20EE68– POWER SYSTEMS LAB

L	T	P	Cr.
0	0	3	1.5

B.Tech. (VI Sem.)

Pre-requisites : Electrical Power Transmission, Power Systems Analysis.

Course Educational Objective: This lab course enables the student to

- Verify the theoretical concepts of power and energy systems through experimentation and analyze the same using simulation tools

Course Outcomes: At the end of the course, the student will be able to:

CO1: Analyse transmission systems under steady state and transient conditions
CO2: Perform fault calculation and network protection
CO3: Understand the performance of renewable energy systems

LIST OF EXPERIMENTS

Cycle-I: Simulation based

1. Determination of Receiving end quantities and the line performance of a medium/long transmission line using MATLAB
2. Using MATLAB code determine:
   (i) Bus admittance matrix by inspection method for a 3-bus power system and obtain
   (ii) Power flow solution by Newton-Raphson method.
3. Determination of Sequence components (Positive, Negative and Zero) of an alternator.
4. Transient analysis of a Single Machine Infinite Bus (SMIB) system.
5. Simulation of LG, LL, LLG and LLL faults on a simple power system using PSCAD/MATLAB.
6. Determine steady state frequency error and frequency deviation response for an
   (i) Isolated power system and (ii) Interconnected power system.
7. Plot the Swing curve for a simple 3 or 4 bus power system using MATLAB / PSCAD.

Cycle-II: Experiment based

8. Plot V-I characteristics of Solar panel at various levels of insolation.
9. Study the effects of temperature and irradiance on Solar cell and plot the characteristics.
10. Study the performance of a Wind turbine system at different wind speeds and plot the characteristics.
11. Determination of Earth resistance in humid and dry earth conditions.
12. Study the Over current protection scheme using numerical relay.
13. Determination of Positive, Negative and Zero sequence reactances for a 3-phase alternator.
14. Determination of ABCD parameters and performance of a transmission line.

Note: Perform at least five experiments from each cycle.

1. DETERMINATION OF RECEIVING END QUANTITIES AND THE LINE PERFORMANCE OF A MEDIUM/LONG TRANSMISSION LINE

Expt.No:

Date:

AIM

(i) To determine the transmission parameters

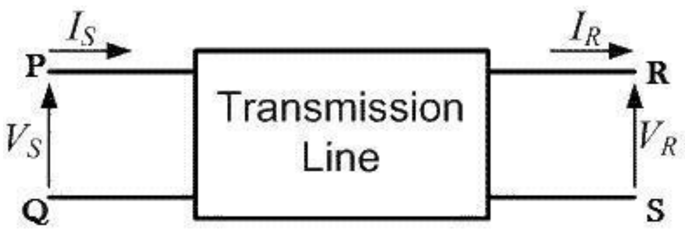
(ii) To understand modelling and performance of medium lines.

SOFTWARE REQUIRED: MATLAB 7.6

THEORY

A major section of power system engineering deals in the transmission of electrical power from one particular place (eg. Generating station) to another like substations or distribution units with maximum efficiency. So its substantial importance for power system engineers to be thorough with its mathematical modeling. Thus the entire transmission system can be simplified to a **two port network** for the sake of easier calculations.

The circuit of a 2 port network is shown in the diagram below. As the name suggests, a 2 port network consists of an input port PQ and an output port RS. Each port has 2 terminals to connect itself to the external circuit. Thus it is essentially a 2 port or a 4 terminal circuit, having



Supply end voltage = V_S

and Supply end current = I_S

Given to the input port P Q.

And there is the Receiving end Voltage = V_R and

Receiving end current = I_R

Given to the output port R S. As shown in the diagram below.

Now the **ABCD parameters** or the transmission line parameters provide the link between the supply and receiving end voltages and currents, considering the circuit elements to be linear in nature. Thus the relation between the sending and receiving end specifications are given using **ABCD parameters** by the equations below.

$V_S = A\ V_R + B\ I_R$

$I_S = C\ V_R + D\ I_R$

FORMULAE:

Single phase Inductance = $10^{-7}[1+4\log(d/r)]$

Capacitance = $3.14*8.854*10^{-12}/\log(d/r)$

Three phase Inductance = $10^{-7}[0.5+2\log(d/r)]$

Capacitance = $2*3.14*8.854*10^{-12}/\log(d/r)$

$D_{equivalent} = [d1*d2*d3]^{1/3}$

where

d = spacing of conductors

r = radius of conductors

ALGORITHM:

STEP 1: Find that the given transmission line is single phase or three phase

STEP 2: If it is single phase, get the value of distance between the conductors.

STEP 3: Get the radius of the conductor

STEP 4 : Using the appropriate formula, find inductance and capacitance.

STEP 5: If the given system is three phase, classify whether it is symmetrical or unsymmetrical

STEP 6: If symmetrical, get the distance between the conductors and radius of the

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.

EXERCISE

1. 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

```
ab=input('value of ab');
bc=input('value of bc');

ca=input('value of ca');

pr=input('receving end power in mw');

vr=input('receving end voltage in kv');

pfr=input('receving end powerfactor');

l=input('length of the line in km');

r=input('resistance/ph/km');

f=input('frequency');

D=input('diameter in m');

rad=D/2;

newrad=(0.7788*rad);

deq=(ab*bc*ca)^(1/3);

L=2*10^(-7)*log(deq/newrad);

C=(2*pi*8.854*10^-12)/log(deq/rad);
```

```
XL=2*pi*f*L*l*1000;

rnew=r*l;

Z=rnew+i*(XL);

Y=i*(2*pi*f*C*l*1000);

A=1+((Y*Z)/2);

D=A;

B=Z;

C=Y*(1+(Y*Z)/4);
vrph=(vr*10^3)/1.732;

irold=(pr*10^6)/(1.732*vr*10^3*.8);

k=sin(acos(pfr));

ir=irold*(pfr-(j*k));

vs=((A*vrph)+(B*ir));

is=((C*vrph)+(D*ir));

angle(vs);

angle(is);

f=angle(vs);

u=angle(is);

PFS=cos(f-u);

eff=((pr*10^6)/(3*abs(vs)*abs(is)*PFS))*100;

reg=(((abs(vs)/abs(A))-abs(vrph))/abs(vrph))*100;

L

C

rnew

A
```

B

C

abs(vs)

abs(is)

angle(vs)*180/pi
angle(is)*180/pi

PFS

eff

reg

RESULT:

Thus the transmission line parameters for different conductor arrangements were determined and verified with MATLAB software.

VIVA QUESTIONS:

1) What is the material used for overhead transmission lines?
2) Why does surge impedance loading (SIL) increase with increase in voltage level?
3) how the corona effect can be detected?
4) On which factors skin effect depends?
5) What are medium transmission lines?
6) What are long transmission lines?
7) What are bundled conductors?
8) Define Ferranti effect.
9) What are the parameters of transmission lines?
10) What is difference between transposed and untransposed conductors?

2. (i) DEVELOP A PROGRAM CODE TO DETERMINE THE BUS ADMITTANCE MATRIX BY INSPECTION METHOD

AIM: To developed a MATLAB program for formation of y-bus by direct inspection method.

APPARATUS:

1. MATLAB Software.

2. Personal computer.

THEORY:

The load flow solution gives the nodal voltages and the phase angle of load bus voltages, real and reactive power flow of the transmission lines, reactive power at generator bus and other variables are specified. This information is essential for continuous monitoring of the current state of the system and for analysis the effectiveness of the alternative plans for future system. Expansion to meet increase load demand. The matrix y_{bus} forms the network model for the load flow studies.

If the interconnection between the various nodes for a given system and the admittance value of each interconnecting circuit are known, then the admittance matrix is formed.

There are two methods for the formation of y_{bus}.

They are 1.Direct Inspection Method

2. Singular Transformation Method

In the direct inspection method the admittance y_{ii} where I=1,2,3,.....n is called the self admittance (or) driving point admittance of node 'i' and equals to the algebraic sum of all the admittances terminating on the node.

Each off-diagonal admittance y_{ij} for i!=j is the mutual admittance or transfer admittance between nodes i and j equals the negative of the sum of all admittance connected directly between the nodes.

In the matrix form

$$I_{bus}=Y_{bus}.V_{bus}$$

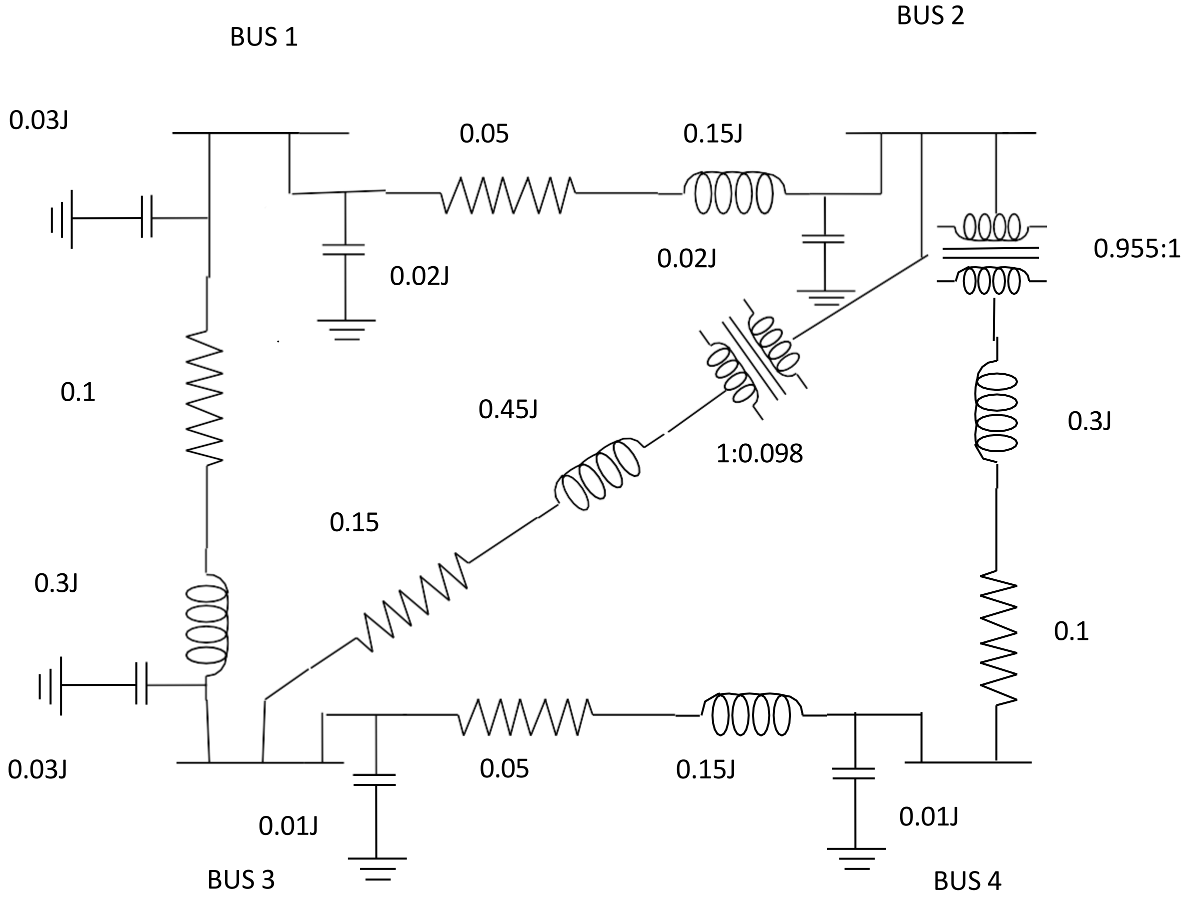
Where y_{bus} denotes the matrix of bus admittance.The dimensions of the y_{bus} matrix is (nxn) where n is the number of buses.The total number of nodes are m=n+1 including the ground node.

y_{bus} is the symmetric matrix except when phase shifting transformers are involved, so that only n(n+1)/2 terms are to be stored for n-bus system. The y_{bus} of large network is very sparse i.e., it has a large number of zero elements. Shunt admittances, are added to the diagonal elements corresponding to the nodes at which they are connected. The off-diagonal elements are unaffected.

Q) Develop a MATLAB program for formation of y-bus for the following data using direct inspection method and also determine theoretically.

Element No.	From bus	To bus	R(p.u)	X(p.u)	Turns ratio(a:1)	Charging Admittance(p.u)
1	1	2	0.05	0.15	-	J0.04
2	1	3	0.1	0.3	-	J0.06
3	2	3	0.15	0.45	0.988:1	-
4	2	4	0.1	0.3	0.957:1	-
5	3	4	0.05	0.15	-	J0.02

SINGLE LINE DIAGRAM:



THEORETICAL CALCULATIONS:

Self impedance:

Y_{11}=$y_{12} + y_{13} + \frac{y_{12}^{'}}{2} + \frac{y_{12}^{'}}{2}$

$= 2 - 6j + 1 - 3j + j0.02 + j0.03$

$= 3 - 8095j p.u$

$Y_{22} = y_{12} + \frac{y_{12}^{'}}{2} + \frac{y_{23}^{'}}{a^2} + \frac{y_{24}^{'}}{a^2}$

= 2-6j+j0.02+ $\frac{0.67-2j}{(0.988)^2} + \frac{1-3j}{(0.957)^2}$

=3.778- 11.30j $p.u.$

$Y_{33} = y_{31} + y_{34} + \frac{y_{13}^{'}}{2} + \frac{y_{34}^{'}}{a^2} + \frac{y_{32}^{'}}{a^2}$ $= 1 - 3j + 0.03j + 0.01j + 2 - 6j + \frac{0.672j}{(0.988)^2}$

$= 3.684 - 11.009j\ p.u.$

$Y_{44} = y_{43} + \frac{y_{43}^{'}}{2} + \frac{y_{42}^{'}}{a^2}$

=2-6j+0.01j+1.09-3.275j

=3.09-9.265j $p.u.$

Mutual impedance:

Y_{12}=$Y_{21} = -y_{21} = -2 + 6j\ p.u$

$Y_{13} = Y_{31} = -y_{31} = -1 + 3j\ p.u$

$Y_{14} = Y_{41} = 0\ p.u$

$Y_{23} = Y_{32} = -\frac{y_{23}^{'}}{a^2} = \frac{-0.67+2j}{(0.988)^2}$ = -0.67+2.0243j $p.u$

$Y_{24} = Y_{42} = \frac{y_{42}^{'}}{a^2} = \frac{-1+3j}{(0.957)^2}$ = -1.0449+3.1348j $p.u$

$Y_{34} = Y_{43} = -Y_{43}$ = -2+6j $p.u$

$\boldsymbol{Y_{bus}}$=[Y_{11} $\quad Y_{12} \quad Y_{13} \quad Y_{14}$

Y_{21} Y_{22} Y_{23} Y_{24}

Y_{31} Y_{32} Y_{33} Y_{34}

Y_{41} Y_{42} Y_{43} Y_{44}]

$\boldsymbol{Y_{bus}}$ = [3-8.95j -2+6j -1+3j 0

-2+6j 3.774-11.306j -0.674+2.024j -1.044+3.134j

-1+3j -0.674+2.024j 3.666-10.96j -2+6j

0 -1.044+3.134j -2+6j 0];

ALGORITHM:

1. Start

2. Enter data of Z

3. Assign all input columns to fb,tb,r,x,y_{sh} and a of Z data

4. Number of branches can be obtained by using fb length

5. Number of buses can be determined from max value of fb and tb

6. Impedance is obtained from r and x

7. Admittance can be obtained by taking inverse of Z

8. Diagonal elements can be obtained by adding all the admittance connected to a single bus considering. Shunt admittance and transformation ratio.

9. Off-diagonal elements can be obtained by making the admittance value equal to the negative of the admittance value equal to the negative of the admittances between the buses considering shunt admittance and transformation ratio.

10. Display y_{bus} matrix

11. Stop

PROGRAM:

```
clc;
clear;
ldata=[1   2   0.05  0.15   1        0.04
       1   3   0.1    0.3    1        0.06
       2   3   0.15  0.45  0.988  0
```

```
          2   4    0.1     0.3      0.957  0
          3   4    0.05  0.15  1           0.02];
fb=ldata(:,1);
tb=ldata(:,2);
r=ldata(:,3);
x=ldata(:,4);
a=ldata(:,5);
sh=ldata(:,6);
z=r+j*x;
y=1./z;
sh=j*sh;
nbranch=length(tb);
nbus=max(max(fb),max(tb));
ybus=zeros(nbus,nbus);
for k=1:nbranch
    ybus(fb(k),tb(k))=-y(k)/a(k);
    ybus(tb(k),fb(k))=ybus(fb(k),tb(k));
end
for m=1:nbus
    for n=1:nbranch
        if fb(n)==m
            ybus(m,m)=ybus(m,m)+(y(n)/a(n)^2)+(sh(n)/2);
        elseif tb(n)==m
            ybus(m,m)=ybus(m,m)+y(n)+(sh(n)/2);
        end
    end
end
fprintf('ybus=\n\n[');
disp(ybus)
fprintf('\b\b] pu');
```

OUTPUT:

Y_{bus} = [

3.0000-8.9500j	-2.0000+6.0000j	-1.0000+3.0000j	0	
-2.0000+6.0000j	3.7740-11.3060j	-0.6740+2.0240j	-1.044+3.134j	
-1.0000+3.0000j	-0.6740+2.0240j	3.666-10.9600j	-2.0000+6.0000j	
0	-1.0440+3.1340j	-2.0000+6.0000j	0	];

RESULT:

Formation of Ybus by Direct Inspection Method using Matlab is developed and also verified with theoretical values.

OBSERVATIONS:

1. Formation of y_{bus} is an easy method.

2. In this y_{bus} formation less time is enough.

3. Most of the elements are zero i.e., sparsity so it requires less memory to store non-zero elements.

4. It is also symmetric so only upper triangular matrix is enough to store it further reduces memory .

5. As it is symmetrical it requires less time of computation as $y_{mn}=y_{nm}$ i.e.,only diagonal elements and half of off-diagonal elements are calculated.y_{bus} is useful to calculate currents, generations.

VIVA QUESTIONS:

1) why the admittance matrix or y bus matrix of a large network is called sparse matrix?
2) What are the advantages of per unit system?
3) What is the need for base values?
4) What is a bus admittance matrix?
5) What is a bus impedance matrix?
6) What are the elements of y bus matrix?
7) What are the elements of Z bus matrix?
8) What is a bus?
9) What is primitive n/w?
10) What are the methods available for forming bus impedance matrix?

2.(ii) POWER FLOW SOLUTION BY USING NEWTON RAPHSON METHOD

AIM:

To develop the MATLAB program for performing the power flow solution of a given power system using Newon Raphson method

APPARATUS:

Computer with MATLAB software

THEORY:

Newton Raphson method can be applied to solve a set of non linear algebraic equations.Convergence is obtained in fewer iterations,compared to other methods irrespective of the size of the power system

The NR method is more complex and memory requirements is more.In NR method polar coordinates are used.The rectangular version is faster in convergence but slightly less reliable than the polar system version.NR method can be applied to the power flow problem in two ways,depending on the bus voltages expressed.

