

AC LOAD FLOW STUDIES USING NUMERICAL METHOD (RELATE THEORETICAL CALCULATION AND MATLAB PROGRAM)

A Project report submitted in partial fulfillment
Of the requirements for the degree of B. Tech in Electrical Engineering

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CERTIFICATE
To whom it may concern

This is to certify that the project work entitled **AC LOAD FLOW STUDIES USING NUMERICAL METHOD (RELATE THEORETICAL CALCULATION AND MATLAB PROGRAM)** is the work carried out by **DEBARATI SIKDAR (11701617064), PRANABESH HAZRA (11701617053), MD NASIR (11701617057)**, the students of B.Tech in the Department of Electrical Engineering, RCC Institute of Information Technology (RCCIIT), Canal South Road, Beliaghata, Kolkata-700015, affiliated to Maulana Abul Kalam Azad University of Technology (MAKAUT), West Bengal, India, during the academic year 2020-21, in partial fulfillment of the requirements for the degree of Bachelor of Technology in Electrical Engineering and this project has not been submitted previously for the award of any other degree, diploma or fellowship.



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PREFACE

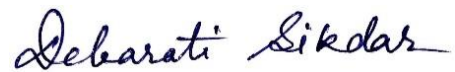
This report comprises the summary of work we **DEBARATI SIKDAR, PRANABESH HAZRA, MD NASIR** achieved during our final year project the task we have chosen to carry out during this year is **AC LOAD FLOW STUDIES USING NUMERICAL METHOD (RELATE THEORETICAL CALCULATIONS AND MATLAB PROGRAM)**. The effort is conducted under the supervision of **Mr. DIPANKAR SANTRA**, Department of Electrical Engineering, RCC Institute of Information Technology.

The goal of this thesis is to do a performance analysis on numerical methods including Gauss-Seidel method for a load flow run to achieve less run time and verify the results obtained in theoretical calculations using the MATLAB program.

ACKNOWLEDGEMENT

It is our great fortune that we have got the opportunity to carry out the project work under the supervision of **Mr. Dipankar Santra** in the Department of Electrical Engineering, RCC Institute of Information Technology (RCCIIT), Canal South Road, Beliaghata, Kolkata-700015, affiliated to Maulana Abul Kalam Azad University of Technology (MAKAUT), West Bengal, India. We express our sincere thanks and deepest sense of gratitude to my guide for his constant support, unparalleled guidance and limitless encouragement.

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ABSTRACT

The goal of this thesis is to do a performance analysis on numerical methods including Gauss-Seidel method for a load flow run to achieve less run time. Unlike the proposed method, the traditional load flow analysis uses only one numerical method at a time. These algorithms perform all the computation for finding the bus voltage angles and magnitudes, real and reactive powers for the given generation and load values, while keeping track of the proximity to convergence of a solution. This work focuses on finding the most effective algorithm. The proposed method is implemented on a 5-bus system and the solutions obtained are verified with MATLAB a commercial software for load flow analysis.

Key Words: Load flow, Gauss-Seidel method, convergence time.

CHAPTER 1

INTRODUCTION TO LOAD FLOW ANALYSIS

1.1 Introduction

Concept of Power Flow:

The power flow analysis is a very important tool in power system analysis. Power flow studies are routinely used in planning, control, and operations of existing electric power systems as well as planning for future expansion. The successful operation of power systems depends upon knowing the effects of adding interconnections, adding new loads, connecting new generators or connecting new transmission line before it is installed. The goal of a power flow study is to obtain complete voltage angle and magnitude information for each bus in a power system for specified load and generator real power and voltage conditions. Once this information is known, real and reactive power flow on each branch as well as generator reactive power can be analytically determined. Due to the nonlinear nature of the problem, numerical methods are employed to obtain solution that is within an acceptable tolerance.

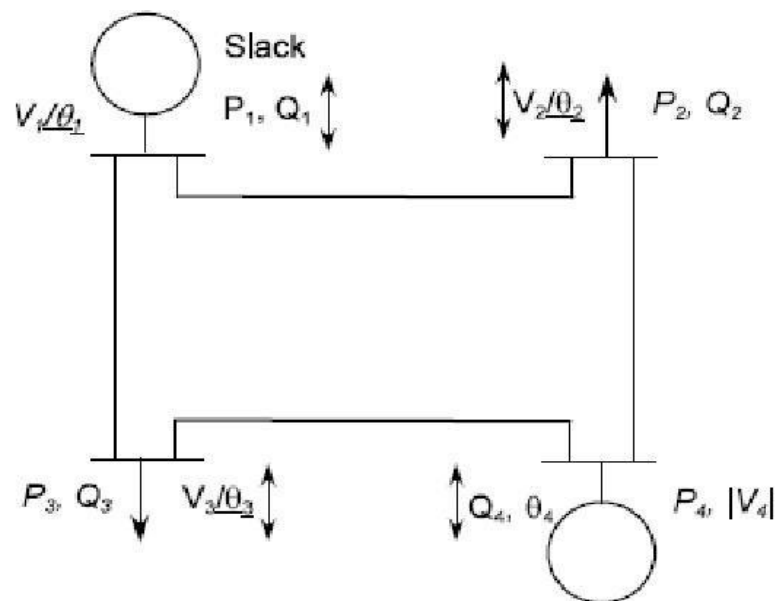


Figure 1 PQ bus system

Load flow studies are one of the most important aspects of power system planning and operation.

