

Comparison of Different Load Flow Techniques & Implementation using Newton Raphson Method

Anshul Shrivastava¹, Pravin Badarayani² and Divyesh Arora³

¹M. Tech Smart Grid, University of Petroleum and Energy Studies, Dehradun, India

^{2,3}M. Tech Renewable Energy University of Petroleum and Energy Studies, Dehradun, India

E-mail: ¹anshu.shri91@gmail.com, ²bpravin233@gmail.com, ³divyesh134@gmail.com

Abstract—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. 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. The purpose of any load flow analysis is to compute precise steady-state voltages magnitudes and angles of all buses in the network, the real and reactive power flows into every line and transformer, under the assumption of known generation and load. Model of power system generates non-linear algebraic equations and to solve these equations, three solution algorithms based on power equations of the methods were adopted. They were applied to test power systems: IEEE 14-bus. The result of the application shows that number of iterations increases proportionally with the number of buses for Gauss-Seidel technique while that of Newton-Raphson method remained almost practically constant even with varying number of buses. The Fast Decoupled method presented a slight increase in number of iterations with increasing number of buses but with faster convergence, when compared with Newton-Raphson methods. The Newton-Raphson method provided the best characteristics of quadratic convergence in minimum number of iterations and this method is best suited for 14 bus system.

1. INTRODUCTION

The state of a power system and the methods of calculating this state are very important in evaluating the operation and control of the power system and the determination of future expansion for this system. The state of any power system can be determined using load flow analysis that calculates the power flowing through the lines of the system. There are different methods to determine the load flow for a particular system such as: Gauss-Seidel, Newton Raphson and the Fast-Decoupled method. In a three phase AC power system active and reactive power flows from the generating station to the load through different networks buses and branches. The flow of active and reactive power is called power flow or load flow. Power flow studies provide a systematic mathematical approach for determination of various bus voltages, their phase angle active and reactive power flows through different branches, generators and loads under steady state condition. Power flow analysis is used to determine the steady state

operating condition of a power system. Power flow analysis is widely used by power distribution professional during the planning and operation of power distribution system.

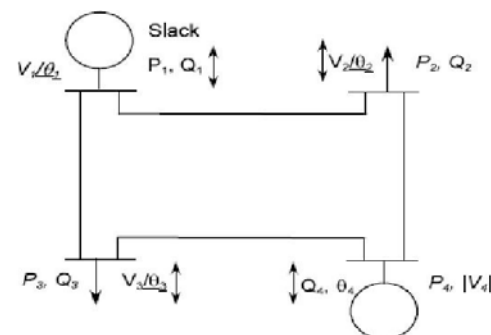


Fig. 1: Power Distribution System

But to go in deep we have to first understand the importance of basic methods, this thesis focus on significance of three basic method of load flow to solve topical power system problem, and provide a comparative analysis of this three, to judge a way to approach problem, reliability to maintain mathematical circumstances, complication in way to result, accuracy, and comparison on scientific ground.

There three methods for load flow studies mainly

- 1 Gauss siedel method
- 2 Newton raphson methods
- 3 Fast decoupled method.

2. OBJECTIVE OF LOAD FLOW STUDY

- ❖ 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

The comparison among basic load flow method will be on parameters to improve the system stability, reliability and accuracy and provide a base study to go further in field of load flow, to develop new and revolutionary techniques to make system futuristic. Load flow is one of the most important tools to analyze the power systems for both planning and operation stages. Load flow is used to determine the static performance of the system. Conventional passive distribution networks are changing to modern active networks which are not radial. Conventional load flow methods should be modified for new networks analysis. Comparison of these methods can be useful to select the best method for a typical network. As a result, some suggestions are proposed to apply the new methods.

Parameters of comparison as following

- ❖ Time:-time is one of most important parameter of comparison because how much time a method take to solve a normal problem, criticize the ability of method. comparison on the basic of time taken by a method will proved a middle way to approach a problem in minimum time.
- ❖ Accuracy:-may a problem solved by a method within the few seconds but the accuracy towards the result less compare to other method or the result is not near to true value so result is not preferable for a power system engineer. Accuracy is soul of this comparison.
- ❖ Complexity: we take complexity as a parameter because of it increase computation time and decrease accuracy way to result. Comparison will proved an idea to approach a normal problem of power system with a less complex computation. And this complexity increase with new computer programs.
- ❖ Convergence rate: Convergence is considered a new trend because technological capabilities were only recently established to allow for cheaper and widespread implementation. The simple concept of convergence allows multiple tasks to be performed on a single device, which effectively conserves space and power. We compare the performance of algorithms by their rate of convergence. The speed at which a convergent sequence approaches its limit is called the rate of convergence.

