Software Implementation in Load Flow Analysis by Newton-Raphson Technique using MATLAB

Nivedita Nayak¹, Dr. A. K. Wadhwaní², Dr. Sulochana Wadhwaní³

¹Research Scholar, Dept of EEE, M.I.T.S, Gwalior, M.P, India, Email: niveditanayak88@gmail.com.
²Research Scholar, Dept of EEE, M.I.T.S, Gwalior, M.P, India, Email: wadhwaní_arun@rediff.com.

Abstract: This paper presents different techniques for solving a set of nonlinear equations with the many assumption that a solution exists. The load flow study is necessary for power system planning and operation, different type of bus classification, improving stability of in power system, flexibility in ac system. It involves Newton-Raphson Method for solving non-linear equations in power systems. It determines that many more computations are required, so that rate of convergence may be achieved. The Newton-Raphson Method is computationally simpler than other non-linear solvers. Several methods for solution of nonlinear equations have been discussed and compared. Power flow analysis is an important toolbox for implicated of numerical analysis applied to a power system in load flow analysis. In this analysis, iterative techniques are used due to their analytical method to analysis of the problem. The objective of this project is to develop a toolbox for power flow analysis that will help to check the performance of calculation become easier. Power flow analysis solved by the use MATLAB programming.

Keywords: Load Flow Analysis, Newton-Raphson Method, Bus Voltage Controller, Real Power, Reactive Power, Iterative Methods, Non-Linear Equations.

I. INTRODUCTION

The power flow analysis is a most important tool in power system analysis. Power flow studies are consistently used in planning of operation, control, and operations of existing electric power systems as well as planning for future expansion. The prosperous operation of power systems which is depends upon knowing the effects of adding some interconnections, adding new loads, connecting new generators or connecting new transmission line and distribution systems before it is installed. The goal of a power flow study is to obtain complete voltage angle $|\delta|$ and magnitude $|V|$ information for each bus in a power system network for specified load and generate real power and voltage conditions [1-3]. As a large AC power system network, the power cannot be stored in any device; the generation of electric power must be in balanced with the load demand. The demand of the load stays on changing some time increasing or some time decreasing. So it becomes necessary for the power system to meet the peak load demand and base load demand for the reliability and proper economic use of power. To make most reliable, stable and suitable system it becomes necessary to perform power flow analysis. There are so many different approaches for the analysis of Power flow in the power system network. Among them the Newton-Raphson is the one which is largely used for the power flow analysis because if its reliability. The other iterative methods for power flow analysis included with Gauss-Seidel, Fast Decoupled etc. The Newton-Raphson method is frequently used for the power flow analysis because it has the advantage of processing large data for system comprising of large branches and buses and gives better, accurate solution. This allows less computer memory to be used for storing the Jacobian elements and to process the program.

Fig. 1 Basic diagram of transmission lines.

In this paper work, presents the fundamental concepts for power flow analysis and the analysis of power system networks up to 14 buses. This work also presents various compensating which helps in improving of the voltage
II. BUS CLASSIFICATION

In a bus Classification each bus has four variables in the power system: voltage magnitude [V], voltage phase angle [θ], real power (P) and reactive power (Q). During the operation in the power system, each bus has two known variables and two unknown variables [2,4]. Generally, the bus must be classified as one of the following bus types:

- **Load (P, Q) buses**
- **Voltage controlled (P, V) buses**
- **Slack or swing bus**
- **Slack bus**

### Fig 2: BUS Classification.

A. **Slack or Swing Bus**

This bus is appraised as the reference bus. It always is connected to a generator of high rating relative value to the other generators. During the operation in power system, the voltage of this bus is must be specified and remains constant in magnitude and angle. Additionally to the generation assigned it according to economic operation, this bus is also responsible for supply the losses of the power system. Usually this type of bus is categorized first for the load flow analysis. This bus sets first of the angular reference for all the other type of buses. Since it is set the angle difference between two voltage sources that principle of the real and reactive power flow between them, the individual angle of the slack bus is not important part [7]. However it sets the reference opposed to which angles of all the other bus voltages are measured by this bus. For this reason the angle of this bus is usually preferential as 0°. Furthermore assumptions are that the magnitude of the voltage of this bus is known.