The load flow gives us the sinusoidal steady state of the entire system – voltages, real and reactive power generated and absorbed and line losses. Since the load is a static quantity and it is the power that flows through transmission lines, the purists prefer to call this Power Flow studies rather than load flow studies.

We shall however stick to the original nomenclature of load flow. Through the load flow studies, we can obtain the voltage magnitudes and angles at each bus in the steady state. This is rather important as the magnitudes of the bus voltages are required to be held within a specified limit. Once the bus voltage magnitudes and their angles are computed using the load flow, the real and reactive power flow through each line can be computed.

Also based on the difference between power flow in the sending and receiving ends, the losses in a particular line can also be computed. Furthermore, from the line flow we can also determine the over and under load conditions.

The steady state power and reactive powers supplied by a bus in a power network is expressed in terms of nonlinear algebraic equations. We therefore would require iterative methods for solving these equations. In this chapter, we shall discuss two of the load flow methods. We shall also delineate how to interpret the load flow results.

1.2 OBJECTIVES OF LOAD FLOW

- Power flow analysis is very important in planning stages of new networks or addition to existing ones like adding new generator sites, meeting increase load demand and locating new transmission sites.
- The load flow solution gives the nodal voltages and phase angles and hence the power injection at all the buses and power flows through interconnecting power channels.
- It is helpful in determining the best location as well as optimal capacity of proposed generating station, substation and new lines.
- It determines the voltage of the buses. The voltage level at the certain buses must be kept within the closed tolerances.
- System transmission loss minimizes.
- Economic system operation with respect to fuel cost to generate all the power needed.
- The line flows can be known. The line should not be overloaded, it means, we should not operate the close to their stability or thermal limits.

1.3 BUS CLASSIFICATION

For load flow studies it is assumed that the loads are constant and they are defined by their real and reactive power consumption. It is further assumed that the generator terminal voltages are tightly regulated and therefore are constant. The main objective of the load flow is to find the voltage magnitude of each bus and its angle when the powers generated and loads are pre-specified. To facilitate this, we classify the different buses of the power system as listed below.

There are 3 types of buses-

- i. Load Buses
- ii. Voltage Controlled Buses
- iii. Slack or swing Buses

Load bus or PQ Bus

- ▶ A bus at which Active power and Reactive power are specified.
- ▶ Magnitude and phase angle of the voltage need to be calculated.
- ▶ This type of buses is most common, comprising 80% of all buses in power system.
- ▶ In these buses no generators are connected and hence the generated real power P_{Gi} and reactive power Q_{Gi} are taken as zero. The load drawn by these buses are defined by real power $-P_{Li}$ and reactive power $-Q_{Li}$ in which the negative sign accommodates for the power flowing out of the bus. This is why these buses are sometimes referred to as P-Q bus. The objective of the load flow is to find the bus voltage magnitude $|V_i|$ and its angle δ_i .

Voltage controlled Bus

- ▶ A bus at which the magnitude of voltage and active power is defined.
- ▶ Reactive power and phase angles need to be determined through load flow equation.
- ▶ This bus is always connected to generator and is also known as PV bus.
- ▶ This type of bus comprises of 10% of all buses in power system.
- ▶ These are the buses where generators are connected. Therefore, the power generation in such buses is controlled through a prime mover while the terminal voltage is controlled through the generator excitation. Keeping the input power constant through turbine-governor control and keeping the bus voltage constant using automatic voltage regulator, we can specify constant P_{Gi} and $|V_i|$ for these buses. This is why such buses are also referred to as P-V buses. It is to be noted that their active power supplied by the generator Q_{Gi} depends on the system configuration and cannot be specified in advance. Furthermore, we have to find the unknown angle δ_i of the bus voltages.

Slack bus

- ▶ Voltage magnitude and voltage phase angle are specified and real and reactive power are to be obtained.
- ▶ Normally there is only one bus of this type present in a given power system.
- ▶ One generator bus is selected as the reference bus.
- ▶ In slack bus voltage angle and magnitude is normally considered $1+j0$ pu.
- ▶ This bus sets the angular reference for all the buses. Since it is the angle difference between two voltage sources that dictates the real and reactive power flow between them, the particular angle of the slack bus is not important.

