# COMPUTER BASED POWER SYSTEM DESIGN LABORATORY

## SYLLABUS

1. Fault analysis (for 3 to 6 bus) and verify the results using MATLAB or any available software for the cases:
   (i) LG Fault
   (ii) LLG Fault
   (iii) LL Fault and
   (iv) 3-Phase Fault
2. Load flow analysis for a given system (for 3 to 6 bus) using
   (i) Gauss Seidal
   (ii) Newton-Raphson
   (iii) Fast Decoupled Method and verify results using MATLAB or any available software.
3. Study of voltage security analysis
4. Study of overload security analysis and obtain results for the given problem using MATLAB or any software.
5. Study of economic load dispatch problem with different methods.
6. Study of transient stability analysis using MATLAB/ETAP Software.

# Experiment No : 1

**OBJECT**

(i) To determine the positive sequence line parameters L and C per phase per kilometer of a three phase single and double circuit transmission lines for different conductor arrangements.

(ii) To understand modeling and performance of medium lines.

**SOFTWARE REQUIRED:** MATLAB

**THEORY**

Transmission line has four parameters namely resistance, inductance, capacitance and conductance. The inductance and capacitance are due to the effect of magnetic and electric fields around the conductor. The resistance of the conductor is best determined from the manufactures data, the inductances and capacitances can be evaluated using the formula.

**Inductance**

The general formula

$$L = 0.2 \ln (D_m / D_s)$$

Where,

$D_m$ = geometric mean distance (GMD)

Ds = geometric mean radius (GMR)

**I. Single phase 2 wire system**

GMD = D

GMR = $re^{-1/4} = r'$

Where, r = radius of conductor

**II. Three phase – symmetrical spacing**

GMD = D

GMR = $re^{-1/4} = r'$

Where, r = radius of conductor

**III. Three phase – Asymmetrical Transposed**

GMD = geometric mean of the three distance of the symmetrically placed conductor = $\sqrt[3]{D_{AB} D_{BC} D_{CA}}$

GMR = $re^{-1/4} = r'$

Where, r = radius of conductors

**Composite conductor lines**

The inductance of composite conductor X, is given by

$L_x = 0.2 \ln (GMD/GMR)$

where,

GMD = $\sqrt[mn]{(D_{aa'} D_{ab'}) \ldots\ldots (D_{na'} \ldots\ldots D_{nm'})}$

**Bundle Conductors**

The GMR of bundled conductor is normally calculated

GMR for two sub conductor = $(Ds * d)^{1/2}$

GMR for three sub conductor = $(Ds * d2)^{1/3}$

GMR for four sub conductor = $1.09 (Ds * d3)^{1/4}$

where, $D_s$ is the GMR of each sub conductor

d= bundle spacing

**Three phase – Double circuit transposed**

The inductance per phase in mH per km is

$$L = 0.2 \ln (GMD / GMR_L) \text{ mH/km}$$

where,

$GMR_L$ is equivalent geometric mean radius and is given by

$$GMR_L = (D_{SA} D_{SB} D_{SC})^{1/3}$$

where,

$D_{SA}$, $D_{SB}$ and $D_{SC}$ are GMR of each phase group and given by

$$D_{SA} = \sqrt[4]{(D_s^b D_{a1a2})^2} = [D_s^b D_{a1a2}]^{1/2}$$

$$D_{SB} = \sqrt[4]{(D_s^b D_{b1b2})2} = [D_s^b D_{b1b2}]^{1/2}$$

$$D_{SC} = \sqrt[4]{(D_s^b D_{c1c2})2} = [D_s^b D_{c1c2}]^{1/2}$$

GMD is the equivalent GMD per phase" & is given by

$$GMD = [D_{AB} * D_{BC} * D_{CA}]^{1/3}$$

where,

$D_{AB}$ , $D_{BC}$ and $D_{CA}$ are GMD between each phase group A-B, B-C, C-A which are given by

$$D_{AB} = [D_{a1b1} * D_{a1b2} * D_{a2b1} * D_{a2b2}]^{1/4}$$

$$D_{BC} = [D_{b1c1} * D_{b1c2} * D_{b2c1} * D_{b2c2}]^{1/4}$$

$$D_{CA} = [D_{c1a1} * D_{c2a1} * D_{c2a1} * D_{c2a2}]^{1/4}$$

**Capacitance**

A general formula for evaluating capacitance per phase in micro farad per km of a transmission line is given by

$$C = 0.0556 / \ln (GMD/GMR) \ \mu F/km$$

Where,

GMD is the “Geometric mean distance” which is same as that defined for inductance under various cases.

**PROCEDURE**

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

**EXERCISES**

A three phase overhead line 200km long R = 0.16 ohm/km and Conductor diameter of 2cm with spacing 4, 5, 6 m transposed. Find A, B, C, D constants, sending end voltage, current, power factor and power when the line is delivering full load of 50MW at 132kV, 0.8 pf lagging, transmission efficiency, receiving end voltage and regulation.

**PROGRAM**

```
d=2e-2;
Dab=4; Dbc=5;Dca=6;
GMD=(Dab*Dbc*Dca)^(1/3);
GMR=(0.7788*d/2);
r=d/2;
R=0.16*200;
L=0.2*log(GMD/GMR)
Ca=(0.0556/log(GMD/r))
f=50;
Xl=2*pi*f*L*200*1e-3;
Yc=2*pi*f*Ca*200*1e-6;
```

```
Z=complex(R, Xl)
Y=j*Yc
A=(1+Y*Z/2)
B=Z
C=Y*(1+(Y*Z/4))
D=A
Pr=50e+6;Vr=(132e+3/sqrt(3));PFR=0.8;
Irm=Pr/(3*Vr*PFR);
Ir=Irm*complex(PFR,-sin(acos(PFR)));
Vs=(A*Vr)+(B*Ir);
Is=(C*Vr)+(D+Ir);
Vsm=abs(Vs)
Ism=abs(Is)
PFS=cos(angle(Vs)-angle(Is))
Ps=3*Vsm*Ism*PFS
eff=100*(Pr/Ps)
Vro=abs(Vsm*(2/Y)/(Z+(2/Y)))
reg=100*(Vro-Vr)/Vr
```

**OUTPUT :**

```
L = 1.2902
Ca = 0.0090
Z = 32.0000 +81.0657i
Y = 0 +5.6337e-004i
A = 0.9772 + 0.0090i
B = 32.0000 +81.0657i
```

C = -2.5391e-006 +5.5694e-004i

D = 0.9772 + 0.0090i

Vsm = 9.5675e+004

Ism = 250.8956

PFS = 0.7998

Ps = 5.7594e+007

eff = 86.8147

Vro = 9.7907e+004

reg = 28.4690

**RESULT**

Thus the positive sequence line parameters L and C per phase per kilometre of a three phase single and double circuit transmission lines for different conductor arrangements were determined and verified with MATLAB software.

