A LAB MANUAL

on

POWER SYSTEM ANALYSIS (20A02601P)

Prepared by

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Department of Electrical and Electronics Engineering

POWER SYSTEMS ANALYSIS LAB

(20A02601P)

III B.TECH II SEMESTER – EEE

List of Experiments

1. Determination of Sequence Impedances of Synchronous Machine
2. Determination of Sub-Transient Reactance of Salient Pole Synchronous Machine
3. L-G Fault Analysis on an Un Loaded Alternator
4. L-L Fault Analysis on Conventional Phases
5. Equivalent Circuit of a Three Winding Transformer
6. Y-Bus Formation Using Matlab
7. Z-Bus Formation Using Matlab
8. Gauss-Seidel Load Flow Analysis Using MATLAB
9. Newton Raphson Load Flow Analysis Using Soft Tools
10. Develop A Model for a Uncontrolled Single Area Load Frequency Control Problem and Simulate the Same Using Soft Tools

Additional Experiments:

1. Develop a Model for a Uncontrolled Two Area Load Frequency Control Problem and Simulate the Same Using Soft Tools.
2. Develop A Program to Solve Swing Equation by Point by Point Method Using Matlab

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EXPERIMENT NO: 1 **DATE:**

DETERMINATION OF SEQUENE IMPEDANCES OF SYNCHRONOUS MACHINE

Aim: To determine the positive, negative and zero sequence impedances synchronous machine.

Apparatus:

S. No	Apparatus	Range	Quantity
1.	Alternator coupled to motor drive	415V, 1KVA, 1500RPM	1
2.	RPM meter	(1-9999) Digital	1
3.	Variac	1-Ø, 230/0-270V AC	1
4.	Patch chords	-	As per requirement

Circuit Diagrams:

1 To determine positive sequence impedance of synchronous machine

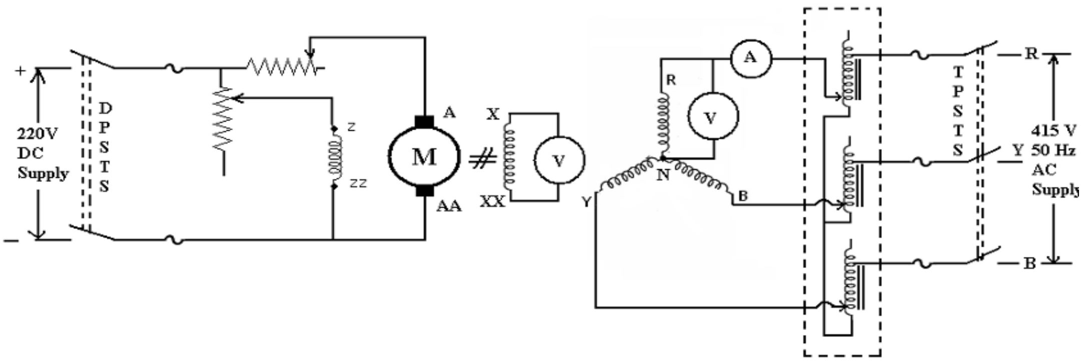


Fig-1.1 positive sequence impedance of synchronous machine

2 To determine negative sequence impedance of synchronous machine

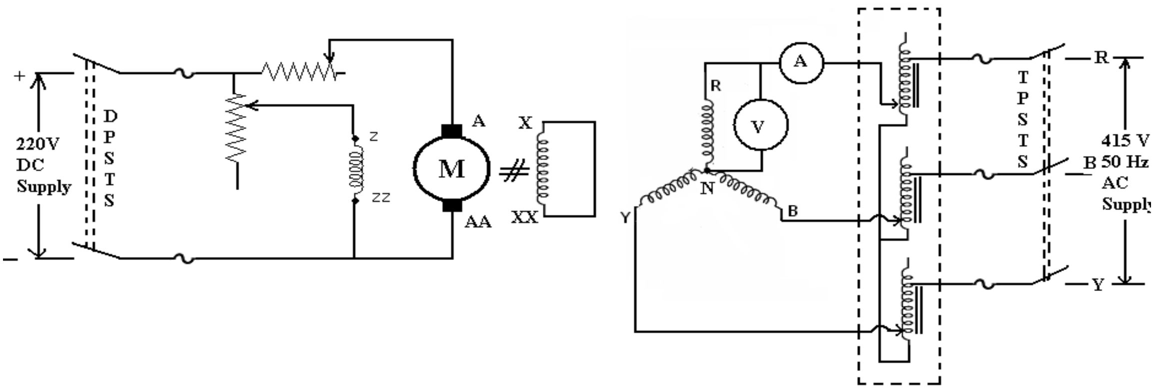


Fig-1.2 positive sequence impedance of synchronous machine

3. To determine zero sequence impedance of synchronous machine

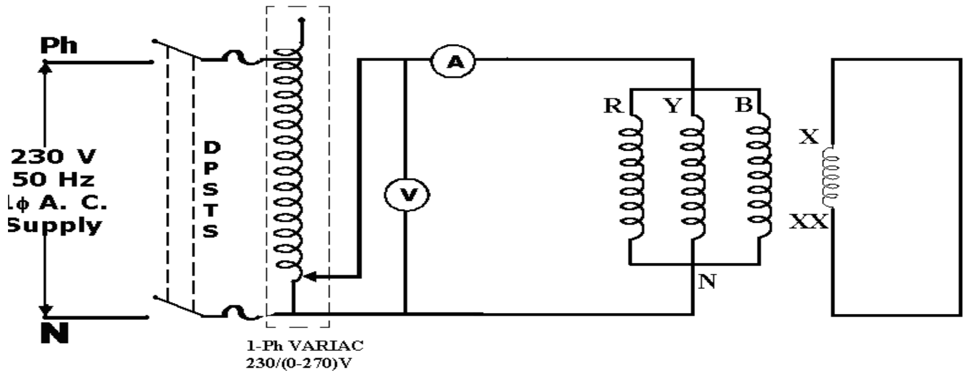


Fig- 1.3 Zero Sequence Impedance of Synchronous Machine

Procedure:

Positive Sequence:

1. Connections are made as per the circuit diagram 1
3 Observing the precautions close the DPST switch
4 Vary the armature and field rheostats of DC motor such that the synchronous machine runs at rated speed.
5 Close the TPST switch and vary three phase auto transformer in steps of 5 volts ranging from 50V – 70V are injected into the stator and note down all the meter readings in each step.
6 The positive sequence reactance is calculated by the formula $Z_1 = V_1 / I_1$

Negative Sequence:

1. Connections are made as per the circuit diagram 2
2. Observing the precautions close the DPST switch
3. Vary the armature and field rheostats of DC motor such that the synchronous machine runs at rated speed.
4. Close the TPST switch and vary three phase auto transformer in steps of 5 volts up to 70V are injected into the stator and note down all the meter readings in each step.
5. The negative sequence reactance is calculated by the formula $Z_2 = V_2 / I_2$

Zero Sequence:

1. Connections are made as per the circuit diagram 3.
2. Observing the precautions close the DPST switch.
3. Vary the single phase auto transformer in steps up to rated current of the machine and note down all the meter readings in each step.
4. The zero sequence reactance is calculated by the formula $Z_0 = V_0 /(\sqrt{3} I_0)$

Tabular column to find positive, negative and zero sequence impedances:

S.No.	Positive Sequence			Negative Sequence			zero sequence		
	V_1 (V)	I_1 (A)	Z_1 Ω	V_2 (V)	I_2 (A)	Z_2 Ω	V_0 (V)	I_0 (A)	Z_0 Ω

Model Calculations:

$Z_1 = V_1/I_1$

$Z_2 = V_2/I_2$

$Z_0 = V_0/(\sqrt{3}I_0)$

Precautions:

1. Avoid loose connections
2. Readings should be taken without parallax error
3. Auto transformer should be in minimum voltage position.

Result:

EXPERIMENT NO: 2 **DATE:**

DETERMINATION OF SUB-TRANSIENT REACTANCE OF SALIENT POLE SYNCHRONOUS MACHINE

Aim: To determine sub-transient direct axis reactance and sub transient quadrature axis reactance of salient pole synchronous machine.

Apparatus:

S. No	Apparatus	Range	Quantity
1.	Alternator coupled to motor drive	415V, 1KVA, 1500RPM	1
2.	RPM meter	(1-9999) Digital	1
3.	Variac	1-Ø, 230/0-270V AC	1
4.	Ammeter	0-2A MI	1
5.	Ammeter	0-2A MC	1
6.	Voltmeter	0-150V MI	1
7.	Patch chords	-	As per requirement

Circuit Diagram:

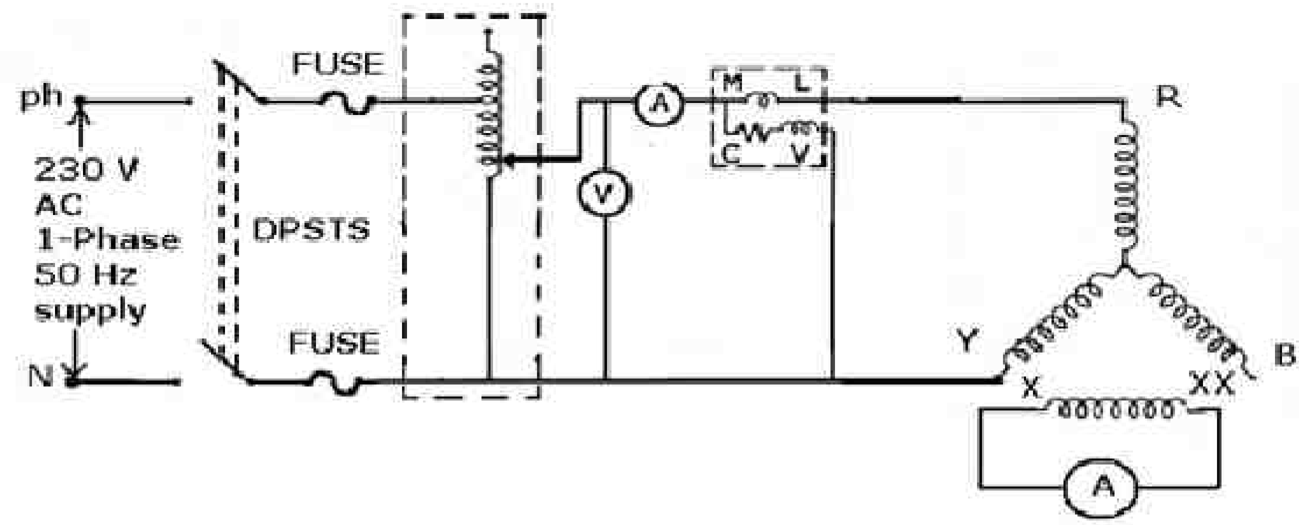


Fig- 2.1: Sub-Transient Reactance of Salient Pole Synchronous Machine

Procedure:

1. Connections are made as per the circuit diagram
2. By varying variac apply some voltage across the stator of alternator. (60, 70, 100V)
3. Twist the mechanical coupling, so that we get maximum and minimum armature currents.
4. Tabulate the readings.
5. Repeat the procedure for other three or four readings.
6. Calculate Xd’’ & Xq’’.

