UNIT 3

POWER FLOW STUDIES

BUS CLASSIFICATION

1.Slack bus or Reference bus or Swing bus:

$|V|$ and δ are specified. P and Q are un specified, and to be calculated.

2.Generator bus or PV bus or Voltage controlled bus:

P and $|V|$ are specified. Q and δ are un specified, and to be calculated

3.Load bus or PQ bus:

P and Q are specified. $|V|$ and δ are un specified, and to be calculated

BUS CLASSIFICATION

Bus Type	Specified Variables	Unspecified Variables
Load Bus or P-Q bus	P-Q	$\|V\|$, δ
Generator bus or voltage controlled Bus or P-V bus	P,$\|V\|$	Q, δ
Stack bus or reference bus or swing bus	$\|V\|$, δ	P, Q

ITERATIVE METHOD

$$I_p = \sum_{q=1}^{n} Y_{pq} V_q$$

$$S_p = P_p - jQ_p = V_P^{\,*} I_p$$

$$\frac{P_p - jQ_p}{V_P^{\,*}} = \sum_{q=1}^{n} Y_{pq} V_q$$

The above Load flow equations are non linear and can be solved by following iterative methods.

1.Gauss seidal method

2.Newton Raphson method

3.Fast Decoupled method

GAUSS SEIDAL METHOD

For load bus calculate |V| and δ from V_p^{k+1} equation

$$V_p^{k+1} = \frac{1}{Y_{pp}} \left[\frac{P_p - jQ_p}{(V_P^{k})^*} - \sum_{q=1}^{p-1} Y_{pq} V_q^{k+1} - \sum_{q=p+1}^{n} Y_{pq} V_q^{k} \right]$$

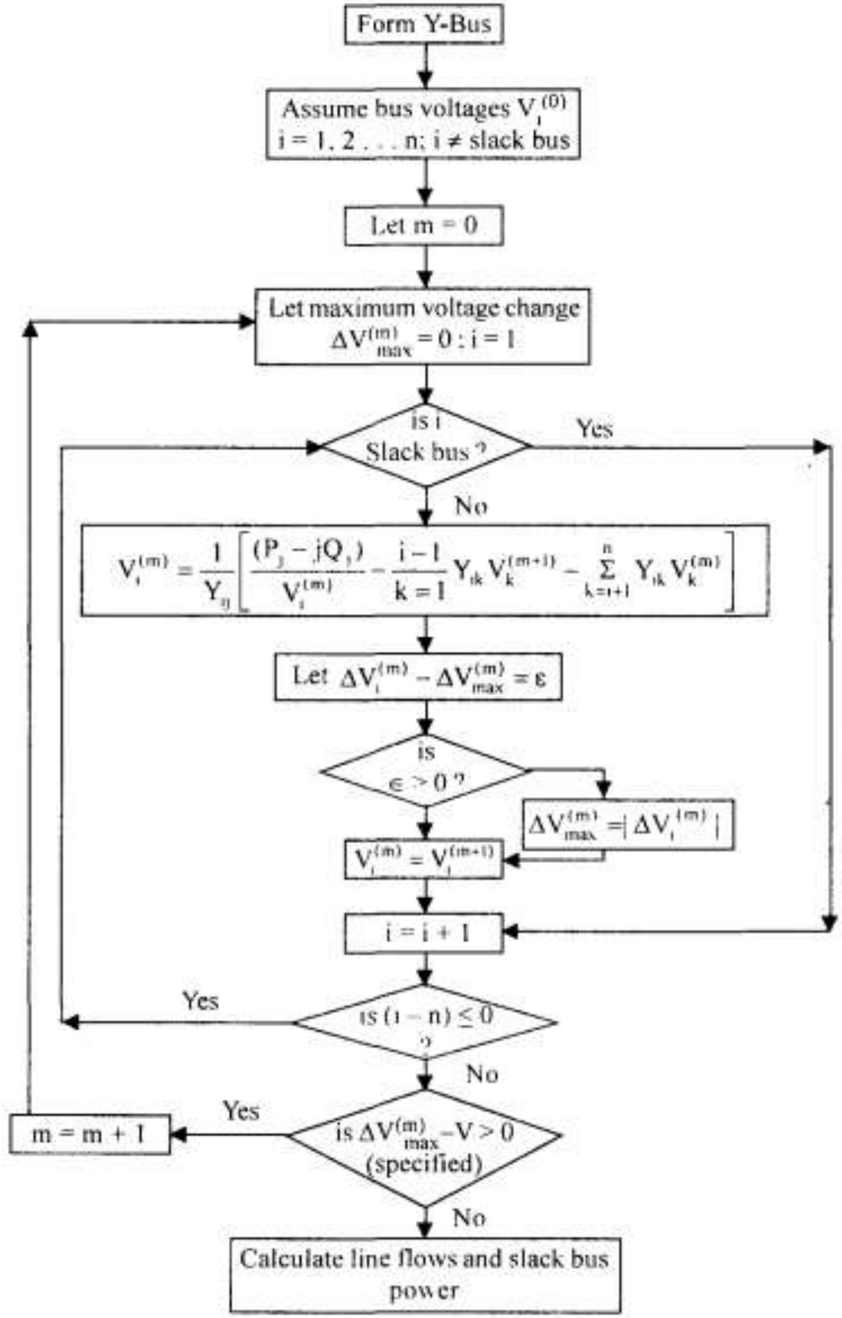
For generator bus calculate Q from Q_P^{K+1} equation

