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Load Flow Analysis Using Newton-Raphson Method

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Abstract

This paper presents a idea of load flow study in power system, different type of bus classification, improving stability of in power system, flexibility in ac system by using Newton-Raphson techniques. The reliability of the Newton-Raphson (NR) approach of Load Flow Solution is comparatively better than the other load flow techniques. Power flow analysis is the known as important resolution of power system analysis. That is necessary for planning of operation, and economic preparation as exchange of power between applicability. The principal of operation of power flow analysis is to find the different parameter magnitude and phase angle of voltage at each bus and the real and reactive power, which is flowing in each transmission lines system. Power flow analysis is an important toolbox is implicated of numerical analysis applied to a power system for load flow analysis. In this analysis, iterative techniques are used due to their analytical method to analysis the problem. The objective of this project 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.

Index Terms— Load flow, Newton-Raphson, voltage controller, real and reactive power.

I. INTRODUCTION

Load flow studies are one of the most important features of power system planning and operating condition. 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.

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.

II. Classification Of Buses

For load flow studies it is considered that the loads are constant and they are defined by their real and reactive power consumption in power system [4]. It is further assumption that the generator terminal voltages are strongly regulated and therefore are constant. The main objective of the load flow analysis is to find the voltage magnitude of each bus and its angle when the powers generated and loads are pre-specified and also losses to be analyzed. Classification of the different buses of the power system shown in below fig. 2

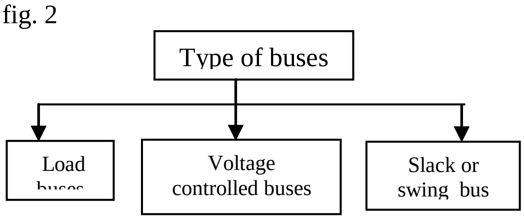

Fig. 1. Bus classification

A. Load Buses

In these buses there are no generators are connected and hence the generated real power P_{Gi} and reactive power Q_{Gi} are taken as zero [3]. The load fraught by these buses are expressed 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

This type of the buses are as where generators are as connected. Therefore the power generation in such buses is controlled concluded a prime mover 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 Bus

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.

Real And Reactive Power Injected In A Bus

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)

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

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

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

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

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

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

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

It is note that,

$$\begin{aligned} &(\cos\delta_i - j\sin\delta_i)(\cos\theta_{ik} + j\sin\theta_{ik})(\cos\delta_k + j\sin\delta_k) \\ &\quad = (\cos\delta_i - j\sin\delta_i)[\cos(\theta_{ik} + \delta_k) + j\sin(\theta_{ik} + \delta_k)] \\ &\quad = \cos(\theta_{ik} + \delta_k - \delta_i) + j\sin(\theta_{ik} + \delta_k - \delta_i) \end{aligned}$$
(6)

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

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

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

III. Preparation Of Data For Load Flow Analysis

Let 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[12]. Then the net real power entered in bus- i is given by eq.(9)

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

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

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

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)

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

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.

IV. Load Flow Analysisby Newton-Raphson Method

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 [13, 17, 18]**.** 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)

$$J \begin{bmatrix} \Delta\delta_2 \\ \vdots \\ \Delta\delta_n \\ \dfrac{\Delta|V_2|}{|V_2|} \\ \vdots \\ \dfrac{\Delta|V_{1+n_p}|}{|V_{1+n_p}|} \end{bmatrix} = \begin{bmatrix} \Delta P_2 \\ \vdots \\ \Delta P_n \\ \Delta Q_2 \\ \vdots \\ \Delta Q_{1+n_p} \end{bmatrix} \tag{12}$$

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

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

It can be seen that the size of the Jacobian matrix is ($n + n_p - 1$) x ($n + n_p - 1$). The dimensions of the submatrices 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 submatrices are given by eq.(14)

$$J_{11} = \begin{bmatrix} \dfrac{\partial P_2}{\partial \delta_2} & \cdots & \dfrac{\partial P_2}{\partial \delta_n} \\ \vdots & \ddots & \vdots \\ \dfrac{\partial P_n}{\partial \delta_2} & \cdots & \dfrac{\partial P_n}{\partial \delta_n} \end{bmatrix} \tag{14}$$