Tabular column for minimum field current:

S.No.	$I_{qmin(A)}$	$V_{qmin(V)}$	W_{qmin}		$Cos\theta_q$	Z_q'' Ω/ph	X_q'' Ω/ph
			Meas	Act			

Tabular column for maximum field current:

S.No.	$I_{qmax(A)}$	$V_{qmax(A)}$	W_{qmax}		$Cos\theta_d$	Z_q'' Ω/ph	X_q'' Ω/ph
			Meas	Act			

Model calculations:

For minimum value of field current at V_q min

$$Cos\theta_q = \frac{w_{d\,\min/2}}{v_{q\,\min/2} * I_{q\,\min}}$$

$$Z_q'' = \frac{Vqmin/2}{Iqmin}$$

$$X_q'' = z_q'' \sin\theta_q$$

For Maximum value of field current at V_d max

$$Cos\theta_d = \frac{w_{d\,\max/2}}{\frac{v_{q\,\max}}{2} * I_{d\,\max}}$$

$$Z_q'' = \frac{Vqmax/2}{Idmax}$$

$$X_d'' = z_d'' \sin\theta_d$$

Precautions:

1. Avoid loose connections
2. Readings should be taken without parallax error
3. Auto transformer should be in minimum position.

Result:

EXPERIMENT NO: 3 **DATE:**

L-G FAULT ANALYSIS ON AN UN LOADED ALTERNATOR

AIM: To determine the fault current on an alternator under LG fault conditions

Apparatus Required:

S.No	Name of the apparatus	Range	Quantity
1	Alternator coupled to motor drive	415V, 1KVA, 1500RPM	1
2	RPM meter	(1-9999) Digital	1
3	Variac	1-Ø, 230/0-270V AC	1
4	Ammeter	(0-2A) MI	1
5	Voltmeter	(0-600V) MI	1
6	Patch chords	-	As per requirement

L-G Fault:

Circuit Diagram:

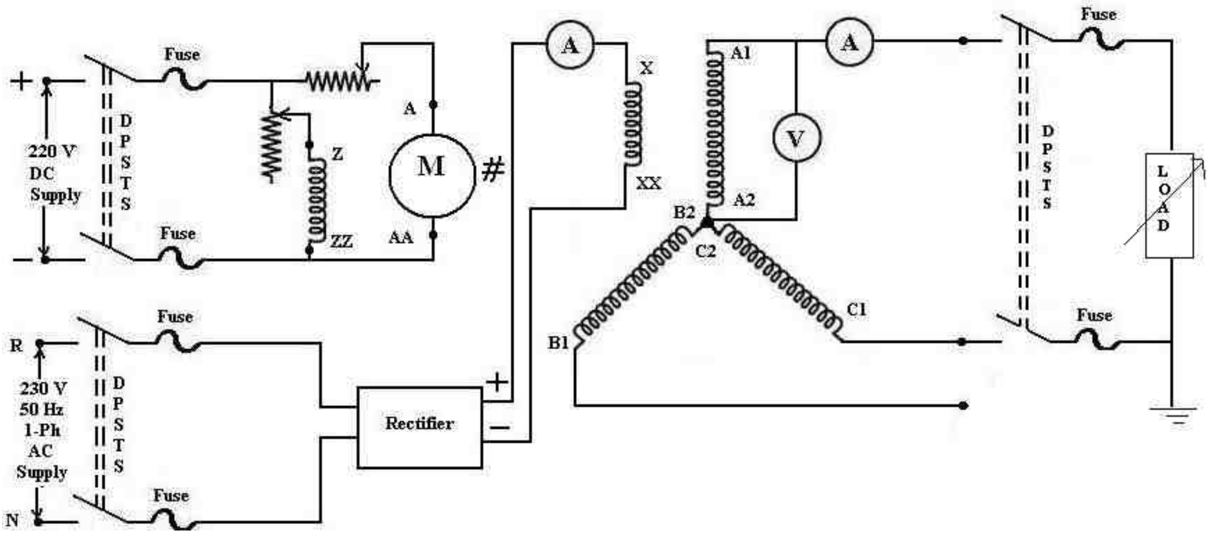


Fig- 3.1: L-G Fault Analysis on An Un Loaded Alternator

Procedure:

1. Connect the circuit as per the circuit diagram of L-G fault
2. Observing the precautions, close the $DPST_1$ switch
3. Field rheostat of motor is adjusted such that the rated speed of the synchronous machine is obtained.
4. Close the $DPST_2$ switch and apply 230V by varying the rectifier and load is applied in steps up to rated current and note down the corresponding current & voltage readings.
5. Tabulate current and voltage readings.

Tabular Column to find L-G Fault Current:

S.no	Current I	Voltage V	Fault Impedance Z_f	Fault current I_f
	(Amps)	(Volts)	(Ohms)	(Amps)

Model Calculations:

L-G Fault:

Fault current=$3I_a^0$, $I_a = \frac{3Ea}{Z1+Z2+Z0+3ZF}$

Fault impedance $Z_f = \frac{V}{I}$

Fault current=

Precautions:

1. Avoid loose connections and wrong connections.
2. Keep the field Rheostat of motor in minimum resistance position and armature rheostat of motor in maximum resistance position.
3. DPST switch must be kept open initially.
4. Initially rectifier must be in minimum position.

Result:

EXPERIMENT NO: 4 **DATE:**

L-L FAULT ANALYSIS ON CONVENTIONAL PHASES

AIM: To determine the fault current on an alternator under L-L fault conditions

Apparatus Required:

S.No	Name of the apparatus	Range	Quantity
1	Alternator coupled to motor drive	415V, 1KVA, 1500RPM	1
2	RPM meter	(1-9999) Digital	1
3	Variac	1-Ø, 230/0-270V AC	1
4	Ammeter	(0-2A) MI	1
5	Voltmeter	(0-600V) MI	1
6	Patch chords	-	As per requirement

Circuit Diagram:

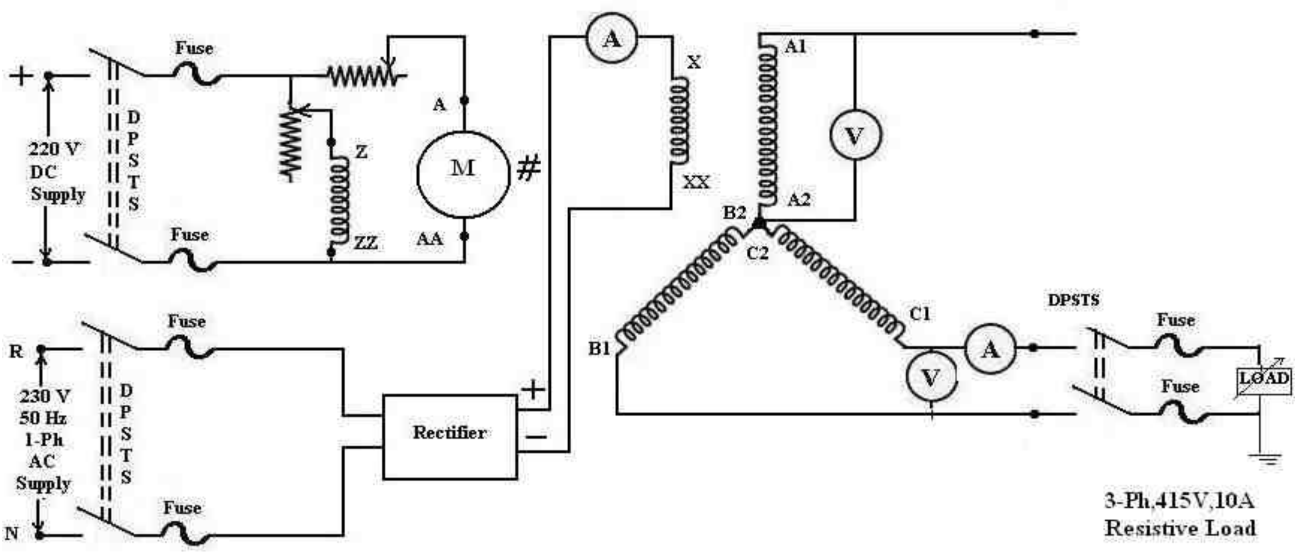


Fig- 4.1: L-L Fault

Procedure:

1. Connect the circuit as per the circuit diagram of L-L fault.
2. Observe the precautions, close the close the $DPST_1$ switch.
3. Adjust the field rheostat of dc motor such that the rated speed of the synchronous machine is obtained.
4. Close the $DPST_1$ switch and apply the field voltage 415V by varying the rectifier.
5. Close the $DPST_2$ switch and 3- Ph load is varied in steps up to rated current.
6. Tabulate current and voltage readings.

Tabular Column to find L-L Fault Current:

S.no	Current I	Voltage V	Fault Impedance Z_f	Fault current I_f or I_b
	(Amps)	(Volts)	(Ohms)	(Amps)

Model Calculations:

L-L Fault: Fault impedance $Z_f = \frac{V}{I}$

$I_a = \frac{Ea}{Z_1 + Z_2 + Z_f} =$

$I_f = \sqrt{3}\, I_a =$

Precautions:

1. Avoid loose connections and wrong connections.
2. Keep the field Rheostat of motor in minimum resistance position and armature rheostat of motor in maximum resistance position.
3. DPST switch must be kept open initially.
4. Initially rectifier must be in minimum position.

Result:

EXPERIMENT NO: 5 **DATE:**

EQUIVALENT CIRCUIT OF A THREE WINDING TRANSFORMER

Aim: To draw the Equivalent Circuit of a Three Winding Transformer by conducting Open circuit and Short Circuit Tests.

Apparatus:

- Three Winding Transformer Trainer Set up
- Patch Cards

Name Plate Details:

Capacity	1 KVA
Primary	0-230VAC
Secondary-1	0-110VAC
Secondary-2	0-64VAC

Circuit Diagram:

For Open Circuit Test (Primary excited & both secondary's are open)

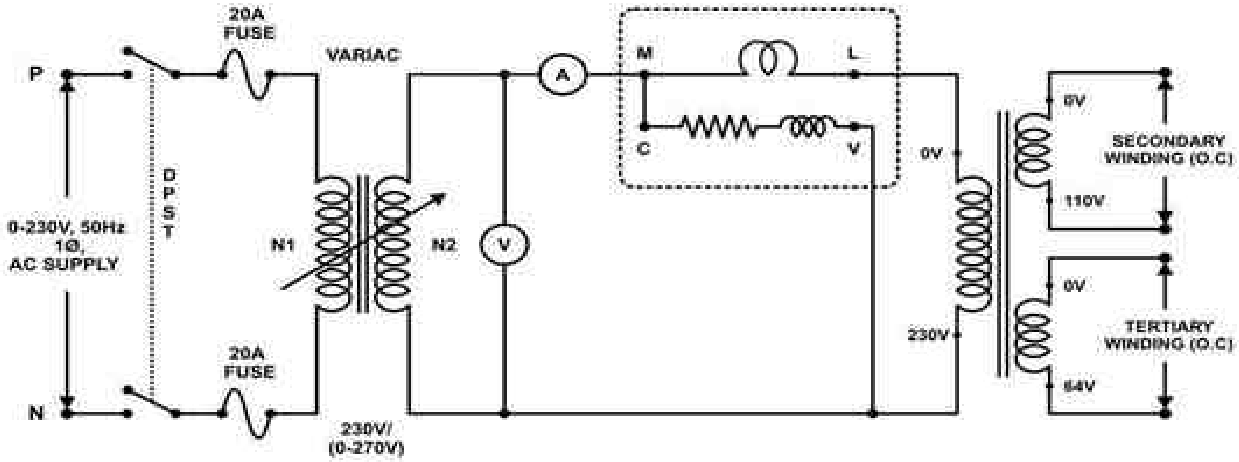


Fig- 5.1: Three Winding Transformer

Procedure:

1. Connections are made as per the above Diagram-1, Connect digital Ammeter , Voltmeter & Power meter as per diagram
2. Keep the dimmer stat in zero (minimum) position.
3. Switch ON the main MCB.
4. Slowly apply the rated input voltage i.e., 220V to the primary of the transformer by varying the dimmer stat.
5. Note down the readings of Voltmeter, Ammeter and Wattmeter.