B. **Generator or Voltage Controlled Bus**

During the operation in power system network the voltage magnitude at this the bus is kept as constant. Also, the active power supplied is kept constant at the magnitude which will be satisfies the economic operation of the power system. Most feasibly, this bus is connected to a generator where the voltage is controlled using the excitation device and the power is controlled using the prime mover controller. Sometimes, this bus is connected to a VAR or reactive power device where the voltage can be controlled by varying the value of the injected VAR to the bus in power system network. This bus is also known as PV bus.

C. **Load Bus**

This bus is not connected with a generator so that neither voltage nor real power can be controlled in this load bus. On the other hand, the load connected to this bus will be change with the active and reactive power at the bus in a casual manner. To solve the load flow problem we have to assume the complex power value which are as real and reactive power (P, Q) at this bus. This bus is also known as PQ bus.

### III. REAL POWER AND REACTIVE POWER INJECTED IN A BUS THROUGH GIVEN EQUATIONS

As for the formulation of the real power and reactive power coming in a bus system, that is necessary to define as the following quantities. Let the voltage at the i-th bus to be denoted by eq.(1)

\[ V_i = |V_i| < \theta_i = |V_i| (\cos \theta_i + j \sin \theta_i) \]  

(1)

Also let us define the self admittance at bus- i by eq.(2)

\[ Y_{ii} = |Y_{ii}| < \Theta_{ii} = |Y_{ii}| (\cos \Theta_{ii} + j \sin \Theta_{ii}) = C_{ii} + j B_{ii} \]  

(2)

Similarly the mutual admittance between the two buses i and j can be written by eq.(3)

\[ Y_{ij} = |Y_{ij}| < \Theta_{ij} = |Y_{ij}| (\cos \Theta_{ij} + j \sin \Theta_{ij}) = C_{ij} + j B_{ij} \]  

(3)

Let us assume the power system contains a total number of nth buses. The current to be injected at bus- i is given by eq.(4)

\[ I_i = Y_{i1}V_1 + Y_{i2}V_2 + \ldots + Y_{in}V_n = \sum_{k=1}^{n} Y_{ik}V_k \]  

(4)
It is to be noted that assuming the current coming in a bus to be positive and that going ahead the bus to be negative [7]. As for a consequence the real power and reactive power come a bus will also be assumed to be positive. The complex power at bus- \( i \) is given by eq.(5)

\[
P_i - jQ_i = V_i^* V_i = \sum_{k=1}^{n} V_{ik} V_k = \sum_{k=1}^{n} \left| V_{ik} \right| V_k \cos \theta_{ik} + j \left| V_{ik} \right| V_k \sin \theta_{ik}
\]

It is note that,

\[
\begin{align*}
\cos \theta_{ik} - j \sin \theta_{ik} & = (\cos \theta_{ik} - j \sin \theta_{ik})(\cos \theta_{ik} + j \sin \theta_{ik}) \\
& = (\cos \theta_{ik} + \cos \theta_{ik} + j \sin \theta_{ik} + j \sin \theta_{ik})
\end{align*}
\]

Therefore substituting in eq.(5), get the real and reactive power given in eq.(7) and (8)

\[
P_i = \sum_{k=1}^{n} \left| V_{ik} \right| V_k \cos \theta_{ik} \\
Q_i = \sum_{k=1}^{n} \left| V_{ik} \right| V_k \sin \theta_{ik}
\]

\[
\begin{align*}
P_i &= \sum_{k=1}^{n} \left| V_{ik} \right| V_k \cos \theta_{ik} \\
Q_i &= \sum_{k=1}^{n} \left| V_{ik} \right| V_k \sin \theta_{ik}
\end{align*}
\]

\[
P_i = P_{G_i} + P_{H_i}
\]

\[
\Delta P_i = P_{\text{load}} - P_{\text{calc}} = P_{G_i} - P_{H_i} - P_{\text{calc}}
\]

\[
\Delta Q_i = Q_{\text{load}} - Q_{\text{calc}} = Q_{G_i} - Q_{H_i} - Q_{\text{calc}}
\]

\[
\begin{pmatrix}
\Delta P_1 \\
\Delta P_2 \\
\vdots \\
\Delta P_n
\end{pmatrix} =
\begin{pmatrix}
\Delta P_{\text{load}} \\
\Delta P_{\text{calc}}
\end{pmatrix}
\]

\[
\begin{pmatrix}
J_{11} & J_{12} \\
J_{21} & J_{22}
\end{pmatrix}
\]

