الجمهورية الجزائرية الديمقراطية الشعبية

People's Democratic Republic of Algeria

وزارة التعليم العالي والبحث العلمي

Ministry of Higher Education and Scientific Research

Mohamed Khider Biskra University

Faculty of Sciences and Technology

Electrical Engineering Department

Field: Electrotechnique

Option: Electrical Grids

Ref:............

A Dissertation for the Fulfillment of the

Requirement of a Master's Degree

Theme

Excel method applied on power flow Analysis

Presented by:

Chabbi ADEM

Presented on: 05 June 2017

Members of Jury:

Mr. . Salhi AHMED	**MCB**	**President**
Mr. Djemai NAIMI	**MCA**	**Supervisor**
Mrs. Tkouti NASSIRA	**MAA**	**Examiner**

Academic Year: *2016 / 2017.*

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Favorable opinion of the supervisor:

Dr. Djemai NAIMI **signature**

Favorable opinion of the Jury President

Dr. Salhi AHMED **signature**

Stamp and signature

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Supervisor by: Dr. Djemai NAIMI

Abstract (Arabic , English, French)

ملخص :

نتطرق في هذه المذكرة ، نقدم المنهجية المستعملة في تطوير برنامج حساب تدفق قدرة الكهربائية في الشبكات الكهربائية باستعمال طريقتين : الطريقة الأولى خوارزمية (نيوتن-رافسون) الطريقة الثانية خوارزمية(غاوس-سيديل)هذه الطريقتين يعتمد عليها برنامج إكسيل المقدم على شكل واجهة رسومية وذالك لتحقيق وقت تنفيذ أقل ,خلافا للطرق التقليدية المقترحة التي تستخدم خوارزمية واحدة فقط في كل مرة.هذا البرنامج اكسيل يعطي كل القيم. زوايا الجهد ، الاستطاعة الفعالة وقيم الطاقة المولدة وقيم الحمولة و الضياعات لقضبان التجميع ،ويقارن وقت التنفيذ مع كل الطرق العددية المستخدم. يتم تطبيق الطريقة المقترحة (طريقةبرنامج إكسيل) على الشبكة الكهربائية أربعة عشر قضيبا للتجميع ويتم التحقق من الحلول التي تم الحصول عليها مع برنامج ماتلاب. الذي يستعمل كل من خوارزمية (نيوتن-رافسون) و (غاوس-سيديل).وكانت نتائج المحاكاة المطبقة على الشبكة الكهربائية مرضية.

الكلمات المفتاحية :تدفق للقدرة الكهربائية الطاقة، غاوس-سيديل، نيوتن-رافسون،ماتلاب، إكسيل. وقت التنفيذ.

Abstract

In this paper we present the methodology used in the development of Power Flow Program in Power grid using two methods: the first algorithm the method (Newton-Raphson) The second method algorithm (Gauss-Seidel) Of the Excel (VBA) program with a graphical interface for a quick implementation of the execution time is less, unlike the only traditional digital methods proposed in a way each time. These algorithms give all the calculations to find the angles Tension, and the values of the power and the values load and losses all buss, and compares the execution time to each numerical methods. The application of the proposed method (Excel program method) on the 14 bus power grid and verified solutions that were obtained with the MATLAB program. That uses both algorithm (Newton-Raphson) and (Gauss-Seidel) simulation results. The results of the simulation applied to the satisfactory Power grid

Keywords : Power flow, Gauss-Seidel method, Newton-Raphson method, MATLAB , Excel (vba). Execution time

Résumé :

Dans ce mémoire, nous présentons la méthodologie utilisée dans le développement du programme de Ecoulement de puissance dans les réseaux électriques en utilisant deux méthodes: le premier algorithme de la méthode (Newton-Raphson) Le deuxième algorithme de méthode (Gauss-Seidel) Par voie de le programme Excel(VBA) avec une interface graphique pour une réalisation rapide du temps d'exécution est moins, contrairement aux méthodes le seul numérique utilisé traditionnelle proposée d'une façon à chaque fois. Ces algorithmes donnent tous les calculs pour trouver les angles Tension , et les valeurs de la puissance et les valeurs charge et pertes dans chaque JB , et compare le temps d'exécution à chaque méthodes numériques. L'application de la méthode proposée (méthode du programme Excel) sur le réseau électrique 14 JB et des solutions vérifiées qui ont été obtenus avec le programme Matlab. Qui utilise à la fois algorithme (Newton-Raphson) et (Gauss-Seidel) résultats de la simulation. Les résultats de la simulation appliquée au réseau électrique satisfaisante

Mots-clés: Ecoulement de puissance, Méthode de Gauss-Seidel, méthode de Newton-Raphson, MATLAB, Excel (VBA). Temps d'exécution

Acknowledgments

Firstly, I would like to thank and praise ***Allah*** above all, ***Allah*** the Almighty, for granting me light, patience and stamina to accomplish my research.

Secondly, I would like to express my sincere gratitude and deep appreciation to my supervisor ***Dr. Djemai NAIMI*** for his endless support, continuous encouragement, and excellent motivation. His guidance helped me in all the time throughout my dissertation since the beginning until the end. I would like to extend my deepest gratitude to the jury members starting from ***Dr. Ahmed SALHI*** , also ***Mrs***.***Tkouti Nassira***.

Yet, I am immensely grateful to all my teachers in the Department of Electrical Engineering, at ***Mohamed Khider University of Biskra***. I am equally grateful and profoundly indebted to those who have taught and trained me throughout the entire educational career of mine. I also extend my heartfelt thanks to my family for backing me up spiritually in the midst of writing this thesis and in my life in general.

Finally yet importantly, I owe a great many thanks to a great many people and well-wishers. This work would have truly been nothing but a distant reality without their assistance, concern, and advice.

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Chapter 1 : Power Flow Analysis

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N	Total number of buses
N_g	Number of generator including the generator at slack bus
k	Node
V_k	Voltage magnitude
δ_k	Voltage angle
P_i	Injected real power
Q_i	Injected reactive power
GS	Gauss-Seidel
NR	Newton-Raphson
n_g	Number of generators
P_{Gi}	Generated active power at Bus I
P_{load}	Active load power
Q_{load}	Reactive load power
P_{losses}	Active transmission losses
Q_{losses}	Reactive transmission losses
V	Vector of bus voltage magnitude with lower and upper limits V^m and V^M
δ	Vector of bus voltage phase angle with lower and upper limits δ^m and δ^M
P_{di}	Demanded power at Bus i
V_{imax}	Maximal tension at Bus i
P_{Gmin}	Minimal generated active power in the grid
V_{imin}	Minimal tension at Bus i
P_{Gmax}	Maximal generated active power in the grid
Q_{Gmax}	Maximal generated reactive power in the grid
Q_{Gmin}	Minimal generated reactive power in the grid
X	Design vector
MATLAB	Matrix Laboratory

PF	Power Flow
Excel	Microsoft Office Excel
VBA	Visual Basic for Applications
$\mathbf{J_1, J_2, J_3, J_4}$	Under matrices of the Jacobian
$\mathbf{Y_{Bus}}$	nodal admittance matrix

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Preface

Preface

The power industry, a capital and technology intensive industry, is a basic national infrastructure. Its security, reliability, and economy have enormous and far-reaching effects on a national economy. An electrical power system is a typical large-scale system. Questions such as how to reflect accurately the characteristics of modern electrical power systems, how to analyze effectively their operating features, and how to improve further the operating performance are always at the forefront of electrical power systems research.

Electrical power system analysis is used as the basic and fundamental measure to study planning and operating problems. In the last century, electrical power researchers have undertaken a great deal of investigation and development in this area, have made great progress in theoretical analysis and numerical calculation, and have written excellent monographs and textbooks. Over the last 20 years, the changes in electrical power systems and other relevant technologies have had a profound influence on the techniques and methodologies of electrical power system analysis.[**XYM 08**]

Beside giving real and reactive power the load flow study provides information about line and transformer loading (as well as losses) throughout the system and voltages at different points in the system for evaluation and regulation of the performance of the power systems. Further study and analysis of future expansion, stability and reliability of the power system network can be easily analyzed through this study**.[PDS 12]**

Growing demand of the power and complexity of the power system network, power system study is an significant tool for an power system operator in order to take corrective actions in time. The advent of digital computers, load-flow solutions were obtained using network analyzers.

The first practical automatic digital solution method appeared in the literature in 1956. The popular traditional 'Gauss-Siedel' iterative method which require minimal computer storage through Y-matrix. Although the performance is satisfactory on different systems but the main drawback is its converging time. To overcome this deficiency led to the development of Zmatrix methods, which converge more reliably but sacrifice some of the advantages of Y-matrix iterative methods, notably storage and speed when applied to large systems.

The other conventional methods like Newton-Raphson method was shown to have powerful convergence properties, but was computationally uncompetitive. Major breakthrough in powersystem network computation came in the mid-l960. Development ordered elimination and after that it leads in to a preeminent general-purpose load-flow approach whichhas been adopted by much of industry **.[PDS 12]**

This work is centered around the power flow in the power system analysis using Excel , so we will present three chapters;two theoretical chapters and the other is practical.

In the first chapter provides an introduction to the power flow analysis . is devoted to the study and analysis of power flow in grid by iterative methods, in particular the Newton-Raphson method Gauss-Siedel given some basic definitions .

In the second chapter,is devoted For definition The method used in our study Concentrate On the use of Excel (vba)

In the third chapter, we will apply a study that represent two comparatives and results between MATLAB and Excel .

Finally, a general conclusion will be briefly and provide in the our work of this thesis and the same time giving also what we could summarize from our work with some perspectives en the future.

Chapter 1

Power Flow Analysis

1.1 Introduction

Whenever a lamp is switched on, starting a motor or supplying a load, it is necessary and in simultaneously produce and transmit electric energy and in the same time with using the generators. All are interconnected by a mesh link network.

The objective of this chapter is to be briefly introduce History Overview and general concepts and Bus Classification and play the role in Power flow analysis. On the other hand, this chapter also studying the Numerical Methods (Gauss-Seidel, Newton-Raphson…..), and ultimately, giving a main conclusion of this chapter.

1.2 Power Flow

1.2.1 Historical

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 **[BST 74].**

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**[JBW 86]**.

In the mid 1960’s major changes in the power system came with the development of very efficient sparsity programmed ordered elimination by Tinny **[BST 74].**

1.2.2 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 **[WFT 67]** .

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, 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 a solution that is within an acceptable tolerance **[GXL 90]** .

Power flow calculation is fundamental in power systems. Power systems are non-linear system of equations in general, the solution for these equations can be found using iterative methods. There are several different iterative methods to solve the power flow problems. The iterative methods give the accurate solution as they approach towards the convergence of the solution by replacing the already calculated value and minimize the tolerance value. There are also some direct methods that converge in less number of iterations compared to iterative methods **[WFT 67].**

The memory requirements and time of calculation increases as the problem size increases (increase in number of buses), so the direct methods are effective for small power system problems. However, it is difficult to say which method is effective as the power flow calculation depends on various factors like the size of the problem, the method used and the type of problem to be solved. In the iterative methods, the memory requirements and the number of iterations increase as the size of the problem increases**[WFT 67].**

For large-sized problems only iterative methods are proved to be efficient. In the past the problem size was small compared to the present day, hence the direct methods were used, and there was an urgent need to find out a method that could ensure the convergence for small-sized and large-sized problems.

The recent development in the field of digital computer technology led for the development of a number of methods for solving the power flow problems. Some of the iterative methods that are mainly used today are Gauss method, Gauss-Seidel method and Newton-Raphson [**REA 10].**

These methods are efficient but the comparisons between the methods are difficult because of differences in computers, programming methods and languages, and the test problems. However, Newton-Raphson method due to its calculation simplifications, fast convergence and reliable results is the most widely used method of large load flow analysis.

In large-sized problems, Newton-Raphson method generates the solution in less time, but for small-sized problems this method is not efficient in terms of time. Many research works are still in process of finding a method that gives an efficient solution that can work for small problems as well as for large problems

1.3 Numerical Techniques for Power Flow Analysis

Power flow analysis is an evaluation process for operation and planning to determine the steady-state condition of a power system given a condition of the system. Power flow analysis is based on a large-scale nonlinear set of equations that require iterative techniques to obtain their solution. There are a number of traditional iterative techniques to solve large non-linear equations. The major methods used in the Power Systems are:

1) Gauss-Seidel method
2) Newton-Raphson method
3) N-R Fast Decoupled Method

1.3.1 Gauss-Seidel method

This is a simple iterative technique based on gauss method that was popular in the early days of digital computer. The more powerful N-R method is however used these days.

The gauss seidel iterative technique is still used for small power systems where program simplicity is more important than computing costs, and in many cases it is used in large scale systems to obtain an initial solution for the continuation of Newton-Raphson method **[JDW 95]** .