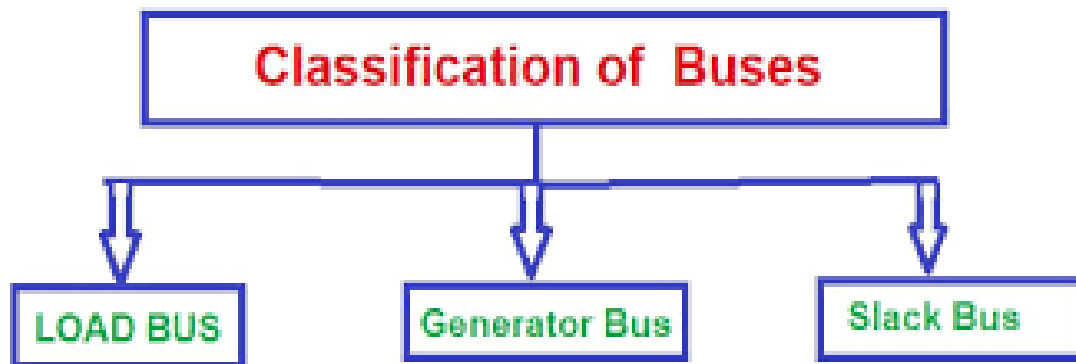


Figure 2 Bus classification

Bus Type	Specified Variables	Unspecified Variables
Load Bus or P-Q bus	P-Q	$ V , \delta$
Generator bus or voltage controlled Bus or P-V bus	$P, V $	Q, δ
Stack bus or reference bus or swing bus	$- V , \delta$	P, Q

Figure 3

Now consider a typical load flow problem in which all the load demands are known. Even if the generation matches the sum total of these demands exactly, the mismatch between generation and load will persist because of the line I^2R losses. Since the I^2R loss of a line depends on the line current which, in turn, depends on the magnitudes and angles of voltages of the two buses connected to the line, it is rather difficult to estimate the loss without calculating the voltages and angles. For this reason, a generator bus is usually chosen as the slack bus without specifying its real power. It is assumed that the generator connected to this bus will supply the balance of the real power required and the line losses.

1.4 OVERVIEW

The power flow algorithm written in this thesis is based on the Gauss-Seidel method. A software program has been developed. The program gives the power flow solution for a given problem as well as computes the complete voltage angle and magnitude information for each bus in a power system for specified load and generator real power and voltage conditions.

Power flow analysis is the backbone of power system analysis and design. They are necessary for planning, operation, economic scheduling and exchange of power between utilities. Power flow analysis is required for many other analyses such as transient stability, optimal power flow and contingency studies. The principal information of power flow analysis is to find the magnitude and phase angle of voltage at each bus and the real and reactive power flowing in each transmission lines.

Power flow analysis is an importance tool involving numerical analysis applied to a power system. In this analysis, iterative techniques are used due to there no known analytical method to solve the problem. This resulted nonlinear set of equations or called power flow equations are generated. To finish this analysis there are methods of mathematical calculations which consist plenty of step depend on the size of system. This process is difficult and takes much time to perform by hand. By develop a toolbox for power flow analysis surely will help the analysis become easier.

Power flow analysis software can help users to calculate the power flow problem. Over the past decade, a few versions of educational software packages using advanced programming languages, such as C, C++, Pascal, or FORTRAN have been developed for power engineering curriculums. These choose an integrated study platform with support of database and GUI functions.

Power flow analysis software developed by the author uses MATLAB software. MATLAB as a high-performance language for technical computation integrates calculation, visualization and programming in an easy-to-use environment, thus becoming a standard instructional tool for introductory and advanced courses in mathematics, engineering and science in the university environment. Most of the students are familiar with it.

MATLAB is viewed by many users not only as a high-performance language for technical computing but also as a convenient environment for building graphical user interfaces (GUI). Data visualization and GUI design in MATLAB are based on the Handle Graphics System in which the objects organized in a Graphics Object Hierarchy can be manipulated by various high and low-level commands. If using MATLAB7 the GUI design more flexible and versatile, they also increase the complexity of the Handle Graphics System and require some effort to adapt to.

1.5 ORGANISATION OF THESIS

1. Contains the introduction. Each part is different from the other and is described along with the necessary theory required to comprehend it.
2. Deals with the literature review. From this we can see before our project who else worked on this topic and how our project is different.
3. Deals with load flow studies or power flow concept, explained with necessary equations for power flow.
4. Deals with conventional methods of numerical methods to solve load flow problems, flowchart and algorithm for MATLAB program.
5. Focuses on the MATLAB program using Gauss-Seidel method.
6. Concludes about the load flow performance by the conventional method from the results obtained from MATLAB.
7. References
8. **Appendix**-software is listed here.

CHAPTER 2
LITERATURE REVIEW

LITERATURE REVIEW

Power flow analysis came into existence in the early 20th century. There were many research works done on the power flow analysis. In the beginning, the main aim of the power flow analysis was to find the solution irrespective of time. Over the last 20 years, efforts have been expended in the research and development on the numerical techniques. Before the invention of digital computers, the load flow solutions were obtained using the network analysis.

