 0.5;
        2 3 0.1 0.3];
nb=data1(1,1);                % no. of buses.
nl=data1(1,2);                % no. of lines
for i=1:nl
    sb(i)=data1(i+1,1);        % sending bus
    eb(i)=data1(i+1,2);        % end bus
    serz(i)=(data1(i+1,3)+data1(i+1,4)*j); % series impedance
end

for j=1:nb
    for k=1:nb
        ybus(j,k)=0;          % initializes all elements of
ybus to zero.
    end
end

for i=1:nl
    j=sb(i);
    k=eb(i);
    ybus(j,j)=ybus(j,j)+1/serz(i);
    ybus(k,k)=ybus(k,k)+1/serz(i);
    ybus(j,k)=ybus(j,k)-1/serz(i);
    ybus(k,j)=ybus(j,k);
end
ybus                            % displays ybus
```

O/P:-

```
ybus =

40.0000  -20.0000  -20.0000     0
-20.0000  46.6667  -10.0000  -16.6667
-20.0000  -10.0000  50.0000  -20.0000
0  -16.6667  -20.0000  36.6667
```

PROGRAM 4 b): Program for the formation of Ybus with line charging--Inspection

Method

```
clear all
%      sb  eb   serr  serx  shty
linedata=[1  2  0.02  0.06 0.03;
          1  3  0.08  0.24 0.025;
          2  3  0.06  0.18 0.02;
          2  4  0.06  0.18 0.02;
          2  5  0.04  0.12 0.015;
          3  4  0.01  0.03  0.01;
          4  5  0.08  0.24 0.025];
sb=linedata(:,1);
eb=linedata(:,2);
nl=max(size(sb));
nb=max(max(sb,eb));
serz=(linedata(:,3)+j*linedata(:,4));
shty=(0+j*linedata(:,5));
ybus=zeros(nb,nb);
for i=1:nl
    j=sb(i);
    k=eb(i);
    ybus(j,j)=ybus(j,j)+1/serz(i)+shty(i);
    ybus(k,k)=ybus(k,k)+1/serz(i)+shty(i);
    ybus(j,k)=-1/serz(i);
    ybus(k,j)=ybus(j,k);
end
ybus
```

O/P:-

ybus =

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

Program 4 c): Formation of Y-bus using Singular Transformation Method with Mutual Coupling (line charging is neglected)

```
clc
clear all
data=[1 2 0.6i 0 0;
      1 3 0.5i 1 0.1i;
      3 4 0.5i 0 0;
      1 2 0.4i 1 0.2i;
      2 4 0.2i 0 0];
fb=data(:,1);
tb=data(:,2);
z=data(:,3);
mc=data(:,4);
mz=data(:,5);
nnode=max(max(fb),max(tb));
nbus=nnode -1;
nline=length(fb);
zpr=zeros(nline,nline);
for k=1:nline
    zpr(k,k)=z(k);
    if mc(k)~=0
        zpr(k,mc(k))=mz(k);
        zpr(mc(k),k)=mz(k); end
end
ypr=inv(zpr);
Acap=zeros(nline,nnode);
for k=1:nline
    Acap(k,fb(k))=1;
    Acap(k,tb(k))=-1;
end
A=Acap(:,2:nnode);
ybus=A'*ypr*A;
ybus
```

O/P:-

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 4 d): Formation of Ybus using Singular Transformation Method without Mutual Coupling

```
clc
clear all
%      fb  tb  Z      hlcy(Admittance)
linedata=[1 2 0.02+0.06i  0.03i
           1 3 0.08+0.24i  0.025i
           2 3 0.06+0.18i  0.02i
           2 4 0.06+0.18i  0.02i
           2 5 0.04+0.12i  0.015i
           3 4 0.01+0.03i  0.01i
           4 5 0.08+0.24i  0.025i];

fb=linedata(:,1);
tb=linedata(:,2);
z=linedata(:,3);
hlcy=linedata(:,4);
y=1./z;
nbus=max(max(fb),max(tb));
ybus=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(1,nbus);
for k=1:nline
    sh(fb(k))=sh(fb(k))+hlcy(k);
    sh(tb(k))=sh(tb(k))+hlcy(k);
end
```

Power system simulation lab manual

```
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;
ybus
```

O/P:-

ybus =

| | | | | |
|-------------------|--------------------|-------------------|-------------------|--------------------|
| 6.2500 -18.7500i | -5.0000 +15.0000i | -1.2500 + 3.7500i | 0 | 0 |
| -5.0000 +15.0000i | 24.3333 -37.0000i | -1.6667 + 5.0000i | -1.6667 + 5.0000i | -16.0000 +12.0000i |
| -1.2500 + 3.7500i | -1.6667 + 5.0000i | 2.9167 - 8.7500i | 0 | 0 |
| 0 | -1.6667 + 5.0000i | 0 | 1.6667 - 5.0000i | 0 |
| 0 | -16.0000 +12.0000i | 0 | 0 | 16.0000 -12.0000i |

PROGRAM 5: FORMATION OF Z-BUS, USING Z-BUS BUILDING ALGORITHM WITHOUT MUTUAL COUPLING

```
clc;
clear;
disp('Zbus Building Algorithm');
zprimary = [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];
[elements,columns]=size(zprimary);
zbus=[];
currentbusno=0;
for count=1:elements
    [rows cols]=size(zbus);
    from=zprimary(count,2);
    to=zprimary(count,3);
    value=zprimary(count,4);
    newbus=max(from,to);
    ref=min(from,to);

