Load Flow Analysis of Six Bus System with Newton Raphson Technique

Jigar Rajendra Thakor[1] Siddhart T. Rabari[2] Lokesh Shah[3] Jay Patel[4] Jignesha Ahir[5]
[1,2]M.Tech Student
[1,2,3,4,5]Department of Electrical Engineering
[1,2,3,4,5]UTU, Surat, India, India

Abstract— In recent times the whole power system network is becoming more and more complex due to Interconnected Power System option, which we choose for better reliability of power supply. This option become worthy initially to emphasis the power transfer. But due to development of more and more regions this system started becoming complex day by day. So, to analyze this whole system and make it flexible one method has introduced which is called Load Flow Analysis. This load flow analysis will give all basic parameters' values, through which we can check whether the system is healthy or not by comparing with the line flow limits of each line. There are also different types of methods available for load flow analysis of whole system but here in this paper, the most suitable and widely considered method, Newton Raphson Method, is used. This load flow analysis is also helpful to handle whole system because we want to transfer more power but in most economical way. Hence, Load Flow Analysis makes the system better, more and most economical power transfer.

Key words: Newton Raphson Method, Load Flow Analysis, Six Bus System

I. Introduction

Initially the power system is just for some particular area. But in recent times it becomes very much complicated due to interconnected power system structure. So to solve the whole system, we have to first consider that "What is power system network parameters?". There are basically four parameters available in any power system network, which are as shown below,

1) Voltage (V)
2) Power angle (δ)
3) Active Power (P)
4) Reactive Power (Q)

In this paper the load flow analysis for six bus system is taken and from that P, Q, V, δ all the results of it recorded.

II. Problem Statement

The objective of the present work is calculating the performance indices for transmission network data using the Newton Raphson Method in six bus system.

III. Research work

A six bus system which is used for this research work is shown in below figure. The line flow data and generator data are given below.

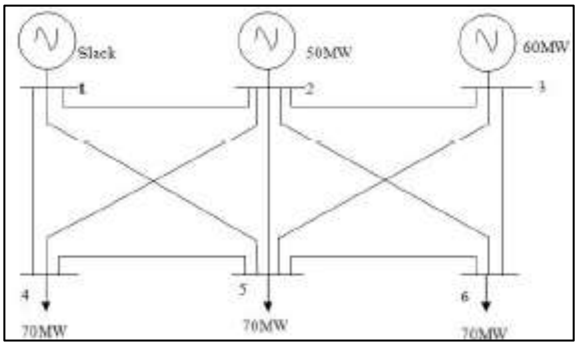


Fig. 1: Six Bus System

Bus number	Bus type	V (p.u.)	P_d (MW)	Q_d (MVAR)	P_g (MW)	Q_g (MVAR)
1	Slack	1.05	0	0	---	---
2	PV	1.05	0	0	50	---
3	PV	1.07	0	0	60	---
4	PQ	1.0	70	70	0	0
5	PQ	1.0	70	70	0	0
6	PQ	1.0	70	70	0	0

Table 1: Bus Data

From bus	To bus	R (p.u)	X (p.u)	Half line charging susceptance (p.u)	Thermal limit (MVA)
1	2	0.1	0.2	0.02	40
1	4	0.05	0.2	0.02	60
1	5	0.08	0.3	0.03	50
2	3	0.05	0.25	0.03	40
2	4	0.05	0.1	0.01	70
2	5	0.10	0.3	0.02	30
2	6	0.07	0.2	0.025	90
3	5	0.12	0.26	0.025	70
3	6	0.02	0.1	0.01	80
4	5	0.2	0.4	0.04	20
5	6	0.1	0.3	0.03	40

Table 2: Line Flow Data

In this paper the load flow analysis is done by Newton Raphson method because it is the easiest method among all other methods of solving the network. Above data is taken as reference for doing Load Flow Analysis. The output of Load Flow Analysis is given in result Annexure.

For the given figure, the Newton Raphson Load flow Analysis is calculated as below,

First of all, the bus admittance matrix is calculated by considering the bus names like Generator bus, Load bus and Slack bus.

A. Slack Bus

The bus connected with largest generator is generally considered as slack bus. (In most of the cases 1^{st} bus is taken as slack bus)

B. Generator Bus

The bus which contains generator connected with it and supplying power is considered as generator bus. Generator bus is denoted as PV bus because its Active power (P) and

Voltage magnitude (V) is known. On the other side the Reactive power (Q) and Power angle (δ) are unknown.

