POWER SYSTEM-II LAB MANUAL

Subject: Power System-II Lab Subject Code:

ELPC 651

B. Tech VI Semester

Department of Electrical Engineering
J. C. Bose University of Science and Technology, YMCA

DEPARTMENT OF ELECTRICAL ENGINEERING

VISION OF THE DEPARTMENT

Electrical Engineering Department congregates the challenges of new technological advancements to provide comprehensively trained, career-focused, morally strong accomplished graduates, cutting-edge researchers by experimental learning which contribute to ever-changing global society and serve as competent engineers.

MISSION OF THE DEPARTMENT

- To commit excellence in imparting knowledge through incubation and execution of high-quality innovative educational programs.
- To develop the Research-oriented culture to build national capabilities for excellent power management.
- To inculcate and harvest the moral values and ethical behavior in the students through exposure of self -discipline and personal integrity.
- To develop a Centre of Research and Education generating knowledge and technologies which lay ground work in shaping the future in the field of electrical engineering.

PROGRAM OUTCOMES (POs)

Graduates of the Electrical Engineering program at JCBUST, YMCA will be able to:

PO1. Apply knowledge of mathematics, science, engineering fundamentals, and electrical engineering specialization to the solution of engineering problems.

PO2. Identify, formulate, review literature, and analyze electrical engineering problems to design, conduct experiments, analyze data, and interpret data.

PO3. Design solutions for electrical engineering problems and design system components of processes that meet the desired needs with appropriate consideration for public health and safety and cultural, societal, and environmental considerations.

PO4. Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions in electrical engineering.

PO5. Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to electrical engineering activities with an understanding of the limitations.

PO6. Apply reasoning informed by contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to professional engineering practice.

PO7. Understand the impact of electrical engineering solutions in societal and environmental contexts, and demonstrate the knowledge and need for sustainable development.

PO8. Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9. Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10. Communicate effectively on complex engineering activities with the engineering committee and with society at large, such as being able to comprehend and write effective reports and design documentation, and make effective presentations in electrical engineering.

PO11. Demonstrate knowledge and understanding of the engineering principles and management principles and apply these to one‘s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12. Recognize the need for, and the preparation and ability to engage in independent research and lifelong learning in the broadest context of technological changes in electrical engineering.

PROGRAM SPECIFIC OUTCOMES (PSOs)

PSO1. To apply state-of-the-art knowledge in analysis design and complex problem solving with effective implementation in the multidisciplinary area of Electrical Engineering with due regard to environmental and social concerns.

PSO2. To prepare graduates for continuous self-learning to apply technical knowledge and pursue research in advanced areas in the field of Electrical Engineering for a successful professional career to serve society ethically.

PROGRAM EDUCATIONAL OBJECTIVES (PEOs)

PEO1. To produce competent electrical engineering graduates with a strong foundation design, analytics and problem solving skills for successful professional careers in industry, research and public service.

PEO2. To provide a stimulating research environment so as to motivate the students for higher studies and innovation in the specific and allied domains of electrical engineering.

PEO3. To encourage the graduates to practice the profession following ethical codes, social responsibility and accountability.

PEO4. To train students to communicate effectively in multidisciplinary environment.

PEO5. To imbibe an attitude in the graduates for life-long learning process.

Syllabus

Power System-II Lab (ELPC-651)

L-T-P	**Internal Marks-15**
0-0-2	**ExternalMarks-35**
	Total-50

List of Experiments

1. To find string efficiency using MATLAB.
2. To find the value of three phase AC supply using MATLAB.
3. To form a admittance matrix (Y bus) of the below given power system.
4. To form Y bus matrix of a given power system using singular transformation.
5. Write a MATLAB program for solving power flow equation using gauss seidel method.
6. To develop program for FDLF algorithm.
7. To carryout load flow analysis of the given power system by Newton Raphson method.
8. To understand the basics of the Economic Dispatch by optimally adjusting the generation schedules of thermal generating units to meet the system demand which are required for unit commitment and economic operation of power systems.
9. To study swing equation and perform on MATLAB.
10. To obtain the bus impedance matrix Z – bus of the given power system network using.
11. To become familiar with various aspects of the transient analysis of Single-Machine-Infinite Bus (SMIB) system.
12. To determine the fault current and voltage in a single transmission line system for the following Y-Δ transformer at specified location for LG, LLG faults.

COURSE OBJECTIVES & OUTCOMES

Course objectives:

1. To provide better understanding of power system analysis through digital simulation.
2. To present a problem-oriented knowledge of power system analysis methods.
3. To address the underlying concepts & approaches behind analysis of power system network using software tools.
4. To identify & formulate solutions to problems relevant to power system using software tools.

Course outcomes:

CO1. Ability to acquire knowledge on Formation of Bus Admittance and Impedance, Matrices, and Solution of Networks

CO2. Evaluate the various parameter of a power system network (min 3 bus) using different load flow techniques.

CO3. Ability to analyze the power flow using GS and NR method.

CO4. Able to understand power system economics and management using different methods.

Mapping of Course Outcomes (COs) with POs and PSOs

COs	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2
CO1	3	3	2	2	3	2	1	2	2	2	3	2	2	3
CO2	2	2	3	2	3	2	2	2	2	2	3	2	2	3
CO3	3	3	3	3	3	2	1	2	2	2	3	3	2	3
CO4	3	3	3	3	3	2	2	2	2	2	2	3	2	3

||General Instructions||
In

Power System Lab

1. Students should come well-prepared for the experiment they will be conducting.
2. Usage of mobile phones in the laboratory is strictly prohibited.
3. Read and understand the experiment manual thoroughly before starting the experiment. Know the objectives, procedures, and safety precautions.
4. Clean your computer with a soft, dry cloth.
5. Ensure all connections are made as per the circuit diagram. Double-check all connections before powering the equipment.
6. Do not switch on the power supply until the instructor has approved your setup. Always start with the minimum voltage/current required and gradually increase as needed.
7. Do not overload machines beyond their rated capacity. Overloading can damage the equipment and pose safety risks.
8. Familiarize yourself with the lab's emergency shutdown procedures, including the location of emergency switches and fire extinguishers.
9. Do not bring food or drinks into the lab to avoid accidental spills, which can lead to electrical hazards.
10. Do not touch any part of the computer with wet hands. Avoid distractions like mobile phones, and do not engage in unnecessary conversation during lab work.
11. Don't damage, remove, or disconnect any labels, parts, cables or equipment
12. . Do not install or download any software or modify or delete any system files on any lab computers
13. If you are unsure about any procedure or face difficulties during the experiment, do not hesitate to ask the lab instructor for guidance.
14. After completing the experiment, shut down the computer properly and switch off the power supply.

Power System- II
(ELPC-651)

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Experiment No. – 1

Aim: To find String Efficiency using MATLAB

Apparatus: MATLAB Software

Theory:

To calculate string efficiency for insulators using MATLAB, you can follow these steps. String efficiency is the ratio of the voltage across the entire string to the product of the number of insulators and the voltage across the bottom insulator. It's calculated as:

The formula for string efficiency is:

- String efficiency = Voltage across the string / (number of discs × voltage across the disc nearest to the conductor)

Program:

```
v1=input ("enter the 1 voltage")
v2=input ("enter the 2 voltage")
v3=input ("enter the 3 voltage")
n=input ("enter the number of insulations")
V=v1+v2+v3
stringefficiency=(V/(n*v3)) *100
```

Observation:

```
enter the 1 voltage 90
v1 = 90
enter the 2 voltages 40
v2 = 40
enter the 3 voltages 70
v3 = 70
enter the number of insulations 5
n = 5
V = 200
stringefficiency = 57.1429
```

Result:

String efficiency is = ______________

Viva Questions:

1. What is string efficiency, and why is it important?
2. How is string efficiency calculated in suspension insulators?
3. What factors affect string efficiency?
4. Can string efficiency be greater than 100%? Why or why not?
5. Why is the voltage distribution unequal across a string of insulators?
6. How does voltage vary from the top to the bottom insulator in a string?
7. What is the role of leakage current in voltage distribution?
8. How does capacitance affect voltage distribution across insulators?
9. What methods are used to improve string efficiency?
10. How does a grading ring improve string efficiency?
11. How can the potential gradient across insulators be reduced?
12. How would you determine string efficiency for a real transmission line?
13. How do environmental factors affect string efficiency?
14. How is the number of insulators chosen for a given voltage level?
15. What is the significance of the capacitance ratio k in string efficiency?
16. What does it mean if the capacitance ratio k is close to 1 or much less than 1?
17. Why are MATLAB simulations useful for analyzing string efficiency?
18. How would you model insulators with varying capacitance in MATLAB?
19. What challenges arise in maintaining high string efficiency in power systems?
20. How are insulation failures related to string efficiency?
21. Why account for uneven voltage distribution in high-voltage transmission?
22. What is a pin-type insulator, and how is it different from a suspension-type insulator?
23. How is the breakdown voltage of an insulator measured in practice?
24. What is corona discharge, and how does it relate to insulators?

Experiment No. – 2

Aim: To find the value of three phase AC supply using MATLAB

Apparatus: MATLAB Software

Theory:

A **three-phase AC supply** is the most common method of generating, transmitting, and distributing electrical power in large-scale electrical networks. It consists of three alternating currents (AC) that are of the same frequency and amplitude but are out of phase with each other by 120 degrees. The three-phase system is widely used because it provides a more stable and efficient power supply compared to a single-phase system.

Components of a Three-Phase System:

1. **Phase Voltage (Phase-to-Neutral Voltage)**: This is the voltage between any one phase and the neutral point. In most systems, the RMS (Root Mean Square) value of the phase voltage is standardized, such as 230V in India for phase-to-neutral supply.
2. **Line Voltage (Phase-to-Phase Voltage)**: This is the voltage between any two phases. The line voltage in a balanced three-phase system is related to the phase voltage.
   For example, in a 230V phase-to-neutral system, the line-to-line voltage is approximately 400V.

