Laboratory Manual

of

Power Systems
LAB COURSE
(EE405)

DEPARTMENT OF ELECTRICAL ENGINEERING
NATIONAL INSTITUTE OF TECHNOLOGY
ANDHRA PRADESH
(AY: 2021-2022)

DEPARTMENT OF ELECTRICAL ENGINEERING

POWER SYSTEMS LAB

Student Details	
Year / Semester	IV B.Tech (EEE) – I Semester
Subject	POWER SYSTEMS LAB
Regulation	
Subject Code	
Roll Number	
Name	

Student Performance Evaluation							
Week / Exercise Number	**Date**	**Marks**				**Signature of Faculty**	**Remarks**
		Lab (5)	**Record (5)**	**Viva (5)**	**Total (15)**		
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							

Total Marks Awarded: _______ (In Words : ____________________________________)

EE405-POWER SYSTEMS LAB

IMPORTANT INSTRUCTIONS FOR STUDENTS

- Wear shoes during the lab experiment.
- Ensure that when you come in the lab you should have lab manual, lab record, pen, pencil, graph paper etc.
- Do not wear loose clothes, when you are doing the experiments on rotating electrical machines.
- Make the connections tightly.
- Connections shall be made so that only necessary meter/equipment is present on the experimental table. These shall be arranged as neatly and clearly as possible
- Before energizing the circuits, please ensure that your connections should be checked by the lab instructor/TA/Lab In charge.
- Use the appropriate rating/range of measuring instruments/meters.
- Please do not touch the machine terminals or the knob of the auto transformer/DSO etc. unnecessarily.
- Increase or decrease the voltage gradually by auto transformer.
- Increase or decrease the load step by step.
- If you have any doubt, ask your lab instructor.
- Handle the lab equipments/measuring instruments carefully.
- Do not use mobile phone, while performing the experiments.
- After completing your experiment, return the measuring instruments to lab persons.

EE405-POWER SYSTEMS LAB

(B.Tech.-EED-IV year-I Semester)

Externals: 60 Marks **L-T-P-C**
Internals: 40 Marks **0-0-3-2**

Course Objectives: To expose the students to the operation and controlling of power system transmission lines, equipment and power flow studies.

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

CO1	Understand the Reactive power control in a Tap Changing Transformer & long transmission lines
CO2	Determine the sequence components of unbalanced voltages and fault currents of Power system elements
CO3	Understand the characteristics of PV array
CO4	Evaluate the breakdown strength of Electrical Insulation and design ground grid for Substation

List of Experiments for the Power Systems Lab

S.No.	Name of the Experiment	Page No.
1	Characteristics of Artificial Transmission Line (a) Regulation and efficiency Characteristics (b) Reactive Power compensation	
2	Determination of Sequence Reactances of Alternator	
3	Characteristics of Numerical overcurrent relay	
4	Formation of Bus admittance matrix by direct inspection method	
5	Power flow solution by using Gauss-Siedel method	
6	Power flow solution by using Newton-Raphson method	
7	Power flow solution by using Fast Decoupled method	
8	Single area and two area load frequency control	
9	Economic load dispatch	
10	Solution of Swing equation using point-by-point method	
11	Distribution Load Flow Solution by using Backward/Forward method	
12	Reactive Power Control using Tap Changing Transformer	
13	Analysis of unbalanced voltages using Symmetrical Component Analyzer	

EXP. NO. : 01
DATE :

CHARACTERISTICS OF ARTIFICIAL TRANSMISSION LINE A) REGULATION AND EFFICIENCY B) REACTIVE POWER COMPENSATION

AIM: To determine the percentage regulation, percentage efficiency of the 200km length Π-section transmission line and also observe the effect of reactive power compensation on receiving end side with different loads.

APPARATUS REQUIRED:

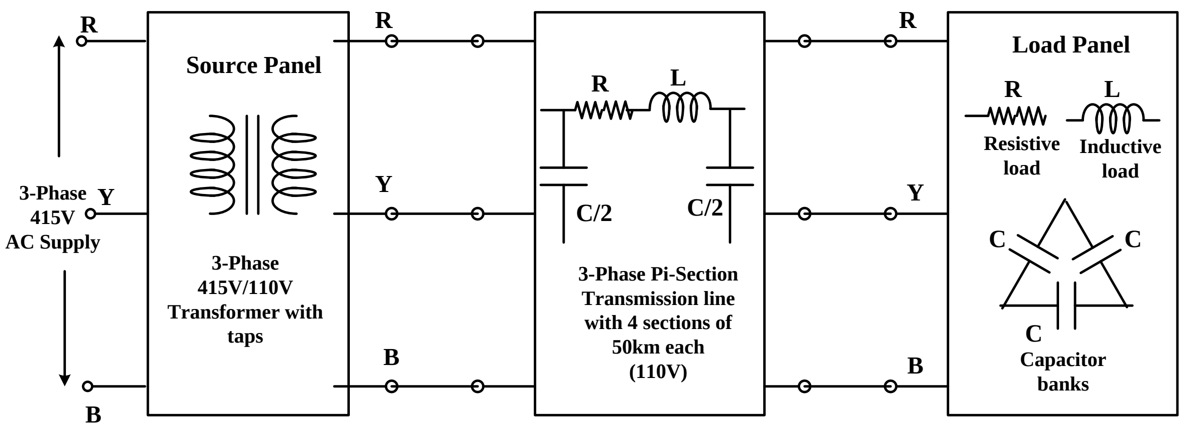
S.No	Name of the Apparatus
1.	Transmission line emulator setup
2.	Patch cords

PRECAUTIONS:

1. All the switches of the transmission line emulator should be at OFF position and all control knobs should be at minimum position before starting the experiment.

TRANSMISSION LINE EMULATOR

Block Diagram:



200km Transmission Line Emulator Setup:

THEORY:

PROCEDURE:

a) Calculation of %Efficiency and %Regulation

1. Connect the sending end panel output terminals to the transmission line input and then, connect the line end terminals to the receiving end panel by considering the required length of the transmission line.
2. Switch on the mains supply to both sending end and receiving end panels.
3. Turn on the ELCB switch and then 3-phase power switch which are provided in source panel.

4. Adjust the sending end output voltage to the rated voltage of 110V with the help of tap changer switch and secondary voltage knob provided on source panel.
5. Now turn on the auxiliary power switch provided on load panel and note down the no load parameters of sending end voltage V_S, current I_S, power factor $\cos\phi_S$, active power P_S and the receiving end voltage V_R, current I_R, power factor $\cos\phi_R$, active power P_R.
6. Now turn on the resistive (R) load by pressing the push button on load panel and increase the R load in steps with the help of resistive load knob provided on load panel. At each step, note down all sending end and receiving end parameters.
7. Repeat the step (6) by switching on both R load and inductive L load and note down all parameters by increasing the load in steps.
8. Now, calculate the percentage efficiency and percentage voltage regulation for each step.

b) Reactive power compensation:

1. Repeat the above steps from step 1 to step 4.
2. Now turn on the auxiliary power switch provided on load panel and adjust some amount of resistive and inductive loads. Note down the parameters of sending end voltage V_S, current I_S, power factor $\cos\phi_S$, reactive power Q_S and the receiving end voltage V_R, load current I_L, load power factor $\cos\phi_L$, reactive power Q_R, inductive load reactive power Q_L, reactive power compensation Q_{comp} by capacitor banks.
3. Now, switch on the capacitor banks in steps by pressing the push buttons provided on load panel. For each capacitor bank switching, note down the all parameters which are mentioned in the above step.

OBSERVATIONS:

CASE 1: For Uncompensated line-regulation and efficiency

S. No.	Type of load	V_S (Volts)	I_S (Amps)	P_S (Watts)	$\cos\phi_S$	V_R (Volts)	I_R (Amps)	P_R (Watts)	$\cos\phi_R$	Percentage Efficiency	Percentage Regulation
1.	No load										
2.	R load										
3.	R load										
4.	R load										
5.	R load										

6.	R load										
7.	RL load										
8.	RL load										
9.	RL load										
10.	RL load										
11.	RL load										

Case 2: For Compensated Line:

S. No.	Type of load	V_S (Volts)	I_S (Amps)	Q_S (VAR)	$\cos\phi_S$	V_R (Volts)	I_L (Amps)	$\cos\phi_L$	Q_R (VAR)	Q_L (VAR)	Q_{Comp} (VAR) $= Q_R - Q_L$
1.	RL load										
2.	RL load (C_1-ON)										
3.	RL load (C_1+C_2-ON)										
4.	RL load (C_1+C_2+C_3 -ON)										
5.	RL load (C_1+C_2+C_3+C_4 -ON)										
6.	RL load (C_1+C_2+C_3+C_4 +C_5 - ON)										

CALCULATIONS:

Percentage Efficiency = (P_R / P_S) *100
Percentage Regulation = $(V_S – V_R)$*100 / V_R

INFERENCES:

1. The receiving end voltage is higher than the sending voltage under no load condition and lightly loaded condition due to capacitance effect of transmission lines.
2. The reactive power drawn by receiving end Q_R can be compensated by connecting the capacitor banks to improve power factor. It is observed by the relation $Q_R = Q_L - Q_{comp}$, where Q_L is inductive load reactive power and Q_{comp} is the reactive power compensation by capacitor banks.

3. The power factor is observed under different types of loads on receiving end side.

VIVA QUESTIONS:

1. What is Ferranti effect?
2. Under which load condition, the voltage regulation becomes zero and negative?
3. What is meant by power factor?
4. What is the need of capacitor banks?
5. What are the different types of methods to improve the power factor?
6. What is meant by reactive power compensation?
7. What is the effect of charging currents in transmission lines?
8. What are the advantages of using bundled conductors in long transmission lines?
9. What is meant by skin effect?
10. What is meant by surge impedance loading?

RESULT:

Lab Instructor **Faculty**

Date: **Date:**

EXP. NO. : 02
DATE :

DETERMINATION OF SEQUENCE REACTANCES OF ALTERNATOR

AIM: To determine the positive, negative and zero sequence reactances of synchronous machine.

NAME PLATE DETAILS:

Particulars	**Alternator**	**DC Motor**	**Auto-transformer**
Type	3-Phase	Shunt	1-Phase and 3-Phase
Rated Power	5kVA	5kW	1kVA and 10kVA
Rated Primary Voltage	415V	220V DC	230V and 415V
Rated Secondary Voltage	-	-	(0-270)V and (0-470)V

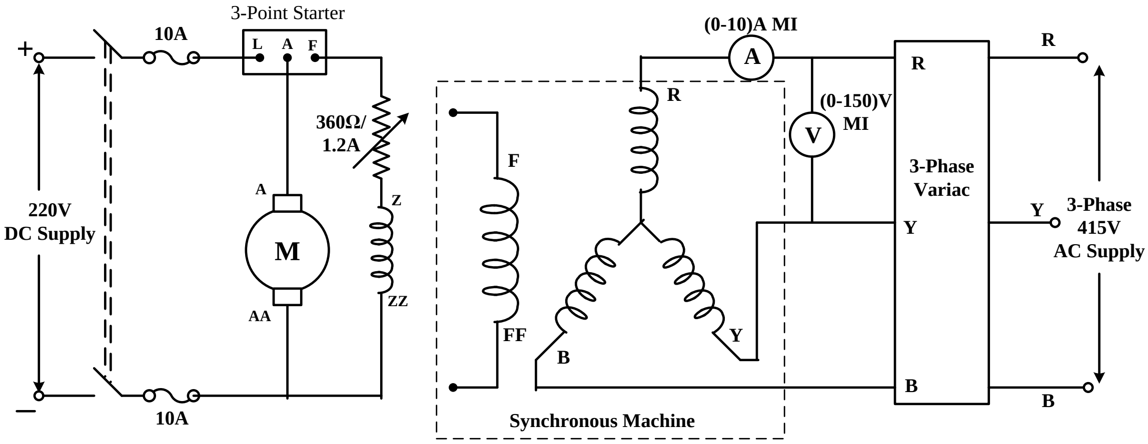
APPARATUS REQUIRED:

S.No	Name of the Apparatus	Range	Type	Quantity
1	Voltmeter	(0-150)V	MI	1
2	Ammeter	(0-10)A	MI	1
3	Rheostat	360Ω/1.2A	Wirewound	1

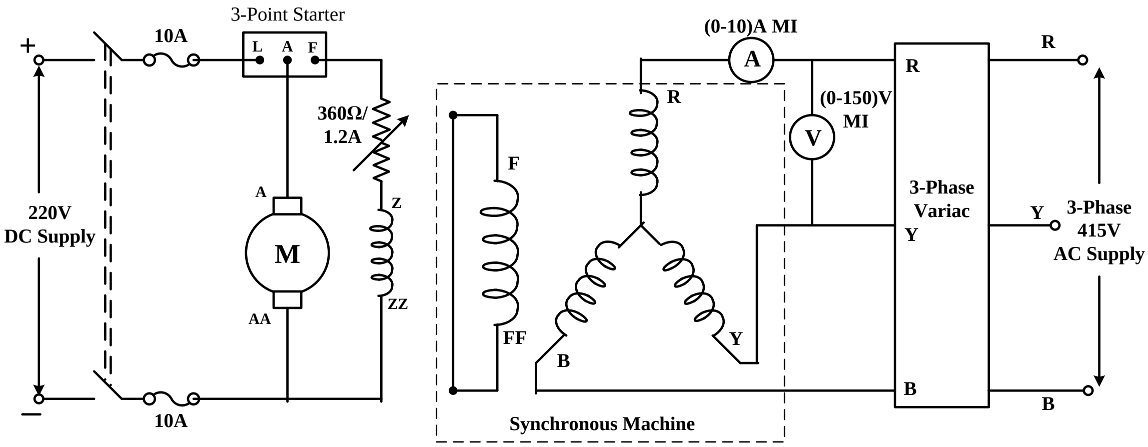
PRECAUTIONS:

1. The auto-transformer voltage should be at minimum position at the time of starting to start the experiment.
2. The DC motor starter should be at minimum position and field rheostat position should be at minimum position before starting the experiment.

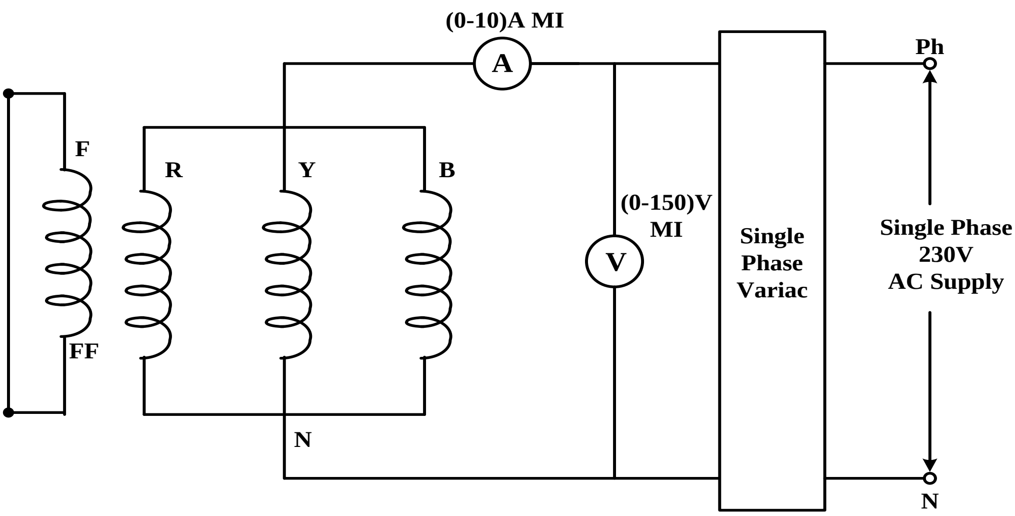
CIRCUIT DIAGRAM FOR DETERMINATION OF POSITIVE SEQUENCE REACTANCE



CIRCUIT DIAGRAM FOR DETERMINATION OF NEGATIVE SEQUENCE REACTANCE



CIRCUIT DIAGRAM FOR DETERMINATION OF ZERO SEQUENCE REACTANCE



THEORY:

PROCEDURE:

A) <u>Determination of positive sequence reactance of synchronous machine:</u>

1. Connections are made as per the circuit diagram.
2. By keeping the field circuit of the synchronous machine in open position, adjust the speed of machine to the rated speed by controlling the field current of DC motor which is coupled to the synchronous machine.
3. Apply a reduced voltage of 100-150V to the stator terminals of the synchronous machine with the help of 3-phase variac and note down corresponding stator current.
4. Calculate the positive sequence reactance from the formula $X_1=V_1/(SQRT(3)*I_1)$ ohms/phase.