## Experiment No : 2

**OBJECT**

(i) To determine Symmetrical component of set of unbalance current:

$V_a = 3\angle 310^0$,

$V_b = 5\angle 105^0$

$V_c = 4\ \angle 12^0$.

(ii) Symmetrical component of set of unbalanced three phase voltages are:

$V_{ao} = 0.6\angle 90^0$,

$V_{a1} = 1.0\angle 30^0$,

$V_{a2} = 0.8\angle -30^0$.

Obtain original unbalance phasors.

**THEORY:**

Symmetrical components allow unbalanced phase quantities such as currents and voltages to be replaced by three separate balanced symmetrical components. Based on the C.L. Fortescue's theory, three phase unbalanced phasors a–b–c, of a three-phase system can be resolved into three balanced systems of phasors as follows.

1. Positive (+ve) sequence components consisting of a set of three-phase components with a phase sequence a–b–c.

2. Negative (–ve) sequence components consisting of a set of three-phase components with a phase sequence a–c–b.

3. Zero (0) sequence components consisting of three single-phase components, all equal in magnitude but with the same phase angles.

Considering the three-phase unbalanced currents $[I_{abc}]$, with the 'symmetrical components transformation matrix (SCTM), denoted as [A], which transforms $[I_{abc}]$ into component currents $[I_a^{012}]$. This can be represented in matrix notations as,

$$[I_{abc}] = [A] \times [I_a^{012}]$$

where,

$$A = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix}$$

And the operator ‘$a$’ is defined as,

$$a = 1\angle 1200 = -0.5 + j0.866$$

$$a^2 = 1\angle 2400 = -0.5 - j0.866$$

$$1 + a + a^2 = 0$$

Therefore, for the symmetrical components of the currents, we have,

$$[I_a^{012}] = [A]^{-1} \times [I_{abc}]$$

Similar expressions exist for voltages. Thus the unbalanced phase voltages in terms of the symmetrical components could be represented. Those familiar with the three-phase technique will be interested in observing the resemblances and the differences between the three-phase and the four-phase techniques.

**MATLAB PROGRAM (i)**

```
Vabc=[3 310;5 105;4 12];
rankfabc=length(Vabc(1,:));
if rankVabc == 2
mag= Vabc(:,1); ang=pi/180*Vabc(:,2);
Vabcr=mag.*(cos(ang)+j*sin(ang));
elseif rankVabc ==1
Vabcr=Vabc;
else
```

```
fprintf('\n Three phasors must be expressed in a one column array in rectangular complex form \n')
fprintf(' or in a two column array in polar form, with 1st column magnitude & 2nd column \n')
fprintf(' phase angle in degree. \n')
return, end
a=cos(2*pi/3)+j*sin(2*pi/3);
A = [1 1 1; 1 a^2 a; 1 a a^2];
Va012=inv(A)*Vabcr;
symcomp= Va012

Vabc0=Va012(1)*[1; 1; 1]
Vabc1=Va012(2)*[1; a^2; a]
Vabc2=Va012(3)*[1; a; a^2]
```

**Results**

```
Q =    3 310
       5 105
       4 12
Sym3Abs =
       1.8852 3.3495 1.3761
       1.8852 3.3495 1.3761
       1.8852 3.3495 1.3761
Sym3Angle =
       36.4890 -106.4364 -8.6327
       36.4890 133.5636 111.3673
       36.4890 13.5636 -128.6327
```

**MATLAB PROGRAM (ii)**

```
Va012=[0.6 90;1.0 30;0.8 -30];
rankf012=length(Va012(1,:));
if rankf012 == 2
mag= Va012(:,1); ang=pi/180*Va012(:,2);
Va012r=mag.*(cos(ang)+j*sin(ang));
elseif rankV012 ==1

Va012r=Va012;
else
fprintf('\n Symmetrical components must be expressed in a one column array in rectangular complex form \n')
fprintf(' or in a two column array in polar form, with 1st column magnitude & 2nd column \n')
fprintf(' phase angle in degree. \n')
return, end
a=cos(2*pi/3)+j*sin(2*pi/3);
A = [1 1 1; 1 a^2 a;1 a a^2];
Vabc= A*Va012r

Vabc0=Va012r(1)*[1; 1; 1]
Vabc1=Va012r(2)*[1; a^2; a]
Vabc2=Va012r(3)*[1; a; a^2]
```

**Result :**

**Vabc**= 3 310

5 105

4 12

## Experiment No : 3

**OBJECT**

To determine the bus admittance and impedance matrices for the given power system network.

**SOFTWARE REQUIRED:** MATLAB

**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 π- 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

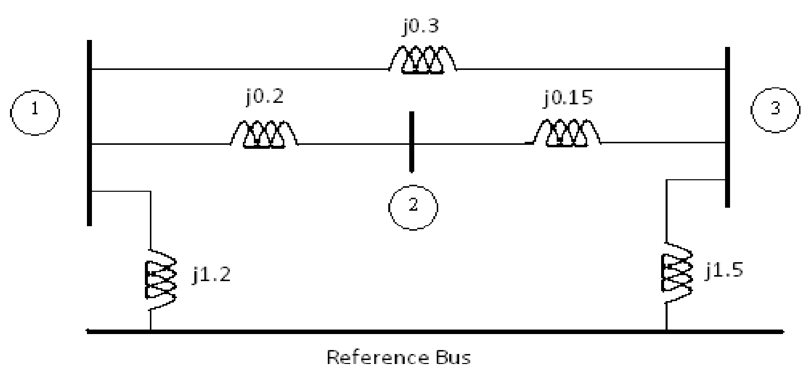
**FORMATION OF Z BUS MATRIX**

In bus impedance matrix the elements on the main diagonal are called driving point impedance and the off-diagonal elements are called the transfer impedance of the buses or nodes. The bus impedance matrix is very useful in fault analysis.