Working Principle

In a three-phase system, the AC voltages for the three phases are offset by 120 degrees from each other. This means that at any given moment, the voltage of one phase is different from the others, and this phase displacement leads to a continuous and balanced power flow. The main components of a three-phase system are:

- **Phase A**: Voltage waveform starting at 0°.
- **Phase B**: Voltage waveform lagging Phase A by 120°.
- **Phase C**: Voltage waveform lagging Phase A by 240°.

These waveforms are sinusoidal, and their sum at any instant is zero in a balanced system, leading to efficient energy transmission.

Advantages of Three-Phase Systems:

1. **Higher Efficiency**: Three-phase power requires fewer conductors for the same amount of power transmitted compared to single-phase systems. This leads to reduced losses in transmission and distribution lines.

2. **Constant Power Delivery**: Unlike single-phase power, which pulses, three-phase power provides a smooth and continuous flow of energy, resulting in less vibration and smoother operation of electrical devices, especially motors.
3. **Reduced Conductor Size**: For the same load power, three-phase systems use smaller and lighter conductors compared to single-phase systems, which saves on material costs.
4. **Better Load Distribution**: Three-phase power systems distribute the load more evenly, which improves the overall stability of the power grid.

Voltage in Three-Phase Systems

- **Phase Voltage**: The voltage measured between any one of the phases (A, B, or C) and the neutral point.
- **Line Voltage**: The voltage between any two of the three-phase conductors. For a balanced system, the line voltage is related to the phase voltage .

Program:

```
clc;

Vin=input ("enter the value of peak voltage")

f=input ("enter frequency")

w=2*pi*f

tm=input ("enter the value of maximum time");

t1=0:02:tm

v1=Vm*sin(w*tm)

v2=Vm*sin(w*tm+120)

v3=Vm*sin(w*tm+240)
```

Observation:

```
enter the value of peak voltage 220
Vm = 220
enter frequency 50
f = 50
w = 314.1593
enter the value of maximum time 0.5
t1 = 0
```

```
v1 = 2.1608e-13
v2 = 127.7345
v3 = 207.9979
```

Result:

Value of V1: ______
Value of V2: ______
Value of V3: ______

Viva questions:

1) What is a three-phase AC supply, and how is it different from a single-phase supply?
2) Why is a three-phase system more efficient than a single-phase system?
3) What is the phase voltage in a three-phase system?
4) How is the line voltage related to the phase voltage in a balanced three-phase system?
5) What is the significance of the 120-degree phase shift in a three-phase system?
6) Why is three-phase power preferred for industrial motors?
7) How is the RMS value of an AC voltage calculated?
8) What is the formula to calculate the line-to-line voltage in a three-phase system?
9) How does the frequency of the supply affect the waveforms in a three-phase system?
10) What is the advantage of using three-phase power for transmission over long distances?
11) How can MATLAB be used to simulate a three-phase AC system?
12) What parameters do you need to generate a three-phase voltage waveform in MATLAB?
13) What is the role of the time vector in simulating AC voltage waveform

Experiment No. – 3

Aim: To form an admittance matrix (Y bus) of the below given power system.

Apparatus: MATLAB software

Theory:

In a power system, **Bus Admittance Matrix** represents the nodal admittances of the various buses. With the help of the transmission line, each bus is connected to the various other buses. Admittance matrix is used to analyse the data that is needed in the load or a power flow study of the buses. It explains the admittance and the topology of the network. The following are the advantages of the bus admittance matrix.

1. The data preparation of the bus admittance matrix is very simple.
2. The formation of the bus admittance matrix and their modification is easy.
3. The bus admittance matrix is a sparse matrix thus the computer memory requirement is less.

$$\begin{bmatrix} I_1 \\ I_2 \\ I_n \end{bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} & Y_{1n} \\ Y_{21} & Y_{22} & Y_{2n} \\ Y_{n1} & Y_{n2} & Y_{n1} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_n \end{bmatrix}$$

The amount of current present in the bus can be calculated with the help of formation of the Admittance matrix. It is expressed as shown above.

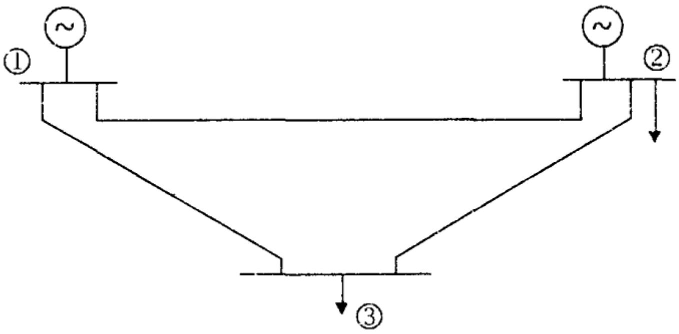
In the simplest form, the above matrix can be written as shown below.

$I = [Y] V$ ss

Where,

- I is the current of the bus in the vector form.
- Y is the admittance matrix
- V is the vector of the bus voltage.

Let us consider the figure given below.



From the above figure, the (3×3) admittance matrix is formed as shown below.

$$Y = \begin{bmatrix} Y_1 + Y_{12} + Y_{13} & -Y_{12} & -Y_{13} \\ -Y_{12} & Y_2 + Y_{12} + Y_{23} & -Y_{23} \\ -Y_{13} & -Y_{23} & Y_3 + Y_{13} + Y_{23} \end{bmatrix}$$

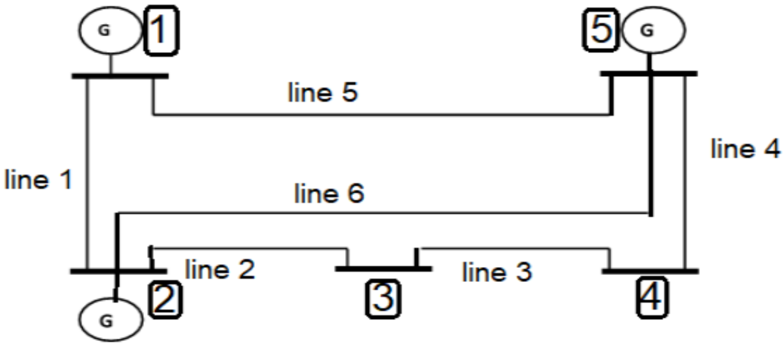
The diagonal elements of the Bus Admittance matrix are known as self-admittances and the off-diagonal elements are known as mutual admittances.

ALGORITHM FOR FORMATION OF Y - BUS MATRIX

Step (1): Initialize [Y-Bus] matrix, that is replace all entries by zero Yij = Yij - yij = Yji = off diagonal element
Step (2): Compute Yii= [Σ yij] + yio= diagonal element j =1 J ≠ i Where yio is the net bus to ground admittance connected at bus i.

Problem:
Form Y bus matrix of the given figure below with the help of the data given:

SINGLE - LINE DIAGRAM



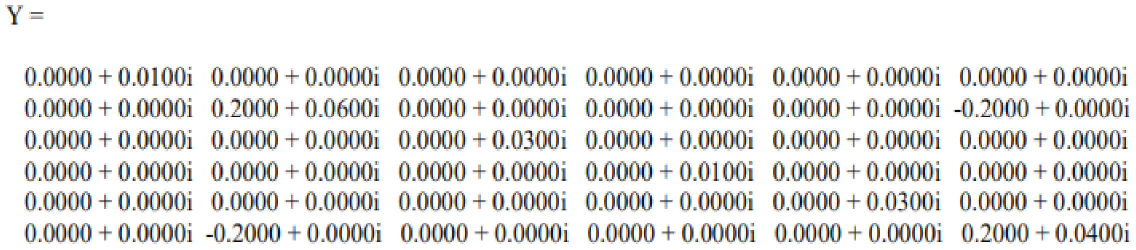
Line no.	Start bus	End bus	Series Impedance (P.U.)	Half-line charging admittance (P.U)	Rating (MW)
1	1	2	0.001 + j0.01	0.001	60
2	2	3	0.002+ j0.02	0.0005	40
3	3	4	0.004 + j0.03	0.0015	60
4	4	5	0.003 + j0.01	0.0001	60
5	5	1	0.004 + j0.03	0.0005	40
6	2	5	0.001 + j0.04	0.002	60

Program:

```
            |line no.||start bus||end bus||series impedance||charging admittance||rating|

linedata = [1  1   2  0.001  0.01  0.001
2           2   3  0.002   0.02    0.0005
3           3   4  0.004   0.03    0.0015
4           4   5  0.003   0.01    0.0001
5           5   1  0.004   0.03    0.0005
6           2   5  0.001   0.04    0.002];

fb = linedata(:,1); tb = linedata(:,2); r = linedata(:,3); x = linedata(:,4);

b = linedata(:,5); z = r + i*x;

y = 1. /z; b = i*b;

nbus = max(max(fb), max(tb)); nbranch = length(fb); Y = zeros (nbus, nbus);

for k=1: nbranch

Y(fb(k), tb(k)) = Y(fb(k), tb(k))-y(k);

Y(tb(k), fb(k)) = Y(fb(k), tb(k));

end

for m =1: nbus

for n =1: nbranch

if fb(n) == m

Y (m, m) = Y (m, m) + y(n)+ b(n);
```

```
elseif

tb(n) == m

Y (m, m) = Y (m, m) + y(n) + b(n);

end

end

end
```

Observation:



```
Y =

   0.0000 + 0.0100i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
   0.0000 + 0.0000i   0.2000 + 0.0600i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i  -0.2000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0300i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0100i   0.0000 + 0.0000i   0.0000 + 0.0000i
   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0300i   0.0000 + 0.0000i
   0.0000 + 0.0000i  -0.2000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0000i   0.2000 + 0.0400i
```

Result:

The Ybus formed is: ________________

Viva Questions:

1. How can you represent different types of loads (e.g., residential, industrial) on a single-line diagram?
2. What is the significance of the colour coding used in single-line diagrams?
3. How can you determine the direction of power flow from a single-line diagram?
4. Can single-line diagrams be used for studying stability analysis?
5. What are the limitations of single-line diagram

Experiment No. – 4

Aim: To form Y bus matrix of a given power system using Singular Transformation.