Static power flow equations used are

$$P_i = \sum_{k=1}^{n} |V_i|\,|V_K||Y_{ik}|\cos(\theta_{ik} + \delta_k - \delta_i)$$

$$Q_i = \sum_{k=1}^{n} |V_i|\,|V_K||Y_{ik}|\cos(\theta_{ik} + \delta_k - \delta_i)$$

The equations P_I and Q_I at each bus in an n bus power system are functions of n bus voltages magnitudes $|V|$ and another ‘n’ number of phase angles $'\delta$’

P_i=$f_1(\delta, |v|)$

Q_i=$f_2(\delta, |v|)$

Where change in P and Q are given by

$\begin{bmatrix}\Delta P\\ \Delta Q\end{bmatrix}$=$\begin{bmatrix}J_1 & J_2\\ J_3 & J_4\end{bmatrix}\begin{bmatrix}\Delta\delta\\ \Delta V\end{bmatrix}$

Jacobian matrix J=$\begin{bmatrix}J_1 & J_2\\ J_3 & J_4\end{bmatrix}$

Diagonal elements of J_1 is given by

$$\frac{\partial p_i}{\partial \delta_i} = \sum_{\substack{k=1 \\ \neq i}}^{n} |V_i V_k Y_{ik}| \sin(\theta_{ik} + \delta_k - \delta_i)$$

Off Daigonal elements of J_1 is given by

$$\frac{\partial p_i}{\partial \delta_k} = -|V_i V_k Y_{ik}| \sin(\theta_{ik} + \delta_k - \delta_i)$$

Diagonal elements ofJ_2 is given by

$$\frac{\partial p_i}{\partial |V_i|} = 2|V_i Y_{ii}| \cos(\theta_{ii}) + \sum_{\substack{k=1 \\ \neq i}}^{n} |V_k Y_{ik}| \cos(\theta_{ik} + \delta_k - \delta_i)$$

Off Diagonal elements ofJ_2 is given by

$$\frac{\partial p_i}{\partial |V_k|} = |V_i Y_{ik}| \cos(\theta_{ik} + \delta_k - \delta_i)$$

Diagonal elements ofJ_3 is given by

$$\frac{\partial Q_i}{\partial \delta_i} = \sum_{\substack{k=1 \\ \neq i}}^{n} |V_i V_k Y_{ik}| \cos(\theta_{ik} + \delta_k - \delta_i)$$

Off Diagonal elements ofJ_3 is given by

$$\frac{\partial Q_i}{\partial \delta_k} = -|V_i V_k Y_{ik}| \cos(\theta_{ik} + \delta_k - \delta_i)$$

Diagonal elements ofJ_4 is given by

$$\frac{\partial Q_i}{\partial |V_i|} = 2|V_i Y_{ii}| \sin \theta_{ii} + \sum_{\substack{k=1 \\ \neq i}}^{n} |V_k Y_{ik}| \sin(\theta_{ik} + \delta_k - \delta_i)$$

Off Diagonal elements ofJ_4 is given by

$$\frac{\partial Q_i}{\partial |V_k|} = |V_i Y_{ik}| \sin(\theta_{ik} + \delta_k - \delta_i)$$

Change in δ and $|V|$ can be calculated as

$$\begin{bmatrix} \Delta\delta \\ \Delta V \end{bmatrix} = J^{-1} \begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix}$$

3. Determine the Voltage Magnitude and for the following data of a power system by using Newton Raphson method after the convergence.

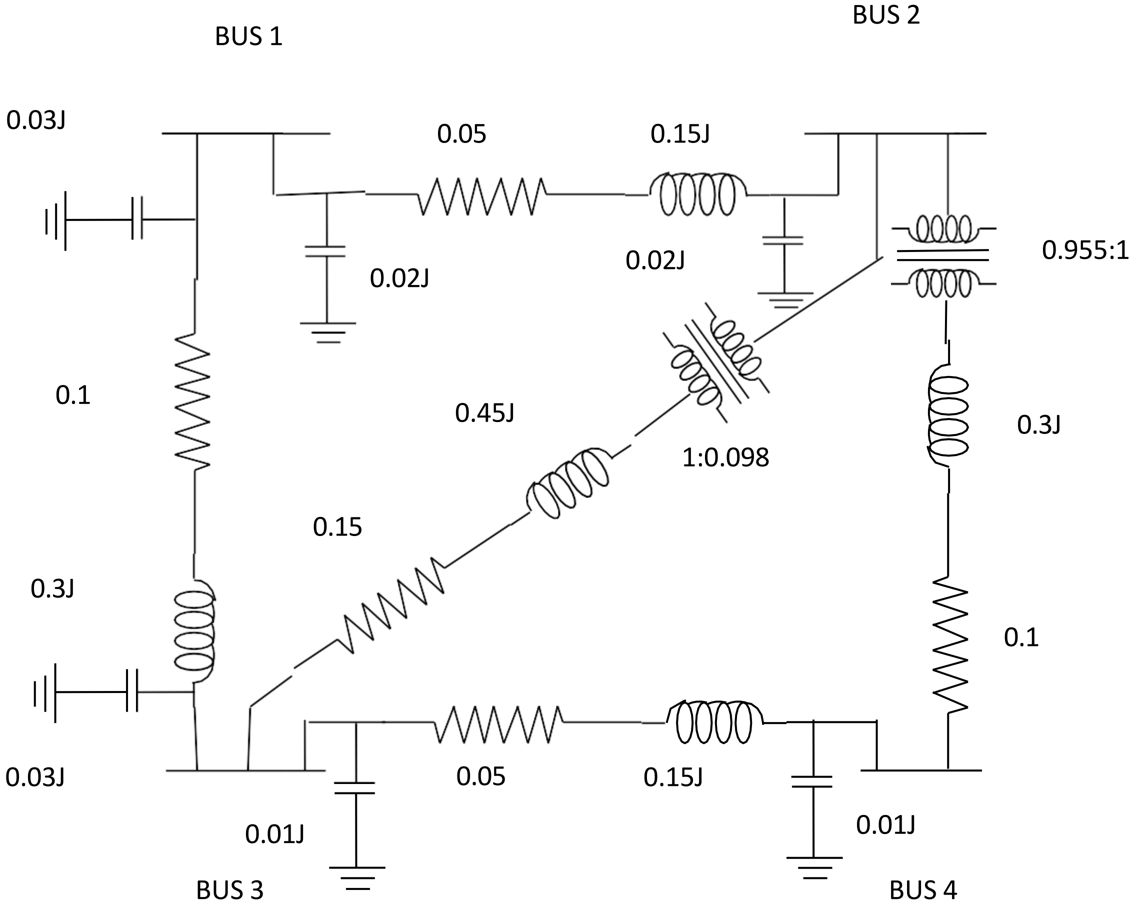
LINE DATA:

ELEMENT NO	FROM BUS	TO BUS	R(PU)	X(PU)	TURNS RATIO(a:1)	CHARGING ADMITTANCE(PU)
1	1	2	0.045	0.13	1:1	0.04
2	1	3	0.2	0.32	1:1	0.03
3	2	3	0.15	0.45	1:0.945	0
4	2	4	0.2	0.32	1:0.986	0
5	3	4	0.045	0.13	1:1	0.015

BUS DATA:

BUS NO	TYPE	V_I (PU)	DELTA(deg)	P(PU)	Q(PU)
1	0	1.05	0	-	-
2	1	-	-	0.45	0.22
3	1	-	-	-0.98	0.4
4	1	-	-	0.32	-0.15

LINE DIAGRAM:



THEORETICAL CALCULATION:

Power flow equations:

$$P_i = \sum_{k=1}^{n} |V_i|\,|V_K|\,|Y_{ik}| \cos(\theta_{ik} + \delta_k - \delta_i)$$

P_2 =-0.0428pu

P_3 =-0.0204pu

P_4=-0.0430pu

$$Q_i = \sum_{k=1}^{n} |V_i|\,|V_K|\,|Y_{ik}| \cos(\theta_{ik} + \delta_k - \delta_i)$$

Q_2 =0.1459PU

Q_3 =0.0708PU

Q_4 =0.14482PU

power residuals:

$\Delta P_2 = P_{2(spe)} - P_{2(cal)}$=0.4928PU

$\Delta P_3 = P_{3(spe)} - P_{3(cal)}$ =-0.9596PU

$\Delta P_4 = P_{4(spe)} - P_{4(cal)}$ =0.3630PU

$\Delta Q_2 = Q_{2(spe)} - Q_{2(cal)} = 0.3654PU$

$\Delta Q_3 = Q_{3(spe)} - Q_{3(cal)}$ =-0.4708PU

$\Delta Q_4 = Q_{4(spe)} - Q_{4(cal)}$ =0.0047PU

JACOBIAN MATRIX:

Diagonal Elements of J1:

$$\frac{\partial p_i}{\partial \delta_i} = \sum_{\substack{k=1\\ \neq i}}^{n} |V_i V_k Y_{ik}| \sin(\theta_{ik} + \delta_k - \delta_i)$$

$\frac{\partial p_2}{\partial \delta_2}$ =11.1657pu

$\frac{\partial p_3}{\partial \delta_3}$ =11.174pu

$\frac{\partial p_4}{\partial \delta_4} = 9.1447pu$

Off diagonal elements of J1:

$$\frac{\partial p_i}{\partial \delta_k} = -|V_i V_k Y_{ik}| \sin(\theta_{ik} + \delta_k - \delta_i)$$

$\frac{\partial p_2}{\partial \delta_3}$ =-2.0243pu

$\frac{\partial p_3}{\partial \delta_2}$ =-2.0243pu

$\frac{\partial p_2}{\partial \delta_4}$ =-3.1348pu

$\frac{\partial p_4}{\partial \delta_2}$ =-3.1348pu

$\frac{\partial p_4}{\partial \delta_3}$ =-6pu

$\frac{\partial p_3}{\partial \delta_4}$ =-6pu

Diagonal elements of J2:

$$\frac{\partial p_i}{\partial |V_i|} = 2|V_i Y_{ii}| \cos(\theta_{ii}) + \sum_{\substack{k=1 \\ \neq i}}^{n} |V_k Y_{ik}| \cos(\theta_{ik} + \delta_k - \delta_i)$$

$\frac{\partial p_1}{\partial V_1}$=3.7288pu

$\frac{\partial p_2}{\partial V_2}$=3.6086pu

$\frac{\partial p_3}{\partial V_3}$=2.9551pu

Off diagonal elements of J2:

$$\frac{\partial p_i}{\partial |V_k|} = |V_i Y_{ik}| \cos(\theta_{ik} + \delta_k - \delta_i)$$

$\frac{\partial p_2}{\partial |V_3|}$ =-0.6748pu

$\frac{\partial p_2}{\partial |V_4|}$ =-1.0449pu

$\frac{\partial p_3}{\partial |V_2|}$ =-0.6748pu

$\frac{\partial p_2}{\partial |V_4|}$ =-1.0499pu

$\frac{\partial p_3}{\partial |V_4|}$ =-2pu

$\frac{\partial p_4}{\partial |V_3|}$ =-2pu

Diagonal elements in J3:

$$\frac{\partial Q_i}{\partial \delta_i} = \sum_{\substack{k=1 \\ \neq i}}^{n} |V_i V_k Y_{ik}| \cos(\theta_{ik} + \delta_k - \delta_i)$$

$\frac{\partial Q_2}{\partial \delta_2}$ =-3.8197pu

$\frac{\partial Q_3}{\partial \delta_3}$ =-3.7248pu

$\frac{\partial Q_4}{\partial \delta_4}$ =-3.0499pu

Off diagonal elements in J3:

$$\frac{\partial Q_i}{\partial \delta_k} = -|V_i V_k Y_{ik}| \cos(\theta_{ik} + \delta_k - \delta_i)$$

$\frac{\partial Q_2}{\partial \delta_3}$ =0.6748pu

$\frac{\partial Q_2}{\partial \delta_4}$ =1.0499pu

$\frac{\partial Q_3}{\partial \delta_2}$ =0.6748pu

$\frac{\partial Q_4}{\partial \delta_2}$ =1.0499pu

$\frac{\partial Q_4}{\partial \delta_3}$ =2pu

$\frac{\partial Q_3}{\partial \delta_4}$ =2pu

Diagonal elements in J4:

$$\frac{\partial Q_i}{\partial |V_i|} = 2|V_i Y_{ii}| \sin \theta_{ii} + \sum_{\substack{k=1 \\ \neq i}}^{n} |V_k Y_{ik}| \sin(\theta_{ik} + \delta_k - \delta_i)$$

$\frac{\partial Q_2}{\partial |V_2|}$ =11.15pu

$\frac{\partial Q_3}{\partial |V_3|}$ =10.747pu

$\frac{\partial Q_4}{\partial |V_4|}$ =8.849pu

Off diagonal elements in J4:

$$\frac{\partial Q_i}{\partial |V_k|} = |V_i Y_{ik}| \sin(\theta_{ik} + \delta_k - \delta_i)$$

$\frac{\partial Q_2}{\partial |V_3|}$=-2.023pu

$\frac{\partial Q_2}{\partial |V_4|}$=-3.1296pu

$\frac{\partial Q_3}{\partial |V_2|}$=-2.023pu

$\frac{\partial Q_4}{\partial |V_2|}$=-3.1296pu

$\frac{\partial Q_3}{\partial |V_4|}$=-5.99pu

$\frac{\partial Q_4}{\partial |V_3|}$=-5.99pu

JACOBIAN MATRIX:

$$J= \begin{bmatrix} 11.4657 & -2.0243 & -3.1348 & 3.7288 & -0.6748 & -1.0449 \\ -2.0243 & 11.174 & -6 & -0.6748 & 3.6086 & -2 \\ -3.1348 & -6 & 9.1447 & -1.0499 & -2 & 2.9551 \\ -3.1897 & 0.67481 & 1.04991 & 11.150 & -2.0231 & -3.1296 \\ 0.6748 & -3.7248 & 2 & -2.023 & 10.747 & -5.99 \\ 1.0499 & 2 & -3.0499 & -3.1296 & -5.99 & 8.849 \end{bmatrix}$$

$$\begin{bmatrix} \Delta\delta_2 \\ \Delta\delta_3 \\ \Delta\delta_4 \\ \Delta V_2 \\ \Delta V_3 \\ \Delta V_4 \end{bmatrix} = J^{-1} \begin{bmatrix} \Delta P_2 \\ \Delta P_3 \\ \Delta P_4 \\ \Delta Q_2 \\ \Delta Q_3 \\ \Delta Q_4 \end{bmatrix} = \begin{bmatrix} 0.0007 \\ -0.1088 \\ -0.0357 \\ 0.0829 \\ 0.0816 \\ 0.0975 \end{bmatrix}$$

ALGORITHM:

1. Read line data and bus data of the given power system

2. Use line data to form Ybus.

3. Use the flat start for given values of bus voltage magnitude and phase angles.

Set $V_i^{(0)} = 1PU$ for i=1,2,3….,n and $\delta_i = 0$

4. claculate p_i(for the buses i=1,2,3)by using equation.

$$P_i = \sum_{k=1}^{n} |V_i|\,|V_K||Y_{ik}|\cos(\theta_{ik} + \delta_k - \delta_i)$$

$$Q_i = \sum_{k=1}^{n} |V_i|\,|V_K||Y_{ik}|\cos(\theta_{ik} + \delta_k - \delta_i)$$

5. check $Q_i^{min} \leq Q_i \leq Q_i^{max}$ for PV buses.If Q_i is with in the limits go to step 6 else set Q_i $=Q_i^{min}$ or Q_i^{max} as the case end treat this i^{th} bus as PQ bus.Re-designate the bus numbers and return to step 1.

6. calculate power mismatches for every iterations

$$\Delta P_i^{\gamma} = P_i(specified) - P_i(calculated)$$

$$\Delta Q_i^{\gamma} = Q_i(specified) - Q_i(calculated)$$

7. calculate the elements of the jaobian matrix.

8. calculate the increment matrix as

$$\begin{bmatrix} \Delta\delta \\ \Delta|V| \end{bmatrix}^{\gamma} = J^{-1} \begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix}^{\gamma}$$

9. update voltage magnitudes and phase angles using the increments as

$$|V|^{\gamma+1} = |V|^{\gamma} + \Delta|V|^{\gamma}$$

$$\delta^{\gamma+1} = \delta^{\gamma} + \Delta\delta^{\gamma}$$

10. check convergence

$$\Delta V_i = |V_i|^{\gamma+1} - \Delta|V_i|^{\gamma} \leq \epsilon$$

$$\Delta\delta_i = \delta_i^{\gamma+1} - \delta_i^{\gamma} \leq \epsilon$$

'ϵ' is error specified. If all convergence conditions are satisfied then goto step 11,otherwise go to step 3 and start the next iteration

11. Using the specified and converged values of bus voltages and phase angles.Calculate the injected power for the slack bus,and the injected reactive powers.