Tabular Column:

Voltage (V)	Current (A)	Power (W)

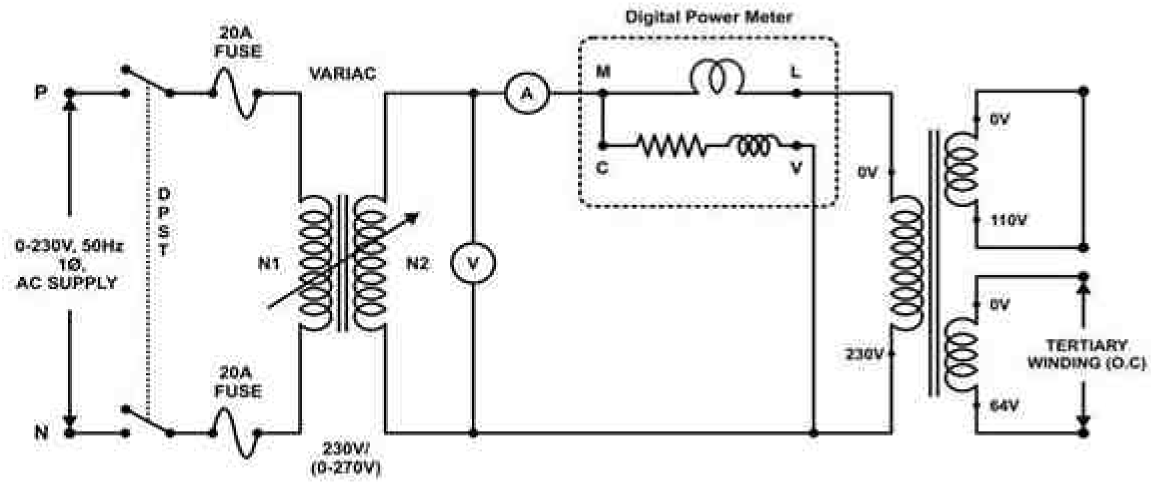
Theoretical Calculations:

Power factor, $COS\O_0 = W_0 / V_0 * I_0$

Core loss resistance, $R_0 = V_0 / I_0 * COS\O_0$

Magnetizing Reactance, $X_0 = V_0 / I_0 * Sin\O_0$

For Short Circuit Test-1 (Primary excited & Secondary Shorted & tertiary winding Open)



Procedure:

1. Connections are made as per the above connection diagram
2. Short Circuit the Secondary winding of the transformer .
3. Keep the dimmer stat in zero (minimum) position.
4. Switch ON the main MCB.
5. Gradually increase the voltage up to the transformer rated current (5A) by varying the dimmer stat.
6. Note down the readings of Voltmeter, Ammeter and Wattmeter.

Tabular Column:

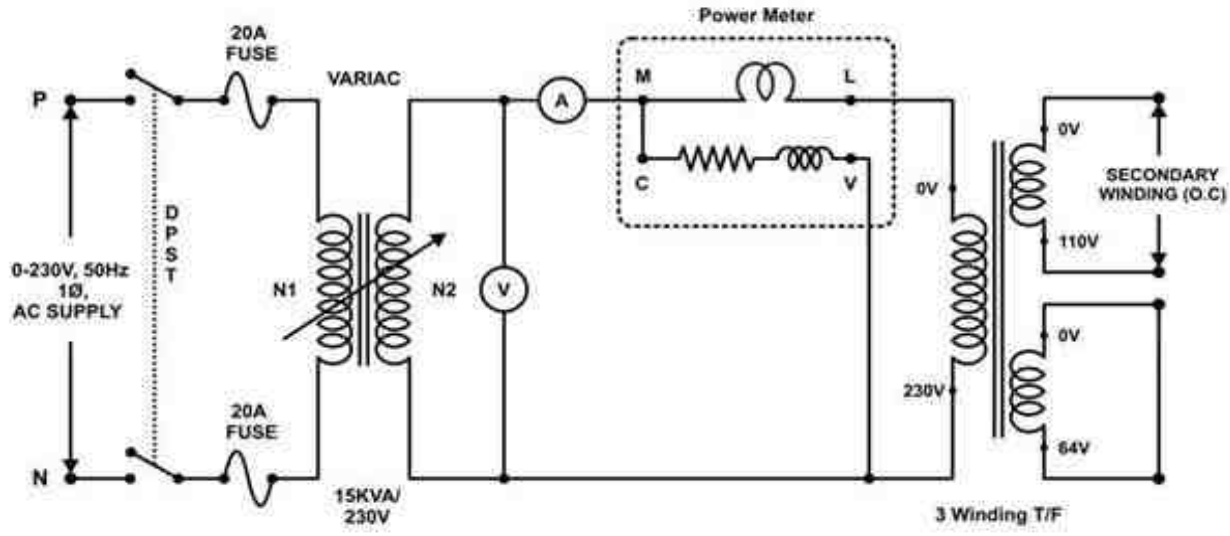
Voltage (V)	Current (A)	Power (W)

Theoretical Calculations:

$$Z_{12} = V_1/ I_1 =$$

$$r_{12} = P_1/ I_1^2 =$$

Short Circuit Test-2 (Primary excited & Secondary (110V) open & tertiary winding (64V) Shorted



Procedure:

1. Connections are made as per the above connection diagram
2. Short Circuit the Secondary winding (64v) of the transformer .
3. Keep the dimmer stat in zero (minimum) position.
4. Switch ON the main MCB.
5. Gradually increase the voltage up to the transformer rated current (5A) by varying the dimmer stat.
6. Note down the readings of Voltmeter, Ammeter and Wattmeter

Tabular Column:

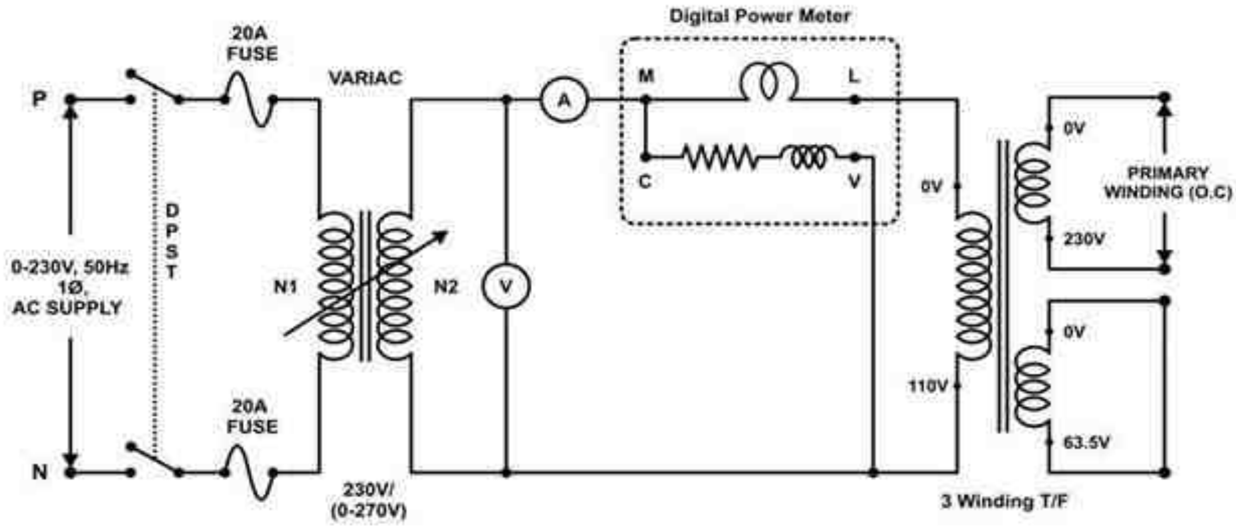
Voltage (V)	Current (A)	Power (W)

Theoretical Calculations:

$$Z_{13} = V_2/ I_2 =$$

$$r_{13} = P_2/ I_2^2 =$$

Short Circuit Test-3 (Secondary (110v) excited & Primary open & tertiary winding (64V) Shorted



Procedure:

1. Connections are made as per the above connection diagram
2. Short Circuit the Secondary winding (64v) of the transformer .
3. Keep the dimmer stat in zero (minimum) position.
4. Switch ON the main MCB.
5. Gradually increase the voltage up to the transformer rated current (5A) by varying the dimmer stat. (note do not apply more than 110VAC)
6. Note down the readings of Voltmeter, Ammeter and Wattmeter

Tabular Column:

Voltage (V)	Current (A)	Power (W)

Theoretical Calculations:

$$Z_{23} = V_3 / I_3 =$$

$$R_{23} = P_3 / I_3^2 =$$

Transferring both values to primary side

$$Z'_{23} = Z_{23} \times \left(\frac{N_1}{N_2}\right)^2 =$$

$$\gamma'_{23} = \gamma_{23} \times \left(\frac{N_1}{N_2}\right)^2 =$$

The equivalent circuit resistance r_1, r_2, r_3 are

$$r_1 = \frac{1}{2}(r_{12} + r_{13} - r'_{23})$$

$$=$$

$$r_2 = \frac{1}{2}(r_{12} + r'_{23} - r_{13})$$

$$=$$

$$r_3 = \frac{1}{2}(r'_{23} + r_{13} - r_{12})$$

Leakage impedance referred to primary side.

$$Z_1 = \frac{1}{2}(Z_{12} + Z_{13} - Z'_{23})$$

$$=$$

$$Z_2 = \frac{1}{2}(Z_{12} + Z'_{23} + Z_{13})$$

$$=$$

$$Z_3 = \frac{1}{2}(Z_{13} + Z'_{23} - Z_{12})$$

Leakage Reactances referred to primary side,

$$X_1 = \sqrt{z_1^2 - r_1^2}$$

$$=$$

$$X_2 = \sqrt{z_2^2 - r_2^2}$$

$$=$$

$$X_3 = \sqrt{z_3^2 - r_3^2}$$

Leakage impedance referred to primary winding,

$$X_1 = r_1 + j\,x_1 =$$

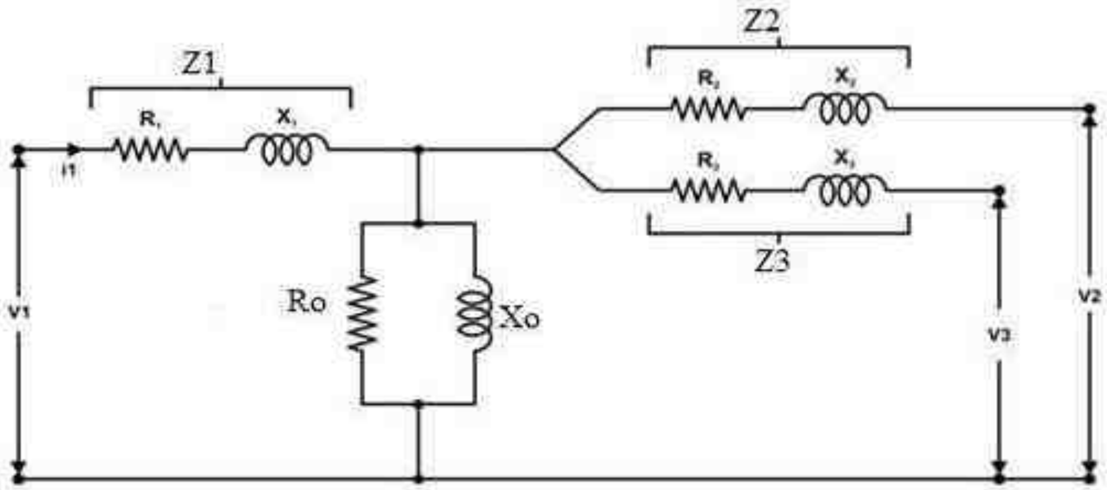
Leakage impedance of secondary winding referred to primary side,

$$Z_2 = r_2 + j\,x_2 \left(\frac{N_2}{N_1}\right)^2$$

Leakage impedance of tertiary winding referred to primary side,

$$Z_3 = r_3 + j\, x_3 \left(\frac{N_2}{N_1}\right)^2$$

From the above values draw the Equivalent circuit, as below



Result:

EXPERIMENT NO: 6 **DATE:**

Y-BUS FORMATION USING MATLAB

Problem : Write a MATLAB program to develop the bus admittance matrix

Aim: To Write a MATLAB program to develop the bus admittance matrix for a given network.