B) <u>Determination of negative sequence reactance of synchronous machine:</u>

1. Connections are made as per the circuit diagram.
2. By shorting the field circuit terminals of the synchronous machine, adjust the speed of machine to the rated speed by controlling the field current of DC motor which is coupled to the synchronous machine.
3. Apply a reduced voltage of 100-150V to the stator terminals of the synchronous machine with the help of 3-phase variac and note down corresponding stator current.
4. Calculate the negative sequence reactance from the formula $X_2=V_2/(SQRT(3)*I_2)$ ohms/phase.

C) <u>Determination of zero sequence reactance of synchronous machine:</u>

1. Connections are made as per the circuit diagram.
2. Short circuit the field terminals of the synchronous machine and connect the stator windings of the machine in parallel.
3. Apply a low voltage to the stator using single phase auto-transformer and note down the corresponding voltage and current readings.
4. Calculate the zero-sequence reactance from the formula $X_0=V_0/(I_0/3)$ ohms/phase.

OBSERVATIONS :

Sequence reactance	**V**	**I**	**X**
Positive Sequence reactance	100	1.5	38.49
Negative Sequence reactance	100	4	14.43
Zero Sequence reactance	10	7.3	4.10

CALCULATIONS:

Positive Sequence reactance $X_1 = \frac{V_1}{\sqrt{3}I_1} =$

Negative Sequence reactance $X_2 = \frac{V_2}{\sqrt{3}I_2} =$

Zero Sequence reactance $X_0 = \frac{V_0}{(I_0/3)} =$

INFERENCE:

1. The relation between the positive sequence reactance, negative sequence reactance and zero sequence reactance of the synchronous machine is observed.

VIVA QUESTIONS:

1. What is the principle of alternator?
2. What is the significance of sequence reactances of alternator?
3. What is the formula for synchronous speed?
4. What is the relation between X_1, X_2 and X_0?
5. Which reactance can be observed under LLL fault condition?
6. The positive and negative sequence reactances can be observed under which fault condition?
7. Which type of fault injects the zero sequence currents?
8. What is the effect of negative sequence currents on alternator?
9. What are the types of alternators in view of construction?

10. In Hydel power plants which type of alternator is used?

RESULT:

Lab Instructor **Faculty**

Date: **Date:**

EXP. NO. : 03
DATE :

CHARACTERISTICS OF NUMERICAL OVERCURRENT RELAY

AIM: To obtain the characteristics of numerical overcurrent relay.

APPARATUS REQUIRED:

1. Numerical overcurrent relay kit – 7SR10 Siemens

Numerical Overcurrent Relay Setup

THEORY:

PROCEDURE:

1. Turn on the power supply to the relay kit.
2. Click ‘Enter’ on the relay keypad and control mode will be displayed.
3. Press the ‘test/reset’ button on the keypad for entering into settings mode.
4. Now, press the down arrow key to go to current protection.
5. Press the test/reset button on the keypad to view and select phase overcurrent and again press the test/reset button and select 51-1 char using the ‘down arrow’.
6. Select desired characteristics using the ‘down/up’ arrow and use the ‘cancel’ button for coming back to control mode.
7. Now rotate the knob provided on the kit to set mode and then, click the start push button.
8. Set the required fault current value and press the stop push button.
9. Now change the knob position to test mode and then, click the start button. Note down the time of tripping of the relay.
10. Repeat the experiment for different fault currents and tabulate the corresponding relay tripping times.
11. Plot the graph between fault current and tripping time which represents the relay characteristic.
12. Repeat the experiment for different characteristics of the relay by changing the characteristics using the keypad.

OBSERVATIONS :

a) Definite time lag characteristic:

S.No.	Fault current in Amps	Relay tripping time in sec
1.		
2.		
3.		
4.		
5.		

b) Normal inverse characteristic:

S.No.	Fault current in Amps	Relay tripping time in sec
1.		
2.		
3.		
4.		
5.		

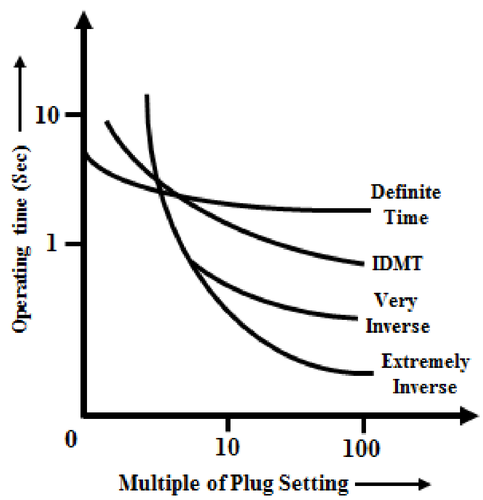
c) Very inverse characteristic:

S.No.	Fault current in Amps	Relay tripping time in sec
1.		
2.		
3.		
4.		
5.		

d) Extreme inverse characteristic:

S.No.	Fault current in Amps	Relay tripping time in sec
1.		
2.		
3.		
4.		
5.		

MODEL GRAPH:



Characteristics of Overcurrent Relays

INFERENCE:

1. The relay characteristics have been observed for different fault currents using overcurrent relay.

VIVA QUESTIONS:

1. What is the principle of relay?
2. What is the difference between definite minimum time and inverse relay?
3. What is the difference between overcurrent relays and distance relays?
4. What are the standards followed for relay characteristics?
5. Which type of relay characteristics is mostly used for transmission lines?
6. The relay operation is decided based on which type sequence components?
7. Define pick up current in relay operation?
8. What is meant by PSM?
9. What is meant by TSM?
10. What are the disadvantages of overcurrent relays compared to distance relays?

RESULT:

Lab Instructor **Faculty**

Date: **Date:**

EXP. NO. : 04
DATE :

FORMATION OF BUS ADMITTANCE MATRIX BY DIRECT INSPECTION METHOD

AIM: To develop a MATLAB program for formation of bus admittance matrix Y_{BUS} by direct inspection method.

APPARATUS REQUIRED:

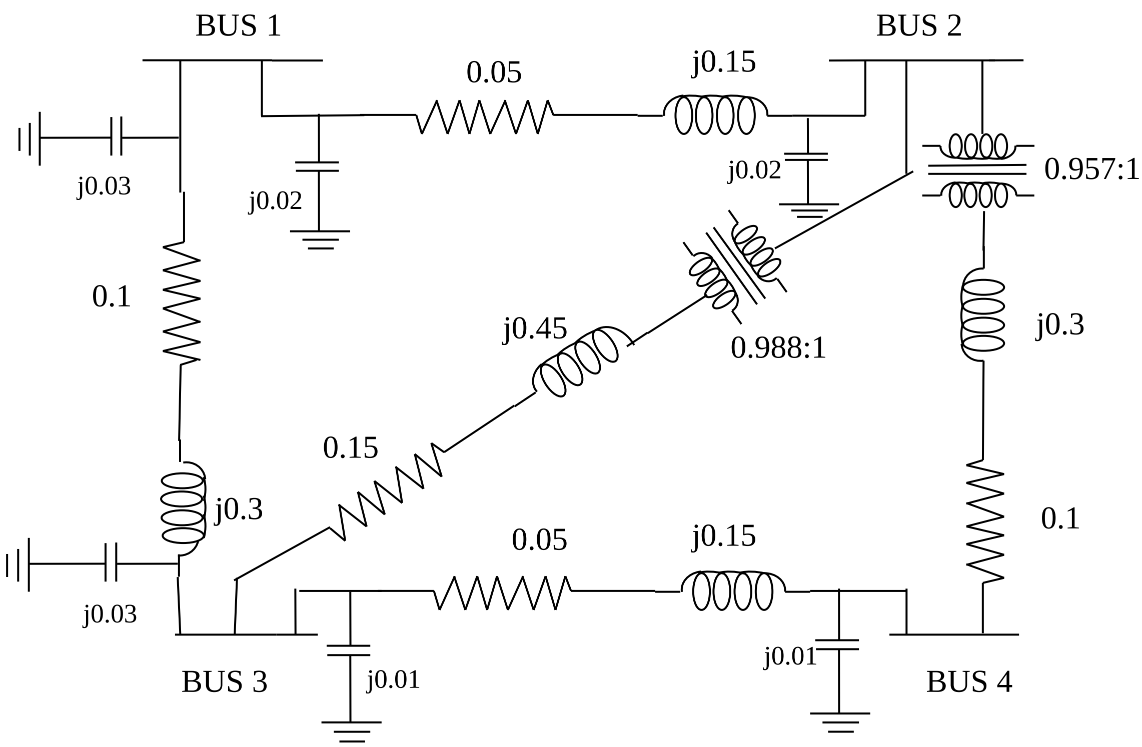
S.No	Name of the Apparatus
1	Personal Computer
2	Matlab Software

THEORY:

LINE DATA:

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**

LINE DIAGRAM



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)/a(n)^2)+(sh(n)/2);
           end
       end
   end
   fprintf('ybus=\n\n[');
   disp(ybus)
```

```
fprintf('\b\b] pu');
```

OUTPUT:

$\boldsymbol{Y_{bus}}$= [3.0000 - 8.9500j -2.0000+6.0000j -1.0000+3.0000j 0

-2.0000+6.0000j 3.7748 -11.3045j -0.6748 + 2.0243j -1.0449+3.1348j

-1.0000+3.0000j -0.6748+2.0243j 3.683-11.0089j -2.0000+6.0000j

0 -1.0449+3.1348j -2.0000+6.0000j 3.0919-9.2656j];

CALCULATIONS:

Self-Admittance:

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

$$Y_{22} = y_{12} + \frac{y'_{12}}{2} + \frac{y'_{23}}{a^2} + \frac{y'_{24}}{a^2} = Y_{33} = y_{31} + y_{34} + \frac{y'_{13}}{2} + \frac{y'_{34}}{2} + \frac{y'_{32}}{a^2} =$$

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

Mutual Admittance:

$$Y_{12} = Y_{21} = -y_{21} =$$

$$Y_{13} = Y_{31} = -y_{31} =$$

$$Y_{14} = Y_{41} =$$

$$Y_{23} = Y_{32} = -\frac{y'_{23}}{a^2} =$$

$$Y_{24} = Y_{42} = -\frac{y'_{42}}{a^2} =$$

$$Y_{34} = Y_{43} = -y_{43} =$$

$$Y_{BUS} = \begin{bmatrix} Y_{11} & Y_{12} & Y_{13} & Y_{14} \\ Y_{21} & Y_{22} & Y_{23} & Y_{24} \\ Y_{31} & Y_{32} & Y_{33} & Y_{34} \\ Y_{41} & Y_{42} & Y_{43} & Y_{44} \end{bmatrix}$$

$$Y_{BUS} =$$

INFERENCES:

1. It is observed that the Y-bus matrix is symmetrical matrix and also it is a sparse matrix.
2. The size of the Y-bus matrix depends upon the number of buses present in the power system.

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 meant by bus in power system?
9. What is meant by a primitive network?
10. What are the methods available for forming bus impedance matrix?

RESULT:

Lab Instructor **Faculty**

Date: **Date:**

EXP. NO.: 05
DATE:

POWER FLOW SOLUTION BY USING GAUSS-SIEDEL METHOD

AIM: To develop the MATLAB program for performing the power flow solution of a given power system network by using Gauss-Siedel method.

APPARATUS REQUIRED:

S.No	Name of the Apparatus
1	Personal Computer
2	Matlab Software

THEORY:

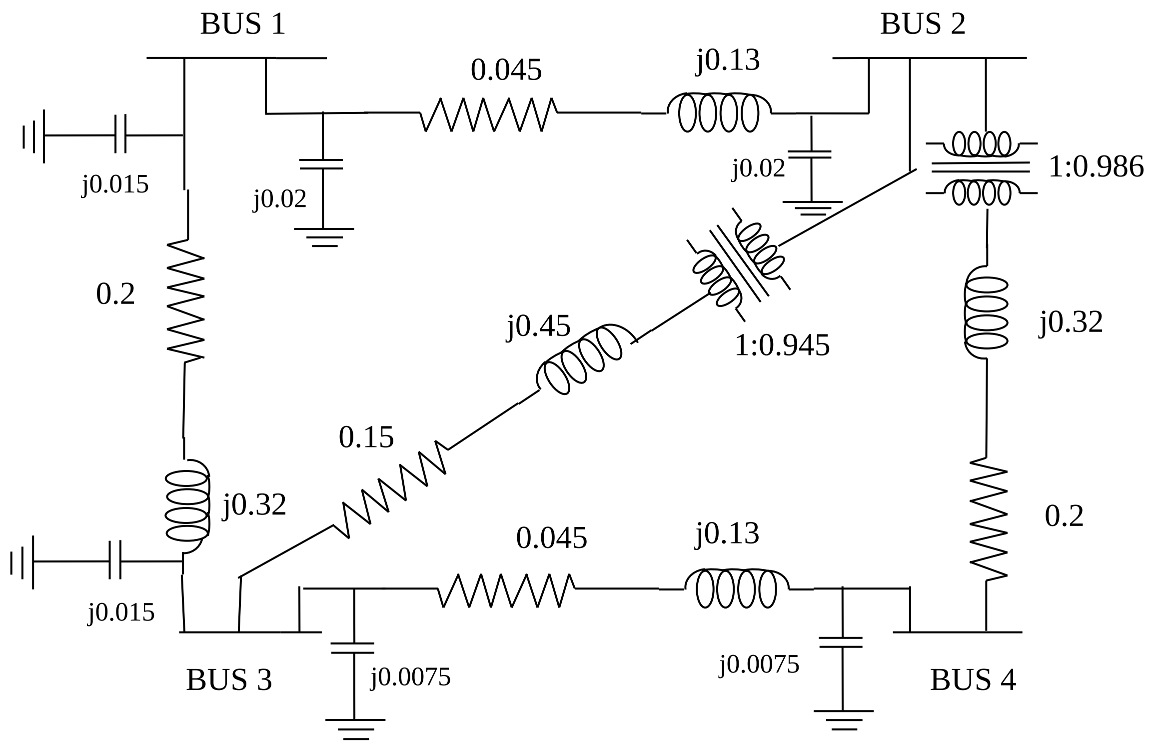
LINE DATA:

ELEMENT NO	FROM BUS	TO BUS	R(p.u.)	X(p.u.)	TURNS RATIO(a:1)	CHARGING ADMITTANCE(p.u.)
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 (p.u.)	Delta (deg)	P(p.u.)	Q(p.u.)
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:



ALGORITHM:

1. Read line data and bus data of the given power system.
2. Use line data to obtain Y_{bus}. For the convergence condition, a reasonable tolerance is to be set.
3. Use the flat start for given values of bus voltage magnitude and phase angles.

   Set $V_i^{(0)} = 1 p.u.$ for i=1,2,3…, n and $\delta_i = 0$
4. The iteration count will be called (N), and will be set to 0 initially.
5. Bus count (B) is set to 0.
6. Check the type of the bus and if it is a slack bus, increment the bus count.
7. If all buses have been considered, move on to the next stage, otherwise, return back to step 6.

8. If the type of bus is a PV bus, then find out the reactive power of the bus Q_i with the given equation

$$\mathrm{Q}_{\mathrm{i,calc}} = -\mathrm{Imag}\left(V_i^* \sum_{k=1}^{k=n} Y_{ik} V_k\right)$$

9. Now check whether the calculated $Q_{i,calc}$ is within the limits or not. If $Q_{i,calc} < Q_{min}$ then take $Q_{i,calc} = Q_{min}$ and consider the bus as PQ bus and update the bus voltage using the equation in step 10. If $Q_{i,calc} > Q_{max}$ then take $Q_{i,calc} = Q_{max}$ and consider the bus as PQ bus and update the bus voltage using the equation in step 10. If $Q_{min} < Q_{i,calc} < Q_{max}$ then consider the bus as PV bus by taking voltage $V_i = V_{i,spec}$ and determine the voltage angle using the equation given below:

$$ang(\mathrm{V_i}) = \mathrm{angle}\left(\frac{1}{Y_{ii}}\left(\frac{P_i - jQ_i}{V_i^*} - \sum_{\substack{k=1 \\ k\neq i}}^{k=n} Y_{ik} V_k\}\right)\right)$$

If it is a PV bus, then go to step 11.

10. If the type of bus is a PQ bus, then update the voltages with the following equation

$$\mathrm{V_i} = \frac{1}{Y_{ii}}\left(\frac{P_i - jQ_i}{V_i^*} - \sum_{\substack{k=1 \\ k\neq i}}^{k=n} Y_{ik} V_k\}\right)$$

11. After incrementing the bus count, if all the buses are considered, move on to the next stage, otherwise, return back to step 6.
12. Calculate the difference between the last iteration voltage and present voltage for each bus.
13. Then chose the maximum difference of voltage and compare with the specified tolerance.
14. If the maximum difference is less than the tolerance, then the convergence is achieved and stop the algorithm. Otherwise, increment the iteration count, and then go to step 5 for next iteration.

PROGRAM:

```
clear all;
clc;
%Busno   Type  vMag  theta    pGen  qGen pLoad qLoad qMin qMax GshPu BshPu
baseMVA = 100;
loadData = [1 1 1.05 0 0 0 0 0 0 0 0 0;
            2 3 1 0 0 0 -45 -22 0 0 0 0;
            3 3 1 0 0 0 98 -40 0 0 0 0;
            4 3 1 0 0 0 -32 15 0 0 0 0];
```

```
nBus = max(loadData(:,1));
yBus = zeros(nBus,nBus);
busNo = loadData(:,1);
busType = loadData(:,2);
vInitial = loadData(:,3);
thetaInitial = loadData(:,4);
pGen = loadData(:,5)/baseMVA;
qGen = loadData(:,6)/baseMVA;
pLoad = loadData(:,7)/baseMVA;
qLoad = loadData(:,8)/baseMVA;
qMin = loadData(:,9)/baseMVA;
qMax = loadData(:,10)/baseMVA;
GshPu = loadData(:,11);
BshPu = loadData(:,12);
pSpec = pGen-pLoad;
qSpec = qGen-qLoad;
vCalcMag = [vInitial];
thetaCalc = [thetaInitial];
vCalcComplex = vCalcMag.*(cos(thetaCalc)+i*sin(thetaCalc));
vIterMag =[vCalcMag];
vIterAngle = [thetaInitial];
vIterComplex = [vCalcComplex];
qCalc = zeros(nBus,1);
qIterCalc = [qCalc];
yBus = [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        ];
clear i
% % GSLF ITERATIONS
for k = 1:100
    for j = 2:nBus
    if (busType(j) == 2)
        qCalc(j)    =sum(vCalcMag(j)*(vCalcMag.').*abs(yBus(j,1:nBus)).*sin(thetaCalc(j)-
thetaCalc(1:nBus,1).'-angle(yBus(j,1:nBus))));
        if (qCalc(j) >= qMax(j))
            qCalc(j) = qMax(j);
            pCalc = pSpec(j)-i*qCalc(j);
            vCalcComplex(j)  =  1/yBus(j,j)*(pCalc/conj(vCalcComplex(j))-  sum(yBus(j,1:j-
1).*vCalcComplex(1:j-1,1).')-sum(yBus(j,j+1:nBus).*vCalcComplex(j+1:nBus,1).'));
        elseif (qCalc(j) <= qMin(j))
            qCalc(j) = qMin(j);
            pCalc = pSpec(j)-i*qCalc(j);
```

```
            vCalcComplex(j) = 1/yBus(j,j)*(pCalc/conj(vCalcComplex(j))- sum(yBus(j,1:j-1).*vCalcComplex(1:j-1,1).')-sum(yBus(j,j+1:nBus).*vCalcComplex(j+1:nBus,1).'));
         else
            pCalc = pSpec(j)-i*qCalc(j);
            vCalcComplex(j) = 1/yBus(j,j)*(pCalc/conj(vCalcComplex(j))- sum(yBus(j,1:j-1).*vCalcComplex(1:j-1,1).')-sum(yBus(j,j+1:nBus).*vCalcComplex(j+1:nBus,1).'));
            vCalcComplex(j) = vInitial(j)*(cos(angle(vCalcComplex(j)))+i*sin(angle(vCalcComplex(j))));
         end
      else
         pCalc = pSpec(j)-i*qSpec(j);
         vCalcComplex(j) = 1/yBus(j,j)*(pCalc/conj(vCalcComplex(j))- sum(yBus(j,1:j-1).*vCalcComplex(1:j-1,1).')-sum(yBus(j,j+1:nBus).*vCalcComplex(j+1:nBus,1).'));
      end
   end
   vIterComplex = [vIterComplex vCalcComplex];
   vIterMag =[vIterMag abs(vCalcComplex)];
   vIterAngle = [vIterAngle angle(vCalcComplex)];
   qIterCalc = [qIterCalc, qCalc];
   err = abs(vIterComplex(:,k+1)-vIterComplex(:,k));
   maxErr(k,1) = max(err);
   vCalcMag = abs(vCalcComplex);
   thetaCalc = angle(vCalcComplex);
   if (maxErr(k,1) <= 0.0001)
      break
   end
 end
No. of iterations
vCalcComplex
```

OUTPUT:

Iteration 1:

Vmag = [1.0500   1.0431   1.0366   1.0485]

Vang = [0   0.0282   -0.0841   -0.0107]

No. of iterations taken for convergence = 13

Voltages at the end of final iteration:

Vmag = [1.0500

1.0837

1.0917

1.1007]

Vang = [0

-0.0027

-0.0981

-0.0355]

CALCULATIONS:

Initially, V_1=1.05∠0, V_2 = 1∠0, V_3 = 1∠0, V_4 = 1∠0

Calculation of bus voltage V_i:

$$V_i = \frac{1}{Y_{ii}}\left(\frac{P_i - jQ_i}{V_i^*} - \sum_{\substack{k=1\\k\neq i}}^{k=n} Y_{ik}V_k\}\right)$$

1st Iteration values:

$$V_2 = \frac{1}{Y_{22}}\left(\frac{P_2 - jQ_2}{V_2^*} - (Y_{21}V_1 + Y_{23}V_3 + Y_{24}V_4)\right)$$

$V_2 =$

$$V_3 = \frac{1}{Y_{33}}\left(\frac{P_3 - jQ_3}{V_3^*} - Y_{31}V_1 + Y_{32}V_2 + Y_{34}V_3\right)$$

$V_3 =$

$$V_4 = \frac{1}{Y_{44}}\left(\frac{P_4 - jQ_4}{V_4^*} - Y_{41}V_1 + Y_{42}V_2 + Y_{43}V_3\right)$$

$V_4 =$

INFERENCES:

1. The Gauss-Siedel method is taking more iterations to converge.
2. It is easy to understand and write the code.
3. It involves simple non-linear algebraic equations.

VIVA QUESTIONS:

1. What are the benefits of conducting load flow study?
2. Can load flow studies are useful for transient analysis of power system?
3. In GS method, when the PV bus is treated as PQ bus?

4. What are the inputs required for conducting load flow studies?
5. What are the parameters to be specified in case of slack bus?
6. What is the need of acceleration factor in GS method?
7. What is the difference between Gauss method and Gauss-Siedel method?
8. Why GS method is not preferred for large power system network?
9. What are the disadvantages of GS method?
10. What are the advantages of GS method?

RESULT:

Lab Instructor **Faculty**

Date: **Date:**

EXP. NO.: 06
DATE:

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 network by using Newton-Raphson method.

APPARATUS REQUIRED:

S.No	Name of the Apparatus
1	Personal Computer
2	Matlab Software

THEORY:

LINE DATA:

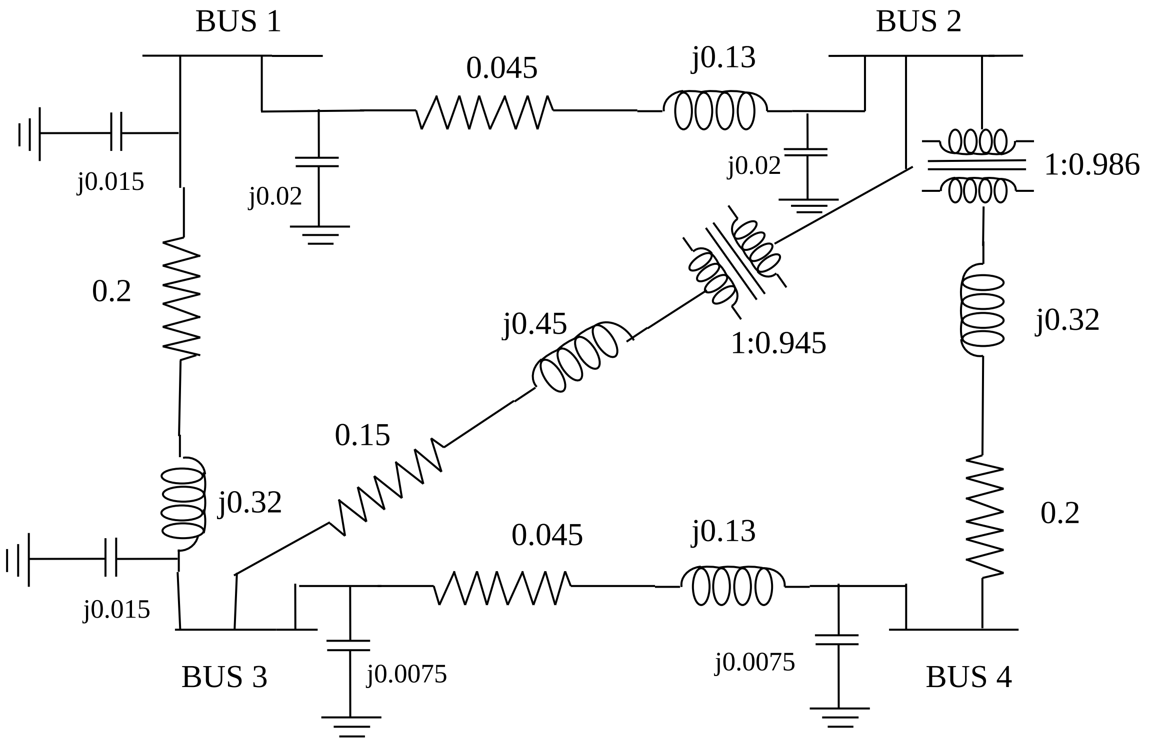
ELEMENT NO	FROM BUS	TO BUS	R(p.u.)	X(p.u.)	TURNS RATIO(a:1)	CHARGING ADMITTANCE(p.u.)
1	**1**	**2**	**0.045**	**0.13**	**1:1**	**0.04**
2	**1**	**3**	**0.2**	**0.32**	**1:1**	**0.03**
3	**2**	**3**	**0.15**	**0.45**	**1:0.945**	**0**

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 (p.u.)	Delta (deg)	P(p.u.)	Q(p.u.)
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:



ALGORITHM:

1. Read line data and bus data of the given power system.
2. Use line data to obtain Y_{bus}.
3. Use the flat start for given values of bus voltage magnitude and phase angles.

   Set $V_i^{(0)} = 1p.u.$ for i=1,2,3…, n and $\delta_i = 0$
4. Calculate P_i and Q_i (for the buses i = 1,2,3) by using equations.

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

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

5. Check $Q_i^{min} \leq Q_i \leq Q_i^{max}$ for PV buses. If Q_i is within the limits go to step 6 else set $Q_i = Q_i^{min}$ or Q_i^{max} based on the limit violation and treat this i^{th} bus as PQ bus. Redesignate the bus numbers and return to step 1.
6. Calculate power mismatches for every iteration

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

7. Calculate the elements of the Jacobian 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 the voltage magnitudes and phase angles using the increments as given below

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

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

10. Check the convergence condition

$$\Delta V_i = |V_i|^{\gamma+1} - \Delta|V_i|^{\gamma} \leq \epsilon \; and \; \Delta\delta_i = \delta_i^{\gamma+1} - \delta_i^{\gamma} \leq \epsilon,$$

where $'\epsilon'$ is the error specified. If all convergence conditions are satisfied then go to step 11, otherwise go to step 4 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)

CALCULATIONS:

Power flow equations:

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

$P_2 =$

$P_3 =$

P_4=

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

$Q_2 =$

$Q_3 =$

$Q_4 =$

Power Residuals:

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

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

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

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

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

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

JACOBIAN MATRIX:

Diagonal Elements of J_1:

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

$\frac{\partial P_2}{\partial \delta_2} =$

$\frac{\partial P_3}{\partial \delta_3} =$

$\frac{\partial P_4}{\partial \delta_4} =$

Off diagonal elements of J_1:

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

$\frac{\partial P_2}{\partial \delta_3} =$

$\frac{\partial P_3}{\partial \delta_2} =$

$$\frac{\partial P_2}{\partial \delta_4} =$$

$$\frac{\partial P_4}{\partial \delta_2} =$$

$$\frac{\partial P_4}{\partial \delta_3} =$$

$$\frac{\partial P_3}{\partial \delta_4} =$$

Diagonal elements of J_2:

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

$$\frac{\partial P_1}{\partial V_1} =$$

$$\frac{\partial P_2}{\partial V_2} =$$

$$\frac{\partial P_3}{\partial V_3} =$$

Off diagonal elements of J_2:

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

$$\frac{\partial P_2}{\partial |V_3|} =$$

$$\frac{\partial P_2}{\partial |V_4|} =$$

$$\frac{\partial P_3}{\partial |V_2|} =$$

$$\frac{\partial P_2}{\partial |V_4|} =$$

$$\frac{\partial P_3}{\partial |V_4|} =$$

$$\frac{\partial P_4}{\partial |V_3|} =$$

Diagonal elements in J_3:

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

$$\frac{\partial Q_2}{\partial \delta_2} =$$

$$\frac{\partial Q_3}{\partial \delta_3} =$$

$$\frac{\partial Q_4}{\partial \delta_4} =$$

Off diagonal elements in J_3:

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

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

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

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

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

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

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

Diagonal elements in J_4:

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

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

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

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

Off diagonal elements in J_4:

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

$$\frac{\partial Q_2}{\partial |V_3|}$$

$$\frac{\partial Q_2}{\partial |V_4|}$$

$$\frac{\partial Q_3}{\partial |V_2|} =$$

$$\frac{\partial Q_4}{\partial |V_2|} =$$

$$\frac{\partial Q_3}{\partial |V_4|} =$$

$$\frac{\partial Q_4}{\partial |V_3|} =$$

JACOBIAN MATRIX:

J =

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

INFERENCES:

1. For the given the power system 1st iteration values are calculated theoretically.
2. By MATLAB code, the values of 1st iteration have been checked and also convergence is checked.
3. The number of iterations is 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 meant by a PQ bus?
5. What is the need for slack bus?
6. What are the operations which utilize the load flow study data?
7. What is meant by a swing bus?
8. Why NR method is preferred for large power system network?
9. What are the disadvantages of NR method?
10. What are the advantages of NR method?

RESULT:

Lab Instructor **Faculty**

Date: **Date:**

EXP. NO.: 07
DATE:

POWER FLOW SOLUTION BY USING FAST DECOUPLED METHOD

AIM: To develop the MATLAB program for performing the power flow solution of a given power system network by using Fast Decoupled method.

APPARATUS REQUIRED:

S.No	Name of the Apparatus
1	Personal Computer
2	Matlab Software

THEORY:

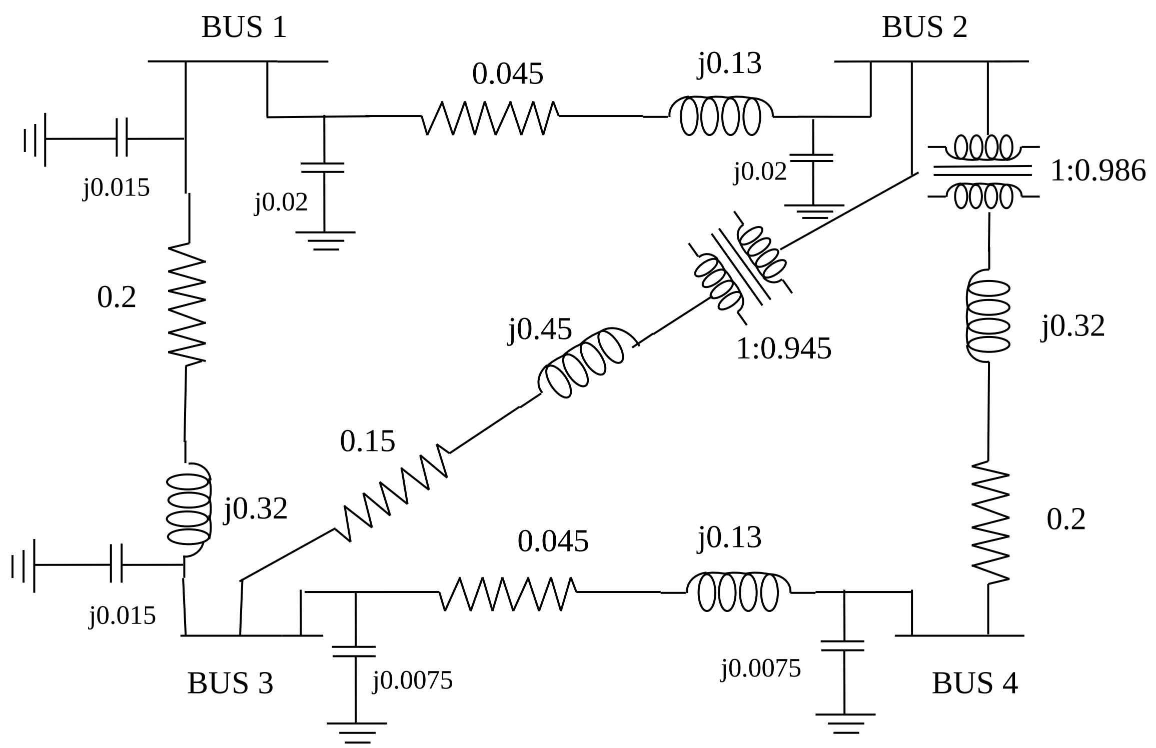
LINE DATA:

ELEMENT NO	FROM BUS	TO BUS	R(p.u.)	X(p.u.)	TURNS RATIO(a:1)	CHARGING ADMITTANCE(p.u.)
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 (p.u.)	Delta (deg)	P(p.u.)	Q(p.u.)
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:



ALGORITHM:

1. Assume a suitable solution for all buses except the slack bus. Let V_i =1+j0 for PQ buses, where bus number i = 2,3, ...n. (n-buses)
2. Set the convergence criterion (ε).
3. Set the iteration count k = 0
4. Set the bus count i = 2

5. Calculate P_i and Q_i using

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

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

6. Compute the real and reactive power mismatches ΔP^k and ΔQ^k. If the mismatches are with in desirable tolerance, then end the program.

7. Normalize the mismatches by dividing each entry by its respective bus voltage magnitude $\Delta P^k = \Delta P_2^k / V_2^k$, ..., $\Delta P^k = \Delta P_n^k / V_n^k$, $\Delta Q^k = \Delta Q_2^k / V_2^k$, ..., $\Delta Q^k = \Delta Q_n^k / V_n^k$
8. Solve for the voltage magnitude and the correction factors ΔV^k and δ^k by using the constant matrices B' and B" which are extracted from the bus admittance matrix Y- bus.

$$[B'] \Delta\delta^k = \Delta P^k$$
$$[B'']\Delta V^k = \Delta Q^k$$

9. Update the voltage magnitude and angle vectors

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

$$V^{k+1} = V^k + \Delta V^k$$

10. Check if all the buses are taken into account if yes go to next step otherwise go to next step. Otherwise go to step 4
11. Advance iteration count k = k+1 go to step 3
12. Evaluate bus and load powers and print the results.

PROGRAM:

