

Performance of Newton-Raphson Techniques in Load Flow Analysis using MATLAB

Nivedita Nayak, Dr. A.K. Wadhvani

Abstract— This paper presents a idea of power flow analysis in power system with different type of bus classification, stability of in power system improved quality, and flexibility by using Newton-Raphson techniques. Power flow analysis is the resolution of power system analysis. That is necessary for planning, operation, economic schedule and exchange of power between explicabilities. The principal information of power flow analysis is utilized to find the magnitude and phase angle of voltage at each bus and the real and reactive power flowing in each transmission lines of bus networks. Power flow analysis is an importance tool foe involving numerical analysis that is applied to a power system. In this analysis, iterative techniques are used to solve the load flow problems. To complete this analysis there are methods of mathematical calculations which consist prosperity of step depend on the size of power system network. This process is so difficult and takes a lot of times for performing by hand. The objective of this paper work is to develop a toolbox for power flow analysis that will help the performance of analysis become easier. Power flow analysis solved by the use MATLAB programming. For a power flow network problem with known complex power (P, Q) loads and some specifications or restrictions on power generations and voltages, solve for any unknown bus voltages and unspecified generation and finally for the complex power flow in the network components are solved by N-R method.

Index Terms— power flow analysis, Newton-Raphson method, bus voltage control, real power, reactive power.

I. INTRODUCTION

Load flow studies are one of the most common and important tool in power system analysis and also known as the “Load Flow” solution which is used for planning and controlling a power system network. This process is also used for determining balanced condition and single phase analysis Problems in the voltage magnitude and phase angle at each bus, the active and reactive power flow voltage magnitude, voltage phase angle, real power injection and reactive power injections.

The load flow analysis gives us the sinusoidal steady state condition of the fully system voltages, real power and reactive power generated and absorbed and line losses. Since the load is a static quantity of power system and it is the power that flows across the transmission lines, the tripper prefer to call this Power Flow studies rather than the load flow studies [2]. We shall however stick to the original terminology of load flow.

Nivedita Nayak, Dept. Electrical Engineering Department, M.I.T.S. Gwalior, India
Dr. A.K. Wadhvani, Electrical Engineering Department, M.I.T.S. Gwalior, India

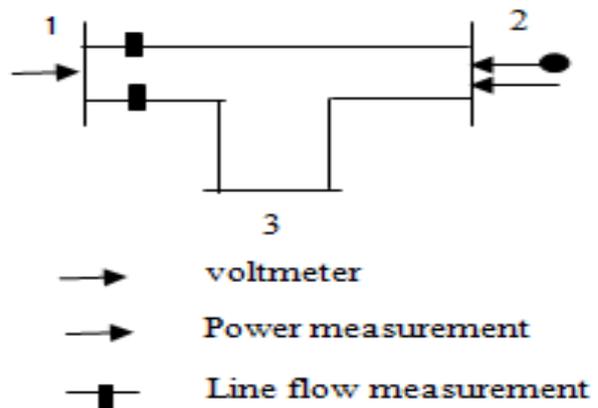


Fig. 1 General bus network in power system

Through the load flow studies the voltage magnitudes and angles at each bus in the steady state obtained. This is rather most important as the load magnitudes of the bus voltages are required to be held within a specific limit and the bus voltage magnitudes and their angles are computed using MATLAB programming in the load flow, the real and reactive power flow constantly of each line. Also based on the difference between real and reactive power flow in the sending end and receiving ends [1], the losses in a particular line can also be computed by load flow analysis in MATLAB programming. Furthermore, from the line flow also determinate by the over and under load conditions.

The steady state power and reactive power supplied by a bus in a power flow network are indicated in terms of nonlinear algebraic equations.

Load flow studies [1,2] are used to protect that power transfer in electrical network from generators to consumers through the grid system that is stable, reliable and economic. Conventional techniques for solving the load flow problem are as iterative, using the Newton-Raphson or the Gauss-Seidel methods.