$$Q_p^{k+1} = -1 * \mathrm{Im} \left\{ (V_P^{k})^* \left[\sum_{q=1}^{p-1} Y_{pq} V_q^{k+1} + \sum_{q=p}^{n} Y_{pq} V_q^{k} \right] \right\}$$

- Check $Q_{p,cal}^{k+1}$ with the limits of Q_p
- If $Q_{p,cal}^{k+1}$ lies within the limits bus p remains as PV bus otherwise it will change to load bus
- Calculate δ for PV bus from V_p^{k+1} equation
- Acceleration factor α can be used for faster convergence
- Calculate change in bus-p voltage

$$\Delta V_p^{k+1} = V_p^{k+1} - V_p^{k}$$

- If $|\Delta V_{max}| < \varepsilon$, find slack bus power otherwise increase the iteration count (k)
- Slack bus power= $\sum S_G - \sum S_L$


Form Y-Bus
Assume bus voltages $V_i^{(0)}$ $i = 1, 2 \ldots n$; $i \neq$ slack bus
Let m = 0
Let maximum voltage change $\Delta V_{max}^{(m)} = 0 : i = 1$
is i Slack bus ?
Yes
No
$V_i^{(m)} = \frac{1}{Y_{ij}}\left[\frac{(P_i - jQ_i)}{V_i^{(m)}} - \sum_{k=1}^{i-1} Y_{ik} V_k^{(m+1)} - \sum_{k=i+1}^{n} Y_{ik} V_k^{(m)}\right]$
Let $\Delta V_i^{(m)} - \Delta V_{max}^{(m)} = \varepsilon$
is $\epsilon > 0$?
$\Delta V_{max}^{(m)} = |\Delta V_i^{(m)}|$
$V_i^{(m)} = V_i^{(m+1)}$
$i = i + 1$
Yes
is $(i - n) \leq 0$?
No
Yes
m = m + 1
is $\Delta V_{max}^{(m)} - V > 0$ (specified)
No
Calculate line flows and slack bus power

NEWTON RAPHSON METHOD

$$P_i - Q_i = \sum_{j=1}^{n} |V_i||V_j||Y_{ij}| \angle \theta_{ij} - \delta_i + \delta_j$$

