DRONACHARYA
College of Engineering

LABORATORY MANUAL

B.Tech. Semester- VI

POWER SYSTEM II LAB

Subject code: LC-EE-304G

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DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING
DRONACHARYA COLLEGE OF ENGINEERING
KHENTAWAS, FARRUKH NAGAR, GURUGRAM (HARYANA)

Table of Contents

Vision and Mission of the Institute

Vision:

To impart Quality Education, to give an enviable growth to seekers of learning, to groom them as World Class Engineers and managers competent to match the expending expectations of the Corporate World has been ever enlarging vision extending to new horizons of Dronacharya College of Engineering

Mission:

M1: To prepare students for full and ethical participation in a diverse society and encourage lifelong learning by following the principle of 'Shiksha evam Sahayata' i.e. Education & Help.

M2: To impart high-quality education, knowledge and technology through rigorous academic programs, cutting-edge research, & Industry collaborations, with a focus on producing engineers& managers who are socially responsible, globally aware, & equipped to address complex challenges.

M3: Educate students in the best practices of the field as well as integrate the latest research into the academics.

M4: Provide quality learning experiences through effective classroom practices, innovative teaching practices and opportunities for meaningful interactions between students and faculty.

M5: To devise and implement programmes of education in technology that are relevant to the changing needs of society, in terms of breadth of diversity and depth of specialization.

Vision and Mission of the Department

Vision:

Our vision for the Electrical and Electronics Engineering (EEE) Department is to be a globally recognized Centre of excellence in education, research, and innovation in the field of electrical and electronics engineering. We strive to produce competent engineers with strong technical knowledge, ethical values, and a passion for lifelong learning. And also to contribute to the sustainable development of society through cutting-edge research, industry collaborations, and community engagement.

Mission:

M1. To provide a high-quality education that equips students with a strong foundation in electrical and electronics engineering.

M2. To conducting pioneering research in diverse areas of electrical and electronics engineering.

M3. To establish strong ties with industry partners to bridge the gap between academia and the professional world.

M4. To instilling ethical values, social responsibility, and environmental consciousness in our students.

M5. To regularly assess and upgrade our teaching methodologies, infrastructure, and facilities.

Programme Educational Objectives (PEOs)

PEO1: Engineers will practice the profession of engineering using a systems perspective and analyse, design, develop, optimize & implement engineering solutions and work productively as engineers, including supportive and leadership roles on multidisciplinary teams.

PEO2: Continue their education in leading graduate programs in engineering & interdisciplinary areas to emerge as researchers, experts, educators & entrepreneurs and recognize the need for, and an ability to engage in continuing professional development and life-long learning.

PEO3: Engineers, guided by the principles of sustainable development and global interconnectedness, will understand how engineering projects affect society and the environment.

PEO4: Promote Design, Research, and implementation of products and services in the field of Engineering through Strong Communication and Entrepreneurial Skills.

PEO5: Re-learn and innovate in ever-changing global economic and technological environments of the 21st century.

Programme Outcomes (POs)

PO1: Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2: Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3: Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO4: Conduct investigations of complex problems: 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.

PO5: Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and software tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

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

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

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

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

PO10: Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO11: Project management and finance: Demonstrate knowledge and understanding of the engineering 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: Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes (PSOs)

PSO1: Equip themselves to potentially rich & employable field of Engineering. Analyse and design electrical machines, circuits, controls and systems which makes the part of Power generation, transmission, distribution, utilization and conservation

PSO2: Pursue higher studies in the contemporary Technologies and multidisciplinary fields with an inclination towards continuous learning in the area of Power quality, high voltage, power electronics and Renewable energy systems

PSO3: Take up-self- employment in Indian and electrical market in designing, implementing and testing analog, digital, embedded and signal processing systems

PSO4: Meet the requirements of the Indian Standards and use knowledge in different domains to identify the research gaps and to provide innovative solutions.

University Syllabus

1. Draw the flow chart and develop the computer program for the formation of the Y Bus of a generalized network.
2. Draw the flow chart and develop the computer program for the formation of the Z Bus of a generalized network.
3. To plot the swing curve and observe the stability.
4. To perform load flow analysis using Gauss Seidel method.
5. To perform load flow analysis using Newton-Raphson method.
6. To study comparison of different load flow methods
7. To develop the program for stability analysis.
8. To observe transmission losses and efficiency with variations in power for the given example.
9. Simulation study on LFC of two area interconnected power system.
10. Simulation study on voltage control in multi area interconnected power system.

Course Outcomes (COs)

Upon successful completion of the course, the students will be able to:

C323.1: To study and develop program for Ybus and Zbus

C323.2: To study swing curve and stability.

C323.3: Write programs for load flow studies.

C323.4: To study losses and efficiency of transmission lines.

C323.5: To study interconnected power system.

CO-PO Mapping

	PO1	**PO2**	**PO3**	**PO4**	**PO5**	**PO6**	**PO7**	**PO8**	**PO9**	**PO10**	**PO11**	**PO12**
CO.1		3			3			2	2	2	2	2
CO.2			2		3			2	2	2	2	2
CO.3				2	3			2	2	2	2	2
CO.4				2	3			2	2	2	2	2
CO.5				2	3			2	2	2	2	2
CO		**3**	**2**	**2**	**3**			**2**	**2**	**2**	**2**	**2**

CO-PSO Mapping

	PSO1	**PSO2**	**PSO3**	**PSO4**
CO.1	2	2	3	2
CO.2	2	2	3	2
CO.3	2	2	3	2
CO.4	2	2	3	2
CO.5	2	2	3	2
CO	**2**	**2**	**3**	**2**

Course Overview

This laboratory provides students with hands-on experience on the analysis, operation, and planning of both transmission and distribution systems. This laboratory has played a role in on-going development of the power system curriculum at institute. This laboratory is to provide students with experience on various power distribution system operating and planning functions, a set of experiments have been designed and are under design for use with MATLAB.

List of Experiments mapped with COs

Sl No.	*List of Experiments*	*Course Outcome*
1.	Draw the flow chart and develop the computer program for the formation of the Y Bus of a generalized network.	CO.1
2.	Draw the flow chart and develop the computer program for the formation of the Z Bus of a generalized network.	CO.1
3.	To plot the power angle curve of Synchronous machines	CO.2
4.	To perform load flow analysis using Gauss Seidel method.	CO.3
5.	To perform load flow analysis using Gauss Seidel method using acceleration factor.	CO.3
6.	To perform load flow analysis using Newton-Raphson method.	CO.3
7.	To study comparison of different load flow methods	CO.3
8.	To perform economic dispatch in power systems	CO.4
9.	To plot the swing curve and observe the stability.	CO.2

DOs and DON'Ts

DOs

1. Enter the lab on time and leave at proper time.
2. Keep the bags outside in the racks.
3. Utilize lab hours in the corresponding experiment.
4. Make the Supply off the Kits/Equipments after completion of Experiments.
5. Maintain the decorum of the lab.

DON'Ts

1. Don't bring any external material in the lab.
2. Don't make noise in the lab.
3. Don't bring the mobile in the lab.
4. Don't enter in Faculty room without permission.
5. Don't litter in the lab.
6. Don't carry any lab equipments outside the lab

General Safety Precautions

Precautions (In case of Injury or Electric Shock)

1. To break the victim with live electric source, use an insulator such as fire wood or plastic to break the contact. Do not touch the victim with bare hands to avoid the risk of electrifying yourself.
2. Unplug the risk of faulty equipment. If main circuit breaker is accessible, turn the circuit off.
3. If the victim is unconscious, start resuscitation immediately, use your hands to press the chest in and out to continue breathing function. Use mouth-to-mouth resuscitation if necessary.
4. Immediately call medical emergency and security. Remember! Time is critical; be best.

Precautions (In case of Fire)

1. Turn the equipment off. If power switch is not immediately accessible, take plug off.
2. If fire continues, try to curb the fire, if possible, by using the fire extinguisher or by covering it with a heavy cloth, if possible, isolate the burning equipment from the other surrounding equipment.
3. Sound the fire alarm by activating the nearest alarm switch located in the hallway.
4. Call security and emergency department immediately:

Emergency : Reception

Security : Main Gate

Guidelines to students for report preparation

All students are required to maintain a record of the experiments conducted by them. Guidelines for its preparation are as follows: -

1) All files must contain a title page followed by an index page. ***The files will not be signed by the faculty without an entry in the index page.***

2) Student's Name, Roll number and date of conduction of experiment must be written on all pages.

3) For each experiment, the record must contain the following

(i) Aim/Objective of the experiment

(ii) Pre-experiment work (as given by the faculty)

(iii) Lab assignment questions and their solutions

(iv) Test Cases (if applicable to the course)

(v) Results/ output

Note:

1. Students must bring their lab record along with them whenever they come for the lab.
2. Students must ensure that their lab record is regularly evaluated.

Lab Assessment Criteria

An estimated 10 lab classes are conducted in a semester for each lab course. These lab classes are assessed continuously. Each lab experiment is evaluated based on 5 assessment criteria as shown in following table. Assessed performance in each experiment is used to compute CO attainment as well as internal marks in the lab course.

Grading Criteria	Exemplary (4)	Competent (3)	Needs Improvement (2)	Poor (1)
AC1: Pre-Lab written work (this may be assessed through viva)	Complete procedure with underlined concept is properly written	Underlined concept is written but procedure is incomplete	Not able to write concept and procedure	Underlined concept is not clearly understood
AC2: Program Writing/ Modeling	Assigned problem is properly analyzed, correct solution designed, appropriate language constructs/ tools are applied, Program/solution written is readable	Assigned problem is properly analyzed, correct solution designed, appropriate language constructs/ tools are applied	Assigned problem is properly analyzed & correct solution designed	Assigned problem is properly analyzed
AC3: Identification of problem & Removal of errors	Able to identify errors and remove them	Able to identify errors and remove them with little bit of guidance	Is dependent totally on someone for identification of errors and their removal	Unable to understand the reason for errors even after they are explicitly pointed out
AC4:Execution & Demonstration	All variants of input /output are tested, Solution is well demonstrated and implemented concept is clearly explained	All variants of input /output are not tested, However, solution is well demonstrated and implemented concept is clearly explained	Only few variants of input /output are tested, Solution is well demonstrated but implemented concept is not clearly explained	Solution is not well demonstrated and implemented concept is not clearly explained
AC5:Lab Record Assessment	All assigned problems are well recorded with objective, design constructs and solution along with Performance analysis using all variants of input and output	More than 70 % of the assigned problems are well recorded with objective, design contracts and solution along with Performance analysis is done with all variants of input and output	Less than 70 % of the assigned problems are well recorded with objective, design contracts and solution along with Performance analysis is done with all variants of input and output	

LAB EXPERIMENTS

EXPERIMENT No. 1

AIM: Draw the flow chart and develop the computer program for the formation of the Y Bus of a generalized network.