3. FORMULATION OF THE LOAD FLOW PROBLEM

Load flow studies are based on a nodal voltage analysis of a power system. As an example, consider the very simple

system represented by the single-line diagram in Fig. 1. Here two generators (1 and 2) are interconnected by one transmission line and are separately connected to a load (3) by two other lines. If the pharos currents injected into the system are I_1 , I_2 , and I_3 , and the lines are modeled by simple series admittances, then it is possible to draw the equivalent circuit for one representative phase of the balanced three-phase system, as shown in Fig. 2.

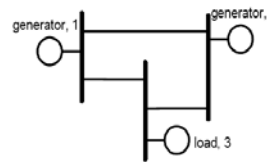


Fig. 1 Single-line diagram of a simple example power system

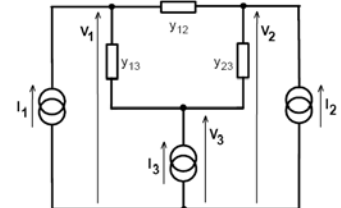


Fig. 2 Equivalent circuit for one phase of the system shown in Fig.1

For the circuit in Fig. 2 the nodal voltage equations can be written directly. For example, at node 1

$$I_1 = (y_{12} + y_{13})V_1 - y_{12}V_2 - y_{13}V_3 \quad (1)$$

In general, for a system with r nodes, then at node n

$$I_n = Y_{n1}V_1 + Y_{n2}V_2 + \dots + Y_{nn}V_n + \dots + Y_{nr}V_r = \sum_{k=1}^r Y_{nk}V_k \quad (2)$$

Where: Y_{nn} = sum of all admittances connected to node n
 Y_{nk} = - (sum of all admittances connected between nodes n and k) = Y_{kn}
 I_n = current injected at node n

For the complete system of r nodes:

$$\begin{bmatrix} I_1 \\ \vdots \\ I_n \\ \vdots \\ I_r \end{bmatrix} = \begin{bmatrix} Y_{11} & \dots & Y_{1n} & \dots & Y_{1r} \\ \vdots & & \vdots & & \vdots \\ Y_{n1} & \dots & Y_{nn} & \dots & Y_{nr} \\ \vdots & & \vdots & & \vdots \\ Y_{r1} & \dots & Y_{rn} & \dots & Y_{rr} \end{bmatrix} \begin{bmatrix} V_1 \\ \vdots \\ V_n \\ \vdots \\ V_r \end{bmatrix} \text{ or } [I] = [Y][V] \quad (3)$$

Where Y = Nodal admittance matrix. Formulation of the load flow problem is most conveniently carried out with the terms in the nodal admittance matrix expressed in polar notation: kn kn kn $Y = Y \angle \theta$. The Excel Workbook (Sheet 2) allows users to enter series impedance data for the three lines and then automatically calculates the terms in the nodal admittance matrix.

Conventional circuit analysis proceeds directly from equation (3) by inverting the nodal admittance matrix and hence solving for the nodal voltages $[V]$. However, the load flow problem is complicated by the lack of uniformity in the data about electrical conditions at the nodes. There are three distinct

types of nodal data, which relate to the physical nature of the power system:

- Load nodes, where complex power $S_n = P_n + jQ_n$ taken from or injected into the system is defined. Such nodes may also include links to other systems. At these load nodes, the voltage magnitude $|V_n|$ and phase angle δ_n must be calculated.
- Generator nodes, where the injected power, P_n , and the magnitude of the nodal voltage $|V_n|$ are specified. These constraints reflect the generator's operating characteristics, in which power is controlled by the governor and terminal voltage is controlled by the automatic voltage regulator. At the generator nodes the voltage phase angle δ_n must be calculated
- Magnitude $|V_n|$ and phase angle δ_n are specified. This node acts as the Reference node and is commonly chosen to have a phase angle $\delta_n = 0^\circ$. The Power and reactive power delivered at this node are not specified. In the system configuration of Fig. 1, which is analyzed in the Excel Workbook, each type of node is represented with node 1 being a floating bus, node 2 being a generator node and node 3 being a load node. Consequently values must be specified for the power (P_2 s) injected at node 2, and the power (P_3 s) and reactive power (Q_3 s) injected at node 3. All three of these power values may be changed by the user, though default values are provided ($P_2 = 1.0$; $P_3 = -1.5$; $Q_3 = -0.2$).
- Negative values indicating that power or reactive power is being drawn from the system. The magnitude of the voltage at node 1 can be specified, with the default value being 1.0 pu, while the phase angle is fixed at $0^\circ (= 1.0 \angle 0^\circ \text{ VI})$. At the generator node (node 2), the voltage magnitude can be set by the user with the default value being 1.1 pu ($2 = 1.1 \angle \delta \text{ V2}$), and the phase angle δ_2 is calculated during the load flow solution. At the load node (node 3) the voltage magnitude and phase angle have to be calculated ($3 \angle \delta_3 = V \angle \delta$). So the complete load flow problem for this particular power system configuration involves the calculation of the voltage magnitude V_3 and the phase angles δ_2, δ_3 .