Apparatus: MATLAB Software

Theory:

Relations between the nine element voltages and the four bus (i.e. tree branch) voltages V1, V2, V3 and V4.

$$
\begin{aligned}
V_{b1} &= V_1 \\
V_{b2} &= V_2 \\
V_{b3} &= V_3 \\
V_{b4} &= V_4 \\
V_{l5} &= V_3 - V_4 \\
V_{l6} &= V_3 - V_2 \\
V_{l7} &= V_1 - V_2 \\
V_{l8} &= V_4 - V_2 \\
V_{l9} &= V_3 - V_1
\end{aligned}
$$

or, in matrix form

$$V = AV_{\text{BUS}}$$

where the bus incidence matrix A is

$$
\begin{array}{c|cccc}
\text{bus} & 1 & 2 & 3 & 4 \\
e & & & & \\
\hline
1 & 1 & 0 & 0 & 0 \\
2 & 0 & 1 & 0 & 0 \\
3 & 0 & 0 & 1 & 0 \\
4 & 0 & 0 & 0 & 1 \\
\hdashline
5 & 0 & 0 & 1 & -1 \\
6 & 0 & -1 & 1 & 0 \\
7 & 1 & -1 & 0 & 0 \\
8 & 0 & -1 & 0 & 1 \\
9 & -1 & 0 & 1 & 0
\end{array}
=
\begin{array}{r}
\text{buses} \\
\hline
\text{elements} \\
\text{branches} \\
\\
\text{links}
\end{array}
\left[\begin{array}{c} A_b \\ \hline A_l \end{array}\right]
=
\left[\begin{array}{c} I \\ \hline A_l \end{array}\right]
$$

This matrix is rectangular and therefore singular. Its elements a*ik* are found as per the following rules:

a*ik* =1 if *i*th element is incident to and oriented away from the kth node (bus)

= – 1 if *i*th element is incident to but oriented towards the kth node

= 0 if the *i*th element is not incident to the kth node

we get,

$$I + J = YAV_{BUS}$$

Pre multiplying by AT,

$$A^T I + A^T J = A^T YAV_{BUS}$$

Each component of the n-dimensional vector ATI is the algebraic sum of the element currents leaving the nodes 1, 2, …, n.

Therefore, the application of the KCL must result in

$$A^T I = 0$$

Similarly, each component of the vector ATJ can be recognized as the algebraic sum of all source currents injected into nodes 1, 2, …, n. These components are therefore the bus currents. Hence, we can write

$$A^T J = J_{BUS}$$

then is simplified to

$$J_{BUS} = A^T YAV_{BUS}$$

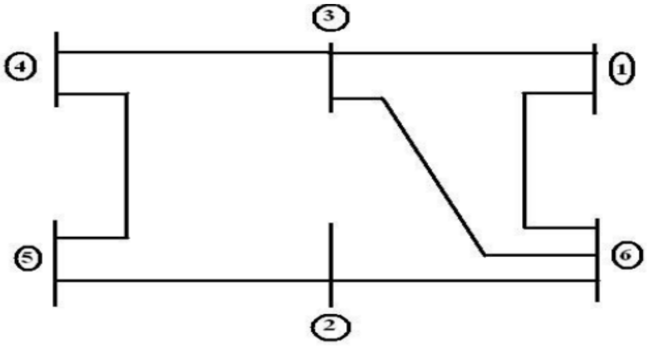
Thus, following an alternative systematic approach, we have in fact, obtained the same nodal current equation. The bus admittance matrix can then be obtained from the formation of YBUS by singular transformation of the primitive Y, i.e.

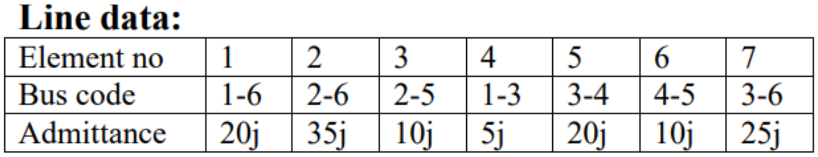
$$Y_{BUS} = A^T YA$$

A computer programme can be developed to write the bus incidence matrix A from the interconnection data of the directed elements of the power system. Standard matrix transpose and multiplication subroutines can then be used to compute YBUS from Equation.

Problem:

For the system defined by the line data determine the YBus admittance matrix by singular transformation method. Select bus no. 1 as reference bus and treat elements 6 & 7 as links





Line data:

Element no	1	2	3	4	5	6	7
Bus code	1-6	2-6	2-5	1-3	3-4	4-5	3-6
Admittance	20j	35j	10j	5j	20j	10j	25j

Program:

```
% Ybus formation by singular transformation method clear;

clc;

%      en     fb     tb     self-adm.   en     mut adm.
Ydata=[1      1      6      20i         0      0
       2      2      6      35i         0      0
       3      2      5      10i         0      0
       4      1      3      5i          0      0
       5      3      4      20i         0      0
       6      4      5      10i         0      0
       7      3      6      25i         0      0];

element=max (Ydata(:,1));

buses=max(max (Ydata(:,2)),max(Ydata(:,3)));

buses=buses-1;

A=zeros(element, buses);

for i=1: element;

if(Ydata(i,2)~=1)A(i,Ydata(i,2)-1)=1;

end
```

```
if(Ydata(i,3)~=1)A(i,Ydata(i,3)-1)=-1;

end

end

%       formation of primitive impedance matrix Yprimitive=zeros (element, element);

for i=1: element, Yprimitive (i, i) =Ydata(i,4); if Ydata(i,5)>0,

Yprimitive (i, Ydata(i,5)) =Ydata(i,6);

Yprimitive (Ydata(i,5), i) =Ydata(i,6); end

end Yprimitive=(Yprimitive);

Ybus=A'*Yprimitive*A;

printf ('\n\t\t Bus admittance matrix\n');

disp (Ybus);
```

Observation:

```
Bus admittance matrix
0      +45.0000i   0               0               0 -10.0000i     0 -35.0000i
0                  0 +50.0000i     0 -20.0000i     0               0 -25.0000i
0                  0 -20.0000i     0    +30.0000i  0 -10.0000i     0
0      -10.0000i   0               0    -10.0000i  0 +20.0000i     0
0      -35.0000i   0 -25.0000i     0               0               0 +80.0000i
```

Result:

Formed Y bus matrix is:___________

Viva Questions:

1. How can you determine the accuracy of the Y bus matrix obtained using singular transformation?

2. What is the relationship between the eigenvalues of the original Y bus matrix and the reduced Y bus matrix?
3. Can singular transformation be used for real-time power system analysis?
4. How does singular transformation handle systems with shunt elements (e.g., capacitors)?
5. What are the computational requirements for singular transformation compared to other methods?

Experiment No. – 5

Aim: Write a MATLAB program for solving power flow equation using Gauss Seidel method

Apparatus: MATLAB Software

Theory:

The Gauss-Seidel method is an iterative technique used to solve power flow equations, which determine bus voltages in a power system.

Steps:

1. **Initialization**: Start with an initial guess for bus voltages.
2. **Equation Update**: For each bus iii, update the voltage using:
$$V_i^{(k+1)} = \frac{1}{Y_{ii}} \left(\frac{P_i - jQ_i}{V_i^{(k)}} - \sum_{j \neq i} Y_{ij} V_j^{(k+1)} \right)$$
3. **Iteration**: Update each bus voltage sequentially, using the latest values.
4. **Convergence**: Check if changes in voltages fall below a set tolerance. Repeat until convergence.

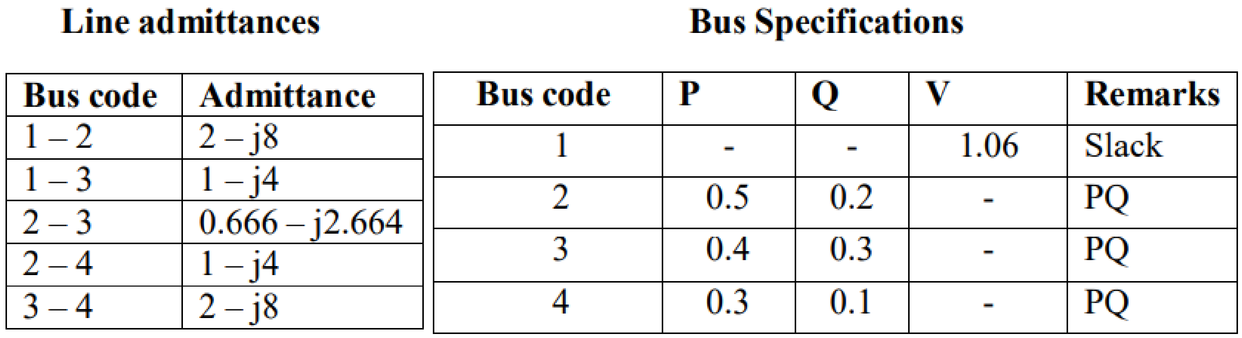
Pros and Cons:

- **Pros**: Simple and memory-efficient.
- **Cons**: Slow convergence, sensitive to initial guesses, impractical for large systems.

The method is useful for small to medium power systems but may struggle with larger, more complex networks.