12. Stop

PROGRAM:

```
Clc;
Clear;
y=    [3-8.95*1j -2+6*1j          -1+3*1j           0
      -2+6*1j     3.774-11.306*1j -0.674+2.024*1j  -1.044+3.134*1j
      -1+3*1j    -0.674+2.024*1j   3.666-10.96*1j  -2+6*1j
       0         -1.044+3.134*1j   -2+6*1j           3-8.99*1j];
ymag=abs(y);
theta=angle(y);
busdata=[1 1.05 0 0 0
          2 1 0 0.45 0.22
          3 1 0 -0.98 0.4
          4 1 0 0.32 -0.15];
busno=busdata(:,1);
vmag=busdata(:,2);
delta=busdata(:,3);
psp=busdata(:,4);
qsp=busdata(:,5);
nbus=max(busno);
vmagnew=vmag;
deltanew=delta;
iteration=0;
tolerance=2;
while(tolerance>0.0001)
pcal=zeros(nbus,1);
qcal=zeros(nbus,1);
for i=1:nbus
for k=1:nbus
pcal(i)=pcal(i)+vmag(i)*ymag(i,k)*vmag(k)*cos(theta(i,k)-delta(i)+delta(k));
qcal(i)=qcal(i)-vmag(i)*ymag(i,k)*vmag(k)*sin(theta(i,k)-delta(i)+delta(k));
end
end
dpa=psp-pcal;
dqa=qsp-qcal;
m=[dpa(2:nbus);dqa(2:nbus)];
tolerance=max(abs(m));
%J1 formulation
J1=zeros(nbus-1,nbus-1);
for i=2:nbus
for k=2:nbus
if(i==k)
```

```
for b=1:nbus
J1(i-1,k-1)=J1(i-1,k-1)+(vmag(i)*ymag(i,b)*vmag(b)*sin(theta(i,b)-delta(i)+delta(b)));
end
J1(i-1,k-1)=J1(i-1,k-1)-(vmag(i)^2*ymag(i,i)*sin(theta(i,i)));
else
J1(i-1,k-1)=J1(i-1,k-1)-vmag(i)*ymag(i,k)*vmag(k)*sin(theta(i,k)-delta(i)+delta(k));
end
end
end
%J2 formulation
J2=zeros(nbus-1,nbus-1);
for i=2:nbus
for k=2:nbus
if(i==k)
for b=1:nbus
J2(i-1,k-1)=J2(i-1,k-1)+vmag(b)*ymag(i,b)*cos(theta(i,b)-delta(i)+delta(b));
end
J2(i-1,k-1)=J2(i-1,k-1)+vmag(i)*ymag(i,i)*cos(theta(i,i));
else
J2(i-1,k-1)=J2(i-1,k-1)+vmag(i)*ymag(i,k)*cos(theta(i,k)-delta(i)+delta(k));
end
end
end
%J3 formulation
J3=zeros(nbus-1,nbus-1);
for i=2:nbus
for K=2:nbus
if(i==K)
for b=1:nbus
J3(i-1,K-1)=J3(i-1,K-1)+vmag(i)*ymag(i,b)*vmag(b)*cos(theta(i,b)-delta(i)+delta(b));
end
J3(i-1,K-1)=J3(i-1,K-1)-vmag(i)*vmag(K)*ymag(i,K)*cos(theta(i,K)-delta(i)+delta(K));
else
J3(i-1,K-1)=J3(i-1,K-1)-vmag(i)*ymag(i,K)*vmag(K)*cos(theta(i,K)-delta(i)+delta(K));
end
end
end
%J4 formulation
J4=zeros(nbus-1,nbus-1);
for i=2:nbus
for k=2:nbus
if(i==k)
for b=1:nbus
J4(i-1,k-1)=J4(i-1,k-1)-vmag(i)*ymag(i,b)*sin(theta(i,b)-delta(i)+delta(b));
end
J4(i-1,k-1)=J4(i-1,k-1)-vmag(i)*ymag(i,i)*sin(theta(i,i));
else
J4(i-1,k-1)=J4(i-1,k-1)-vmag(i)*ymag(i,k)*sin(theta(i,k)-delta(i)+delta(k));
end
end
end
        J=[J1 J2
           J3 J4]
        x=inv(J)*m;
```

```
deldelta=x(1:nbus-1);
delvmag=x(nbus:end);
vmagnew(2:nbus)=vmagnew(2:nbus)+delvmag;
deltanew(2:nbus)=deltanew(2:nbus)+deldelta;
delta=deltanew;
vmag=vmagnew;
iteration=iteration+1;
if(iteration==1)
iteration
vmag
fprintf('\b\b(pu)\n');
delta
fprintf('\b\b(radians)\n');
end
end
iteration
vmag
fprintf('\b\b(pu)\n');
delta
fprintf('\b\b(radians)\n');
```

OUTPUT:

```
J =

   11.4580   -2.0240   -3.1340    3.7300   -0.6740   -1.0440
   -2.0240   11.1740   -6.0000   -0.6740    3.6080   -2.0000
   -3.1340   -6.0000    9.1340   -1.0440   -2.0000    2.9560
   -3.8180    0.6740    1.0440   11.4540   -2.0240   -3.1340
    0.6740   -3.7240    2.0000   -2.0240   10.8960   -6.0000
    1.0440    2.0000   -3.0440   -3.1340   -6.0000    8.8460
```

```
iteration =
```

1

vmag =

1.0500
1.0937
1.1078
1.1180(pu)

delta =

0
0.0005
-0.1098
-0.0360(radians)

J =

13.2951	-2.5273	-3.8763	4.6241	-0.4891	-1.0162
-2.3476	12.9173	-7.2286	-0.9888	3.0328	-2.6997
-3.7832	-7.5939	11.3771	-1.2941	-1.7354	3.7227
-3.9716	0.5419	1.1361	12.4195	-2.2814	-3.4671
1.0815	-5.6384	3.0183	-2.1464	12.4893	-6.4654
1.4154	1.9225	-3.3379	-3.4591	-6.8548	9.7884

J =

13.0551	-2.4591	-3.7755	4.5061	-0.5174	-1.0196

```
   -2.3067   12.6576   -7.0414   -0.9435    3.1009   -2.5911
   -3.6940   -7.3439   11.0379   -1.2610   -1.7808    3.5943
   -3.9792    0.5648    1.1219   12.3213   -2.2528   -3.4310
    1.0223   -5.3513    2.8513   -2.1289   12.2473   -6.3989
    1.3663    1.9438   -3.3102   -3.4093   -6.7279    9.6482
```

J =

```
   13.0587   -2.4599   -3.7775    4.5053   -0.5182   -1.0195
   -2.3080   12.6647   -7.0464   -0.9430    3.1050   -2.5892
   -3.6958   -7.3472   11.0431   -1.2617   -1.7840    3.5930
   -3.9825    0.5657    1.1222   12.3242   -2.2531   -3.4317
    1.0220   -5.3500    2.8501   -2.1297   12.2487   -6.4014
    1.3673    1.9477   -3.3151   -3.4103   -6.7294    9.6521
```

iteration =

     4

vmag =

    1.0500
    1.0837
    1.0918
    1.1008(pu)

delta =

0

-0.0027

-0.0981

-0.0355(radians)

RESULT:

For a given power system using Newton Raphson method convergence is obtained both theoretically and practically.

COMMENTS:

1. For the given the power system 1st iteration values are calculated theoretically.
2. Bymatlabcode,the values of 1st iteration have been checked and also convergence is checked.
3. The number of iterations are very less and convergence obtained is fast.

VIVA QUESTIONS:

1) What is the need for load flow study?
2) What are the different types of buses?
3) Define voltage controlled bus?
4) What is a PQ bus?
5) What is the need for slack bus?
6) What is the need for load flow study?
7) What is swing bus?
8) What are the advantages of GS method?
9) What are the disadvantages of NR method?
10) What are the advantages of NR method?

3. TRANSIENT ANALYSIS OF A SINGLE MACHINE INFINITE BUS SYSTEM.

Aim:

To obtain the transient stability analysis using equal area criteria.

Apparatus:

1. Personal computer.
2. MATLAB software

.

Theory:

The transient studies determination of whether or synchronism is maintained after the machine has been subjected to severe disturbance this may be sudden application of load,loss of generation,loss of load or a fault on the system.In amount disturbance oscillation are of such amplitude that linearization is not permissible and non-linear swing equation must be solved.

A method known as equal area criterion can be used for a quick prediction of stability.This method is based in the graphical interpretation of the energy stored in the rotating mass as an aid to determine if the machine maintains it's stability after a disturbance.

Consider a synchronous machine connected to an infinite bus,the swing equation with damping neglected is given by,

$$\frac{H}{\Pi fo}\frac{\partial^2\delta}{\partial t^2} = P_m - P_o = P_a$$

Where P_a is acceleration power from above equation

we have, $\frac{\partial^2\delta}{\partial t^2} = \frac{\Pi fo}{H}(P_m - P_o)$

Multiplying both sides of above equation by $\frac{2d\delta}{dt}$,we get

$$\frac{2d\delta}{dt} * \frac{\partial^2\delta}{\partial t^2} = \frac{2\Pi fo}{H}(P_m - P_o)\frac{d\delta}{dt}$$

$$\left(\frac{d\delta}{dt}\right)^2 = \frac{2\Pi fo}{H}\int_{\delta o}^{\delta}(Pm - Po)\ d\delta$$

$$\frac{d\delta}{dt} = \sqrt{\frac{2\Pi fo}{H}\int_{\delta o}^{\delta}(Pm - Po)\ d\delta}$$

For stability,the speed must become zero at simulation the disturbance

$$\int_{\delta o}^{\delta}(Pm - Po)\ d\delta = 0$$

$P_m > P_o$ =>The accelerating power of the rotor is positive and power angle increases.The excess energy stored in rotor during the initial acceleration is

$$\int_{\delta o}^{\delta}(Pm - Po)\ d\delta = \text{area abc} = \text{Area } A_1$$

$P_m < P_o$ Causing the order to accelerate towards synchronous speed until $\delta = \delta_{maz}$

$$\int_{\delta 1}^{\delta max} (Pm - Po)\ d\delta = \text{areabde= Area } A_2$$

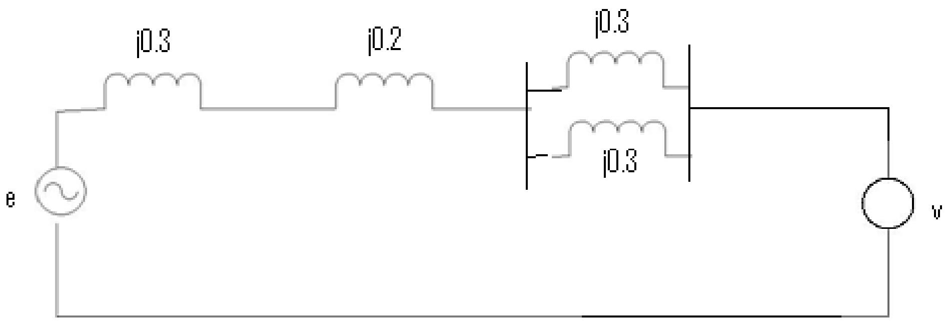
$$|area\ A_1| = |area\ A_2|$$

This is known as equal area criteria.

The current flowing through infinite bus is given by

I=S*/V*=0.8-j0.074/1=0.8-0.074jpu

Before fault



Transfer reactance between internal voltage and infinite bus is given by

$X1=0.3+0.2+\frac{0.3*3}{0.+0.3}=0.65pu$

The transient internal voltage is $E^{|}$=v+j*x=1+0.65j*(0.8-0.074j)

=1.048+0.52j

= 1.17< 26.38pu

$p_e=p_{emax1}\sin\delta_0=\frac{EV}{X1}\sin\delta_0=\frac{1.171*1}{0.65}\sin\delta_0=1.8\sin\delta_0$

Internal operating angle,so

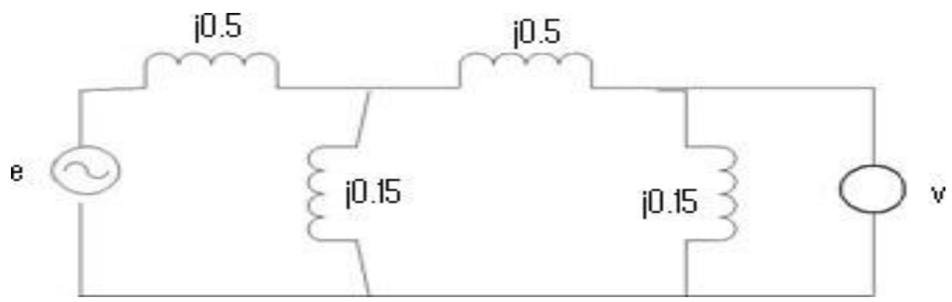
$\text{Sin}\delta_0 = \frac{0.8}{1.8} = 0.4$

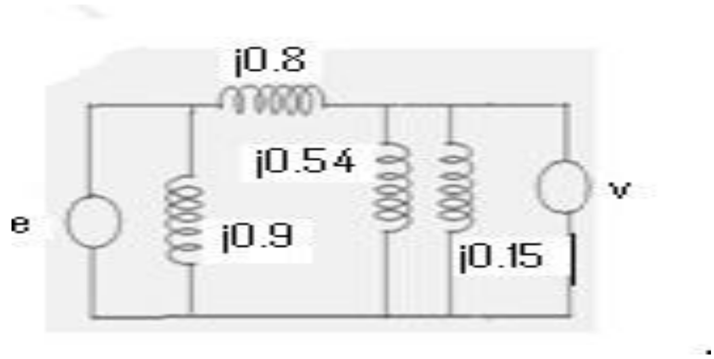
δ_0=26.07deg

=0.4605rad

During fault

Fault occurs at middle of the line





X_2=X_d+X_t+X_{l1}+ $\frac{(X_d+X_t)*X_{l1}}{\frac{X_{l2}}{2}}$

=0.3j+0.2j+0.3j+$\frac{0.5j*0.3j}{0.15j}$

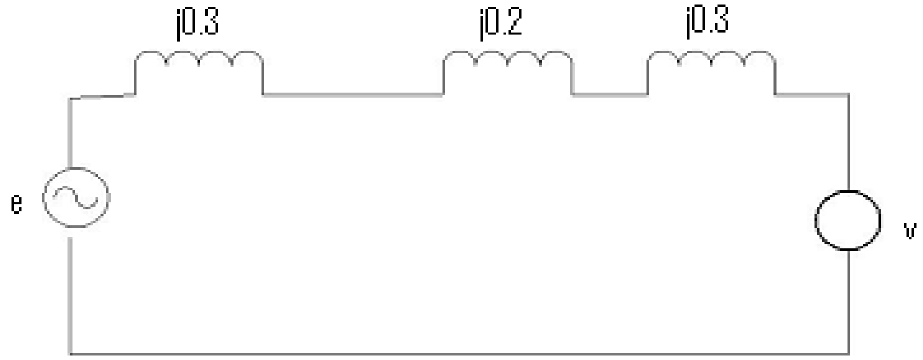
=0.8j+0.1j

=1.8jpu

Power flow after fault,p_{e2}=p_{m2} Sinδ=EVSinδ/x= $\frac{1.71*1}{1.8}$ Sinδ

=0.65Sinδ

AFTER FAULT:



X_3=0.3j+0.2j+0.3j=0.8jp.u

Power flow after fault $p_{e3}=\frac{EV}{X1}\sin\delta$=(1.17*1/0.8)Sin$\delta$=1.4625Sin δ

δ_{max}=180-$\sin^{-1}(\frac{P_m}{P_{m3}})$

=180-$\sin^{-1}(\frac{0.8}{1.4625})$=146.838deg=2.5628rad

Apply equal area criterion

$\int_{\delta_0}^{\delta_{cr}}(p_m\text{-}p_{m2}*\text{Sin}\delta)d\delta+\int_{\delta_{cr}}^{E_{max}}(p_m\text{-}p_{m3}*\text{Sin}\delta)\,d\delta$

$\cos\delta_{cr}=\frac{p_m(\delta_{max}-\delta_0)+p_{m3}\cos\delta_{max}-p_{m2}\cos\delta_0}{p_{m3}-p_{m2}}$ = -0.15355

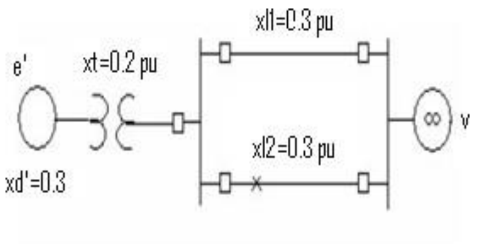
critical clearing angle

$\delta_{cr}=98.833deg$

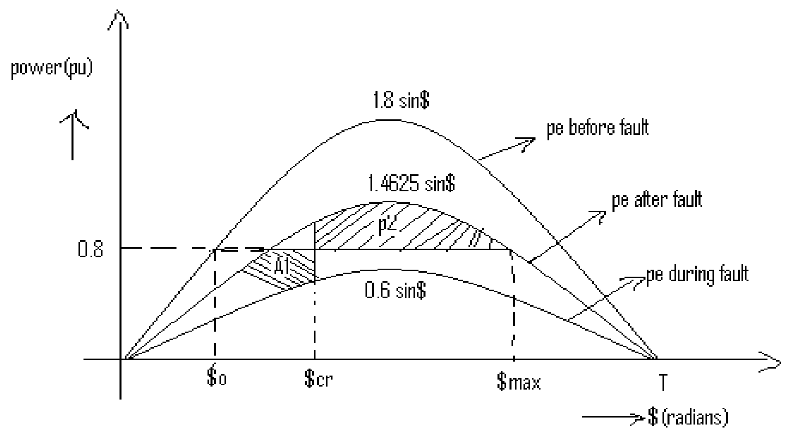
Critical clearing time

$t_c=\sqrt{\frac{2H*(\delta_C-\delta_0)}{\pi*F*p_m}}$ =0.289sec

Q) A 50 Hz synchronous generator having inertial constant H=5MJ/MVA and a direct axis reactor x_d=0.3 p.u is connected to an infinite bus through a purely reactive circuit. Reactances are marked on the diagram on a common system base. The generator is delivering real power P_e=0.8 p.u. to and Q=0.074 p.u. to the infinite bus at a voltage of 1.0 p.u. A 3 phase fault occurs at the middle of the lines, the fault is cleared and the faulted line is isolated. Determine the critical clearing angle and corresponding time.



Model Graph:



ALGORITHM:

1. Start the program.
2. Initialize the values of P_L,Q_L,V,H,f_o,X_{L11},X_{L2},X_d and X_t.
3. Calculate the complex power and current flowing in infinite bus.
4. Calculate the transient internal voltage by using the formula $E^l = V+jX_lI$.
5. Calculate the transfer reactance between internal voltage and infinite bus before fault.
6. Evaluate initial operating angle by using power angle equation$P_e=P_{max}\sin\delta$

   Where $P_{max}=\frac{EV}{X}$.

7. Calculate the δ_{max}byusing$\delta_{max}= \prod - \delta_o$.
8. Then calculate by using equal area criteria and critical clearing time$t_c=\sqrt{\frac{2H(\delta-\delta o)}{\prod foPm}}$.
9. Repeat the above step 5,6 during fault.
10. Repeat the step 5,6&7post fault condition.
11. Stop.

PROGRAM:

```
clc;
clear;
P=0.8;
xt=0.2;
Pe=P;
Q=0.074;
V=1; N=5;
F0=60;
S=P-1i*Q;
I=S/V;
xd1=0.3;
x11=0.3;
x12=0.3;
x1=xd1+xt+((x11*x12)/(x11+x12))
fprintf('\b\b\t(p.u)\n');
e=V+1i*x1*I;
E=abs(e);
Ean=(180/pi)*angle(e);
p1max=(E*V)/x1;
```

```
pm=0.8;
x2=xd1+xt+x11+((xd1+xt)*(x11)/(x12/2))
fprintf('\b\b\t(p.u)\n');
p2max=(E*V)/x2;
x3=xd1+xt+x11
fprintf('\b\b\t(p.u)\n');
p3max=(E*V)/x3
do=asind(Pe/p1max);
D0=asin(Pe/p1max);
dmax1=180-asind(pm/p3max);
Dmax1=(pi/180)*dmax1;
dc1=acosd((1/(p3max-p2max))*(pm*(Dmax1-D0)+p3max*cosd(dmax1)-p2max*cosd(do)))
fprintf('\b\b\t(p.u)\n');
Dc1=(pi/180)*dc1;
tc=sqrt((2*H*(Dc1-D0))/(pi*fo*(pm-p2max)*sin(dc1))); de1=[0:0.1:180];
D=del*(pi/180);
Plot(d,p1max*sin(d),d,p2max*sin(d),d,p3max*sin(d))
x1label('Delta(radians)')
ylabel('power(p.u)')
```

OUTPUT:

```
x1=
    0.6500 (p.u)
x2=
    1.800 (p.u)
x3=
    0.800 (p.u)
dcl=
    98.8340 (degrees)
>>
```

RESULT:

Hence analysis of transient stability using equal area criterion is done theoretically and practically.

OBSERVATIONS:

1. When system losses stability so must be greater than .
2. Transient stability can be improved by
   i. Increase of system voltage by use of VAR.
   ii. Use of high speed excitation system.
   iii. Reduction on transfer reactance.
   iv. Use of high speed reclosing breakers.

VIVA QUESTIONS:

1) Define transient stability
2) Define stability
3) Define steady state stability
4) Define swing curve? What is the use of swing curve.
5) What is steady state stability limit?
6) Define equal area criterion.
7) What is transient stability limit?
8) What is transient state stability limit?
9) Define power angle.
10) Define critical clearing time and critical clearing angle .