```
clc
clear all;
baseMVA = 100;
loadData = [1 1 1.05 0 0 0 0 0 0 0 0 0;
        2 3 1 0 0 0 -45 -22 0 0 0 0;
        3 3 1 0 0 0 98 -40 0 0 0 0;
        4 3 1 0 0 0 -32 15 0 0 0 0];
```

```
N = max(loadData(:,1));
busNo = loadData(:,1);
busType = loadData(:,2);
vMagSpec = loadData(:,3);
thetaSpec = loadData(:,4);
pGen = loadData(:,5)/baseMVA;
qGen = loadData(:,6)/baseMVA;
pLoad = loadData(:,7)/baseMVA;
qLoad = loadData(:,8)/baseMVA;
qMin = loadData(:,9)/baseMVA;
qMax = loadData(:,10)/baseMVA;
GshPu = loadData(:,11);
BshPu = loadData(:,12);
pSpec = pGen-pLoad;
qSpec = qGen-qLoad;

M= sum (busType == 1| busType == 2);% no of Generators in the system

l = zeros(N,1) ; % flag for  violating generators

vMagCalc = [vMagSpec];
thetaCalc = [thetaSpec];

vIterMag =[vMagCalc];
thetaIter = [thetaCalc];

pCalc = zeros(N,1);
qCalc = zeros(N,1);
yBus = [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        ];
yBusMag = abs(yBus);
yBusAng = angle(yBus);
%% Fast Decoupled Load Flow Algorithm
%% Step 1 Take Flat start and start iteration counter k=1
for k = 1:100
    for i= 2:M
        qCalc(i,1) = sum(vMagCalc (i,1)*
vMagCalc(1:N,1).*yBusMag(i,1:N).'.*sin(thetaCalc(i,1)-thetaCalc(1:N,1)-
yBusAng(i,1:N).'));
     if (qCalc(i,1) >= qMin(i,1) & qCalc(i,1) <= qMax(i,1))
           vMagCalc(i,1) = vMagCalc(i,1); % assume this calculated voltage as specified
voltage for PV bus
```

```
        elseif (qCalc(i,1) > qMax(i,1))
            qSpec(i,1) = qMax(i,1);
            l(i,1) = 1;
        elseif (qCalc(i,1) < qMin(i,1))
             qSpec(i,1) = qMin(i,1);
             l(i,1) = 1;
     end
    end
L = sum(l); % total number of generators violated the limit
genIndex = busNo(logical(l));
l(:,1) = 0;

% unknown vector diemension Calculation
pEqns = busNo(2:N,1);
qEqns = [busNo(M+1:N,1); genIndex];
thetaUnknown = busNo (2:N,1);
vUnknown = [busNo(M+1:N,1); genIndex];
% jacobian Matrices

%MisMatchVector calculations
pSpecDelM = zeros(N-1,1);
qSpecDelM = zeros(N-M+L,1);

pSpecDelM = pSpec(2:N,1);
qSpecDelM = qSpec(qEqns);

pCalcDelM = zeros(N-1,1);
qCalcDelM = zeros(N-M+L,1);

for i=1:N-1
    pCalcDelM(i,1) = sum(vMagCalc (pEqns(i,1),1)*
vMagCalc(1:N,1).*yBusMag(pEqns(i,1),1:N).'.*cos(thetaCalc(pEqns(i,1),1)-
thetaCalc(1:N,1)-yBusAng(pEqns(i,1),1:N).'));
end
delP = pSpecDelM-pCalcDelM;
for i=1:N-M+L
    qCalcDelM(i,1) = sum(vMagCalc (qEqns(i,1),1)*
vMagCalc(1:N,1).*yBusMag(qEqns(i,1),1:N).'.*sin(thetaCalc(qEqns(i,1),1)-
thetaCalc(1:N,1)-yBusAng(qEqns(i,1),1:N).'));
end
delQ = qSpecDelM- qCalcDelM;

delM =[delP;delQ];
err = abs(delM);
```

```
Err = max(err);

