LOAD FLOW ANALYSIS OF POWER SYSTEMS

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Abstract-

This paper gives a brief view of Load Flow, classification of different types of buses, Load Flow equations and the various methods of solution of load flow problems. Moreover it tells us the comparison between different load flow solutions. Also the importance and objectives of load flow studies.
Load flow studies in power system constitutes a study of predominant importance. In load flow analysis we undertake the entire network with all the generators, loads and transmission lines. Power flow equation is formulated on the basis of nodal admittance form. There are some powerful and accurate numerical solution methods for solving power flow problem. One widely used a Newton-Raphson method. We'll have a review of all in this paper.
Keywords- Load flow analysis, Load Flow solution, Newton-Raphson method.

1. Introduction-

In a three phase ac power system, active power (P) and reactive power (Q) flows from the generating stations to load through different network buses and transmission lines. These powers are supplied by generators at generating buses. This flow of active and reactive power is called Load Flow or Power Flow.
For a long time load flow studies were carried out by means of special purpose analog computer, called ac network analyzer, but the high speed computers have replaced them. This change from the ac network analyzer to the digital computer has resulted in greater flexibility, economy and quicker operation. However, the network analyzer is still used in initial planning stages.
Determination of power system networks is possible by using either mesh current or nodal voltage techniques. A power flow study is a steady state analysis whose target is to determine the voltages, currents, real and reactive power flows in a system under a given load conditions. The purpose of power flow studies is to plan ahead and account for various hypothetical situations. For example, if a transmission line is to be taken off line for maintenance, can the remaining lines in the system handle the required loads without exceeding their rated values.

2. Formulation of power-flow study-

A bus is a node at which one or many lines, one or many loads and generators are connected. It is not necessary that all of these be connected all of these be connected at every bus. The bus is indicated by a vertical line at which several components are connected. In realistic power system, there are many types of buses (like 100 or more) but each bus is connected to only small number (usually two or three) of the remaining buses.
There are three types of buses-

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a) Generator Bus (P-V bus) - This bus is also called as P-V bus. In this type true or active power P are specified, and the voltage magnitude is maintained constant at a specified value by adjusting the field current of synchronous generator. The reactive power generation Q and phase angle δ of voltage is computed. V and δ are unknown.

b) Load Bus (P-Q) - This bus is also called P-Q bus and the total injected power is specified. In this real and reactive power are specified, and for which bus voltage has to be calculated. The magnitude and phase angle of the voltage has to be computed. All buses having no generators are load buses. Q and δ are unknown.

c) Slack bus – It is also called as reference bus. At this bus magnitude and phase angle of the voltage are specified. The phase angle is mostly set to zero. The active and reactive powers at this bus are to be determined through the solution of equations. In here P and Q are unknown.

Power flow equations are non- linear, thus can't be solved analytically. A numeric iterative algorithm is required to solve such equations. Procedure follows as-

a) Create a bus admittance matrix Ybus for the power system.

b) Make an initial estimate for the voltages (both magnitude and phase angle) at each bus in the system.

c) Substitute in the power flow equations and determine the deviations from the solution.

d) Update the estimated voltages based on some commonly known numerical algorithms (e.g., Newton-Raphson or Gauss-Seidel).

e) Repeat the above process until the deviations from the solution are minimal.

3. Load Flow equation determination-

A power network is composed of transmission lines, transformers, reactors, loads and generators. A transmission line is represented by an equivalent π circuit with a series impedance (R+jX) from node i to j.