4. Simulation of LG, LL, LLG and LLL faults on a simple power system using PSCAD/MATLAB.

AIM:

To develop a MATLAB program for obtaining the fault current and voltages of a given power system for the occurrence of symmetrical fault

APPARUTUS:

Computer with MATLAB software

THEORY :

That fault on the power system which gives rise to symmetrical fault currents (i.e. equal fault currents in the lines with 120o displacement) is called a symmetrical fault. The symmetrical fault occurs when all the three conductors of a 3-phase line are brought together simultaneously into a short circuit condition. The symmetrical fault is the most severe and imposes more heavy duty on the circuit breaker.

It has already been known that 3-phase short-circuit faults result in symmetrical fault currents i.e. fault currents in the three phases are equal in magnitude but displaced 120o electrical from one another. Therefore, problems involving such faults can be solved by considering one phase only as the same conditions prevail in the other two phases. The procedure for the solution of such faults involves the following steps :

(i) Draw a single line diagram of the complete network indicating the rating, voltage and percentage reactance of each element of the network.

(ii) Choose a numerically convenient value of base kVA and convert all percentage reactances to this base value.

(iii) Corresponding to the single line diagram of the network, draw the reactance diagram showing one phase of the system and the neutral. Indicate the % reactances on the base kVA in the reactance diagram. The transformer in the system should be represented by a reactance in series. (iv) Find the total % reactance of the network upto the point of fault. Let it be z%.

(v) Find the full-load current corresponding to the selected base kVA and the normal system voltage at the fault point. Let it be I.

(vi) Then various short-circuit calculations are :

Short-circuit current, ISC = I ×100/ %z

Short-circuit kVA = Base kVA × 100/ %z

<u>Line-Line-line fault (or) Balanced fault:</u>

Va1=Ea-Ir1*Z1

Va2=-Ir2*Z2

Va0=-Ir0*Z0

The fault current is given by IR1=Ea/Z1

If fault impedence is present

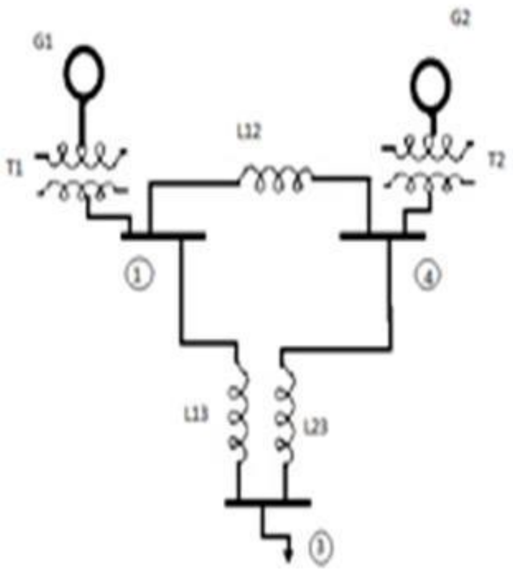
The fault current is given by IR1=Ea/(Z1+Zf)

Q).The single line diagram of a power system is shown in the figure .The neutral of each generator through a current limiting reactor of 0.25pu on a 100MVA base .The system data is expressed in pu with common base MVA s 100MVA is tabulated below . The generators are running on no load at their rated voltages and frequencies with their emfs in their phases. Determine the fault current with their emfs in phase .A balanced 3-phase symmetrical fault at bus 3 through a fault impedenceZf=j0.1

Item	Base MVA	Voltage rating(KV)	1 X (pu)	2 X (pu)	0 X (pu)
G1	100	20	0.15	0.15	0.05
G2	100	20	0.15	0.15	0.05
T1	100	20/220	0.1	0.1	0.1

T2	100	20/220	0.1	0.1	0.1
L12	100	220	0.125	0.125	0.3
L13	100	220	0.125	0.125	0.35
L23	100	220	0.15	0.15	0.7125

LINE DIAGRAM:



THEORETICAL CALCULATIONS:

Step1:

1) Adding a branch b/w new bus and reference bus

Zbus=[0.25]

2) Adding a branch b/w new bus and old bus

Zbus= [0.25j 0.25j = [0.25j 0.25j

0.25j 0.25j+0.125j] 0.25j 0.375j]

3) Adding a branch b/w new bus and old bus

Zbus[0.25j 0.25j 0.25j

0.25j 0.375j 0.25j

0.25 0.25 0.4j]

4) Adding a branch b/w two old bus

Zbus=ZbusOld-(1/Zjj+Zii-2Zij+Zb)*[Zii-Zjj*[Zi1-Z1j............. Zin-Zj]

.

.

Zni-Znj]

Zbus=[0.15 0.1 0.15

0.1 0.15 0.1

0.15 0.1 0.3]

5) Adding a branch b/w two old bus

Zbus=ZbusOld-(1/Zjj+Zb)*[Zii-Zjj*[Zi1-Z1j .... Zin-Zj]

.

.

Zni-Znj]

Zbus=[0.145 0.105 0.13

0.105 0.145 0.12

0.130 0.120 0.22]

Assume E1=E2=E3=1.0pu,Zf=j0.1ohms

Fault current If3=E3/(Z33+Zf)

= 1/(0.22+0.1)j

=-j3.125pu

[Ia		[1 1 1		[0		[3.125<-90deg
Ib	=	1 a^2 a	*	-j3.125	=	3.125<-150deg
Ic]		1 a a^2]		0]		3.125<30deg]

Positive sequence components of voltage

V1(f)=E1-Z13*I3(f)=0.593pu

V2(f)=E2-Z23*I3(f)=0.625pu

V3(f)=E1-Z33*I3(f)=0.3125pu

Fault current in lines

I12=(V2(f)-V1(f))/Zl12 =-j0.25pu

I13=(V3(f)-V1(f))/Zl13=-j1.875pu

I23=(V3(f)-V2(f))/Zl23=-j1.25pu

PROGRAM:

```
clc;
clear;
zdata=[1 1 0 0.25
      2 1 2 0.125
      3 1 3 0.15
      4 3 2 0.25
      5 2 0 0.25];
element=max(zdata(:,1));
zbus=[];

presentbus=0;
for count=1:elements
      [rows,cols]=size(zbus);
from=zdata(count,2);
to=zdata(count,3);
valve=zdata(count,4);
newbus=max(from,to);
ref=min(from,to);
%type1 a new element is added from newbus to ref bus
ifnewbus>presentbus&&ref==0
zbus=[zbus zeros(rows,1);zeros(1,cols) valve];
fprintf('zbus=\n[');
disp(zbus);
fprintf('\b\b]p.u');
presentbus=newbus;
continue
end
%type2 a new element is added from newbus to oldbusotherthan ref bus
ifnewbus>presentbus&&ref~=0
zbus=[zbuszbus(:,ref);zbus(ref,:) value+zbus(ref,ref)];
fprintf('\n\n zbus=\n[');
disp(zbus);
fprintf('\b\b]p.u');
presentbus=newbus;
continue
end
%type3 a new element is added beteenoldbus to ref bus
ifnewbus<=presentbus&&ref==0
zbus=zbus-(1/(zbus(newbus,newbus)+value))* zbus(:,newbus)*zbus(newbus,:);
fprintf('\n\n zbus=\n[');
disp(zbus);
fprintf('\b\b]p.u');
presentbus=newbus;
continue
end
%type4 a new element is added beteen two oldbuses
ifnewbus<=presentbus&&ref~=0
      zbus=zbus-(1/(zbus(from,from)+value+zbus(to,to)-2*zbus(from,to))* ((zbus(:,from)-
zbus(:,to))*(zbus(from,:)-zbus(to,:)));
fprintf('\n\n zbus=\n[');
```

```
disp(zbus);
fprintf('\b\b]p.u');
presentbus=newbus;
continue
end
end
zbus
zf=j*0.1;
  v1=1;
  v2=1;
  v3=1;
  i3fault=v3/(j*zbus(3,3)+zf);
  i3pos=i3fault;
  i3neg=0;

  i3zeros=0;
fprintf('\b\bpu')
  i3zpn=[i3zero;i3pos;i3neg];
  v1fault=v1-(j*zbus(1,3)*i3fault);
  v2fault=v2-(j*zbus(2,3)*i3fault);
  v3fault=v3-(j*zbus(3,3)*i3fault);
   i21fault=(v2fault-v1fault)/(j*zbus(1,2));
   i31fault=(v1fault-v3fault)/(j*zbus(1,3));
   i23fault=(v2fault-v3fault)/(j*zbus(2,3));
   v1fault
fprintf('\b\bp.u')
   v2fault
fprintf('\b\bp.u')
   v3fault
fprintf('\b\bp.u')
   i21fault
fprintf('\b\bp.u')
   i13fault
fprintf('\b\bp.u')
   i23fault
fprintf('\b\bp.u')
```

OUTPUT:

Zbus=

[0.1450 0.1050 0.1300

0.1050 0.1450 0.1200

0.1300 0.1200 0.2200]pu

V1fault=

0.5983pu

V2fault=

0.6250pu

V3fault=

0.3125pu

I21fault=

0.00-0.296j pu

I13fault=

0.0000-2.1635j pu

I23fault=

0.000-2.6042j pu

RESULT:

Symmetrical fault analysis using Zbus is done both theoretically and practically

COMMENTS:

For the given power system the fault current is calculated for the 3-phase fault at bus 3 and observed the fault current is different in each line as it is dependent line impedance

UNSYMMETRICAL FAULT ANALYSIS USING Z-BUS

Q).The single line diagram of a power system is shown in fig. The neutral of each generator is grounded through a current limiting reactor of j0.25 pu on a 100MVA base.The generator is running on no load at their rated voltage and rated frequency with current for the following faults :

a)LG fault at buss-3 through Z_f =0.1j pu

a) LL fault at buss-3 through Z_f =0.1j pu

a) LLG fault at buss-3 through Z_f =0.1j pu

Item	Base MVA	Voltage Rating	X^1(pu)	X^2(pu)	X^0(pu)
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	0.1	0.1	0.1
T_2	100	20/220	0.1	0.1	0.1
L_{12}	100	220	0.125	0.125	0.3
L_{13}	100	220	0.125	0.15	0.35
L_{23}	100	220	0.125	0.125	0.7125

AIM:

To develop a MATLAB code for determining the fault current for the given power system for occurrence of unsymmetrical fault.

APPARATUS:

1.MATLAB software

2.Computer

THEORY:

Various types of unsymmetrical faults that occur in power system are

(i) Shunt type faults:

1. Single-line-to-ground (1LG) fault
2. Line-to-line (LL) fault
3. Double-line-to-ground (2LG) fault

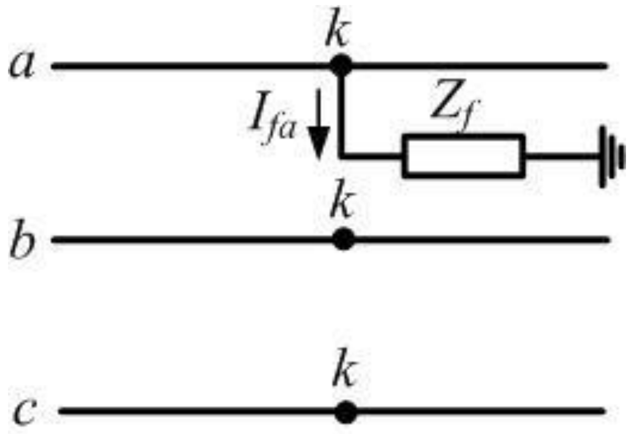
(ii) Series type faults:

1. Open conducter fault

1. Single-line-to-ground (1LG) fault:

Let a 1LG fault has occurred at node *k* of a network. The faulted segment is then as shown in Fig.where it is assumed that phase-a has touched the ground through an impedance *Zf*. Since the system is unloaded before the occurrence of the fault we have

$I_{fb}=I_{fc}=0$



The symmetrical fault components of the fault currents are

$$I_{fa012} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix}\begin{bmatrix} I_{fa} \\ 0 \\ 0 \end{bmatrix}$$

Also the phase-a voltage at the fault point is given by

$$V_{ka} = Z_f I_{fa}$$

$$I_{fa0} = I_{fa1} = I_{fa2} = \frac{I_{fa}}{3} \qquad (1.1)$$

This implies that the three sequence currents are in series for the 1LG fault. Let us denote the zero, positive and negative sequence Thevenin impedance at the faulted point as Z_{kk0}, Z_{kk1} and Z_{kk2} respectively.

$$V_{ka0} = -Z_{kk0} I_{fa0}$$

$$V_{ka1} = V_f - Z_{kk1} I_{fa1} \tag{1.2}$$

$$V_{ka2} = -Z_{kk2} I_{fa2}$$

Then from (1.1) and (1.2) we can write

$$\begin{aligned} V_{ka} &= V_{ka0} + V_{ka1} + V_{ka2} \\ &= V_f - (Z_{kk0} + Z_{kk1} + Z_{kk2}) I_{fa0} \end{aligned} \tag{1.3}$$

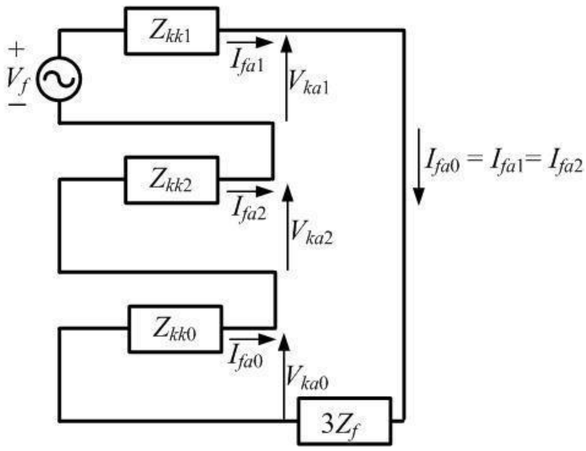
Again since

$$V_{ka} = Z_f I_{fa} = Z_f (I_{fa0} + I_{fa1} + I_{fa2}) = 3Z_f I_{fa0}$$

we get from (1.3)

$$I_{fa0} = \frac{V_f}{Z_{kk0} + Z_{kk1} + Z_{kk2} + 3Z_f}$$

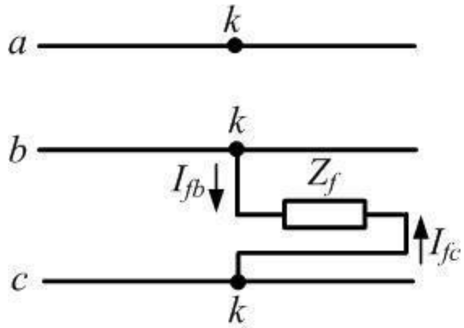
The Thevenin equivalent of the sequence network is shown in Fig



2. Line-to-line (LL) fault:

The faulted segment for an L-L fault is shown in Fig. where it is assumed that the fault has occurred at node k of the network. In this the phases b and c got shorted through the impedance Z_f. Since the system is unloaded before the occurrence of the fault we have

$$I_{fa} = 0 \tag{2.1}$$



Also since phases b and c are shorted we have

$$I_{fb} = -I_{fc} \tag{2.2}$$

Therefore from (2.1) and (2.2) we have

$$I_{fa012} = C\begin{bmatrix} 0 \\ I_{fb} \\ -I_{fb} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 0 \\ \left(a - a^2\right)I_{fb} \\ \left(a^2 - a\right)I_{fb} \end{bmatrix} \tag{2.3}$$

We can then summarize from (2.3)

$$\begin{aligned} I_{fa0} &= 0 \\ I_{fa1} &= -I_{fa2} \end{aligned} \tag{2.4}$$

Therefore no zero sequence current is injected into the network at bus k and hence the zero sequence remains a dead network for an L-L fault. The positive and negative sequence currents are negative of each other.

Now from Fig. we get the following expression for the voltage at the faulted point

$$V_{kb} - V_{kc} = Z_f I_{fb} \tag{2.5}$$

Again

$$
\begin{aligned}
V_{kb}-V_{kc} &= V_{kb0}+V_{kb1}+V_{kb2}-V_{kc0}-V_{kc1}-V_{kc2} \\
&= (V_{kb1}-V_{kc1})+(V_{kb2}-V_{kc2}) \\
&= (a^2-a)V_{ka1}+(a-a^2)V_{ka2} \\
&= (a^2-a)(V_{ka1}-V_{ka2})
\end{aligned}
$$

(2.6)

Moreover since $I_{fa0} = I_{fb0} = 0$ and $I_{fa1} = -I_{fb2}$, we can write

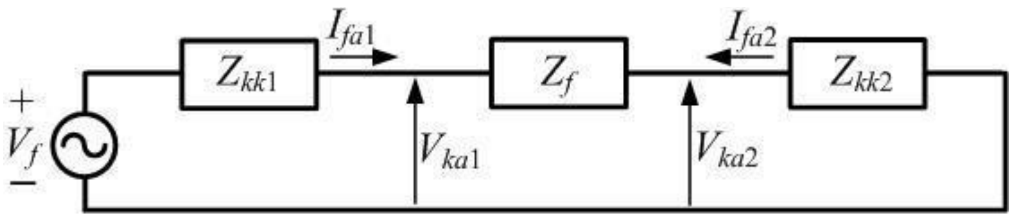
$$I_{fb} = I_{fb1} + I_{fb2} = a^2 I_{fa1} + aI_{fb2} = (a^2-a)I_{fa1} \tag{2.7}$$

Therefore combining (2.5)-(2.7) we get

$$V_{ka1} - V_{ka2} = Z_f I_{fa1} \tag{2.8}$$

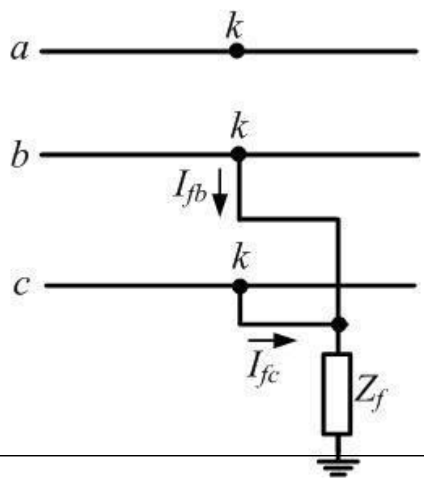
Equations (2.5) and (2.8) indicate that the positive and negative sequence networks are in parallel. The sequence network is then as shown in Fig. 8.6. From this network we get

$$I_{fa1} = -I_{fa2} = \frac{V_f}{Z_{kk1} + Z_{kk2} + Z_f}$$



3. Double-line-to-ground (2LG) fault:

The faulted segment for a 2LG fault is shown in Fig.where it is assumed that the fault has occurred at node *k* of the network. In this the phases b and c got shorted through the impedance Z_f to the ground. Since the system is unloaded before the occurrence of the fault we have the same condition as $I_{fa} = 0$ for the phase-a current. Therefore



$$I_{fa0} = \frac{1}{3}\left(I_{fa} + I_{fb} + I_{fc}\right) = \frac{1}{3}\left(I_{fb} + I_{fc}\right) \tag{3.1}$$

$$\Rightarrow 3I_{fa0} = I_{fb} + I_{fc}$$

Also the voltages of phases b and c are given by

$$V_{kb} = V_{kc} = Z_f\left(I_b + I_c\right) = 3Z_f I_{fa0} \tag{3.2}$$

Therefore

$$V_{ka012} = C\begin{bmatrix} V_{ka} \\ V_{kb} \\ V_{kb} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} V_{ka} + 2V_{kb} \\ V_{ka} + \left(a + a^2\right)V_{kb} \\ V_{ka} + \left(a + a^2\right)V_{kb} \end{bmatrix} \tag{3.3}$$