    %Type-1 Modification
    %A new element is added from new bus to reference bus
    if newbus>currentbusno & ref==0
        disp('Adding Z =');
        disp(value);
        disp('between buses:');
        disp(from);
        disp(to);
        disp('This impedance is added between a new bus and reference(Type1)');
        zbus=[zbus zeros(rows,1)
              zeros(1,cols) value]
        currentbusno=newbus;
        continue
    end

    %Type-2 Modification
    %A element is added from new bus to old bus other than reference bus
    if newbus>currentbusno & ref~=0
        disp('Adding Z =');
        disp(value);
        disp('between buses:');
        disp(from);
```

```
        disp(to);
        disp('This impedance is added between a new bus and an existing bus(Type2)');
        zbus=[zbus zbus(:,ref)
              zbus(ref,:) value+zbus(ref,ref)]
        currentbusno=newbus;
        continue
    end

% Type-3 Modification
% A new element is added between an old bus and reference bus
if newbus<=currentbusno & ref==0
    disp('Adding Z =');
    disp(value);
    disp('between buses:');
    disp(from);
    disp(to);
    disp('This impedance is added between an existing bus and reference(Type3)');
    zbus=zbus-1/(zbus(newbus,newbus)+value)*zbus(:,newbus)*zbus(newbus,:)
    continue
end

% Type-4 Modification
% A new element is added between two old buses(bus-2 to 3)
if newbus<=currentbusno & ref~=0
    disp('Adding Z =');
    disp(value);
    disp('between buses:');
    disp(from);
    disp(to);
    disp('This impedance is added between two existing buses(Type4)');

    zbus=zbus-1/(value+zbus(from,from)+zbus(to,to)-2*zbus(from,to))*((zbus(:,from)-zbus(:,to))
    )*((zbus(from,:)-zbus(to,:))))
    continue
end
end
```

OUTPUT:

Zbus Building Algorithm

Adding Z =

0.2500

between buses:

1

0

This impedance is added between a new bus and reference(Type1)

zbus =

0.2500

Adding Z =

0.1000

between buses:

2

1

This impedance is added between a new bus and an existing bus(Type2)

zbus =

0.2500 0.2500

0.2500 0.3500

Adding Z =

0.1000

between buses:

3

1

This impedance is added between a new bus and an existing bus(Type2)

Power system simulation lab manual

zbus =

| | | |
|--------|--------|--------|
| 0.2500 | 0.2500 | 0.2500 |
| 0.2500 | 0.3500 | 0.2500 |
| 0.2500 | 0.2500 | 0.3500 |

Adding Z =

0.2500

between buses:

2

0

This impedance is added between an existing bus and reference(Type3)

zbus =

| | | |
|--------|--------|--------|
| 0.1458 | 0.1042 | 0.1458 |
| 0.1042 | 0.1458 | 0.1042 |
| 0.1458 | 0.1042 | 0.2458 |

Adding Z =

0.1000

between buses:

2

3

This impedance is added between two existing buses(Type4)

zbus =

| | | |
|--------|--------|--------|
| 0.1397 | 0.1103 | 0.1250 |
| 0.1103 | 0.1397 | 0.1250 |
| 0.1250 | 0.1250 | 0.1750 |

PROGRAM 6: Determination of bus current, bus power & line flows for a specified voltage bus

```
clc
clear all
%      fb  tb  z
linedata=[1  2  0.02+0.04i;
          1  3  0.01+0.03i;
          2  3  0.0125+0.025i];
vb=[1.05+0.0i;
    0.98-0.06i;
    1.00-0.05i];
fb=linedata(:,1);
tb=linedata(:,2);
z=linedata(:,3);
nl=max(size(fb));
y=1./z;
for k=1:nl
    il(fb(k),tb(k))=y(k)*(vb(fb(k))-vb(tb(k)));
    il(tb(k),fb(k))=-il(fb(k),tb(k));
end
fprintf('the line currents:\n');
il
for k=1:nl
    lf(fb(k),tb(k))=vb(fb(k))*conj(il(fb(k),tb(k)));
    lf(tb(k),fb(k))=vb(tb(k))*conj(il(tb(k),fb(k)));
    ll(k)=lf(fb(k),tb(k))+lf(tb(k),fb(k));
end
fprintf('the line flows:\n');
lf
fprintf('the line losses:\n');
ll
for k=1:nl
    bp(k)=sum(lf(k,:));
    ibus(k)=conj(bp(k)/vb(k));
end
fprintf('the bus powers:\n');
bp
fprintf('the bus currents:\n');
ibus
```

Power system simulation lab manual

O/P:-

the line currents:

il =

$$\begin{matrix} 0 & 1.9000 - 0.8000i & 2.0000 - 1.0000i \\ 1.9000 - 0.8000i & 0 & -0.6400 + 0.4800i \\ 2.0000 - 1.0000i & -0.6400 + 0.4800i & 0 \end{matrix}$$

the line flows:

lf =

$$\begin{matrix} 0 & 1.9950 + 0.8400i & 2.1000 + 1.0500i \\ 1.9100 + 0.6700i & 0 & -0.6560 - 0.4320i \\ 2.0500 + 0.9000i & -0.6640 - 0.4480i & 0 \end{matrix}$$

the line losses:

ll =

$$3.9050 + 1.5100i \quad 4.1500 + 1.9500i \quad -1.3200 - 0.8800i$$

the bus powers:

bp =

$$4.0950 + 1.8900i \quad 1.2540 + 0.2380i \quad 1.3860 + 0.4520i$$

the bus currents:

ibus =

$$3.9000 - 1.8000i \quad 1.2600 - 0.3200i \quad 1.3600 - 0.5200i$$