Type of buses

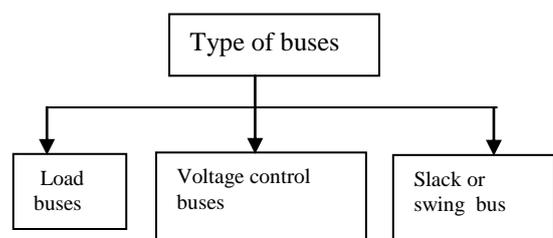


Fig. 2. Bus classification

A. Load Buses or PQ Buses

Here, the real power $|P|$ and reactive power $|Q|$ are specified. It is also known as *Load Bus*. In these type of buses

there are no generators are connected in power network and hence the generated real power P_{Gi} and reactive power Q_{Gi} are taken as zero [3]. The load distraught by these buses are indicated by real load load power $-P_{Li}$ and reactive load power $-Q_{Li}$ in which the negative sign indicates for the power flowing other direction of the bus [5, 6, 9]. By this why these buses are sometimes referred to as P-Q bus. The objective of the load flow analysis is to find the bus voltage magnitude $|V_i|$ and its angle δ_i ad losses.

B. Voltage Controlled Buses or PV buses

Here, the real power $|P|$ and the voltage magnitude $|V|$ are specified. It is also known as *Generator Bus*.

In this type of the buses generators are as connected. Therefore the power generation in such buses is controlled concluded a creator while the terminal voltage is controlled concluded the generator excitation. Keeping the input power as constant power through over turbine-governor control and keeping the bus voltage constant using automatic voltage regulator, and that is specify over as constant generator power P_{Gi} and magnitude of voltage $|V_i|$ for these type of buses. This is why such type of buses is also associated to as P-V buses [10]. It is to be cleared that the reactive power supplied by the generator Q_{Gi} depends on the system configuration and cannot be specified in advance. Furthermore to find the unknown angle δ_i of the bus voltage in voltage controlled bus.

C. Slack or Swing or reference Bus

For the balance the active and reactive power in the system slack buses are required. It is also known as the Reference Bus or the Swing Bus.

Customarily 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.

TABLE (1) Type of power flows in bus system

Buses	Real power (P)	Reactive power (Q)	Voltage magnitude (V)	Phase angle (δ)
P-Q bus	known	known	unknown	unknown
P-V bus	known	unknown	known	unknown
Slack bus	unknown	unknown	known	known

III. REAL AND REACTIVE POWER EQUATIONS IN A BUS NETWORK

For the calculation of the real power and reactive power are 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)

$$V_i = |V_i| \angle \delta_i = |V_i| (\cos \delta_i + j \sin \delta_i) \tag{1}$$

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

$$Y_{ii} = |Y_{ii}| \angle \theta_{ii} = |Y_{ii}| (\cos \theta_{ii} + j \sin \theta_{ii}) = G_{ii} + jB_{ii} \tag{2}$$

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

$$Y_{ij} = |Y_{ij}| \angle \theta_{ij} = |Y_{ij}| (\cos \theta_{ij} + j \sin \theta_{ij}) = G_{ij} + jB_{ij} \tag{3}$$

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

$$I_i = Y_{i1}V_1 + Y_{i2}V_2 + \dots + Y_{in}V_n = \sum_{k=1}^n Y_{ik}V_k \tag{4}$$

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)

$$P_i - jQ_i = V_i^* I_i = V_i^* \sum_{k=1}^n Y_{ik}V_k = |V_i| (\cos \delta_i - j \sin \delta_i) \sum_{k=1}^n |Y_{ik}| V_k (\cos \theta_{ik} + j \sin \theta_{ik}) (\cos \delta_k + j \sin \delta_k) = \sum_{k=1}^n |Y_{ik}| V_i V_k (\cos \delta_i - j \sin \delta_i) (\cos \theta_{ik} + j \sin \theta_{ik}) (\cos \delta_k + j \sin \delta_k) \tag{5}$$

It is note that,

$$(\cos \delta_i - j \sin \delta_i) (\cos \theta_{ik} + j \sin \theta_{ik}) (\cos \delta_k + j \sin \delta_k) = (\cos \delta_i - j \sin \delta_i) [\cos(\theta_{ik} + \delta_k) + j \sin(\theta_{ik} + \delta_k)] = \cos(\theta_{ik} + \delta_k - \delta_i) + j \sin(\theta_{ik} + \delta_k - \delta_i) \tag{6}$$