We thus get the following two equations from (3.3)

$$V_{ka1} = V_{ka2} \tag{3.4}$$

$$3V_{ka0} = V_{ka} + 2V_{kb} = V_{ka0} + V_{ka1} + V_{ka2} + 2V_{kb} \tag{3.5}$$

Substituting (3.2) and (3.4) in (3.5) and rearranging we get

$$V_{ka1} = V_{ka2} = V_{ka0} - 3Z_f I_{fa0} \tag{3.6}$$

Also since $I_{fa} = 0$ we have

$$I_{fa0} + I_{fa1} + I_{fa2} = 0 \tag{3.7}$$

The Thevenin equivalent circuit for 2LG fault is shown in Fig. From this figure we get

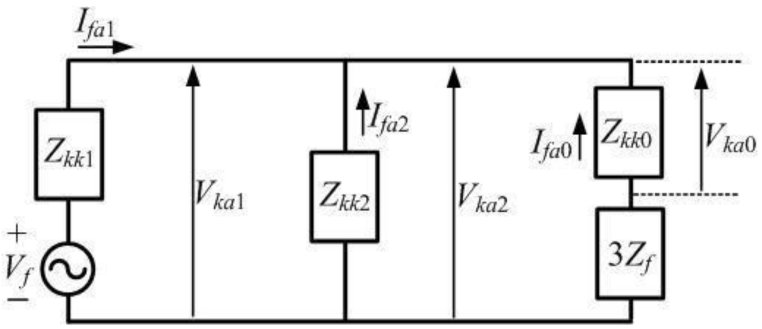
$$I_{fa1} = \frac{V_f}{Z_{kk1} + Z_{kk2} \| \left(Z_{kk0} + 3Z_f\right)}$$

$$= \frac{V_f}{Z_{kk1} + \dfrac{Z_{kk2}\left(Z_{kk0} + 3Z_f\right)}{Z_{kk2} + Z_{kk0} + 3Z_f}}$$

The zero and negative sequence currents can be obtained using the current divider principle as

$$I_{fa0} = -I_{fa1}\left(\frac{Z_{kk2}}{Z_{kk2} + Z_{kk0} + 3Z_f}\right)$$

$$I_{fa2} = -I_{fa1}\left(\frac{Z_{kk0} + 3Z_f}{Z_{kk2} + Z_{kk0} + 3Z_f}\right)$$



THEORETICAL CALCULATIONS:

Positive sequence network is given by

$$Z_{bus1} = \begin{bmatrix} 0.145j & 0.105j & 0.1301j \\ 0.105j & 0.145j & 0.12j \\ 0.1301j & 0.12j & 0.22j \end{bmatrix} \text{p.u}$$

Negative sequence network is given by

$$Z_{bus2} = \begin{bmatrix} 0.145j & 0.105j & 0.1301j \\ 0.105j & 0.145j & 0.12j \\ 0.1301j & 0.12j & 0.22j \end{bmatrix} \text{p.u}$$

Zero sequence network of the power system is given by

$Z_0 = [0.9j]$ p.u

$Z_0 = \begin{bmatrix} 0.9j & 0.9j \\ 0.9j & 1.2j \end{bmatrix}$ p.u

$$Z_0=\begin{bmatrix}0.9j & 0.9j & 0.9j\\0.9j & 1.2j & 0.9j\\0.9j & 0.9j & 1.25j\end{bmatrix}-\frac{1}{1.2j+1.25j+0.7125j}\begin{bmatrix}0\\0.3j\\-0.35j\end{bmatrix}\begin{bmatrix}0 & 0.3j & -0.35j\end{bmatrix}$$

$$=\begin{bmatrix}0.9j & 0.9j & 0.9j\\0.9j & 1.2j & 0.9j\\0.9j & 0.9j & 1.25j\end{bmatrix}-\frac{1}{1.3625j}\begin{bmatrix}0 & 0 & 0\\0 & 0.09 & -0.105\\0 & -0.105 & 0.1225\end{bmatrix}$$

$$=\begin{bmatrix}0.9j & 0.9j & 0.9j\\0.9j & 1.134j & 0.977j\\0.9j & 0977j & 1.1601j\end{bmatrix}\text{p.u}$$

$$Z_0=\begin{bmatrix}0.9j & 0.9j & 0.9j\\0.9j & 1.134j & 0.977j\\0.9j & 0977j & 1.1601j\end{bmatrix}-\frac{1}{1.134j+0.1j}\begin{bmatrix}0.9j\\1.134j\\0.977j\end{bmatrix}\begin{bmatrix}0.9j & 1.134j & 0.977j\end{bmatrix}$$

$$=\begin{bmatrix}0.2436j & 0.073j & 0.1875j\\0.073j & 0.092j & 0.0792j\\0.1875j & 0.0792j & 0.3866j\end{bmatrix}\text{p.u}$$

$$\Rightarrow\quad Z_0=\begin{bmatrix}0.2436j & 0.073j & 0.1875j\\0.073j & 0.092j & 0.0792j\\0.1875j & 0.0792j & 0.3866j\end{bmatrix}\text{p.u}$$

For LG fault at bus3 through Z_f = j0.1 P.U

$$I_{31}=\frac{E_a}{Z_1+Z_2+Z_0+3Z_f}=\frac{1}{j0.2201+j0.2201+j0{,}3564+3(j0.1)}=\frac{1}{j1.1268}=-j0.8874\text{ p.u}$$

Fault current = $I_{f3}=3\,I_{31}=3(-j0.8874)=-j2.6622$ p.u

For LL fault at bus3 through Z_f = j0.1 P.U

$$I_{31}=\frac{E_a}{Z_1+Z_2+3Z_f}=\frac{1}{j0.2201+j0.2201+3(j0.1)}=-j1.8511\text{p.u}$$

Fault current = $I_{f3}=-j\sqrt{3}\,I_{31}=-j\sqrt{3}\,(-j1.8511)=-3.2061$ p.u

For LLG fault at bus3 through Z_f = j0.1 P.U

$$I_{31}=\frac{E_a}{Z_1+Z_2//(Z_0+3Z_f)}=\frac{1}{j0.2201+\frac{j0.2201\,(j0.3864+j0.3)}{j0.3864+j0.3+j0.2201}}=-j2.5852\text{ p.u}$$

$V_{a1}=V_{a2}=E_a-I_{31}Z_1$

$$I_{30}=-\frac{E_a-I_{31}Z_1}{Z_0+3Z_f}=-\frac{1-(-j2.5052)(j0.2201)}{j0.3864+j0.3}=j0.6275\text{p.u}$$

Fault current = $I_{f3}=3*I_{30}=-3\,(-j0.6275)=-1.8824$p.u

ALGORITHM:

1. Start

2. Enter Z data for the +ve ,-ve and zero sequence networks

3. Calculate the Positive Sequence, negative sequence and zero sequence bus impudence matrix according to the data i.e., Z_{bus1}, Z_{bus2} and Z_{bus0}

4. calculate fault sequence currents and total fault current when fault is occurred at j^{th} bus during

L-G fault,

$$I_f = \frac{3E_{a1}}{Z_1 + Z_2 + Z_0 + 3Z_f}$$

L-L fault,

$$I_f = \frac{-j\sqrt{3}E_a}{Z_1 + Z_2 + Z_f}$$

5. Stop

PROGRAMME:

```
clear;
clc
j=squrt(-1);
zdata=[ 1  0  1  0.25
2 1 2 0.125
3 1 3 0.15
4 3 2 0.25
5 2 0 0.25];
elements =max (zdata (:,1));
zbus=[];
presentbus=0;
for count=1:elements
[row, cols]=sie(zbus);
from=zdata (count,2);
to=zdata (count,3);
value=zdata (count,4);
newbus=max(from,to);
ref=min(from to,);
%type1 a new element is added from newbus to ref bus
if newbus>presentbus &&ref==0
zbus=[zbus zeros(rows,1);zeros(1,cols) value];
fprintf('zbus=\n[');
disp(zbus);
fprint('\b\b]p.u')
presentbus=newbus;
continue
end
%type2 a new element is added from newbus to old bus other than ref bus
if newbus>poresentbus && ref~=0
zbus=[zbus zbus(:,ref);zbus(ref,:) value+zbus(ref,ref)];
fprintf('\n\n zbus=\n[');
disp(zbus);
```

```
fprintf(‘\b\b]p.u’)
presentbus=newbus;
continue
end
%type3 a new element is added between old bus and ref bus
if newbus<=presentbus && ref ==0
zbus=zbus-(1/zbus(newbus,newbus)+value))*zbus(:,newbus)*zbus(newbus,:);
fprintf(‘\n\n zbus=\n[’);
disp(zbus);
fprintf(‘\b\b]p.u’)
continue
end
%type4 a new element is added between two old buses
if newbus<=presentbus && ref ~=0
zbus=zbus-1/(zbus(from,from)+value+zbus(to,to)-
2*zbus(from,to))*((zbus (:,from)-zbus(:,to))*(zbus(from,:)-zbus(to,:)));
fprintf(‘\n\n zbus=\n[’);
disp(zbus);
fprintf(‘\b\b]p.u’)
continue
end
end
clc
zbus
zbus1=j*zbus
zbus2=zbus1
ydata= [ 1 4 1 0.9
2  1  2  0.3
3  1  3  0.35
4  3  2  0.7125
5  2  4  0.1];
fb=ydata(:,2);
tb=ydata(:,3);
x=ydata(:,4);
z = i*x;
y = 1./z;
nbus=max(max(fb),max(tb));
nbranch = length(fb);
ybus = zeros(nbus,nbus);
%formation of offf diagonal element
for k= 1:nbranch
ybus(fb(k),tb(k))=-y(k);
ybus(tb(k),fb(k))=ybus(fb(k),tb(k));
end
%formation of diagonal elements
from m=1:nbus
from n=1:nbranch
if fb(n)==m | | tb(n) == m
ybus(m,m)=ybus(m,m)+y(n);
end
end
end
ybus(:,4)=[];
ybus(4,:)=[];
```

```
Z=inv(ybus);
zbus0=z
zf=i*0.1;
disp('(a) single line to ground fault at bus 3 through z=0.1)
I3zero=(1)/zbus2(3,3)+zbus1(3,3)+zbus0(3,3)+3*zf);
If1=3*I3zeros;
If1
disp('(b)line to line fault at bus 3 through z=0.1')
I3zero =0;
I3pos=1.0/(zbus2(3,3))+zbus1(3,3)+zf);
If2=squrt(3)*I3pos;
I3neg=-I3pos;
If2
disp('(c) double line to ground faultat bus3 through z=j*0.1');
I3pos=1.0/(zbus1(3,3)+zbus2(3,3)*(zbus0(3,3)+3*zf)/(zbus2(3,3)+zbus0(3,3)+3*zf)));
I3neg=-(1.0-zbus1(3,3)*I3pos)/zbus2(3,3);
I3zero=-(1.0-zbus1(3,3)*I3pos)/(zbus0(3,3)+3*zf);
If3=3*I3zero;
If3
```

OUTPUT:

```
zbus=

0.1450  0.1050  0.1300
0.1050  0.1450  0.1200
0.1300  0.1200  0.2200 pu

zbus1=

0.0000+0.1450i    0.0000+0.1050i  0.0000+0.1300i
0.0000+0.1050i    0.0000+0.1450i  0.0000+0.1200i
0.0000+0.1300i    0.0000+0.1200i  0.0000+0.2200i pu

zbus2=

0.0000+0.1450i   0.0000+0.1050i   0.0000+0.1300i
0.0000+0.1050i   0.0000+0.1450i   0.0000+0.1200i
0.0000+0.1300i   0.0000+0.1200i   0.0000+0.2200i pu

zbus0=

0.0000+0.2436i   0.0000+0.0729i  0.0000+0.1874i
0.0000+0.0729i   0.0000+0.0919i  0.0000+0.0792i
0.0000+0.1874i   0.0000+0.0792i  0.0000+0.3864i pu

(a) single line to ground fault at bus 3 through z=j*0.1
If1=
0.0000-2.6633i pu

(b) line to line fault at bus 3 through z=j*0.1
If2=

0.0000-3.2075i pu
```

(c) double line to ground fault at bus 3 through z=j*0.1
If3=

0.0000-1.8834i pu

RESULT:

Unsymmetrical fault analysis is done by using Z-bus both practically and theoretically

VIVA QUESTIONS:

1) How many types of fault occurs in the power system?
2) What are unsymmetrical faults?
3) What are symmetrical faults?
4) Mention the causes of electrical faults.
5) What are the fault clearing devices?
6) How to reduce LG fault?
7) How to eliminate the three phase fault?
8) What are the effects of faults in power system?
9) What is the need of protection in power system?
10) How to eliminate the effect of LLG fault?

5. (i) DETERMINATION OF STEADY STATE FREQUENCY ERROR AND FREQUENCY DEVIATION RESPONSE FOR AN ISOLATED POWER SYSTEM

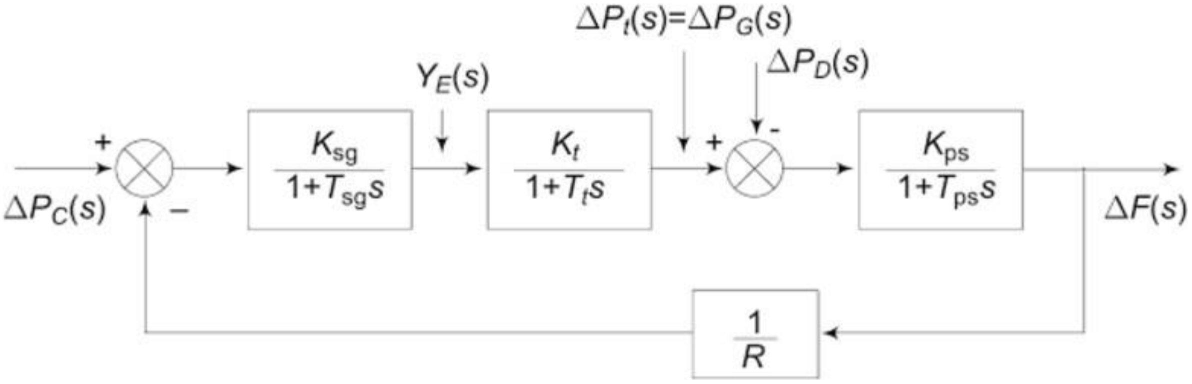
AIM : i) To determine frequency response of an isolated power system without integral controller using MATLAB/Simulink

ii) To determine frequency response of an isolated power system with integral controller using MATLAB/Simulink.

Apparatus : Personal computer with MATLAB software

Theory :

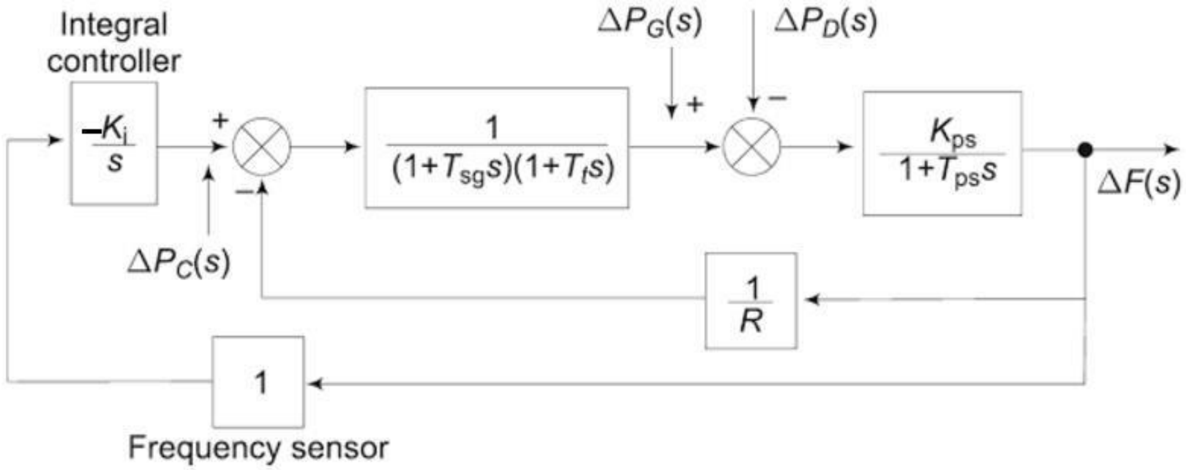
The complete block diagram of an isolated power system without controller is shown in the following fig



Where

ΔP_C = commanded increase in power
K_{sg} = Gain of speed governor
Tsg = Time constant of speed governor
R = Speed regulation of governor
K_t = Gain of turbine
T_t = Time constant of turbine
K_{ps} = Power system gain
Tps = Power system time constant
ΔP_D = Load demand
ΔF = Change in frequency
$\Delta P_t = \Delta P_G$ = Incremental turbine power output

The complete block diagram of an isolated power system with integral controller is shown in the following fig



➔ **With integral controller, the steady state frequency error becomes zero.**

CALCULATIONS:

Problem:

Obtain the frequency deviation response of an isolated power system with and without PI controller using MATLAB/Simulink.