SOFTWARE REQUIRED: MATLAB

THEORY:

Formation of Y Bus Matrix

Bus admittance matrix is often used in power system studies. In most of power system studies it is necessary to form Y-bus matrix of the system by considering certain power system parameters depending upon the type of analysis. For example, in load flow analysis it is necessary to form Y-bus matrix without taking into account the generator impedance and load impedance. In short circuit analysis the generator transient reactance and transformer impedance taken in account, in addition to line data. Y-bus may be computed by inspection method only if there is no natural coupling between the lines. Shunt admittance are added to the diagonal elements corresponding to the buses at which these are connected. The off-diagonal elements are unaffected. The equivalent circuit of tap changing transformer may be considered in forming[y-bus] matrix.

FORMULA USED

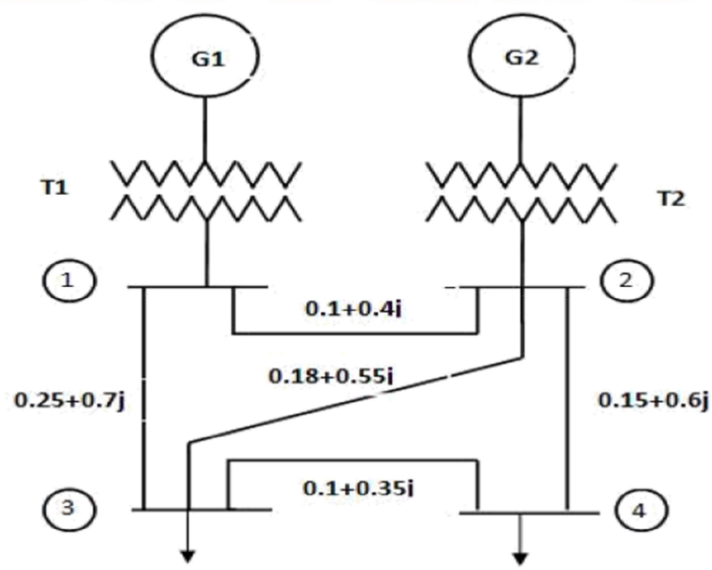
$Y_{ii}=\Sigma\, Y_{ij}$ for j=1 to n

$Y_{ij}= -Y_{ij}= -1/Z_{ij}$

$Y_{ij}=Y_{ji}$

Where, Y_{ii} = Sum of admittance connected to bus

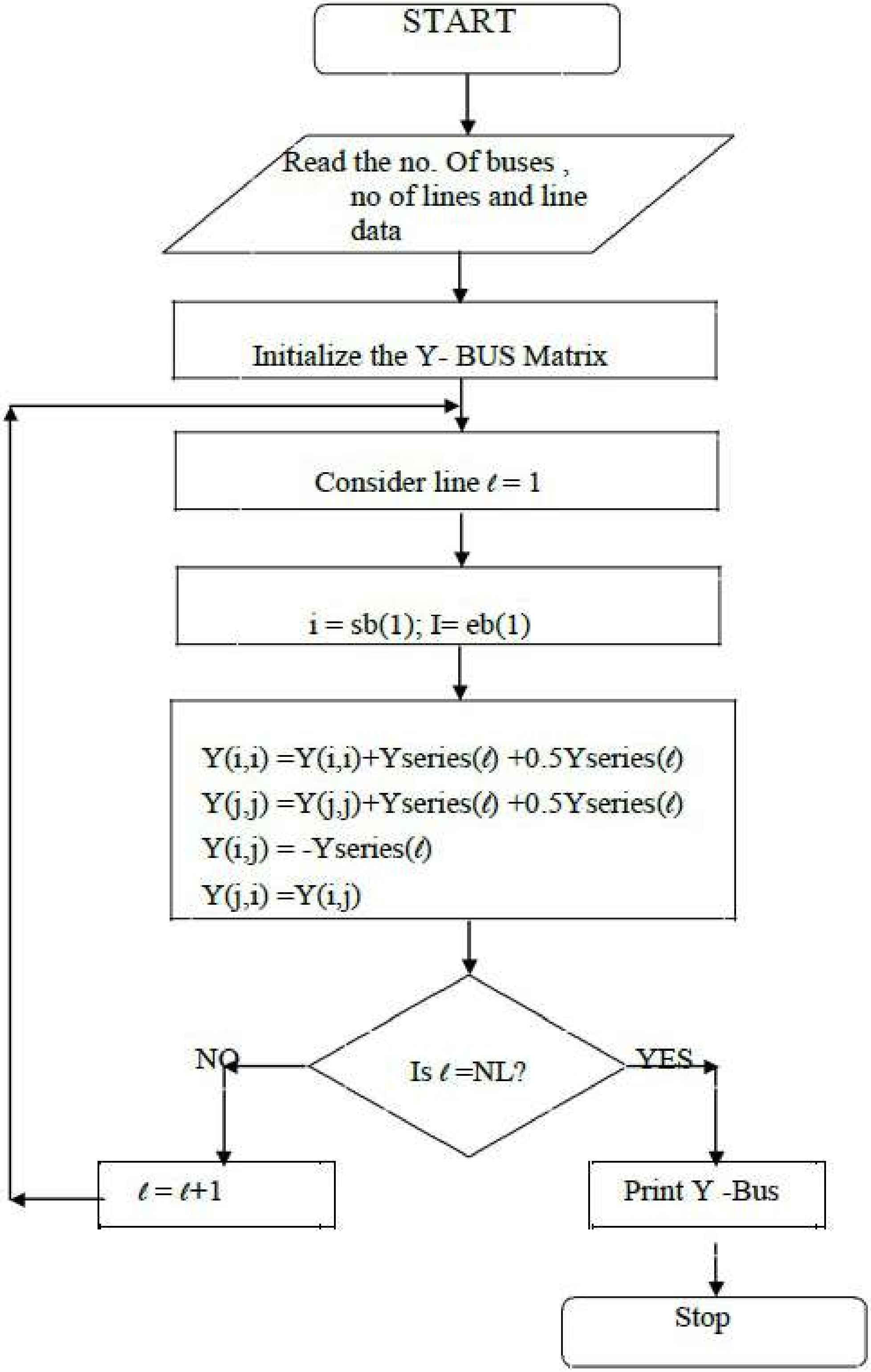
Y_{ij} = Negative admittance between buses



Exercise:

Line number	Starting Bus	Ending Bus	Series Line Impedance	Line Changing Admittance
1	1	2	0.1+0.4j	0.15j
2	2	4	0.15+0.6j	0.02j
3	2	3	0.18+0.55j	0.018j
4	3	4	0.1+0.35j	0.012j
5	3	1	0.25+0.7j	0.03j

Flowchart:


START
Read the no. Of buses , no of lines and line data
Initialize the Y- BUS Matrix
Consider line ℓ = 1
i = sb(1); I= eb(1)
Y(i,i) =Y(i,i)+Yseries(ℓ) +0.5Yseries(ℓ)
Y(j,j) =Y(j,j)+Yseries(ℓ) +0.5Yseries(ℓ)
Y(i,j) = -Yseries(ℓ)
Y(j,i) =Y(i,j)
Is ℓ =NL?
NO
YES
ℓ = ℓ+1
Print Y -Bus
Stop

```
linedata = [1    1    2    0.1     0.4j     0.15j;
            2    2    4    0.15    0.6j     0.02j;
            3    2    3    0.18    0.55j    0.018j;
            4    3    4    0.1     0.35j    0.012j;
            5    3    1    0.25     0.7j    0.03j]
```

Program:

```
linedata = input('line data in matrix form - Line no. S. Bus E. Bus r x b');
sb = linedata(:,2);
eb = linedata(:,3);
r = linedata(:,4);
x = linedata(:,5);
b = linedata(:,6);
z = r + x;
y = 1./z;
nbus = max(max(sb),max(eb));
nbranch = length(sb);
Y = zeros(nbus,nbus);

for k=1:nbranch
      Y(sb(k),eb(k)) = Y(sb(k),eb(k))-y(k);
      Y(eb(k), sb(k)) = Y(sb(k),eb(k)); end

for m =1:nbus
       for n =1:nbranch
              if sb(n) == m
                          Y(m,m) = Y(m,m) + y(n)+ b(n)/2;
              elseif eb(n) == m
                          Y(m,m) = Y(m,m) + y(n) + b(n)/2;
              end
       end
end

Y_bus=Y
```


RESULT:

Thus, the bus admittance matrix of the given power system using inspection method was found and verified by theoretical calculation.

EXPERIMENT No. 2

AIM: Draw the flow chart and develop the computer program for the formation of the Z Bus of a generalized network.

SOFTWARE REQUIRED: MATLAB

THEORY:

Formation of Z Bus Matrix

In bus impedance matrix the elements on the main diagonal are called driving point impedance and the off-diagonal elements are called the transfer impedance of the buses or nodes. The bus impedance matrix are very useful in fault analysis. The bus impedance matrix can be determined by two methods. In one method we can form the bus admittance matrix and then taking its inverse to get the bus impedance matrix. In another method the bus impedance matrix can be directly formed from the reactance diagram and this method requires the knowledge of the modifications of existing bus impedance matrix due to addition of new bus or addition of a new line (or impedance) between existing buses.