CIRCUIT DIAGRAM:

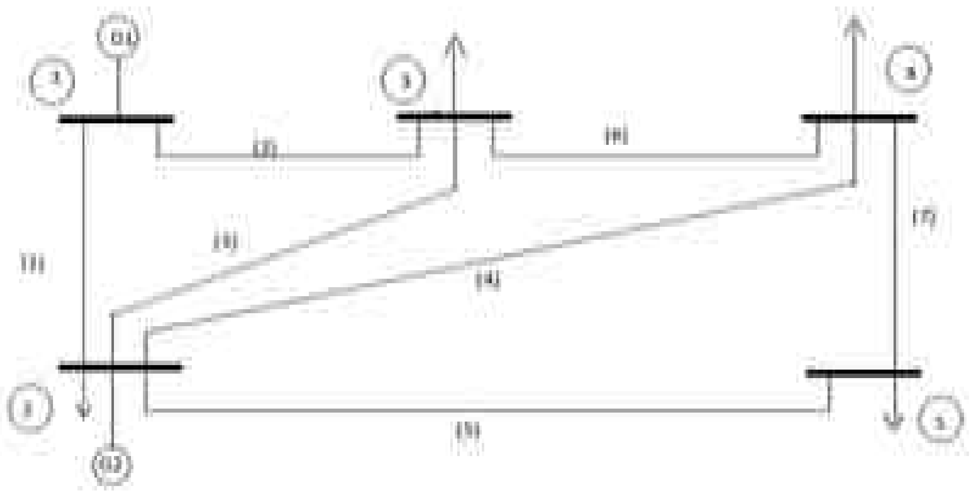


Fig. Machine 5 - Bus System

Table: Bus Classification

Type of Bus	No. of Buses
Slack Bus	1
Generator Bus	1
Load Bus system	3

Table: Impedances and Line charging admittance for the IEEE 5-bus system

MATLAB Program for YBUS with shunt capacitance of the power system

```
%                      Line code
%       Bus bus   R      X     1/2 B    = 1 for lines
%       nl  nr  p.u.   p.u.   p.u.     > 1 or < 1 tr. tap at bus nl
linedata=[ 1      2        0.02     0.06     0.03
           1      3        0.08     0.24     0.025
           2      3        0.06     0.18     0.02
           2      4        0.06     0.18     0.02
           2      5        0.04     0.12     0.015
           3      4        0.01     0.03     0.01
           4      5        0.08     0.24     0.025    ];
j=sqrt(-1);
nl=linedata(:,1);  nr=linedata(:,2);
```

```
R=linedata(:,3);  X=linedata(:,4);
BC=j*linedata(:,5);
a=linedata(:,6);
nbr=length(linedata(:,1)); nbus=max(max(nl),max(nr));
Z=R+j*X;
Y=ones(nbr,1)./Z;
for n=1:nbr
   if a(n)<=0 a(n)=1;
   else end
   Ybus=zeros(nbus,nbus);
for k=1:nbr;
       Ybus(nl(k),nr(k))=Ybus(nl(k),nr(k))-Y(k)/a(k)
       Ybus(nr(k),nl(k))=Ybus(nl(k),nr(k))
end
end
for n=1:nbus
   for k=1:nbr
      if nl(k)==n
         Ybus(n,n)= Ybus(n,n)+Y(k)/(a(k)^2)+BC(k)
      else  if nr(k)==n
            Ybus(n,n)=Ybus(n,n)+Y(k)+BC(k)
     else, end
      end
   end
end
```

Output:

Ybus=

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

Precautions:

1. Check and write the program without errors.
2. Properly turn on and turn off your pc

Results:

EXPERIMENT NO: 7 **DATE:**

Z-BUS FORMATION USING MATLAB

Problem: Write a MATLAB program to develop the bus impedance matrix

Aim: To Write a MATLAB program to develop the bus impedance matrix for a given network.

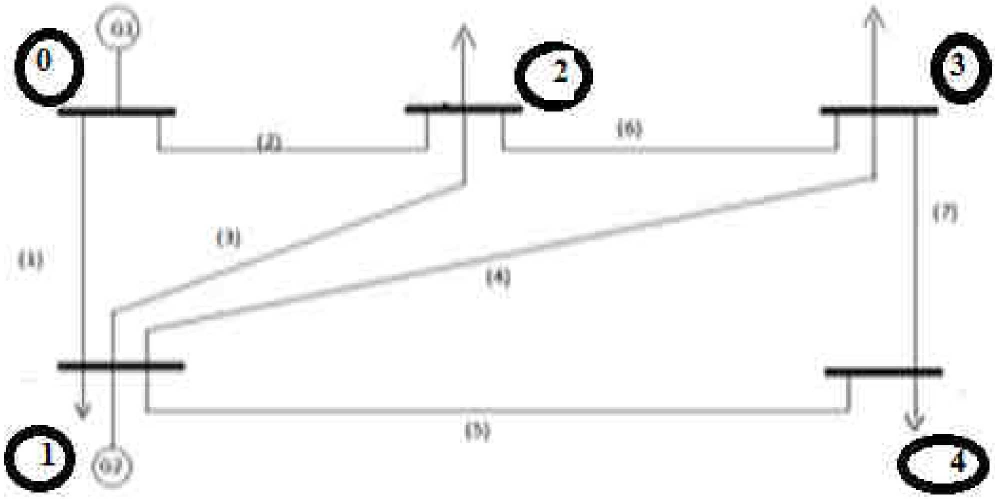


Fig. -Machine 5-Bus System

Table: Bus Classification

Type of Bus	No. of Buses
Slack Bus	1
Generator Bus	2
Load Bus system	3

Table: Impedances and Line charging admittance for the IEEE 5-bus syst

MATLAB Program for the formation of Z_{bus} without shunt capacitance of the power system

```
%*Formation of Zbus without shunt capacitance of the power system*%
linedata=[ 0    1  0.02    0.06
           0    2  0.08    0.24
           1    2  0.06    0.18
           1    3  0.06    0.18
           1    4  0.04    0.12
           2    3  0.01    0.03
           3    4  0.08    0.24];
% function [Zbus] = zbuild(linedata)
nl = linedata(:,1);
nr = linedata(:,2);
```

```
R = linedata(:,3);
X = linedata(:,4);
nbr=length(linedata(:,1)); nbus = max(max(nl), max(nr));
for k=1:nbr
if R(k) == inf | X(k) ==inf
    R(k) = 99999999; X(k) = 99999999;
else, end
end

ZB = R + j*X;
Zbus = zeros(nbus, nbus);
tree=0;  %%%%new
% Adding a branch from a new bus to reference bus 0
for I = 1:nbr
  ntree(I) = 1;
if nl(I) == 0 | nr(I) == 0
if nl(I) == 0      n = nr(I);
elseif nr(I) == 0  n = nl(I);
end
if abs(Zbus(n, n)) == 0   Zbus(n,n) = ZB(I);tree=tree+1; %%new
else Zbus(n,n) = Zbus(n,n)*ZB(I)/(Zbus(n,n) + ZB(I));
end
             ntree(I) = 2;
else,end
end

% Adding a branch from new bus to an existing bus
while tree < nbus  %%% new

for n = 1:nbus
     nadd = 1;
if abs(Zbus(n,n)) == 0
for I = 1:nbr
if nadd == 1;
if nl(I) == n | nr(I) == n
if nl(I) == n      k = nr(I);
elseif nr(I) == n  k = nl(I);
end
if abs(Zbus(k,k)) ~= 0
for m = 1:nbus
if m ~= n
                        Zbus(m,n) = Zbus(m,k);
                        Zbus(n,m) = Zbus(m,k);
else, end
end
                      Zbus(n,n) = Zbus(k,k) + ZB(I); tree=tree+1; %%new
                      nadd = 2;  ntree(I) = 2;
else, end
else, end
else, end
end
else, end
end
 end%%%%%%new

% Adding a link between two old buses
for n = 1:nbus
for I = 1:nbr
if ntree(I) == 1
if nl(I) == n | nr(I) == n
if nl(I) == n     k = nr(I);
elseif nr(I) == n k = nl(I);
end
            DM = Zbus(n,n) + Zbus(k,k) + ZB(I) - 2*Zbus(n,k);
for jj = 1:nbus
```

```
                AP = Zbus(jj,n) - Zbus(jj,k);
for kk = 1:nbus
                     AT = Zbus(n,kk) - Zbus(k, kk);
                     DELZ(jj,kk) = AP*AT/DM;
end
end
                Zbus = Zbus - DELZ;
                ntree(I) = 2;
else,end
else,end
end
end
  Zbus
```

Output:

Zbus =

[0.0169 + 0.0506i   0.0126 + 0.0377i   0.0134 + 0.0403i   0.0157 + 0.0471i
0.0126 + 0.0377i   0.0297 + 0.0891i   0.0263 + 0.0789i   0.0171 + 0.0514i
0.0134 + 0.0403i   0.0263 + 0.0789i   0.0317 + 0.0951i   0.0195 + 0.0586i
0.0157 + 0.0471i   0.0171 + 0.0514i   0.0195 + 0.0586i   0.0437 + 0.1310i];

Result:

EXPERIMENT NO: 8 **DATE:**

Gauss-Seidel load flow analysis using MATLAB

Problem: for the IEEE-5 bus system shown in figure, obtain the complete load flow solution using Gauss-seidal load flow analysis method using MATLAB.

Aim: To develop a computer program to solve the set of non linear load flow equations using Gauss seidal load flow algorithm.