Assume

Tsg = 0.4
Tt = 0.5
Tps = 20
Kps = 100
R = 3
Ksg = 10
Kt = 0.1
Ki = 0.09
ΔP_D =0.01

The steady state frequency can be obtained as

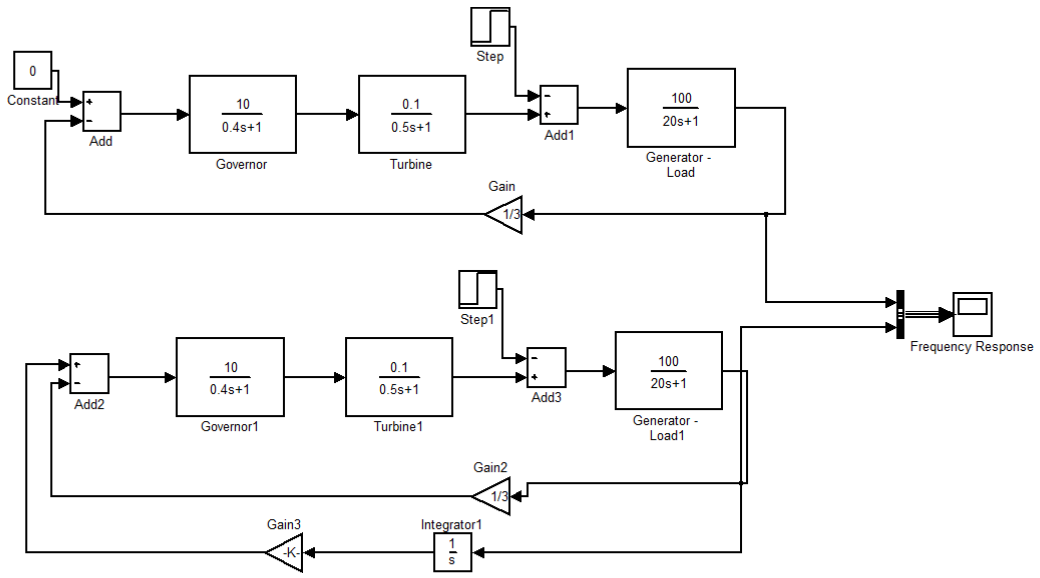
$$\Delta f(t) = -\frac{RK_{ps}}{R+K_{ps}}\left\{1-\exp\left[-\frac{t}{T_{ps}}\left(\frac{R}{R+K_{ps}}\right)\right]\right\}\Delta P_D$$

Taking $R = 3$, $K_{ps} = 1/B = 100$, $T_{ps} = 20$, $\Delta P_D = 0.01$ pu

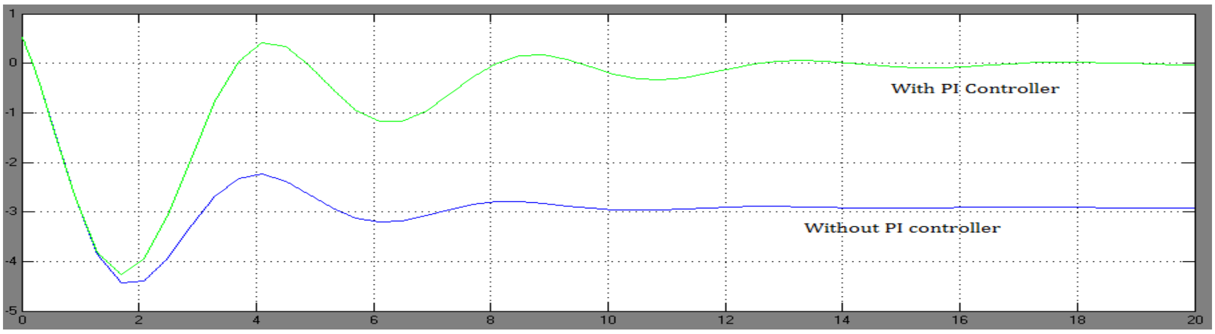
$$\Delta f(t) = -0.029\,(1-e^{-1.717t})$$

$$\Delta f|_{\text{steady state}} = -0.029 \text{ Hz}$$

SIMULINK BLOCK DIAGRAM:



Frequency Response:



RESULT :

The frequency response and steady state frequency error of an isolated power system are determined with & without PI controller using MATLAB/SIMULINK.

Steady state frequency error without PI controller = –0.0029 Hz

Steady state frequency error with PI controller = 0

<u>VIVA QUESTIONS:</u>

1) What is the function of LFC?
2) Define inertia constant.
3) What is meant by control area?
4) What is frequency deviation?
5) Define steady state frequency error.
6) What is the major control loops used in large generators?
7) What is the exciter?
8) How the real power can be controlled in a power system?
9) State the basic role of ALFC
10) What is area control error?

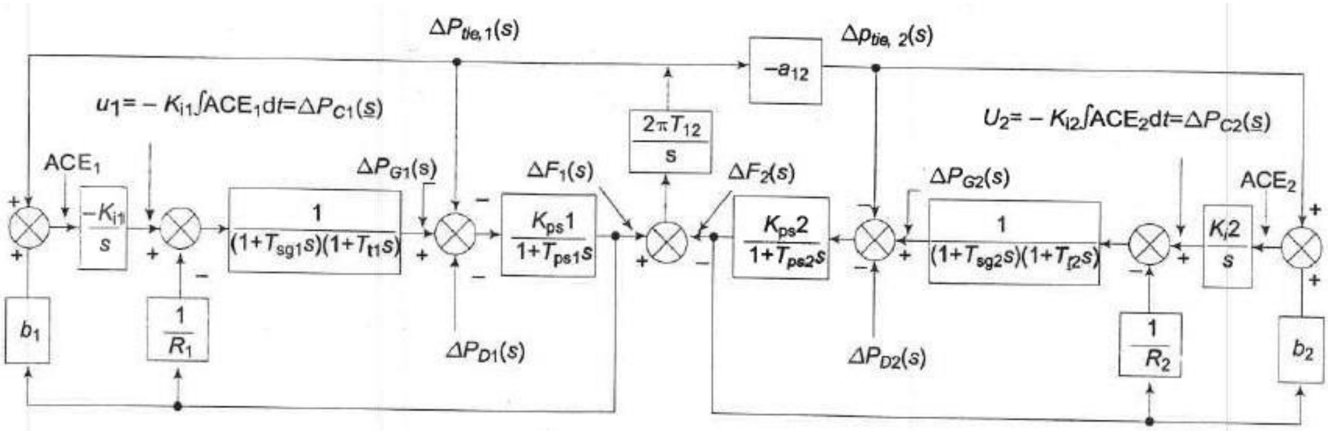
5 (ii). DETERMINATION OF STEADY STATE FREQUENCY ERROR, CHANGE IN TIE-LINE POWER FLOW AND FREQUENCY DEVIATION RESPONSE, FOR AN INTERCONNECTED POWER SYSTEM

AIM : To determine frequency response of an interconnected(Two area) power system with Tie line control using MATLAB/Simulink

Apparatus : Personal computer with MATLAB software

Theory :

The complete block diagram of a two area power system with tie line power



control is shown in the following fig

Where

ΔP_C = commanded increase in power

Tsg = Time constant of speed governor

R = Speed regulation of governor

T_t = Time constant of turbine

K_{ps} = Power system gain

Tps = Power system time constant

ΔP_D = Load demand

ΔF = Change in frequency

ΔP_G = Incremental turbine power output

b = Frequency bias constant

R = speed regulation of governor

ΔP_{tie} = Change in tie line power

ACE = Area control error

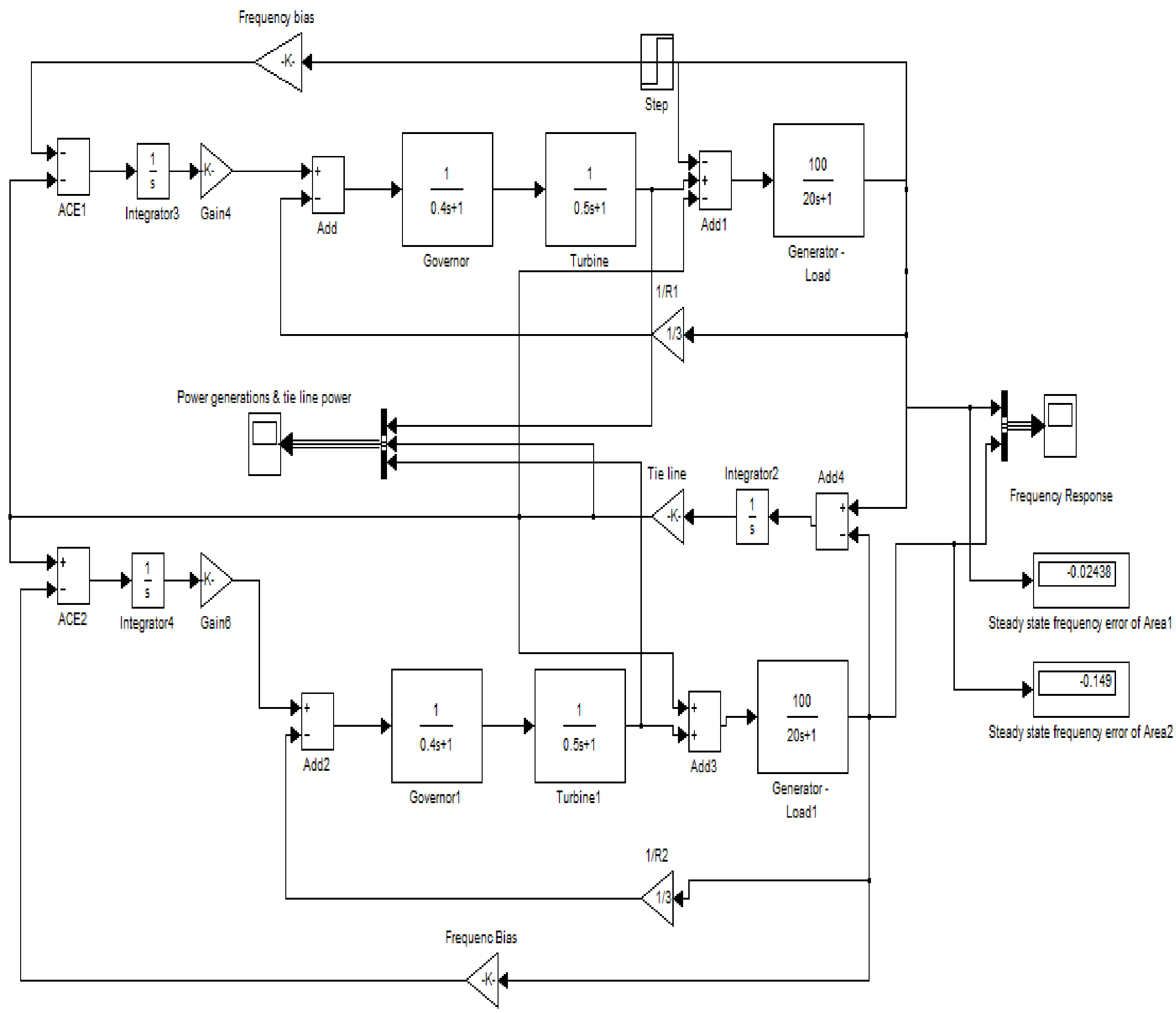
Problem:

Obtain the frequency deviation response of an interconnected power system with tie line control using MATLAB/Simulink.

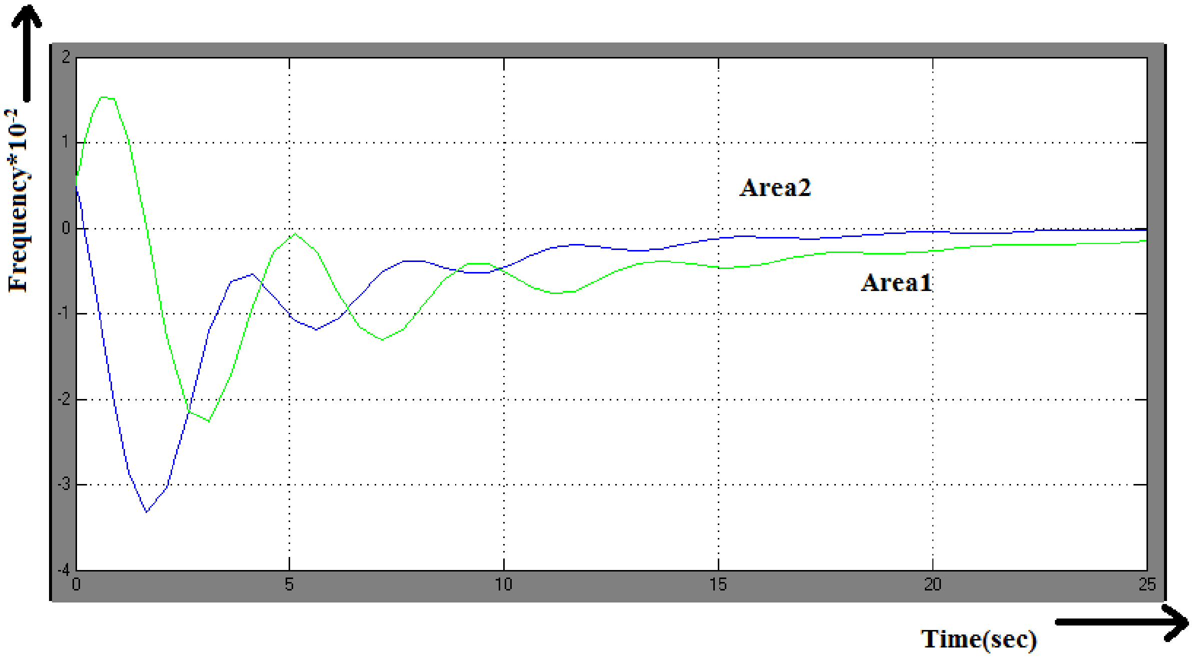
Assume

$$T_{sg} = 0.4$$
$$T_t = 0.5$$
$$T_{ps} = 20$$
$$K_{ps} = 100$$
$$R = 3$$
$$K_{sg} = 1$$
$$K_t = 1$$
$$K_i = 0.09$$
$$K_i \text{ for tie line} = 0.05$$
$$\Delta P_D = 0.01$$
$$b = 0.425$$

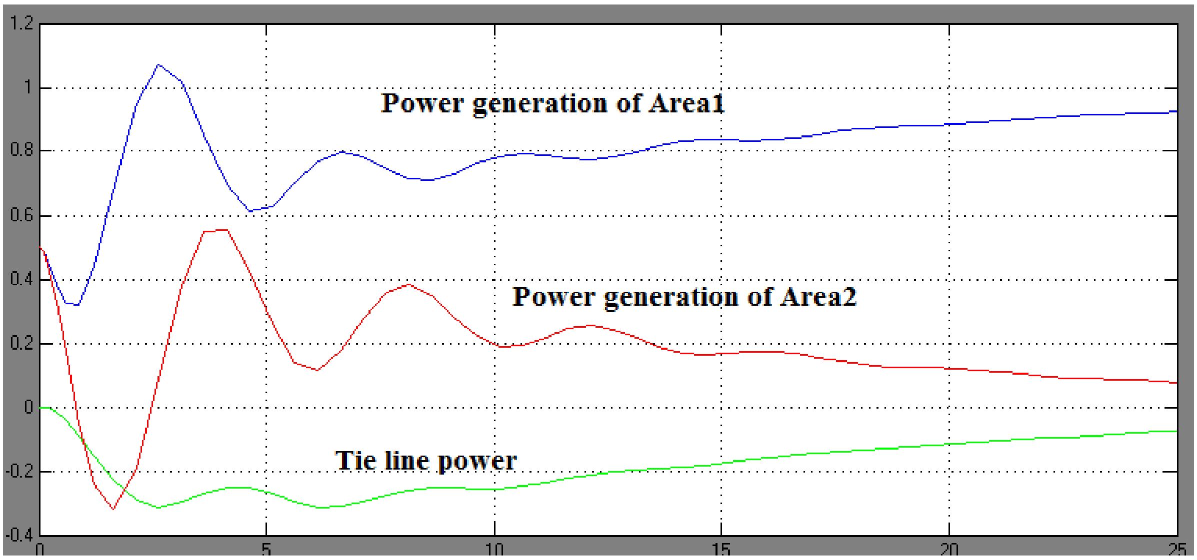
SIMULINK BLOCK DIAGRAM:



Frequency Response:



Tie line power response:



RESULT :

The frequency response, steady state frequency error and tie line power of an interconnected power system are determined using MATLAB/SIMULINK.

VIVA QUESTIONS:

1) Write the tie line power deviation equation
2) What is the diff. between large and small signal analysis?
3) What is the use of secondary loop?
4) What are the effects of generator loading in AVR loop?
5) What is the need for large mechanical forces in speed-governing system?
6) Specify the disadvantage of ALFC loop.
7) What is two area control?
8) What are the adv. Of interconnected power system?
9) Write the static performance of AVR loop.
10) What are the assumptions made in dynamic response of an ALFC loop?

7. Plot the Swing curve for a simple 3 or 4 bus power system using MATLAB / PSCAD.

Aim:

Determination of swing curve and critical clearing time of the machine connected to infinite bus.

Problem statement:

A 20MVA, 50Hz generator delivers 18MW over a double circuit line to an infinite bus. The generator has kinetic energy of 2.52 MJ/MVA at rated speed. The generator transient reactance is Xd'=0.35pu. Each transmission circuit has R=0 and a reactance of 0.2pu on a 20MVA base. |E'| =1.1pu and infinite bus voltage V=1.0 at 0 degree. A three phase short circuit occurs at the mid point of the transmission lines. Plot swing curves with fault cleared by simultaneous opening of breakers at both ends of the line at 2.5 cycles and 6.25 cycles after the occurrence of fault. Also plot the swing curve over the period of 0.5 seconds if the fault is sustained.

Appartus required: Matlab software

Theory: Refer the modern power system analysis by D P Kothari & I J Nagarth

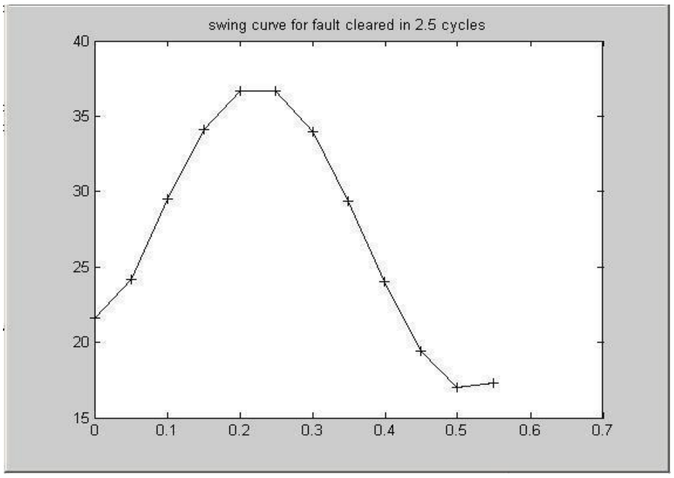
Procedure:

- Do the hand calculations and solve the problem.
- Note down the theoretical results.
- Double click on matlab icon in the desktop.
- Type **edit** and press enter to get the Editor window.
- Type the program.
- Save and run the program.
- Enter the inputs in the command window and see the output response.
- Note down the simulated results.