The bus impedance matrix can be determined by two methods. In one method we can form the bus admittance matrix and then taking its inverse to get the bus impedance matrix. In another method the bus impedance matrix can be directly formed from the reactance diagram and this method requires the knowledge of the modifications of existing bus impedance matrix due to addition of new bus or addition of a new line (or impedance) between existing buses.

**PROCEDURE**

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




**PROGRAM**

**% busdate Ns Nr Z**

```
clc;
clear all;
Zm= [1 2 0.2j
2 3 0.15j
1 3 0.3j] ;
Zs=[1.2j 0 1.5j] ;
```

```
Ns=Zm( :,1) ; Nr=Zm( :,2) ; Y=zeros(3) ;
for i=1 :3
Y(Ns(i),Nr(i))=-1/Zm(i,3) ;
end
Y=Y+Y.';
for i=1 :3
if Zs(i)~=0
Y(i,i)=(1/Zs(i))-sum(Y(i, :)) ;
else
Y(i,i)=-sum(Y(i, :)) ;
end
end
Y
Z=inv(Y)
```

**OUTPUT**

```
Y =
0 - 9.1667i 0 + 5.0000i 0 + 3.3333i
0 + 5.0000i 0 -11.6667i 0 + 6.6667i
0 + 3.3333i 0 + 6.6667i 0 -10.6667i

Z =
0 + 0.6968i 0 + 0.6581i 0 + 0.6290i

0 + 0.6581i 0 + 0.7548i 0 + 0.6774i

0 + 0.6290i 0 + 0.6774i 0 + 0.7137i
```

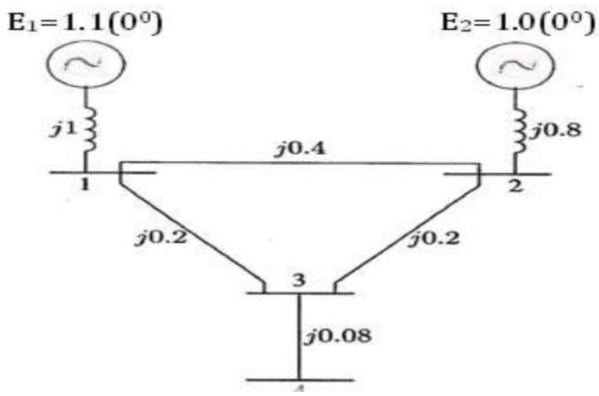
**RESULT**

Thus the bus Impedance and admittance matrix for the given system were determined and verified using MATLAB.

## Experiment No : 4

**OBJECT**

To determine the bus admittance and impedance matrices for the given power system network.




```
Z=[ 0 1 0 1.0
0 2 0 0.8
1 2 0 0.4
1 3 0 0.2
2 3 0 0.2
3 4 0 0.08];
nl=zdata(:,1); nr=zdata(:,2); R=zdata(:,3); X=zdata(:,4);
nbr=length(zdata(:,1)); nbus = max(max(nl), max(nr));
Z = R + j*X; %branch impedance
y= ones(nbr,1)./Z; %branch admittance
Ybus=zeros(nbus,nbus); % initialize Ybus to zero
for k = 1:nbr; % formation of the off diagonal elements
if nl(k) > 0 & nr(k) > 0
Ybus(nl(k),nr(k)) = Ybus(nl(k),nr(k)) - y(k);
```

```
Ybus(nr(k),nl(k)) = Ybus(nl(k),nr(k));
end
end
for n = 1:nbus % formation of the diagonal elements
for k = 1:nbr
if nl(k) == n | nr(k) == n
Ybus(n,n) = Ybus(n,n) + y(k);
else, end
end
end
Ibus =[-j*1.1;-j*1.25;0;0];
Zbus= inv(Y)
Vbus = Zbus* Ibus
```

**Experiment No : 5**

**OBJECT**

To understand, in particular, the mathematical formulation of power flow model in complex form

and a simple method of solving power flow problems of small sized system using Gauss-Seidel iterative

algorithm.

**THEORY**

The GAUSS – SEIDEL method is an iterative algorithm for solving a set of non-linear load flow

equations.