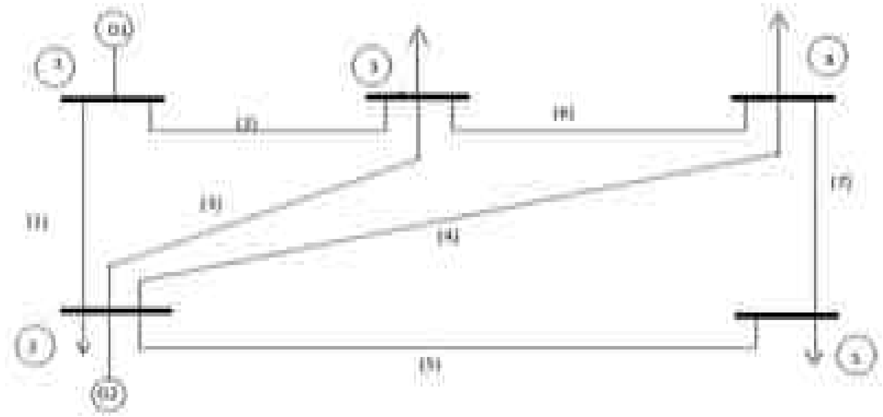


Fig. Machine 5 - Bus System

Table: Bus Classification

Type of Bus	No. of Buses
Slack Bus	1
Generator Bus	1
Load Bus system	3

Table: Impedances and Line charging admittance for the IEEE 5-bus system

Bus Code p-q	Impedance Zpq	Line Charging Ypq/2	Off nominal Tap setting

Program

```
clc
basemva=100; accuracy=0.001; accel=1.4;
maxiter=100;
%                    Line code
%        Bus bus   R      X     1/2 B   = 1 for lines
%        nl  nr  p.u.   p.u.   p.u.     > 1 or < 1 tr. tap at bus nl
linedata=[ 1 2 0.02 0.06 0.03  1
         1 3 0.08 0.24 0.025 1
         2 3 0.06 0.18 0.02  1
         2 4 0.06 0.18 0.02  1
         2 5 0.04 0.12 0.015 1
         3 4 0.01 0.03 0.01  1
         4 5 0.08 0.24 0.025 1];
%IEEE5-BUS  TEST SYSTEM
%bus bus voltage  angle   load    generator   static mvar
%no code   mag    degree mw mvar   mw mvar   qmin qmax +qc/-q1
busdata=[1  1 1.06 0 0 0 0 0 0 0    0
        2 2 1.0 0 20 10 40 30 0 0 0
        3 0 1.0 0 45 15 0 0 0 0   0
        4 0 1.0 0 40 5 0 0 0 0    0
        5 0 1.0 0 60 10 0 0 0 0   0];
lfybus
lfgauss
busout
lineflow
```

Output:

Ybus=

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

Power Flow Solution by Gauss-Seidel Method
Maximum Power Mismatch = 0.000406446
No. of Iterations = 11

Bus No.	Voltage Mag.	Angle Degree	------Load------ MW	Mvar	---Generation--- MW	Mvar	Injected Mvar
1	1.060	0.000	0.000	0.000	131.091	90.823	0.000
2	1.000	-2.061	20.000	10.000	40.000	-61.605	0.000

3	0.987	-4.636	45.000	15.000	0.000	0.000	0.000
4	0.984	-4.957	40.000	5.000	0.000	0.000	0.000
5	0.972	-5.765	60.000	10.000	0.000	0.000	0.000
Total			**165.000**	**40.000**	**171.091**	**29.218**	**0.000**

Line Flow and Losses

--Line--		**Power at bus & line flow**			**--Line loss--**		**Transformer**
from	**to**	**MW**	**Mvar**	**MVA**	**MW**	**Mvar**	**tap**
1		131.091	90.823	159.479			
	2	89.323	73.998	115.992	2.486	1.086	
	3	41.788	16.821	45.046	1.518	-0.693	
2		20.000	-71.605	74.346			
	1	-86.837	-72.912	113.388	2.486	1.086	
	3	24.471	-2.518	24.601	0.359	-2.871	
	4	27.713	-1.724	27.767	0.461	-2.554	
	5	54.660	5.558	54.942	1.215	0.729	
3		-45.000	-15.000	47.434			
	1	-40.270	-17.514	43.913	1.518	-0.693	
	2	-24.112	-0.352	24.114	0.359	-2.871	
	4	19.396	2.862	19.606	0.040	-1.823	
4		-40.000	-5.000	40.311			
	2	-27.253	-0.830	27.265	0.461	-2.554	
	3	-19.356	-4.685	19.915	0.040	-1.823	
	5	6.598	0.519	6.619	0.043	-4.652	
5		-60.000	-10.000	60.828			
	2	-53.445	-4.829	53.663	1.215	0.729	
	4	-6.555	-5.171	8.349	0.043	-4.652	
Total loss					**6.122**	**-10.778**	

Result:

EXPERIMENT NO: 9 **DATE:**

NEWTON RAPHSON LOAD FLOW ANALYSIS USING SOFT TOOLS

Problem: for the IEEE-5 bus system shown in figure, obtain the complete load flow solution using Newton Raphson load flow analysis method using MATLAB.

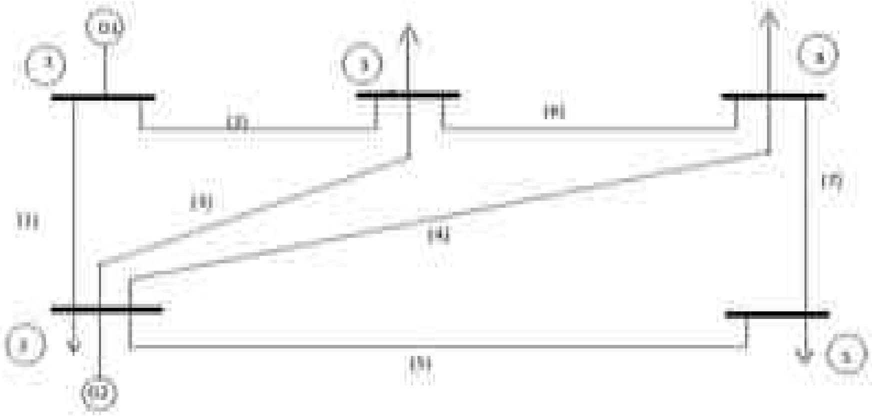


Fig-9.1 Machine 5 - Bus System

Table: Bus Classification

Type of Bus	**No. of Buses**
Slack Bus	1
Generator Bus	1
Load Bus system	3

Table: Impedances and Line charging admittance for the IEEE 5-bus system

Bus Code **p-q**	**Impedance** **Zpq**	**Line Charging** **Ypq/2**	**Off nominal** **Tap setting**

Table: Scheduled generation and loads and assumed bus voltages for IEEE 5-bus system

Bus No	Assumed bus voltage	Generation		Load	
		MW	Mvar	MW	Mvar

Aim: To develop a computer program to solve the set of non linear load flow equations using Newton Rhapshon load flow Method.

Program

```
clear
basemva=100; accuracy=0.001; accel=1.4;
maxiter=100;
%                    Line code
%      Bus bus   R     X     1/2 B   = 1 for lines
%      nl  nr  p.u.   p.u.   p.u.    > 1 or < 1 tr. tap at bus nl
linedata=[ 1 2 0.02 0.06 0.03  1
     1 3 0.08 0.24 0.025 1
     2 3 0.06 0.18 0.02  1
     2 4 0.06 0.18 0.02  1
     2 5 0.04 0.12 0.015 1
     3 4 0.01 0.03 0.01  1
     4 5 0.08 0.24 0.025 1];
%IEEE5-BUS  TEST SYSTEM
%bus bus voltage  angle   load    generator   static mvar
%no code   mag    degree mw mvar   mw mvar   qmin qmax +qc/-q1
busdata=[1 1 1.06          0 0 0 0 0 0 0    0
    2 2 1.0      0 20 10 40 30 0 0 0
    3 0 1.0      0 45 15 0 0 0 0   0
    4 0 1.0      0 40 5 0 0 0 0    0
    0 1.0 0      60 10 0 0 0 0     0];
lfybus
lfnewton
busout
lineflow
```

Result:

Ybus=

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

Power Flow Solution by Newton-Raphson Method
Maximum Power Mismatch = 7.81261e-005
No. of Iterations = 3

Bus No.	Voltage Mag.	Angle Degree	Load MW	Load Mvar	Generation MW	Generation Mvar	Injected Mvar
1	1.060	0.000	0.000	0.000	131.114	90.815	0.000
2	1.000	-2.061	20.000	10.000	40.000	-61.607	0.000
3	0.987	-4.637	45.000	15.000	0.000	0.000	0.000
4	0.984	-4.957	40.000	5.000	0.000	0.000	0.000
5	0.972	-5.765	60.000	10.000	0.000	0.000	0.000
Total			**165.000**	**40.000**	**171.114**	**29.208**	**0.000**

Line Flow and Losses

Line from	Line to	Power at bus & line flow MW	Mvar	MVA	Line loss MW	Line loss Mvar	Transformer tap
1		131.114	90.815	159.494			
	2	89.331	73.995	115.997	2.486	1.087	
	3	41.791	16.820	45.049	1.518	-0.692	
2		20.000	-71.607	74.348			
	1	-86.846	-72.908	113.392	2.486	1.087	
	3	24.473	-2.518	24.602	0.360	-2.871	
	4	27.713	-1.724	27.767	0.461	-2.554	
	5	54.660	5.558	54.942	1.215	0.729	
3		-45.000	-15.000	47.434			
	1	-40.273	-17.513	43.916	1.518	-0.692	
	2	-24.113	-0.352	24.116	0.360	-2.871	
	4	19.386	2.865	19.597	0.040	-1.823	
4		-40.000	-5.000	40.311			
	2	-27.252	-0.831	27.265	0.461	-2.554	
	3	-19.346	-4.688	19.906	0.040	-1.823	
	5	6.598	0.518	6.619	0.043	-4.652	
5		-60.000	-10.000	60.828			
	2	-53.445	-4.829	53.663	1.215	0.729	
	4	-6.555	-5.171	8.349	0.043	-4.652	
Total loss					**6.122**	**-10.777**	

EXPERIMENT NO: 10 **DATE:**

DEVELOP A MODEL FOR A UNCONTROLLED SINGLE AREA LOAD FREQUENCY CONTROL PROBLEM AND SIMULATE THE SAME USING SOFT TOOLS.

SIMULINK model for a single area load frequency problem

Problem: Develop a SIMULINK model for single area power system to investigate the load frequency dynamics for a step load disturbance in the area. The parameters of the single area power system are as follows.

T_g=0.3sec, K_g=20

T_t= 0.5sec, K_t=.2

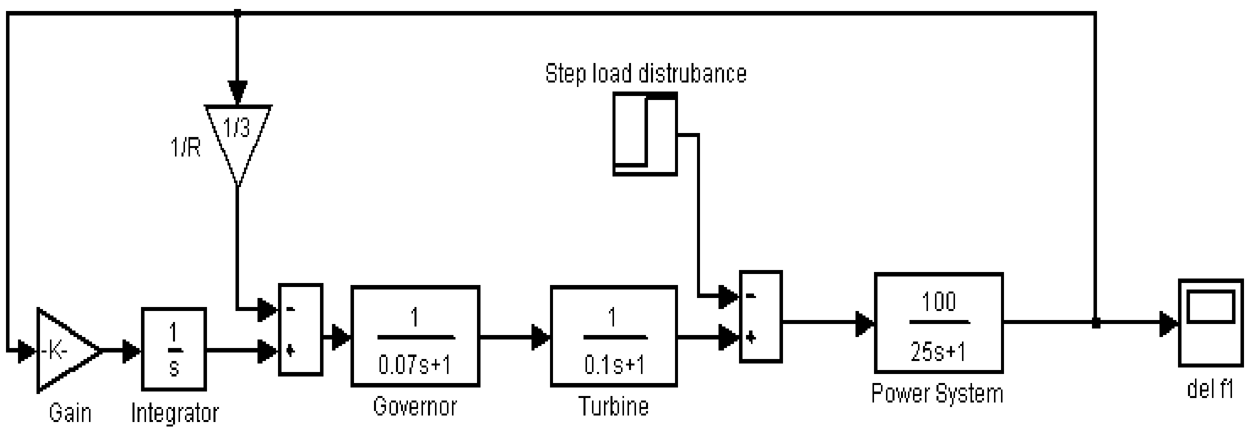
K_{ps}=100, T_{ps}=25sec, R=3

Aim: To develop a SIMULINK model for a single area power system to study the load frequency dynamics.