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

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

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

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

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

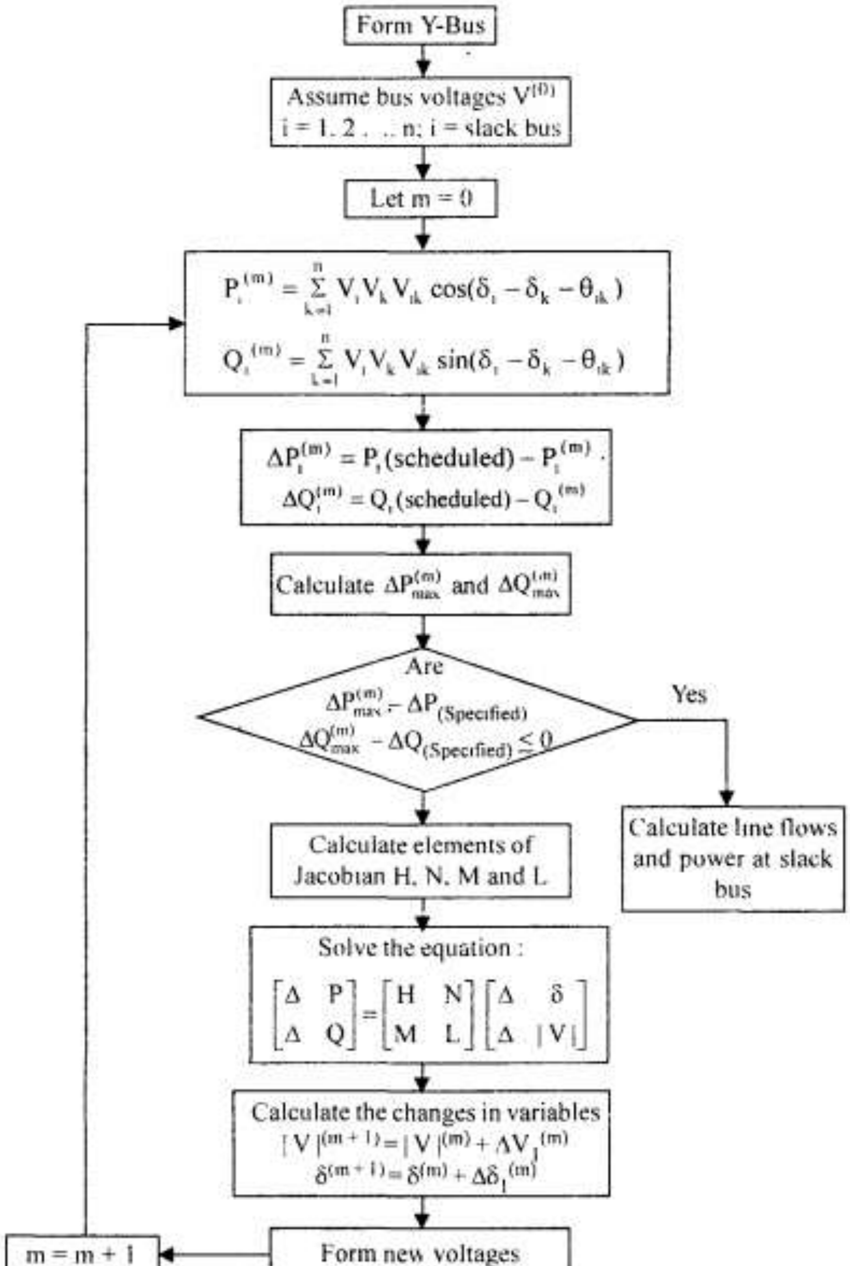
- Calculate |V| and δ from the following equation

$$\delta_i^{k+1} = \delta_i^k + \Delta\delta^k$$

$$\left|V_i^{k+1}\right| = \left|V_i^k\right| + \Delta\left|V_i^k\right|$$

- If $\begin{array}{l}\Delta P_i^k < \varepsilon \\ \Delta Q_i^k < \varepsilon\end{array}$

- stop the iteration otherwise increase the iteration count (k)