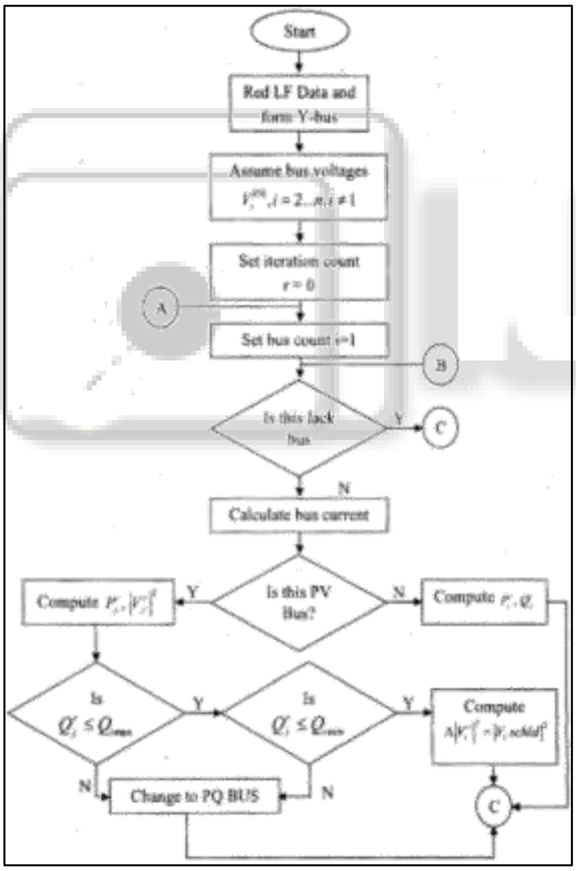
C. Load Bus

The bus which contains load connected with it and no generators are available at that bus, is considered as load bus. This bus contains only outgoing power lines, no incoming power lines are available at these buses.

The load bus is denoted as PQ bus because its Active power (P) and Reactive power (Q) is known. On the other hand, Voltage magnitude (V) and Power angle (δ) are unknown at these buses.

This is the basic information regarding any power system network for doing Load flow analysis. As shown in Table 1 in this network, Bus 1 is considered as Slack bus, Bus 2 and 3 are considered as Generator buses, Bus 4,5 and 6 are considered as load buses.

There are different types of methods available for calculating load flow analysis but here we use Newton Raphson Load flow Analysis method. The procedure of Newton Raphson Load flow method is shown in below flow chart.



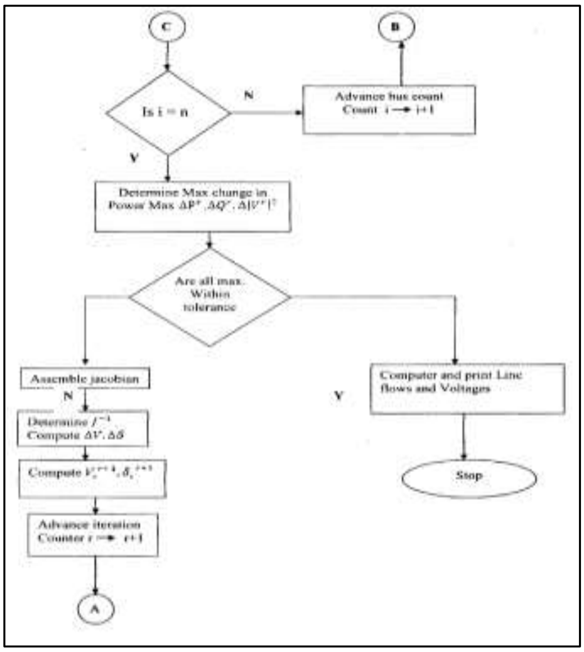


Fig. 2 Newton Raphson Load flow Analysis Flow chart

Power flow equations are formulated in polar form for the n bus system in terms of bus admittance matrix Y as:

$$I_i = \Sigma_{j=1}^{n} Y_{ij} V_j$$

where, i, j are to denote ith and jth bus.

Expressing in polar form:

$$I_i = \Sigma_{j=1}^{n} |Y_{ij}||V_j| \angle \Theta_{ij} + \delta_j$$

The current can be expressed in terms of the active and the reactive power at bus i as:

$$P_i = \Sigma_{j=1}^{n} |V_i||V_j||Y_{ij}| \cos(\Theta_{ij} - \delta_i + \delta_j)$$

$$I_i = P_i - jQ_i / V_i^*$$

So,

$$P_i - jQ_i = |V_i| \angle -\delta_i \; \Sigma_{j=1}^{n} |Y_{ij}||V_j| \angle \Theta_{ij} + \delta_j$$

Separating the real and imaginary parts:

$$P_i = \Sigma_{j=1}^{n} |V_i||V_j||Y_{ij}| \cos(\Theta_{ij} - \delta_i + \delta_j)$$

$$Q_i = -\Sigma_{j=1}^{n} |V_i||V_j||Y_{ij}| \sin(\Theta_{ij} - \delta_i + \delta_j)$$