All the calculations done in gauss-seidel method are same as the gauss method except in the equation (1.2) the value of x calculated at one equation immediately replaces the x calculated form previous iteration. Equation (1.2) changes to:

$$x_i^{k+1} = \frac{1}{a_{ii}}\left(b_i - \sum_{\substack{i=1 \\ i\neq j}}^{n} a_{ij}x_j^{k+1}\right) \qquad (1.1)$$

1.3.2 Newton-Raphson method

The Gauss-Seidel method is very simple but convergence becomes increasingly slow as the system size grows. The Newton-Raphson technique converges fast in less than 4-5 iterations regardless of system size. This technique is mainly useful for large-sized system with thousands of buses **[JDW 95,GLA 90].**

Consider a function $f(x) = 0$, and its derivative $f'(x)$, we begin with a first guess x0. Provided the function is reasonably well-behaved a better approximation x1 is

$$x_1 = x_0 - \frac{f(x_0)}{f'(x_0)} \qquad (1.2)$$

Geometrically, x_1 is the intersection point of the tangent line to the graph of f, with the x-axis. The process is repeated until a sufficiently accurate value is reached:

$$x_{k+1} = x_k - \frac{f(x_k)}{f'(x_k)} \qquad (1.3)$$

1.3.3 N-R Fast Decoupled Method

The Fast Decoupled Power Flow Method is one of the improved methods, which is based on a simplification of the Newton-Raphson method and reported by Stott and Alsac in 1974 [16].

This method, like the Newton-Raphson method, offers calculation simplifications, fast convergence and reliable results and became a widely used method in load flow analysis. However, fast decouple for some cases, where high resistance-to-reactance (R/X) ratios or heavy loading (low voltage) at some buses are present, does not converge well because it is an approximation method and make some assumption to simplify Jacobian matrix (1.6).For these cases, many efforts and developments have been made to overcome these convergence obstacles. Some of them targeted the convergence of systems with high R/X ratios, and others with low voltage buses [**[BST 74]** , **[ADI 14]** .

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_1 & J_3 \\ J_2 & J_4 \end{bmatrix} \begin{bmatrix} \Delta\delta \\ \Delta|V| \end{bmatrix} \qquad (1.4)$$

This method is a modification of Newton-Raphson, which takes the advantage of the weak coupling between $P-\delta$ and $Q-V$ due to the high X:R ratios. The Jacobian matrix of Equation (1.6) is reduced to half by ignoring the element of J2 and J3. Equation (1.6) is simplified as:

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_1 & 0 \\ 0 & J_4 \end{bmatrix} \begin{bmatrix} \Delta\delta \\ \Delta|V| \end{bmatrix} \qquad (1.5)$$

1.4 Bus Classification

In power system each bus or node is associated with four quantities, real and reactive powers, bus voltage magnitude and phase angle. In a load flow solution two out of the four quantities are specified and th remaining two are required to be obtained through the solution of the equations. Depending upon which quantities have been specified, the buses are classified into three categories. They are:

1.4.1 *Generator bus or PV bus*

At this bus the voltage magnitude corresponding to the generation voltage and real power P_G corresponding to its ratings are specified. It is required to find out the reactive power generation Q_G and the phase angle of the bus voltage.

1.4.2 *Load bus or PQ bus*

Here the real and the reactive components or power are specified. It is desired to find out the voltage magnitude and the phase angle through the load flow solution. It is required to specify P_D and Q_D at such a bus at a load bus voltage can be allowed to vary within the permissible values.

1.4.3 *Slack bus or reference bus*

In a power system there are mainly two types of buses, load and generator buses. For these buses we have specified the real power P injections. Now $\sum_{i=1}^{n} P_i =$ real power lost PL where Pi is the power injections at the buses, which is taken as positive for generator buses and is negative for load buses. The losses remain unknown until the load flow solution is complete. It is for this reason that generally one of the generator buses is made to take the additional real and reactive power to supply transmission losses.

That is why this type of bus is also known as the slack bus or reference bus. At this bus, the voltage magnitude V and the phase angle δ are specified, whereas real power and reactive power P_G and Q_G are obtained through the load flow solution. The table 1.1 includes a summary of:

Table 1.1: Bus Classification

Type of Bus	Known Quantities	Quantities to be specified
Generator bus	**P, Q**	**|V| , δ**
Load bus	**P, |V|**	**Q, δ**
Slack bus	**|V|, δ**	**P, Q**

1.5 Formation of Y Bus Admittance matrix

The transmission lines connecting electric networks are linear elements. They can be modeled as equivalent circuit based on impedance matrix (Z) or admittance matrix(Y) . Each element in impedance matrix (Z_{ij}) defines the venin's equivalent impedance between the two buses (i) and (j). The diagonal elements of impedance matrix equals to the venin's equivalent impedance between the bus and ground. The impedance matrix is widely applied in the fault analysis of power systems. The admittance matrix is the inverse of the impedance matrix. The admittance matrix is common be used to model the electric network for solving the power flow **[JDG 11]**.The diagonal elements in admittance matrix (Y_{ii}) is called self-admittance and it includes the sum of all admittance connected to the bus.

The off diagonal elements (Y_{ij}) are called mutual admittance and it includes the negative value of admittance between buses (i) and (j). The following equations demonstrate the relation between injected current (I) and the bus voltage (V) based on admittance matrix method shown in **Figure 1-1**

$$I = Y \times V \ ,V = \begin{cases} -yij & i \neq j \\ \sum_{j=1}^{N} yij & i = j \end{cases} . \qquad (1.6)$$

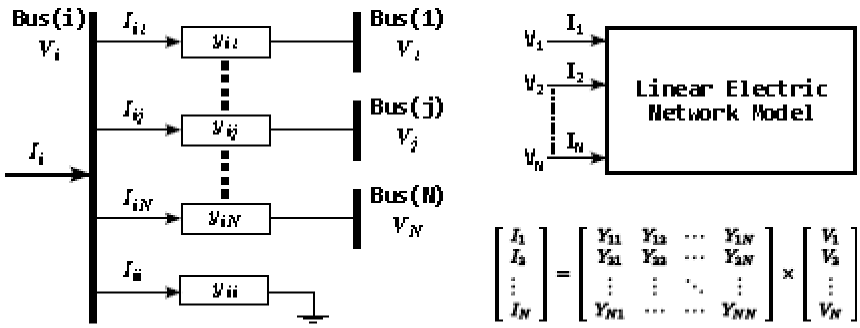

Figure 1.1: Linear network model based on admittance matrix method

1.6 Formation of Power Flow Equations

The power flow problem is the computation of voltage magnitude and phase angle at each bus in a power system under system steady conditions. As a by-product of this calculation, real and reactive power are calculated, as well as equipment losses, can be computed**[JDG 03]** . the input data for the power flow consists of bus data, transmission line data, and transformer data .The first step in a power flow is the calculation of bus admittance matrix Y bus, the Y bus can be constructed from the transmission line and transformer input data Using Y bus, we can write nodal equation for a power system network as:

$$\boldsymbol{I} = \boldsymbol{Y}_{\mathbf{bas}} * \boldsymbol{V} \tag{1.7}$$

where I is the n column vector of source currents injected into each bus and V is the n column vector of bus voltages. For bus k, the kth equation in (1.7) is:

$$\mathrm{I}_i = \sum_{j=1}^{n} Yji\, Vi \tag{1.8}$$

The complex power delivered to bus k is:

$$S_i = P_i + jQ_i = VI_i \tag{1.9}$$

Power flow equations by Gauss and Gauss-Seidel are based on nodal equations (1.8), where each current source Ik is calculated from (1.9). Using (1.8) in (2.9)

$$S_i = P_i + jQ_i = VI_i \left[\sum_{j=1}^{n} Y_{ij} \;\; V_i \right] \tag{1.10}$$

i=1.2.3.4…………..n

(1.10) can be rewritten in polar form as

$$P_i + jQ_j = V_k \sum_{j=1}^{n} Y_{ij} V_i e^{j(\delta_i - \delta_j - \theta_{ij})} \tag{1.11}$$

Taking the real and imaginary parts of (1.11), power balance equations can be written as

$$P_i = V_i \sum_{j=1}^{n} Y_{ji} V_j \cos(\delta_i - \delta_j - \theta_{ji}) \tag{1.12}$$

$$Q_i = V_i \sum_{j=1}^{n} Y_{ji} V_j \sin(\delta_i - \delta_j - \theta_{ji}) \tag{1.13}$$

or when the Y_{ki} is expressed in rectangular coordinates

$$P_i = V_i \sum_{j=1}^{n} V_j [G_{ij} \cos(\delta_i - \delta_j) + B_{ij} \sin(\delta_i - \delta_j)] \tag{1.14}$$

Where

$$Q_i = V_i \sum_{j=1}^{n} V_j [G_{ij} \sin(\delta_i - \delta_j) - B_{ij} \cos(\delta_i - \delta_j)] \tag{1.15}$$

$$G_{ij} = |Y_{ij}| \cos(\theta_{ij}) \tag{1.16}$$

$$B_{ij} = |Y_{ij}| \sin(\theta_{ij}) \tag{1.17}$$

1.7 Algorithms for Power Flow methods

Gauss-Seidel method is an iterative method for solving a set of non-linear equations. This method starts with an assumption of a set of solution vector. In this method the new calculated voltage value immediately replaces the present value and is used in the solution of the subsequent equations. This process is repeated for all the other variables for the completion of current iteration. If the solution is converged to a certain tolerance value then the iteration is stopped else the iteration process is repeated till convergence is achieved. This method is more dependent on the initially assumed values. The general load flow equation of the Gauss method is:

$$V_i = \frac{1}{Y_{ii}}\left(\frac{S_i}{V_i} - \sum_{\substack{j=1\\ j\neq i}}^{n} Y_{ji}V_j\right) \qquad (1.18)$$

Equation (1.18) can be rewritten in a new form to update the value of V_i^k with new calculated voltage V_i^{k+1} :

$$V_i^{k+1} = \frac{1}{Y_{ii}}\left(\frac{P_i - jQ_i^k}{(V_i^k)}\sum_{\substack{j=1\\ j\neq i}}^{n} Y_{ji}V_i^k\right) \qquad (1.19)$$

In Equation (1.19) the value of the reactive power Qi for a generator bus is unknown and can be calculated from the equation (1.15). As a general start the initial voltage magnitude |Vi| and the phase angle δi can be initialized to 1pu and 0 degrees. In doing so, there are total of (n-1) load flow equations for n buses as the voltage magnitude and the phase angle for the slack busare already specified and the remaining unknown's real power Piand the reactive power Qi can be calculated from the power flow equations (1.14) and equation (1.15).

The value of the reactive power calculated at the generator bus has to be checked if thisvalue violates the reactive power generation at that bus (if it is less than the minimum reactivepower generation or more than the maximum reactive power generation).If it violates thereactive power generation limits than the bus time will be switched to load bus fo r that iteration.If Q_i is less than Q_{min} then it will be set to Q_{min} or if Q_i is more than Q_{max} then it will be set Q_{max} . If the reactive power is within the limits, it is substituted in the e quation for the calculationof the voltage magnitude.

1.7.1 Algorithm for Gauss-Seidel (GS) Method

Gauss-Seidel Method is done by the following steps:

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

Step 2: Choose a tolerance value ε .

Step 3: Assume the initial voltage values to be 1pu and 0degree 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*=slack bus or PV bus update the value of Q_i using equation (1.15).

Step 6: Calculate the new bus voltage V_i from the load flow equation (1.17).

Step 7: Find the difference in the voltages

$$\Delta v_i^{k+i} = v_i^{k+i} - v_i^k$$

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 ΔV_i^k at all the buses is within the chosen tolerance value

$$\Delta V_i^{k+1} < \varepsilon$$

1.7.2 Algorithm for Newton-Raphson (NR) method

Power flow solutions by Newton-Raphson are based on the nonlinear powerflow equations given by (1.14) and (1.15).

Equations (1.14) and (1.15) are analogous to the nonlinear equation of the form y = f(x), we define x, y and f are vectors for the power flow problem asLet the composite vector of δ and |V| is $x = \begin{bmatrix} \delta \\ |V| \end{bmatrix}$

$$\delta = \begin{bmatrix} \delta_2 \\ \delta_3 \\ : \\ : \\ \delta n \end{bmatrix} \quad \text{and} \quad |V| = \begin{bmatrix} |V_2| \\ |V_3| \\ : \\ : \\ |Vn| \end{bmatrix}$$

And

$$y = \begin{bmatrix} P \\ Q \end{bmatrix} = \begin{bmatrix} P_2 \\ : \\ P_n \\ Q_2 \\ : \\ Q_n \end{bmatrix} \tag{1.20}$$

$$f(x) = y = \begin{bmatrix} P(x) \\ Q(x) \end{bmatrix} \tag{1.21}$$

where all *V*, *P* and *Q* terms are in per-unit and δ terms are in radians. The slack bus variables are omitted from (2.18), since they are already knownNewtonRaphson method is a complex calculation involving derivative of real power and reactive power with respect to V and δ .