FORMULA USED

$Y_{ii}=\Sigma\ Y_{ij}$ for j=1 to n

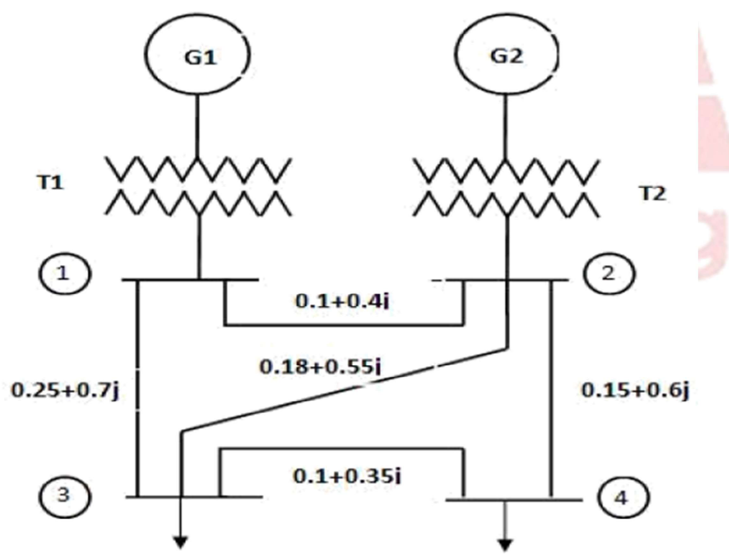
$Y_{ij}= -Y_{ij}= -1/Z_{ij}$

$Y_{ij}=Y_{ji}$

Where, Y_{ii} = Sum of admittance connected to bus

Y_{ij} = Negative admittance between buses

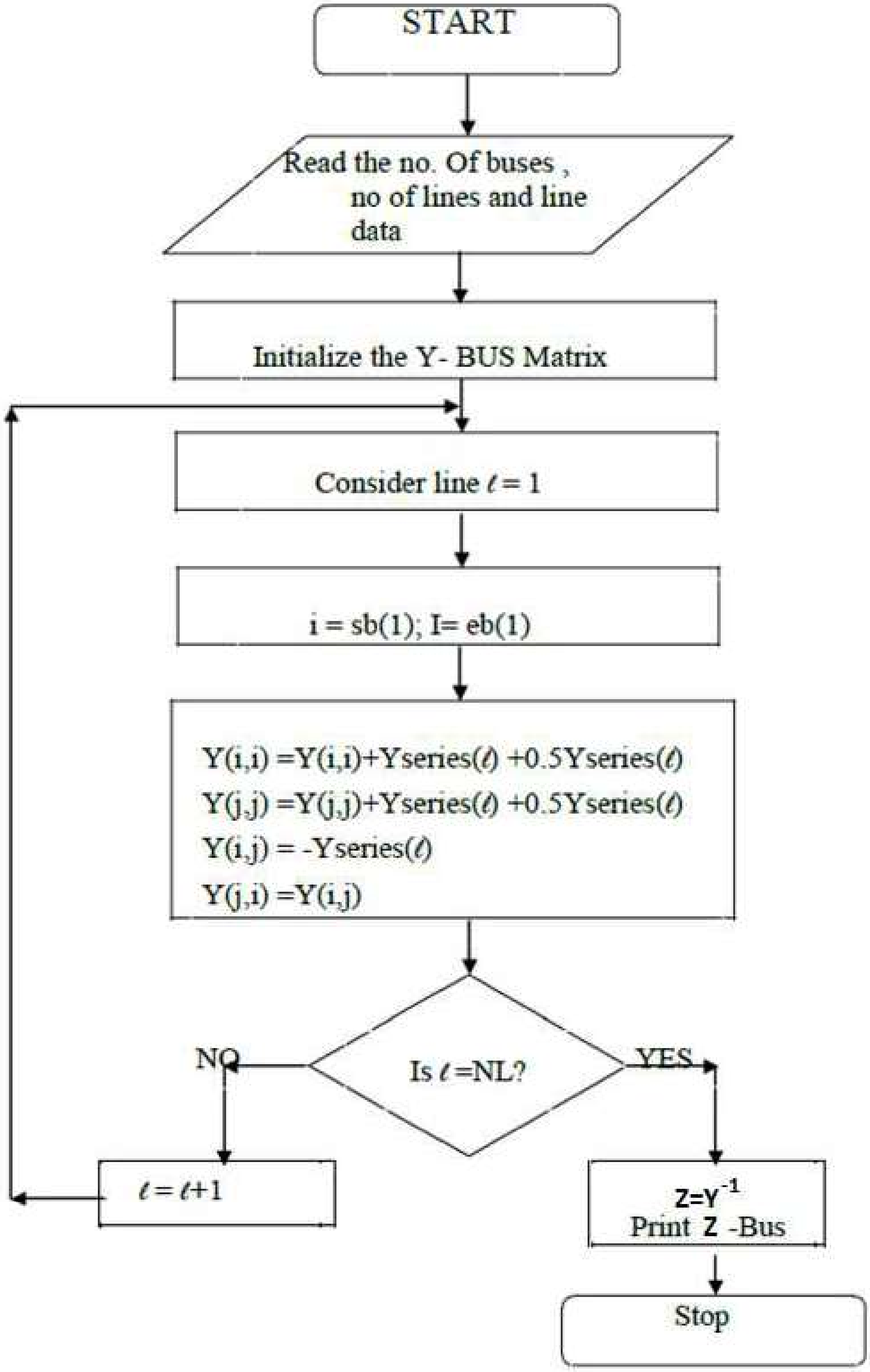
$Z_{bus}=[Y_{bus}]^{-1}$



Exercise:

Line number	Starting Bus	Ending Bus	Series Line Impedance	Line Changing Admittance
1	1	2	0.1+0.4j	0.15j
2	2	4	0.15+0.6j	0.02j
3	2	3	0.18+0.55j	0.018j
4	3	4	0.1+0.35j	0.012j
5	3	1	0.25+0.7j	0.03j

Flowchart:


START
Read the no. Of buses , no of lines and line data
Initialize the Y- BUS Matrix
Consider line ℓ = 1
i = sb(1); I= eb(1)
Y(i,i) =Y(i,i)+Yseries(ℓ) +0.5Yseries(ℓ)
Y(j,j) =Y(j,j)+Yseries(ℓ) +0.5Yseries(ℓ)
Y(i,j) = -Yseries(ℓ)
Y(j,i) =Y(i,j)
Is ℓ =NL?
NO
YES
ℓ = ℓ+1
Z=Y-1
Print Z -Bus
Stop

```
linedata = [1   1   2   0.1    0.4j    0.15j;
            2   2   4   0.15   0.6j    0.02j;
            3   2   3   0.18   0.55j   0.018j;
            4   3   4   0.1    0.35j   0.012j;
            5   3   1   0.25   0.7j    0.03j]
```

Program:

```
linedata = input('line data in matrix form - Line no. S. Bus E. Bus r x b');
sb = linedata(:,2);
eb = linedata(:,3);
r = linedata(:,4);
x = linedata(:,5);
b = linedata(:,6);
z = r + x;
y = 1./z;
nbus = max(max(sb),max(eb));
nbranch = length(sb);
Y = zeros(nbus,nbus);

for k=1:nbranch
    Y(sb(k),eb(k)) = Y(sb(k),eb(k))-y(k);
    Y(eb(k), sb(k)) = Y(sb(k),eb(k)); end

for m =1:nbus
    for n =1:nbranch
        if sb(n) == m
            Y(m,m) = Y(m,m) + y(n)+ b(n)/2;
        elseif eb(n) == m
            Y(m,m) = Y(m,m) + y(n) + b(n)/2;
        end
    end
end

Y_bus=Y
Z_bus=inv(Y)
```

RESULT:

Thus, the bus impedance matrix of the given power system using inspection method was found and verified by theoretical calculation.

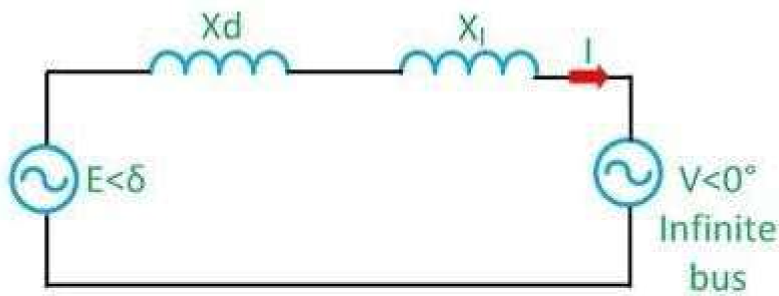
EXPERIMENT No. 3

AIM: To plot the power angle curve of Synchronous machines

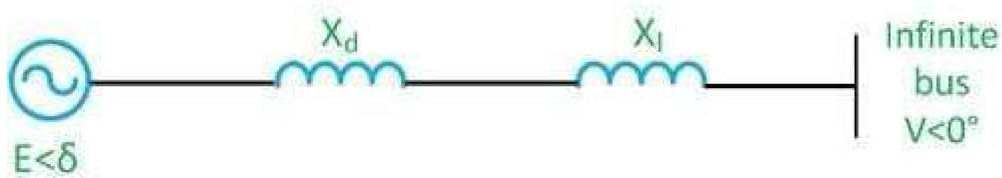
SOFTWARE REQUIRED: MATLAB

THEORY:

Consider a synchronous machine connected to an infinite bus through a transmission line of reactance Xl shown in a figure below. Let us assume that the resistance and capacitance are neglected.



Equivalent diagram of synchronous machine connected to an infinite bus through a transmission line of series reactance X_l is shown below:



Let,

V = V<0º – voltage of infinite bus

E = E<δ – voltage behind the direct axis synchronous reactance of the machine.