Form Y-Bus
Assume bus voltages $V^{(0)}$
$i = 1, 2, \ldots n$; i = slack bus
Let m = 0
$P_i^{(m)} = \sum_{k=1}^{n} V_i V_k V_{ik} \cos(\delta_i - \delta_k - \theta_{ik})$
$Q_i^{(m)} = \sum_{k=1}^{n} V_i V_k V_{ik} \sin(\delta_i - \delta_k - \theta_{ik})$
$\Delta P_i^{(m)} = P_i(\text{scheduled}) - P_i^{(m)}$
$\Delta Q_i^{(m)} = Q_i(\text{scheduled}) - Q_i^{(m)}$
Calculate $\Delta P_{max}^{(m)}$ and $\Delta Q_{max}^{(m)}$
Are
$\Delta P_{max}^{(m)} - \Delta P_{(Specified)}$
$\Delta Q_{max}^{(m)} - \Delta Q_{(Specified)} \leq 0$
Yes
Calculate line flows and power at slack bus
Calculate elements of Jacobian H, N, M and L
Solve the equation :
$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} H & N \\ M & L \end{bmatrix} \begin{bmatrix} \Delta \delta \\ \Delta |V| \end{bmatrix}$
Calculate the changes in variables
$|V|^{(m+1)} = |V|^{(m)} + \Delta V_i^{(m)}$
$\delta^{(m+1)} = \delta^{(m)} + \Delta \delta_i^{(m)}$
Form new voltages
m = m + 1

FAST DECOUPLED METHOD

- J_2 & J_3 of Jacobian matrix are zero

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{pmatrix} J_1 & 0 \\ 0 & J_4 \end{pmatrix} \begin{bmatrix} \Delta \delta \\ \Delta |V| \end{bmatrix}$$

$$\Delta P = J_1 \Delta \delta = \left[\frac{\partial P}{\partial \delta} \right] \Delta \delta$$

$$\Delta Q = J_4 \Delta |V| = \left[\frac{\partial Q}{\partial |V|} \right] \Delta |V|$$

$$\frac{\Delta P}{\Delta |V_i|} = -B^{'} \Delta \delta$$

$$\frac{\Delta Q}{\Delta |V_i|} = -B^{''} \Delta |V|$$

$$\Delta \delta = -\left[B^{'} \right]^{-1} \frac{\Delta P}{\Delta |V|}$$

$$\Delta |V| = -\left[B^{''} \right]^{-1} \frac{\Delta Q}{\Delta |V|}$$

$$\delta_i^{k+1} = \delta_i^k + \Delta\delta^k$$

$$\left|V_i^{k+1}\right| = \left|V_i^k\right| + \Delta\left|V_i^k\right|$$

- ❖This method requires more iterations than NR method but less time per iteration
- ❖It is useful for in contingency analysis

COMPARISION BETWEEN ITERATIVE METHODS

Gauss – Seidal Method

1. Computer memory requirement is less.
2. Computation time per iteration is less.
3. It requires less number of arithmetic operations to complete an iteration and ease in programming.
4. No. of iterations are more for convergence and rate of convergence is slow (linear convergence characteristic.
5. No. of iterations increases with the increase of no. of buses.

NEWTON – RAPHSON METHOD

- Superior convergence because of quadratic convergence.
- It has an 1:8 iteration ratio compared to GS method.
- More accurate.
- Smaller no. of iterations and used for large size systems.
- It is faster and no. of iterations is independent of the no. of buses.
- Technique is difficult and calculations involved in each iteration are more and thus computation time per iteration is large.
- Computer memory requirement is large, as the elements of jacobian matrix are to be computed in each iteration.
- Programming logic is more complex.

FAST DECOUPLED METHOD

- It is simple and computationally efficient.
- Storage of jacobian matrix elements are60% of NR method
- computation time per iteration is less.
- Convergence is geometric, 2 to 5 iterations required for accurate solutions
- Speed for iterations is 5 times that of NR method and 2-3 times of GS method.