Jacobian matrix is the matrix formed out of the derivatives of power with V and δ and is indicated by J, w here

$$J = \begin{bmatrix} J_{11} & J_{12} \\ J_{21} & J_{22} \end{bmatrix} \tag{1.22}$$

Where $J_{11} = \dfrac{\partial P_i(x)}{\partial \delta_j}$

$$J_{12} = \frac{\partial P_i(x)}{\partial |V_j|}$$

$$J_{21} = \frac{\partial Q_i(x)}{\partial \delta_j}$$

$$J_{22} = \frac{\partial Q_i(x)}{\partial |V_j|} \quad \text{i = 1, 2, 3… n and j = 1, 2, 3… n}$$

The iterative process for Newton-Raphson metho

$$J^k \Delta x^k = -f(x^k) \tag{1.23}$$

$$\Delta P(x) = \begin{bmatrix} P_2 - P_2(x) \\ : \\ P_n - P_n(x) \end{bmatrix} \tag{1.24}$$

$$\Delta Q(x) = \begin{bmatrix} Q_2 - Q_2(x) \\ : \\ Q_n - Q_n(x) \end{bmatrix} \tag{1.25}$$

$\Delta P(x)$ and $\Delta Q(x)$ are the mismatch vectors then equation (1.23) can be expressed as

$$f(x) = -\begin{bmatrix} \Delta P(x) \\ \Delta Q(x) \end{bmatrix} \tag{1.26}$$

It is well known that a small change in phase angle changes the flow of active power and does not affect much the flow of reactive power. Similarly a small change in nodal voltage affects the flow of reactive power whereas active power practically does not change. Keeping these facts in mind and using the polar coordinates, the set of linear load flow equations can be written in matrix form as follows:

$$\begin{bmatrix} j_{11}^{k} & j_{11}^{k} \\ j_{11}^{k} & j_{11}^{k} \end{bmatrix} \begin{bmatrix} \Delta\delta^{k} \\ \Delta|V|^{k} \end{bmatrix} = \begin{bmatrix} \Delta P(x^{k}) \\ \Delta Q(x^{k}) \end{bmatrix} \qquad (1.27)$$

Here J_{11} correspond to the elements which exist and are not zero in most cases.

J and J_{21} corresponds to the elements $\frac{\partial P_i(x)}{\partial |V_j|}$ *and* $\frac{\partial Q_i(x)}{\partial \delta_j}$ respectively which does not exist and, therefore, are zero J_{22} corresponds to the elements $\frac{\partial Q_i(x)}{\partial |V_j|}$ which exist and are not zero To find x^{k+1}, equation (1.26) is solved for Δ^{xk} and use equation (1.27).

At this point the mismatch vector and the Jacobian matrix are updated and the iteration is continued.

$$x^{k+} = x^{k} + \Delta x^{k} \qquad (1.28)$$

Steps to perform Newton-Raphson method

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

Step 2: Assume an initial set of bus voltage and set bus n as the reference bus.

Step 3: Calculate the real Power Pi using the equation (1.14).

Step 4: Calculate the reactive Power Qi using the equation (1.15).

Step 5: Form the Jacobian matrix.

Step 6: Find the power differences ΔP_i and ΔQ_i for all the i=1, 2, 3… (n-1).

Step 7: Choose the tolerance values.

Step 8: Stop the iteration if all ΔP_i and ΔQ_i are within the tolerance values.

Step 9: Substitute the values obtained in step 4 and step 5 in the equation (1.20), and then find the vectors and

Step 10: Update the values $|V_i|$ and θ_i for all i, using $x^{k+1} = x^{k} + \Delta x^{k}$

Step 11: Repeat the steps from 3.

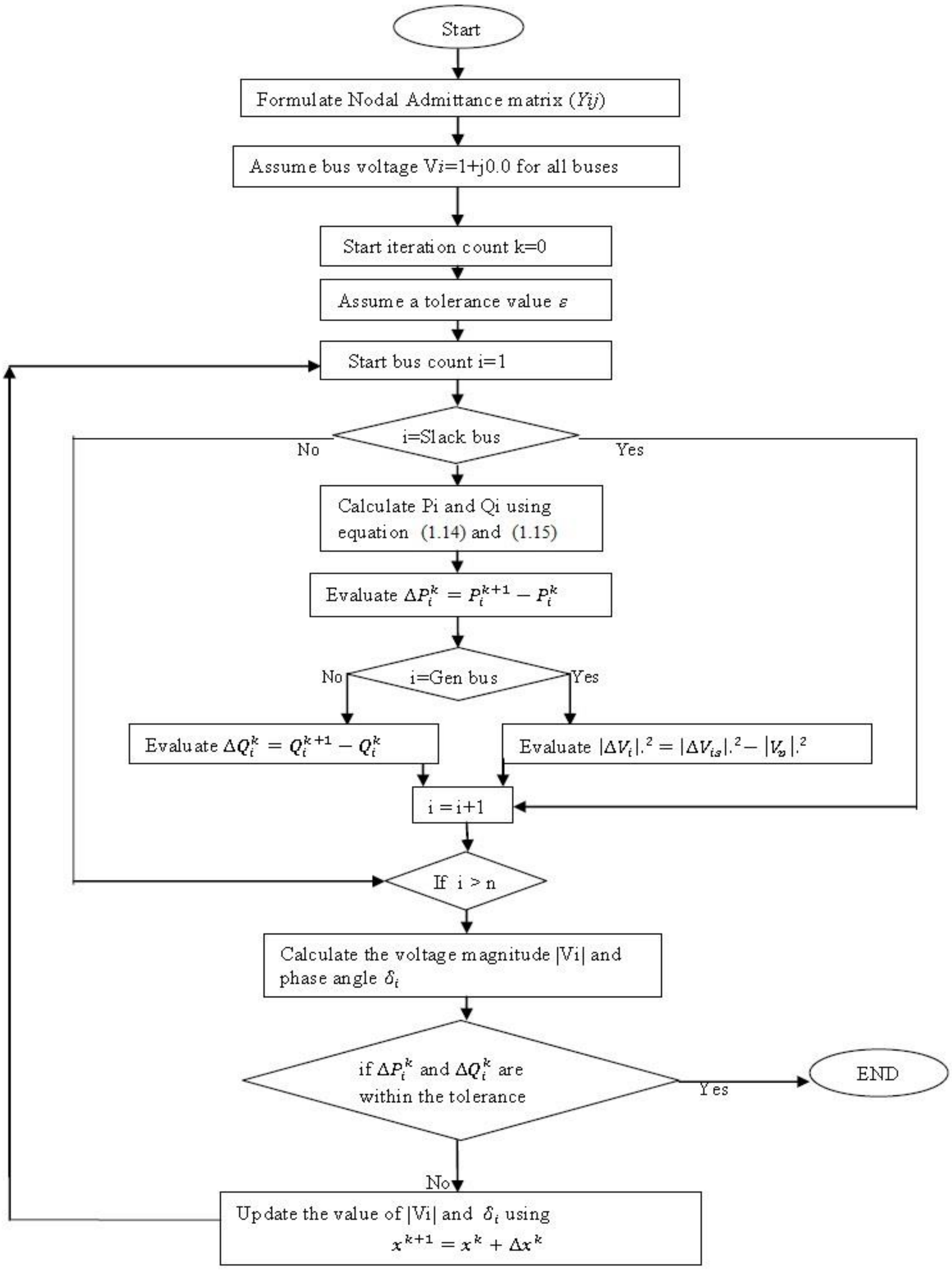

Figure 1.2: Flow Chart for load flow solution using Gauss-Seidel method

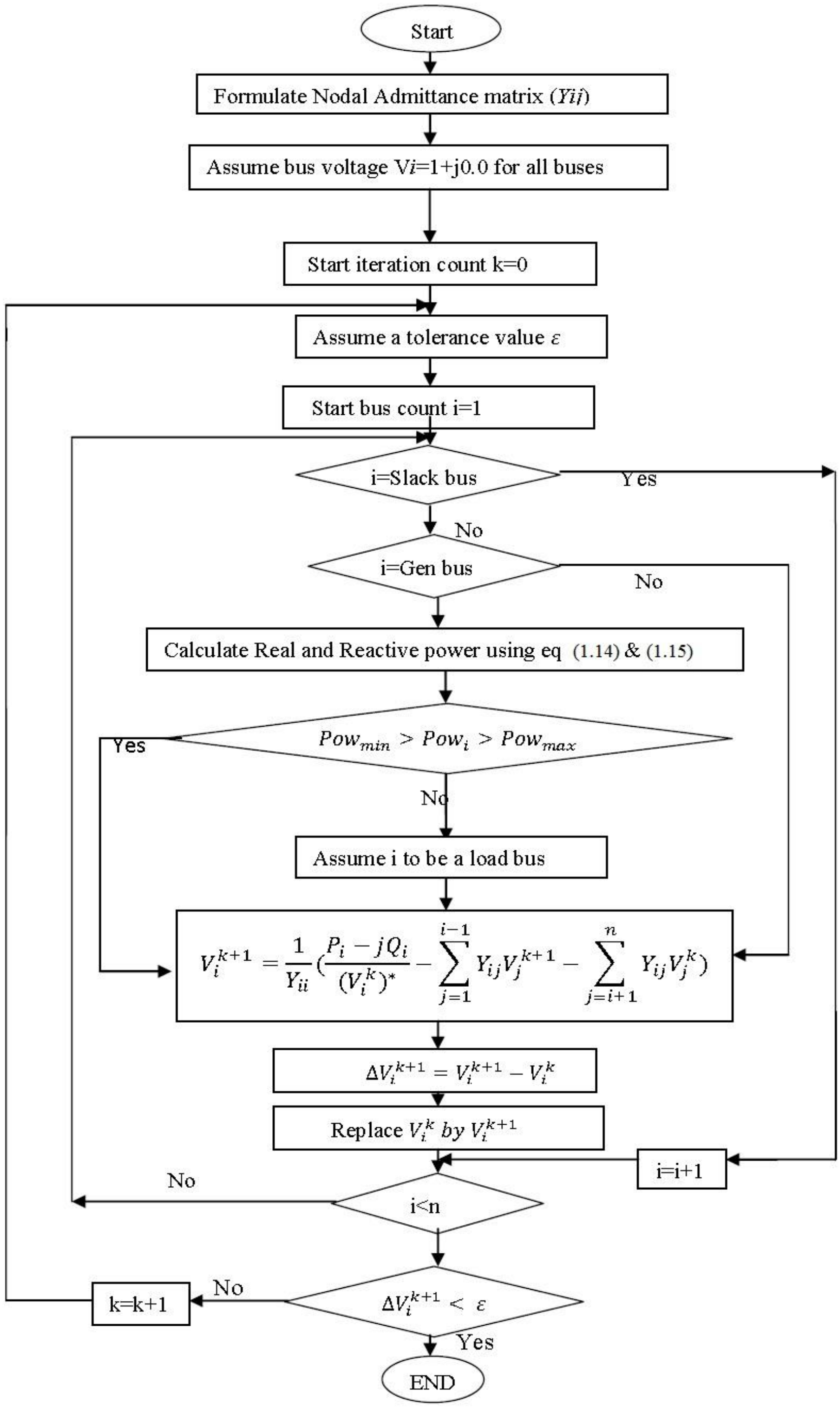

Figure 1.3: Flow Chart for load flow solution using Newton-Raphson method

1.8 Conclusion

In this chapter we had seen a brief survey of the necessity of calculating the power flow, in which the calculation of the power flow has been formulated, and it has been said that this problem can’t be solved easily by the hand Because of the plurality of variables And it was proposed to look for results of this problem using numerical methods.

We have said that there exist several numerical methods for the calculation of power flow, and this problem has been formulated by the two most usable methods, the method of Gauss-Seidel and that of Newton-Raphson to continue our work to study the problem of the power flow

Chapter 2

Applications of power flow Analysis in Excel (VBA)

2.1 Introduction

Power flow analysis is the most important and essential approach to investigating problems in power system operating and planning. Based on a specified generating state and transmission network structure, Power flow analysis solves the steady operation state with node voltages and branch power flow in the power system. Load flow analysis can provide a balanced steady operation state of the power system, without considering system transient processes. Hence, the mathematic model of load flow problem is a nonlinear algebraic equation system without differential equations.**[XYM 08]**

Using digital computers to calculate Power flow started from the middle of the 1950s. Since then, a variety of methods has been used in load flow calculation. The Development of these methods is mainly led by the basic requirements of load flow Calculation.**[XYM 08]**

In this chapter, we intend to talk intensively about the (GUI) Graphical User Interface and how to deal with it. We are talking in detail about a program that uses the Power flow analysis built in VBA Excel and a method of generalization with input and output based on (Gauss-Sidel, Newton-Rafson), And finishing by giving a main conclusion to this chapter.

2.2 The Concept of VBA

VBA stands for Visual Basic for Applications an event-driven programming language from Microsoft that is now predominately used with Microsoft office applications such as MS-Excel, MS-Word, and MS-Access.

It helps techies to build customized applications and solutions to enhance the capabilities of those applications. The advantage of this facility is that you NEED NOT have visual basic installed on our PC, however, installing Office will implicitly help in achieving the purpose.

You can use VBA in all office versions, right from MS-Office 97 to MS-Office 2013 and also with any of the latest versions available. Among VBA, Excel VBA is the most popular. The advantage of using VBA is that you can build very powerful tools in MS Excel using linear programming. **[MKR 12]**

2.3 Design Features and data management

We tried to give higher importance to user-friendliness and IEEE data standards in the design and development of this tool. VBA is used to implement the algorithms. The details of GUI, data input and output; design and developmental platforms are provided in the sections below.

2.3.1 User-friendly Interface

The MS Excel is designed in such a way to provide information on different sheets to minimize the burden of understanding and also to provide clarity in presentation of the information. The first worksheet provides a single menu wherein users can make necessary choices on what is required. Based on the selection, user is taken automatically to a separate sheet for that specific selected task and then user can come back to the front sheet with the help of a hyperlink. A screen shot of the first sheet is provided below.