The non-linear load flow equation is given by

1 Pp – j Qp p-1 n

Vp

k+1 = - □ Ypq Vq

k+1 - □ Vq

k

Ypp **(**Vp

k)* q = 1 q=p+1

The reactive power of bus-p is given by

p-1 n

QP

k+1 =(-1) x Im **(**Vp

k)* □ Ypq Vq

k+1 + □ Ypq Vq

k

q = 1 q=p

**PROCEDURE**

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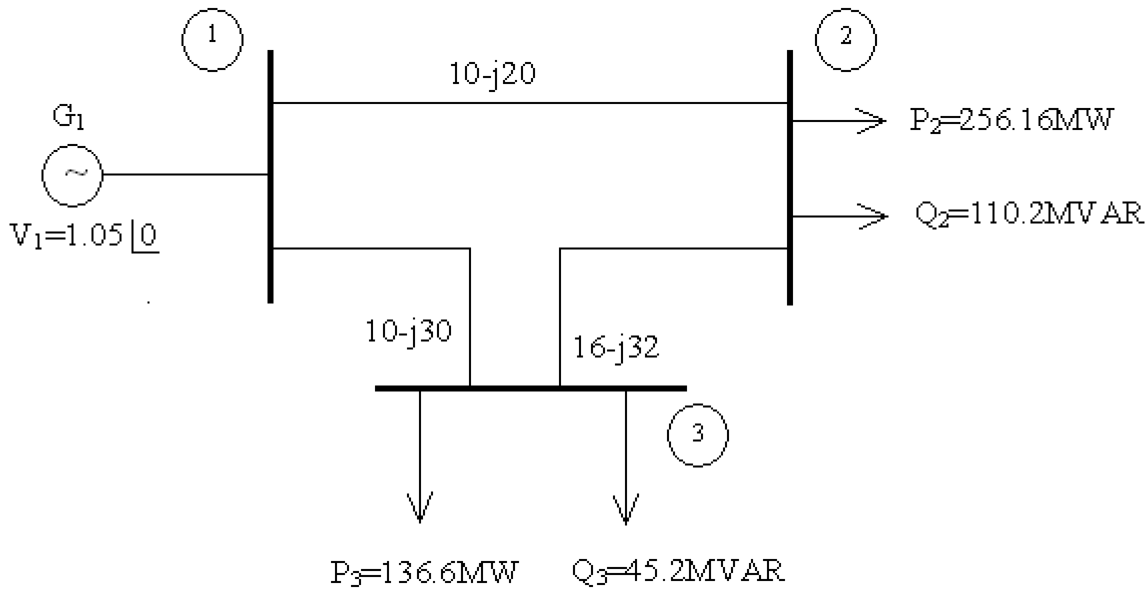
**EXERCISE**

The figure shows the single line diagram of a simple 3 bus power system with generator at bus-1. The
magnitude at bus 1 is adjusted to 1.05pu. The scheduled loads at buses 2 and 3 are marked on the
diagram. Line impedances are marked in p.u. The base value is 100kVA. The line charging
susceptances are neglected. Determine the phasor values of the voltage at the load bus 2 and 3.

(i) Find the slack bus real and reactive power.

(ii) Verify the result using MATLAB.




**PROGRAM**

```
V=[1.05 1 1]';
P=[0 -2.5616 -1.366]';
Q=[0 -1.102 -0.452]';
linedata=[1 2 10-20i
2 3 16-32i
1 3 10-30j];
ns=linedata(:,1);
nr=linedata(:,2);
yy=linedata(:,3);
nl=length(ns);
nb=max(max(ns),max(nr));
y=zeros(nb);
```

```
for i=1:nl
y(ns(i),nr(i))=-yy(i);
end
y=y+y.';
for i=1:nb
y(i,i)=-sum(y(i,:));
end
y
S=complex(P,-Q);
for i=2:nb
V(i)=S(i)/(y(i,i)*conj(V(i)));
for j=1:nb
if j~=i
V(i)=V(i)-(y(i,j)*V(j)/y(i,i));
end
end
end
disp('Phasor Voltages:');

V
Ss=conj(V(1))*y*V;
disp('Slack bus real Power:');
Ps=real(Ss(1))
disp('Slack bus reactive Power:');
Qs=-imag(Ss(1))
```

**OUTPUT**

y =

20.0000 -50.0000i -10.0000 +20.0000i -10.0000 +30.0000i

-10.0000 +20.0000i 26.0000 -52.0000i -16.0000 +32.0000i

-10.0000 +30.0000i -16.0000 +32.0000i 26.0000 -62.0000i

Phasor Voltages:

V =

1.0500

0.9826 - 0.0309i

1.0012 - 0.0349i

Slack bus real Power:

Ps = 2.9705

Slack bus reactive Power:

Qs = 2.2603

**RESULT**

Load flow solution for the given problem was solved using Gauss-Seidal method and verified using MATLAB software.

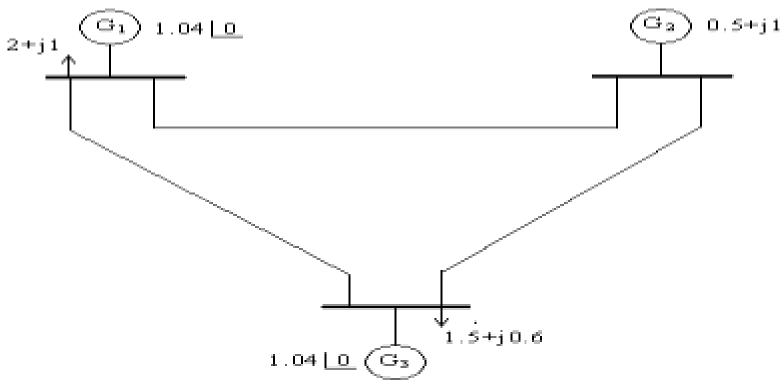
**Experiment No : 6**

## OBJECT

To determine the power flow analysis using Newton – Raphson method

## EXERCISE

Consider the 3 bus system each of the 3 line bus a series impedance of 0.02 + j0.08 p.u and a total shunt
admittance of j0.02 p.u. The specified quantities at the bus are given below.




| Bus | Real load demand, $P_D$ | Reactive Load demand, $Q_D$ | Real power Generation, $P_G$ | Reactive Power Generation, $Q_G$ | Voltage Specified |
|---|---|---|---|---|---|
| 1 | 2 | 1 | - | - | $V_1$=1.04 |
| 2 | 0 | 0 | 0.5 | 1 | Unspecified |
| 3 | 1.5 | 0.6 | 0 | $Q_{G3}$ = ? | $V_3$ = 1.04 |