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

$$P_i = \sum_{k=1}^n |Y_{ik}| V_i V_k \cos(\theta_{ik} + \delta_k - \delta_i) \tag{7}$$

$$Q_i = - \sum_{k=1}^n |Y_{ik}| V_i V_k \sin(\theta_{ik} + \delta_k - \delta_i) \tag{8}$$

IV. DATA FOR LOAD FLOW ANALYSIS IN BUS NETWORK

Let us assume the real power and reactive power generated at bus- i which is denotes by P_{Gi} and Q_{Gi} respectively. Also let us denote the real power and reactive power consumed at the i^{th} bus by P_{Li} and Q_{Li} respectively[2]. Then the net real power entered in bus- i is given by eq.(9)

$$P_{i,net} = P_{Gi} - P_{Li} \tag{9}$$

Let the sending power calculated by the load flow program be $P_{i, calc}$. Then the given by eq.(10)

$$\Delta P_i = P_{i, inj} - P_{i, calc} = P_{Gi} - P_{Li} - P_{i, calc} \quad (10)$$

The mis-matching between the actual entered power and calculated [6] values is given by In a similar type of the mismatch between the reactive power entered and calculated values is given by eq.(11)

$$\Delta Q_i = Q_{i, inj} - Q_{i, calc} = Q_{Gi} - Q_{Li} - Q_{i, calc} \quad (11)$$

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 (δ) are not known a derivable, a bilateral procedure must be used to determine the bus voltages [9,13, 15] (V) and their angles (δ) in order to calculating the mismatches. It is familiar with that mismatches ΔP_i and ΔQ_i reduced with the 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.

II. V. NEWTON-RAPHSON METHOD IS APPLIED ON LOAD FLOW PROBLEMS

Let us consider, that an n -bus power system contains a total n_p number of P-Q (load bus) buses while the number of P-V (generator bus) buses be n_g such that $n = n_p + n_g + 1$. Bus-1 is assumed to be the slack or reference bus. We shall further use the mismatch equations of ΔP_i and ΔQ_i given in (10) and (11) respectively. The technique of Newton-Raphson load flow is similar to that of solving a system of nonlinear equations using the Newton-Raphson method [7, 8, 9]. At each iteration is to form a Jacobian matrix and to solve for the corrections. For the load flow problem, this equation is of the form eq (9) which is given by eq.(12)

$$J \begin{bmatrix} \Delta \delta_2 \\ \vdots \\ \Delta \delta_n \\ \frac{\Delta |V_2|}{|V_2|} \\ \vdots \\ \frac{\Delta |V_{1+n_g}|}{|V_{1+n_g}|} \end{bmatrix} = \begin{bmatrix} \Delta P_2 \\ \vdots \\ \Delta P_n \\ \Delta Q_2 \\ \vdots \\ \Delta Q_{1+n_g} \end{bmatrix} \quad (12)$$

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

$$J = \begin{bmatrix} J_{11} & J_{12} \\ J_{21} & J_{22} \end{bmatrix} \quad (13)$$

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 sub matrices are as follows:

J_{11} : $(n - 1) \times (n - 1)$, J_{12} : $(n - 1) \times n_p$, J_{21} : $n_p \times (n - 1)$ and J_{22} : $n_p \times n_p$