In the year 1956 the first practical automatic digital solution was found. The early generation computers were built with less memory storage, the Y-Bus matrix iterative method was well suitable for these computers. Although performance was satisfactory on many power flow problems, the time taken to convergence was very slow and sometimes they never converged. In order to overcome the difficulties of this method a new method was developed based on the Z-Bus matrix.

This new method converges more reliably compared to the Y-Bus matrix method, but it requires more memory storage when solving large problems. During this time, the iterative methods were showing very powerful convergence properties but were difficult in terms of computation. In the mid 1960's major changes in the power system came with the development of very efficient sparsity programmed ordered elimination by Tinny.

CHAPTER 3
LOAD FLOW STUDIES

3.1 REAL AND REACTIVE POWER INJECTED IN A BUS

For the formulation of the real and reactive power entering a bus, we need to define the following quantities. Let the voltage at the i^{th} bus be denoted by,

$$V_i = |V_i| \angle \delta_i = |V_i|(\cos \delta_i + j \sin \delta_i) \quad (3.1)$$

Also, let us define the self-admittance at bus- i as,

$$Y_{ii} = |Y_{ii}| \angle \theta_{ii} = |Y_{ii}|(\cos \theta_{ii} + j \sin \theta_{ii}) = G_{ii} + jB_{ii} \quad (3.2)$$

Similarly, the mutual admittance between the buses i and j can be written as,

$$Y_{ij} = |Y_{ij}| \angle \theta_{ij} = |Y_{ij}|(\cos \theta_{ij} + j \sin \theta_{ij}) = G_{ij} + jB_{ij} \quad (3.3)$$

Let the power system contains a total number of n buses. The current injected at bus- i is given as,

$$\begin{aligned} I_i &= Y_{i1}V_1 + Y_{i2}V_2 + \dots + Y_{in}V_n \\ &= \sum_{k=1}^n Y_{ik}V_k \end{aligned} \quad (3.4)$$

It is to be noted we shall assume the current entering a bus to be positive and that leaving the bus to be negative. As a consequence, the power and reactive power entering a bus will also be assumed to be positive. The complex power at bus- i is then given by,

$$\begin{aligned} P_i - jQ_i &= V_i^* I_i = V_i^* \sum_{k=1}^n Y_{ik}V_k \\ &= |V_i|(\cos \delta_i - j \sin \delta_i) \sum_{k=1}^n |Y_{ik}V_k|(\cos \theta_{ik} + j \sin \theta_{ik})(\cos \delta_k + j \sin \delta_k) \end{aligned}$$

$$\begin{aligned}
& n \\
& = \sum_{k=1}^n |Y_{ik} V_i V_k| (\cos\delta_i - j\sin\delta_i) (\cos\theta_{ik} + j\sin\theta_{ik}) (\cos\delta_k + j\sin\delta_k) \quad (3.5) \\
& \\
& = (\cos\delta_i - j\sin\delta_i) [\cos(\theta_{ik} + \delta_k) + j\sin(\theta_{ik} + \delta_k)] \\
& \\
& = \cos(\theta_{ik} + \delta_k - \delta_i) + j\sin(\theta_{ik} + \delta_k - \delta_i)
\end{aligned}$$

Therefore, substituting in (3.5) we get the real and reactive power as,

$$\begin{aligned}
& n \\
& P_i = \sum_{k=1}^n |Y_{ik} V_i V_k| \cos(\theta_{ik} + \delta_k - \delta_i) \quad (3.6) \\
& k=1
\end{aligned}$$

$$\begin{aligned}
& n \\
& Q_i = - \sum_{k=1}^n |Y_{ik} V_i V_k| \sin(\theta_{ik} + \delta_k - \delta_i) \quad (3.7) \\
& k=1
\end{aligned}$$

3.2 PREPARATION OF DATA FOR LOAD FLOW

Let real and reactive power generated at bus-i be denoted by P_{Gi} and Q_{Gi} respectively. Also let us denote the real and reactive power consumed at the i^{th} bus by P_{Li} and Q_{Li} respectively. Then the net real power injected in bus-i is,

$$P_{i,\text{inj}} = P_{Gi} - P_{Li} \quad (3.8)$$

Let the injected power calculated by the load flow program be $P_{i,\text{calc}}$.

Then the mismatch between the actual injected and calculated values is given by,

$$\Delta P_i = P_{i,\text{inj}} - P_{i,\text{calc}} = P_{Gi} - P_{Li} - P_{i,\text{calc}} \quad (3.9)$$

In a similar way the mismatch between the reactive power injected and calculated values is given by,

$$\Delta Q_i = Q_{i,\text{inj}} - Q_{i,\text{calc}} = Q_{Gi} - Q_{Li} - Q_{i,\text{calc}} \quad (3.10)$$

The purpose of the load flow is to minimize the above two mismatches. It is to be noted that

(3.6) and (3.7) are used for the calculation of real and reactive power in (3.9) and (3.10).