## PROGRAM

```
% Given data
Pd=[2 0 1.5];Qd=[1 0 0.6];Pg=[0 0.5 0];Qg=[0 1 0];
Pnet=Pg-Pd;Qnet=Qg-Qd;
V=[1.04 1 1.04];
Vm=abs(V);Va=angle(V);
```

```
% Ybus formation
Yse=2.94-11.76i;Ysh=0.01i;
Yd=2*(Yse+Ysh);
Y=[Yd -Yse -Yse; -Yse Yd -Yse;-Yse -Yse Yd];
Ym=abs(Y); Ya=angle(Y);
% Calculation
P=[0 0 0];
for i=2:3
for j=1:3
P(i)=Vm(i)*Vm(j)*Ym(i,j)*cos(Va(i)-Va(j)-Ya(i,j));
Q(i)=Vm(i)*Vm(j)*Ym(i,j)*sin(Va(i)-Va(j)-Ya(i,j));
end
end
delP=Pnet-P;delQ=Qnet-Q;
A=zeros(3);B=zeros(3);C=zeros(3);D=zeros(3);
% Jacobian Matrix formation
for i=2:3
for j=1:3
if i~=j
A(i,j)=Vm(i)*Vm(j)*Ym(i,j)*sin(Va(i)-Va(j)-Ya(i,j));
B(i,j)=Vm(i)*Vm(j)*Ym(i,j)*cos(Va(i)-Va(j)-Ya(i,j));
C(i,j)=-B(i,j);
D(i,j)=A(i,j);
end
end
A(i,i)=-Q(i)-((V(i)^2)*Ym(i,i)*sin(Ya(i,i)));
B(i,i)=P(i)+((V(i)^2)*Ym(i,i)*cos(Ya(i,i)));
```

```
C(i,i)=P(i)-((V(i)^2)*Ym(i,i)*cos(Ya(i,i)));
D(i,i)=Q(i)-((V(i)^2)*Ym(i,i)*sin(Ya(i,i)));
end
J=[A(2:3,2:3) B(2:3,2);C(2,2:3) D(2,2)]
V=inv(J)*[delP(2:3) delQ(2)]';
Vm=abs(V);Va=angle(V);
disp('Real Power:');

P

disp('Reactive Power:');Q
disp('Phase Angle Profile:');V(1:2)*180/pi
disp('Voltage Profile:');V(3)
```

**Output :**

```
J =
35.7304 -12.2304 2.8224
-12.2304 0 -3.0576
-8.9376 3.0576 11.2696
Real Power:
P =
0 -3.0576 6.3598
Reactive Power:
Q =
0 -12.2304 25.4176
Phase Angle Profile:
ans =
19.9296
57.1488
```

Voltage Profile:

ans =

1.1792

**RESULT**

Thus the power flow for the given problem was solved using Newton Raphson method and verified using MATLAB software.

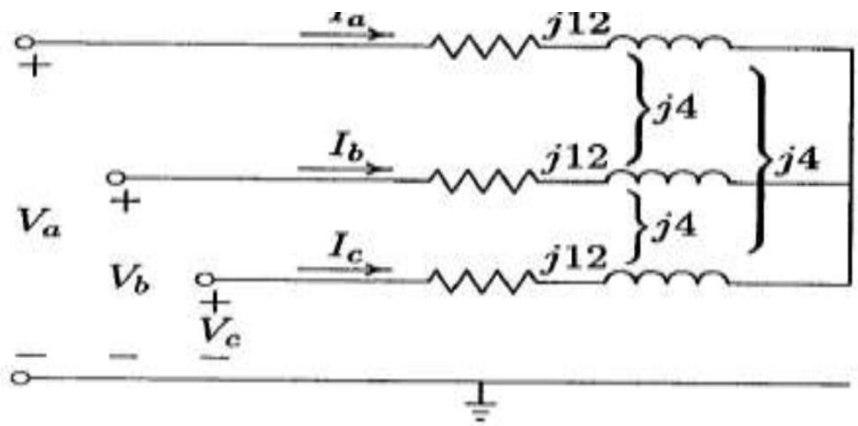
**Experiment No : 7**

**OBJECT**

Determine the Line current using Symmetrical components.

**EXERCISE**

A balance three-phase voltage of 100 volt lint to neutral. This applied to balance star connected load with underground neutral as shown in fig. the three-phase load consists of 3 mutual coupled reactance. Each has (phase) series reactance of Zs=j12ohm and mutual coupling between phases is Zm=j4ohm. Determine line current using symmetrical components.




$ZS = j * 12;$

$Zm = j * 4;$

$Va1 = 100;$

$Z012 =$ $[ZS + 2 * Zm \ 0 \ 0$

$0 \ ZS - Zm \ 0$

$0 \ 0 \ ZS - Zm];$ % symmetrical component matrix

$V012 = [0; Va1; 0];$ % symmetrical component of phase voltage

$I012 = inv(Z012) * V012;$ % symmetrical component of line current

$a = \cos(2 * pi/3) + j * \sin(2 * pi/3);$

```
A =  [1 1 1;
      1 a^2 a;
      1 a a^2] ;            % Transformation Matrix
Iabc = A * I012;            % Line current (Rectangular form)
Iabcp = rec2pol(Iabc) % Line current (Polar form)
```

**MATLAB RESULT**

Iabcp = **12. 5(−900)**

**12. 5(1500)**

**12. 5(300)**

**OBJECT**

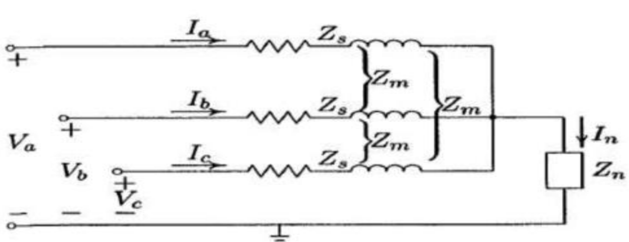
To determine the Impedance matrix, symmetrical components of voltage, current, & complex power delivered to the load in terms of symmetrical components.

**EXERCISE:**

A three-phase unbalanced source with the following phase-to-neutral voltages

$$\mathbf{V}^{abc} = \begin{bmatrix} 200 & \angle 25^\circ \\ 100 & \angle -155^\circ \\ 80 & \angle 100^\circ \end{bmatrix}$$

is applied to the circuit in figure. The load series impedance per phase is Zs=8+j24 and the mutual impedance between phases is Zm=j4. The load and source neutrals are solidly grounded.




Determine

(a) The load sequence impedance matrix Z012=A-1ZabcA

(b) The symmetrical components of voltage.

(c) The symmetrical components of current.

(d) The load phase currents.