$$J_{12} = \begin{bmatrix} |V_2|\dfrac{\partial P_2}{\partial |V_2|} & \cdots & |V_{1+n_p}|\dfrac{\partial P_2}{\partial |V_{1+n_p}|} \\ \vdots & \ddots & \vdots \\ |V_2|\dfrac{\partial P_n}{\partial |V_2|} & \cdots & |V_{1+n_p}|\dfrac{\partial P_n}{\partial |V_{1+n_p}|} \end{bmatrix} \tag{15}$$

$$J_{21} = \begin{bmatrix} \dfrac{\partial Q_2}{\partial \delta_2} & \cdots & \dfrac{\partial Q_2}{\partial \delta_n} \\ \vdots & \ddots & \vdots \\ \dfrac{\partial Q_{1+n_p}}{\partial \delta_2} & \cdots & \dfrac{\partial Q_{1+n_p}}{\partial \delta_n} \end{bmatrix} \tag{16}$$

$$J_{22} = \begin{bmatrix} |V_2|\frac{\partial Q_2}{\partial |V_2|} & \cdots & |V_{1+n_o}|\frac{\partial Q_2}{\partial |V_{1+n_o}|} \\ \vdots & \ddots & \vdots \\ |V_2|\frac{\partial Q_{1+n_o}}{\partial |V_2|} & \cdots & |V_{1+n_o}|\frac{\partial Q_{1+n_o}}{\partial |V_{1+n_o}|} \end{bmatrix}$$

(17)

V. 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. 2, angle changes in PV bus when real and reactive power consumed at different bus systems are shown in fig. 3 and angle changes in PQ bus when real and reactive power consumed at different bus systems are shown in fig. 4.

TABLE1. The proper identification of different bus system analysis is given by below table(1)

S.No.	Type of buses	No. of buses	Bus no.
1.	Slack bus	1	Bus1
2.	Generator bus	4	Bus2,Bus3, Bus6, Bus8
3.	Load bus	9	Bus4,Bus5, Bus7,Bus9, Bus10,Bus11, Bus12,Bus13, Bus14,

No. of buses = 14
Load step = 0.05

VI. 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 $|\delta|$ 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, 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-Rahpson 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 2(a) & 2(b) shows losses

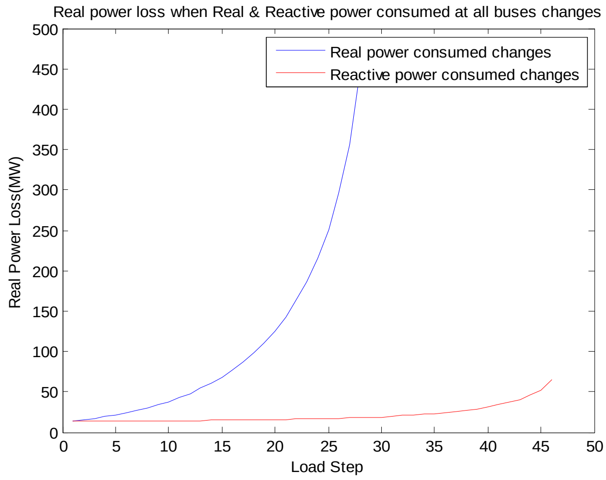

Fig. 2(a)

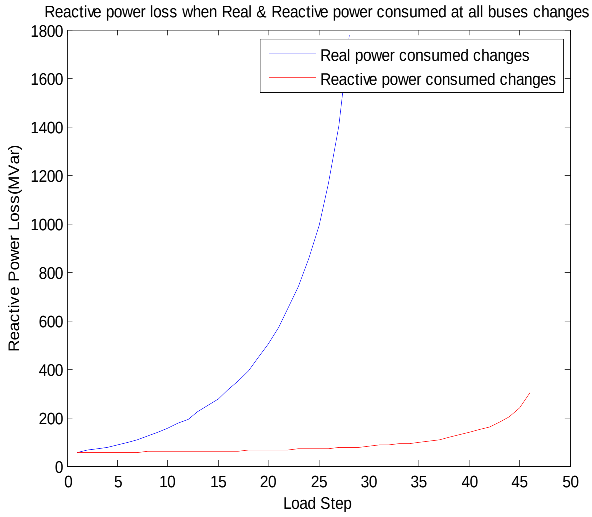

Fig. 2(b)

In fig. 3 (a) & 3(b) Smallest angle change in Bus 2 and Highest angle change in Bus 6