X_d = synchronous / transient resistance of the machine

The complex power delivered by the generator to the system is

$$S = VI$$

$$S = V\left[\frac{E < \delta - V < 0^0}{j(X_d + X_l)}\right]$$

Let, $X_d + X_l = X$

$$S = V\left[\frac{E < \delta}{X < 90^0} + j\frac{V}{X}\right]$$

$$S = \frac{EV}{X} < (90^0 - \delta) - j\frac{V^2}{X}$$

$$S = V\left[\frac{EV}{X}sin\delta + j\frac{EV}{X}cos\delta - j\frac{V^2}{X}\right]$$

$$P_e + jQ_e = \frac{EV}{X}sin\delta + j\left(\frac{EV}{X}cos\delta - \frac{V^2}{X}\right)$$

Active power transferred to the system

$$P_e = \frac{EV}{X}sin\delta$$

The reactive power transferred to the system

$$Q_e = \frac{EV}{X}cos\delta - \frac{V^2}{X}$$

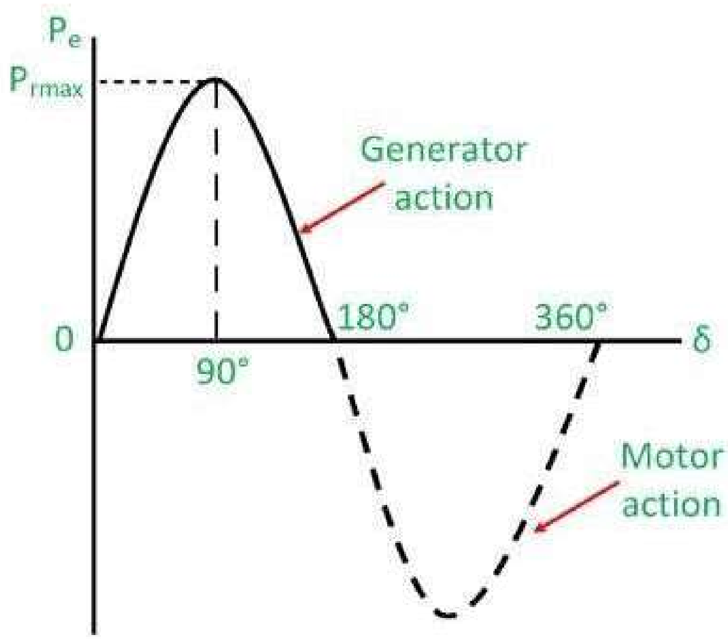
The maximum steady-state power transfers occur when δ = 0

$$P_e = \frac{EV}{X}sin90^0$$

$$(\sin 90^0 = 1)$$

$$P = \frac{EV}{X}$$

$$P_e = P_{emax}sin\delta$$



The graphical representation of P_e and the load angle δ is called the power angle curve. It is widely used in power system stability studies. The power angle curve is shown below. Maximum power is transferred when δ = 90º. As the value of load angle δ is above 90, Pe decreases and becomes zero at δ = 180º. Above 180º, Pe becomes negative, which show that the direction of power flow is reversed, and the power is supplied from infinite bus to the generator. The value of Pe is often called pull out power. It is also called the steady-state limit.

The total reactance between two voltage sources E and X is called the transfer reactance. The maximum power limit is inversely proportion to the transfer reactance.

Program:

```
V=1;
Xd =0.3;
Xt =0.2; Xq=0.1;
dd = acos (25*pi/180);
 Ed = 0.85
 Pmax = Ed*V/(Xd+Xd)
 delta = 0:.01:pi;
 P = Pmax*sin(delta);
 plot(delta*180/pi, P)
```


RESULT:

Power angle curve of Synchronous machines has been plotted.

EXPERIMENT No. 4

AIM: To perform load flow analysis using Gauss Seidel method.

SOFTWARE REQUIRED: MATLAB

THEORY:

To understand, in particular, the mathematical formulation of power flow model in complex form and a simple method of solving power flow problems of small sized system using Gauss-Seidel iterative algorithm. The GAUSS – SEIDEL method is an iterative algorithm for solving a set of non-linear load flow equations. The non-linear load flow equation is given by

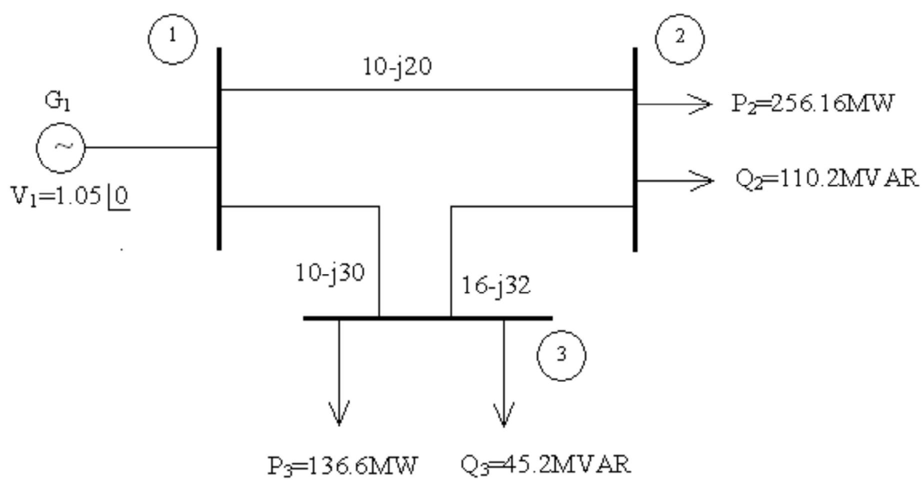
$$V_p^{k+1} = \frac{1}{Y_{pp}}\left[\frac{P_p - j\,Q_p}{(V_p^k)^*} - \sum_{q=1}^{p-1} Y_{pq} V_q^{k+1} - \sum_{q=p+1}^{n} V_q^{k}\right]$$

The reactive power of bus-p is given by

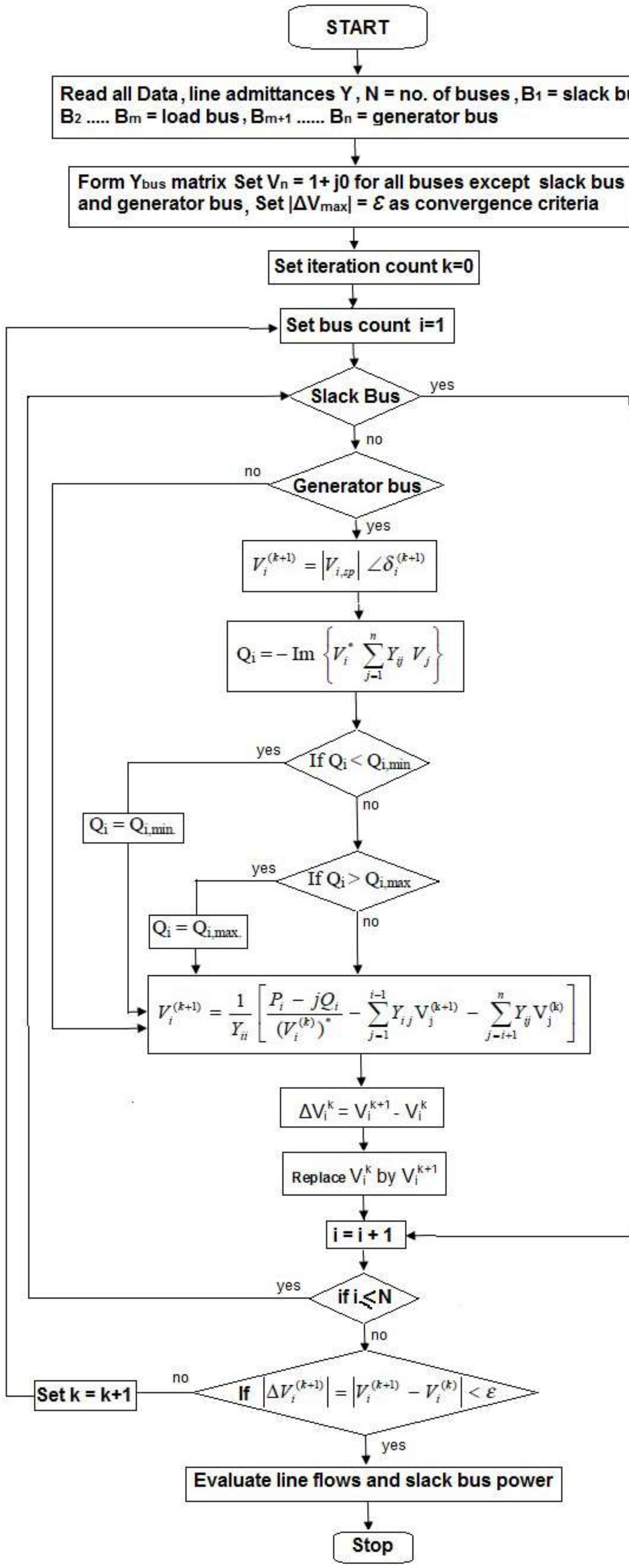
$$Q_P^{k+1} = (-1) \times \mathrm{Im}\left[(V_p^k)^* \left[\sum_{q=1}^{p-1} Y_{pq} V_q^{k+1} + \sum_{q=p}^{n} Y_{pq} V_q^{k}\right]\right]$$

Exercise:

The figure shows the single line diagram of a simple 3 buses power system with generator at bus 1. The magnitude at bus 1 is adjusted to 1.05 pu. The scheduled loads at buses 2 and 3 are marked on the diagram. Line impedance are marked in pu. The base value is 100 MVA. The line charging susceptances are neglected. Determine the phasor values of the voltage at the load buses 2 and 3. Find the slack bus real and reactive power. Verify the result using MATLAB.