Load Frequency Control: Frequency regulation is the method to control the system frequency by maintaining a continuous balance between the generation and load demand within a control area. Whenever the power system is subjected to disturbances i.e. change in generation or load, the mismatch between the load and generation causes the system frequency to change. The off-nominal frequency can directly impact on power system operation and system reliability.

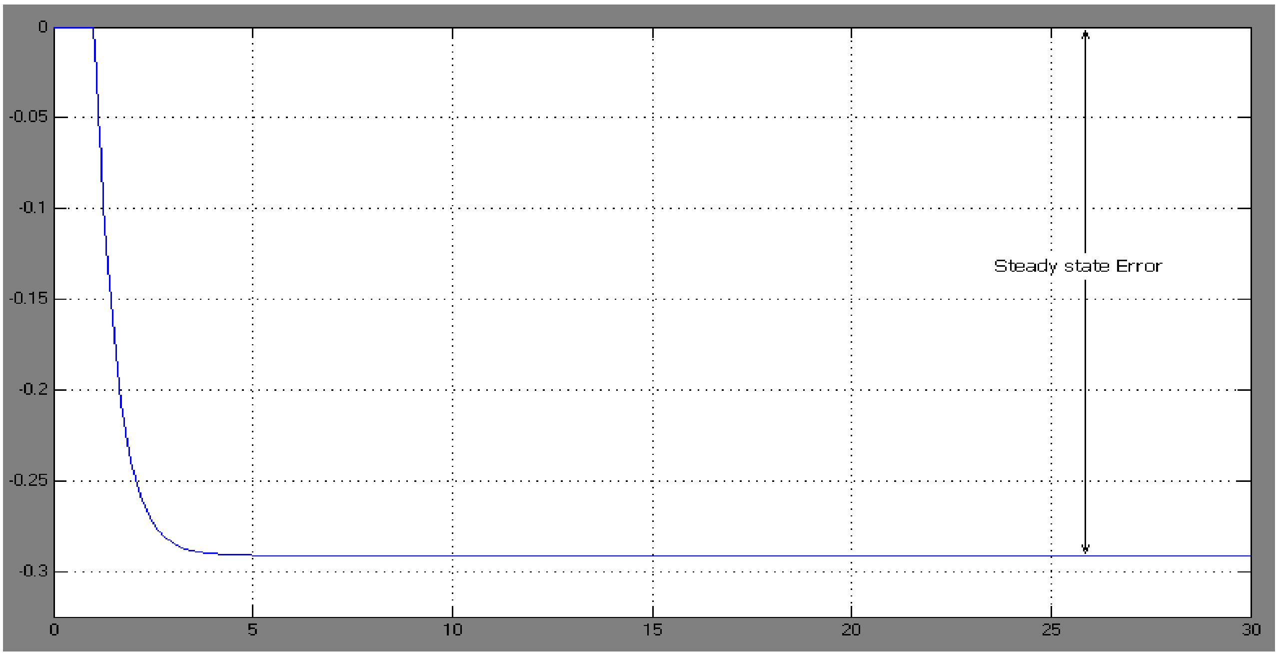
AGC Controller: The function of the controller is to generate, raise or lower the command signals to the speed gear changer of the prime mover in response to the area control error (ACE) signal by performing mathematical manipulations of amplification and integration of this signal and manipulated the generation to minimize the mismatch between load demand and generation.

SIMULINK Block diagram representation of single area power system.

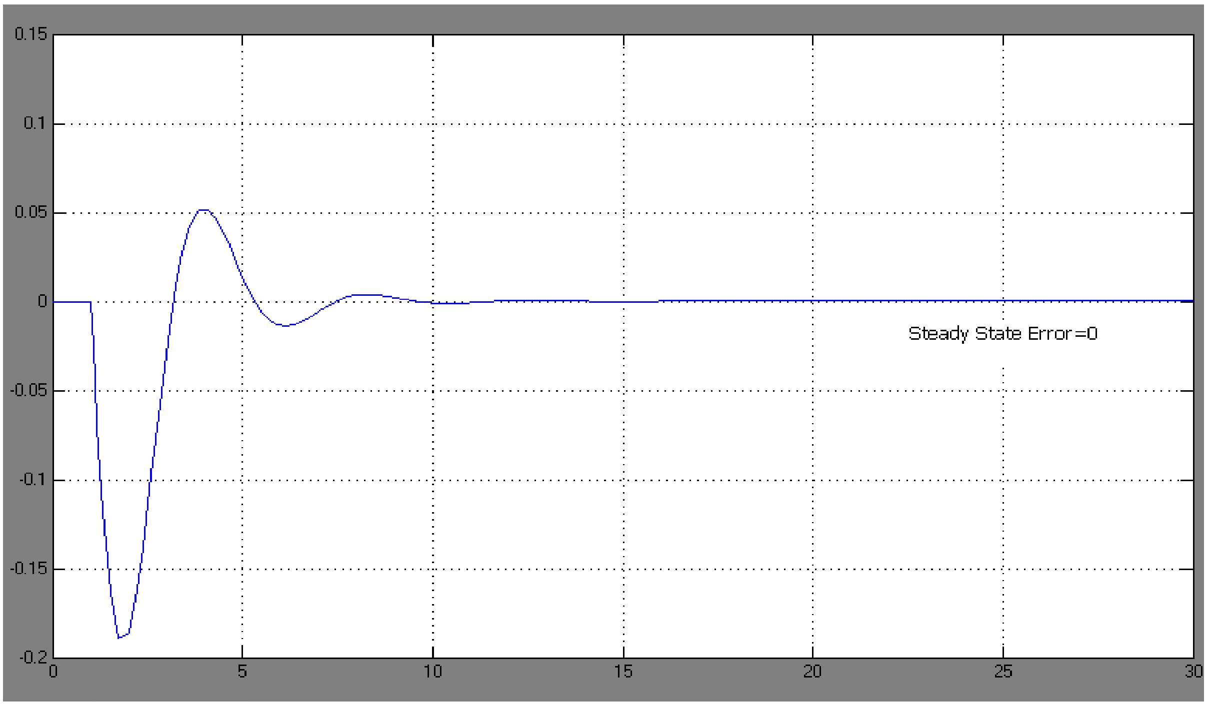


Output

Change in frequency without integral controller



Change in frequency with integral controller



Result: The load frequency dynamics in a single area power system has been investigated and the influence of integral controller on the LFC dynamics was investigated.

EXPERIMENT NO: 11 **DATE:**

DEVELOP A MODEL FOR A UNCONTROLLED TWO AREA LOAD FREQUENCY CONTROL PROBLEM AND SIMULATE THE SAME USING SOFT TOOLS.

SIMULINK model for a two area load frequency problem

Problem: Obtain the **MATLAB/SIMULINK** model representation for 0.01stepload disturbance of two area power system to plot frequency and tie-line power dynamics in the controlled and uncontrolled case, use the following data.

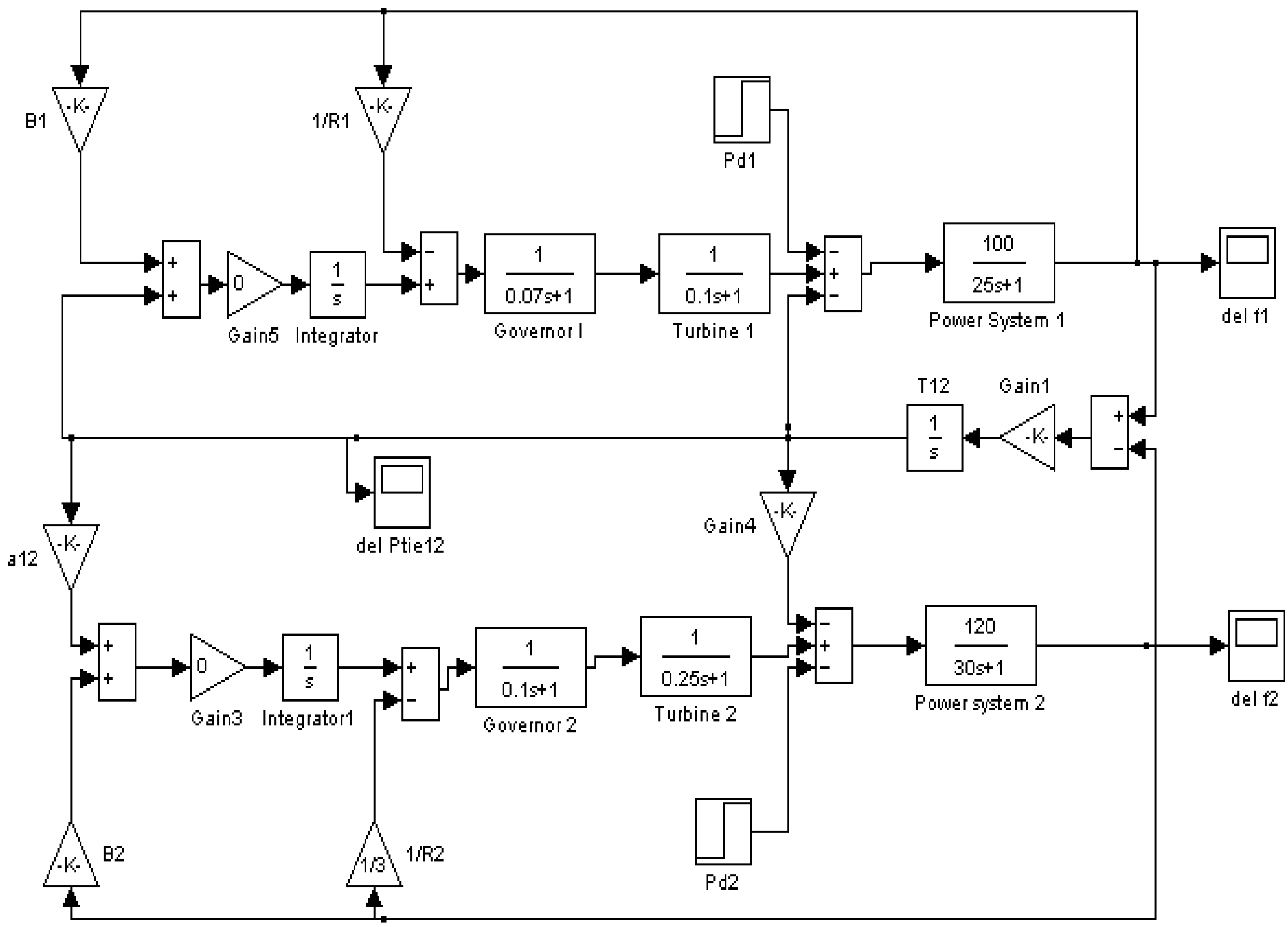
$T_{g1}=T_{g2}=0.45$sec, $K_{g1}=K_{g2}=1$

$T_{t1}= T_{t2}=0.55$sec, $K_{t1}=K_{t2}=1$

$K_{p1}=120$, $K_{p2}=80$, $T_{p1}=10$sec, $T_{p2}=20$sec, $R_1=2.5$, $R_2=3.625$, $T_{12}=0.4$