Problem:

The system data for a load flow solution are given below. Determine the voltages by Gauss – Seidal method



Line admittances

Bus code	Admittance
1 – 2	2 – j8
1 – 3	1 – j4
2 – 3	0.666 – j2.664
2 – 4	1 – j4
3 – 4	2 – j8

Bus Specifications

Bus code	P	Q	V	Remarks
1	-	-	1.06	Slack
2	0.5	0.2	-	PQ
3	0.4	0.3	-	PQ
4	0.3	0.1	-	PQ

Program:

```
clc;

clear all;

n=input ('no of buses');

l=input ('no of lines');

s=input ('impedance 1 or admittance 2');

for i=1: l

a=input ('starting bus');

b=input ('ending bus');

t=input ('admittance or impedance value');

if s==1

y(a, b)=1/t;

else

y(a, b)=t;

end

y(b, a)=y(a,b);

end

ybus=zeros (n, n);

for i=1: n

for j=1: n

if i==j

for k=1: n

ybus (i, j) =ybus (i, j) +y (i, k);

end
```

```
else

ybus (i, j) =-y (i, j);

end

ybus (j, I) =ybus (i, j);

end

end

ybus

p=zeros (1, n);

q=zeros (1, n);

v=zeros (1, n);

pv=input ('no of pv buses');

pq=input('no of pq buses');

s=input ('slack bus number');

v(s)=input ('slack bus voltage');

acc=input ('acceleration factor');

for i=1: pv

b(i)=input ('pv bus number');

p(b(i)) =input ('real power');

v(b(i)) =input ('voltage value');

qmin(b(i)) =input ('min value of q');

qmax(b(i)) =input ('max value of q');

end

for i=1: pq

c(i)=input ('pq bus number');

p(c(i)) =input ('real power');
```

```
p(c(i)) =-p(c(i));

q(c(i)) =input ('reactive power');

q(c(i)) =-q(c(i));

v(c(i)) =1+0i;

end

e=v;

e

enew(s)=v(s);

it=0;

yy=zeros(1,n);

for ii=1: n

ypq(ii)=0;

if ii~=s

flag=0;

gen=0;

for j=1:pv

if ii==b(j)

flag=1;

end

end

if flag==1

for k=1:n

yy(ii)=yy(ii)+ybus(ii,k)*v(k);

end

qcal(ii)=-imag(conj(v(ii))*yy(ii));
```

```
if qcal(ii)<qmin(ii)

qcal(ii)=qmin(ii);

elseif qcal(ii)>qmax(ii)

qcal(ii)=qmax(ii);

else

qcal(ii)=qcal(ii);

gen=1;

end

else

qcal(ii)=q(ii);

end

for k=1: n

if k~=ii

ypq(ii)=ypq(ii)+ybus(ii,k)*e(k);

end

end

enew(ii)=(((p(ii)-qcal(ii))/conj(e(ii)))-ypq(ii))/ybus(ii,ii);

dele(ii)=enew(ii)-e(ii);

enew(ii)=e(ii)+acc*dele(ii);

if gen==1 ang=angle(enew(ii)); enew(ii)=v(ii)*cos(ang)+v(ii)*sin(ang)*sqrt (-1);

end

e(ii)=enew(ii);

end

end

disp('voltages');
```

enew

Observation:

```
No. of buses 4
No. of lines 5

impedance 1 or admittance 22
starting bus 1
ending bus 2

admittance or impedance value 2-8i
starting bus 1
ending bus 3

admittance or impedance value 1-4i
starting bus 2
ending bus 3

admittance or impedance value 0.666-2.664i
starting bus 2
ending bus 4

admittance or impedance value 1-4i
starting bus 3
ending bus 4

admittance or impedance value 2-8i

  ybus =

  3.0000 -12.0000i -2.0000            + 8.0000i     -1.0000     + 4.0000i     0
  -2.0000 + 8.0000i         3.6660      -14.6640i     -0.6660 + 2.6640i          -1.0000 + 4.0000i
  -1.0000 + 4.0000i         -0.6660 + 2.6640i          3.6660      -14.6640i     -2.0000 + 8.0000i
         0      -1.0000 + 4.0000i -2.0000 + 8.0000i 3.0000 -12.0000i

No. of pv buses 0
No. of pq buses 3

Slack bus number 1
slack bus voltage 1.06
```

```
acceleration factor 1

pq bus number 2
real power 0.5
reactive power 0.2

pq bus number 3
real power 0.4
reactive power 0.3

pq bus number 4
real power 0.3
reactive power 0.1

e =1.0600  1.0000  1.0000  1.0000
voltages enew =1.0600 1.0119 - 0.0289i 0.9929 - 0.0261i 0.9855 - 0.0486i
```

Result:

Thus load flow analysis by Gauss – Seidal method was done for the given power system.

Viva Questions:

1. What is the Gauss-Seidel method and how is it applied to power flow analysis?

2. What are the key assumptions made in the Gauss-Seidel method?

3. How do you initialize bus voltages in the Gauss-Seidel method?

4. What is the difference between a PQ bus and a PV bus in power flow analysis?

5. How do you check for convergence in the Gauss-Seidel method?

6. Why is the Gauss-Seidel method slower for large systems?

7. What is the role of the Y-bus matrix in the Gauss-Seidel method?

8. What are the advantages and disadvantages of the Gauss-Seidel method compared to the Newton-Raphson method?

9. How does the choice of the initial guess affect the convergence of the Gauss-Seidel method?

10. Can the Gauss-Seidel method be used for solving unbalanced power flow problems? Why or why not?

Experiment No. – 6

Aim: To develop a program for the FDLF algorithm.

Apparatus: MATLAB Software

Theory:

The **Fast Decoupled Load Flow (FDLF)** algorithm is an efficient method for solving power flow problems, offering faster computation by simplifying the power flow equations. It decouples active and reactive power equations based on the weak coupling between them.

Key Concepts:

1. **Active power (P)** is primarily affected by changes in voltage angles θ\thetaθ.
2. **Reactive power (Q)** is influenced by voltage magnitudes |V|.

Simplified Equations:

- For voltage angles: $\Delta\theta = [B']^{-1}\Delta P$
- For voltage magnitudes: $\Delta V = [B'']^{-1}\Delta Q$

Where B – susceptance

Steps:

1. **Initialize** bus voltage magnitudes and angles.
2. **Solve** decoupled equations for θ\theta and VVV.
3. **Update** voltages and angles.
4. **Check convergence** and repeat until the solution stabilizes.

Advantages:

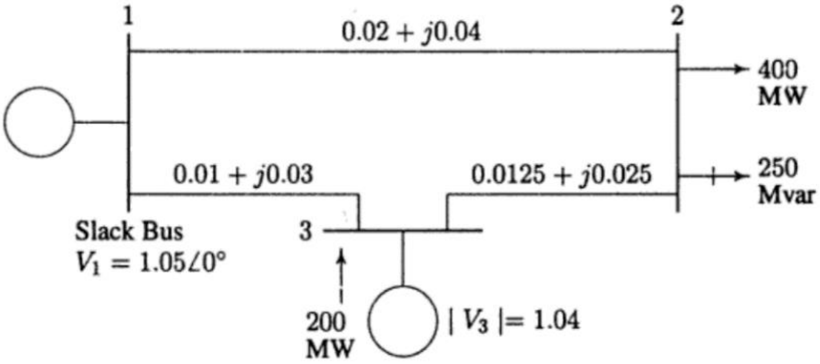
- Faster and less memory-intensive than Newton-Raphson.
- Efficient for large systems.

Limitations:

- Accuracy may decrease in heavily loaded or ill-conditioned systems.
- Not ideal for systems with high R/X ratios.

Problem:

Solve below system using FLDF:



Program:

```
%% Program for FDLF
b=busdat;  l=linedat;
nb=length(b(:,1));
n1=find(b(:,2)>1);  % finds index of non slack buses
n2=find(b(:,2)>2);  % finds index of pq buses
Y=ybusf(l);      % Ybus function
B1 =imag (Y (n1, n1));
B11=imag (Y(n2, n2));
Ps=b(:,5)-b(:,7);   dP=Ps;  % schedule powers and
Qs=b(:,6)-b(:,8);   dQ=Qs;  % initial values
d=b(:,4);V=b(:,3);
while (max(abs(dP(n1)))>0.0001||max(abs(dQ(n2)))>0.0001)
   S=(V.*exp(-1i*d)). *(Y*(V.*exp(1i*d))); % S= (V L-d)x(Yx(V Ld))
   dP=Ps-real(S); dQ=Qs+imag(S); % S=V*I || S=P-jQ
   d(n1) =d(n1)-B1\ dP(n1)./V(n1);
   V(n2)=V(n2)-B11\dQ(n2). /V(n2);
end
display(V); D=d*180/pi; display(D); % Volt & Degrees
```

Line data-

```
function d = linedat
%     |FromBus|ToBus|Impedance|LineCharging|
d = [    1      2    .02+.04j     0j;
         1      3    .01+.03j     0j;
         2      3    .0125+.025j  0j;];
```

Busdata-

```
function d = busdat
Slack=1; PV=2; PQ=3;
%     |Bus | Type | Vsp |del| PGi | QGi | PLi | QLi |
d = [   1   Slack 1.05   0    0     0     0     0;
       2    PQ    1.00  0    0     0    4.0   2.5;
       3    PV    1.04  0   2.0    0     0     0;];
```

Ybusf-

```
function Y = ybusf(ld)
fb = ld(:,1);    tb = ld(:,2);
y = 1./ld(:,3);   b = ld(:,4) + y;
nb = max(max(fb,tb));
Y = zeros(nb);
Y(nb*(fb-1)+tb)=-y;
Y(nb*(tb-1)+fb)=-y;
for m=1:nb
   Y(m,m)=Y(m,m)+sum(b(fb==m))+sum(b(tb==m));
end
```

Observation:

```
V = 1.0500
    0.9717
    1.0400

D =      0
   -2.6964
   -0.4988
```

Result:

Voltage: _______
Reactive power: _________
Active power: __________

Viva Questions:

1. What is the Fast Decoupled Load Flow (FDLF) algorithm and how does it differ from the Newton-Raphson method?
2. How does the FDLF algorithm simplify the power flow equations?
3. What are the key assumptions made in the FDLF method?
4. Explain the decoupling of active power P and voltage angles (theta) in the FDLF method.
5. How does the FDLF algorithm handle reactive power Q and voltage magnitudes V?
6. What are the main advantages of using the FDLF method over other power flow methods?
7. Why might the FDLF method have reduced accuracy compared to the Newton-Raphson method?
8. What is the role of the B' and B'' matrices in the FDLF algorithm?
9. In what types of power systems is the FDLF method most effective?
10. How does the initial guess for voltages affect the performance and convergence of the FDLF method?