Figure 2.1: Graphical User Interface(GUI)

As can be seen in the figure (2.1), users can choose to create a new system manually using an interactive interface or can import from an existing file. Once the data is ready, user can select a specific study either AC or DC load flow. When AC load flow is selected, the user is presented with another menu as shown below. If the user wants all the studies to be done automatically, then 'Compare AC Method' can be chosen to so that the application does all the studies and then provides exhaustive information on all studies that includes both numerical data and graphical information with comparison. Figure (2.2) shows the user screen for setting up study parameters for the iterative methods.

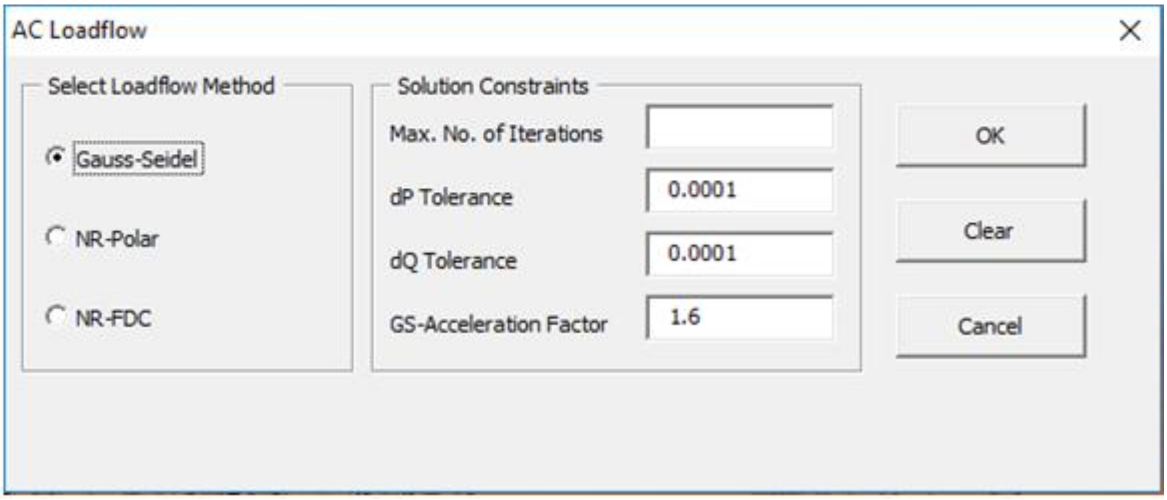

Figure 2.2: AC Load Flow Form

2.3.2 Data input and output

As stated earlier, the system data can be provided manually or from an existing file. The application is designed to be fully compliant with IEEE Common Format for Exchange of Solved Load Flow Data, which makes the data transfers from one standard source to another. The input data consists of bus data, data and study parameters etc. For the implementation of logic, a specific set of numerical codes are provided to different types of buses as per the IEEE standards. Table 2.1 provides the details of bus codes and types.

Table 2.1: Bus Types and Codes

Bus Code	Bus Type Description
0	Load Bus
1	Generator Bus
2	Regulated Generator Bus
3	Slack/Swing Bus

For manual entry of the bus data, users are provided with an easy interface as shown in figure 2-3.

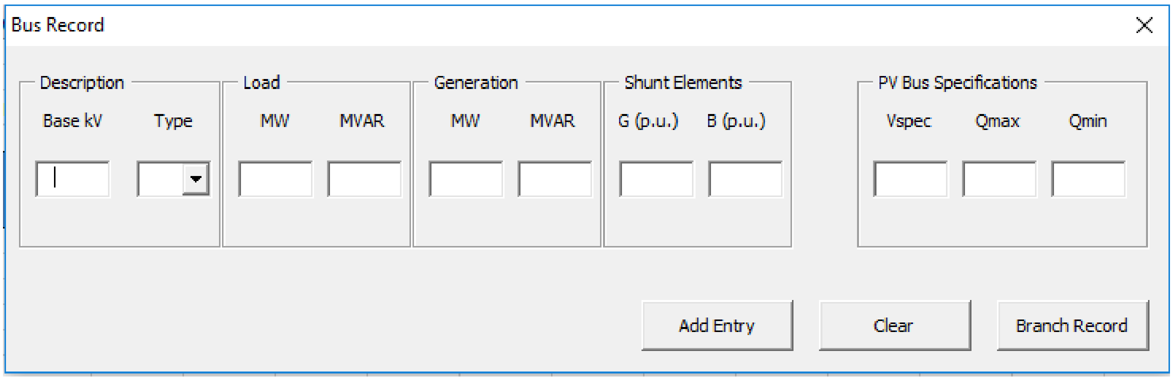

Figure 2.3: Bus Record Form

When the user completes the entering of the bus data, then the application presents the same in a separate sheet named 'Bus_Data'. The input bus data for IEEE 14 bus is shown in figure 2.4.

LOAD FLOW DATA 19-08-1993 1962 IEEE 14 Bus Test Case Back to CoverPage

MVA Base 100

BUS DATA FOLLOWS 14 Items Clear Bus Data Save CaseData

Bus Id.	Bus Name	Nominal kV	Bus Area	Bus Zone	Bus Type	|V| (p.u.)	δ (deg.)	P_Load (MW)	Q_Load (MVAR)	P_Gen (MW)	Q_Gen (MVAR)	Base (kV)	Generator Specifications Vspec (p.u.)	Q_Max. (MVAR)	Q_Min. (MVAR)	Shunt G (p.u.)	Shunt B (p.u.)	Seq. Number
1	Bus1	HV	1	1	3	1.06	0	0	0	0	0	0	1.06	0	0	0	0	1
2	Bus2	HV	1	1	2	1.045	0	21.7	12.7	40	0	0	1.045	50	-40	0	0	2
3	Bus3	HV	1	1	2	1.01	0	94.2	19	0	0	0	1.01	40	0	0	0	3
4	Bus4	HV	1	1	0	1	0	47.8	-3.9	0	0	0	1	0	0	0	0	4
5	Bus5	HV	1	1	0	1	0	7.6	1.6	0	0	0	1	0	0	0	0	5
6	Bus6	LV	1	1	2	1.07	0	11.2	7.5	0	0	0	1.07	24	-6	0	0	6
7	Bus7	ZV	1	1	0	1	0	0	0	0	0	0	1	0	0	0	0	7
8	Bus8	TV	1	1	2	1.09	0	0	0	0	0	0	1.09	24	-6	0	0	8
9	Bus9	LV	1	1	0	1	0	29.5	16.6	0	0	0	1	0	0	0	0.19	9
10	Bus10	LV	1	1	0	1	0	9	5.8	0	0	0	1	0	0	0	0	10
11	Bus11	LV	1	1	0	1	0	3.5	1.8	0	0	0	1	0	0	0	0	11
12	Bus12	LV	1	1	0	1	0	6.1	1.6	0	0	0	1	0	0	0	0	12
13	Bus13	LV	1	1	0	1	0	13.5	5.8	0	0	0	1	0	0	0	0	13
14	Bus14	LV	1	1	0	1	0	14.9	5	0	0	0	1	0	0	0	0	14

Bus Type	Description
0	Load Bus
1	Generator Bus
2	Regulated Generator
3	Slack/Swing Bus

Figure 2.4: Bus Data for the IEEE 14-Bus Test Case

Similarly the numerical codes are attached to different types of sections. A complete list of different section codes and types is provided in Table 2.2. It can be seen that power transformers are modelled with all their control elements and configurations. Even the single and double lines are represented by circuit numbers as per the IEEE specification. Figure 2.5 shows the user interface screen for collecting the branch information. **[MKR 12]**

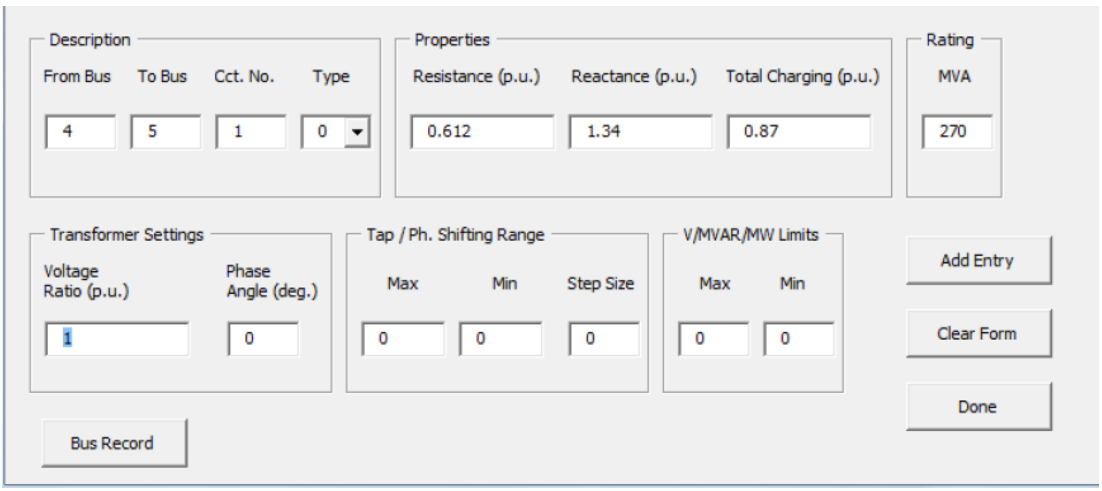

Figure 2.5: Branch Record Form

Table 2.2: Section Types and Codes

Section Code	Section Type Description
0	Transmission Line
Transformer	
1	Fixed Voltage Ratio and/or Fixed Phase Angle
2	Fixed Phase Angle and Variable Voltage Ratio with Voltage Control
3	Fixed Phase Angle and Variable Voltage Ratio with MVAR Control
4	Fixed Voltage Ratio and Variable Phase Angle with MW Control
Side No	**Description**
0	The controlled bus is one of the t/f terminals
1	The remote controlled bus is near the tap side
2	The remote controlled bus is near the impedance side
Circuit #	Description
1	Single Line
2 to 9	Used for Numbering of Parallel Lines

When the user completes the entering of the branch data, then the application presents the same in a separate sheet named ‘Branch_Data’.

2.4 Design Implementation and Programming

The design of the application is implemented using VBA with interactive GUI for data manipulation and to undertake computation of the load flow problem with the four different methods. The following sections provide information on the implementation of the design process

2.4.1GUI and Form Design

The built-in 'Microsoft Visual Basic Editor' of the MS Excel is used to develop the forms for the users to input data and make selections. To reduce the complexity in operating this application only five forms are designed. Figure 2.6 shows a screen shot of the built-in editor along with one of the forms that was designed

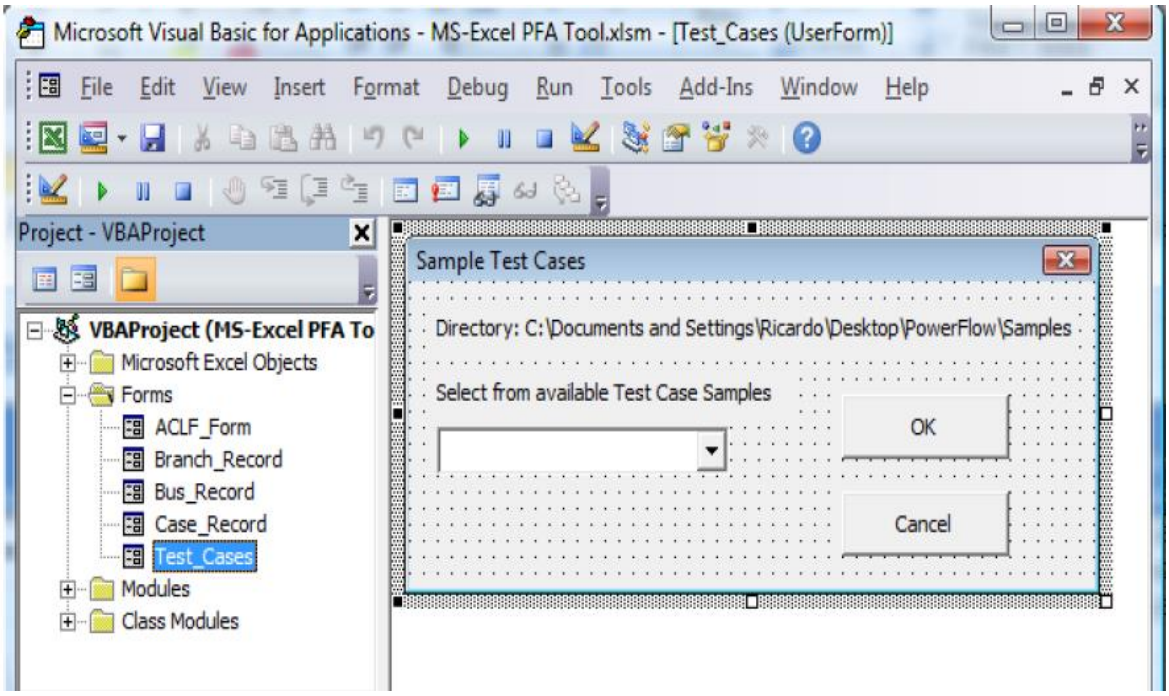

Figure 2.6: Typical VBA User Form

2.4.2Modular Codin

The source code is divided into several modules, functions and macros. A VBA module consists of different functions and macros. Then a macro is a set of commands and functions to do a specific task and can be called, repeatedly, whenever required to perform that specific task. This ensures the modularity of the source code and thus source code becomes re-usable resulting in higher productivity in developmental process. The data flow through different major modules in this application is shown in the figure 2.7.