However, since the magnitudes of all the voltages and their angles are not known prior, an iterative procedure must be used to estimate the bus voltages and their angles in order to calculate the mismatches. It is expected that mismatches ΔP_i and ΔQ_i reduce with each iteration and the load flow is said to have converged when the mismatches of all the buses become less than a very small number.

CHAPTER 4
Load Flow Conventional Method

4.1 Gauss-Seidel Method

Gauss-Seidel method is also known as the method of successive displacements.

To illustrate the technique, consider the solution of the non-linear equation given by,

$$F(x)=0 \quad (1)$$

Above function is rearrange and written as,

$$x=g(x) \quad (2)$$

If $x^{(k)}$ is an initial estimate of the variable x , the following iterative sequence is formed,

$$X^{(k+1)}=g(x^{(k)}) \quad (3)$$

A solution is obtained when the difference between the absolute value of the successive iteration is less than a specified accuracy, i.e.,

$$|x^{(k+1)}-x^{(k)}|\leq\varepsilon \quad (4)$$

Where ε is the desired accuracy.

The process is repeated until the change in variable is within the desired accuracy. So, the Gauss-Seidel method needs much iteration to achieve the desired accuracy, and there is no guarantee for the convergence.

LOAD FLOW BY GAUSS-SEIDEL METHOD

The basic power flow equations (3.6) and (3.7) are nonlinear. In an n -bus power system, let the number of PQ buses be n_p and the number of PV (generator) buses be n_g such that $n = n_p + n_g + 1$. Both voltage magnitudes and angles of the P-Q buses and voltage angles of the P-V buses are unknown making a total number of $2n_p + n_g$ quantities to be determined. Amongst the known quantities are $2n_p$ numbers of real and reactive powers of the P-Q buses, $2n_g$ numbers of real powers and voltage magnitudes of the P-V buses and voltage magnitude and angle of the slack bus. Therefore, there are sufficient numbers of known quantities to obtain a solution of the load flow problem. However, it is rather difficult to obtain a set of closed form equations from (3.6) and (3.7). We therefore have to resort to obtain iterative solutions of the load flow problem.

At the beginning of an iterative method, a set of values for the unknown quantities are chosen. These are then updated at each iteration. The process continues till errors between all the known and actual quantities reduce below a pre-specified value. In the Gauss-Seidel load flow we denote the initial voltage of the i^{th} bus by $V_i^{(0)}$, $i = 2, \dots, n$. This should read as the voltage of the i^{th} bus at the 0^{th} iteration, or initial guess. Similarly, this voltage after the first iteration will be denoted by $V_i^{(1)}$. In this Gauss-Seidel load flow the load buses and voltage controlled, buses are treated differently. However, in both these types of buses we use the complex power equation given in (3.5) for updating the voltages. Knowing the real and reactive power injected at any bus we can expand (3.5) as,

$$P_{i,\text{inj}} - jQ_{i,\text{inj}} = V_i^* \sum_{k=1}^n Y_{ik} V_k = V_i^* [Y_{i1} V_1 + Y_{i2} V_2 + \dots + Y_{ii} V_i + \dots + Y_{in} V_n] \quad (4.1)$$

We can rewrite (4.1) as,

$$V_i = 1/Y_{ii} [(P_{i,\text{inj}} - jQ_{i,\text{inj}})/V_i^* - Y_{i1} V_1 - Y_{i2} V_2 - \dots - Y_{in} V_n] \quad (4.2)$$

Let us start the procedure with bus-2. Since this is load bus, both the real and reactive power into this bus is known. We can therefore write from (4.2),

$$V_2^{(1)} = 1/Y_{22} [(P_{2,\text{inj}} - jQ_{2,\text{inj}})/V_2^{*(0)} - Y_{21} V_1 - Y_{23} V_3^{(0)} - Y_{24} V_4^{(0)} - Y_{25} V_5^{(0)}] \quad (4.3)$$

The first iteration voltage of bus-3 is given by,

$$V_3^{(1)} = 1/Y_{33} [(P_{3,\text{inj}} - jQ_{3,\text{inj}})/V_3^{*(0)} - Y_{31} V_1 - Y_{32} V_2^{(1)} - Y_{34} V_4^{(0)} - Y_{35} V_5^{(0)}] \quad (4.4)$$

Now in case of PV bus although its real power is specified, its reactive power is unknown. Therefore, to update the voltage of this bus, we must first estimate the value of reactive power of that bus by using formula,

$$Q_{i,inj} = -\text{Im}\left[V_i^* \sum_{k=1}^n Y_{ik} V_k\right] = -\text{Im}\left[V_i^* \{Y_{i1} V_1 + Y_{i2} V_2 + \dots + Y_{in} V_n\}\right] \quad (4.5)$$

And hence we can write the kth iteration values as,

$$Q_{i,inj}^{(k)} = -\text{Im}\left[V_i^{*(k-1)} \{Y_{i1} V_1 + Y_{i2} V_2^{(k)} + \dots + Y_{in} V_n^{(k-1)}\}\right] \quad (4.6)$$

However sometimes the magnitude of the voltage obtained is not equal to the magnitude given. We must therefore force this voltage magnitude to be equal to that specified. This is accomplished by,

$$V_{\text{corrected}} = |V| \times V^{(1)} / |V^{(1)}|$$

This will correct the voltage magnitude while retaining the phase. The corrected iteration is used in the next iteration.