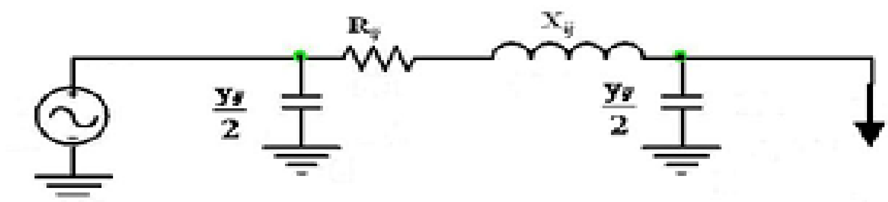

Figure 1: π circuit model of a transmission line

From the network shown above, the current coming out of nodes (buses) i, j can be written as-

$$I_i = V_i \frac{y_{ij}}{2} + (V_i - V_j).(G_{ij} + B_{ij})$$

$$I_j = V_j \frac{y_{ij}}{2} + (V_j - V_i).(G_{ij} + B_{ij})$$ ....(1)

(Gij + Bij) is the admittance of the transmission line connecting nodes i and j and is the reciprocal of the impedance $R_{ij} + X_{ij}$. Equation (1) can be re-written as-

$$I_i = V_i \left(\frac{y_{ij}}{2} + (G_{ij} + B_{ij})\right) - V_j.(G_{ij} + B_{ij})$$

$$I_j = V_j \left(\frac{y_{ij}}{2} + (G_{ij} + B_{ij})\right) - V_i.(G_{ij} + B_{ij}) \quad \text{.............(2)}$$

Hence in Y matrix form it will be written as-

$$\begin{bmatrix} I_i \\ I_j \end{bmatrix} = \begin{bmatrix} Y_{ii}/a^2 & Y_{ij}/a \\ Y_{ji}/a & Y_{jj} \end{bmatrix} . \begin{bmatrix} V_i \\ V_j \end{bmatrix} \quad \text{.........................(3)}$$

The equation describing the power flow coming out of load can be written using Y matrix, this equation is called as load flow equation. Given as-

$$P_i + j\,Q_i = V_i . \sum_j (V_j . Y_{ij})^* \quad \text{....................................(4)}$$

4. Methods of solution of load flow problems-

There are various methods of solution of load flow problems. Earlier the method used followed an iterative process by assigning estimated values to the unknown bus voltages and calculating an entire new value for each bus voltage from the estimated value at the other buses, the real power specified, and the specified reactive power or voltage magnitude. A new set of values for voltage is thus obtained for each bus and still used to calculate another set of bus voltages in a sequential algorithms. The iterative process is repeated until the changes at each bus are less than a specified tolerance value.
Certain iterative methods are as follows-

a) Gauss Seidel method- The number of iterations in this method are reduced. In this method the values of unknowns immediately replace the previous values in the next step.

Basic Equations-

$$[I] = [Y]\,[V] \qquad (1)$$

$$P\text{-}jQ = V^* I \qquad (\text{NB} \quad P+jQ = V I^*) \qquad (2)$$

Constraints (Bus specifications)-

$$\text{GB} \rightarrow P, |V| \quad , \quad \text{LB} \rightarrow P, Q \text{ (or } \cos\phi) \quad \& \ \text{SB} \rightarrow |V|, \angle\theta$$

Assume the voltages of slack + all P-Q buses. In general for any bus k in an N bus power system, the bus voltage can be followed as-

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$I_k = (P_k - jQ_k)/V_k^*$

$$V_k = \frac{1}{Y_{kk}}[I_k - \sum_{\substack{n=1 \\ k\neq n}}^{N} Y_{kn}V_n] \qquad k = 2, \dots N$$

$$V_k = \frac{1}{Y_{kk}}[\frac{P_k - jQ_k}{V_k^*} - \sum_{\substack{n=1 \\ n\neq k}}^{N} Y_{kn}V_n] \qquad k = 2, \dots N$$

The previous set of equations is non- linear. It is however possible to linearize this set by initially estimating values of the unknown bus voltages & hence applying Gauss Seidel technique for solution.
Process for solution:
All buses- PQ slack …..(1)
a) Find-

P_k , Q_k at 2,…N

b) Assemble Ybus.
c) Iterative computation of bus voltages (use flat voltages start i.e. V=1)
d) Compare bus voltages.
e) Immediately substitute computed voltages in success expression.
f) At the end of the first iteration compare guessed and computed values and insure tolerance limit satisfied for all voltages values.
g) If not proceed to another iteration.
h) If convergence is reached print out your result.