(e) The complex power delivered to the load in terms of symmetrical components,

(f) The complex power delivered to the load by summing up the power in each pahse,

**MATLAB Program:**

```
Zabc=[8+j*24 j*4 j*4;j*4 8+j*24 j*4;j*4 j*4 8+j*24];
(i) %load sequence impedance matrix
a=cos(2*pi/3)+j*sin(2*pi/3);
P = [1 1 1; 1 a a^2; 1 a^2 a];
Q= [1 1 1; 1 a^2 a; 1 a a^2];
Z012=(1/3)*P*Zabc*Q
Vabc=[200 25;100 -155;80 100];
(ii) % Symmetrical Component of Voltage
rankfabc=length(Vabc(1,:));
if rankVabc == 2
mag= Vabc(:,1); ang=pi/180*Vabc(:,2);
Vabcr=mag.*(cos(ang)+j*sin(ang));
elseif rankVabc ==1
Vabcr=Vabc;
else
fprintf('\n Three phasors must be expressed in a one column array in rectangular complex form \n')
fprintf(' or in a two column array in polar form, with 1st column magnitude & 2nd
```

```
column \n')
fprintf(' phase angle in degree. \n')
return, end
a=cos(2*pi/3)+j*sin(2*pi/3);
A = [1 1 1; 1 a^2 a; 1 a a^2];
Va012=inv(A)*Vabcr;
symcomp= Va012
Tpol= [abs(symcomp) angle(symcomp)*180/pi]
(iii) % symmetrical components of current.
Ia012= Inv(Z012)*symcomp
(iv) % load phase currents.
rankI012=length(Ia012(1,:));
if rankI012 == 2
mag= Ia012(:,1); ang=pi/180*Ia012(:,2);
Ia012r=mag.*(cos(ang)+j*sin(ang));
elseif rankI012 ==1
Ia012r=Ia012;
else
fprintf('\n Symmetrical components must be expressed in a one column array in
rectangular complex form \n')
fprintf(' or in a two column array in polar form, with 1st column magnitude & 2nd
column \n')
fprintf(' phase angle in degree. \n')
return, end
 a=cos(2*pi/3)+j*sin(2*pi/3);
A = [1 1 1; 1 a^2 a; 1 a a^2];
Iabc= A*Ia012r;
```

Qpol= [abs(Iabc) angle(Iabc)*180/pi]

(v) % complex power delivered to the load in terms of symmetrical components

S3ph= 3*(V012.')*conj(I012)

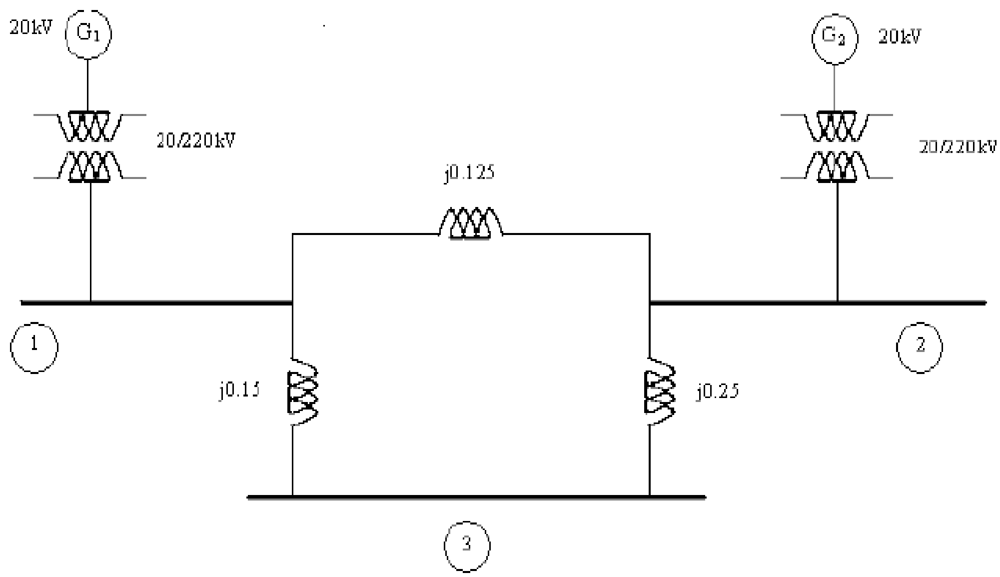
(vi) % complex power delivered to the load by summing up the power in each phsae,

S3-o=3[Va *conj( Ia )+ Va*conj Ib+ Va*conj Ic*]

```
The result is
Z012 =
        8.00 + 32.00i    0.00 +  0.00i    0.00 +  0.00i
        0.00 +  0.00i    8.00 + 20.00i    0.00 +  0.00i
        0.00 -  0.00i    0.00 -  0.00i    8.00 + 20.00i

V012p =
         47.7739      57.6268
        112.7841      -0.0331
         61.6231      45.8825

I012p =
          1.4484     -18.3369
          5.2359     -68.2317
          2.8608     -22.3161

Iabcp =
          8.7507     -47.0439
          5.2292     143.2451
          3.0280      39.0675

S3ph =
        9.0471e+002+ 2.3373e+003i

S3ph =
        9.0471e+002+ 2.3373e+003i
```

## Experiment No : 8

**EXERCISE:** The one line diagram of a simple power system is shown in figure. The neutral of each generator is grounded through a current limiting reactor of 0.25/3 per unit on a 100MVA base. The system data expressed in per unit on a common 100 MVA base is tabulated below. The generators are running on no load at their rated voltage and rated frequency with their emf in phase. Determine the fault current for balanced three phase fault at bus 3 through a fault impedance, Zf = j0.1 per unit.




| Item | Base MVA | Voltage Rating kV | $X^1$ | $X^2$ | $X^0$ |
|---|---|---|---|---|---|
| $G_1$ | 100 | 20 | 0.15 | 0.15 | 0.05 |
| $G_2$ | 100 | 20 | 0.15 | 0.15 | 0.05 |
| $T_1$ | 100 | 20/220 | 0.10 | 0.10 | 0.10 |
| $T_2$ | 100 | 20/220 | 0.10 | 0.10 | 0.10 |
| $L_{12}$ | 100 | 220 | 0.125 | 0.125 | 0.30 |
| $L_{13}$ | 100 | 220 | 0.15 | 0.15 | 0.35 |
| $L_{23}$ | 100 | 220 | 0.25 | 0.25 | 0.7125 |