The sub matrices are given by eq.(14)

$$J_{11} = \begin{bmatrix} \frac{\partial P_2}{\partial \delta_2} & \dots & \frac{\partial P_2}{\partial \delta_n} \\ \vdots & \ddots & \vdots \\ \frac{\partial P_n}{\partial \delta_2} & \dots & \frac{\partial P_n}{\partial \delta_n} \end{bmatrix} \quad (14)$$

$$J_{12} = \begin{bmatrix} |V_2| \frac{\partial P_2}{\partial |V_2|} & \dots & |V_{1+n_g}| \frac{\partial P_2}{\partial |V_{1+n_g}|} \\ \vdots & \ddots & \vdots \\ |V_2| \frac{\partial P_n}{\partial |V_2|} & \dots & |V_{1+n_g}| \frac{\partial P_n}{\partial |V_{1+n_g}|} \end{bmatrix} \quad (15)$$

$$J_{21} = \begin{bmatrix} \frac{\partial Q_2}{\partial \delta_2} & \dots & \frac{\partial Q_2}{\partial \delta_n} \\ \vdots & \ddots & \vdots \\ \frac{\partial Q_{1+n_g}}{\partial \delta_2} & \dots & \frac{\partial Q_{1+n_g}}{\partial \delta_n} \end{bmatrix} \quad (16)$$

$$J_{22} = \begin{bmatrix} |V_2| \frac{\partial Q_2}{\partial |V_2|} & \dots & |V_{1+n_g}| \frac{\partial Q_2}{\partial |V_{1+n_g}|} \\ \vdots & \ddots & \vdots \\ |V_2| \frac{\partial Q_{1+n_g}}{\partial |V_2|} & \dots & |V_{1+n_g}| \frac{\partial Q_{1+n_g}}{\partial |V_{1+n_g}|} \end{bmatrix} \quad (17)$$

III. RESULT

Load flow analysis is carried out at different bus system test. The voltage output when real and reactive power consumed at all bus changes shown in fig. 3, fig 4, fig 5(a), and 5(b). And also shows the steeply change in voltage in different buses.

IV. CONCLUSION

The principal information obtained from the calculation of power flow study is the magnitude of voltage |V| and phase angle $|\delta|$ 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 $|\delta|$ 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 by 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.

In fig. 3 shows steeply change in Bus 9 and bus 14 And small change in voltage in Bus 4 and bus 5

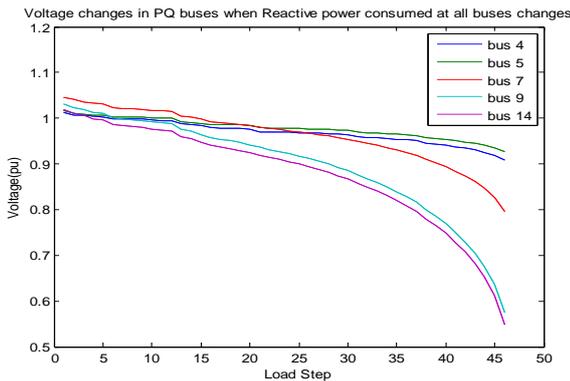


Fig. 3

In fig. 4 shows steeply change in Bus 2 and bus 5

And small change in voltage in Bus 7 and bus 9

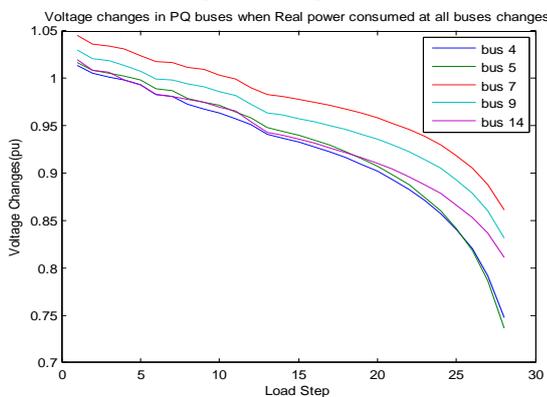


Fig. 4

In fig. 5(a) and fig. 5(b) shows steeply change in Bus 3 And small change in voltage in Bus 8

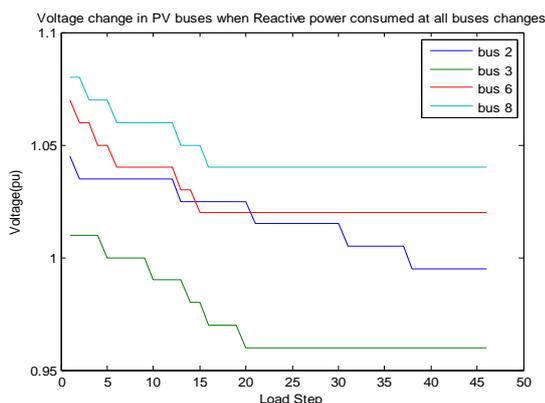


Fig. 5(a)