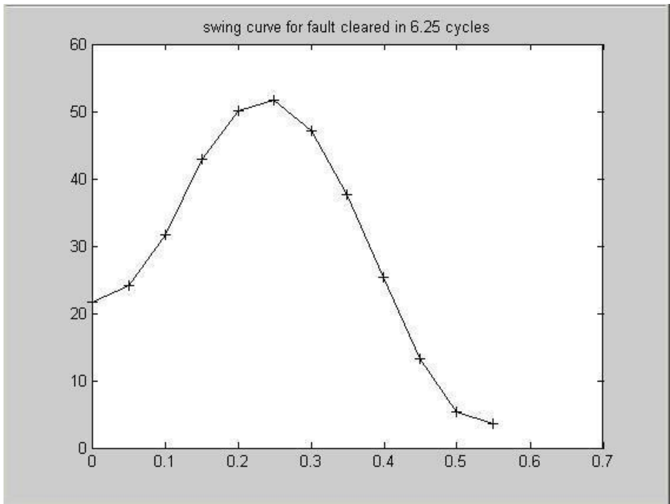
Program:

```
%swing curve
clear;
clc;
t=0;
tf=0;
tfl=0.5;
tc=0.05;     %tc=0.05,0.125,0.5 sec for 2.5cycles,6.25cycle & 25cycle resp
ts=0.05;
m=2.52/(180*50);
i=2;
dt=21.64*pi/180;
ddt=0;
time(1)=0;
ang(1)=21.64;
pm=0.9;
pm1=2.44;
pm2=0.88;
pm3=2.00;
while t<tfl,
   if (t==tf),
      pam=pm-pm1*sin(dt);
      pap=pm-pm2*sin(dt);
      paav=(pam+pap)/2;
      pa=paav;
   end
   if (t==tc),
      pam=pm-pm2*sin(dt);
      pap=pm-pm3*sin(dt);
      paav=(pam+pap)/2;
      pa=paav;
   end
   if (t>tf&t<tc),
      pa=pm-pm2*sin(dt);
   end
   if (t>tc),
      pa=pm-pm3*sin(dt);
   end
   ddt=ddt+(ts*ts*pa/m);
   dt=(dt*180/pi+ddt)*pi/180;
   dtdg=dt*180/pi;
   t=t+ts;
   time(i)=t;
   ang(i)=dtdg;
   i=i+1;
end
axis([0 0.6 0 160])
plot(time,ang,'k+-')
title('swing curve for fault cleared in 2.5 cycles')
```

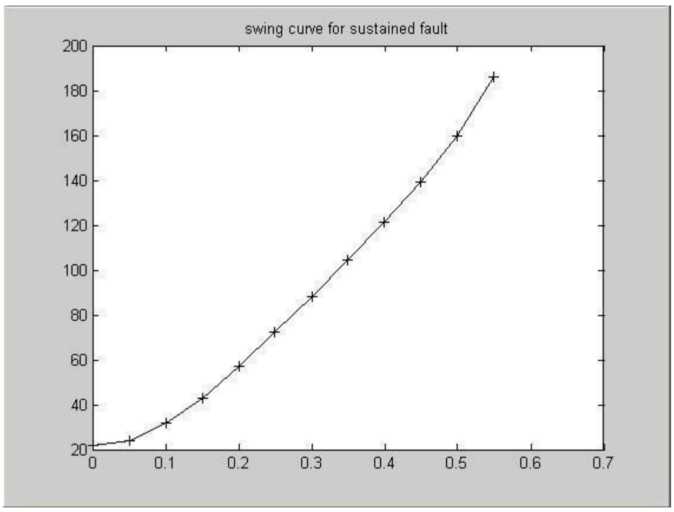
Swing curve for fault cleared in 2.5 cycles (tc=0.05)



Swing curve for fault cleared in 6.25 cycles (tc=0.125)



Swing curve for sustained fault (tc=0.5)



CYCLE -II

6. PLOT V-I CHARACTERISTICS OF A SOLAR PANEL AT VARIOUS LEVELS OF INSULATION

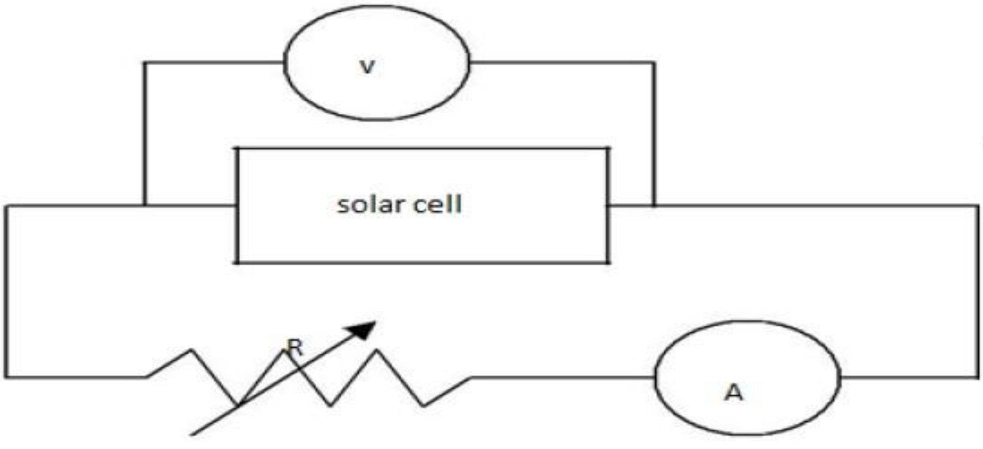
Aim:

- ➔ To observe the relationship of current, voltage and power in a solar cell.
- ➔ To plot the I-V curve of a solar cell in excel and to identify the maximum power point, the short circuit current, and the open circuit voltage.

Apparatus required:

S.no	Name of the apparatus	Range	Quantity
1	Solar module	10w,V_{OC}=21.5V;I_{SC}=0.62A	1
2	Multimeter		2
3	Variable Resistor		1
4	Artificial Light Source	230V;200W	1
5	Alligator clips and wire	--------	

Circuit diagram:



Theory:

At short circuit, the solar module produces electric current but no voltage. At open circuit, the solar module produces voltage but no current. Electric power is defined as the product of the current and the voltage. Hence, in both the short circuit and open circuit, the solar module produces no power.

Somewhere in between these two operating points is the Maximum Power point of the solar module where the maximum power possible is being generated. By taking current and voltage measurements of a solar module while supplying power to a variable resistor, gives the current-voltage relation, or what is called as IV curve of a solar module. This relation is graphed using a spreadsheet such as Microsoft Excel. The current and voltage of each data set is multiplied together to yield the corresponding power at that operating point. The power is then plotted as a function of voltage. The maximum value of the power curve is at the maximum power point of the solar module.

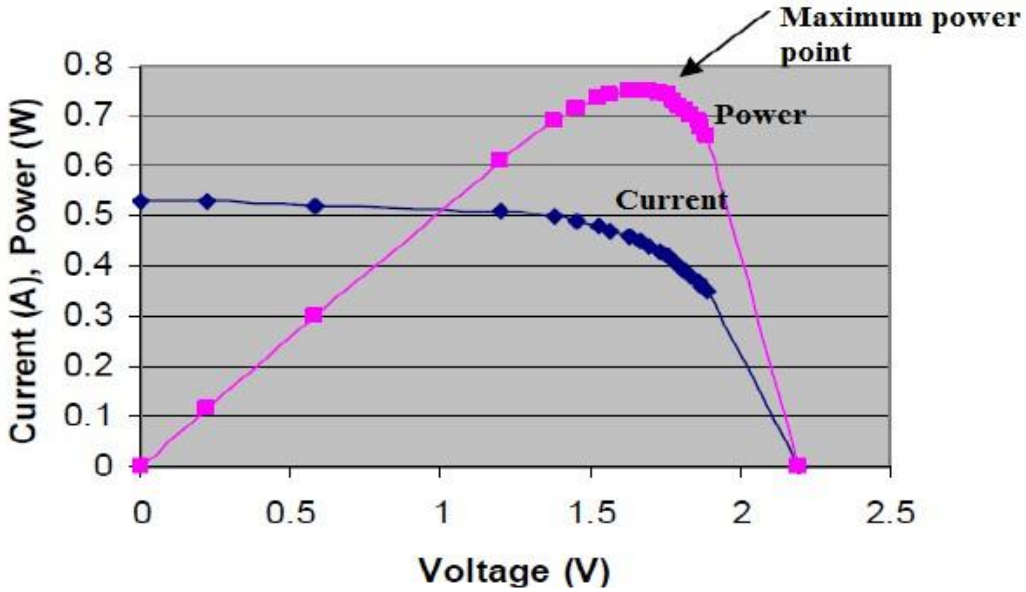
Procedure:

1. Set the circuit as per the circuit diagram (Ammeter is in series, Voltmeter parallel)
2. Set the solar cell facing towards a source of artificial light, such as an overhead projector light.
3. Measure the Short Circuit Current (by having maximum resistance) and Open Circuit Voltage (by disconnecting the variable resistor)
4. Change the resistance of the variable resistor, until a change in 10 milli-ampere occurs. Record the new current and voltage
5. When the rate of changes of voltage has increased, students should decrease the change in current (about 1 mA) to obtain more data points. Record the current and voltage measurement
6. Continue this until the maximum resistance in the variable resistor (when voltage = 0)
7. Place the data in MS. Excel. Plot the IV curve, with current in the vertical axis, and voltage in the horizontal axis.
8. The current and voltage of each data set is then multiplied together giving a value for power and placed in the adjacent column
9. Plot another graph, with power in the vertical axis, and the voltage in the horizontal axis. This is the power graph
10. Indicate the maximum power in the power curve, and find the respective voltage and current.

Tabular form:

S.no	Voltage (volts)	Current (m.amp)	Power (watts)

Identify V_{oc}-open circuit voltage, I_{sc} -short circuit currentModel graph:



Result:

Maximum Power = ……………………………..

Voltage at maximum power point = ………

Current at maximum power point = ……….

Open circuit voltage (V_{OC}) =......................

Short Circuit Current(I_{SC}) =...........................

VIVA QUESTIONS:

1) What is meant by insulation?
2) How to calculate the insulation level of the panel?
3) Draw the VI characteristics of solar panel.
4) What is photo voltaic (solar electricity) or "PV"?
5) How can we get electricity from the sun?
6) How long do photovoltaic (PV) systems last?
7) What are the components of a photovoltaic (PV) system?
8) What's the difference between PV and other solar energy technologies?
9) Can I use photovoltaics (PV) to power my home?
10) How big a solar energy system do I need?

7. Determination of Sequence components (Positive, Negative and Zero) of an alternator.

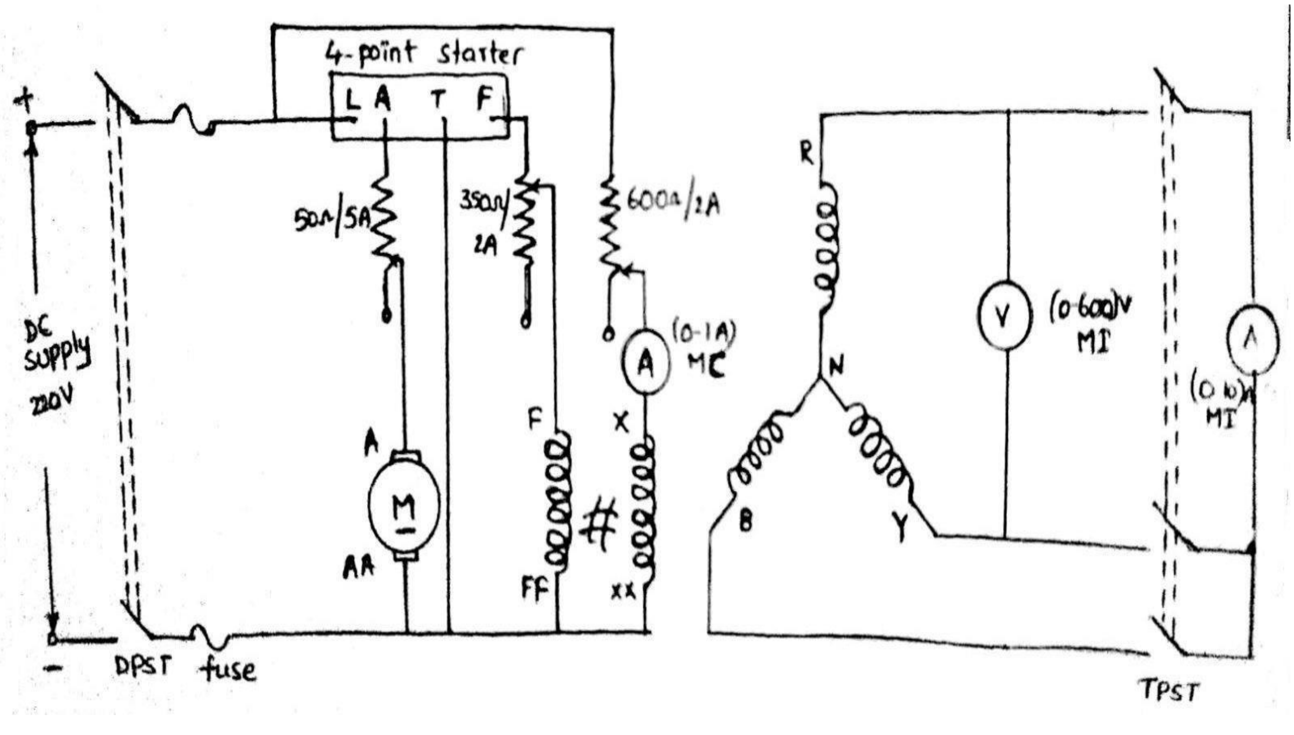
Aim:To find out the positive ,negative and zero sequence impedances of an alternator.

Apparatus:

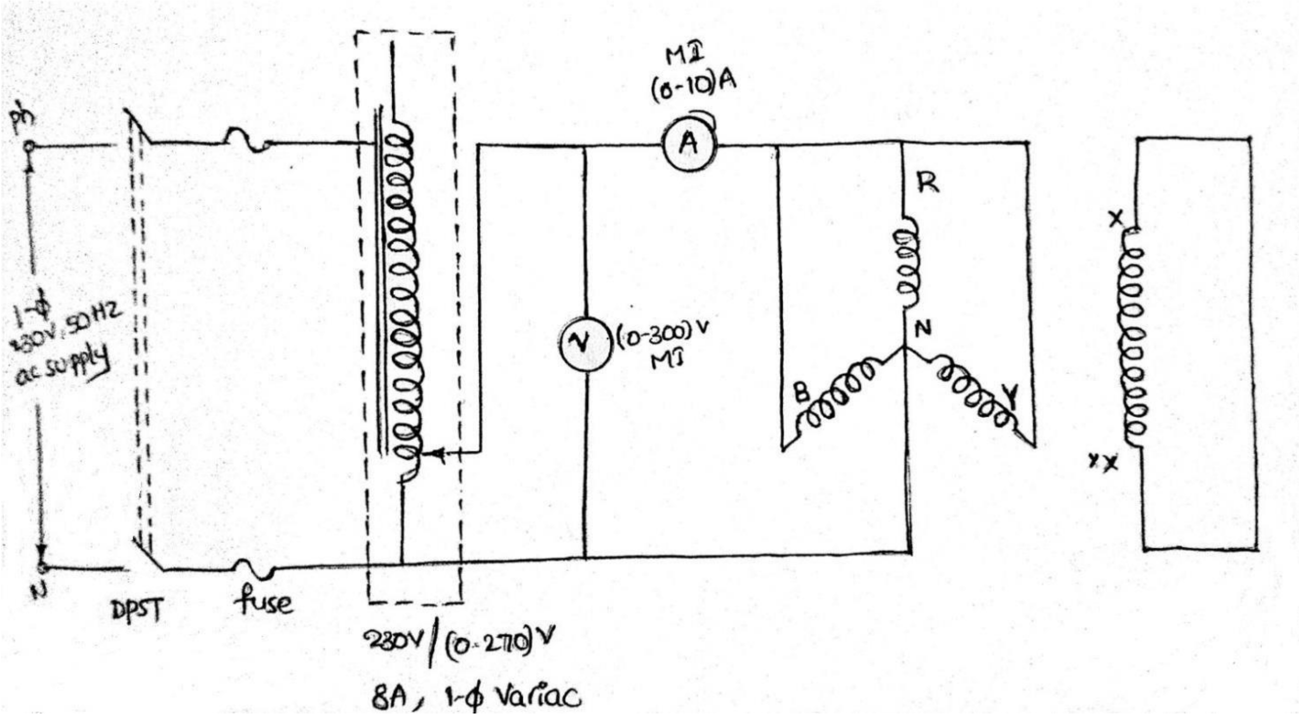
S.no	Name	Range	Type	Qty
1	1-ϕ variac	230/(0-270)V,6A	-	1
2	Ammeter	(0-10)A (0-1)A	MI MC	2 1
3	Voltmeter	(0-600)V (0-150)V (0-30)V	MI MI MI	1 1 1
4	Rheostat	50 Ohm/5A 350 Ohm/2A 600 Ohm/2A	Wire Wound Wire Wound Wire Wound	1 1 1
5	DC motor-Alternator set	-	-	1

Circuit diagram:

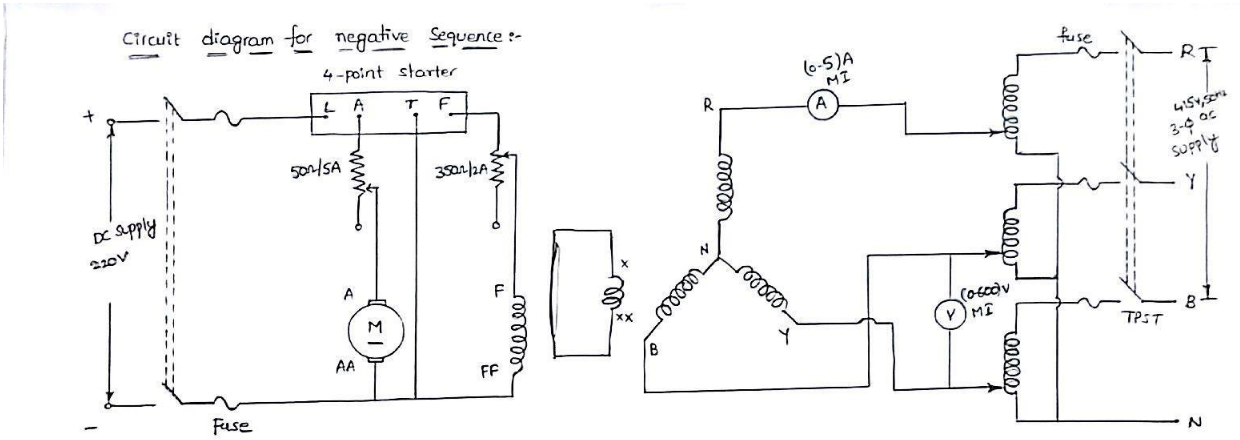
For positive sequence:



For zero sequence:



For negitive sequence:



Name plate details :-

DC Motor	Alternator
kW - 5kW	o/p - 5KVA
N - 1500 rpm	N - 1500 rpm
V - 220V	Ia - 9A
Ia - 20 amp	If - 3A Y Connected
If - 1.0 amp	Vf - 220V

Procedure:

For positive sequence impedance:

1) Connections are given as per circuit diagram.
2) Supply is given to the circuit.
3) Bring the motor to rated speed by varying armature rheostat and field rheostat.
4) By varying the field rheostat vary the alternator speed so that open circuit voltage varies.
5) Vary the circuit voltage until the rated current is built.
6) Positive sequence impedance $= \frac{V_{OC}}{I_{SC}}$

For negative sequence impedance:

1) Connections are given as per circuit diagram.
2) Short circuit the field of the alternator before doing the experiment.
3) Apply the reduced voltage through the alternator by using variac until the ammeter reads the rated current.
4) Note down the readings of voltmeter and ammeter negative sequence impedance $=V/I_a$

For zero sequence impedance:

1) Connections are given as per circuit diagram.
2) Keep the field terminals of alternator short circuit.
3) Apply reduced voltage to alternator through 1-ϕ variac.
4) Note down the voltmeter and ammeter values.
5) Zero sequence impedance =3V/I.

Precautions:

1) Connections must be tight.
2) Readings are note down without parallax error.

Tabular form for OC test:

S.no	I_f(Amps)	V_{OC}/phase

Tabular form for SC test:

S.no	I_f(Amps)	I_{SC}/Phase

Tabular form for Negative sequence impedance:

S.no	V(volts)	I(amps)	Z=V/ $\sqrt{3}I_a$

Tabular form for Zero sequence impedance:

S.no	V(volts)	I(amps)	Z_O=3V/I

Result: The positive , negative and zero sequence impedances are determined.