Recalling V_k:

$$V_k = \frac{1}{Y_{kk}}[\frac{P_k - jQ_k}{V_k^*} - \sum_{\substack{n=1 \\ n\neq k}}^{N} Y_{kn}V_n] \qquad k = 2, \dots N$$

For an iteration r

$$V_k^r = \frac{1}{Y_{kk}}[\frac{P_k - jQ_k}{(V_k^{*})^{(r-1)}} - \sum_{\substack{n=1 \\ n\neq k}}^{N} Y_{kn}V_n^{(r-1)}] \qquad k = 2, \dots N$$

For the succeeding iteration (r+1)

$$V_k^{(r+1)} = \frac{1}{Y_{kk}}[\frac{P_k - jQ_k}{V_k^{*\,r}} - \sum_{\substack{n=1 \\ n\neq k}}^{N} Y_{kn}V_n^r] \qquad k = 2, \dots N$$

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$$\therefore \Delta V_k^{r+1} = V_k^{r+1} - V_k^r$$

To satisfy convergence ➔ $\Delta V_k^{r+1} \approx \in$

N.B. Solution is ensured when all bus voltages have converged to within the specified tolerance limit. Computation of line flows between any two buses k & n will be-

$$S_{kn} = P_{kn} + JQ_{kn} = V_k I_{kn}^* = V_k(V_k^* - V_n^*) y_{kn}^*$$

$$S_{nk} = P_{nk} + JQ_{nk} = V_n(V_n^* - V_k^*) y_{nk}^*$$

5. Comparison between different load flow solutions-

a) Gauss Seidel method is well known and established while Newton Raphson method is most recent ad most sophisticated method of power flow studies.
b) Polar coordinates are preferred for N-R while rectangular coordinates for Gauss Seidel method.
c) Time taken to perform one iteration of computation is lesser in Gauss Seidel method while compared to N-R method but the number of iterations required for G-S method are more than N-R method.
d) In G-S method rate of convergence is slow plus convergence characteristic is linear while N-R method has quadrature convergence characteristics.
e) G-S method takes more computer time and costs more than N-R method.
f) G-S method is used to compute the solution of small system problems while N-R method is used with advantage for large power systems.

6. Importance of load flow studies-

Load Flow studies provide a systematical mathematical approach for determination of various bus voltages, their phase angle, active and reactive power flow through different branches, generators and loads under steady state conditions.
Load flow studies also help in determination of best size as well as the most favorable locations for power capacitors both for power factor improvement and also for raising network voltages.
Thus it also helps in determination of best locations as well as optimal capacity of the proposed generating stations, substations and new lines. Load Flow is an essential and vital part in power system studies. It helps in calculating line losses for different power flow conditions. It prepares software for online operation, control and monitoring of the power system.
It also helps in analyzing the effect of temporary loss of generating station or transmission path on the power flow.

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7. Conclusion-

This paper proposed the basics of Load Flow. It helped in knowing us the importance of load flow in power systems. It reports the various methods of solutions of power flow equations. These are viz. Gauss Seidel method, Newton Raphson method. The algorithms of Gauss Seidel method are discussed. The above two methods are compared with respect to different parameters. The above method is found to be more accurate. The method undergone few iterations but these were comparatively lesser than the iterations performed in N-R method which is a bit complex and time taking. This paper reviews different objectives and importance of load flow in power systems.

8. References-

a) John J. Grainger and William D. Stevenson Jr., "Power System Analysis", McGraw-Hill, Inc., 1994.

b) J.B Gupta- Load flows (Overview of the topic), 2011

c) A.E Guile and W.D Paterson, Electrical Power System

d) W.D Stevenson, Elements of Power System Analysis, McGraw-Hill, 4th edition 1982