4.2 Numerical problem and solution of Gauss-Seidel method:

PROBLEM:-

For a 5-bus system:

The admittance will be given as-

<u>Bus code</u>	<u>Admittance</u>
1-2	$2 - j8$
1-4	$1 - j4$
1-5	$j0.2$
2-3	$0.666 - j2.664$
3-4	$1 - j4$
4-5	$2 - j8$

Active and Reactive power given as:-

<u>Bus NO.</u>	<u>P</u>	<u>Q</u>	<u>V</u>	<u>Remarks</u>
1	—	—	1.06	Reference Bus
2	0.5	0.2	$1 + j0$	P-Q Bus
3	0.4	0.3	$1 + j0$	"
4	0.3	0.1	$1 + j0$	"

5 0.5 0.2 $17j0$ P-Q Bus

Using Gauss-Seidal Method, Determine the phasor values of all voltages (P-Q Bus)?

Ans → For calculating the phasor values of all voltages, 1st we find out the Bus admittance matrix of the given network.

The Bus admittance matrix of the system is given as -

$$Y_{bus} = \begin{bmatrix} Y_{11} & Y_{12} & Y_{13} & Y_{14} & Y_{15} \\ Y_{21} & Y_{22} & Y_{23} & Y_{24} & Y_{25} \\ Y_{31} & Y_{32} & Y_{33} & Y_{34} & Y_{35} \\ Y_{41} & Y_{42} & Y_{43} & Y_{44} & Y_{45} \\ Y_{51} & Y_{52} & Y_{53} & Y_{54} & Y_{55} \end{bmatrix}$$

$$Y_{11} = Y_{12} + Y_{14} + Y_{15} = 3 - 11.8j$$

$$Y_{22} = Y_{12} + Y_{23} = 2.666 - 10.664j$$

$$Y_{33} = Y_{23} + Y_{34} = 1.666 - 6.664j$$

$$Y_{44} = Y_{34} + Y_{45} + Y_{14} = 4 - 16j$$

$$Y_{55} = Y_{15} + Y_{45} = 2 - 7.8j$$

$$Y_{12} = Y_{21} = -Y_{12} = -2 + j8$$

$$Y_{14} = Y_{41} = -Y_{14} = -1 + j4$$

$$Y_{23} = Y_{32} = -0.666 + j2.664$$

$$Y_{34} = Y_{43} = -1 + j4$$

$$Y_{45} = Y_{54} = -2 + j8$$

The iterative formula of phasor voltage is given by,

$$V_i^{[k+1]} = \frac{1}{Y_{ii}} \left[\frac{P_i - jQ_i}{V_i^{*(k)}} - \sum_{\substack{j=1 \\ j \neq i}}^n Y_{ij} V_j^{[k]} \right]$$