Experiment No.: -7

Aim: - To carryout load flow analysis of the given power system by Newton Raphson method.

Apparatus: MATLAB Software

Theory:

Step-1: Assume a flat voltage profile 1 + j0 for all buses (nodes) except the slack bus. The voltage of the slack bus is the specified voltage and it is not modified in any iteration.

Step-2: Assume a suitable value of ε called convergence criterion. Hence ε is a specified change in the residue that is used to compare the critical residues (Δ P and Δ Q or Δ V) at the end of each iteration.

Step-3: Set iteration count k = 0, and assumed voltage profile of the buses are denoted as V10, V20 ...Vn0 except slack bus.

Step-4: Set bus count p = 1.

Step-5: Check for slack bus. If it is a slack bus then go to Step 13, otherwise go to next step.

Step-6: Calculate the real and reactive power of bus-p using the following equation.

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

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

Step-7: Calculate the change in real power, change in real power, $\Delta P_k = Pp_{,spec} - P_{pk}$; where $Pp_{,spec}$ = Specified real power for bus-p.

Step-8: Check for Generator bus. If it is a Generator bus go to next step, otherwise go to Step 12.

Step-9: Check for reactive power limit violation of Generator buses. For this compare the calculated reactive power Qpk with specified limits. If the limit is violated go to Step 11, otherwise go to next step.

Step-10: If the calculated reactive power is within the specified limits then consider this bus as Generator bus. Now calculate the voltage residue (change in voltage) using the following equation.

$| \Delta V_{pk}|^2 = |V_p|_{spec}^2 - |V_{pk}|^2$ where $|V_p|_{spec}$ = specified voltage.

Step-11: If the reactive power limit is violated then treat this bus as a load bus. Now the specified reactive power for this bus will correspond to the limit violated.

i.e., if $Q_{pk} < Q_p$, min then $Qp_{, spec} = Qp_{, min}$

(Or) if $Q_{pk} > Q_p$, min then $Qp_{, spec} = Qp_{, max}$

Step-12: Calculate the change in reactive power for load bus (or for the Generator bus treated as load bus). Change in reactive power, $\Delta Qp_k = |Qp_{, spec}| - Qp_k$

Step-13: Repeat steps 5 to12 until all residues (change in P and Q or V) are calculated. For this increment the bus count by 1 and go to Step 5, until the bus count is n.

Step-14: Determine the largest of the absolute value of the residue (i.e., find the largest among ΔP_k, ΔQ_k or $|\Delta Vp_k|^2$. Let this largest change be ΔE.

Step-15: Compare ΔE and ε. If $\Delta E < \varepsilon$ then to Step 20, If $\Delta E > \varepsilon$ go to next step.

Step-16: Determine the elements of Jacobian matrix (**J**) by partially differentiating the load flow equations and evaluating the equation using Kth iteration values.

Step-17: Calculate the increments in real and reactive part of voltages.

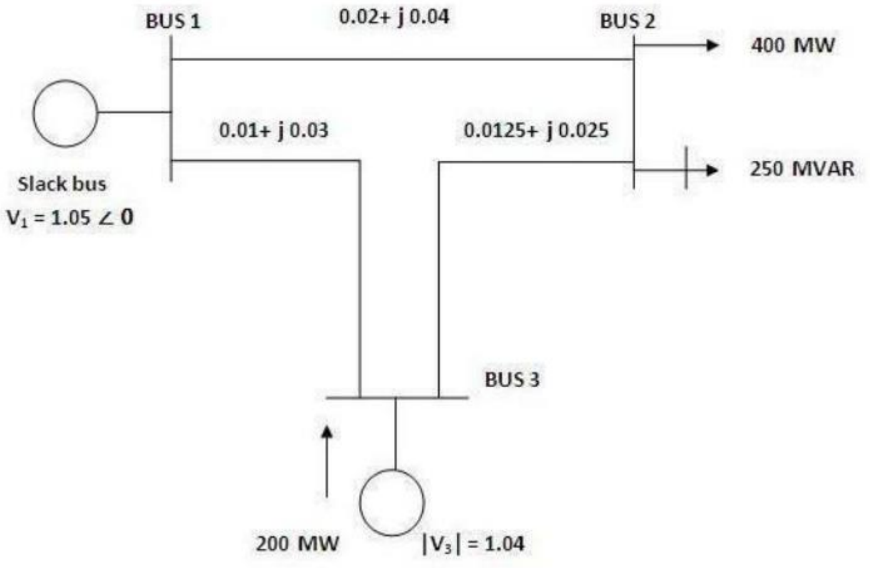
Step-18: Calculate the new bus voltage.

Step-19: Advance the iteration count, i.e., k = k + 1 and go to Step 4.

Step-20: Calculate the line flow.

Problem:

Figure shows the one-line diagram of a three-bus power system with generators at buses 1& 3. The magnitude of voltage at bus1 is adjusted to 1.05 per unit. The magnitude of voltage at bus 3 is fixed at 1.04pu with a real power generation of 200 MW. A load consists of 400 MW and 250 MVAR is taken from bus2. Line impedances are marked in per unit on a 100MVA base and the line charging susceptance are neglected.



Program:

```
clear all;

clc;

v=[1.05;1.0;1.04];

d=[0;0;0];

ps=[-4;2.0];

qs=-2.5;

n= input('Enter the number of buses ');

fprintf('Enter your choice');

p= input ('1. impedance, 2. admittance');

if (p==1)

for q= 1:n

for r=q+1:n

fprintf('Enter the impedance value between %d-%d',q,r); z(q,r)=input(':');

if (z(q,r)==0)

y(q,r)=0;

else

y(q,r)=inv(z(q,r));
```

```
end

y(r,q)= y(q,r);

end

end

elseif (p==2)

for a= 1:n

for b=a+1:n

fprintf('Enter the admittance value between %d-%d',a,b); y(a,b)=input(':');

y(b,a)= y(a,b);

end

end

else

fprintf('enter the correct choice');

end

ybus=zeros(n,n);

for a = 1:n

for b=1:n

if (a==b)

for c = 1:n

ybus(a,a)= ybus(a,a)+ y(a,c);

end

else

ybus(a,b)=-y(b,a);

end

end

end
```

```
ybus
y=abs(ybus); t=angle(ybus);
iter=0;
pwracur=0.00025;% Power accuracy
dc=10;% Set the maximum power residual to a high value
while max(abs(dc))>pwracur
iter=iter+1
p=[v(2)*v(1)*y(2,1)*cos(t(2,1)d(2)+d(1))+v(2)^2*y(2,2)*cos(t(2,2))+v(2)*v(3)*y(2,3)*cos(t(2,3)d(2)+d(3));v(3)*v(1)*y(3,1)*cos(t(3,1)d(3)+d(1))+v(3)^2*y(3,3)*cos(t(3,3))+v(3)*v(2)*y(3,2)*cos(t(3,2)-d(3)+d(2))];
q=v(2)*v(1)*y(2,1)*sin(t(2,1)d(2)+d(1))v(2)^2*y(2,2)*sin(t(2,2)v(2)*v(3)*y(2,3)*sin(t(2,3)-d(2)+d(3));
j(1,1)=v(2)*v(1)*y(2,1)*sin(t(2,1)-d(2)+d(1))+v(2)*v(3)*y(2,3)*sin(t(2,3)-d(2)+d(3));
j(1,2)=-v(2)*v(3)*y(2,3)*sin(t(2,3)-d(2)+d(3));
j(1,3)=v(1)*y(2,1)*cos(t(2,1)d(2)+d(1))+2*v(2)*y(2,2)*cos(t(2,2))+v(3)*y(2,3)*cos(t(2,3)-d(2)+d(3));
j(2,1)=-v(3)*v(2)*y(3,2)*sin(t(3,2)-d(3)+d(2));
j(2,2)=v(3)*v(1)*y(3,1)*sin(t(3,2)-d(3)+d(1))+v(3)*v(2)*y(3,2)*sin(t(3,2)-d(3)+d(2));
j(2,3)=v(3)*y(2,3)*cos(t(3,2)-d(3)+d(2));
j(3,1)=v(2)*v(1)*y(2,1)*cos(t(2,1)-d(2)+d(1))+v(2)*v(3)*y(2,3)*cos(t(2,3)-d(2)+d(3));
j(3,2)=-v(2)*v(3)*y(2,3)*cos(t(3,2)-d(2)+d(3));
j(3,3)=-v(1)*y(2,1)*sin(t(2,1)-d(2)+d(1))-2*v(2)*y(2,2)*sin(t(2,2)v(3)*y(2,3)*sin(t(2,3)-d(2)+d(3));
dp=ps-p;
dq=qs-q;
dc=[dp;dq]
```

```
dx=j\dc

d(2)=d(2)+dx(1);

d(3)=d(3)+dx(2);

v(2)=v(2)+dx(3);

v,d,delta=180/pi*d;

end

p1=v(1)^2*y(1,1)*cos(t(1,1))+v(1)*v(2)*y(1,2)*cos(t(1,2)d(1)+d(2))+v(1)*v(3)*y(1,3)*

cos(t(1,3)-d(1)+d(3));

q1=-v(1)^2*y(1,1)*sin(t(1,1))-v(1)*v(2)*y(1,2)*sin(t(1,2)-

d(1)+d(2)+v(1)*v(3)*y(1,3)*sin(t(1,3)-d(1)+d(3));

q3=-v(3)*v(1)*y(3,1)*sin(t(3,1)-d(3)+d(1))-v(3)*v(2)*y(3,2)*sin(t(3,2)-d(3)+d(2))-

v(3)^2*y(3,3)*sin(t(3,3));
```

Observation:

Enter number of buses:

Enter number of choice:

Result:

Thus, the load flow analysis using is performed by Newton-Raphson method and a program is developed using MATLAB to find the solution of load flow for given power system and the output is verified.