if (Err > 0.0001)
   bDash = zeros(N-1,N-1);
bDdash = zeros(N-M+L, N-M+L);
bDash = -1*imag(yBus (2:N,2:N));
for i = 1:N-M+L
   for j = 1:N-M+L
      bDdash(i,j) = -1*imag(yBus(qEqns(i),vUnknown(j)));
   end
end
bDash;
bDdash;
%update the voltages first. as voltage and theta equations are decoupled.
delV = bDdash\delQ;
for i = 1:length(vUnknown)
   vMagCalc(vUnknown(i,1),1) = vMagCalc(vUnknown(i,1),1)+delV(i,1);
end
%use most recent updated volatages in updating theta. It is causing fast
%convergence
delTheta = bDash\(delP./vMagCalc(2:N,1));
thetaCalc(2:N,1) = thetaCalc(2:N,1)+ delTheta;
k
vMagCalc
thetaCalc
% vIterMag =[vIterMag  vMagCalc];
% thetaIter = [thetaIter thetaCalc];
else
  break;
end
end
vMagCalc
thetaCalc
```

OUTPUT:

Iteration 1:

Vmag = [1.0500   1.0940   1.1433   1.1277]

Vang = [0   0.0276   -0.0687   -0.0003]

No. of iterations taken for convergence: 11

Vmag = [1.0500

1.0837

1.0918

1.1008]

Vang = [0

-0.0027

-0.0981

-0.0355]

CALCULATIONS:

Power flow equations:

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

$P_2 =$

$P_3 =$

$P_4 =$

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

$Q_2 =$

$Q_3 =$

$Q_4 =$

Power Residuals:

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

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

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

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

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

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

$$\frac{\Delta Q_i}{V_i} = B''\Delta V_i$$

For 1st iteration, the flat voltage profile is chosen i.e. $V_i = 1\angle 0^0$ p.u. and $B'' = -imag(Y_{bus})$ of PQ buses. Therefore,

$$\Delta V_i = [B'']^{-1}\Delta Q_i$$

$$\begin{bmatrix} \Delta V_2 \\ \Delta V_3 \\ \Delta V_4 \end{bmatrix} =$$

$$\begin{bmatrix} V_{2new} \\ V_{3new} \\ V_{4new} \end{bmatrix} = \begin{bmatrix} V_{2old} \\ V_{3old} \\ V_{4old} \end{bmatrix} + \begin{bmatrix} \Delta V_2 \\ \Delta V_3 \\ \Delta V_4 \end{bmatrix} =$$

Now, the change in rotor angles $\Delta\delta_i$ is calculated by

$$\frac{\Delta P_i}{V_i} = B'\Delta\delta_i$$

Where, $V_i = V_{inew}$ p.u. and $B' = -imag(Y_{bus})$ of PQ and PV buses. Therefore,

$$\Delta\delta_i = [B']^{-1}\frac{\Delta P_i}{V_i}$$

$$\begin{bmatrix} \Delta\delta_2 \\ \Delta\delta_3 \\ \Delta\delta_4 \end{bmatrix} =$$

$$\begin{bmatrix} \delta_{2new} \\ \delta_{3new} \\ \delta_{4new} \end{bmatrix} = \begin{bmatrix} \delta_{2old} \\ \delta_{3old} \\ \delta_{4old} \end{bmatrix} + \begin{bmatrix} \Delta\delta_2 \\ \Delta\delta_3 \\ \Delta\delta_4 \end{bmatrix} =$$

Vmag =

delta =

INFERENCES:

1. The decoupling of P-δ and Q-V allows this method to converge faster than the G-S method.
2. The memory requirement decreases as some of the Jacobian elements become zero.

VIVA QUESTIONS:

1. What is the difference between Decoupled method and Fast Decoupled method?
2. What is the difference between NR method and Fast Decoupled method?
3. What is the difference between NR method and Fast Decoupled method?
4. What are the assumptions followed in Fast Decoupled method?
5. What is the other name of slack bus?
6. Why PV bus is termed as voltage-controlled bus?
7. Why PQ bus is termed as load bus?
8. What is meant by a decoupling?
9. What are the disadvantages of Fast Decoupled method?
10. What are the advantages of Fast Decoupled method?

RESULT:

Lab Instructor **Faculty**

Date: **Date:**

EXP. NO. : 08
DATE :

SINGLE AREA AND TWO AREA LOAD FREQUENCY CONTROL

AIM: To determine the i) frequency response of an isolated power system with and without integral controller using MATLAB/Simulink. ii) frequency response of an interconnected (Two area) power system with Tie line control using MATLAB/Simulink.

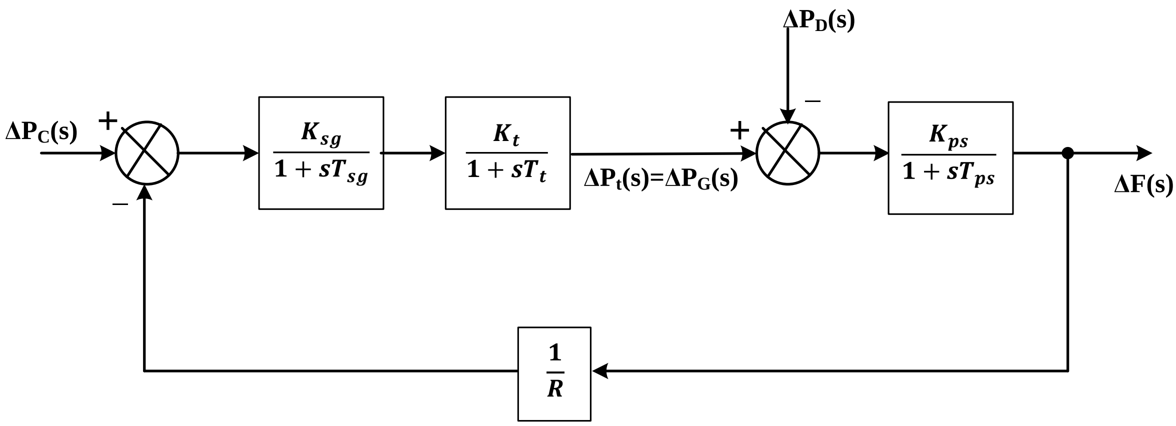
APPARATUS REQUIRED:

S.No	Name of the Apparatus
1	Personal Computer
2	Matlab Software

THEORY:

i) Single Area Load Frequency control

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



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

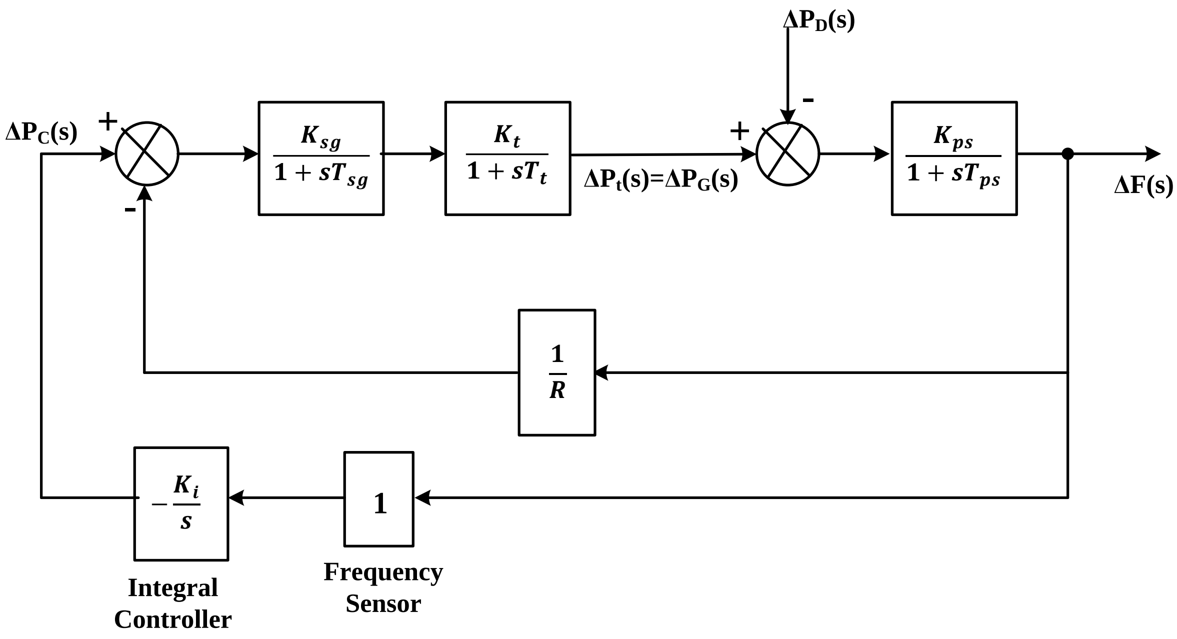
ΔP_D = Load demand

ΔF = Change in frequency

$\Delta P_t = \Delta P_G$ = Incremental turbine power output

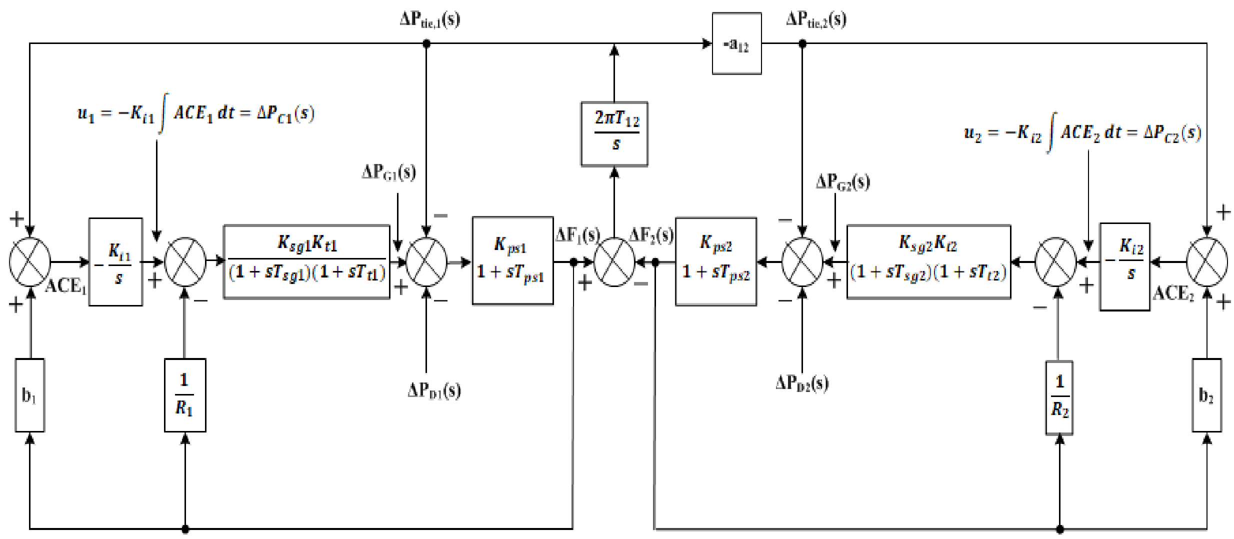
ii) Single Area Load Frequency control with Integral Controller

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



Where, K_i is the integral controller gain. By adding the integral controller, the steady state frequency error becomes zero.

iii) Two Area Power System with tie-line:



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:

a) Single Area Load Frequency control

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

Calculations:

The steady state frequency can be obtained as

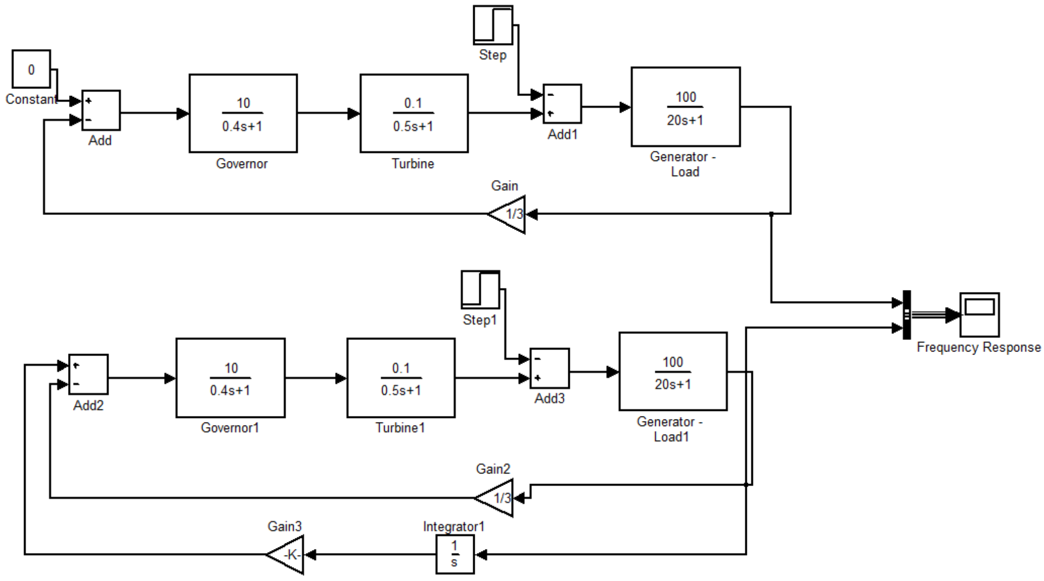
$$\Delta f(t) = -\frac{RK_{ps}}{R+K_{ps}}\left\{1 - exp\left[-\frac{t}{T_{ps}}\left(\frac{R}{R+K_{ps}}\right)\right]\right\}\Delta P_D$$

Substituting R = K_{ps} = $1/B$ = T_{ps} = ΔP_D =

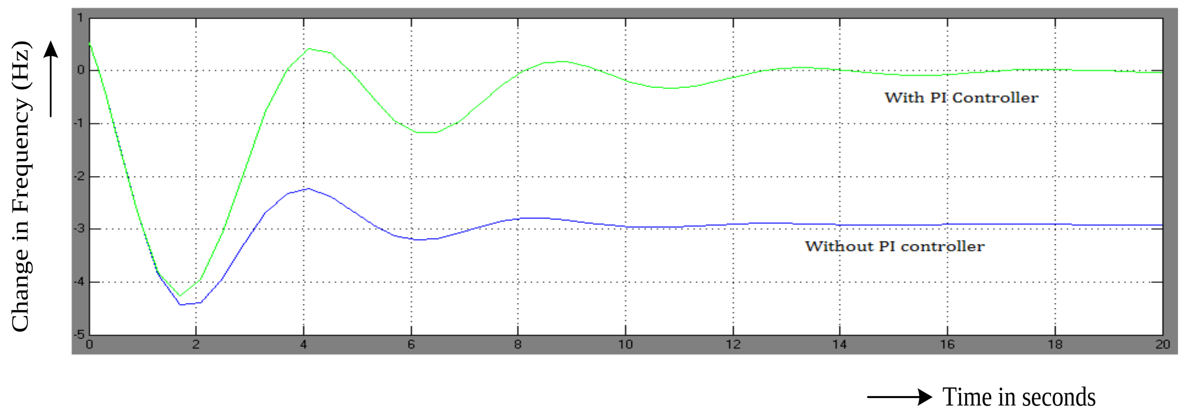
$$\Delta f(t) =$$

$$\Delta f\,|_{\text{steady state}} =$$

SIMULINK DIAGRAM:



Frequency Response:



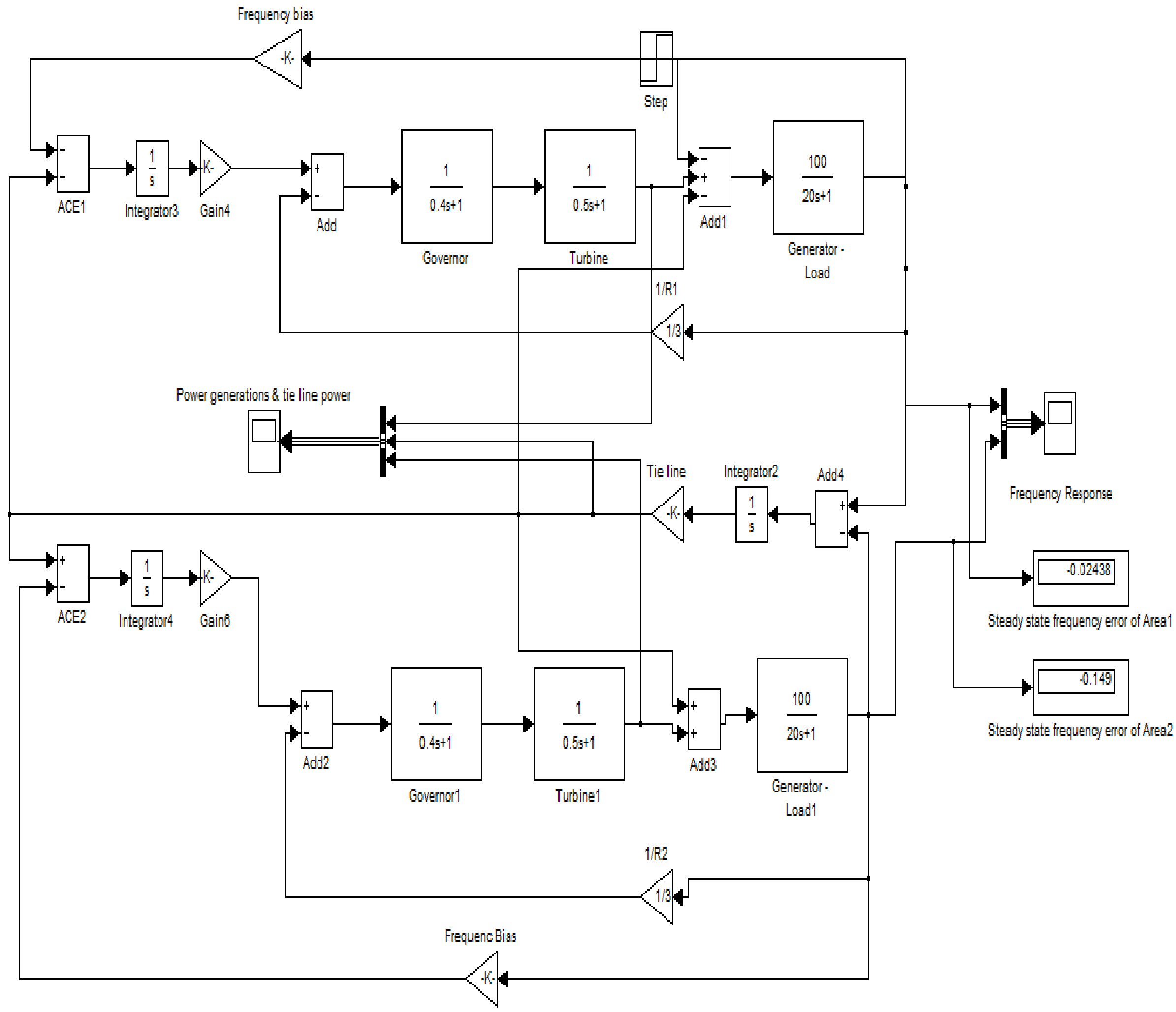
b) Two Area Load Frequency control

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

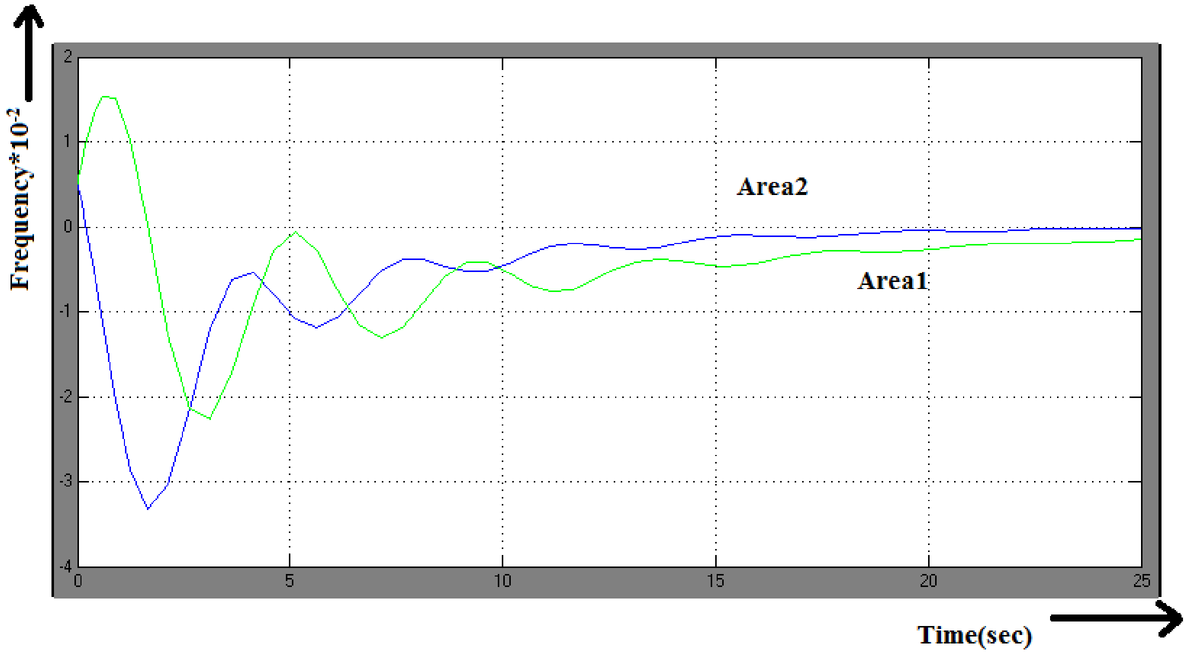
Assume

Tsg = 0.4
Tt = 0.5
Tps = 20
Kps = 100
R = 3
Ksg = 1
Kt = 1
Ki = 0.09
Ki for tie line = 0.05
$\Delta P_D = 0.01$
b = 0.425

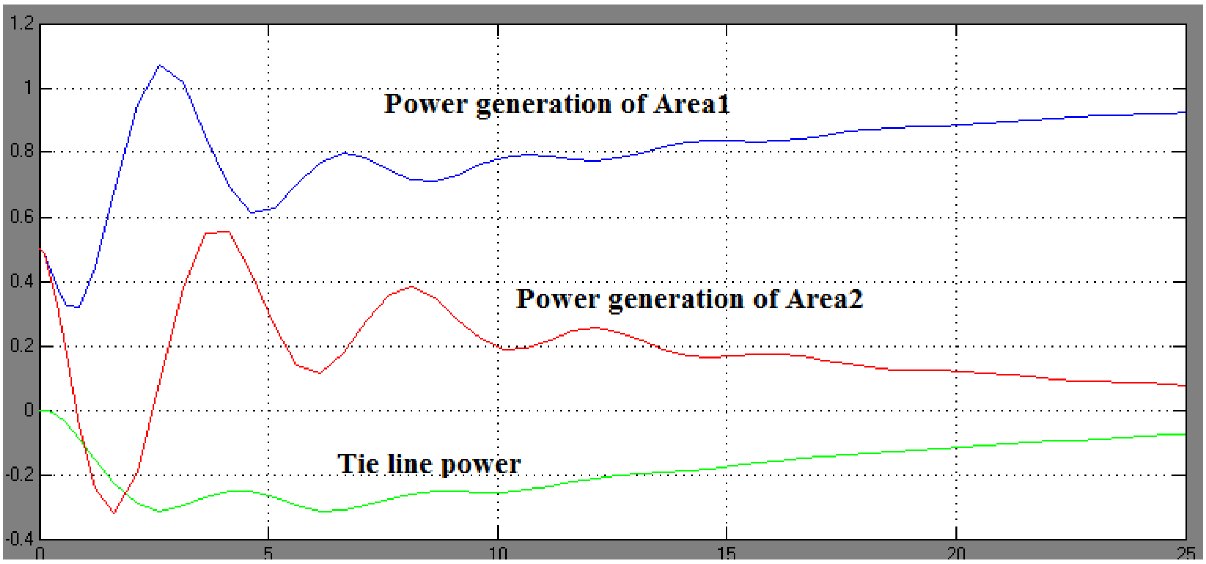
SIMULINK DIAGRAM:



Frequency Response:



Tie line power response:



INFERENCES:

1. The addition of integral controller is allowing the steady state frequency error to become zero.
2. The tie line power carries the excess power available in one area and supplies it to the other area where the load requirement is more than the generation.

VIVA QUESTIONS:

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 disadvantage of ALFC loop?

7) What is two area control?

8) What are the advantages of interconnected power system?

9) What is the function of AVR loop?

10) What are the assumptions made in dynamic response of an ALFC loop?

RESULT:

Lab Instructor **Faculty**

Date: **Date:**

EXP. NO. : 9

DATE :

ECONOMIC LOAD DISPATCH

AIM: To find the i) optimum loading of two units for the given load neglecting transmission losses using MATLAB. ii) optimum loading of two units for the given load with penalty factors using MATLAB.

APPARATUS REQUIRED:

S.No	Name of the Apparatus
1	Personal Computer
2	Matlab Software

THEORY:

i) Optimum loading of two units for the given load neglecting transmission losses

Problem:

Incremental fuel costs in rupees per MWh for a plant consisting of two units are:

$$\frac{dF_1}{dP_{g1}} = 0.2P_1 + 40 \; and \; \frac{dF_2}{dP_{g2}} = 0.25P_2 + 30 \; Rs/MWh$$

Assume that both units are operating at all times, and total load varies from 40 MW to 250 MW, and the maximum and minimum loads on each unit are to be 125 MW and 20 MW respectively. How will the load be shared between the two units as the system load varies over the full range? What are the corresponding values of the plant incremental costs?

ALGORITHM:

1. Start the program by taking the inputs: the number of generators N_g, the fuel cost coefficients α_i, β_i, and γ_i. Also give the inputs of load demand P_d, generation minimum and maximum limits P_{gi}^{min}, P_{gi}^{max}, where i =1,2, ……, N_g.
2. Select a suitable value of lambda λ and incremental lambda Δλ.
3. Take the first unit.
4. Calculate P_{gi} using equation $P_{gi} = (\lambda - \beta_i) / \alpha_i$.
5. If $P_{gi} > P_{gi}^{max}$ then set $P_{gi} = P_{gi}^{max}$ otherwise check whether lower limit exceeded or not i.e. if $P_{gi} < P_{gi}^{min}$ then set $P_{gi} = P_{gi}^{min}$.
6. If the calculated power P_{gi} is within the minimum and maximum limits, then go for next generator and repeat the steps 4 and 5.
7. After calculating the power generations for all units, calculate $\Delta P = \sum_{i=0}^{N_g} P_{gi} - P_d$
8. If calculated power ΔP is less than the tolerance value ε, then print the generations and its cost.
9. If calculated power ΔP is more than the tolerance value ε, then check whether the ΔP > 0 or not. If ΔP > 0, set λ = λ - Δλ, otherwise set λ = λ + Δλ.
10. With the updated value of λ, go to step 3.

MATLAB PROGRAM:

```
% the demand is taken as 231.25 MW, n is no of generators, Pd stands for load
%demand; alpha and beta arrays denote alpha beta coefficients for given
%generator
clc
clear all;
n=2; Pd = 231.25; alpha=[0.20 0.25]; beta=[40 30];
% initial guess for lamda
lamda =20; lamdaprev = lamda;
% tolerance is eps and increment in lamda is deltalamda
eps=1; deltalamda=0.25;
% the min. and max. limits of each generating unit are stored in arrays Pgmin and Pgmax.
Pgmax= [125 125]; Pgmin= [20 20];
Pg = 100*ones(n,1);
while abs(sum(Pg)-Pd) > eps
    for i = 1:n
        Pg(i)=(lamda-beta(i))/alpha(i);
```

```
        if Pg(i)>Pgmax(i)
            Pg(i)=Pgmax(i);
        end
        if Pg(i)<Pgmin(i)
            Pg(i)=Pgmin(i);
        end
    end
    if (sum(Pg)-Pd)<0
        lamdaprev=lamda;
        lamda=lamda+deltalamda;
    else
        lamdaprev=lamda;
        lamda=lamda-deltalamda;
    end
end
disp('The final value of Lamda is') lamdaprev
disp('The distribution of load shared by two units is') Pg
```

Expected Output:

```
The final value of Lamda is
lamdaprev =  61.2500
The distribution of load shared by two units is Pg
= 106.2500

  125.0000
```

Calculations:

For 1st iteration:

Let $\lambda = 20$, $\Delta\lambda = 0.25$, $\varepsilon = 1$, and P_{g1}, P_{g2} are 100MW, then $\Delta P = | P_{g1} + P_{g2} - P_D | =$.
From the given problem $\alpha_1 = 0.2$, $\alpha_2 = 0.25$ and $\beta_1 = 40$, $\beta_2 = 30$.

$P_{g1} = (\lambda - \beta_1) / \alpha_1 =$

$P_{g2} = (\lambda - \beta_2) / \alpha_2 =$

$P_{g1} + P_{g2} - P_D =$

Now, again calculate ΔP and repeat the above calculation until the condition ($\Delta P < \varepsilon$) satisfied.

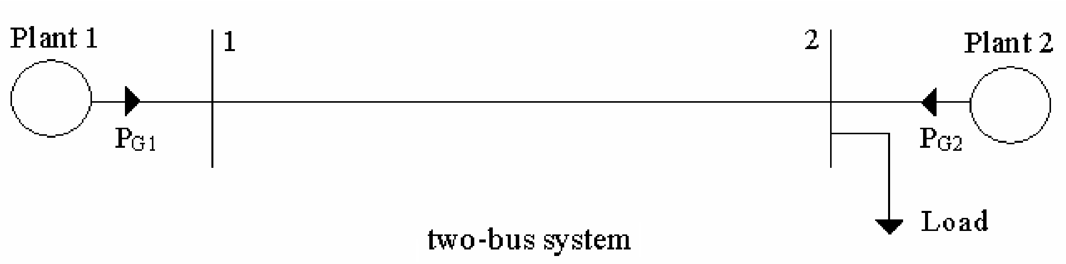
ii) <u>Optimum loading of two units for the given load with penalty factors:</u>

Problem:

A two-bus system is shown in figure. If 100 MW is transmitted from plant 1 to the load, a transmission loss of 10 MW is incurred. Find the required generation for each plant and the power received by load when the system λ is Rs 25/MWh. The incremental fuel costs of the two plants are given below:

$$\frac{dC_1}{dP_{G1}} = 0.02P_{G1} + 16\ Rs/MWh$$

$$\frac{dC_2}{dP_{G2}} = 0.04P_{G2} + 20\ Rs/MWh$$



ALGORITHM:

1. Start the program by taking the inputs: the number of generators N_g, the fuel cost coefficients α_i, β_i, and γ_i. Also give the inputs of load demand P_d, generation minimum and maximum limits P_{gi}^{min}, P_{gi}^{max}, where i =1,2, ……, N_g.
2. Also give the inputs of loss coefficient matrix B for the given system.
3. Select a suitable value of lambda λ and incremental lambda Δλ.
4. Start the iteration count and take the first unit.
5. Calculate $\sigma_i = B_i*Pg - B_{ii}*P_{gi}$ and then calculate

   $$P_{gi} = ((1–\beta_i) / (\lambda-(2* \sigma_i))) / (\alpha_i / \lambda +2*B_{ii});$$
6. If $P_{gi} > P_{gi}^{max}$ then set $P_{gi} = P_{gi}^{max}$ otherwise check whether lower limit exceeded or not i.e. if $P_{gi} < P_{gi}^{min}$ then set $P_{gi} = P_{gi}^{min}$.
7. If the calculated power P_{gi} is within the minimum and maximum limits, then go for next generator and repeat the steps 5 and 6.
8. After calculating the power generations for all units, calculate the loss P_L using the equation $P_L = P_g' B P_g$
9. Now calculate $\Delta P = \sum_{i=0}^{N_g} P_{gi} - P_d - P_L$
10. If calculated power ΔP is less than the tolerance value ε, then print the generations and its cost.
11. If calculated power ΔP is more than the tolerance value ε, then check whether the ΔP > 0 or not. If ΔP > 0, set λ = λ - Δλ, otherwise set λ = λ + Δλ.

12. With the updated value of λ, go to step 4.

MATLAB Program:

```
% this program finds the optimal loading of generators including penalty factors
% Pd stands for load demand, alpha and beta arrays denote alpha beta coefficients
% for given generators, and n is the no of generators

clc
clear all;
n=2; Pd=237.04;
alpha = [0.020 0.04]; beta = [16 20];
% initial guess for lamda is 20; tolerance is eps and increment in lamda is deltalamda
lamda = 20; lamdaprev = lamda;
eps = 1; deltalamda = 0.25;
% the min. and max. limits of each generating unit are stored in arrays Pgmin and Pgmax
Pgmax = [200 200]; Pgmin = [0 0];

B = [0.0010  0

0        0];

noofiter=0;   PL=0;   Pg   =
zeros(n,1);  while  abs(sum(Pg)-
Pd-PL)>eps
for i=1:n,
sigma=B(i,:)*Pg - B(i,i)*Pg(i);
Pg(i)=(1-beta(i)/(lamda-(2*sigma)))/(alpha(i)/lamda+2*B(i,i));
if Pg(i)>Pgmax (i)
Pg(i)=Pgmax (i);
end
if Pg(i)<Pgmin(i)
Pg(i)=Pgmin(i);
end
end
PL = Pg'*B*Pg;
if (sum(Pg)-Pd-PL)<0
lamdaprev=lamda;
```

```
lamda=lamda+deltalamda;
else
lamdaprev=lamda;
lamda=lamda-deltalamda;
end
noofiter=noofiter + 1; Pg;
end
disp ('The no of iterations required are')
noofiter
disp ('The final value of lamda
is') lamdaprev
disp ('The optimal loading of generators including penalty factors is')
Pg
disp('The losses
are') PL
```

Expected Output:

The no of iterations required
are noofiter = 21
The final value of lamda
is lamdaprev = 25
The optimal loading of generators including penalty factors is Pg =
128.5714
125.0000
The losses are PL =
16.5306

Calculations:

For 1st iteration:

Let Pgmin = 0 and Pgmax = 200.
Let $\lambda = 20$, $\Delta\lambda = 0.25$, $\varepsilon = 1$, and P_{g1}, P_{g2}, and P_L are 0MW, then

$\Delta P = | P_{g1} + P_{g2} – P_D – P_L | =$.

From the given problem $\alpha_1 = 0.02$, $\alpha_2 = 0.04$ and $\beta_1 = 16$, $\beta_2 = 20$, the loss coefficients are $B_{11} = 0.001$, $B_{12} = B_{21} = 0$, $B_{22} = 0$.

$$\sigma_1 = B_{1:}*Pg - B_{11}*P_{g1} =$$

$$\sigma_2 = B_{2:}*Pg - B_{22}*P_{g2} =$$

$P_{g1} = ((1-\beta_1) / (\lambda-(2*\sigma_1))) / (\alpha_1 / \lambda + 2*B_{11}) =$

$P_{g2} = ((1-\beta_2) / (\lambda-(2*\sigma_2))) / (\alpha_2 / \lambda + 2*B_{22}) =$

Now loss $P_L = Pg' * B*Pg =$

Now, again calculate ΔP and repeat the above calculation until the condition ($\Delta P < \varepsilon$) satisfied.

INFERENCES:

1. The lambda iteration method is one of the simplest iterative method for solving economic load dispatch problem.
2. The lambda iteration method solution depends on number of generators as the method is slow under such cases.

VIVA QUESTIONS:

1) What is the function of economic load dispatch (ELD) in power system?

2) What are the units of fuel cost and incremental fuel cost?

3) What is the use of penalty factor?

4) What are the fuel cost coefficients in ELD problem?

5) What is the significance of the loss coefficients in ELD problem?

6) What is the relation between diagonal and off-diagonal loss coefficients?

7) In economic operation of a power system, the effect of increased penalty factor between a generating plant and system load current is?

8) What is the value of penalty factor for plant-1 when entire load is concentrated at plant-1?

9) What is meant by a load factor?

10) For a n-bus system, how many loss coefficients exist?

RESULT:

Lab Instructor **Faculty**

Date: **Date:**

EXP. NO. : 10
DATE :

SOLUTION OF SWING EQUATION USING POINT-BY-POINT METHOD

AIM: To solve the swing equation of the given problem using point-by-point method and write a MATLAB program to verify the result.

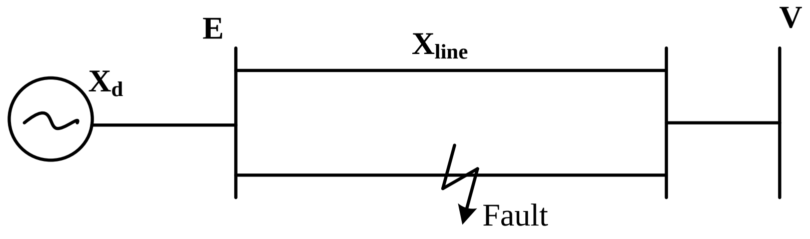
APPARATUS REQUIRED:

S.No	Name of the Apparatus
1	Personal Computer
2	Matlab Software

THEORY:

Problem:

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



ALGORITHM:

1. Read the input data such as generator voltage E, infinite bus voltage V, transmission line reactance x, fault clearing time tc and kinetic energy.
2. Give the inputs after calculating the moment of inertia m, mechanical power input pm, reactance during fault xdf, reactance after the fault xaf and the initial rotor angle δ_0.
3. Take the step time Δt and start the iterative loop.
4. If the time t is less than the tc then the reactance is xdf, otherwise the reactance is xaf.
5. Calculate the maximum power pmax and accelerating power pa with the initial rotor angle.

$$p_{max} = \frac{EV}{X} \; and \; p_a = p_m - p_{max} sin\delta$$

6. Now find the change in rotor angle $\Delta\delta$ as

$$\Delta\delta = \Delta\delta + \Delta t^2 \left(\frac{p_a}{m}\right)$$

7. Now find out the new rotor angle as $\delta = \delta + \Delta\delta$ and new time $t = t + \Delta t$.
8. Repeat the loop from the step 4 to step 7 until the condition t < required time (T) is violated.

MATLAB PROGRAM:

Program 1: Save this part in another m-file with name swing.m

```
%Defining the function swing function[time ang]=swing(tc)
function[time ang]=swing(tc)
k=0; V=1; E=1.1; pm=0.9; T=0.5; delT=0.05; ddelta=0; time (1) = 0; ang (1) = 21.64;
xdf=1.25; xaf=0.55; t=0;
delta=21.64*pi/180; i=2; m=2.52/(180*50);
while t<T
    if t<tc
        x=xdf;
    else
        x=xaf;
    end
    pmax=(E*V)/x;
    pa=pm-pmax*sin(delta);
    ddelta=ddelta+(delT^2*(pa/m));
    delta=(delta*180/pi+ddelta)*(pi/180);
    deltadeg=delta*180/pi;
    t=t+delT;
    time(i)=t;
    ang(i)=deltadeg;
    i=i+1;
```

```
end
```

<u>Program 2</u>: Main program that is dependent on swing.m

```
%solution of Swing equation by point-by-point method clc
clear all
close all
for i=1:2
tc=input('enter the value of clearing time:\n');
[time,ang]=swing(tc)
t(:,1)=time;
a(:,i)=ang;
end
plot(t,a(:,1),'*-',t,a(:,2),'d-')
axis([0 0.5 0 inf])
t,a
```

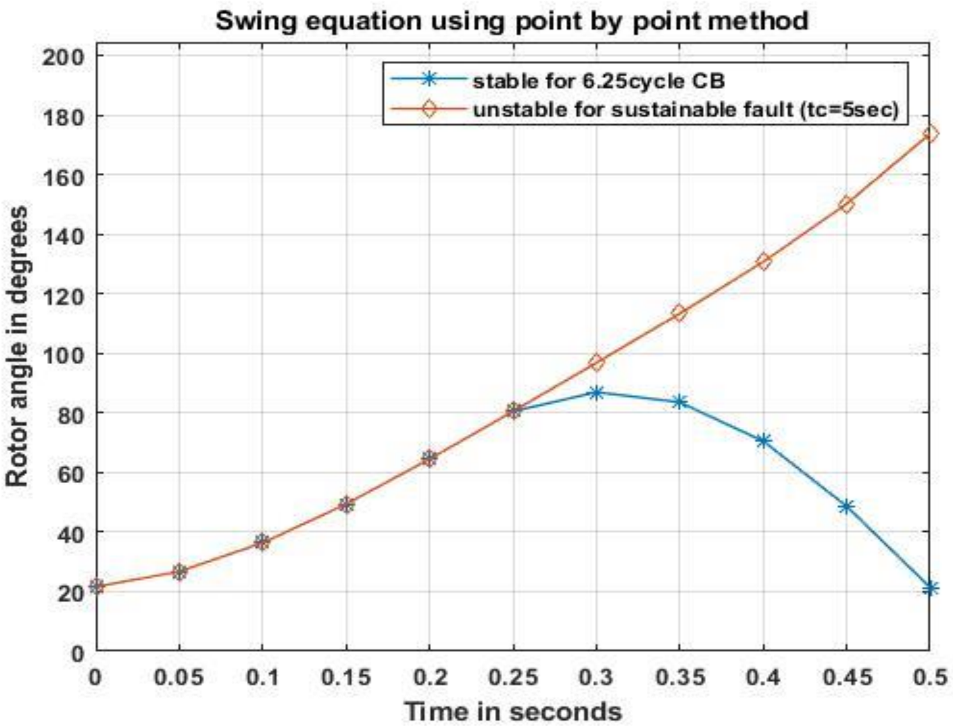
<u>Inputs to the program 2</u>:

Enter the value of clearing time as

0.25 sec, and 5 sec

Expected Output:

```
t = [ 0    0.0500    0.1000    0.1500    0.2000    0.2500    0.3000    0.3500    0.4000    0.4500
0.5000    0.5500]
% tc =   0.25sec      5sec
angle =[21.6400   21.6400
         26.7782   26.7782
         36.4122   36.4122
          49.4180   49.4180
          64.4921   64.4921
          80.5108   80.5108
          86.9523   96.8155
          83.5977  113.3543
          70.5330  130.7153
          48.6677  150.1568
          21.4293  173.7239
         -4.2975  204.4679 ]
```



CALCULATIONS:

E = 1.1p.u., V = 1p.u., X_d = 0.35p.u., X_{line} = 0.2, Rated power = 20MVA, power output =18MW

Mechanical power input P_m under steady state condition = P_e = 18/20 = 0.9p.u.

In steady state, $\boldsymbol{P_m = P_e = \frac{EV}{X} sin(\delta_0) = P_{max} sin(\delta_0)}$

X = X_d + X_{line}/2 =.

$$\boldsymbol{P_{max} = \frac{EV}{X} =}$$

Now, initial rotor angle $\delta_0 = \sin^{-1}(P_m/P_{max})$ =

Now, calculate the equivalent reactance of the circuit during fault by using delta to star and vice versa. Then, the reactance during the fault X_{df} = 1.25p.u.

The circuit breaker opens the faulty line within the clearing time t_c and then, the equivalent reactance of the circuit X_{af} = 0.55p.u.

If the time t < t_c, consider the reactance X = X_{df}, otherwise consider the reactance X = X_{af}.

Let t_c = 0.25sec, and the program starts with t = 0 after the occurrence of fault. Hence, the reactance X = X_{df} is considered. Calculate new $\boldsymbol{P_{max}}$

$$\boldsymbol{P_{max} = \frac{EV}{X} =}$$

Now, calculate the accelerating power P_a by choosing the initial rotor angle δ_0

$$\boldsymbol{P_a = P_m - P_e = P_m - P_{max} sin(\delta_0) =}$$

The moment of inertia

$$\boldsymbol{M = \frac{SH}{180^0 f}}$$

where S is selected as 1p.u. and inertia constant H is given as 2.52 MJ/MVA. Frequency f = 50Hz

$$\boldsymbol{M =}$$

Now, find the change in rotor angle Δδ and let the step time Δt = 0.05sec, then

$$\Delta\delta = \Delta\delta + \Delta t^2 \left(\frac{P_a}{M}\right) =$$

The new rotor angle as δ = δ + Δδ = and

new time t = t + Δt =

Repeat the above process until the time t exceeds the required time T.

INFERENCES:

1. The swing equation is very helpful in finding critical clearing angle and time.
2. For multi-machine system, the point-by-point method is very useful in finding the transient stability and critical clearing time.

VIVA QUESTIONS:

1) Define swing equation?

2) What is the significance of swing equation?

3) Which method is useful for single machine infinite bus (SMIB) system in finding the transient stability?

4) What are the methods used for multi-machine system in transient stability analysis?

5) What is meant by an accelerating power?

6) What are the methods to improve the transient stability?

7) What is the difference between steady state stability and transient stability?

8) What is the maximum power limit for system stability?

9) Define moment of inertia in transient stability?

10) What is the unit for inertia constant?

RESULT:

Lab Instructor **Faculty**

Date: **Date:**

EXP. NO.: 11
DATE:

Distribution Load Flow Solution by using Backward/Forward Sweep method

AIM: To develop the MATLAB program for performing the power flow solution of a given Distribution system network by using Backward/Forward Sweep method.

APPARATUS REQUIRED:

S.No	Name of the Apparatus
1	Personal Computer
2	Matlab Software

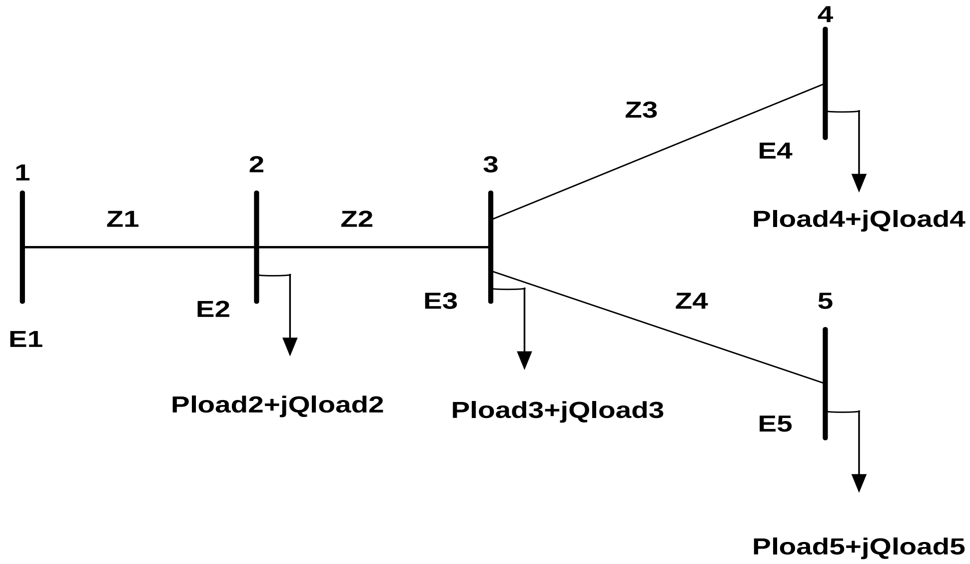
THEORY:

Problem:

LINE and LOAD DATA:

ELEMENT NO	FROM BUS	TO BUS	R(p.u.)	X(p.u.)	Active load (kW) at TO bus	Reactive load (kvar) at TO bus
1	1	2	0.0922	0.0477	100	60
2	2	3	0.4930	0.2511	90	40
3	3	4	0.3660	0.1864	120	80
4	3	5	0.3811	0.1941	60	30

LINE DIAGRAM:



In distribution system,

Pinj = -Pgen+Pload;

Qinj = -Qgen+Qload;

Assume the guess voltages i.e., flat voltage profile:

E1=1+j0;
E2=1+j0;
E3=1+j0;
E4=1+j0;
E5=1+j0;

Pair of terminals is referred as port. Transformer and transmission line will act as two port network. Power system or distribution network will act as multi-port network. Standard practise for two port network is current entering the port is taken as positive and same concept is used for multi-port power system or distribution system. From above figure, for example, I5 represent the current leaving the bus-5.

Therefore, at bus 5,

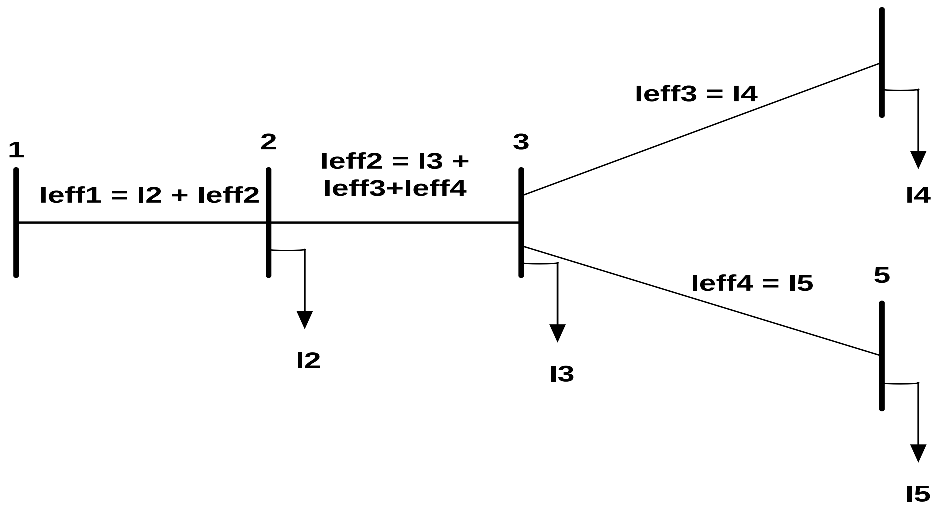
E5I5* = -(Pinj(5)+jQinj(5));

I5 = conj(-(Pinj5+jQinj5) /E5)

Similarly, I4 = conj(-(Pinj4+jQinj4) /E4)

Therefore, Ii = conj(-(Pinj(i)+jQinj(i)) /E(i))

BACKWARD SWEEP

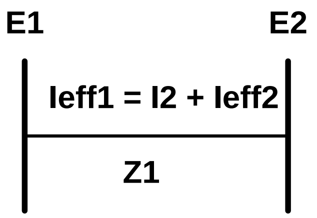


Ieff(1)=I2+Ieff(2);
Ieff(2)=I3+Ieff(3)+Ieff(4);
Ieff(3)=I4;
Ieff(4)=I5;

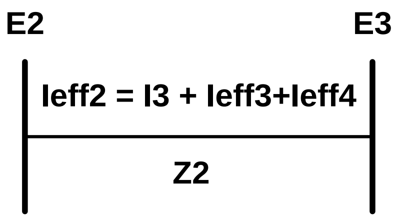
Ieff(i) is the value of current supplied by the 'i'th node beyond its interconnectivity including its own load current. Iload and Ieff values will be changing from iteration to iteration. The process of calculating Ieff vector is referred as backward sweep calculation.

FORWARD SWEEP

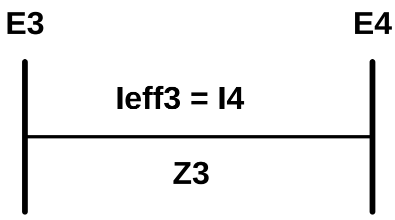
E1=1+j0 is maintained as constant for all iterations



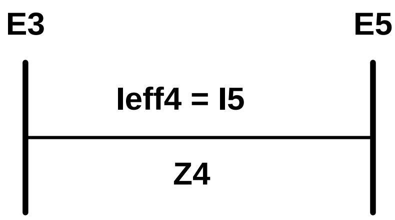
E2 = E1 – Z1*Ieff1



E3 = E2 – Z2*Ieff2



E4 = E3 – Z3*Ieff3



E5 = E3 – Z4*Ieff4

In Forward and Backward sweep method, individual bus voltages are calculated similar to the gauss seidel method and hence, det(delEmax) condition is used as convergence check criterion.

ALGORITHM:

STEP 1: //Read the input data//
a. Read n, nline, epsilon, itermax

b. Read LP(k), LQ(k), R(k), X(k), for k=1 to nline

c. Read Pgen(i), Qgen(i), Pload(i), Qload(i), for i=1 to n

STEP 2: //Print out the input data and cross check it//
STEP 3: //Calculate Pinj and Qinj vectors as below//
For i=1 to n
Pinj(i)=Pgen(i)-Pload(i);
Qinj(i)=Qgen(i)-Qload(i);
//end –i//
STEP 4: //Retain Eold(i) vector//

Eold(i)=E(i);
STEP 5: //set iter =0;
STEP 6: //set det(delEmax)=0;
STEP 7: //Calculate load currents at all buses except slack bus//
For i=2 to n
Iload(i)= -(complex(Pinj(i), -Qinj(i))/conj(E(i)));
//end –i//

STEP 8: //Calculate Ieff(i)//
//BACKWARD SWEEP//
STEP 9: //FORWARD SUBSTITUTION//
For k=1 to nline
P=lp(k);
Q=lq(k);
Iline=Ieff(Q);
E(Q)=E(P)-complex(R(k),X(k))*Iline;

```
          //end –k//
STEP 10: //Calculate delE vector and calculate det(delEmax)//
          For i=2 to n
              delE(i)=E(i)-Eold(i);
              Eold(i)=E(i);
              If (det(delE(i))>(det(delEmax)))
              Set det(delEmax)=det(delE(i));
             //end –i//
          If (det(delEmax)<=epsilon)
            Goto STEP 100;
STEP 11: iter = iter+1;
         If (iter>=itermax) Goto STEP 90
         Else, Goto STEP 6
```

STEP 12: //Problem converged in iter iterations. Calculate line flows, line losses and print them//

STOP

STEP 13: //Problem not converged in itermax iterations. Print out the existing results//

STOP

PROGRAM:

```
tic;
clc;
clear all;
ip=fopen('Radial_ip.m','r++');
op=fopen('DLF_Radial_op.m','w++');
BKVA=fscanf(ip,'%g',1);
BKV=fscanf(ip,'%g',1);
nbus=fscanf(ip,'%d',1);
nline=fscanf(ip,'%d',1);
nslack=fscanf(ip,'%d',1);
epsilon=fscanf(ip,'%f',1);
itermax=fscanf(ip,'%d',1);
linedata=fscanf(ip,'%f',[5,nline]);
linedata=linedata';
LNo=linedata(:,1);
LP=linedata(:,2);
LQ=linedata(:,3);
r=linedata(:,4);
x=linedata(:,5);
bz=(BKV*BKV*1000)/BKVA;
R=r/bz;
X=x/bz;
load_data=fscanf(ip,'%f',[5,nbus]);
load_data=load_data';
load_data=load_data./BKVA;
BusNo=load_data(:,1);
PGen=load_data(:,2);
QGen=load_data(:,3);
Pload=load_data(:,4);
Qload=load_data(:,5);
```

```
%%%     NLCONT(I) Vector Formation   %%%%%%%%%%%
%   Initialization of NLCONT(I) Vector
for i=1:nbus
   NLCONT(i)=0;
end
%Updating NLCONT(I) Vector
for k=1:nline
   P=LP(k);
   Q=LQ(k);
   NLCONT(P)=NLCONT(P)+1;
   NLCONT(Q)=NLCONT(Q)+1;
end
%%%     FORMATION OF RESERVATION CHART          %%%%%

ITAGF(1)=1;
ITAGTO(1)=NLCONT(1);
for i=2:nbus
   ITAGF(i)=ITAGTO(i-1)+1;
   ITAGTO(i)=ITAGTO(i-1)+NLCONT(i);
end

% Initialization of IFILL(I) Vector  %%%%
for i=1:nbus
   IFILL(i)=0;
end
for k=1:nline
   P=LP(k);
   Q=LQ(k);
   LPQ=ITAGF(P)+IFILL(P);
   LQP=ITAGF(Q)+IFILL(Q);
   ADJQ(LPQ)=Q;
   ADJL(LPQ)=k;
   ADJQ(LQP)=P;
   ADJL(LQP)=k;
   IFILL(P)=IFILL(P)+1;
   IFILL(Q)=IFILL(Q)+1;
end

% Calculation of Primitive impedance of all lines
for k=1:nline
   zline(k)=complex(R(k),X(k));
end

% Assume Flat Voltage Start for all Buses
for i=1:nbus
   E(i)=complex(1,0);
   Eold(i)=E(i);
end

% Calculation of Pinj and Qinj at each BUS
```

```
for i=2:nbus
    Pinj(i)=PGen(i)-Pload(i);
    Qinj(i)=QGen(i)-Qload(i);
end

% Iterative Process starts
for iter=1:itermax
     itr(iter)=iter;
     delEmax=0;

    %  Calculation of Current Injections
    for i=2:nbus
        Iinj(i)=complex(Pinj(i),-Qinj(i))/conj(E(i));
    end

    %  Calculation of Effective Currents= Ieff at all buses
    for p=nbus:-1:1
        Ieff(p)=Iinj(p);
        for j=ITAGF(p):ITAGTO(p)
            q=ADJQ(j);
            if(q>p)
                Ieff(p)=Ieff(p)+Ieff(q);
            end
        end
    end

    %  Calculation of Voltages at Receiving side
    for k=1:nline
         P=LP(k);
        Q=LQ(k);
        E(Q)=E(P)+zline(k)*Ieff(Q);
    end

    %  Calculation of delE(i) avlues
    for i=2:nbus
        delE(i)=E(i)-Eold(i);
     end

    %  Finding of delEmax value
    for i=2:nbus
        if (abs(delE(i))>delEmax)
            delEmax=abs(delE(i));
        end
    end
    delEmax1(iter+0)=delEmax;
%      Check for convergence
    if (delEmax<=epsilon)

        fprintf(op, '\nThe Problem is converged in %d iterations\n',iter);
        fprintf(op,'\nBus No.   Voltage Magnitude    Angles \n');
        for i=1:nbus
```

```
        fprintf(op,'\t%d\t\t %6.6f\t\t\t\t%6.6f\t \n',i,abs(E(i)),angle(E(i))*180/pi);
      end
      break;
    end
  Eold=E;
end
itr
delEmax1
% Calculation of Line flows and Line losses
  for k=1:nline
     p=LP(k);
     q=LQ(k);
     Ipq=(E(p)-E(q))/zline(k);
     Spq=E(p)*conj(Ipq);
     Iqp=(E(q)-E(p))/zline(k);
     Sqp=E(q)*conj(Iqp);
     Sloss(k)=Spq+Sqp;
     Ploss(k)=real(Sloss(k));
     Qloss(k)=imag(Sloss(k));
  end

  sum=0;
  for k=1:nline
    sum=sum+Sloss(k);
    Tot_Ploss=real(sum)*BKVA;
    Tot_Qloss=imag(sum)*BKVA;
  end

  fprintf(op,'\nTotal Active Power Loss, P(kW) = %f\n',Tot_Ploss);
  fprintf(op,'Total Reactive Power Loss, Q(kVAr) = %f\n',Tot_Qloss);