2.5 Source code development

As stated already, the source code consists of eleven modules and a single class module. Table 2.3 provides information of a few selected modules. A special module is dedicated to contain all the smaller (auxiliary) functions that were common to the power flow methods as well as those used for unit testing. These functions include subroutines - print_Array (A, lngt); print_Matrix(M,nrow, ncol); clear_results; to rect; flat_start; GS_soln_cond;NR_soln_cond; calc_mismatch; aclf_usrfrm. **[MKR 12]**

For instance, the function 'flat_start' is used to set initial estimates prior to a power flow study employing any one the methods. Where given, voltage magnitudes are set to those specified else they set to 1. All voltage angles are set to zero. The function 'NR_soln_cond' reads the solution conditions for the Newton Raphson and Fast Decoupled methods from their corresponding results worksheet. If no conditions are provided, defaults values are set. The defaults are the same as those stated for the GS_soln_cond. (less an acceleration factor).

The function 'calc_mismatch' computes the differences in real power, for all buses except slack bus, and reactive power, for all load buses, between specified values and values calculated using updated voltages. This routine is also used to perform convergence checks.

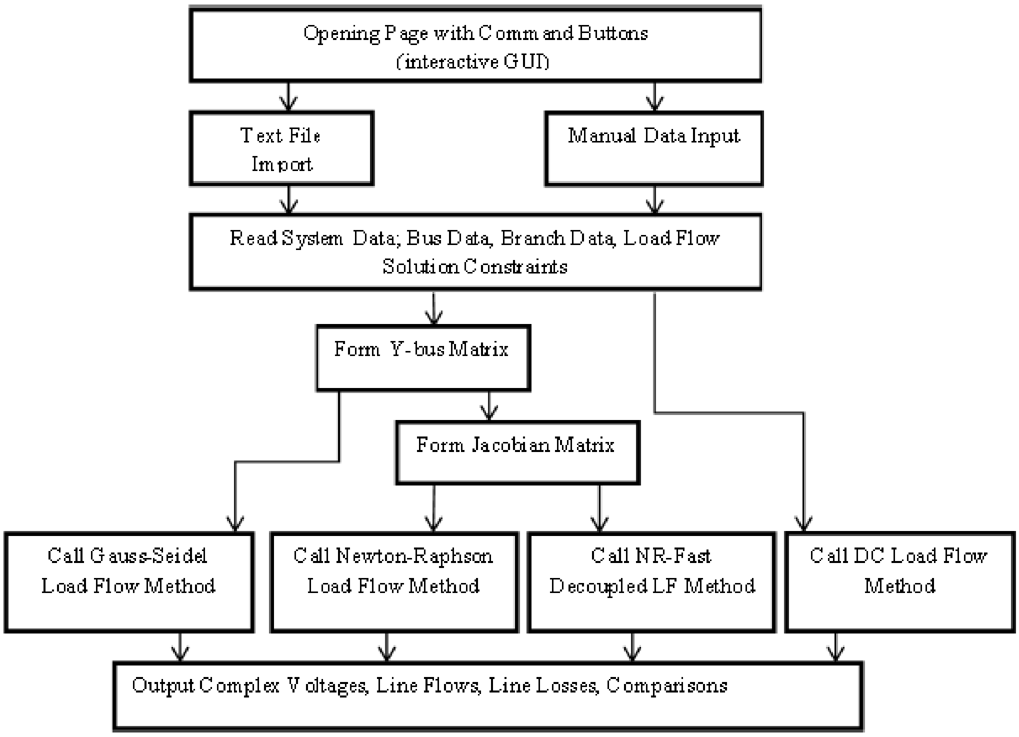

Figure 2.7: Data Flow Diagram

C Timer Class Module

For the purpose of comparisons, it was necessary to include within each implemented power flow algorithm provision for timing. With reference to the chosen criteria, the required measurements were the time taken per iteration and that of the total time for the solution, regardless of whether convergence was attained or not.

Since the time taken per iteration to perform a load-flow, on relatively smaller power systems is in the order of milliseconds, the resolution of the built-in vba code timer was insufficient. Instead, a class module was implemented using the Query Performance Counter and used to determine the time taken for computations.

Table 2.3: Modules, Subroutines and their descriptions

Module Name and Subroutines	**Description**
Import CaseData Subroutines: Import_CaseData; Enter_CaseData	This module consists of two functions to facilitate data input. First function allows importing from IEEE common data format. The implementation of the method is centered on MS-Excel's Open Text workbook function. The second function accepts bus and branch records entered using GUI and transfers into the respective worksheets of Bus_Data and Branch_Data.
BusData Subroutine:get_BusData; clear_BusData	This module reads data from Bus_Data worksheet by parsing each record in turn and enters them into arrays for use by other modules.
Gauss Seidel; Subroutines:PF_gs; print_GS_Results;	This module performs a Gauss-Seidel Load flow, using rectangular coordinates. Output along with numerical results at different intermediate stages is transferred to GS_Results worksheet.
LineFlows Subroutines; calc_lineflows	This module calculates the real and reactive power flows through lines and transformers, using the complex voltages from the results of the different load flow methods.

2.6 Conclusion

A successful case of design, development and implementation of Microsoft Excel Based Power System Load Flow tool has been presented. Four popular load flow Algorithms have been implemented. The accuracy and effectiveness of tool is Verified and benchmarked with existing standard software. This tool can Significantly enhance classroom teaching experience and also learning experience; And hence provides an economic and alternative solution for power system load Flow analysis.

Chapter 3

Comparative Analysis

3.1 Introduction

In the previous chapter we have seen the methods to analysis power flow, their types and Its basics. We will now take this study as a reference point for applying it to a model of power systems, using Excel and MATLAB In an analytical study of a set of models power systems, comparing and interpreting the results and drawing conclusions .

3.2 Working strategy

In this work plan, we will study the power flow this study will be on Test model (IEEE-14) using the MATLAB program to compare the results Accredited in Newton-Raphson and Gauss-seidel The study will be based on the extraction and comparison of three results for me confirmed by the validity and effectiveness of the program Excel and it is Is represented in

- voltage |V| end voltage Angle δ
- Line Flows P,Q
- Losses ΔP,ΔQ

Easy and simple way to work without any complexity in the comparison procedure and work plan outlined in detail in the Figure 3.1

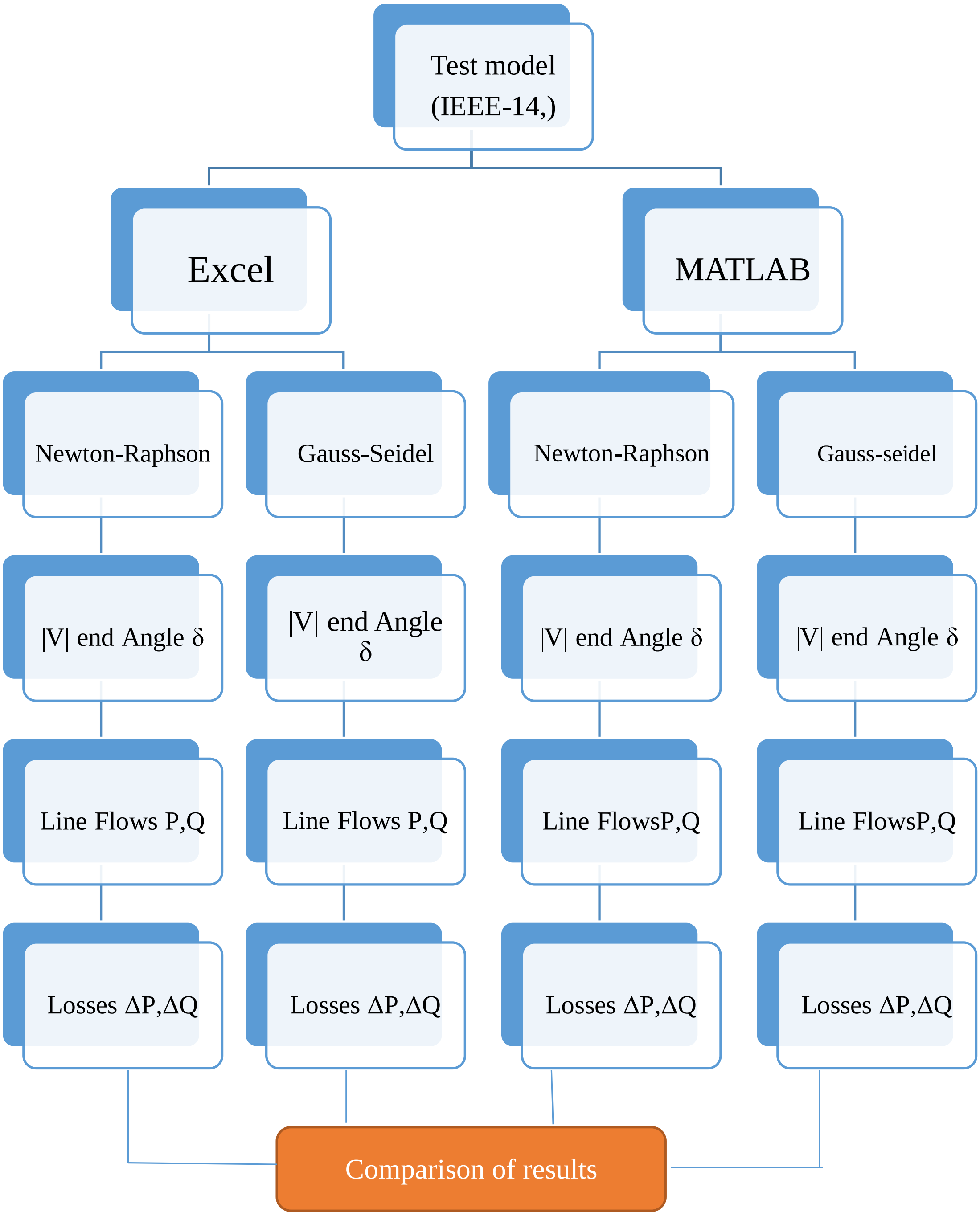

Figure 3.1: Working strategy

3.3 Test system

For the application of our work, we chose a model of the power systems IEEE-14, the choice of this model was carried out according to two main reasons:

1) A suitable models that provides us with a correct data base. Again thanks to this average number of JB's that makes this work applicable on either larger or lower sizes.

2) A standard models applicable for different studies, which allowed us to compare our results of work with other methods and procedure.

A database of our network is illustrated in the Appendix.

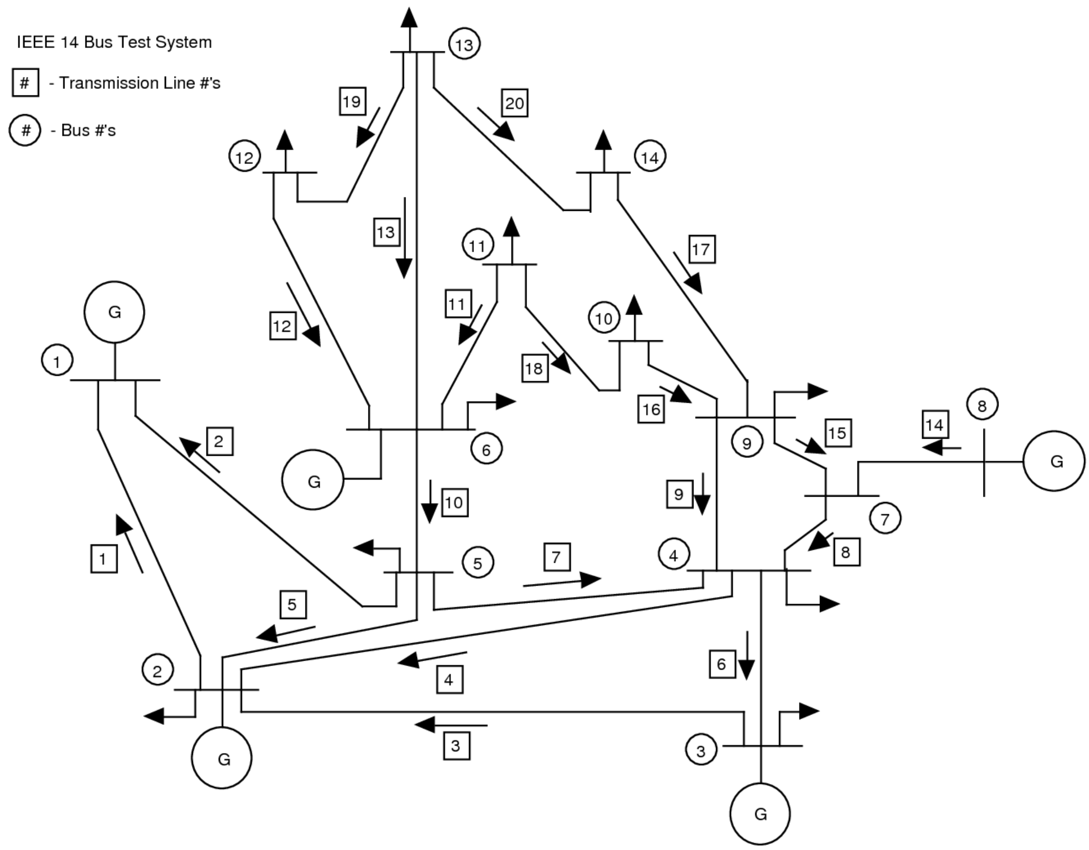

Figure 3.2: Single-line diagram of the IEEE14 Bus power system.