Viva Questions:

1. What is Economic Load Dispatch (ELD) and why is it important in power systems?
2. How is the objective function for ELD formulated?
3. Why are transmission losses ignored in this simplified ELD model?
4. What are the main constraints in the ELD problem?
5. Explain the role of the Lagrange multiplier in solving the ELD problem.
6. What is the significance of equal incremental costs in ELD?
7. How does the cost function for a generator typically vary with power output?
8. What happens if a generator reaches its generation limits during the dispatch process?
9. How do you ensure that the total power generated equals the load demand?
10. What are the advantages and limitations of ELD without considering transmission losses?

Experiment 8

Aim: To understand the basics of the Economic Dispatch by optimally adjusting the generation schedules of thermal generating units to meet the system demand which are required for unit commitment and economic operation of power systems.

Apparatus: MATLAB Software

Theory:

Economic Load Dispatch (ELD) with losses aims to minimize the total generation cost while considering transmission losses. The power generated must not only meet the load demand but also account for the energy lost during transmission.

Objective

Minimize the total cost: $C_{\text{total}} = \sum_{i=1}^{n} (a_i + b_i P_i + c_i P_i^2)$

where Ploss (transmission losses) is calculated using B-coefficients:

$$P_{\text{loss}} = \sum_{i=1}^{n} \sum_{j=1}^{n} P_i B_{ij} P_j$$

Solution

Using the **Lagrange multiplier** method, the optimal condition becomes:

$$\frac{dC_i}{dP_i} = \lambda \times (1 + \frac{\partial P_{\text{loss}}}{\partial P_i})$$

Here, the **penalty factor** adjusts each generator's cost to account for transmission losses.

ALGORITHM:

Step 1:Choose appropriate value of Lagrangian multiplier λ

Step 2:Start iteration iter=0

Step 3:Iteration iter=iter+1

Step 4:Solve for power generated by ith unit using equation $Pi^{(k)}=(\lambda^{(k)} - bi)/2(ai+ \lambda^{(k)} Bii)$

Step 5:Check if any Pi is beyond or below the inequality constant If Pi < Pi,min, fix Pi= Pi,min

If Pi>Pi,max, fix Pi= Pi,max

Step 6:Calculate the power loss using the equation $PL=\sum Bii\ Pi^2$

Step 7:Calculate power mismatch using the formula, $\Delta P^{(k)}=PD+PL^{(k)}-\sum Pi^{(k)}$

Step 8:If $\Delta P^{(k)}>0$, then increment λ, λnew=λ+0.001 and go to step 3 else go to step 9

Step 9:If $\Delta P^{(k)}<0$, then decrement λ, λnew=λ-0.001 and go to step 3 else go to step 10

Step 10:If ΔP is less than tolerance value , print the values of generated power and losses

Step 11:Stop

Problem:

For the given line data calculate the cost of distribution considering the losses:

a	b	c	fc	max	min
0.00142	7.20	510	1.1	600	150
0.00194	7.85	310	1	400	100
0.00482	7.97	78	1	200	50

Program:

```
clc;

clear all;

 % a    b  c  fc       max    min

data=  [0.00142      7.20    510    1.1 600    150

        0.00194      7.85    310    1    400    100

        0.00482      7.97    78     1    200    050];

ng=length(data(:,1));

a=data(:,1);

b=data(:,2);

c=data(:,3);

fc=data(:,4);

pmax=data(:,5);
```

```
pmin=data(:,6);

%       loss=[0.00003 0.00009 0.00012]; loss=[ 0 0 0];

C=fc.*c; B=fc.*b; A=fc.*a; la=1; pd=850; acc=0.2; diff=1;

while acc<(abs(diff));

for i=1:ng;

p(i)= (la-B(i))/(2*(la*loss(i)+A(i)));

if p(i)<pmin(i);

p(i)=pmin(i);

end;

if p(i)>pmax(i);

p(i)=pmax(i);

end;

end;

LS=sum(((p.*p).*loss));

diff=(pd+LS-sum(p));

if diff>0

la=la+0.001;

else la=la-0.001;

end;

end;

PowerShared=p

Lambda=la

Loss=LS
```

Observation:

a) When loss = [0.00003 0.00009 0.00012]

```
Power Shared =        435.1026 299.9085 130.6311

Lambda = 9.5290

Loss = 15.8222
```

b) When loss   = 0

```
Power Shared = 393.0858 334.5361 122.1992

Lambda = 9.1490

Loss = 0

lambda = 12.1034

GENERATING UNIT OPTIMAL GENERATION(MW)

ans = 1.0000  177.2999
      2.0000  489.8232

INCREMENTAL FUEL COST AND PENALTY FECTORS ARE UNIT NO. IFC L

ans = 1.0000   10.6184   1.1398
      2.0000   11.3410   1.0672

CHECK LAMBDA=IFC*L UNIT NO. LAMBDA

ans = 1.0000   12.1034
      2.0000   12.1034

TOTAL GENERTION COST(Rs./hr)

totgencost = 7.3862e+03
```

Result:

Using MATLAB program Optimal scheduling of generators is done for the given three generator system by Lamda iteration method with and without loss and the calculated values of this system are verified with the output result.

Viva Questions:

1. What is the difference between Economic Load Dispatch with and without losses?
2. How are transmission losses accounted for in the ELD problem?
3. What are B-coefficients and how are they used in calculating transmission losses?
4. Explain the objective function of ELD with losses.
5. What is the significance of the penalty factor in ELD with losses?
6. How is the Lagrange multiplier method used to solve ELD with losses?
7. Why do incremental costs need to be adjusted when transmission losses are considered?
8. What is the formula for transmission losses and what role does it play in ELD?
9. How do you ensure that the total power generated equals the load demand plus losses?

Experiment No: - 9

Aim:- To study swing equation and perform on MATLAB

Apparatus: MATLAB software

Theory:

The swing equation is a non-linear differential equation that describes the motion of a synchronous generator's rotor in a power system. It's used to analyse the transient stability of synchronous generators.

$$\frac{2H}{\omega_s}\frac{d^2\delta}{dt^2} = P_a = P_m - P_e$$

The swing equation uses the following variables:

- M: The moment of inertia of the rotating masses of the machine
- δ: The rotor angle in electrical radians
- Pm: The mechanical input power to the generator
- Ps: The electrical output power from the generator
- d2δ/dt2: The angular acceleration of the rotor.
-

Problem:

A 20 MVA, 50Hz generator delivers 18MW over a double circuit line to an infinite bus. The generator has KE 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.

Program:

```
%Defining the function swing

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

end

%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
```

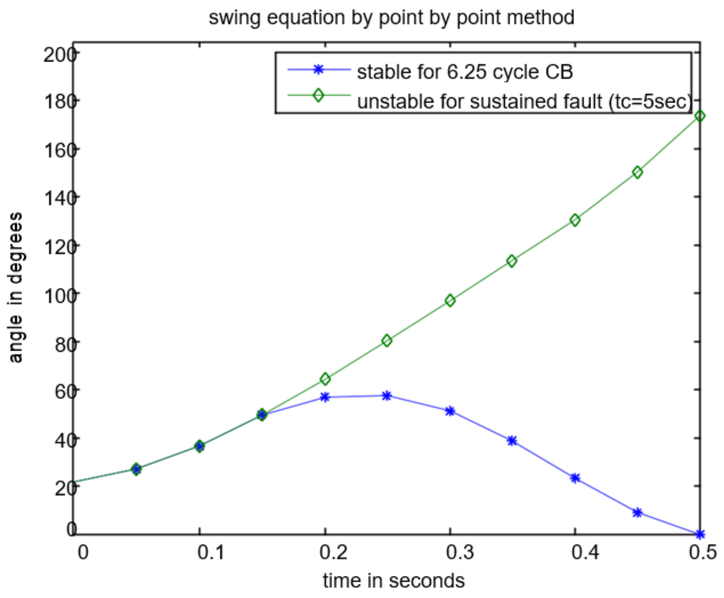
Observation:

Inputs to main program:

Enter the value of clearing time as

0.25 sec, and

5 sec



Result:

The following variables calculated using swing equation are: _______

Viva questions:

1. What is the significance of the swing equation in power system analysis?
2. Explain the terms Pm, Pe, and H in the swing equation.
3. How is the swing equation used to study power system stability?
4. What are the factors that affect the stability of a power system as per the swing equation?
5. How can the swing equation be solved numerically?
6. What is the difference between small signal stability and transient stability?
7. How can the swing equation be used to study voltage stability?
8. Can you explain the concept of critical clearing time?
9. How does the swing equation account for damping in a power system?
10. What are the limitations of the swing equation?

Experiment No. - 10

Aim: To obtain the bus impedance matrix Z – bus of the given power system network using MATLAB.

