Decoupled Load Flow Method :-

In a power system operating in steady-state, there is a strong interdependence between active powers and bus voltage angles. Similarly, there is a strong interdependence between between reactive powers and voltage magnitudes. Thus real power changes, (ΔP) are less sensitive to changes in voltage magnitude and mainly sensitive to change in bus voltage angles. Similarly the reactive power changes (ΔQ) are less sensitive to changes in angles and are mainly sensitive to change in voltage magnitude. In other words the coupling b/w active power (P) and the bus voltage magnitude |V| is relatively weak. Similarly, the coupling b/w reactive power (Q) and bus voltage phase angle is also weak. This weak coupling is utilized in the development of decoupled load flow (DLF) method. in which P is decoupled from ΔV and Q is decoupled from $\Delta\delta$. With these assumption Jacobian Matrix becomes -

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_{11} & \cancel{J_{12}}^{\,0} \\ \cancel{J_{21}}^{\,0} & J_{22} \end{bmatrix} \begin{bmatrix} \Delta\delta \\ \Delta V \end{bmatrix}$$

$$J_{11} = \frac{\partial P}{\partial \delta} \quad J_{12} = \cancel{\frac{\partial P}{\partial V}}^{\,0}$$

$$J_{21} = \cancel{\frac{\partial Q}{\partial \delta}}^{\,0} \quad J_{22} = \frac{\partial Q}{\partial V}$$

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

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

$$S_i = P_i - jQ_i = \bar{V}_i^* \bar{I}_i = V_i^* \sum_{k=1}^{n} \bar{Y}_{ik} \bar{V}_k$$

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

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

$\bar{V}_i = V_i \angle \delta_i$

$\bar{V}_k = V_k \angle \delta_k$

$\bar{Y}_{ik} = Y_{ik} \angle \theta_{ik}$

Transmission Lines are highly inductive in nature, Hence

$Y_{ik} = G_{ik} + jB_{ik}$

$\boxed{G_{ik} << B_{ik}}$

difference of two δ's are not very less (approx zero)

$\boxed{\delta_i - \delta_k = 0}$

These two assumption have been considered

$$\left.\frac{\partial P_i}{\partial \delta_j}\right|_{i \neq j} = -V_i Y_{ij} V_j \sin(\theta_{ij} + \delta_j - \delta_i)$$

[Partial derivative of All terms, where $k \neq j$ (independent of δ_j) will be zero)

$$= -V_i Y_{ij} V_j \left[\sin\theta_{ij} \cos(\delta_j - \delta_i) + \cos\theta_{ij} \sin(\delta_j - \delta_i)\right]$$

$$= -V_i V_j \left[B_{ij} \cos(\delta_j - \delta_i) + \cancel{G_{ij}}^{\,0} \cancel{\sin(\delta_j - \delta_i)}^{\,0}\right]$$

$$= -V_i V_j B_{ij} \cos(\delta_j - \delta_i)$$

$$\neq 0$$

$$\left.\frac{\partial P_i}{\partial \delta_j}\right|_{i=j} = \frac{\partial P_i}{\partial \delta_i} = V_i \sum_{\substack{k=1 \\ k \neq i}}^{n} Y_{ik} V_k \sin(\theta_{ik} + \delta_k - \delta_i)$$

(Partial derivative of i^{th} term will be zero

$$= V_i \sum_{\substack{k=1 \\ k \neq i}}^{n} V_k Y_{ik} \left[\sin\theta_{ik} \cos(\delta_k - \delta_i) + \cancel{\cos\theta_{ik}}^{\,0} \cancel{\sin(\delta_k - \delta_i)}^{\,0}\right]$$

$$\neq 0$$

Similarly, we can findout value of $J_{12} = 0$, $J_{21} = 0$ & $J_{22} \neq 0$. Hence this method reduces the computation part of N-R method. The DLF method requires less memory in storing the Jacobian as compare to NR method. ~~However, the time required~~ DLF method requires more no. of iterations for convergence because of the approximations made in it.