**PROGRAM**

```
clc;
clear all;
Zm=[1 2 0.125 0.3
1 3 0.15 0.35
2 3 0.25 0.7125];
Zs1=[0.25 0.25 0];
Zs0=[0.4 0.4 0];
Ns=Zm( :,1); Nr=Zm( :,2) ;
Y1=zeros(3); Y0=zeros(3);
for i=1 :3
Y1(Ns(i),Nr(i))=-1/(j*Zm(i,3));
Y0(Ns(i),Nr(i))=-1/(j*Zm(i,4));
end
Y1=Y1+Y1.';Y0=Y0+Y0.';
for i=1:3
if Zs1(i)==0
Y1(i,i)=-sum(Y1(i,:));
else
Y1(i,i)=(1/(j*Zs1(i)))-sum(Y1(i,:));
end
if Zs0(i)==0
Y0(i,i)=-sum(Y0(i,:));
else
Y0(i,i)=(1/(j*Zs0(i)))-sum(Y0(i,:));
end
end
```

```
Z1=inv(Y1);Z0=inv(Y0);Z2=Z1;
Zf=0.1j;Vpf=1;Ib=100/20;
Zf1=Z1(3,3);Zf2=Z2(3,3);Zf0=Z0(3,3);
disp('Symmetrical three phase fault current:kA');
If=abs(Vpf/(Zf1+Zf))*Ib
disp('Single Line to Ground Fault Current:kA');
If=abs((3*Vpf)/(Zf1+Zf2+Zf0+Zf))*Ib
disp('Line to Line Fault Current:kA');
If=abs(-j*sqrt(3)*(Vpf/(Zf1+Zf2+Zf)))*Ib
disp('Double Line to Ground Fault Current:kA');

Ifa1=Vpf/(Zf1+(Zf2*(Zf0+(3*Zf))/(Zf2+Zf0+(3*Zf))));
Ifa0=-Ifa1*(Zf2/(Zf2+Zf0+(3*Zf)));
If=abs(3*Ifa0*Ib)
```

**OUTPUT**

Symmetrical three phase fault current:kA

If = 15.6250

Single Line to Ground Fault Current:kA

If = 15.3065

Line to Line Fault Current:kA

If = 16.0375

Double Line to Ground Fault Current:kA

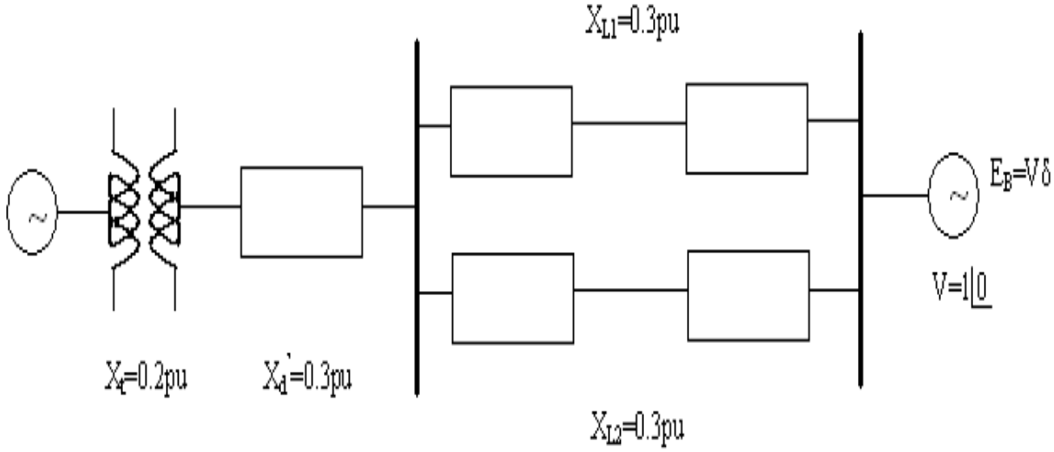
If = 8.8238

**RESULT**

Modeling and analysis of power systems under faulted condition was studied. Fault level, post-fault voltages and currents for different types of faults, for the given network under symmetric and unsymmetrical conditions were computed and verified using MATLAB Software.

## Experiment No : 9

**EXERCISE:** A 60Hz synchronous generator having inertia constant H = 5 MJ/MVA and a direct axis transient reactance Xd1 = 0.3 per unit is connected to an infinite bus through a purely reactive circuit as shown in figure. Reactances are marked on the diagram on a common system base. The generator is delivering real power Pe = 0.8 per unit and Q = 0.074 per unit to the infinite bus at a voltage of V = 1 per unit.




a) A temporary three-phase fault occurs at the sending end of the line at point F. When the fault is cleared, both lines are intact. Determine the critical clearing angle and the critical fault clearing time.

b) Verify the result using MATLAB program.