The mis-matching between the actual entered power and calculated [11] values is given by In a similar type of the mismatch between the reactive power entered and calculated values is given by eq.(11)

\[
\begin{align*}
\Delta P_i &= P_{\text{load}} - P_{\text{calc}} = P_{G_i} - P_{H_i} - P_{\text{calc}} \\
\Delta Q_i &= Q_{\text{load}} - Q_{\text{calc}} = Q_{G_i} - Q_{H_i} - Q_{\text{calc}}
\end{align*}
\]

The purpose of the load flow analysis is to minimize the above two mismatching. It is to be noted that eq.(7) and eq.(8) are used for the calculation of real and reactive power in eq.(10) and eq.(11). Since the magnitudes of all the voltages \(|V|\) and their angles \((\delta)\) are not known a derivable, a bilateral procedure must be used to determine the bus voltages [9,13, 15] (V) and their angles \((\delta)\) in order to calculating the mismatches. It is familiar with that mismatches \(\Delta P_i\) and \(\Delta Q_i\) reduced with each iteration and the load flow analysis said to have come together when the mismatches of all the buses become less than a very small number.

\[
\begin{pmatrix}
\Delta P_1 \\
\Delta P_2 \\
\vdots \\
\Delta P_n
\end{pmatrix} =
\begin{pmatrix}
\Delta P_{\text{load}} \\
\Delta P_{\text{calc}}
\end{pmatrix}
\]

Whereas the Jacobian matrix is divided into submatrices as given by eq.(13)

\[
\begin{pmatrix}
J_{11} & J_{12} \\
J_{21} & J_{22}
\end{pmatrix}
\]

\[
\begin{align*}
\Delta P_i &= P_{\text{load}} - P_{\text{calc}} = P_{G_i} - P_{H_i} - P_{\text{calc}} \\
\Delta Q_i &= Q_{\text{load}} - Q_{\text{calc}} = Q_{G_i} - Q_{H_i} - Q_{\text{calc}}
\end{align*}
\]

\[
\begin{pmatrix}
\Delta P_1 \\
\Delta P_2 \\
\vdots \\
\Delta P_n
\end{pmatrix} =
\begin{pmatrix}
\Delta P_{\text{load}} \\
\Delta P_{\text{calc}}
\end{pmatrix}
\]

Whereas the Jacobian matrix is divided into submatrices as given by eq.(13)

\[
\begin{pmatrix}
J_{11} & J_{12} \\
J_{21} & J_{22}
\end{pmatrix}
\]

It can be seen that the size of the Jacobian matrix is \((n+n_p-1) \times (n+n_p-1)\). The dimensions of the submatrices are as follows:
J11: \((n-1) \times (n-1)\),
J12: \((n - 1) \times n_p\),
J21: \(n_p \times (n - 1)\) and
J22: \(n_p \times n_p\).
The submatrices are given by eq.(14)

\[
J_{11} = \begin{bmatrix}
\frac{\partial P_1}{\partial V_1} & \cdots & \frac{\partial P_1}{\partial V_n} \\
\vdots & & \vdots \\
\frac{\partial P_n}{\partial V_1} & \cdots & \frac{\partial P_n}{\partial V_n}
\end{bmatrix}
\]