3.4 Applications And Performance Analysis

3.4.1 power system IEEE14

The IEEE-14 bus system in Excel and MATLAB and is used to find the power flow using the following methods

a) Gauss-Seidel method

b) Newton-Raphson method

and the time taken to get the solution in these methods is calculated

The details of the IEEE-14 bus system are :

- Number of buses – 14
- Number of generators – 5
- Number of transmission lines – 20
- Number of transformers – 3

The buses with generators connected to it are called the generators buses or PV buses.

The buses with loads connected to it are called the load buses or PQ buses.

For this system Bus 1 is chosen as the slack bus.

3.4.1.1 Results Gauss-Seidel method

a) Tensions |V| end voltages Angle δ

We start first with the voltage |V| end voltage Angel δ . After the program execution with the previous indicated parameters, we obtain these coming results**:**

Table 3.1: Complex Bus Tensions comparison Results Gauss-Seidel

Bus (N°)	Excel		MATLAB	
	|V|	Angle δ	|V|	Angle δ
1	1.06	0	1.0600	0
2	1.045	-4.987	1.0450	-4.9873
3	1.01	-12.741	1.0100	-12.7424
4	1.014	-10.255	1.0142	-10.2564
5	1.017	-8.764	1.0172	-8.7646
6	1.07	-14.416	1.0700	-14.4176
7	1.05	-13.25	1.0503	-13.2518

8	**1.09**	**-13.25**	**1.0900**	**-13.2518**
9	**1.034**	**-14.831**	**1.0337**	**-14.8322**
10	**1.033**	**-15.04**	**1.0326**	**-15.0411**
11	**1.047**	**-14.846**	**1.0475**	**-14.8477**
12	**1.054**	**-15.267**	**1.0535**	**-15.2683**
13	**1.047**	**-15.307**	**1.0471**	**-15.3080**
14	**1.021**	**-16.063**	**1.0213**	**-16.0646**

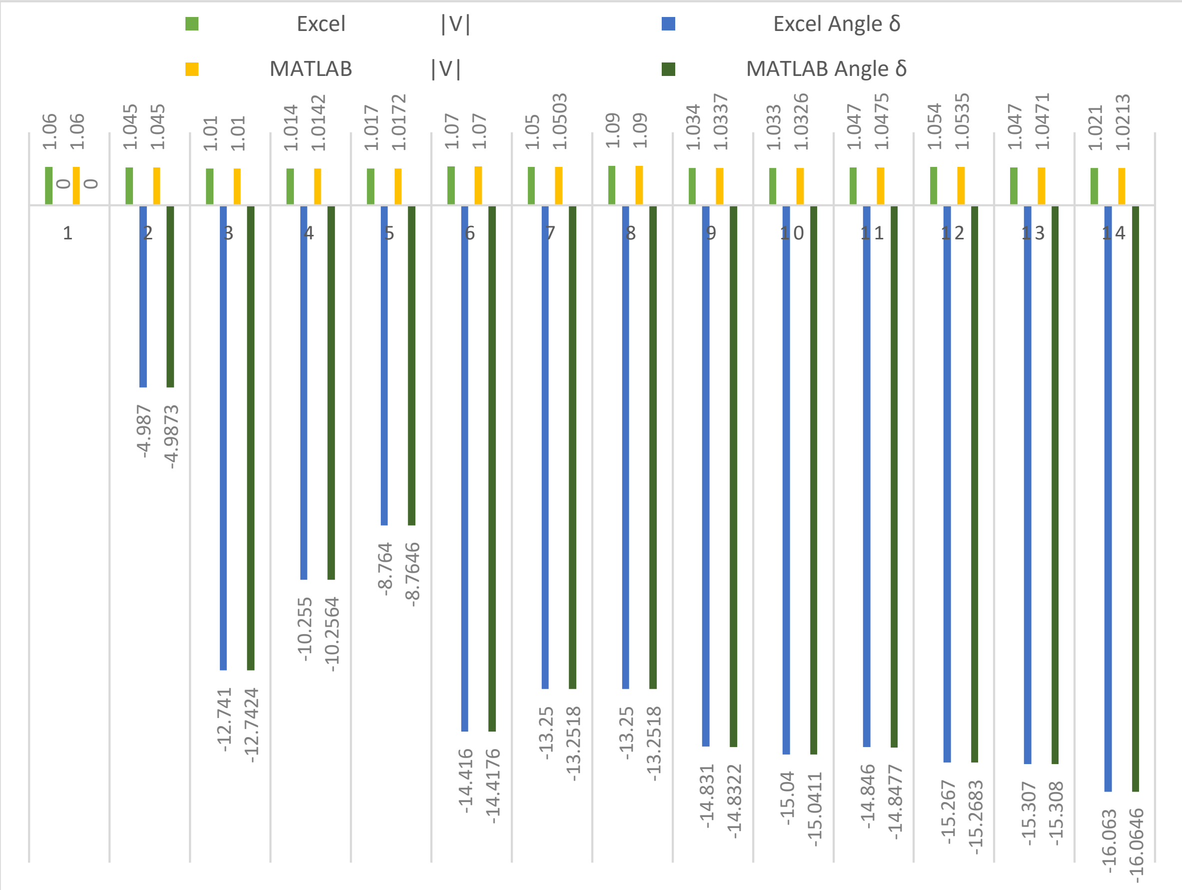

Figure3.3: Complex Bus voltage comparison Results Gauss-Seidel

Figure 3.4: Verification of voltage constraint.

b)Discussion and Interpretation

The results of the study of the power flow obtained by the Gauss-Seidel algorithm are grouped in Table (3.1) and Figur (3.3).Note that the convergence is After 150 iterations, which makes this method a bit slow although it needs a small calculation time per iteration. In addition, convergence is not always guaranteed, it depends strongly on the initial conditions. For this, this method is less used for the analysis of more complex networks where it requires a large number of iterations and convergence is not necessarily assured.

According to the figures (3.4), we can say that the Results obtained by the Requirements imposed by the PF, in our grid

Allowed range:

$$Vi\ min \leq Vi \leq Vi\ max \qquad (3.1)$$

Note:

We must keep the respect of the constraints imposed to the grid is ensured by the PF for the studied cases in this thesis

c)Line Flows P,Q and Losses ΔP,ΔQ

the results of the power flow of an power systems, the Table (3.2) Table(3.3) More clearly in Figure(3.5) of the power flow of an IEEE network at 14 is illustrated on the diagram, where the distribution of the active power in the lines is represented by the Reactive power. refer to active and reactive losses in the line.in Both a program in Gauss-Seidel

Table 3.2: Line Flows and Losses in Excel Results Gauss-Seidel

(N°)	Line Details		From-To Flow		To-From Flow		Losses	
	From Bus	To Bus	P (MW)	Q (MVAR)	P (MW)	Q (MVAR)	ΔP(MW)	ΔQ(MVAR)
1	1	2	157.01	-20.43	-152.7	27.73	4.3	7.29
2	1	5	75.52	4.91	-72.75	1.22	2.77	6.13
3	2	3	73.35	3.55	-71.02	1.64	2.33	5.19
4	2	4	55.97	0.47	-54.3	0.99	1.67	1.46
5	2	5	41.7	2.46	-40.78	-3.35	0.92	-0.88
6	3	4	-23.18	6.49	23.57	-6.82	0.39	-0.32
7	4	5	-59.8	12.55	60.28	-11.02	0.48	1.53
8	4	7	26.62	-16.82	-26.62	18.83	0	2.02
9	4	9	15.04	-2.95	-15.04	4.22	0	1.27
10	5	6	42.54	-19.2	-42.54	24.5	0	5.3

11	6	11	8.16	8.23	-8.05	-8	0.11	0.23
12	6	12	8.03	3.09	-7.95	-2.93	0.08	0.17
13	6	13	18.26	9.64	-18.01	-9.15	0.25	0.49
14	7	8	0	-23.65	0	24.54	0	0.89
15	7	9	27.22	16.26	-27.22	-15.25	0	1
16	9	10	4.5	-0.28	-4.5	0.3	0.01	0.02
17	9	14	8.74	0.72	-8.65	-0.53	0.09	0.19
18	10	11	-4.5	-6.09	4.55	6.2	0.04	0.1
19	12	13	1.85	1.33	-1.84	-1.32	0.01	0.01
20	13	14	6.35	4.67	-6.25	-4.47	0.1	0.2
	Totals						**13.55**	**32.28**

Table 3.3: Line Flows and Losses in MATLAB Results Gauss-Seidel

(N°)	**Line Details**	**From-To Flow**			**To-From Flow**		**Losses**	
	From Bus	**To Bus**	**P (MW)**	**Q (MVAR)**	**P (MW)**	**Q (MVAR)**	**ΔP(MW)**	**ΔQ(MVAR)**
1	**1**	**2**	**157.03**	**-20.44**	**-152.7**	**27.73**	**4.3**	**7.30**
2	**1**	**5**	**75.52**	**4.71**	**-72.75**	**1.03**	**2.77**	**5.74**
3	**2**	**3**	**73.35**	**3.25**	**-71.02**	**1.37**	**2.33**	**4.62**
4	**2**	**4**	**55.97**	**0.36**	**-54.3**	**0.21**	**1.67**	**1.5**
5	**2**	**5**	**41.7**	**1.46**	**-40.78**	**-4.10**	**0.92**	**-2.34**
6	**3**	**4**	**-23.18**	**4.91**	**23.57**	**-8.41**	**0.39**	**-3.50**
7	**4**	**5**	**-59.81**	**10.80**	**60.29**	**-12.78**	**0.48**	**1.98**
8	**4**	**7**	**27.22**	**-18.94**	**-27.22**	**17.38**	**0**	**1.65**
9	**4**	**9**	**15.52**	**-4.95**	**-15.25**	**2.54**	**0**	**2.25**
10	**5**	**6**	**42.65**	**-22.93**	**-45.64**	**24.31**	**0**	**1.95**
11	**6**	**11**	**8.16**	**7.50**	**-8.05**	**-8.70**	**0.11**	**1.20**
12	**6**	**12**	**8.03**	**2.36**	**-7.95**	**-3.93**	**0.08**	**1.28**
13	**6**	**13**	**18.26**	**8.90**	**-18.01**	**-9.85**	**0.25**	**0.95**
14	**7**	**8**	**0**	**-23.65**	**0**	**24.54**	**0**	**0.89**
15	**7**	**9**	**27.22**	**16.26**	**-27.22**	**-15.25**	**0**	**1**
16	**9**	**10**	**4.5**	**-0.28**	**-4.5**	**0.03**	**0.01**	**0.02**
17	**9**	**14**	**8.74**	**0.72**	**-8.65**	**-0.53**	**0.09**	**0.19**

18	10	11	-4.5	-6.10	4.55	6.2	0.04	0.1
19	12	13	1.85	1.33	-1.84	-1.32	0.01	0.01
20	13	14	6.35	4.67	-6.25	-4.47	0.1	0.2
	Totals						13.55	26.99

Figure 3.5: Losses in MATLAB and Excel Gauss-Seidel

d) Comparison

In comparing the results of active power Losses and reactive power Losses We find convergent results in relation to active power Losses but for reactive power Losses Note differences in each (2-5) (3-4) (5-6)(6-11) More illustrated in Table (3.4)

Table 3. 4 Differences between MATLAB and Excel Gauss-Seidel in Losses

		Excel		MATLAB	
(N°)	**Line**	**Losses ΔP(MW)**	**Losses ΔQ (MVAR)**	**Losses ΔP (MW)**	**Losses ΔQ(MVAR)**
5	**(2-5)**	**0.92**	**-0.88**	**0.92**	**-2.34**
6	**(3-4)**	**0.39**	**-0.32**	**0.39**	**-3.5**
10	**(5-6)**	**0**	**5.3**	**0**	**1.95**
11	**(6-11)**	**0.11**	**0.23**	**0.11**	**1.2**

e) Discussion and Interpretation

According to the figures (3.5) Table (3.4) , we can say that the Results obtained by the Requirements imposed by the PF, in our grid

Allowed range:

$$Qi\ min \leq Qi \leq Qi\ max \tag{3.2}$$

This is why the differences in the reactive power Losses In a program Excel

3.4.1.2 Newton-Raphson method

a)voltage | |V| end Angle δ

We start first with the voltage |V| end voltage Angel δ . After the program execution with the previous indicated parameters, we obtain these coming results**:**

Table 3.5: Complex Bus voltage comparison Newton-Raphson

Bus (N°)	**Excel**		**MATLAB**	
	|V|	**Angle δ**	**|V|**	**Angle δ**
1	**1.06**	**0**	**1.0600**	**0**
2	**1.045**	**-4.987**	**1.0450**	**-4.9873**

3	1.01	-12.742	1.0100	-12.7424
4	1.014	-10.256	1.0142	-10.2564
5	1.017	-8.765	1.0172	-8.7646
6	1.07	-14.418	1.0700	-14.4176
7	1.05	-13.252	1.0503	-13.2518
8	1.09	-13.252	1.0900	-13.2518
9	1.034	-14.832	1.0337	-14.8322
10	1.033	-15.041	1.0326	-15.0411
11	1.047	-14.848	1.0475	-14.8477
12	1.054	-15.268	1.0535	-15.2683
13	1.047	-15.308	1.0471	-15.3080
14	1.021	-16.065	1.0213	-16.0646