%   plot(itr,delPmax1,'--ko',itr,delQmax1,'r+:')
  Tot_Ploss
  fclose all;
  toc;
```

<u>INPUT:</u>

Base KVA = 100
Base KV = 12.66
No.of buses = 5
No.of lines = 4
Slack bus/substation bus = 1
Epsilon value = 0.0001
Maximum no.f iterations = 100

<u>Line data</u>

LNo	FB	TB	R(Ω)	X(Ω)
1	1	2	0.0922	0.0477 0
2	2	3	0.4930	0.2511 0

3	3	4	0.3660	0.1864 0
4	3	5	0.3811	0.1941 0

Load Data

BNo	PG	QG	PL(kW)	QL(kVAR)
1	0	0	0	0
2	0	0	100	60
3	0	0	90	40
4	0	0	120	80
5	0	0	60	30

OUTPUT:

Nbus = 5

Nline = 4

Itermax = 100

Epsilon = 0.0001

The Problem is converged in 2 iterations

Bus No.	Voltage Magnitude	Angles
1	1.000000	0.000000
2	0.999724	0.000612
3	0.998657	0.002816
4	0.998289	0.005294
5	0.998478	0.002739

Total Active Power Loss, P(kW) = 0.457125

Total Reactive Power Loss, Q(kVAr) = 0.233663

CALCULATIONS:

Initially, $E_1=1\angle 0$, $E_2 = 1\angle 0$, $E_3 = 1\angle 0$, $E_4 = 1\angle 0$, $E_5 = 1\angle 0$

1st Iteration values:

Backward Sweep

Iinj(i) = complex(Pinj(i),-Qinj(i))/conj(E(i))   // Cal. of injections

Iinj(1) =
Iinj(2) =
Iinj(3) =
Iinj(4) =
Iinj(5) =

Ieff(p)=Ieff(p)+Ieff(q); ***// Det. Of branch currents***

Ieff(1) = Iinj(2) + Ieff(2) =
Ieff(2) = Iinj(3)+ Ieff(4) + Ieff(5) =
Ieff(3) = Iinj(4) =
Ieff(4) = Iinj(5) =

Forward Sweep

E(Q)=E(P)+zline(k)*Ieff(Q) // Det. Of bus voltages

E1 =

E2 = E1-Z1* *Ieff(1) =*

E3 = E2-Z2* *Ieff(2) =*

E4 = E3-Z3* *Ieff(3) =*

E5 = E3-Z4* *Ieff(4) =*

INFERENCES:

1. The Backward/Forward Sweep method is taking less iterations to converge.
2. It is easy to understand and write the code.
3. It uses Kirchhoff's Laws.

VIVA QUESTIONS:

1. What is the necessity for having DLFs?
2. What are the merits and demerits of Backward/Forward Sweep method?
3. Does this method work for DG cases?
4. What is the effect of load increment on the convergence characteristics?
5. What is the effect of Resistance increment on the convergence characteristics?
6. What is the R/X ratio of distribution lines compared to transmission lines?
7. What are the types of distribution configurations?
8. Why forward-backward sweep method is not applicable for mesh connected system?
9. Which parameter is used in design of distribution feeders?
10. Which parameter is used in design of distributors?

RESULT:

For a given Distribution system network, the load flow solution is obtained by using Backward/Forward Sweep method and the simulation results checked theoretically.

Lab Instructor **Faculty**

Date: **Date:**

EXP. NO. : 12

DATE :

REACTIVE POWER CONTROL USING TAP CHANGING TRANSFORMER

AIM: To conduct the experiment of reactive power control by connecting the tap changing transformers in parallel and determine the reactive power shared by each transformer with a suitable tap position under different loading conditions.

NAME PLATE DETAILS:

Particulars	**Transformer**	**Auto-transformer**
Type	Single Phase with taps	Single Phase
Rated Power	1kVA	2kVA
Rated Primary Voltage	230V	230V
Rated Secondary Voltage	230V	0-270V

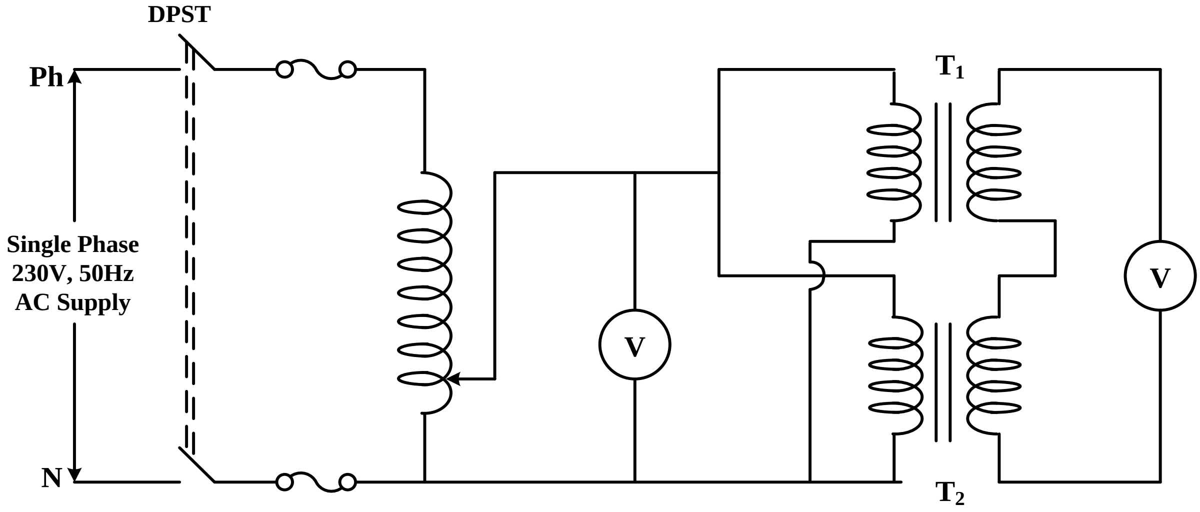
APPARATUS REQUIRED:

S.No	Name of the Apparatus	Range	Type	Quantity
1	Wattmeters	300V, 10A	-	2
2	Voltmeters	(0-300)V	MI	3
3	Ammeters	(0-5)A	MI	2
4	Ammeter	(0-10)A	MI	1
5	Rheostat			1

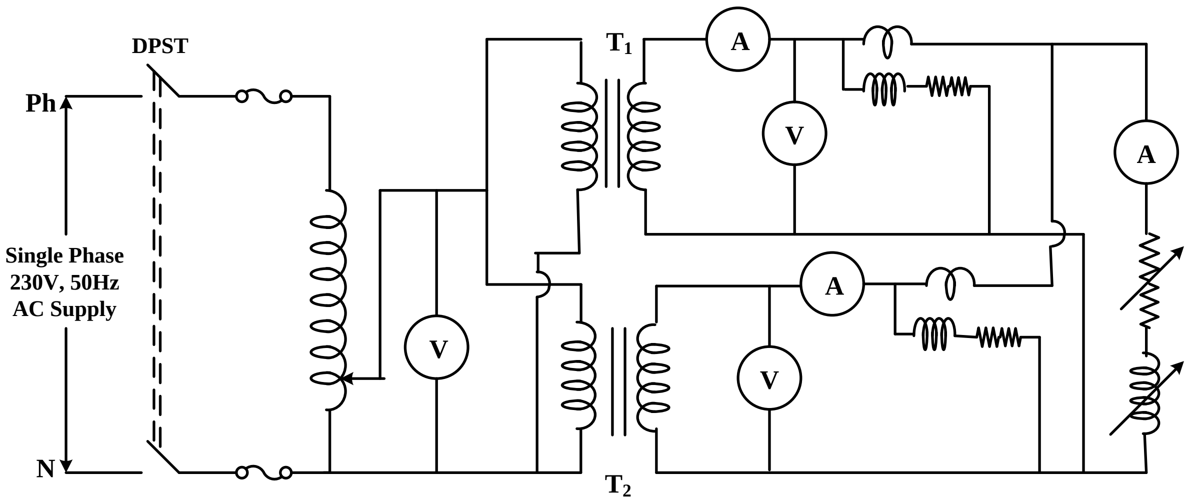
PRECAUTIONS:

1. The auto-transformer voltage should be at minimum position at the time of starting to start the experiment.

CIRCUIT DIAGRAM FOR POLARITY TEST



CIRCUIT DIAGRAM FOR REACTIVE POWER CONTROL



THEORY:

PROCEDURE:

1. Connections are made as per the circuit diagram of polarity test.
2. By keeping the auto-transformer or variac position at zero voltage, switch on the supply.
3. Apply some voltage to the primary of transformers by using the variac for observing the secondary winding polarities.
4. Observe the reading of the voltmeter in secondary circuit. If it shows the twice of the applied voltage, then the secondaries of the transformers are said to be in phase. If voltmeter shows zero, then the secondary voltages are 180 degrees out of phase. In this case, the secondary terminals of any transformer need to be interchanged.
5. After the completion of the polarity test, make the connections as per the circuit diagram for reactive power control. Initially, the transformer T_1 is kept at nominal tap position.
6. By keeping the variac at minimum output voltage position and the load resistance (R) and load inductance (L) at maximum positions, switch on the supply.
7. Apply a voltage of about 200V to the primaries of the two transformers. By keeping R in maximum position, the inductance value is adjusted for a load current of 2A. Note down the readings of all meters in the circuit.
8. The tap setting of transformer T_1 is then changed to the next lower value. By keeping the same load, note down the readings of all meters.
9. The above procedure is repeated by changing the tapping of T_1.
10. By changing the load current to another value, the above procedure is repeated.
11. Calculate the %reactive power contribution of T_1 from the above set of readings for different tap settings.

OBSERVATIONS:

<u>Case1:</u> Load current=<u>2</u>A

Input Voltage =<u>200</u>V

S. No.	Tap position	V_1 (V)	I_1 (A)	W_1 (Watts)	V_2 (V)	I_2 (A)	W_2 (Watts)	Q_1 (VAR)	Q_2 (VAR)	%REACTIVE power shared by $T_1=Q_1/(Q_1+Q_2)$
1.	100%									
2.	86.6%									

Case2: Load current =1A

Input Voltage =200V

S. No.	**Tap position**	**V_1 (V)**	**I_1 (A)**	**W_1 (Watts)**	**V_2 (V)**	**I_2 (A)**	**W_2 (Watts)**	**Q_1 (VAR)**	**Q_2 (VAR)**	**%REACTIVE power shared by $T_1=Q_1/(Q_1+Q_2)$**
1.	100%									
2.	86.6%									

CALCULATIONS:

%REACTIVE power shared by transformer $T_2=Q_2/(Q_1+Q_2)$

INFERENCE:

1. The reactive power can be controlled with the help of tap changing transformer and it is observed experimentally.

VIVA QUESTIONS:

1. What is the principle of transformer?
2. What is the significance of reactive power?
3. What is meant by reactive power control?
4. What is the relation between reactive power and power factor?
5. What is the difference between active power and reactive power?
6. If the transmission line is drawing more reactive power, what happens to the voltage of the load side equipment?
7. Which side of the transformer provided with the tappings?
8. What are the different types of tap changing transformers in power system?
9. What is the use of auto-transformer?
10. Why the transformer ratings are represented with apparent power?

RESULT:

Lab Instructor **Faculty**

Date: **Date:**

EXP. NO. : 13
DATE :

ANALYSIS OF UNBALANCED VOLTAGES USING SYMMETRICAL COMPONENT ANALYZER

AIM: To determine the positive and negative sequence components of a 3-phase unbalanced voltage using symmetrical component analyzer for a 3-wire system.

NAME PLATE DETAILS:

Particulars	Transformer	Auto-transformer
Type	Single Phase	Single Phase
Rated Power	1kVA	1kVA
Rated Primary Voltage	230V	230V
Rated Secondary Voltage	230V	0-270V

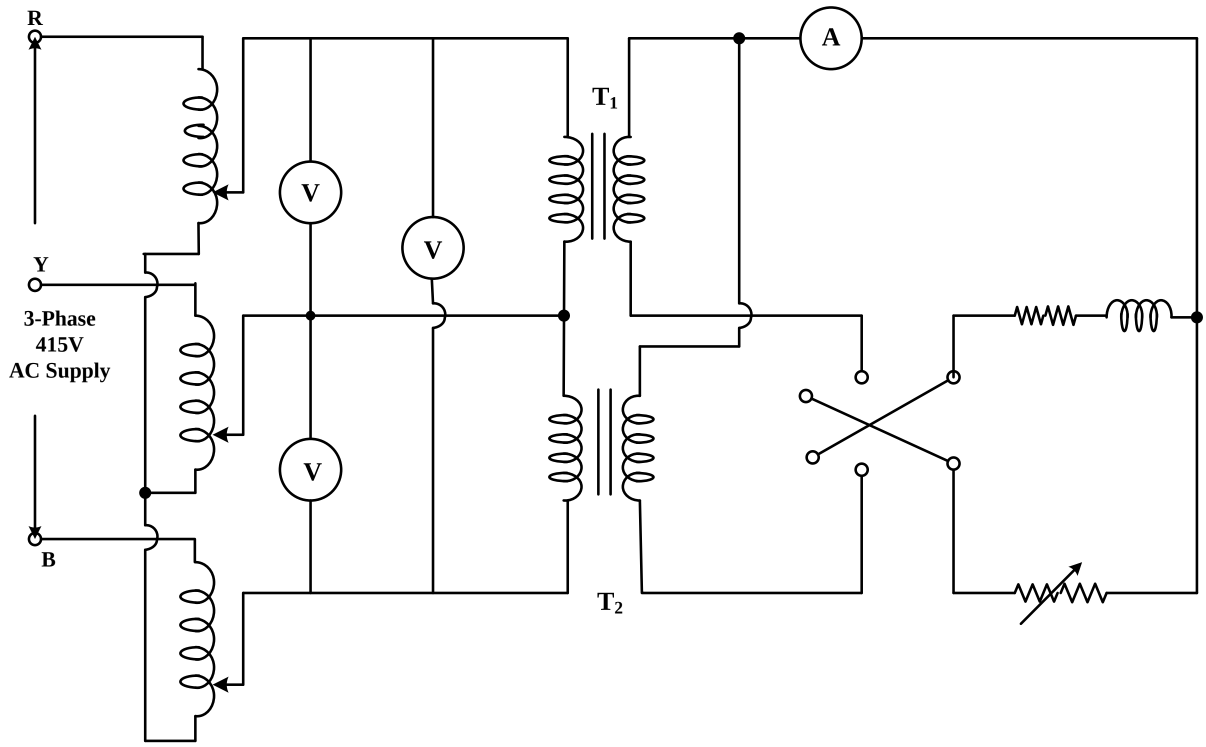
APPARATUS REQUIRED:

S.No	Name of the Apparatus	Range	Type	Quantity
1	Voltmeters	(0-300)V	MI	3
2	Ammeters	(0-500)mA	MI	1
3	Rheostats	145Ω, 1.4A	Wirewound	1
4	Inductor			1

PRECAUTIONS:

1. The auto-transformer voltage should be at minimum position at the time of starting to start the experiment.
2. Do not apply more voltage beyond the rating of the transformers.

CIRCUIT DIAGRAM



THEORY:

PROCEDURE:

1. Make the connections as per the circuit diagram.
2. The coil has an impedance of 22+j105 **Ω** . to get the required impedance angle of 60˚ an additional resistance of 38.6 **Ω**.(R_I) is to be connected in series. Then Z=121.2∟60˚**Ω**
3. By using the auto-transformers, apply the balanced voltages such that the voltmeters connected on supply side read same voltage. Note down the ammeter reading and then calculate the meter constant k volts/mA. In this way, the ammeter is calibrated

in terms of sequence components of line-to-line voltage by applying a set of balanced voltages.

4. Now, apply a set of unbalanced voltages using the three single- phase auto-transformers and note down the line-to-line voltages. Then, calculate the positive sequence voltage by multiplying the ammeter reading with meter constant obtained in step 3.
5. After interchanging the impedances Z_a and Z_b, apply the same set of unbalanced voltages and then note down the ammeter reading. Finally, calculate the negative sequence voltage by multiplying the ammeter reading with meter constant obtained in step 3.
6. Repeat the steps 4 and 5 with three sets of unbalanced voltages and calculate the positive and negative sequence components for each set.
7. The above results are verified analytically from the standard symmetrical component equations. In the above expressions the angle between the line to line voltages are also to be taken into account, which are obtained by constructing the triangles from the line voltages.

OBSERVATIONS:

S.No.	**Load Condition**	**V_{RY} (Volts)**	**V_{YB} (Volts)**	**V_{BR} (Volts)**	**I_P (Amps)**	**I_N (Amps)**	**V_{a1} (Volts)**	**V_{a2} (Volts)**
1.	Balanced	100	100	100	250	0	100	0
2.	Unbalanced	80	120	130	265	60	106	24
3.	Unbalanced	100	144	147	310	60	124	24
4.	Unbalanced	136	188	148	285	75	114	30

CALCULATIONS:

Meter constant (k) = (V/I) under balanced condition
Positive sequence component of line-to-line voltage $V_{a1} = k*I_p$
Negative sequence component of line-to-line voltage $V_{a2}= k*I_N$
Using the line voltages measured and either from graphical plotting or application of Cosine rule we can calculate the sequence voltages.

INFERENCES:

1. The positive sequence and negative sequence components exist in the case of unbalanced voltages.
2. The unbalanced components of voltage can be represented with the help of symmetrical components.

VIVA QUESTIONS:

1. What is the significance of sequence components?
2. How the unbalanced voltages can be represented with sequence components?
3. Define a positive sequence component in power system?
4. Define a negative sequence component in power system?
5. Define a zero sequence component in power system?
6. Which of the sequence impendences are equal for a fully transposed transmission line?
7. Suppose I_A, I_B and I_C are a set of unbalanced current phasors in a three-phase system. The phase-B zero sequence current $I_{B0} = 0.1\angle 0^0$ p.u. If phase-A current $I_A = 1.1\angle 0^0$p.u. and phase-C current $I_C = (1\angle 120^0+0.1)$ p.u., then I_B in p.u. is?
8. What is the neutral current of three phase system in terms of zero sequence component of current for a L-G fault?
9. What is the relation between the sequence reactances of transformer?
10. How the phase-B voltage can be represented in terms of symmetrical components?

RESULT:

Lab Instructor **Faculty**

Date: **Date:**