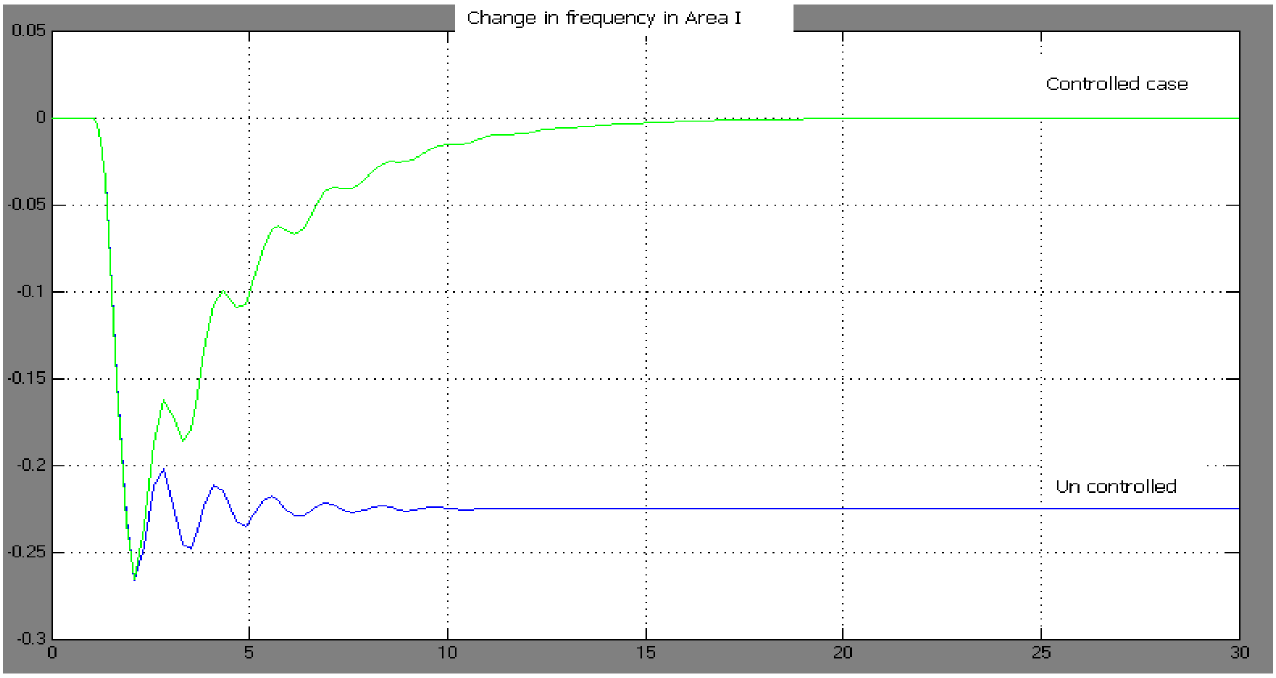
Aim: To develop a SIMULINK model for a two area power system to study the load frequency dynamics.

Block diagram of two area power system

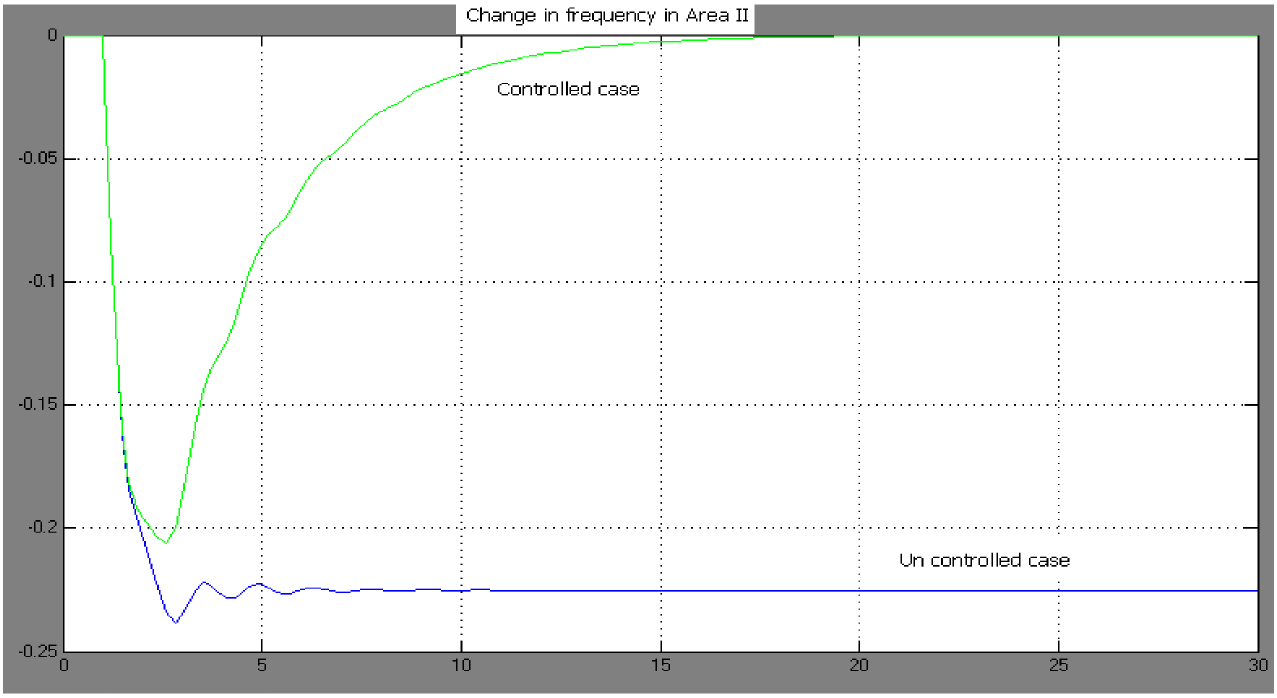


Output:

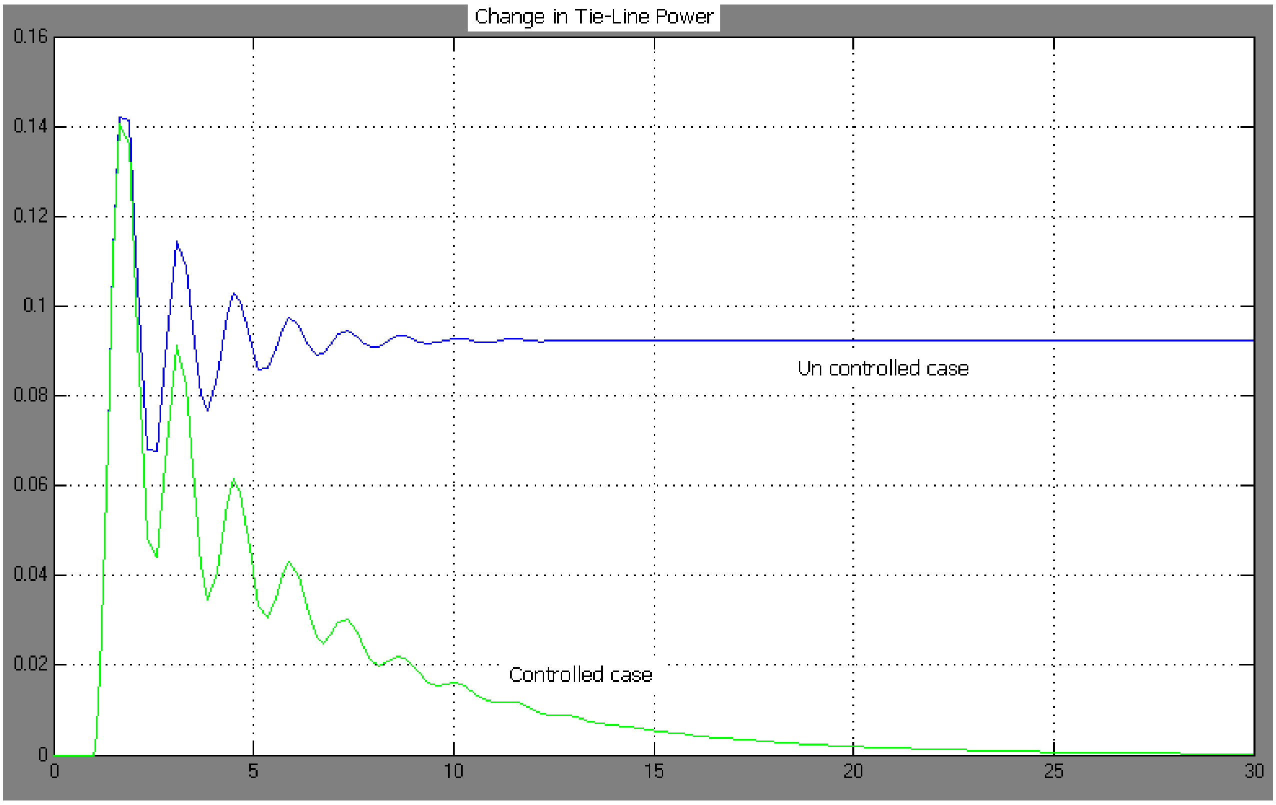
Change in frequency in area 1



Change in frequency in area 2



Change in Tie-line power



Result: The load frequency dynamics in a two area power system has been investigated and the influence of integral controller on the LFC dynamics was investigated.

DEVELOP A PROGRAM TO SOLVE SWING EQUATION BY POINT BY POINT METHOD USING MATLAB

Problem: Investigate the stability of the power system given using swing equation solved by Point-by-Point method.

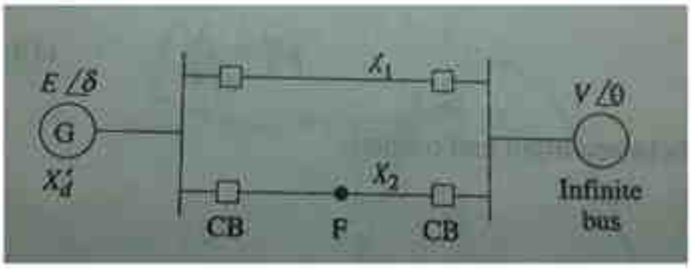
System data:f = 50hz generator 50 MVA supplying 50 MW with inertia constant 'H' = 2.7 MJ/MVA at rated speed. E = 1.05 pu, V = 1 pu, X1 = X2 = 0.4 pu. three phase fault at line 2.

(a) plot swing curve for a sustained fault up to a time of 5 secs.

(b) Plot swing curve if fault is cleared by isolating line in 0.1 seconds.

(c) Find the critical clearing angle

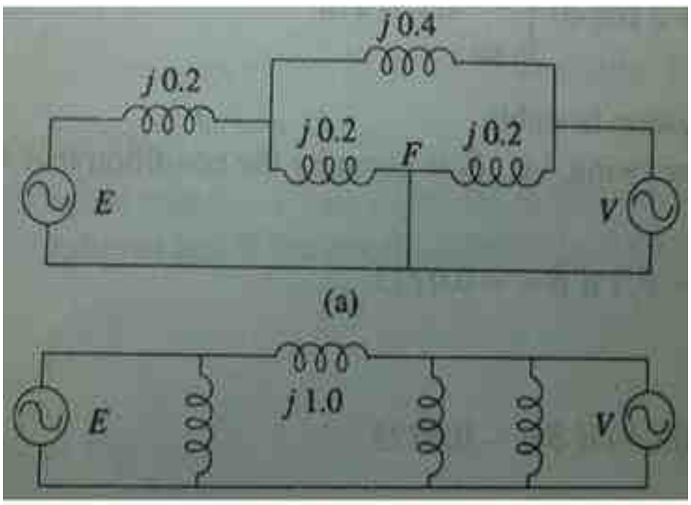
One line diagram



Aim: To solve the swing equation using Point-by-point method and apply it to investigate the stability of the power system.