Flowchart:


START
Read all Data, line admittances Y, N = no. of buses, B1 = slack bus
B2 ..... Bm = load bus, Bm+1 ...... Bn = generator bus
Form Ybus matrix Set Vn = 1+ j0 for all buses except slack bus and generator bus, Set |ΔVmax| = ε as convergence criteria
Set iteration count k=0
Set bus count i=1
Slack Bus
yes
no
Generator bus
no
yes
If Qi < Qi,min
yes
no
Qi = Qi,min
If Qi > Qi,max
yes
no
Qi = Qi,max
ΔVi^k = Vi^k+1 - Vi^k
Replace Vi^k by Vi^k+1
i = i + 1
if i ≤ N
yes
no
Set k = k+1
no
yes
Evaluate line flows and slack bus power
Stop

Program:

```
clc;
data=[1 1 2 10-j*20
2 1 3 10-j*30
3 2 3 16-j*32];
elements=max(data(:,1));
bus=max(max(data(:,2)),max(data(:,3)));
y=zeros(bus,bus);

for p=1:bus,
    for q=1:elements,
        if(data(q,2)==p|data(q,3)==p)
            y(p,p)=y(p,p)+data(q,4);
        end
    end
end

for p=1:bus,
        for q=1:bus,
            if (p~=q)
                for r=1:elements
                    if((data(r,2)==p&data(r,3)==q)|(data(r,2)==q&data(r,3)==p))
                        y(p,q)=-(data(r,4));
                    end
                end
            end
        end
end

a1=input('enter p2 in MW: ');
b1=input('enter q2 in MVAR: ');
a2=input('enter p3 in MW: ');
b2=input('enter q3 in MVAR: ');
pu=input('enter the base value in MVA: ');
p2=(a1/pu);
q2=(b1/pu);
p3=(a2/pu);
q3=(b2/pu);
dx1=1+j*0;
dx2=1+j*0;
v1=1.05+j*0;
v2=1+j*0;
v3=1+j*0;
iter=0;
```

```
disp('iter v2 v3');
while(abs(dx1)&abs(dx2)>=0.00001)&iter<10;
iter=iter+1;
v2=(((p2-j*q2)/conj(v2))+(-y(1,2)*v1)+(-y(2,3)*v3))/y(2,2);
v3=(((p3-j*q3)/conj(v3))+(-y(1,3)*v1)+(-y(2,3)*g1))/y(3,3);
s1=v1*(v1*(y(1,1)+ v2*y(1,2)+ v3*y(1,3)));
fprintf ('%g',iter),disp([v2,v3]);
end
s1
```

RESULT:

Thus, load flow analysis using Gauss Seidel method was performed and verified by theoretical calculation.

EXPERIMENT No. 5

AIM: To perform load flow analysis using Gauss Seidel method using acceleration factor.

SOFTWARE REQUIRED: MATLAB

THEORY:

The GAUSS – SEIDEL method is an iterative algorithm for solving a set of non-linear load flow equations. The non-linear load flow equation is given by

$$V_p^{k+1} = \frac{1}{Y_{pp}}\left[\frac{P_p - j\,Q_p}{(V_p^k)^*} - \sum_{q=1}^{p-1} Y_{pq} V_q^{k+1} - \sum_{q=p+1}^{n} V_q^k\right]$$

The reactive power of bus-p is given by

$$Q_P^{k+1} = (-1) \times \mathrm{Im}\left[(V_p^k)^* \left[\sum_{q=1}^{p-1} Y_{pq} V_q^{k+1} + \sum_{q=p}^{n} Y_{pq} V_q^k\right]\right]$$

Acceleration Factors in Gauss-Seidel Method

In the Gauss-Seidel method, a large number of the iteration is required to arrive at the specified convergence. The rate of convergence can be increased by the use of the acceleration factor to the solution obtained after each iteration. The Acceleration factor is a multiplier that enhances correction between the values of voltage in two successive iterations.

Let us consider the acceleration Factor for the p^{th} bus.

- $V_i^{(k)}$ is the value of the voltage at the k^{th} iteration.
- $V_i^{(k+1)}$ is the value of the voltage at the $(k+1)^{th}$ iteration.
- $V_{i\alpha}^{(k+1)}$ is the accelerated new value of the voltage at the $(k+1)^{th}$ iteration.
- k is the iteration count
- α is the accelerating factor

Then,

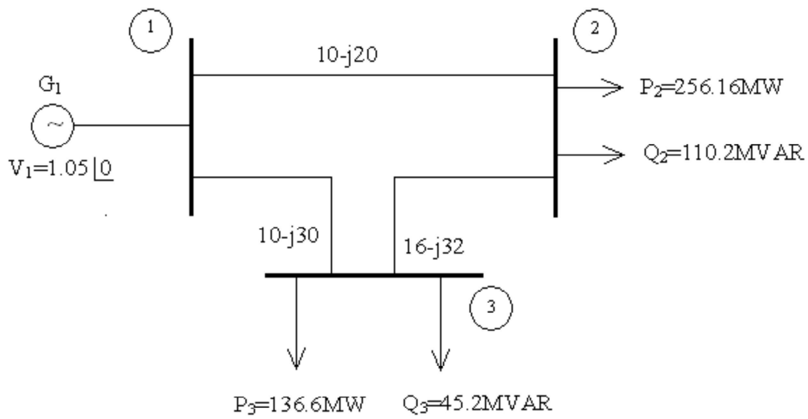
$$V_{i\,(\text{accelerated})}^{(k+1)} = V_i^{(k)} + \alpha\left[V_i^{(k+1)} - V_i^{(k)}\right]$$

Thus, after calculating $V_i^{(k+1)}$ at $(k+1)^{th}$ iteration, we calculate the value of new estimated bus voltage $V_{i\alpha}^{(k+1)}$ and this new value replaces the previously calculated value.

The choice of a specific value of the acceleration factor depends upon the system parameters. The optimum value of α usually lies in the range of 1.2 to 1.6 for most of the systems

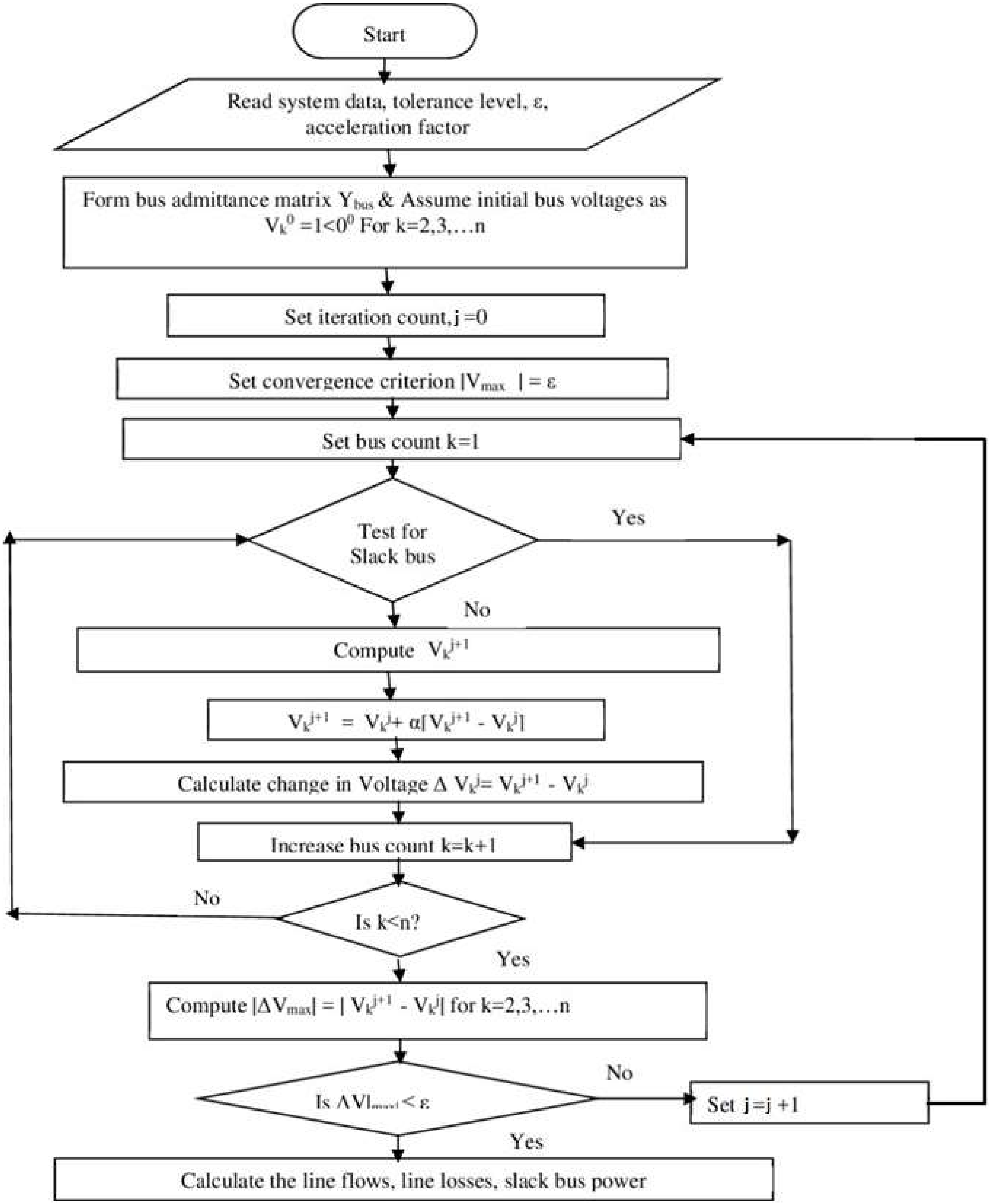
Exercise:

The figure shows the single line diagram of a simple 3 buses power system with generator at bus 1. The magnitude at bus 1 is adjusted to 1.05 pu. The scheduled loads at buses 2 and 3 are marked on the diagram. Line impedance are marked in pu. The base value is 100 MVA. The line charging susceptance's are neglected. Determine the phasor values of the voltage at the load buses 2 and 3. Find the slack bus real and reactive power. Verify the result using MATLAB. The acceleration factor is 1.2.