**PROGRAM**

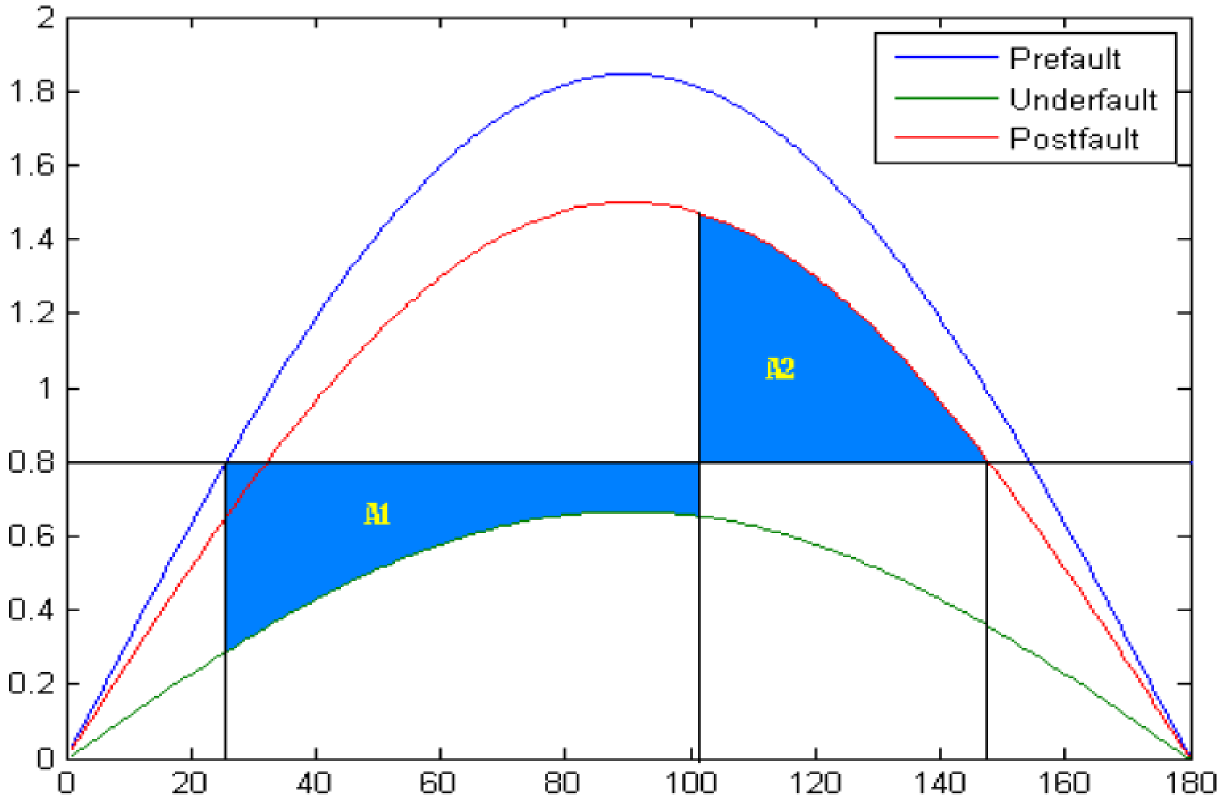
```
Pm=0.8;E=1.2;V=1;H=5;f=60;
X1=0.65;X2=1.8;X3=0.8;
Pm1=E*V/X1;
Pm2=E*V/X2;
Pm3=E*V/X3;
```

```
Do=asin(Pm/Pm1)
Dm=pi-asin(Pm/Pm3)
A1=Pm*(Dm-Do);A2=Pm3*cos(Dm); A3=Pm2*cos(Do);
Dcr=acos((A1+A2-A3)/(Pm3-Pm2))
disp('Critical Clearing Angle:');
Dcr*180/pi
disp('Critical Clearing Time:');
Tcr=sqrt((2*H*(Dcr-Do))/(pi*f*Pm))
D=1:180;Dr=D*pi/180;
P1=Pm1*sin(Dr);
P2=Pm2*sin(Dr);
P3=Pm3*sin(Dr);
Pm=0.8;
plot (D,P1,D,P2,D,P3,D,Pm);
legend('Prefault','Underfault','Postfault');
```

**OUTPUT:**

```
Do = 0.4482
Dm = 2.5791
Dcr = 1.7701
Critical clearing angle:
ans = 101.4190
Critical clearing time:
Tcr = 0.2961
```

**POWER ANGLE CURVE:**




**RESULT**

Transient and small signal stability analysis of Single-Machine-Infinite Bus (SMIB) system was

studied and simulated using simulation software.

## Experiment No : 10

**EXERCISE**

The fuel cost functions for three thermal plants in \$/h are given by

$C_1 = 500 + 5.3\, P_1 + 0.004\, P_1^2$ ; $P_1$ in MW

$C_2 = 400 + 5.5\, P_2 + 0.006\, P_2^2$ ; $P_2$ in MW

$C_3 = 200 + 5.8\, P_3 + 0.009\, P_3^2$ ; $P_3$ in MW

The total load , $P_D$ is 975MW.

**Generation limits**

$200 \leq P1 \leq 450$ MW

$150 \leq P2 \leq 350$ MW

$100 \leq P3 \leq 225$ MW

Find the optimal dispatch and the total cost in \$/h by analytical method. Verify the result using MATLAB program.

**PROGRAM**

```
disp('Without Equality Constraints');
F=	[0.004 5.3 500
	0.006 5.5 400
	0.009 5.8 200];
Pd=975;A=F(:,1);B=F(:,2);C=F(:,3);n=length(A);
I=ones(n,1);L1=B./A;L2=I./A;
Lambda=((2*Pd)+sum(L1))/(sum(L2))
P=zeros(n,1);
for i=1:n
P(i)=(Lambda-B(i))/(2*A(i));
end
```

```
P
disp('Fuel Cost:');
FC=sum((A.*P.*P)+(B.*P)+C)
disp('After equality constraints:');
F=[0.006 5.5 400
0.009 5.8 200];
Pd=975-450;A=F(:,1);B=F(:,2);C=F(:,3);n=length(A);
I=ones(n,1);L1=B./A;L2=I./A;
Lambda=((2*Pd)+sum(L1))/(sum(L2))
P=zeros(n,1);
for i=1:n
P(i)=(Lambda-B(i))/(2*A(i));
end
PN=[450;P]
FC1=sum((A.*P.*P)+(B.*P)+C);FC2=(0.004*450^2)+(5.3*450)+500;
disp('Fuel Cost:');
FC=FC1+FC2
```

**OUTPUT:**

```
Lambda = 9.1632
P =482.8947
305.2632
186.8421
Fuel Cost:
FC = 8.2280e+003
After equality constraints:
Lambda = 9.4000
```

PN =

450.0000

325.0000

200.0000

Fuel Cost:

FC = 8.2363e+003

**RESULT:**

Economic load dispatch for the given problem was solved using classical method with and without line losses and verified using MATLAB software.