The line diagram of the system during the fault is shown in the figure.

Impedance diagram during fault



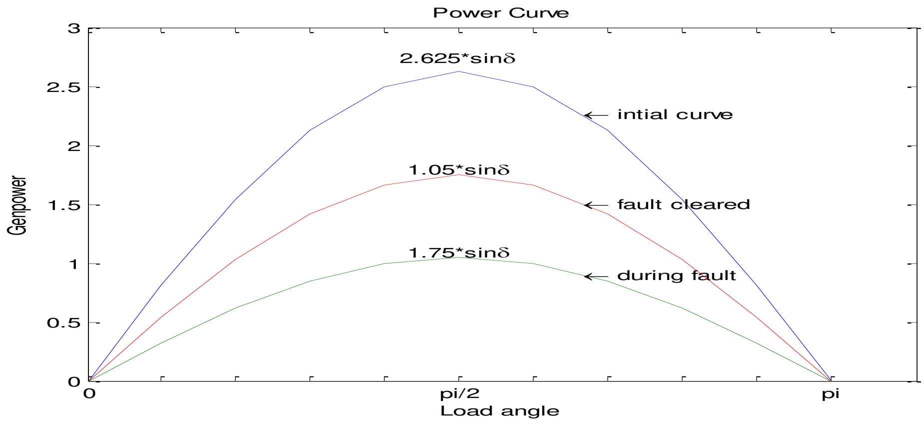
Program:

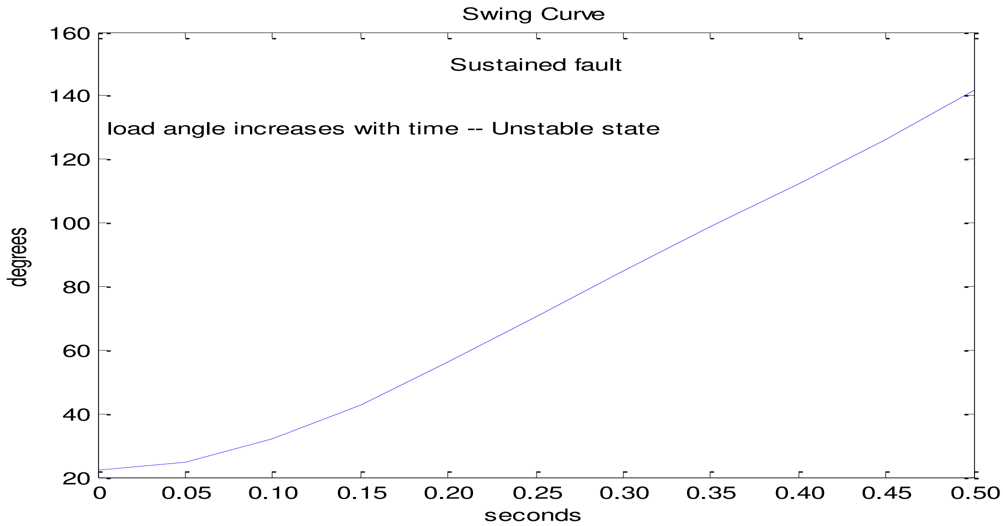
```
clc;
close all

E = 50; V =1; Xd = 0.2; X1 =0.4; X2 = 0.4;H = 2.7;

% prefault condition

del = 0:pi/10:pi;
del1 =del;
del2 = del;

M = 2.7/(180*50);                    % angular momentum = H/180*f
Peo = (1.05/0.4)*sin(del);           % Initial power curve
Po = 1 ;% power output in pu = 50 MW/50 MVA
delo = asind(0.4/1.05);              % initial load angle in degrees //Pe =
(E*V/X) sin(delo)
% During fault

Pe2 = 1.05*sin(del1);                % Power curve during fault

%Post fault condition

Pe3 = (1.05/0.6)*sin(del2);          % Power curve after clearing fault

%%  Primary Power curve plot Figure-1

plot(del,Peo);
set(gca,'XTick',0:pi/10:pi);
set(gca,'XTickLabel',{'0','','','','','pi/2','','','','','pi'});
title('Power Curve');
xlabel('Load angle');
ylabel('Genpower');
text((2/3)*pi,(1.05/0.4)*sin((2/3)*pi),'\leftarrowintial
curve','HorizontalAlignment','left');
text(pi/2,2.75,'2.625*sin\delta','HorizontalAlignment','center');
holdall
plot(del1,Pe2);
text((2/3)*pi,1.05*sin((2/3)*pi),'\leftarrow during
fault','HorizontalAlignment','left');
text(pi/2,1.80,'1.05*sin\delta','HorizontalAlignment','center');
plot(del2,Pe3);
text((2/3)*pi,(1.05/0.6)*sin((2/3)*pi),'\leftarrow fault
cleared','HorizontalAlignment','left');
text(pi/2,1.1,'1.75*sin\delta','HorizontalAlignment','center');
holdoff


t = 0.05;         % time step preferably 0.05 seconds
t1 = 0:t:0.5;

%% (a) sustained fault at t = 0

% for discontinuity at t = 0 , we take the average of accelerating power
% before and after the fault
% at t = 0-, Pa1 = 0
% at t = 0+. Pa2 = Pi - Pe2
% at t =  0 ,Pa =Pa1+Pa2/2


Pao = (1 - (1.05*sind(delo)))/2;      % at the instant of fault del1 = delo
Pa(1) = Pao;
cdel(1) = 0;
d1 = t^2/M;
```

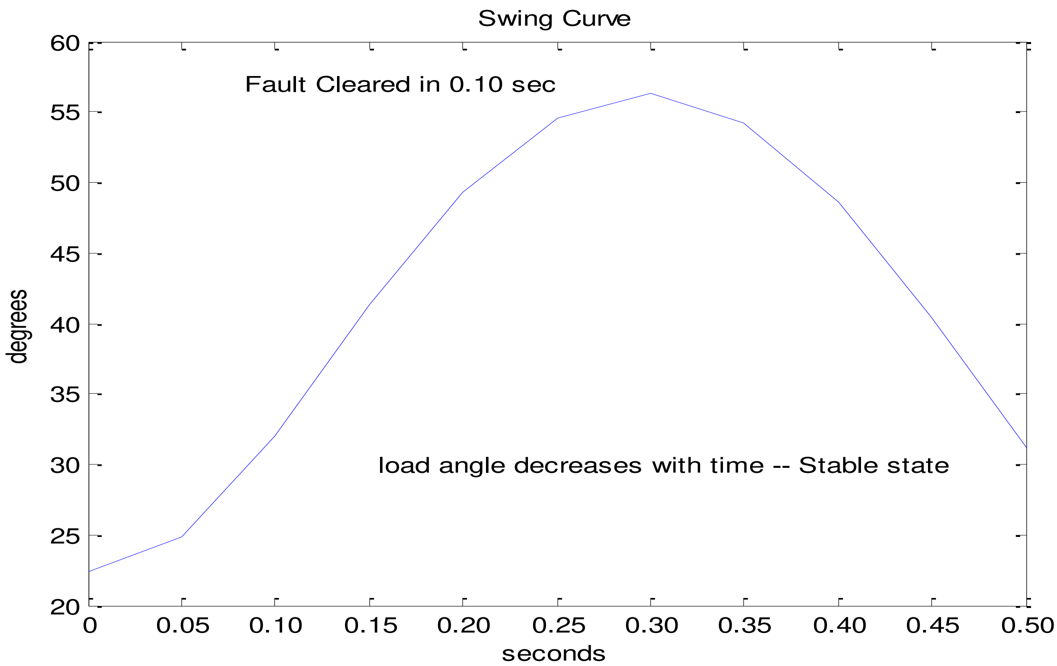
```
fori = 1:11

ifi == 1

d2(i) = d1*Pa(i);
del(i) = delo;

else
cdel(i) = cdel(i-1)+d2(i-1);

del(i)  = del(i-1)+cdel(i);

Pe(i) = 1.05*sind(del(i));

Pa(i) = 1 - Pe(i);

d2(i) = d1*Pa(i);
end
end
%% swing curve 1 plot

figure (2);
plot(t1,del);
set(gca,'Xtick',0:0.05:0.5);
set(gca,'XtickLabel',{'0','0.05','0.10','0.15','0.20','0.25','0.30','0.35',
'0.40','0.45','0.50'});
title('Swing Curve');
xlabel('seconds');
ylabel('degrees');
text(0.30,150,'  Sustained fault','HorizontalAlignment','right');
text(0.001,130,' load angle increases with time -- Unstable
state','HorizontalAlignment','left');
%% (b) Fault cleared in 0.10 seconds ,2nd step ---- 3rd element [1]0
[2]0.05,[3]0.10
Pafo = (1 - (1.05*sind(delo)))/2;      % at the instant of fault del1 =
delo
Paf(1) = Pao;
cdelf(1) = 0;
d1f = t^2/M;

fori = 1:2

ifi == 1

d2f(i) = d1*Pa(i);
delf(i) = delo;

else
cdelf(i) = cdelf(i-1)+d2f(i-1);
delf(i)  = delf(i-1)+cdelf(i);
Pef(i) = 1.05*sind(delf(i));
Paf(i) = 1 - Pef(i);
d2f(i) = d1*Paf(i);
end

end
% after clearing fault, power curve shift to Pe3
fori = 3:11
ifi == 3

cdelf(i) = cdelf(i-1)+d2f(i-1);
delf(i)  = delf(i-1)+cdelf(i);
Pef(i) = 1.05*sind(delf(i));
Paf(i) = 1 - Pef(i);
      a1 = Paf(i);
d2f(i) = d1*Paf(i);
```

```
       a2 = d2f(i);
Pef(i) = 1.75*sind(delf(i));
Paf(i) = 1 - Pef(i);
d2f(i) = d1*Paf(i);
Paf(i) = (Paf(i)+ a1)/2;
d2f(i) = (d2f(i) + a2)/2;

else

cdelf(i) = cdelf(i-1)+d2f(i-1);
delf(i)  = delf(i-1)+cdelf(i);
Pef(i) = 1.75*sind(delf(i));
Paf(i) = 1 - Pef(i);
d2f(i) = d1*Paf(i);
end
end

figure (3);
plot(t1,delf);
set(gca,'Xtick',0:0.05:0.5);
set(gca,'XtickLabel',{'0','0.05','0.10','0.15','0.20','0.25','0.30','0.35',
'0.40','0.45','0.50'});
title('Swing Curve');
xlabel('seconds');
ylabel('degrees');
text(0.25,57,' Fault Cleared in 0.10 sec','HorizontalAlignment','right');
text(0.15,30,' load angle decreases with time -- Stable
state','HorizontalAlignment','left');
%% (c) critical clearing angle
delo = delo*(pi/180);       % initial load angle in rad
delm = pi - asin(1/1.75);   % angle of max swing

c1 = ((delm-delo)-(1.05*cos(delo))+(1.75*cos(delm)))/(1.75-1.05);
cclang = acos(c1);                                 % critical clearing angle
in rad
cclang = (180/pi)*(cclang);                     % critical clearing angle in
degree
cclang = int16(cclang);                         % converting to integer
fprintf('\n\n\t\t Critical Clearing angle is %d degree \n',cclang);
```

Output







Result: The stability of the given system is investigated by using swing equation. The system is stable when the fault is cleared before the critical clearing time; the corresponding critical clearing angle for stability is 112^o**.**