VIVA QUESTIONS:

1) What is positive sequence component?
2) What is negative sequence component?
3) What is zero sequence component?
4) The synchronous reactance of an alternator is due to _____.
5) What are the effects of Unbalanced three phase stator currents?
6) What is the shape of short circuit characteristic of alternator?
7) Mention the fault in which only positive sequence reactance is present.
8) What is the speed of Negative sequence currents with respect to field winding?
9) Give the winding connection when Zero sequence current can flow from a transmission line to a transformer.
10) In which fault the positive sequence component of voltage at fault point is zero.

8. OVER CURRENT PROTECTION USING NUMERICAL RELAY

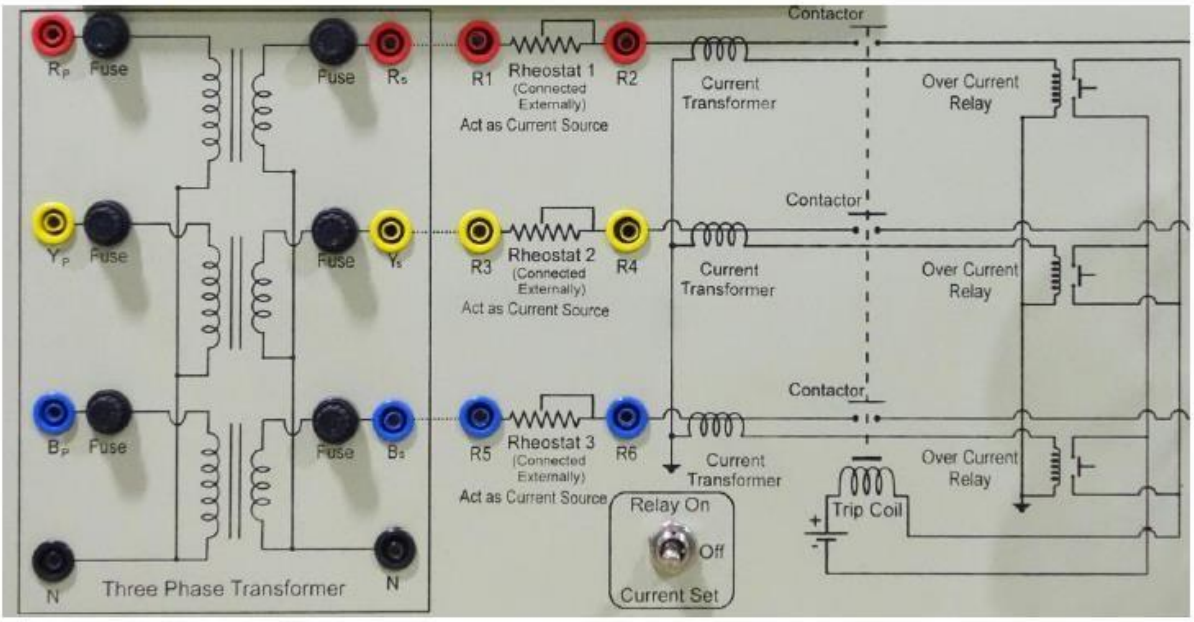
Aim:

To study the Characteristics of over Current Relay at different plug settings.

Apparatus:

- Patch Cords
- Rheostats 110 Ohms, 5A – 3 Nos.
- Bulb colored 230V, 40W/100W- 3 Nos.
- Three Phase variac, 10A

Circuit diagram



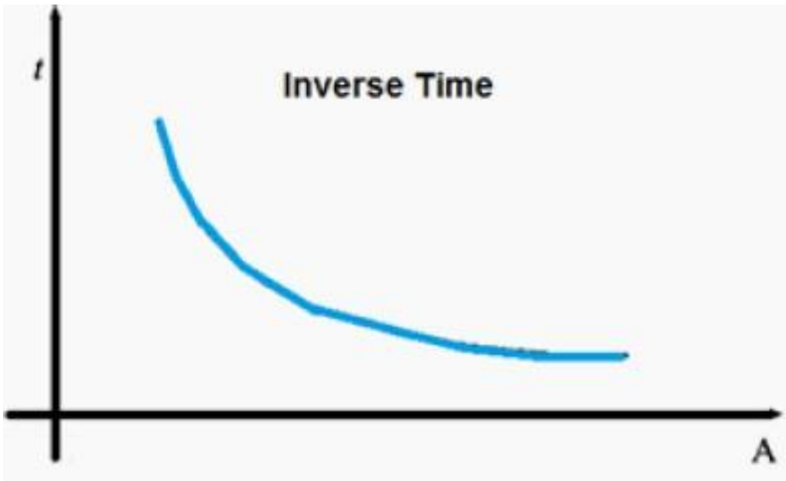
Theory:

Inverse Time Over current Relays (IDMT Relay)

In this type of relays, operating time is inversely changed with current. So, high current will operate over current relay faster than lower ones. There are standard inverse, very inverse and extremely inverse types.

Discrimination by both ‘Time’ and ‘Current’, the relay operation time is inversely proportional to the fault current.

Inverse Time relays are also referred to as Inverse Definite Minimum Time (IDMT) relay.



Model Graph

Normal Inverse Time Over current Relay :

The accuracy of the operating time may range from 5 to 7.5% of the nominal operating time as specified in the relevant norms. The uncertainty of the operating time and the necessary operating time may require a grading margin of 0.4 to 0.5 seconds.
Normal inverse time Over current Relay is relatively small change in time per unit of change of current.
Application: Most frequently used in utility and industrial circuits, especially applicable where the fault magnitude is mainly dependent on the system generating capacity at the time of fault.

Procedure

1. Make sure that the Three Phase Mains and the MCB of panel is at “Off” position.
2. Strictly follow the precautions mentioned below.
3. Supply MCB placed at the back side of the control panel for protection purpose.
4. Now insert the external rheostat to terminals R1 & R2 as shown in figure.
5. Now insert the external rheostat to terminals R3 & R4 as shown in figure.
6. Now insert the external rheostat to terminals R5 & R6 as shown in figure.
7. Connect three 15W / 40W or 100W bulbs to three phase loads section on the control panel.
8. Check all the connections once again as per the connection diagram.
9. Connect single phase mains cord to single phase socket provided at the back side of the control panel for auxiliary supply.
10. Connect three phase mains supply to the input of three phase variac and the output of this variac will be connected to the control panel through three phase socket provided with the control panel.
11. Ensure that the three phase variac is at zero position.

12. Switch "On" the Single Phase Supply as well as Reset switch.

13. Initially keep three phase Variac at Zero position and toggle switch in "Off" position.

14. Then press upper arrow key, select group1, go to overcurrent by pressing the same key. Select inverse curve and current at which relay actuate. It is preset to 1A

15. Now switch toggle switch (placed at the front plate) move to current set, set the current at any value between 1A to 3A.

16. The current set by the user can be displayed on LCD.

17. Note that all three phase current can be displayed simultaneously on single frame of LCD.

18. Once the current is set, turn the toggle switch to relay On position

19. By the time user turn the toggle switch to relay On position, Relay will activate and count the trip time which can be measured and displays on LCD.

20. User can record all these reading into observation table.

21. Once the relay gets tripped, LED will blinked in the front that can be removed by pressing CLEAR button (at the front of the numerical relay)

22. After experimenting, move the toggle switch to Off position, rheostats will move to maximum resistance position.

23. Switch Off the MCB provided at the back side of the control panel

Observation Table:

For Over current relay:

S. No	Current in R Phase	Current in Y Phase	Current in B Phase	Tripping Time of the Numerical Relay
1				
2				
3				

Precautions:

- Before performing any experiment make sure that earthing of your laboratory is proper and it is connected to the back side of the panel.
- Do not touch Control Panel and Rheostat at a time to avoid shock.
- 5Amp, 110Ohm rheostat should be connected in series as per connection diagram and must be fixed at maximum resistance.
- LCD placed in the front will display all the three phase current and tripping time in a single frame.
- Use Three phase variac as suggested to avoid any abnormal conditions.

RESULT: The characteristics of an over current relay are plotted.

VIVA QUESTIONS:

1) Where does Negative phase sequence relay is employed?
2) What is the operation principle of differential relay?
3) What is percentage differential relay?
4) Where Impedance relay, Reactance relay and Mho relays are employed?
5) What is meant by reach point of the relay?
6) Explain the working of an Over current relay and mention the types of it?
7) How to select the pickup value of a relay?
8) When do we use IDMT relays and DTOC relays?
9) What is SF6 Circuit Breaker?
10) What are the different types of circuit breakers?

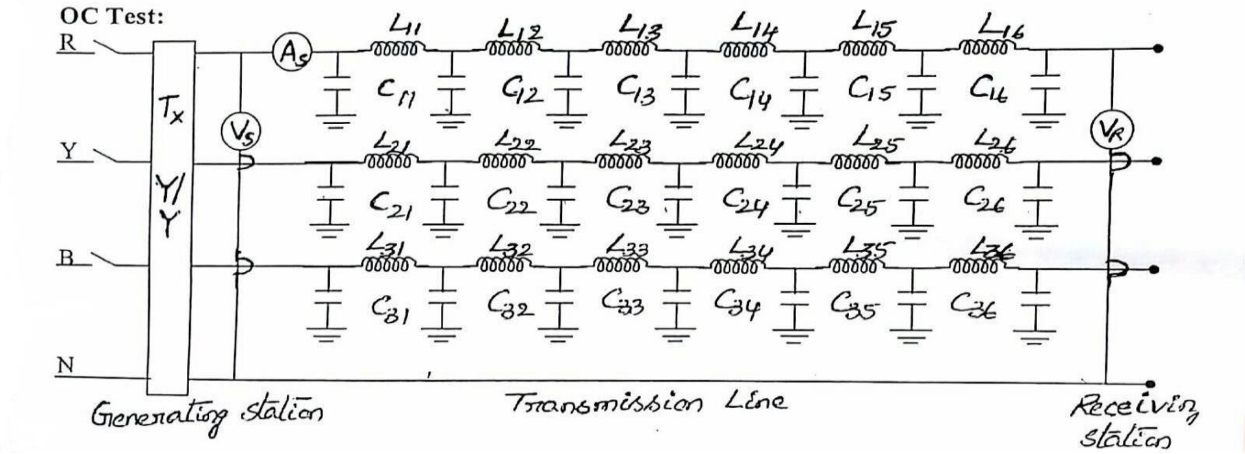
9. Determination of ABCD parameters and performance of a transmission line.

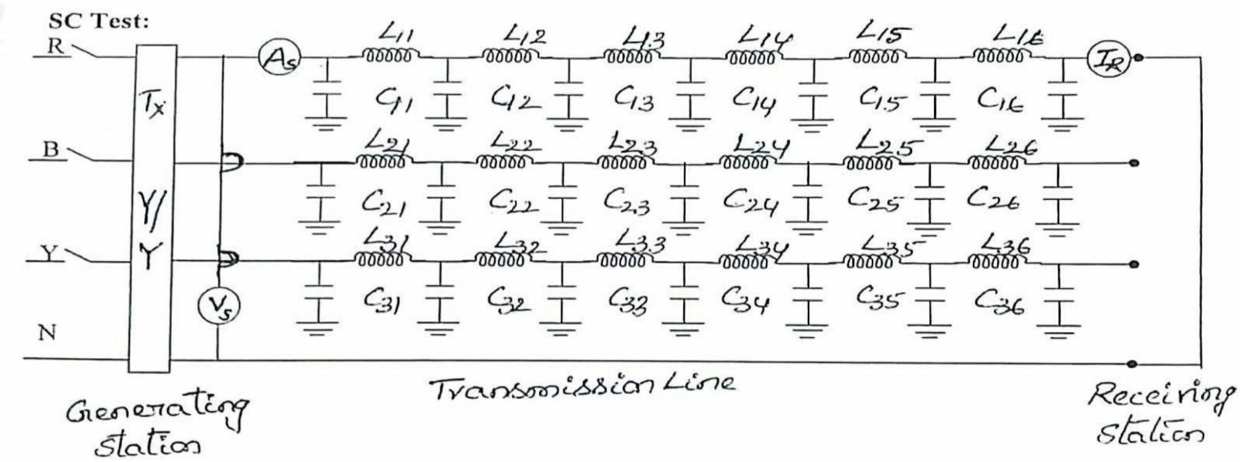
Aim: To find A B C D parameters and to prove Ferranti effect.

Apparatus:

1) Ammeters, digital 0-20A, 2
2) Voltmeters, digital 0-750v, 2
3) Generating and transformer tap position., 110v

Circuit diagram:





Theory:

The important considerations in the design and generation of a transmission line and determination of voltage drop, line loss and efficiency of transmission. These values are greatly influenced by line constants R,L,C of transmission line. Depending upon the manner in which capacitance is taken into account the OH transmission lines are classified as

1) Short transmission line: In which the length of the over head transmission line is up to about 50 km.

2) Medium transmission line: The length of over head transmission line about 50-150 km

3) Long transmission line: The length of over head transmission line is greater than 150 km

The sending end voltage (V_s) and sending end current (I_s) can be expresses as

$V_S = AV_R + BI_R$ $I_S = CV_R + DI_R$

$A = V_S/V_R| I_R=0$ $B = V_S/I_R | V_R = 0$ $C=I_S/V_R |I_R = 0$ $D= I_S/I_R| V_R = 0$

Procedure:

OC Test:

1) Connections are given as per the circuit diagram.
2) Voltmeters are connected both at receiving & sending ends.
3) Supply is given and ammeters & voltmeters are energized.
4) Note the readings for different lengths 30,60, ------------ ,180 kms.
5) Readings are tabulated and A,B&C parameters are evaluated.

SC Test :

1) connections are made as per the circuit diagram.
2) Ammeter is connected at receiving end.
3) Observe that the receiving end voltage is more than sending end voltage.
4) Tabulate the reading and corresponding parameters are calculated.

Tabular form:

OC Test:

S. No	Distance Km	V_S	V_R	I_S	$A=V_S/V_R\|I_R=0$	$C=V_S/V_R\|I_R=0$
R-Phase						
Y-Phase						
B-Phase						

SC Test:

S. No	Distance Km	V_S	V_R	I_S	$B=V_S/I_R\|V_R=0$	$D=I_S/I_R\|V_R=0$

Precautions:

1. OC &SC tests should be conducted only at 110v.
2. Readings should be taken without parallax error.

Result: The A, B, C & D parameters are calculated and the Ferranti effect is proved.

10. Determination of Earth resistance in humid and dry earth conditions.

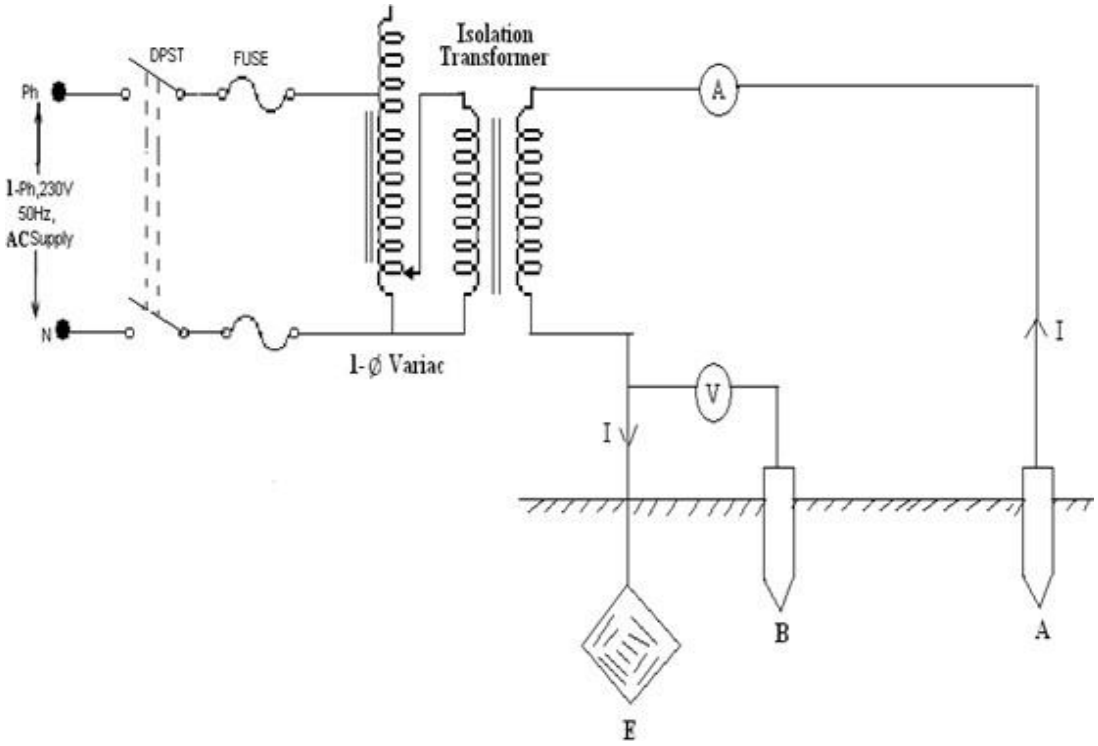
MEASUREMENT OF EARTH RESISTANCE

AIM: To measure the earth installation resistance by

a) Fall of potential method.

b) Earth tester.

(a) CIRCUIT DIAGRAM:



APPARATUS:

S.NO	NAME OF ITEM	RANGE	TYPE	QTY

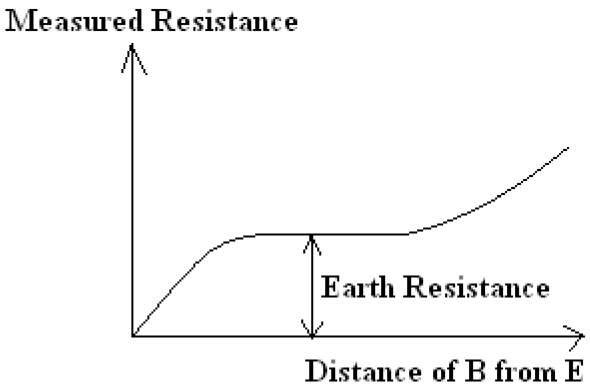
PROCEDURE:

1) Connect the circuit diagram as shown.
2) Place second auxiliary electrode B nearer to earth plate E, and first auxiliary electrode A far away from earth plate.
3) Keeping 1-Φ variac in minimum output voltage position, close DPST.
4) Apply some voltage using variac and note down voltmeter and ammeter readings
5) Changing position of second auxiliary electrode B repeat above procedure.
6) Plot the variation of earth resistance against the distance of B from E.
7) The correct value for the resistance of earth connection is that measured, when B is at such a distance that the resistance lies on the horizontal part of the curve.

TABULAR COLUMN:

S.NO	V	I	Distance between B and E	Resistance

MODEL GRAPH:



VIVA QUESTIONS:

1) What is the importance of earth installation?
2) What are the factors on which earth resistance depend?
3) How to improve earth installation resistance?
4) Which method is superior for finding earth resistance? Why?
5) What is earth megger?
6) What is the difference between earth megger and insulation megger?
7) What is the purpose of isolation transformer?
8) What is the importance of grounding?
9) Differentiate earthing and grounding.
10) Mention the value of earth resistance.