(14)

\[
J_{12} = \begin{bmatrix}
\frac{\partial P_1}{\partial V_1} & \cdots & \frac{\partial P_1}{\partial V_n} \\
\vdots & & \vdots \\
\frac{\partial P_n}{\partial V_1} & \cdots & \frac{\partial P_n}{\partial V_n}
\end{bmatrix}
\]

\[
J_{21} = \begin{bmatrix}
\frac{\partial Q_1}{\partial V_1} & \cdots & \frac{\partial Q_1}{\partial V_n} \\
\vdots & & \vdots \\
\frac{\partial Q_n}{\partial V_1} & \cdots & \frac{\partial Q_n}{\partial V_n}
\end{bmatrix}
\]

(15)

\[
J_{22} = \begin{bmatrix}
\frac{\partial Q_1}{\partial V_1} & \cdots & \frac{\partial Q_1}{\partial V_n} \\
\vdots & & \vdots \\
\frac{\partial Q_n}{\partial V_1} & \cdots & \frac{\partial Q_n}{\partial V_n}
\end{bmatrix}
\]

(16)

\[
J_{22} = \begin{bmatrix}
\frac{\partial Q_1}{\partial V_1} & \cdots & \frac{\partial Q_1}{\partial V_n} \\
\vdots & & \vdots \\
\frac{\partial Q_n}{\partial V_1} & \cdots & \frac{\partial Q_n}{\partial V_n}
\end{bmatrix}
\]

(17)

VI. RESULT

Load flow analysis is carried out at different bus system test, the output of losses when real and reactive power consumed at all bus changes shown in fig. 3, 4, 5, 6, angle changes in PQ bus when real and reactive power consumed at different bus systems are shown in fig. 7, 8 and angle changes in PV bus when real and reactive power consumed at different bus systems are shown in fig. 9, 10. The voltage output when real and reactive power consumed at all bus changes shown in fig. 11, 12, 13, 14. And also shows the steeply change in voltage in different buses.

VII. CONCLUSION

In this paper realized that the importance of Power flow or load-flow studies are necessary part for planning of future expansion of power systems as well as in determinations the best operation in existing power systems. The principal information obtained from the calculation of power flow study is the magnitude of voltage \(|V|\) and phase angle \(\theta\) of the power losses at each bus section, and the real and reactive power flowing in each line in power system. In this paper work formulated the algorithm and designed the MATLAB programming for bus admittance matrix, which is converting polar form to rectangular form. Newton Raphson method is suitable for analyzing the load flow of the bus systems. The Voltage magnitude \(|V|\) and angles \(\theta\) of a bus system were observed for different values of Reactance loading and the findings have been presented in this work. From the analysis observation, it is concluded that increasing the reactance loading resulted is also depends on increased voltage regulation.

Newton-Raphson has simple calculations and is easy to execute, in Newton-Raphson approach the number of buses increase, number of iterations decreases. On the other words, in Newton-Raphson method, the calculations are complex, but the number of iterations is low even when the number of buses is high. That is why Newton-Raphson method is more reliable and popular than other methods. It gives better results as comparative to other approaches. For a large power systems Newton-Raphson (N-R) method is found to be more efficient and practical from the point of view for computational techniques and convergence characteristics which are useful of load flow analysis.

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**Fig. 3: Real & Reactive power loss when Real power consumed at all buses changes.**
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Fig. 4: Real & Reactive power loss when reacted power consumed at all buses changes.

Fig. 5: Real power loss when Real & Reactive power consumed at all buses changes.

Fig. 6: Reactive power when Real & Reactive power consumed all buses changes.

Fig. 7: Angle changes in PQ buses when Real power consumed at all buses changes.

Fig. 8: Angle changes in PQ buses when Reactive power consumed at all buses changes.

Fig. 9: Angle changes in PV buses when Real power consumed changed at all buses.

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Fig. 10: Angle changes in PV buses when Reactive power consumed at all buses changes.

Fig. 11: Voltage changes in PQ buses when Real power consumed at all buses changes.

Fig. 12: Voltage changes in PQ buses when Reactive power consumed at all buses changes.

Fig. 13: Voltage changes in PV buses when Real power consumed at all buses changes.

Fig. 14: Voltage changes in PV buses when Reactive power consumed at all buses changes.

IX. REFERENCES


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