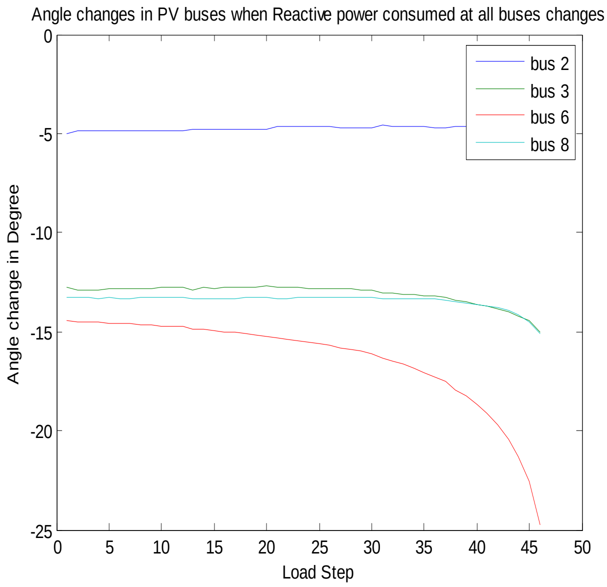

Fig. 3(a)

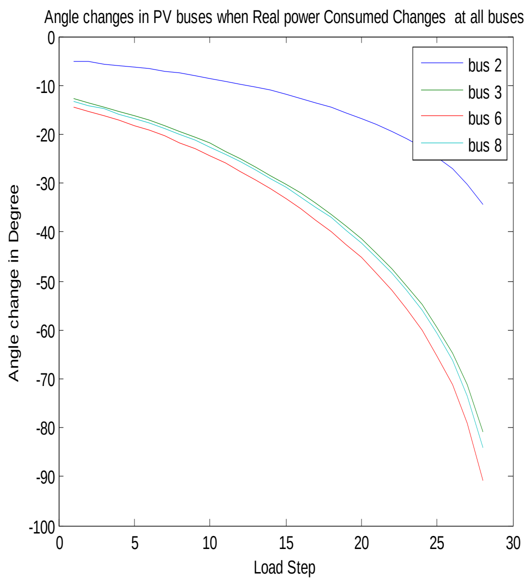

Fig. 3(b)

In fig. 4(a) & 4(b) Smallest angle change in Bus 5 and Highest angle change in Bus 14

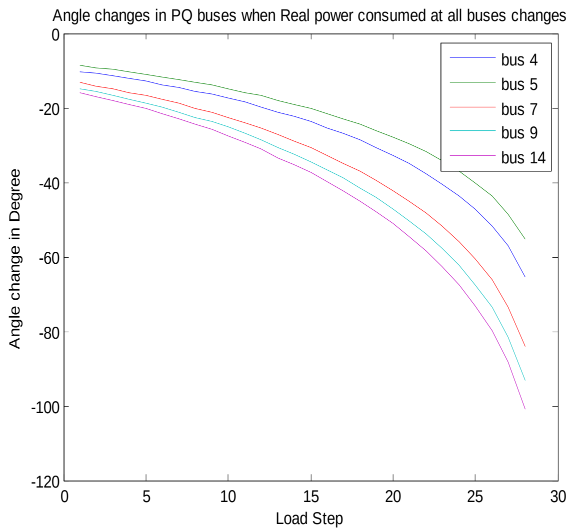

Fig. 4(a)

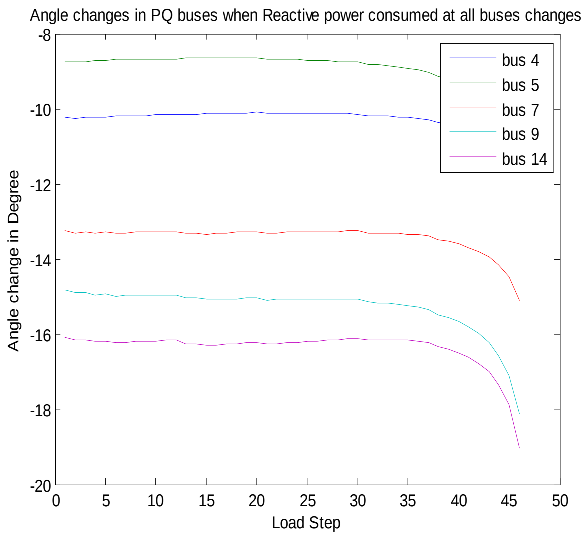

Fig. 4(b)

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