Apparatus: MATLAB Software

Theory:

Z - bus matrix is an important matrix used in different kinds of power system studies such as short circuit study, load flow study, etc In short circuit analysis, the generator and transformer impedances must be taken into account. In contingency analysis, the shunt elements are neglected while forming the Z-bus matrix, which is used to compute the outage distribution factors. Z-bus can be easily obtained by inverting the Y-bus formed by inspection method or by analytical method. Taking inverse of the Y-bus for large systems is time consuming; Moreover, modification in the system requires the whole process to be repeated to reflect the changes in the system. In such cases, the Z–bus is computed by Z–bus building algorithm.

ALGORITHM FOR FORMATION OF Z-BUS MATRIX

Step 1 : Read the values such as number of lines, number of buses and line data, Generator data and Transformer data.

Step 2 : Initialize Ybus matrix. Y-bus [i] [j] = complex (0.0,0.0) for all values of i and j

Step 3 :Compute Y- bus Matrix by considering only line data.

Step 4 : Modify the Ybus matrix by adding the combined transformer and the generator admittances to the respective diagonal elements of Y– bus matrix.

Step 5 : Compute the Z– bus matrix by inverting the modified Ybus matrix.

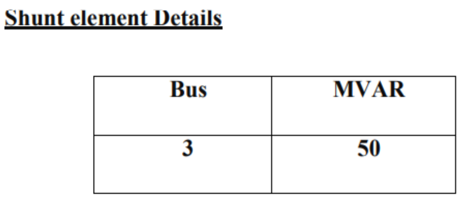
Step 6 : Check the inversion by multiplying modified Ybus and Z-bus matrices to see whether the resulting matrix is unity matrix or not. If it is unity matrix, the result is correct.

Step 7 :Print Z-bus matrix

Problem:

Line Specification

Line no.	Start bus	End bus	Series impedance (P.U.)	Half-line charging admittance (P.U.)	Rating MW
1	1	2	0.001 + j 0.015	0.001	60
2	2	3	0.002 + j 0.021	0.005	40
3	3	1	0.004 + j 0.046	0.0015	65



Shunt element Details

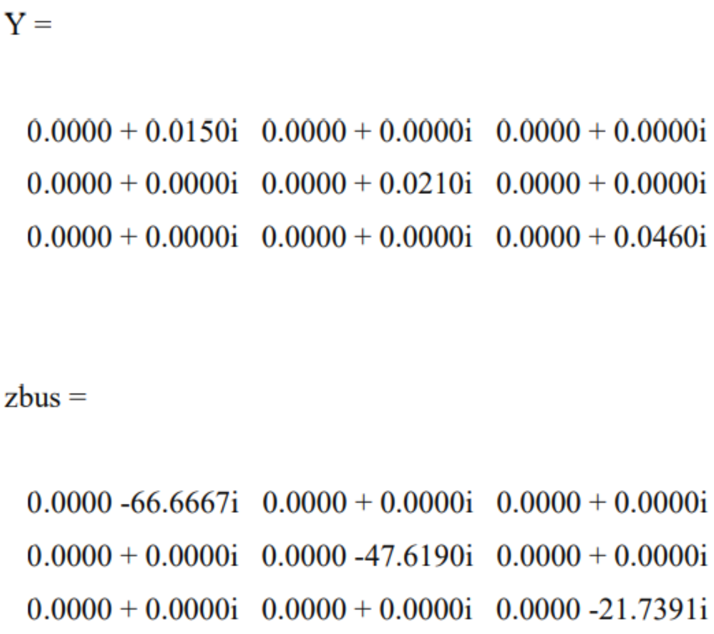
Bus	MVAR
3	50

Program:

```
linedata = [1 1 2 0.001 0.015 0.001 2 2 3 0.002 0.021 0.0005 3 3 1 0.004 0.046 0.0015 ];
fb = linedata(:,1);
tb = linedata(:,2);
r = linedata(:,3);
x = linedata(:,4);
b = linedata(:,5);
z = r + i*x; y = 1./z;
b = i*b;
nbus = max(max(fb),max(tb));
nbranch = length(fb);
Y = zeros(nbus,nbus);
for k=1:nbranch
Y(fb(k),tb(k)) = Y(fb(k),tb(k))-y(k);
Y(tb(k),fb(k)) = Y(fb(k),tb(k));
end
for m =1:
nbus for n =1:nbranch
if fb(n) == m
Y(m,m) = Y(m,m) + y(n)+ b(n);
elseif tb(n) == m
Y(m,m) = Y(m,m) + y(n) + b(n);
```

```
end

end

end

Y zbus = inv(Y)
```

Observation:



```
Y =

  0.0000 + 0.0150i   0.0000 + 0.0000i   0.0000 + 0.0000i
  0.0000 + 0.0000i   0.0000 + 0.0210i   0.0000 + 0.0000i
  0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 + 0.0460i


zbus =

  0.0000 -66.6667i   0.0000 + 0.0000i   0.0000 + 0.0000i
  0.0000 + 0.0000i   0.0000 -47.6190i   0.0000 + 0.0000i
  0.0000 + 0.0000i   0.0000 + 0.0000i   0.0000 -21.7391i
```

Result:

Thus, for a given system bus impedance matrix was formulated using MATLAB package.

Viva questions:

1. What is the Z-bus matrix in power systems?
2. How is the Z-bus matrix derived from the Y-bus matrix?
3. What is the primary use of the Z-bus matrix in power systems?
4. Which method is used to calculate the Z-bus matrix?
5. Why is the Z-bus matrix preferred for fault analysis?
6. What is the relationship between Z-bus and Y-bus matrices?
7. Can the Z-bus matrix be directly calculated?
8. What is the Z-bus building algorithm?
9. Why might the Y-bus matrix be non-invertible?
10. What is the significance of diagonal elements in the Z-bus matrix?
11. How do off-diagonal elements in the Z-bus matrix impact system analysis?
12. What does a zero element in the Z-bus matrix indicate?

13. How do you handle singular Y-bus matrices when calculating Z-bus?
14. What is Kron's reduction in Z-bus matrix calculation?

Experiment No. – 11

Aim: To become familiar with various aspects of the transient analysis of Single-Machine-Infinite Bus (SMIB) system.

Apparatus: MATLAB Software

Theory:

Stability: Stability problem is concerned with the behaviour of power system when it is subjected to disturbance and is classified into small signal stability problem if the disturbances are small and transient stability problem when the disturbances are large.

Transient stability: When a power system is under steady state, the load plus transmission loss equals to the generation in the system. The generating units run a synchronous speed and system frequency, voltage, current and power flows are steady. When a large disturbance such as three phase fault, loss of load, loss of generation etc., occurs the power balance is upset and the generating units rotors experience either acceleration or deceleration. The system may come back to a steady state condition maintaining synchronism or it may break into subsystems or one or more machines may pull out of synchronism. In the former case the system is said to be stable and in the later case it is said to be unstable.

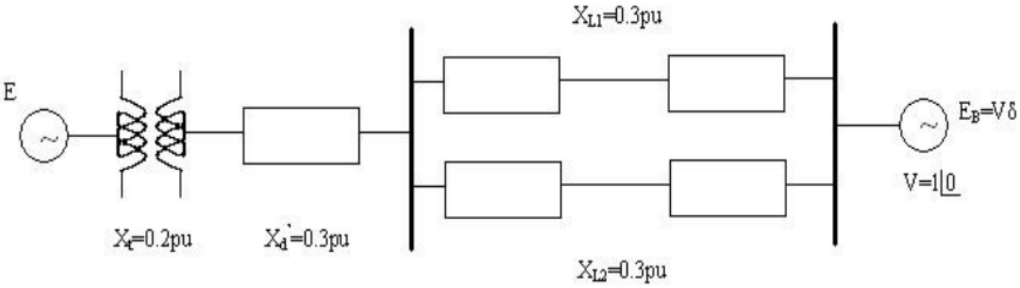
Small signal stability: When a power system is under steady state, normal operating condition, the system may be subjected to small disturbances such as variation in load and generation, change in field voltage, change in mechanical toque etc., The nature of system response to small disturbance depends on the operating conditions, the transmission system strength, types of controllers etc. Instability that may result from small disturbance may be of two forms,

i. Steady increase in rotor angle due to lack of synchronising torque.
ii. Rotor oscillations of increasing magnitude due to lack of sufficient damping torque.

Problem:

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

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



Program:

```
function eacfault(Pm, E, V, X1, X2, X3)

if exist('Pm')~=1

Pm = input('Generator output power in p.u. Pm = '); else, end if exist('E')~=1

E = input('Generator e.m.f. in p.u. E = '); else, end if exist('V')~=1

V = input('Infinite bus-bar voltage in p.u. V = '); else, end if exist('X1')~=1

X1 = input('Reactance before Fault in p.u. X1 = '); else, end if exist('X2')~=1

X2 = input('Reactance during Fault in p.u. X2 = '); else, end if exist('X3')~=1

X3 = input('Reactance aftere Fault in p.u. X3 = '); else, end

Pe1max = E*V/X1; Pe2max=E*V/X2; Pe3max=E*V/X3; delta = 0:.01:pi;

Pe1 = Pe1max*sin(delta); Pe2 = Pe2max*sin(delta); Pe3 = Pe3max*sin(delta);

d0 =asin(Pm/Pe1max); dmax = pi-asin(Pm/Pe3max);

cosdc = (Pm*(dmax-d0)+Pe3max*cos(dmax)-Pe2max*cos(d0))/(Pe3max-Pe2max);

if abs(cosdc) > 1

fprintf('No critical clearing angle could be found.\n')

fprintf('system can remain stable during this disturbance.\n\n')

return

else, end

dc=acos(cosdc);

if dc > dmax
```