where,

i = bus number

P_i = Active power of i th bus

Q_i = Reactive power of i th bus

1st Iteration:-

If we put $k=0$, at voltage formula then,

putting $i=2,3,4,5$ respectively then

$$V_2^{(1)} = 1.07366 + 0.0397j$$

$$V_3^{(1)} = 1.0564 + j0.0458$$

$$V_4^{(1)} = 1.0252 + j0.0161$$

$$V_5^{(1)} = 1.0370 + 0.0545j$$

2nd Iteration:-

For calculating 2nd iterative values of all voltages of load bus, we put

$k=1$, At voltage equation,

we will get -

$$V_2^{(2)} = 1.0403 + 0.0501j$$

$$V_3^{(2)} = 1.0238 + 0.0562j$$

$$V_4^{(2)} = 0.9916 + 0.0265j$$

$$V_5^{(2)} = 1.00364 + 0.0649j$$

So, After 2nd iteration the values of voltages of each buses should be =

$$V_1 = 1.06$$

$$V_2 = 1.0403 + 0.0501j$$

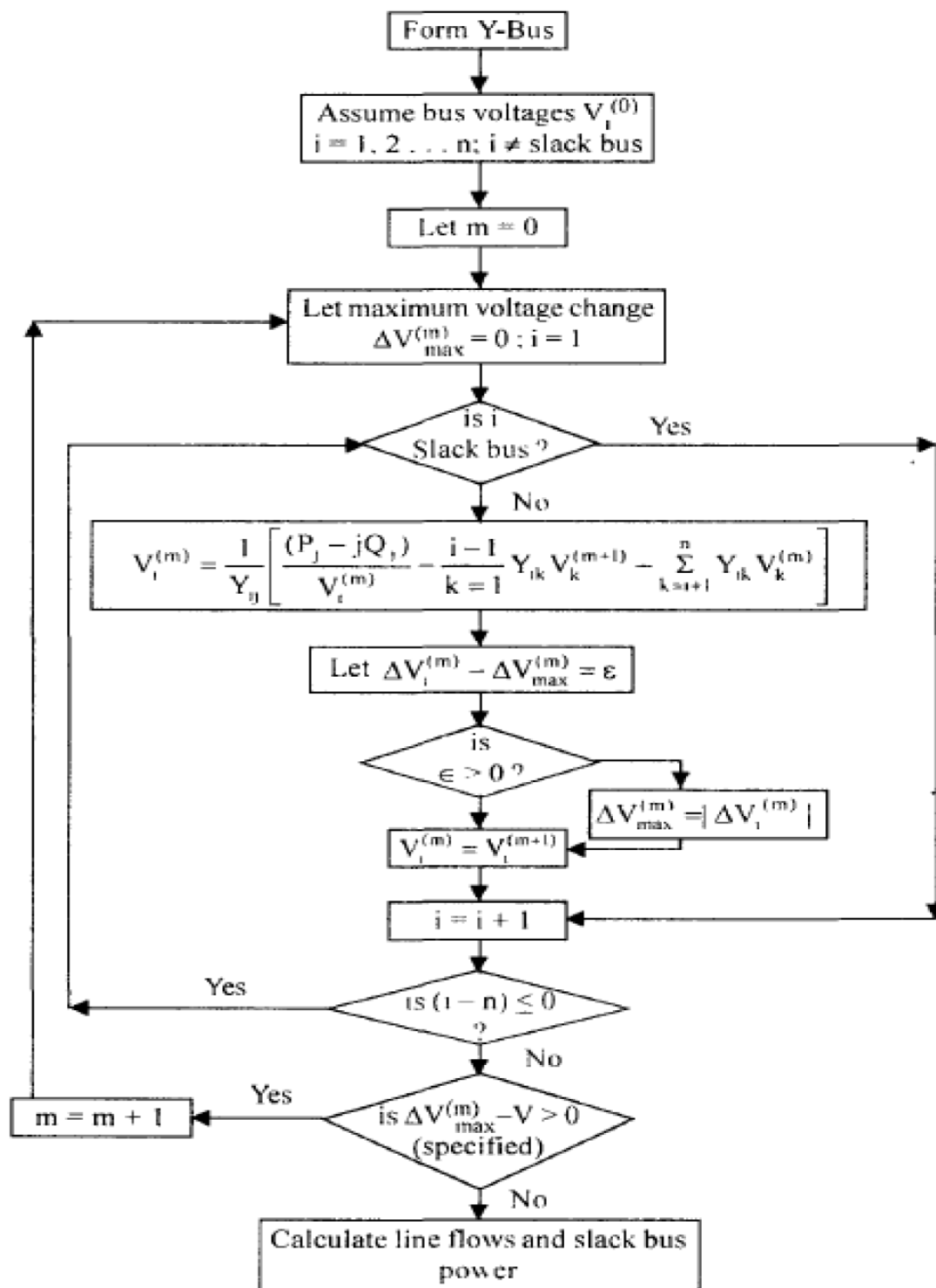
$$V_3 = 1.0238 + 0.0562j$$

$$V_4 = 0.9916 + 0.0265j$$

$$V_6 = 1.0034 + 0.0649j$$

This is the final answer →

4.3 Flow-chart for implementing Gauss-Seidel method:



4.4 ALGORITHM OF GAUSS-SEIDEL

Step 1: Form the nodal admittance matrix (Y_{ij}).

Step 2: Choose a tolerance value.

Step 3: Assume the initial voltage values to be 1 pu and 0 degree except for the slack bus.

Step 4: Start iteration for bus $i = 1$ with count 0.

Step 5: Check for the slack bus if for $i = \text{slack bus}$ or PV bus update the value of Q_i .

Step 6: Calculate the new bus voltage V_i from the load flow equation.

Step 7: Find the difference in the voltages,

$$dV_i^{(k+1)} = V_i^{(k+1)} - V_i^{(k)}$$

Step 8: The new calculated value of the bus voltage is updated in the old bus voltage value and is used for the calculations at the next bus.

Step 9: Go for the next bus and repeat the steps 5 to 7 until a new set of values of bus voltages are obtained for all the buses.