Fast Decoupled Load Flow Method :—

Assumptions —

$$\left\{\begin{array}{l} G_{ik} << B_{ik} \\ \delta_i - \delta_j = 0 \\ Q_i << V_i^2 B_{ii} \end{array}\right\}$$

$$\left.\frac{\partial P_i}{\partial \delta_j}\right|_{i \neq j} = -V_i Y_{ij} V_j \sin(\theta_{ij} + \delta_j - \delta_i)$$

$$= -V_i V_j Y_{ij} [\sin\theta_{ij} \cancelto{1}{\cos(\delta_j - \delta_i)} + \cos\theta_{ij} \cancelto{0}{\sin(\delta_j - \delta_i)}]$$

$$= -V_i V_j B_{ij}$$

$$\left.\frac{\partial P_i}{\partial \delta_i}\right|_{i = j} = V_i \sum_{\substack{k=1 \\ k \neq i}}^{n} Y_{ik} V_k \sin(\theta_{ik} + \delta_k - \delta_i) =$$

$$= V_i \sum_{k=1}^{n} Y_{ik} V_k \sin(\theta_{ik} + \delta_k - \delta_i) - V_i Y_{ii} V_i \sin(\theta_{ii} + \cancel{\delta_i} - \cancel{\delta_i})$$

$$= -Q_i - V_i^2 B_{ii} \simeq -V_i^2 B_{ii} \quad \text{(from assumptions)}$$

$$\left.\frac{\partial Q_i}{\partial V_j}\right|_{i = j} = -\sum_{k=1}^{n} Y_{ik} V_k \sin(\theta_{ik} + \delta_k - \delta_i) - V_i Y_{ii} \sin\theta_{ii}$$

$$= \frac{Q_i}{V_i} - V_i B_{ii} \simeq -V_i B_{ii}$$

$$\left.\frac{\partial Q_i}{\partial V_j}\right|_{i \neq j} = -V_i Y_{ij} \sin(\theta_{ij} + \delta_j - \delta_i) = -V_i B_{ij}$$

From DLF method, we have

$$\underset{(n-1)\times 1}{\Delta P} = \underset{(n-1)\times(n-1)}{\left[\frac{\partial P}{\partial \delta}\right]} \underset{(n-1)\times 1}{[\Delta \delta]}$$

$$\underset{(m-1)\times 1}{\Delta Q} = \underset{(m-1)\times(m-1)}{\left[\frac{\partial Q}{\partial V}\right]} \underset{(m-1)\times 1}{[\Delta V]}$$

For the i^{th} Bus

$$\Delta P_i = \sum_{j=2}^{n} \left(\frac{\partial P_i}{\partial \delta_j}\right) \Delta \delta_j$$

$$= \sum_{j=2}^{n} (-V_i V_j B_{ij}) \Delta\delta_j$$

$$\frac{\Delta P_i}{V_i} = \sum_{j=1}^{n} -V_j B_{ij} \Delta\delta_j$$

$$\frac{\Delta P_i}{V_i} = \sum_{j=1}^{n} -B_{ij} \Delta\delta_j$$

B_{ij} ↳ constt.

In general

$$\boxed{\left[\frac{\Delta P}{V}\right] = \left[-B_P\right]\left[\Delta\delta\right]}$$

Similarly,

$$\Delta Q_i = \sum_{j=2}^{m} \left(\frac{\partial Q_i}{\partial V_j}\right) \Delta V_j$$

$$= \sum_{j=2}^{m} (-V_i B_{ij}) \Delta V_j$$

$$\frac{\Delta Q_i}{V_i} = \sum_{j=2}^{m} (-B_{ij}) \Delta V_i$$

B_{ij} ↳ constt.

$$\boxed{\left[\frac{\Delta Q}{V}\right] = \left[-B_Q\right]\left[\Delta V\right]}$$

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