The Jacobian matrix gives the linearized relationship between small changes in $\Delta\delta_i^{(k)}$ and voltage magnitude $\Delta[V_i^{k}]$ with the small changes in real and reactive power $\Delta P_i^{(k)}$ and $\Delta Q_i^{(k)}$.

$$\begin{bmatrix} \Delta P_2^{(k)} \\ \vdots \\ \Delta P_n^{(k)} \\ \Delta Q_2^{(k)} \\ \vdots \\ \Delta Q_n^{(k)} \end{bmatrix} = \left[\begin{array}{c|c} \begin{pmatrix} \frac{\partial P_2^{(k)}}{\partial \delta_2^{(k)}} & \cdots & \frac{\partial P_2^{(k)}}{\partial \delta_n^{(k)}} \\ \vdots & \ddots & \vdots \\ \frac{\partial P_n^{(k)}}{\partial \delta_2^{(k)}} & \cdots & \frac{\partial P_n^{(k)}}{\partial \delta_n^{(k)}} \end{pmatrix} & \begin{pmatrix} \frac{\partial P_2^{(k)}}{\partial |V_2|} & \cdots & \frac{\partial P_2^{(k)}}{\partial |V_n|} \\ \vdots & \ddots & \vdots \\ \frac{\partial P_n^{(k)}}{\partial |V_2|} & \cdots & \frac{\partial P_n^{(k)}}{\partial |V_n|} \end{pmatrix} \\ \hline \begin{pmatrix} \frac{\partial Q_2^{(k)}}{\partial \delta_2^{(k)}} & \cdots & \frac{\partial Q_n^{(k)}}{\partial \delta_2^{(k)}} \\ \vdots & \ddots & \vdots \\ \frac{\partial Q_n^{(k)}}{\partial \delta_2^{(k)}} & \cdots & \frac{\partial Q_n^{(k)}}{\partial \delta_n^{(k)}} \end{pmatrix} & \begin{pmatrix} \frac{\partial Q_2^{(k)}}{\partial |V_2|} & \cdots & \frac{\partial Q_2^{(k)}}{\partial |V_n|} \\ \vdots & \ddots & \vdots \\ \frac{\partial Q_n^{(k)}}{\partial |V_2|} & \cdots & \frac{\partial Q_n^{(k)}}{\partial |V_n|} \end{pmatrix} \end{array} \right] \begin{bmatrix} \Delta \delta_2^{(k)} \\ \vdots \\ \Delta \delta_n^{(k)} \\ \Delta |V_2^{(k)}| \\ \vdots \\ \Delta |V_n^{(k)}| \end{bmatrix}$$

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

The diagonal and the off-diagonal elements of J1 are,

$$\partial P_i / \partial \delta = \Sigma_{i,j=1}^{n} |V_i||V_j||Y_{ij}| \cos(\Theta_{ij} - \delta_i + \delta_j)$$

$$\partial Q_i / \partial \delta = -\Sigma_{i,j=1}^{n} |V_i||V_j||Y_{ij}| \sin(\Theta_{ij} - \delta_i + \delta_j)$$

Similarly we can find the diagonal and off-diagonal elements of J2, J3 and J4.

The terms $\Delta P(k)$ and $\Delta Qi(k)$ are the difference between the scheduled and calculated values, known as power residuals given by,

$$\Delta P_i^{(k)} = P_i^{(sch)} - \Delta P_i^{(k)}$$

$$\Delta Q_i^{(k)} = Q_i^{(sch)} - \Delta Q_i^{(k)}$$

The new estimates for phase angles and bus voltages are

$$\delta_i^{(k+1)} = \delta_i^{(k)} + \Delta\delta_i^{(k)}$$

$$|V_i^{(k+1)}| = |V_i^{(k+1)}| + |\Delta V_i^{(k)}|$$

IV. RESULT

	Active Power					
	1	2	3	4	5	6
1	107.86	28.69	0	43.58	35.60	0
2	-28.69	50	2.93	33.09	15.51	26.24
3	0	-2.93	60	0	19.11	43.77
4	-43.58	-33.09	0	-70	4.083	0
5	-35.60	-15.51	-19.11	-4.08	-70	1.61
6	0	-26.24	-43.77	0	-1.61	-70

Table 3:

	Reactive Power					
	1	2	3	4	5	6
1	15.869	-15.41	0	20.12	35.60	0
2	15.419	74.35	-12.26	46.05	15.35	12.39
3	0	12.26	89.62	0	23.17	60.72
4	-20.12	-46.05	0	-70	-4.94	0
5	-35.60	-15.35	-23.17	4.94	-70	-9.66
6	0	-12.39	-60.72	0	9.66	-70

Table 4: Load Flow Analysis Result

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