Step 10: Continue the iteration from 5 to 9 until the value of dV_i^k at all the buses is within the chosen tolerance value,

$$dV_i^{(k+1)} < \epsilon, \text{ where } k \text{ gives the number of iterations.}$$

CHAPTER 5
MATLAB PROGRAM OF GAUSS-SEIDEL

MATLAB PROGRAM

```
clear % Gauss Seidal method for load flow solution
y12= 2-8j;
y23= 0.666-2.664j;
y34= 1-4j;
y45= 2-8j;
y15= 0.2j;

p2= 0.5;
q2= 0.2;
p3= 0.4;
q3= 0.3;
p5= 0.5;
q5= 0.2;

v1= 1.06;
v2= 1+0j;
v3= 1+0j;
v4= 1+0j;
v5= 1+0j;

iter=0;

for k=1:20
    iter=iter+1
    v2=((p2-q2)/conj(v2) +y12*v1+y23*v3)/(y12+y23)
    v3=((p3-q3)/conj(v3) +y23*v2+y34*v4)/(y23+y34)
    v5=((p5-q5)/conj(v5) +y15*v1+y45*v4)/(y15+y45)
end
```

CHAPTER 6
RESULT AND LIMITATIONS

6.1 RESULT:

Gauss-Seidel Iteration output:

Ybus =

Column 1 through 5

3-11.8j	-2+8j	0	-1+4j	-0.2j
-2+8j	2.66+10.66j	-0.66+2.66j	0	0
0	-0.66+2.66j	1.66-6.66j	-1+4j	0
-1+4j	0	-1+4j	4-16j	-2+8j
-0.2j	0	0	-2+8j	2-7.8j

Enter the acceleration constant: 1.6

GS LOAD FLOW CONVERGES IN ITERATIONS index= 24

FINAL VOLTAGE ARE:

$$v_2 = 1.0688 + 0.0493i$$

$$v_3 = 1.0752 + 0.0974i$$

$$v_4 = 1.0760 + 0.1073i$$

$$v_5 = 1.0811 + 0.1437i$$

6.2 Limitations of Gauss-Seidel method:

GS method is very useful for very small systems. It is easily adoptable; it can be generalized and it is very efficient for systems having less number of buses. However, GS load flow analysis fails to converge in systems with one or more of the features as under:

- Systems having large number of radial lines
- Systems with short and long lines terminating on the same bus
- Systems having negative values of transfer admittances
- Systems with heavily loaded lines, etc.

GS method successfully converges in the absence of the above problems. However, convergence also depends on various other set of factors such as: selection of slack bus, initial solution, acceleration factor, tolerance limit, level of accuracy of results needed, type and quality of computer/ software used, etc.

6.3 Limitations of Us:

The output value of MATLAB program and the value of calculation are not matched sometimes after 2 decimal place. It may be decimal point error of us.

CHAPTER 7
CONCLUSION AND FUTURE SCOPE

7.1 CONCLUSION:

The load flow case problem has been successfully solved for interconnected systems with Gauss-Seidel load flow method and obtained results have been compared to the theoretical calculations which came to be same. The Gauss-Seidel method was successfully designed and implemented to solve the Load flow problem.

7.2 FUTURE SCOPE:

This project concentrates on MATLAB programming to enable the users to calculate power flow problem easily. MATLAB is used to program the power flow solution and GUI interface helps a user to use easily.

To achieve all the project's objectives, the developer must have fulfilled all the scope below:

- i. Studies MATLAB programming.
- ii. Identify appropriate command for MATLAB M-files
- iii. Build MATLAB program for the power flow analysis using M-files

CHAPTER 8

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APPENDIX(SOFTWARE)

MATLAB (matrix laboratory) is a multi-paradigm numerical computing environment. A proprietary programming language developed by MathWorks, MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs written in other languages, including C, C++, C#, Java, Fortran and Python.

Although MATLAB is intended primarily for numerical computing, an optional toolbox uses the MuPAD symbolic engine, allowing access to symbolic computing abilities. An additional package, Simulink, adds graphical multi-domain simulation and model-based design for dynamic and embedded systems.

VERSION: 2016a

Structures

MATLAB has structure data types. Since all variables in MATLAB are arrays, a more adequate name is "structure array", where each element of the array has the same field names. In addition, MATLAB supports dynamic field names (field look-ups by name, field manipulations, etc.). Unfortunately, MATLAB JIT does not support MATLAB structures, therefore just a simple bundling of various variables into a structure will come at a cost.

Functions

When creating a MATLAB function, the name of the file should match the name of the first function in the file. Valid function names begin with an alphabetic character, and can contain letters, numbers, or underscores. Functions are often case sensitive.

Function handles

MATLAB supports elements of lambda calculus by introducing function handles, or function references, which are implemented either in .m files or anonymous/nested functions.

Classes and object-oriented programming

MATLAB supports object-oriented programming including classes, inheritance, virtual dispatch, packages, pass-by-value semantics, and pass-by-reference semantics. However, the syntax and calling conventions are significantly different from other languages. MATLAB has value classes and reference classes, depending on whether the class has handle as a super-class (for reference classes) or not (for value classes).