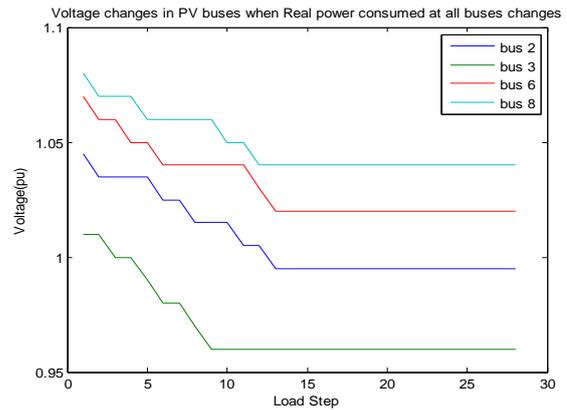


Fig. 5(b)

REFERENCES

- [1] A.E. Guile and W.D. Paterson, "Electrical power systems," Vol. 2", (Pergamon Press, 2nd edition, 2012).
- [2] W.D. Stevenson Jr., "Elements of power system analysis," (McGraw-Hill, 4th edition, 2011).
- [3] W. F. Tinney, C. E. Hart, "Power Flow Solution by Newton's Method," IEEE Transactions on Power Apparatus and systems , Vol. PAS-86, pp. 1449-1460, November 2004.
- [4] W. F. Tinney, C. E. Hart, "Power Flow Solution by Newton's Method," IEEE TRANS. POWER APPARATUS AND SYSTEMS, Vol. PAS-86, pp. 1449-1460, November 2006.
- [5] Carpentier "Optimal Power Flows", Electrical Power and EnergySystems," Vol.1, April 1999, pp 959-972.
- [6] D.I.Sun, B.Ashley, B.Brewer, A.Hughes and W.F.Tinney, "Optimal Power Flow by Newton Approach", IEEE Transactions on Power Apparatus and systems, vol.103, No.10, 2007, pp2864-2880.
- [7] W. R. Klingman and D. M. Himmelblau, "Nonlinear programming with the aid of a multiple-gradient summation technique," J. ACM, vol. 11, pp. 400-415, October 2008.
- [8] H. Dommel, "Digital methods for power system analysis," (in German), Arch. Elektrotech., vol. 48, pp. 41-68, February 1963 and pp. 118-132, April 2010.
- [9] D. Das, H.S.Nagi and D.P. Kothari, "Novel Method for solving radial distribution networks," Proceedings IEE Part C (GTD), vol.141, no. 4, pp. 291 – 298, 2009.
- [10] T.K.A. Rahman and G.B. Jasmon, "A new technique for voltage stability analysis in a power system and improved loadflow algorithm for distribution network," Energy Management and Power Delivery Proceedings of EMPD '95; vol.2, pp.714 – 719, 2011.
- [11] S. Ghosh and D. Das, "Method for Load-Flow Solution of Radial Distribution Networks," Proceedings IEE Part C (GTD), vol.146, no.6, pp.641 – 648, 1999.
- [12] S. Jamali. M.R.Javdan. H. Shateri and M. Ghorbani , "Load Flow Method for Distribution Network Design by Considering Committed Loads," Method, "IEEE TRANS. POWER APPARATUS AND SYSTEMS, Vol. PAS-86, pp. 1449-1460, November 2009.
- [13] 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.
- [14] P. Acharjee and S.K. Goswami, "Simple but reliable two-stage GA based load flow", Electric Power Components and Syst., Vol. 36, No. 1, pp.47-62, 2008.
- [15] 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.
- [16] P. Acharjee, and S.K. Goswami, "Chaotic Particle Swarm Optimization based reliable algorithm to overcome the limitations of conventional power flow methods", IEEE/PES Power Syst. Conf. and Exposition (PSC), pp.1-7, 15-18 March, 2009