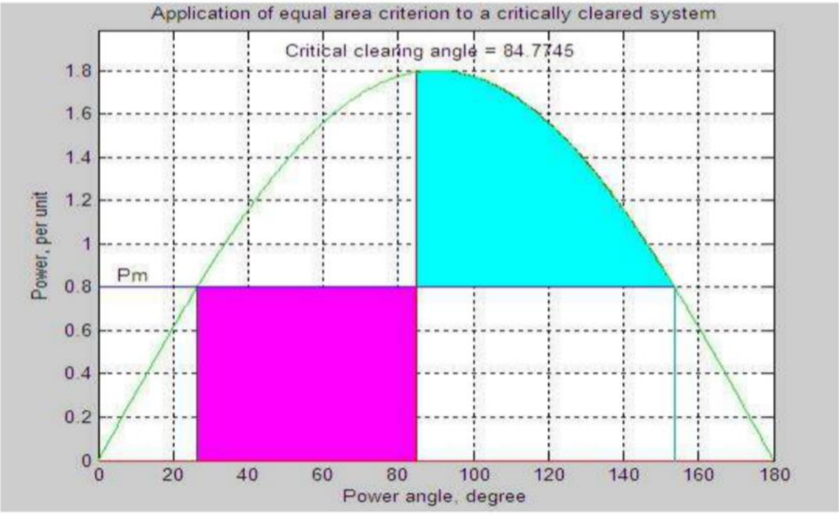
```
fprintf('No critical clearing angle could be found.\n')

fprintf('System can remain stable during this disturbance.\n\n')

return

else, end

Pmx=[0          pi-d0]*180/pi; Pmy=[Pm Pm];

x0=[d0 d0]*180/pi; y0=[0 Pm]; xc=[dc dc]*180/pi; yc=[0 Pe3max*sin(dc)];

xm=[dmax dmax]*180/pi; ym=[0 Pe3max*sin(dmax)];

d0=d0*180/pi; dmax=dmax*180/pi; dc=dc*180/pi;

x=(d0:.1:dc);

y=Pe2max*sin(x*pi/180);

y1=Pe2max*sin(d0*pi/180);

y2=Pe2max*sin(dc*pi/180);

x=[d0 x dc];

y=[Pm y Pm];

xx=dc:.1:dmax;

h=Pe3max*sin(xx*pi/180);

xx=[dc xx       dmax];

hh=[Pm h        Pm];

delta=delta*180/pi;

if X2 == inf

fprintf('\nFor this case tc can be found from analytical formula. \n') H=input('To find tc
enter Inertia Constant H, (or 0 to skip) H = ');

if H ~= 0

d0r=d0*pi/180; dcr=dc*pi/180;

tc = sqrt(2*H*(dcr-d0r)/(pi*60*Pm));
```

```
else, end

else, end

%clc

fprintf('\nInitial power angle        = %7.3f \n', d0)

fprintf('Maximum angle swing       = %7.3f \n', dmax)

fprintf('Critical clearing angle = %7.3f \n\n', dc)

if X2==inf & H~=0

fprintf('Critical clearing time          = %7.3f sec. \n\n', tc)

else, end

h = figure; figure(h);

fill(x,y,'m')

hold;

fill(xx,hh,'c')

plot(delta, Pe1,'-', delta, Pe2,'r-', delta, Pe3,'g-', Pmx, Pmy,'b-', x0,y0, xc,yc, xm,ym), grid

Title('Application of equal area criterion to a critically cleared system')

xlabel('Power angle, degree'), ylabel(' Power, per unit')

text(5, 1.07*Pm, 'Pm')

text(50, 1.05*Pe1max,['Critical clearing angle = ',num2str(dc)])

axis([0 180    0 1.1*Pe1max])

hold off;
```

Observation:

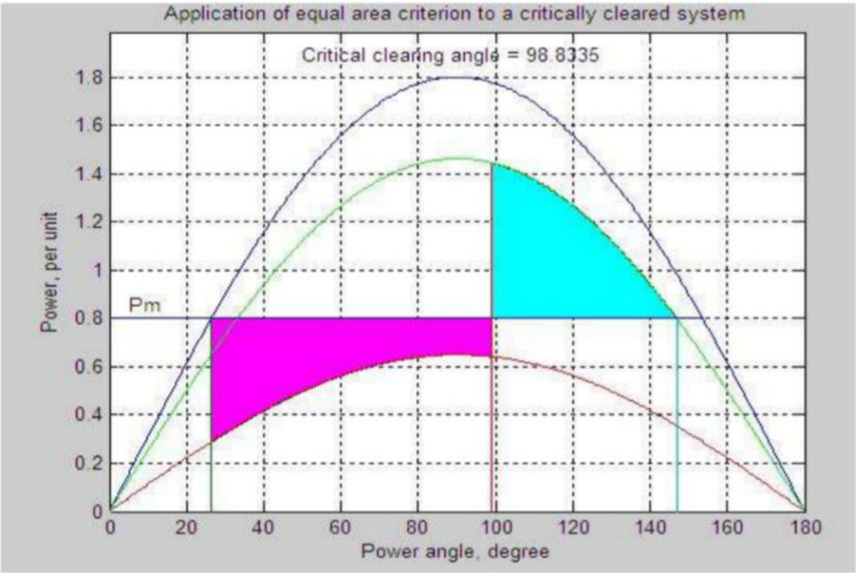
a) To find tc enter Inertia Constant H, (or 0 to skip) H = 5

```
Initial power angle           =    26.388

Maximum angle swing           =    153.612

Critical clearing angle       =    84.775

Critical clearing time        =    0.260 sec.
```



b) Initial power angle 26.388

Maximum angle swing 146.838
Critical clearing angle 98.834



Result:

Various aspects of the transient analysis of Single-Machine-Infinite Bus (SMIB) system has been studied.

Viva Question:

1. What is transient stability in a power system?
2. How does transient stability differ from steady-state stability?
3. What factors affect the transient stability of a power system?
4. What is the critical clearing time, and why is it important?

5. How does fault location impact transient stability?
6. What methods are used to improve transient stability?
7. How does the equal area criterion help in analyzing transient stability?
8. What role does rotor angle play in transient stability?

Experiment No. – 12

Aim: To determine the fault current and voltage in a single transmission line system for the following Y-Δ transformer at specified location for LG, LLG faults.

Apparatus: MATLAB Software

Theory:

Fault analysis is the process of determining the nature and characteristics of faults that can occur in a power system. Its key objectives include:

- Studying the type, location, and progression of faults
- Calculating fault currents and voltages
- Selecting protective devices and relay settings
- Rating equipment to withstand fault currents
- Ensuring power system stability during faults
- Locating faulty equipment for repair

Fault analysis helps provide continuous and reliable electric power by maintaining safety margins between normal loads and equipment ratings.

It minimizes equipment damage, downtime, and costs from faults through coordinated protection schemes.

Types of Faults in Power System

The faults in the power system are mainly categorized into two types:

1. Open Circuit Fault
2. Short Circuit Fault

1. **Open Circuit Fault:**

The open circuit fault happens due to the failure of one or two conductors. These faults take place in series with the line so referred as series fault. Such types of faults have a strong impact on the reliability of the system. The open circuit fault is classified as:

- Open Conductor Fault
- Two conductors Open Fault
- Three conductors Open Fault

2.**Short Circuit Fault:**

The short-circuit fault is commonly divided into symmetrical and asymmetrical types. These faults are further categorized as one of five types. In order of frequency of occurrence, they are:

- Asymmetrical Faults:

Asymmetrical faults mandate the calculation of positive negative and zero sequence components separately.

Single Line to Ground Fault: This type of fault occurs when you have one of the phases (A, B or C) is shorted with the ground.

Line to Line Fault: This type of fault occurs when you have one of the phases (A, B or C) is shorted with the ground.

Double Line to Ground Fault: This type of fault occurs when two phases are shorted with the ground together (A-B-G, B-C-G or C-A-G)

- Symmetrical Faults:

Symmetrical faults do not give rise to zero sequence or negative sequence components because they are perfectly balanced, symmetrical faults only have positive sequence values.

Three Phase Line to Ground Fault: The 3-phase to ground faults are faults in where all the phases (A, B and C) are shorted together and they are grounded.

Three Phase Line to Line Fault: The three phase faults occur when you have A, B and C phases are shorted together but ground is not involved.

Problem:

Consider a unsymmetrical fault occurring at three bus having impedances as follows z12 = j*.8; z13 = j*.4; z23 = j*.4; calculate the fault.

Program:

```
z12 = j*.8; z13 = j*.4; z23 = j*.4;

Ybus = j*[-8.75 1.25 2.5

 1.25 -6.25 2.5

 2.5 2.50 -5.0];

Zbus = inv(Ybus)

Zf = j*.16;

V0=[1; 1; 1];

I3F = V0(1)/(Zbus(3,3)+Zf)
```

```
VF = V0-I3F*Zbus(:,3)

I12 = (VF(1) - VF(2))/z12

I13 = (VF(1) - VF(3))/z13

I23 = (VF(2) - VF(3))/z23
```

Observation:

```
Zbus = 0.0000 + 0.1600i   0.0000 + 0.0800i   0.0000 + 0.1200i
       0.0000 + 0.0800i   0.0000 + 0.2400i   0.0000 + 0.1600i
       0.0000 + 0.1200i   0.0000 + 0.1600i   0.0000 + 0.3400i
I3F = 0.0000 - 2.0000i
VF = 0.7600
     0.6800
     0.3200
I12 = 0.0000 - 0.1000i
I13 = 0.0000 - 1.1000i
I23 = 0.0000 - 0.9000i
```

Result:

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

Viva Question:

1. What is a fault in a power system?
2. Explain the difference between symmetrical and unsymmetrical faults.
3. Why is fault current calculation important in power systems?
4. What happens to voltage and current during a short-circuit fault?
5. How does a protective relay detect faults?
6. What methods are used to calculate fault current?
7. What is the role of symmetrical components in fault analysis?
8. What is a bus impedance matrix, and how is it used in fault analysis?
9. What are sequence networks, and why are they important?
10. Why is a three-phase fault considered the most severe?