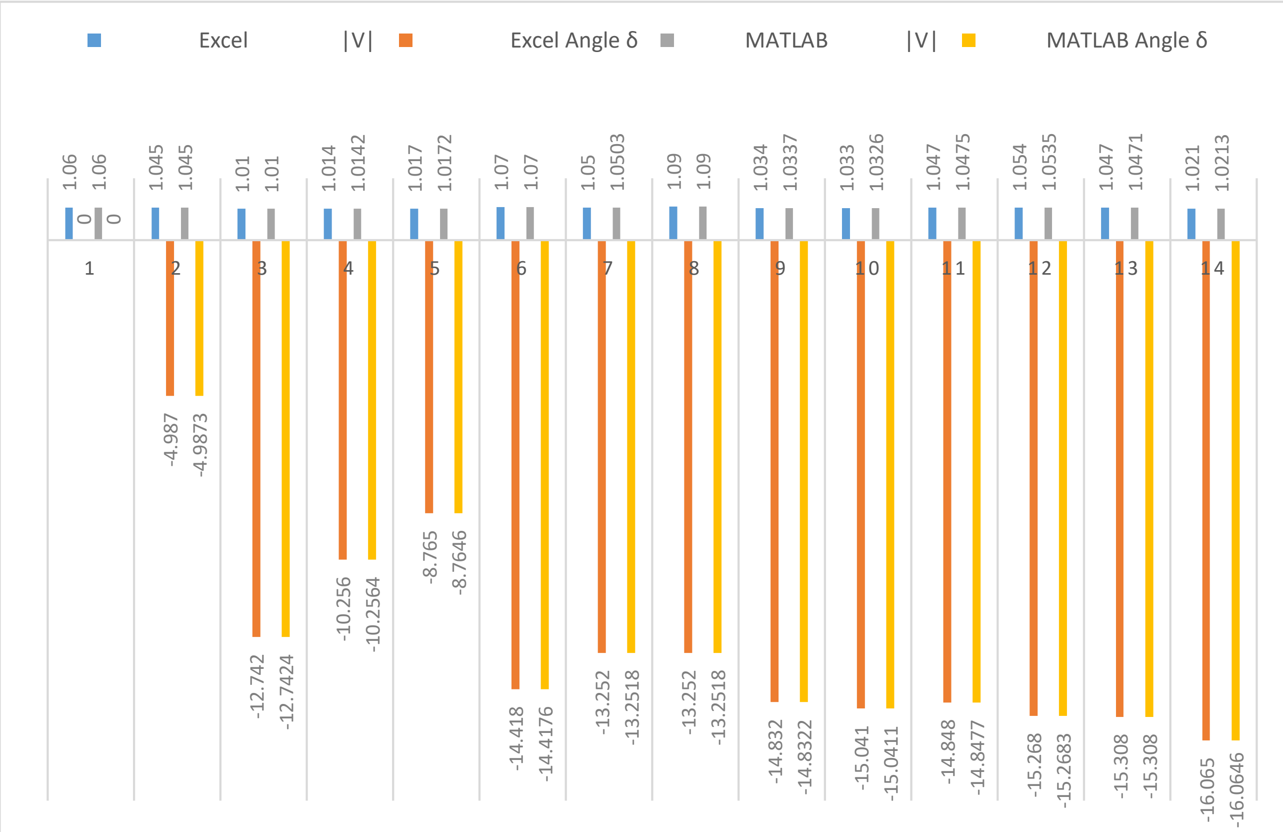

Figure 3.6: Complex Bus voltage comparison Results Newton-Raphson

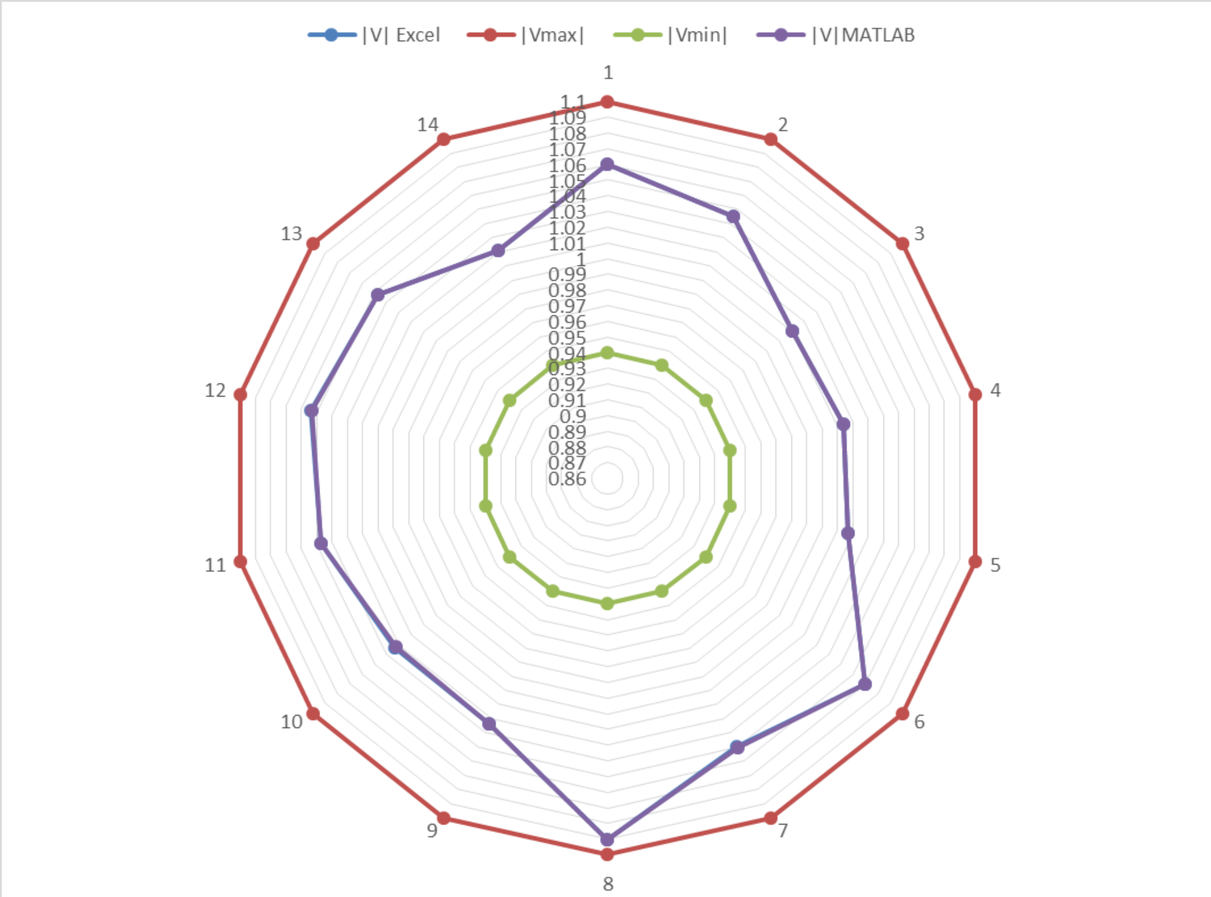

Figure 3.7: Verification of voltage constraint.

b) Discussion and Interpretation

By applying the Newton-Raphson algorithm to calculate the load distribution on an IEEE 14 power systems , the results of table (3.5) and Figure (3.6) are obtained. It is noted that the number of iterations necessary to satisfy the convergence condition is smaller than that of the Gauss-Seidel method. The same results as those of the Gauss-Seidel algorithm are obtained after only 50 iterations. This result is expected, since the convergence of the Newton-Raphson method is quadratic. Also, the convergence of this method depends on the initial conditions but to a lesser degree than that of Gauss-Seidel. All this makes the Newton-Raphson method the most appropriate for analyzing the power flow of an electrical network. However, this algorithm requires an important storage space especially for large networks where it becomes unusable due to insufficient memory.

According to the figures (3.7), we can say that the Results obtained by the Requirements imposed by the PF, in our grid

Allowed range:

$$Vi\ min \leq Vi \leq Vi\ max$$

Note:

We must keep the respect of the constraints imposed to the grid is ensured by the PF for the studied cases in this thesis

c)Line Flows P,Q and Losses ΔP,ΔQ

The results of the power flow of an power systems, the Table 3.6 Table 3.7 More clearly in Figure 3.8 of the power flow of an IEEE network at 14 is illustrated on the diagram, where the distribution of the active power in the lines is represented by the Reactive power. refer to active and reactive losses in the line in Both a program in Newton-Raphson

Table 3.6: Line Flows and Losses in Excel Newton-Raphson

(N°)	Line Details		From-To Flow		To-From Flow		Losses	
	From Bus	To Bus	P (MW)	Q (MVAR)	P (MW)	Q (MVAR)	ΔP(MW)	ΔQ(MVAR)
1	1	2	157.01	-20.43	-152.7	27.73	4.3	7.29
2	1	5	75.52	4.91	-72.75	1.22	2.77	6.13
3	2	3	73.35	3.55	-71.02	1.64	2.33	5.19
4	2	4	55.97	0.47	-54.3	0.99	1.67	1.46
5	2	5	41.7	2.46	-40.78	-3.35	0.92	-0.88
6	3	4	-23.18	6.49	23.57	-6.82	0.39	-0.32
7	4	5	-59.8	12.55	60.28	-11.02	0.48	1.53
8	4	7	26.62	-16.82	-26.62	18.83	0	2.02
9	4	9	15.04	-2.95	-15.04	4.22	0	1.27
10	5	6	42.54	-19.2	-42.54	24.5	0	5.3
11	6	11	8.16	8.23	-8.05	-8	0.11	0.23
12	6	12	8.03	3.09	-7.95	-2.93	0.08	0.17

13	6	13	18.26	9.64	-18.01	-9.15	0.25	0.49
14	7	8	0	-23.65	0	24.54	0	0.89
15	7	9	27.22	16.26	-27.22	-15.25	0	1
16	9	10	4.5	-0.28	-4.5	0.3	0.01	0.02
17	9	14	8.74	0.72	-8.65	-0.53	0.09	0.19
18	10	11	-4.5	-6.09	4.55	6.2	0.04	0.1
19	12	13	1.85	1.33	-1.84	-1.32	0.01	0.01
20	13	14	6.35	4.67	-6.25	-4.47	0.1	0.2
	Totals						13.45	32.29

Table 3.7: Line Flows and Losses in MATLAB Newton-Raphson

(N°)	Line Details		From-To Flow		To-From Flow		Losses	
	From Bus	To Bus	P (MW)	Q (MVAR)	P (MW)	Q (MVAR)	ΔP(MW)	ΔQ(MVAR)
1	1	2	156.974	-20.426	-152.70	27.725	4.269	7.299
2	1	5	75.439	4.520	-72.676	1.568	2.763	6.088
3	2	3	73.366	3.544	-71.035	1.652	2.331	5.196
4	2	4	56.082	-0.284	-54.406	1.398	1.676	1.114
5	2	5	41.523	2.039	-40.616	-2.888	0.907	-0.849
6	3	4	23.573	-7.396	-23.191	4.822	0.382	-2.574
7	4	5	61.495	-12.242	-60.991	12.510	0.504	0.268
8	4	7	27.973	-9.907	-27.973	11.617	0	1.71
9	4	9	16.003	-0.326	-16.003	1.625	0	1.299
10	5	6	44.278	11.816	-44.278	-7.380	0	4.436
11	6	11	7.459	4.217	-7.398	-4.090	0.061	0.127
12	6	12	7.823	2.532	-7.751	-2.381	0.072	0.151
13	6	13	17.825	7.496	-17.609	-7.071	0.216	0.425
14	7	8	0.047	-18.362	-0.047	18.891	0	0.529
15	7	9	27.946	6.792	-27.946	-5.981	0	0.811
16	9	10	5.156	3.625	-5.144	-3.595	0.012	0.03
17	9	14	9.322	3.203	-9.210	-2.966	0.112	0.237
18	10	11	3.891	2.320	-3.76	-2.285	0.131	0.035
19	12	13	1.656	0.855	-1.649	-0.848	0.007	0.007