4. MATLAB IN LOAD FLOW

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 develops by the author use MATLAB software. MATLAB as a high-performance language for technical computation integrates calculation, visualization and programming in an easy-to-use environment, thus becomes 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.

5. MATLAB GUI

A graphical user interface (GUI) is a pictorial interface to a program. A good GUI can make programs easier to use by providing them with a consistent appearance and with intuitive controls like pushbuttons, list boxes, sliders, menus, and so forth. [6][7][8]. The GUI should behave in an understandable and predictable manner, so that a user knows what to expect when he or she performs an action. For example, when a mouse click occurs on pushbutton, the GUI should initiate the action described on the label of the button. This chapter introduces the basic elements of the MATLAB GUIs [6] [7] [8]. The chapter does not contain a complete description of components or GUI features, but it does provide the basics required to create functional GUIs for your programs [6]. Applications that provide GUIs are generally easier to learn and use since the person using the application does not need to know what commands are available or how they work [7] [8]. The action that results from a particular user action can be made clear by the design of the interface [6] [7] [8].

A graphical user interface provides the user with a familiar environment in which to work. This environment contains pushbuttons, toggle buttons, lists, menus, text boxes, and so forth [5] [6] [7] [8]. All of which are already familiar to the user, so that he or she can concentrate on using the application

rather than on the mechanics involved in doing things. However, GUIs are harder for the programmer because a GUI-based program must be prepared for mouse clicks (or possibly keyboard input) for any GUI element at any time [5] [6] [7]. Such inputs are known as events, and a program that responds to events is said to be *event driven*. The three principal elements required to create a MATLAB Graphical User Interfaces are [6]:-

- **Components.** Each item on a MATLAB GUI (pushbuttons, labels, edit boxes, etc.) is a graphical component. The types of components include graphical controls (pushbuttons, edit boxes, lists, sliders, etc.), static elements (frames and text strings), menus, and axes. Graphical controls and static elements are created by the function control, and menus are created by the functions menu and context menu. Axes, which are used to display graphical data, are created by the function axes [5] [6] [7] [8].
- **Figures.** The components of a GUI must be arranged within a figure, which is a window on the computer screen. In the past, figures have been created automatically whenever we have plotted data. However, empty figures can be created with the function figure and can be used to hold any combination of components [6].
- **Callbacks.** Finally, there must be some way to perform an action if a user clicks a mouse on a button or types information on a keyboard. A mouse click or a key press is an event, and the MATLAB program must respond to each event if the program is to perform its function. For example, if a user clicks on a button, that event must cause the MATLAB code that implements the function of the button to be executed. The code executed in response to an event is known as a call back. There must be a callback to implement the function of each graphical component on the GUI [6].

6. CONCLUSION

The well-known properties of these algorithms: speed, rate of convergence and the convergence characteristics were confirmed by the case study results. It indicates that Newton Raphson method is more reliable because it converges faster with quadratic convergence characteristics and least number of iterations when compared with the other two methods, In general the Newton Raphson algorithm takes the least number of iteration to converge despite its longer computing time. The number of iteration for the Gauss-Seidel increases directly as the number of the buses of the network, whereas the number of iterations for the Newton Raphson method remains practically constant, independent of the system size. However, since the convergence characteristics of the Fast decouple method is geometric compare to the quadratic convergence of the Newton Raphson, thus it has more number of iteration. Therefore because of high accuracies obtained in only a few

iterations, the Newton Raphson method is important for use and more reliable than any of the methods.

7. FUTURE SCOPE

This Project concentrates on comparison of different load flow techniques and solution of problem by MATLAB programming.

- Comparison of load flow techniques will provide optimal result, which is useful for developing load flow techniques.
- Comparison will provide advantages about different load flow techniques.
- Software like matlab will provide us easy, fast and reliable solution for load flow problems.

REFERENCES

- [1] D. Chakraborty, C. P. Sharma, B. Das, K. Abhishek and T. Malakar, "Distribution load flow solution using genetic algorithm", 3rd IEEE Int. Conf. on Power Syst. , Kharagpur, India, Dec. 27-29, 2009.
- [2] H. Yang, F. Wen, L. Wang and S. N. Singh, "Newton-downhill algorithm for distribution power flow analysis", 2nd IEEE Int. Conf. on Power and Energy, Johor Baharu, Malaysia, Dec. 1-3, 2008.
- [3] Da Costa V. M. , Martins M. and Preira J. L. R. , "An augmented Newton-Raphson power flow formulation based on current injections", Electrical Power and Energy Syst. , Vol. 23, pp. 305-312, 2001.
- [4] M. Aliakbar-Golkar, "Design and operation of distribution systems", K. N. Toosi University, Tehran, 2001.
- [5] Electrical power system (sixth edition) book by C. L. Wadhwa.
- [6] Power system stability and control book by Prabha-Kundur.