Theoretical Calculations (till 3 Iterations):

Flowchart:


Start
Read system data, tolerance level, ε, acceleration factor
Form bus admittance matrix Y_{bus} & Assume initial bus voltages as $V_k^0 = 1\angle 0^0$ For k=2,3,…n
Set iteration count, j =0
Set convergence criterion |V_{max} | = ε
Set bus count k=1
Test for Slack bus
Yes
No
Compute V_k^{j+1}
$V_k^{j+1} = V_k^j + \alpha[V_k^{j+1} - V_k^j]$
Calculate change in Voltage $\Delta V_k^j = V_k^{j+1} - V_k^j$
Increase bus count k=k+1
No
Is k<n?
Yes
Compute $|\Delta V_{max}| = |V_k^{j+1} - V_k^j|$ for k=2,3,…n
No
Is $|\Delta V|_{max} < \varepsilon$
Set j=j +1
Yes
Calculate the line flows, line losses, slack bus power

Program:

```
clc;
data=[1 1 2 10-j*20
2 1 3 10-j*30
3 2 3 16-j*32];
elements=max(data(:,1));
bus=max(max(data(:,2)),max(data(:,3)));
y=zeros(bus,bus);

for p=1:bus,
    for q=1:elements,
        if(data(q,2)==p|data(q,3)==p)
            y(p,p)=y(p,p)+data(q,4);
        end
    end
end

for p=1:bus,
        for q=1:bus,
            if (p~=q)
                for r=1:elements
                    if((data(r,2)==p&data(r,3)==q)|(data(r,2)==q&data(r,3)==p))
                        y(p,q)=-(data(r,4));
                    end
                end
            end
        end
end

a1=input('enter p2 in MW: ');
b1=input('enter q2 in MVAR: ');
a2=input('enter p3 in MW: ');
b2=input('enter q3 in MVAR: ');
pu=input('enter the base value in MVA: ');
alpha=input('acceleration factor: ');
p2=(a1/pu);
q2=(b1/pu);
p3=(a2/pu);
q3=(b2/pu);
dx1=1+j*0;
dx2=1+j*0;
v1=1.05+j*0;
v2=1+j*0;
v3=1+j*0;
iter=0;
```

```
disp('iter v2 v3');
while(abs(dx1)&abs(dx2)>=0.00001)&iter<10;
iter=iter+1;
g2=(((p2-j*q2)/conj(v2))+(-y(1,2)*v1)+(-y(2,3)*v3))/y(2,2);
g3=(((p3-j*q3)/conj(v3))+(-y(1,3)*v1)+(-y(2,3)*g2))/y(3,3);
dx2=g2-v2;
dx3=g3-v3;
v2=v2+alpha*dx2;
v3=v3+alpha*dx3;
s1=v1*(v1*(y(1,1)+ v2*y(1,2)+ v3*y(1,3)));
fprintf ('%g',iter),disp([v2,v3]);
end
s1
```

RESULT:

Thus, load flow analysis using Gauss Seidel method with acceleration factor was performed and verified by theoretical calculation.

EXPERIMENT No. 6

AIM: To perform load flow analysis using Newton-Raphson method.

SOFTWARE REQUIRED: MATLAB

THEORY:

Load flow study in power system parlance is the steady state solution of the power system network. The main information obtained from this study comprises the magnitudes and phase angles of load bus voltages, reactive powers at generator buses, real and reactive power flow on transmission lines, other variables being specified. This information is essential for the continuous monitoring of current state of the system and for analyzing the effectiveness of alternative plans for future system expansion to meet increased load demand. Newton-Raphson method is an iterative method that approximates the set of nonlinear simultaneous equations to a set of linear simultaneous equations using Taylor's series expansion and the terms are limited to first approximation. The rate of convergence is fast as compared to the FDLF program and also it is suitable for large size system. So, we go for N-R method. The non-linear equations governing the power system network are,

$$I_p = \sum_{p \in q} Y_{pq} V_p \quad for\ all\ p$$

where I_p is the current injected into bus p.
The complex power in p^{th} bus is given by,

$$S_p = V_p I_p^*$$

$$= V_p \left[\sum_{q=1}^{n} Y_{pq} V_q \right]^* \qquad = V_p \left[\sum_{q=1}^{n} Y_{pq}^* V_q^* \right]; \quad p = 2, ...n. \qquad (1)$$

$$Let,\ V_p = |V_p| e^{j\delta p}$$

$$V_q = |V_q| e^{j\delta q}$$

$$\delta_{pq} = \delta_p - \delta_q \quad \text{and}$$

$$Y_{pq} = |Y_{pq}| e^{j\theta pq}$$

In polar co-ordinates, the power on p^{th} bus is given as,

$$S_p = P_p + jQ_p = \sum_{q=1}^{n} |V_p||V_q|\ e^{j\delta\ pq}\ |Y_{pq}|\ e^{j\theta pq} \qquad (2)$$

Separating the Real and Imaginary parts we get,

$$P_p = \sum_{q=1}^{n} |V_p||V_q||Y_{pq}|\cos(\delta_p + \theta_{pq} - \delta_q)$$

$$Q_p = \sum_{q=1}^{n} |V_p||V_q||Y_{pq}|\sin(\delta_p + \theta_{pq} - \delta_q) \qquad (3)$$

The Newton –Raphson method requires that a set of linear equations be formed expressing the relationship between the changes in real and reactive powers and the components of the bus voltages as follows:

$$\begin{bmatrix} \Delta P_2^{(r)} \\ \vdots \\ \vdots \\ \vdots \\ \Delta P_n^{(r)} \\ --- \\ \Delta Q_2^{(r)} \\ \vdots \\ \vdots \\ \vdots \\ \Delta Q_n^{(r)} \end{bmatrix} = \begin{bmatrix} \frac{\partial P_2}{\partial \delta_2}^{(r)} & \cdots & \frac{\partial P_2}{\partial \delta_n}^{(r)} & | & \frac{\partial P_2}{\partial |V_2|}^{(r)} & \cdots & \frac{\partial P_2}{\partial |V_n|}^{(r)} \\ \vdots & \ddots & \vdots & | & \vdots & \ddots & \vdots \\ \frac{\partial P_n}{\partial \delta_2}^{(r)} & \cdots & \frac{\partial P_n}{\partial \delta_n}^{(r)} & | & \frac{\partial P_2}{\partial |V_2|}^{(r)} & \cdots & \frac{\partial P_n}{\partial |V_n|}^{(r)} \\ ------ & & & | & ------ & & \\ \frac{\partial Q_2}{\partial \delta_2}^{(r)} & \cdots & \frac{\partial Q_2}{\partial \delta_n}^{(r)} & | & \frac{\partial Q_2}{\partial |V_2|}^{(r)} & \cdots & \frac{\partial Q_2}{\partial |V_n|}^{(r)} \\ \vdots & \ddots & \vdots & | & \vdots & \ddots & \vdots \\ \frac{\partial Q_n}{\partial \delta_2}^{(r)} & \cdots & \frac{\partial Q_2}{\partial \delta_n}^{(r)} & | & \frac{\partial Q_n}{\partial |V_2|}^{(r)} & \cdots & \frac{\partial Q_n}{\partial |V_n|}^{(r)} \end{bmatrix} \begin{bmatrix} \Delta \delta_2^{(r)} \\ \vdots \\ \vdots \\ \vdots \\ \Delta \delta_n^{(r)} \\ ---- \\ \Delta |V|_2^{(r)} \\ \vdots \\ \vdots \\ \vdots \\ \Delta |V_n^{(r)}| \end{bmatrix} \qquad (4)$$

where, the coefficient matrix is known as Jacobian matrix.

In the above equation, bus 1 is assumed to be the slack bus. The Jacobian matrix gives the linearized relationship between small changes in voltage angle $\Delta\delta_i^{(r)}$ and voltage magnitude $\Delta|V_i^{(r)}|$ with the small changes in real and reactive power $\Delta P_i^{(r)}$ and $\Delta Q_i^{(r)}$. Elements of the Jacobian matrix are the partial derivatives of (2) and (3) evaluated at $\Delta\delta_i^{(r)}$ and $\Delta|V_i^{(r)}|$.

The above relationship can be written in a compact form as,

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_{11} & J_{12} \\ J_{21} & J_{22} \end{bmatrix} \begin{bmatrix} \Delta \delta \\ \Delta |V| \end{bmatrix} \qquad (5)$$

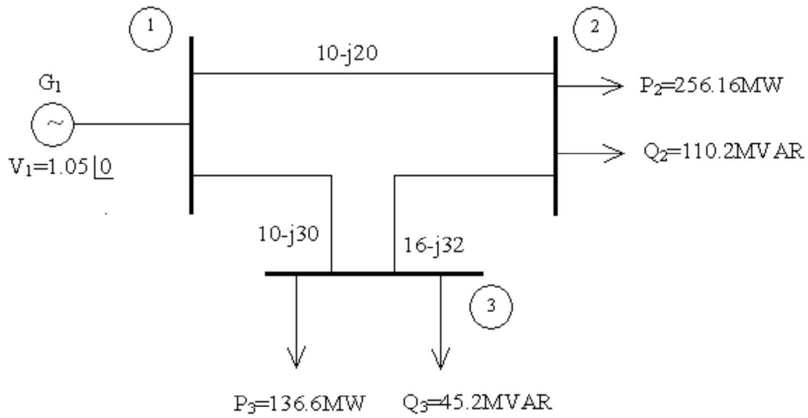
on when solved for Δδ, ΔV gives the correction to be applied to |V| and δ, i.e.