20	13	14	5.719	2.192	-5.661	-2.073	0.058	0.119
	Totals						13.443	26.339

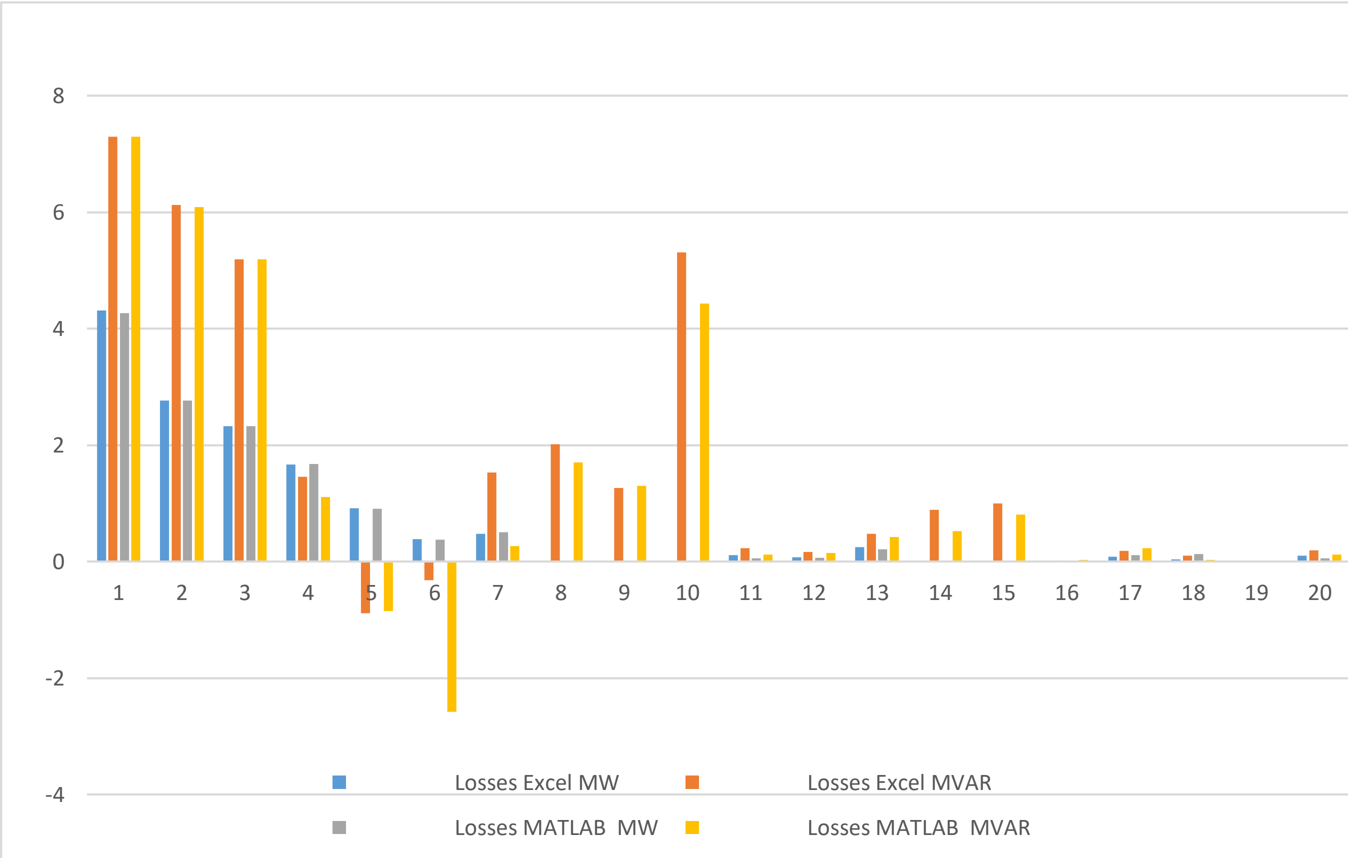

Figure3.8 : Line Flows in MATLAB and Excel Newton-Raphson

d) Comparison

In comparing the results of active power Losses and reactive power Losses We find convergent results in relation to active power Losses but for reactive power Losses Note differences in each (2-5) (3-4) (5-6)(6-11) More illustrated in Table (3.8)

Table 3.8 Differences between MATLAB and Excel Newton-Raphson

		Excel		MATLAB	
(N°)	Line	Losses ΔP(MW)	Losses ΔQ (MVAR)	Losses ΔP (MW)	Losses ΔQ(MVAR)
5	(2-5)	2.33	5.19	2.331	5.196
6	(3-4)	0.39	-0.32	0.907	-2.574
10	(5-6)	0	5.3	0	4.436
11	(6-11)	0.11	0.23	0.061	0.127

e) Discussion and Interpretation

According to the figures (3.8) Table (3.8), we can say that the Results obtained by the Requirements imposed by the PF, in our grid

Allowed range:

$$Qi\ min \leq Qi \leq Qi\ max \tag{3.2}$$

Same thing for the generated powers:

$$Pgmin \leq Pg \leq Pgmax \tag{3.3}$$

This is why the differences in the reactive power Losses In a program Excel

f) Power Injected PI QI (Newton-Raphson)

In the previous comparisons we find that Newton and Raphson are the closest in the results of the Goss Seder from which we take the results of the injected power and compare them in the table (3.9). figures (3.9)

Table (3.9): Comparison Power Injected for the N-R method

Bus N°	MATLAB		Excel	
Power Injected	P I (pu)	Q I (pu)	P I (pu)	Q I (pu)
1	2.3259	-0.15196	2.325	-0.1553
2	0.183	0.35821	0.183	0.3421
3	-0.942	0.08299	-0.942	0.0813
4	-0.478	-0.04	-0.478	0.039
5	-0.076	-0.016	-0.076	-0.016
6	-0.112	0.1657	-0.112	0.141
7	0	0	0	0
8	0	0.24926	0	0.2454
9	-0.295	-0.166	-0.295	-0.166
10	-0.09	-0.058	-0.09	-0.058
11	-0.035	-0.018	-0.035	-0.018
12	-0.091	-0.016	-0.061	-0.016
13	0.135	-0.058	-0.135	-0.058
14	-0.149	-0.05	-0.149	-0.05

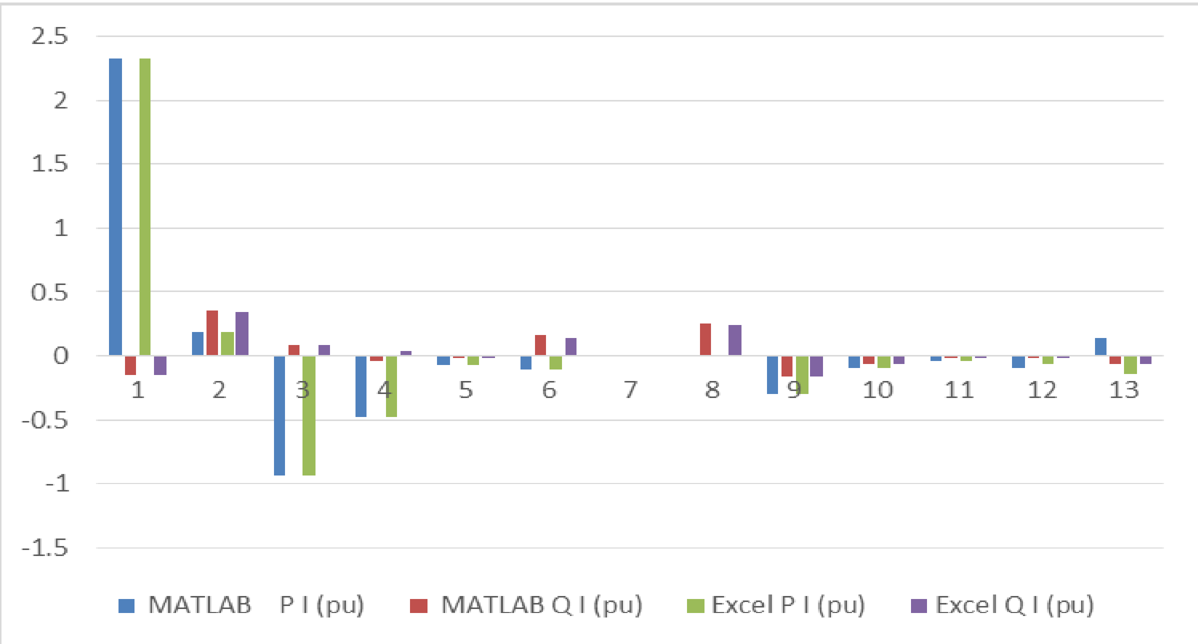

Figure3.9:Comparison Power Injected for the N-R method

g) Discussion and Interpretation

According to the figures (3.9) Table (3.9), we can say that the Results obtained by the Requirements imposed by the PF, in our grid

Allowed range:

$$Vi\ min \le Vi \le Vi\ max$$

$$Qi\ min \le Qi \le Qi\ max$$

Same thing for the generated powers:

$$Pgmin \le Pg \le Pgmax$$

3.5 Compare execution time

As a perspective those calculation they apply it on the laptop of characters i5-2430M , 4GB RAM In the both Program MATLAB and EXCEL by the same Number of Iteration and the result in the table.

Table (3.10): Execution time Performance Data of the load flow methods

METHOD	Number of Iterations	Total Solution Time (s)
N-R in Excel	**75**	**0.0048938**
N-R in MATLAB	**75**	**0.016**
G-S in Excel	**150**	**0.18093**
G-S in MATLAB	**150**	**0.110583**

Through the table (3.10), there's little difference between execution time in a method G-S and with excellence in implementation MATLAB and the difference is obvious and noticeable in the method N-R , at the time of execution in EXCEL

3.6 Conclusion

In this final chapter, we tried to do a comparative analysis between two methods N-R and G-S using Excel and MATLAB , by applying them on a grid of 14 Bus to see their efficiency on the system. Before doing that, we tried to deal with two main functions which are voltage |V| end voltage Angle δ and also Line Flows P,Q and Losses ΔP,ΔQ.

The Program Excel (vba) written has been satisfying results in achieving the goals set forth for a Power flow study, while maintaining the accuracy of the power flow calculation, It is worth mentioning that some problems in calculating power reactive the and so problems in programming though it keeps within the limits $Qi\ min \leq Qi \leq Qi\ max$ on the other hand the results were in both voltage |V| end voltage Angle δ and also Line Flows P and Losses ΔP Close and satisfactory Comparative With MATLAB.

Research has been done to conclude a numerical technique for a power flow to converge with less convergence time, tests were done under various conditions and Switching from Gauss-Seidel method to Newton-Raphson method was found to ensure less convergence time.

Finally A successful case of design, development and implementation of Microsoft Excel Based Power System Load Flow tool has been presented comparison was reasonable Reasonable results and less execution time .

General Conclusion & Perspectives

General Conclusion and Perspectives

The power flow study in a power system constitutes a study of paramount importance. The study reveals the electrical performance and power flows (real and reactive) for specified condition when the system is operating under steady state

In this thesis, a comparative study was conducted to verify the performance of the two methods on the power grid by taking the same parameters

The different methods are programmed in MATLAB software as reference and Excel as test subject taking into account the technical constraints imposed by the system, thanks to the PF algorithm (Newton-Raphson) and (Gauss-Seidel).

Research has been done to conclude a numerical technique for a power flow to converge with less convergence time, tests were done under various conditions and Switching from Gauss-Seidel method to Newton-Raphson method was found to ensure less convergence time. Gauss and Gauss-Seidel methods are good for small system where the computation complexity is less. Though Gauss and Gauss-Seidel methods require fewest numbers of arithmetic operations and less average time to complete iteration, for a large system there convergence time is slower compared to Newton-Raphson method.

To determine the effectiveness of the application for larger systems with higher number of buses, the three standard systems IEEE-14, IEEE-30, IEEE-57 bus systems have been studied and number of iterations have been determined. One major finding is that the built-in function for matrix inversion 'MINVERSE' of Microsoft Excel can handle matrices only up to size of 52x52 ,and don't combine with standards Jacobian matrix j=1,2,3….n .Which can't handle large systems.

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Appendix

Appendix

- 14 Bus power grid.

Bus data :

```
             1        2       3        4       5       6       7       8        9        10      11
%           |Bus  | Type  | Vsp  | delta  | PGi  | QGi  | PLi  | QLi  |  Qmin  | Qmax  |Shunt_C|
BusData    =[1       1      1.060    0      2.3259  -0.15196   0      0        0        0     0
              2       3      1.045    0        .40     0.48521    .217   .127     -.4      .5     0
              3       3      1.010    0         0      0.27299    .942   .190     -0       .4     0
              4       2      1.0      0         0      0          .478  -.039      0        0     0
              5       2      1.0      0         0      0          .076   .016      0        0     0
              6       3      1.070    0         0      0.2407     .112   .075     -.06     .24    0
              7       2      1.0      0         0      0           0.0    0.0      0        0     0
              8       3      1.090    0         0      0.24926     0.0    0.0     -.06     .24    0
              9       2      1.0      0         0      0           .295   .166      0       0     0
             10       2      1.0      0         0      0           .09    .058      0       0     0
             11       2      1.0      0         0      0           .035   .018      0       0     0
             12       2      1.0      0         0      0           .061   .016      0       0     0
             13       2      1.0      0         0      0           .135   .058      0       0     0
             14       2      1.0      0         0      0           .149   .05       0       0     0];
%*****************************************************************************************
```

Line data :

```
%           |  From |  To   |    R      |    X      |      ysh/2 |    TS     |
%           |  Bus  | Bus   |   pu      |   pu      |       pu   |    TAP    |
LineData    =[1       2        0.01938    0.05917     0.0264          1
               1       5        0.05403    0.22304     0.0246          1
               2       3        0.04699    0.19797     0.0219          1
               2       4        0.05811    0.17632     0.0170          1
               2       5        0.05695    0.17388     0.0173          1
               3       4        0.06701    0.17103     0.0064          1
               4       5        0.01335    0.04211     0.0             1
               4       7        0.0        0.20912     0.0          0.978
               4       9        0.0        0.55618     0.0          0.969
               5       6        0.0        0.25202     0.0          0.932
               6      11        0.09498    0.19890     0.0             1
               6      12        0.12291    0.25581     0.0             1
               6      13        0.06615    0.13027     0.0             1
               7       8        0.0        0.17615     0.0             1
               7       9        0.0        0.11001     0.0             1
               9      10        0.03181    0.08450     0.0             1
               9      14        0.12711    0.27038     0.0             1
              10      11        0.08205    0.19207     0.0             1
              12      13        0.22092    0.19988     0.0             1
              13      14        0.17093    0.34802     0.0             1 ];
%************************************************************************
%************************************************************************
```