FORMULATION OF POWER FLOW PROBLEM IN POLAR COORDINATES

The power flow problem can also be solved by using Newton-Raphson method. In fact, among the numerous solution methods available for power flow analysis, the Newton-Raphson method is considered to be the most sophisticated and important. Many advantages are attributed to the Newton-Raphson (N-R) approach.

Gauss-Seidel (G-S) is a simple iterative method of solving n number load flow equations by iterative method. It does not require partial derivatives. Newton-Raphson method is based on Taylor's series and partial derivatives.

The N-R method is recent, needs less number of iterations to reach convergence, takes less computer time hence computation cost is less and the convergence is certain. The N-R method is more accurate, and is insensitive to factors like slack bus selection, regulating transformers etc. and the number of iterations required in this method is almost independent of the system size.

The drawbacks of this method are difficult solution technique, more calculations involved in each iteration resulting in large computer time per iteration and the large requirement of computer memory but the last drawback has been overcome through a compact storage scheme.

Convergence can be considerably speeded up by performing the first iteration through the G-S method and using the values of voltages so obtained for starting the N-R iterations. These voltages are used to compute active power P at every bus except the swing bus and also reactive power Q wherever reactive power is specified.

The difference between the specified and calculated values is used to determine the correction of bus voltages. The process of iteration is continued till the difference in the specified and calculated values of P, Q and V are within the given permissible limit.

Before explaining the application of N-R method to the power flow problems, it is useful to review this method in its general form.

Quantities associated with each bus in a system

Each bus in a power system is associated with four quantities and they are real power (P), reactive power (Q), magnitude of voltage (V), and phase angle of voltage (δ).

Work involved (or) to be performed by a load flow study

(i). Representation of the system by a single line diagram

(ii). Determining the impedance diagram using the information in single line diagram

(iii). Formulation of network equation

(iv). Solution of network equations

Iterative methods to solve load flow problems

The load flow equations are non linear algebraic equations and so explicit solution as not possible. The solution of non linear equations can be obtained only by iterative numerical techniques.

Mainly used for solution of load flow study

The Gauss seidal method, Newton Raphson method and Fast decouple method

Flat voltage start

In iterative method of load flow solution, the initial voltages of all buses except slack bus assumed as 1+j0 p.u. This is referred to as flat voltage start

Classification of Buses

Bus

The meeting point of various components in a power system is called a bus. The bus is a conductor made of copper or aluminum having negligible resistance .At some of the buses power is being injected into the network, whereas at other buses it is being tapped by the system loads.

Bus admittance matrix

The matrix consisting of the self and mutual admittance of the network of the power system is called bus admittance matrix (Ybus).

Methods available for forming bus admittance matrix

Direct inspection method.

Singular transformation method.(Primitive network)

Different types of buses in a power system

Types of bus	Known or specified quantities	Unknown quantities or quantities to be determined
Slack or Swing or Reference bus	V, δ	P,Q
Generator or Voltage control or PV bus	P, V	Q, δ
Load or PQ bus	P, Q	V, δ

Need for slack bus

The slack bus is needed to account for transmission line losses. In a power system the total power generated will be equal to sum of power consumed by loads and losses. In a power system only the generated power and load power are specified for buses. The slack bus is assumed to generate the power required for losses. Since the losses are unknown the real and reactive power are not specified for slack bus.

Effect of acceleration factor in load flow study

Acceleration factor is used in gauss seidal method of load flow solution to increase the rate of convergence. Best value of A.F=1.6

Generator buses are treated as load bus

If the reactive power constraint of a generator bus violates the specified limits then the generator is treated as load bus.

Formulation of Load flow Equation

The complex power injected by the generating source into the ith bus of a power system is given as:

$$S_i = P_i + j\,Q_i = V_i\,I_i^* \qquad i = 1, 2, \ldots, n$$

where Vi is the voltage at the ith bus with respect to ground and Ii* is the complex conjugate of source current Ii injected into the bus.

It is convenient to handle load flow problem by using Ii rather than Ii*. So, taking the complex conjugate of above equation), we have

$$Si^* = Pi - j\,Qi = Vi^* I_i\,; \qquad n = 1, 2, 3, \ldots, n$$

$$Substituting\ I_i = \sum_{k=1}^{n} Y_{ik} V_k\ form\ Eq.\,(6.8)\,in\ above\ equation,\ we\ have -$$

$$S_i^* = P_i - jQ_i = V_i^* \sum_{k=1}^{n} Y_{ik} V_k\,; \quad i = 1, 2, \ldots, n$$

Equating real and imaginary parts, we have

$$\text{Real power} = P_i = R_e\left\{V_i^* \sum_{k=1}^{n} Y_{ik} V_k\right\}$$

$$\text{Reactive power} = Q_i = -I_m\left\{V_i^* \sum_{k=1}^{n} Y_{ik} V_k\right\}$$

$$\text{In polar form } V_i = V_i \angle\delta_i,\ V_i^* = V_i \angle -\delta_i$$

$$\text{and } Y_{ik} = Y_{ik} \angle\theta_{ik}.$$

So real and reactive power can now be expressed as

$$\text{Real power, } P_i = V_i \sum_{k=1}^{n} V_k Y_{ik} \cos(\theta_{ik} + \delta_k - \delta_i)$$

$$\text{Reactive power, } Q_i = -V_i \sum_{k=1}^{n} V_k Y_{ik} \sin(\theta_{ik} + \delta_k - \delta_i)$$

Above Equations are known as static load flow equations. (SLFE). These equations are nonlinear equations and, therefore, only a numerical solution is possible. For each of the n system buses we have two such equations giving a total of 2n equations (n real flow power equations and n reactive power flow equations).

Each bus is characterized by four variables Pi, Qi, Vi and δi giving a total of 4n variables. To obtain a solution it is necessary to specify two variables at each bus so that the number of unknowns is reduced to 2n.