$$|V|^{(r+1)} = |V|^{(r)} + \Delta|V|^{(r)}$$

$$\delta^{(r+1)} = \delta^{(r)} + \Delta\delta^{(r)}$$

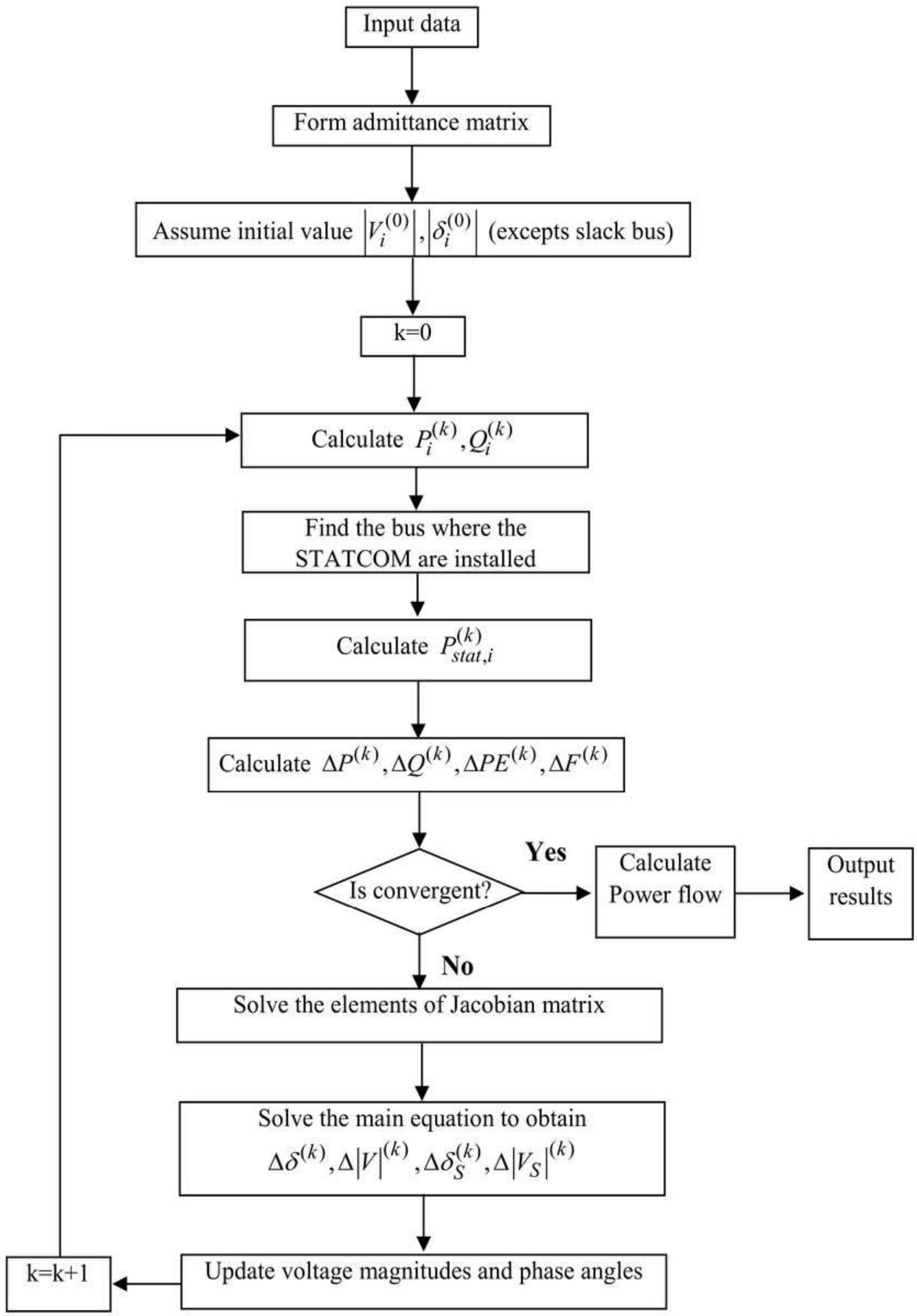
Exercise:

The figure shows the single line diagram of a simple 3 buses power system with generator at bus 1. The magnitude at bus 1 is adjusted to 1.05 pu. The scheduled loads at buses 2 and 3 are marked on the diagram. Line impedance are marked in pu. The base value is 100 MVA. The line charging susceptance's are neglected. Determine the phasor values of the voltage at the load buses 2 and 3. Find the slack bus real and reactive power. Verify the result using MATLAB.



Theoretical Calculations (till 3 Iterations):

Flowchart:


Input data
Form admittance matrix
Assume initial value $|V_i^{(0)}|, |\delta_i^{(0)}|$ (excepts slack bus)
k=0
Calculate $P_i^{(k)}, Q_i^{(k)}$
Find the bus where the STATCOM are installed
Calculate $P_{stat,i}^{(k)}$
Calculate $\Delta P^{(k)}, \Delta Q^{(k)}, \Delta PE^{(k)}, \Delta F^{(k)}$
Is convergent?
Yes
Calculate Power flow
Output results
No
Solve the elements of Jacobian matrix
Solve the main equation to obtain $\Delta\delta^{(k)}, \Delta|V|^{(k)}, \Delta\delta_S^{(k)}, \Delta|V_S|^{(k)}$
Update voltage magnitudes and phase angles
k=k+1

Program:

```
clear all;
clc;
n=input('Enter the number of buses');
for i=1:n
    for j=1:n
        fprintf('Enter the Admittance Value Between %d & %d',i,j)
        y(i,j)=input('');
    end
end

yb(n,n)=0;
for i=1:n
    for j=1:n
        if i==j
          for k=1:n
              yb(i,j)=yb(i,j)+y(i,k);
          end
        else
           yb(i,j)=-y(i,j);
        end
    end
end

mag(1)=1.05;
for i=2:n
    mag(i)=1;
end

th(1:n)=0;
for i=1:n
    acp(i)=input('enter real power value:');
end
for i=1:n
    acq(i)=input('enter reactive power value:');
end
my=abs(yb);
an=angle(yb);
g=real(yb);
b=imag(yb);
yb mag th acp acq
Pp(n)=0;
Qq(n)=0;
for i=2:n
    for j=1:n
        Pp(i)=Pp(i)+mag(i)*my(i,j)*mag(j)*cos(an(i,j)-th(i)+th(j));
        Qq(i)=Qq(i)-mag(i)*my(i,j)*mag(j)*sin(an(i,j)-th(i)+th(j));
```

```
        end
    end

    Pp Qq
    for i=2:n
        for j=2:n
            if i~=j
                j1(i,j)=mag(i)*mag(j)*(g(i,j)*sin(th(i)-th(j))-b(i,j)*cos(th(i)-th(j)));
                j3(i,j)=-mag(i)*mag(j)*(g(i,j)*cos(th(i)-th(j))+b(i,j)*sin(th(i)-th(j)));
                j2(i,j)=-j3(i,j);
                j4(i,j)=j1(i,j);
            else
                j1(i,j)=-Qq(i)-b(i,j)*(mag(i)^2);
                j2(i,j)=Pp(i)+g(i,j)*(mag(i)^2);
                j3(i,j)=Pp(i)-g(i,j)*(mag(i)^2);
                j4(i,j)=Qq(i)-b(i,j)*(mag(i)^2);
            end
        end
    end

    ja1(1:n-1,1:n-1)=j1(2:n,2:n);
    ja2(1:n-1,1:n-1)=j2(2:n,2:n);
    ja3(1:n-1,1:n-1)=j3(2:n,2:n);
    ja4(1:n-1,1:n-1)=j4(2:n,2:n);
    jacob=[ja1 ja2;ja3 ja4]
    delp(1:n-1)=acp(2:n)-Pp(2:n);
    delq(1:n-1)=acq(2)-Qq(2);
    Char=inv(jacob)*[delp delq]';
    Chth(2:n)=Char(1:n-1);
    Chmag(2:n)=Char(n:2*n-2);
    mag=mag+Chmag;
    th=th+Chth; fprintf('the voltage values for buses');
    mag fprintf('The angle values for buses');
    th
```

RESULT:

Thus, load flow analysis using Newton Raphson method was performed and verified by theoretical calculation.

EXPERIMENT No. 7

AIM: To study comparison of different load flow methods.

THEORY:

Power flow, or load flow, is widely used in power system operation and planning. The power flow model of a power system is built using the relevant network, load, and generation data. Power engineers are required to plan, design, and maintain the power system to operate reliably and within safe limits. Numerous power flow studies are required to ensure that power is adequately delivered at all times despite normal load fluctuations and undesirable events such as contingencies. Daily fluctuations in the power system operations cause power flow mismatches at busbars. As a result, the busbars voltage magnitude and angle adjust instantly until an equilibrium is reached between the load and the transmitted power. This new equilibrium point can also be obtained from simulation using power flow methods.

The Outputs of the power flow model include voltages at different buses, line flows in the network, and system losses. These outputs are obtained by solving nodal power balance equations. Since these equations are nonlinear, the following iterative techniques are commonly used to solve this problem.

Power flow studies consist in determining the voltage magnitude and angle at each busbar until there is an equilibrium in active and reactive power at which point power mismatches are insignificant. Calculating the final values of the busbars voltage is not always straightforward especially for heavily loaded and complex systems.

The starting point of solving power flow problems is to identify the known and unknown variables in the system. Based on these variables, buses are classified into three types: slack, generation, and load buses as shown in the following table:

Types of Bus	Variables			
	Real power, P	Reactive Power, Q	Voltage Magnitude |V|	Voltage Angle
Slack Bus	Unknown	Unknown	Known	known
Generator Bus (PV)	known	Unknown	Known	Unknown
Load Bus(PQ)	Known	Known	Unknown	Unknown

Newton-Raphson Power Flow Method:

Newton Raphson method is a numerical technique for solving non-linear equations. It is often classified as iterative root finding scheme. The reason it is called root finding is, it is geared towards solving equations like f(x)=0 (or f(x)=0). The solution to such an equation, call it x* (or x*), is clearly a root of the function f(x) (or f(x)). The first order Newton-Raphson (NR) method is considered as the state of the art for power flow calculations. This method has been widely used in industry applications.

It is iterative because it requires a series of successive approximations to the solutions. The procedure is generally as follows. First, guess a solution. Unless we are very fortunate, the guess will be, of course, wrong. So, we determine an update to the "old" solution that moves to a "new" solution with the intention that the "new" solution is closer to the correct solution than was the "old" solution.

A key aspect to this type of procedure is the way we obtain the update. If we can guarantee that the update is always improving the solution, such that the "new" solution is in fact always closer to the correct solution than the "old" solution, then such a procedure can be guaranteed to work if only we are willing to compute enough updates, i.e., if only we are willing to iterate enough times.

Advantages

- Fast convergence if the initial guess is close to the solution
- Easy to convert to multiple dimensions, can be used to polish a root found by other methods
- Large region of convergence
- Time required for per iteration in Newton Raphson method is larger than Gauss Seidel method but the overall time for iterative process is less because of a smaller number of iterations for convergence.

Disadvantages

- Each iteration takes much longer.
- More complicated to code, particularly when implementing sparse matrix algorithms.

Gauss-Seidel Power Flow Method:

In Gauss Seidel method, the computations appear to be serial. Further, each component of new iteration depends upon all previously computed components. Updates cannot be done simultaneously. In addition to this, new iteration depends on the order in which equations are examined. If this ordering is changed, the components of new iteration (and not just their order) also change. These limitations persuade engineers and researchers to go for Newton Raphson method.

Advantages

- Gauss Seidel method is easy to program.
- Each iteration is relatively fast (computational order is proportional to number of branches and number of buses in the system).
- Acquires less memory space than NR method.

Disadvantages

- Tends to converge relatively slowly, although this can be improved with acceleration.
- Has tendency to miss solutions, particularly on large systems.
- Tends to diverge on cases with negative branch reactance (common with compensated lines).
- Need to program using complex numbers.

Fast Decoupled Power Flow Method:

In high voltage transmission systems, the voltage angles between adjacent buses are relatively small. In addition, X/R ratio is high. These two properties result in a strong coupling between real power and voltage angle and between reactive power and voltage magnitude. In contrary, the coupling between real power and voltage magnitude, as well as reactive power and voltage angle, is weak. Considering adjacent buses, real power flows from the bus with a higher voltage angle to the bus with a lower voltage angle. Similarly, reactive power flows from the bus with a higher voltage magnitude to the bus with a lower voltage magnitude.

Fast-decoupled power flow technique includes two steps:

- decoupling real and reactive power calculations.
- obtaining of the Jacobian matrix elements directly from the Y-bus.

As the size of matrix becomes very large for a big bus system so for faster and less memory allocation, we prefer decoupled load flow where we take P independent of V and Q Independent of δ, and thus those Jacobian elements are taken as zero.

Advantages

- The convergence is faster than other methods.
- The memory requirement is very less than the other methods like as Newton Raphson method, Gauss-Seidel method, etc.
- This method is less complicated than other methods, therefore it is more easy method to calculate the power flow.
- The number of iteration and size of equation used is less.

Disadvantages

- Take more iterations though time needs for each iteration is less than NR method
- The accuracy of the fast-decoupled load flow is mainly dependent on three factors:
- System size and structure;
- Convergence tolerances; and
- Level of system Loading

Particularly in large systems with heavy loading the relatively small error in the state variables may cause larger errors in real and reactive power flow, but these errors are small in comparison with the line ratings. The accuracy of the solution is a controllable parameter and it can be improved by using a smaller convergence tolerance.

Comparison of the Load Flow Methods:

Load Flow Method	Speed	Accuracy	Solution Robustness
Gauss-Seidel	Very Slow	Approximate	Robust
Newton Raphson	Slow	Accurate	Robust
Fast Decoupled	Fast	Accurate	Less Robust

Industry Application of Power Flow Methods:
Commercial power systems are complicated. It is not possible to analyze power flow through hand calculations. Physical models of power systems were analyzed through network analyzers in laboratories between 1929 and early 1960. Afterwards, invention of digital computers replaced the analog methods with numerical methods. Initially, linear methods were proposed to analyze power flow analysis. Among these, Cramer's method, Gauss elimination and LU factorization are notable. However, these methods cannot handle complex, nonlinear and big power systems. Therefore, iterative techniques i.e., Gauss Seidel method, Newton Raphson method are developed to solve complex power systems.

There are a number of very high-quality commercial power flow programs on the market today, some of which include those developed by the Electric Power Research Institute (EPRI), Power Technologies Incorporated (PTI), Operation Technology, Inc., and EDSA. Most of today's commercial software packages are menu-driven from a Windows environment. Few of the commonly used software are discussed briefly as below:

- **ETAP software** is used for simulation because of its extension of real time intelligent power management systems for monitoring, controlling, automating and optimizing power systems. It is a high impact software used for power flow analysis is generation, transmission and distribution systems of electric power engineering.
- **PowerWorld Simulator** is a software package designed to simulate high voltage power systems up to 100,000 buses. PowerWorld uses the Newton-Raphson iteration method, which provides an efficient and accurate solution. It also computes the Jacobian (Admittance Matrix), so that the one-line diagram characteristics can be ported to other analysis programs.
- **CYME** is a software which main objective is to analyze the steady-state performance of the power system under various operating conditions. It is the basic analysis tool for the planning, design and operation of any electrical power systems, be they distribution, industrial or transmission networks. The Power Flow module utilizes state-of-the-art sparse matrix/vector methods and multiple solution algorithms.

RESULT: Comparison of different load flow methods has been studied.

EXPERIMENT No. 8

AIM: To perform economic dispatch in power systems

THEORY:

Mathematical Model for Economic Dispatch of Thermal Units

Without Transmission Loss:

Statement of Economic Dispatch Problem

In a power system, with negligible transmission loss and with N number of spinning thermal generating units the total system load PD at a particular interval can be met by different sets of generation schedules

$\{PG_1^{(k)}, PG_2^{(k)}, \ldots\ldots PG_N^{(K)}\}$; $k = 1,2,\ldots\ldots NS$

Out of these NS set of generation schedules, the system operator has to choose the set of schedules, which minimize the system operating cost, which is essentially the sum of the production cost of all the generating units. This economic dispatch problem is mathematically stated as an optimization problem.

Given: The number of available generating units N, their production cost functions, their operating limits and the system load PD,

To determine: The set of generation schedules,

$$PG_i; \quad i = 1,2\ldots\ldots N \qquad \textbf{(1)}$$

Which minimize the total production cost,

$$\text{Min} \; ; F_T = \sum_{i=1}^{N} F_i (PG_i) \qquad \textbf{(2)}$$

and satisfies the power balance constraint

$$\phi = \sum_{i=1}^{N} PG_i - PD = 0 \qquad \textbf{(3)}$$

and the operating limits

$$PG_{i,min} \leq PG_i \leq PG_{i,\,,max} \qquad \textbf{(4)}$$

The units production cost function is usually approximated by quadratic function

$$F_i (PG_i) = a_i PG^2{}_i + b_i PG_i + c_i \; ; \quad i = 1,2,\ldots\ldots N \qquad \textbf{(5)}$$

where ai , bi and ci are constants

Necessary conditions for the existence of solution to ED problem

The ED problem given by the equations (1) to (4). By omitting the inequality constraints (4) tentatively, the reduce ED problem (1),(2) and (3) may be restated as an unconstrained optimization problem by augmenting the objective function (1) with the constraint f multiplied by LaGrange multiplier, l to obtained the LaGrange function, L as

$$\text{Min} : L (PG_1 \ldots\ldots PG_N , \lambda) = \sum_{i=1}^{N} F_i(PG_i) - \lambda \left[\sum_{i=1}^{N} PG_i - PD\right] \qquad \textbf{(6)}$$

The necessary conditions for the existence of solution to (6) are given by

$\partial L / \partial PG_i = 0 = dF_i (PG_i) / dPG_i - \lambda$; i = 1, 2,……..N **(7)**

$\partial L / \partial \lambda = 0 = \sum_{i=1}^{N} PG_i - PD$ **(8)**

The solution to ED problem can be obtained by solving simultaneously the necessary conditions (7) and (8) which state that the economic generation schedules not only satisfy the system power balance equation (8) but also demand that the incremental cost rates of all the units be equal be equal to λ which can be interpreted as "incremental cost of received power".

When the inequality constraints (4) are included in the ED problem the necessary condition (7) gets modified as

$dF_i (PG_i) / dPG_i = \lambda$ for $PG_{i,min} \le PG_i \le PG_{i,,max}$

$\le \lambda$ for $PG_i = PG_{i,,max}$

$\ge\lambda$ for $PG_i = PG_{i,,mi}$ (9)

Economic Schedule

$PG_i = (\lambda - b_i)/ 2a_i$; i=1,2…………….N **(10)**

Incremental fuel cost

$\lambda = [PD + \sum_{i=1}^{N}(b_i/2a_i)] / \sum_{i=1}^{N} (1/2a_i)$ **(11)**

PROCEDURE:

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

EXERCISE:

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

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

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

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

The total load, P_D is 800MW.Neglecting line losses and generator limits, find the optimal dispatch and the total cost in $/h by analytical method. Verify the result using MATLAB program.

PROGRAM:

```
alpha = [500; 400; 200];
beta = [5.3; 5.5; 5.8]; gamma = [0.004; 0.006; 0.009];
PD = 800;
DelP = 10;
lamda = input('Enter estimated value of Lamda = ');
fprintf(' ')
disp(['Lamda P1 P2 P3 DP'...
    'grad Delamda'])
```

```
iter = 0;
while abs(DelP) >= 0.001
        iter = iter + 1;
        P = (lamda - beta)./(2*gamma);
        DelP = PD - sum(P);
        J = sum(ones(length(gamma),1)./(2*gamma));
        Delamda = DelP/J;
        disp([lamda,P(1),P(2),P(3),DelP,J,Delamda])
        lamda = lamda + Delamda;
end
totalcost = sum(alpha + beta.*P + gamma.*P.^2)
```

MANUAL CALCULATION: *Do your calculations here…*

RESULT: Thus, economic dispatch in power systems has been performed and verified.

EXPERIMENT No. 9

AIM: To perform economic dispatch in power systems

THEORY:

Mathematical Model for Economic Dispatch of Thermal Units

Without Transmission Loss:

Statement of Economic Dispatch Problem

In a power system, with negligible transmission loss and with N number of spinning thermal generating units the total system load PD at a particular interval can be met by different sets of generation schedules

$\{PG_1^{(k)}, PG_2^{(k)}, \ldots\ldots PG_N^{(K)}\}$; $k = 1,2,\ldots NS$

Out of these NS set of generation schedules, the system operator has to choose the set of schedules, which minimize the system operating cost, which is essentially the sum of the production cost of all the generating units. This economic dispatch problem is mathematically stated as an optimization problem.

Given: The number of available generating units N, their production cost functions, their operating limits and the system load PD,

To determine: The set of generation schedules,

$$PG_i; \quad i = 1,2\ldots N \quad \textbf{(1)}$$

Which minimize the total production cost,

$$\text{Min}\ ; F_T = \sum_{i=1}^{N} F_i(PG_i) \quad \textbf{(2)}$$

and satisfies the power balance constraint

$$\phi = \sum_{i=1}^{N} PG_i - PD = 0 \quad \textbf{(3)}$$

and the operating limits

$$PG_{i,min} \le PG_i \le PG_{i,\ ,max} \quad \textbf{(4)}$$

The units production cost function is usually approximated by quadratic function

$$F_i(PG_i) = a_i PG_i^2 + b_i PG_i + c_i\ ; \quad i = 1,2,\ldots N \quad \textbf{(5)}$$

where ai , bi and ci are constants

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    lamda = lamda + Delamda;
end
totalcost = sum(alpha + beta.*P + gamma.*P.^2)
```

MANUAL CALCULATION: *Do your calculations here…*

RESULT: Thus, economic dispatch in power systems has been performed and verified.

This lab manual has been updated by

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Crosschecked By
HOD ECE & EEE

Please spare some time to provide your valuable feedback.