16/12/19.

Unit-2

Power flow Studies

Necessity of Load flow Studies:

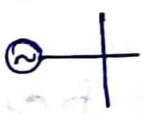
→ The performance of power System network can be analysed with the help of Voltage at the load point provided that the System is working in Steady State Condition.

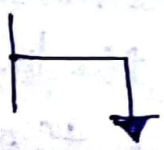
→ The load flow Studies is defined as the analysis of the Unknown electrical quantities for a power System network by knowing the known parameters at that particular buses under Steady State Condition.

→ At each and every bus 4 electrical quantities Specified known as V, δ, P, Q based On the known and Unknown parameters, the buses are classified as three types.

1. Generator bus (or) PV bus (or) Voltage Control bus.
2. Load bus (or) PQ bus
3. Slack bus (or) reference bus

Bus	known Values	Unknown Values
1. Generator bus	P, V	Q, δ
2. Load bus	P, Q	V, δ





www.Jntufastupdates.com Scanned by CamScanner

3. Slack bus V, δ P, Q -

Generator bus:

→ In Generator bus the real power generation (P_g) and Voltage magnitude (V_g) can be Specified.

→ At a generator bus, the reactive power (Q_g) and Voltage angle (δ_g) are the Values that are not known and are to be computed.

→ In practical power System network almost 90% of the buses are load and the remaining 10% are the generator buses.

Load bus:

→ A bus where there is only load Connected and no generation exists is Called as load or PQ bus

→ At this bus real and reactive load demand (P_d) and (Q_d) are drawn from the Supply. That's why this load bus is also known as PQ bus.

→ The other two Unknown quantities at a load bus are Voltage magnitude and phase angle at that bus.

Slack bus:

In a power System network as power flows from the generators to the loads through transmission lines power loss Occurs due to losses in the line Conductors. If these losses are included then

www.Jntufastupdates.com Scanned by CamScanner

the power balance eqns are

$P_g = P_d + P_l$

$Q_g = Q_d + Q_l$

where (d is demand and l is losses)

where P_g and Q_g are total real and reactive generations, P_d and Q_d are the total real and reactive demands and P_l and Q_l are the power losses in the transmission network.

The Values of P_g, Q_g, P_d and Q_d are either known are estimated and the P_l and Q_l remains unknown before the analysis of the network.

There is a purpose One of the generators Or generating bus is Specified as Slack bus Or Slir Swing bus and this bus the generation P_g and Q_g are not Specified and the Voltage magnitude is Specified at this bus and for that the Voltage phase angle ie δ is also fixed at this bus (generally it is Specified as 0 So that all Voltage phase angles of the remaining buses are measured with respect to add Voltage at this bus.

For this reason the Slack bus is also known as reference bus

All the System losses are Supplied by the generation at this bus.

www.Jntufastupdates.com Scanned by CamScanner

Load flow problem: (or) Static load flow equation: (or) Static power flow equation:-

We know that according to ohm's law:

$$V = IR$$

$$V = IZ$$

$$I = \frac{V}{Z}$$

$$I = VY$$

$$[I_{BUS}]_{nx1} = [Y_{BUS}]_{nxn} [V_{BUS}]_{nx1}$$

From the above eqn Current at k^{th} row

$$I_k = Y_{k1}V_1 + Y_{k2}V_2 + \cdots + Y_{kn}V_n$$

$$\boxed{I_k = \sum_{i=1}^{n} Y_{ki}V_i} \quad -(1)$$

We know that the Complex power injected at k^{th} bus

$$S_k = V_k I_k^* = P_k + jQ_k \quad -(*) \quad -(A)$$

where P_k is real or active power injected at k^{th} bus. which is calculated by $P_{kG} - P_{kd}$

Similarly Q_k is reactive power injected at k^{th} bus which is calculated by $Q_{kG} - Q_{kd}$

Taking conjugate on b.s. to eqn (*)

$$S_k^* = V_k^* I_k$$

From eqn (1) $S_k^* = V_k^* \sum_{i=1}^{n} Y_{ki}V_i = P_k - jQ_k \quad (A)$

www.Jntufastupdates.com Scanned by CamScanner

$$P_K - JQ_K = \sum_{i=1}^{n} V_K^* Y_{Ki} V_i$$

$$V_K = |V_K| \angle \delta_K$$

$$Y_{Ki} = |Y_{Ki}| \angle \theta_{Ki}$$

$$V_i = |V_i| \angle \delta_i$$

$$P_K - JQ_K = \sum_{i=1}^{n} \left[|V_K| \angle -\delta_K \right] \left[|Y_{Ki}| \angle \theta_{Ki} \right] \left[|V_i| \angle \delta_i \right]$$

$$= \sum_{i=1}^{n} |V_K| |Y_{Ki}| |V_i| \angle \delta_i - \delta_K + \theta_{Ki}$$

$$P_K = \sum_{i=1}^{n} |V_K| |Y_{Ki}| |V_i| \cos(\delta_i - \delta_K + \theta_{Ki}) \quad -(2)$$

$$Q_K = \sum_{i=1}^{n} |V_K| |Y_{Ki}| |V_i| \sin(\delta_i - \delta_K + \theta_{Ki}) \quad -(3)$$

From eqns (2) & (3) there are n real and n reactive power flow equations giving a total of 2n power flow equations.

→ At each bus there are 4 Variables P, Q, V, δ giving a total of 4n Variables. (n buses)

If at every bus 2 Variables are Specified the remaining 2 Variables at every bus Can be found by Solving 2n powes flow eqns (eqn (2) & (3))

The eqn (2) & (3) are known as Static load flow or Static power flow equations.

The Variable at each and every bus have an operating Constraints described as

1. Voltage Constraint:

* The Voltage magnitude $|V_K|$ must Satisfies the.

www.Jntufastupdates.com Scanned by CamScanner

Where $V_{k min} < V_k < V_{k max}$.

This limit arises due to the fact that the power system equipment is designed to operate at fixed voltage with allowable variations. (5-10% of rated value)

2. The voltage angle δ_i which must satisfy

$$|\delta_k - \delta_i| \leq \{\delta_k - \delta_i\}_{max}$$

3. Real power Constraint.

$$P_{k min} \leq P_k \leq P_{k max}$$

4. Reactive power Constraint

$$Q_{k min} \leq Q_k \leq Q_{k max}$$

From eqn ① & Ⓐ

$$I_k = \sum_{i=1}^{n} Y_{ki} V_i \quad -①$$

$$S_k^* = V_k^* \sum_{i=1}^{n} Y_{ki} V_i = P_k - jQ_k$$

$$I_k = Y_{k1} V_1 + Y_{k2} V_2 + \cdots + Y_{kk} V_k + \cdots Y_{kn} V_n$$

$$I_k = Y_{kk} V_k + \sum_{\substack{i=1 \\ \neq k}}^{n} Y_{ki} V_i$$

$$I_k = Y_{k1} V_1 + Y_{k2} V_2 + \cdots Y_{kn} V_n$$

$$I_k = \sum_{i=1}^{n} Y_{ki} V_i \quad -①$$

$$Y_{kk} V_k = I_k - \sum_{\substack{i=1 \\ \neq k}}^{n} Y_{ki} V_i$$

www.Jntufastupdates.com Scanned by CamScanner

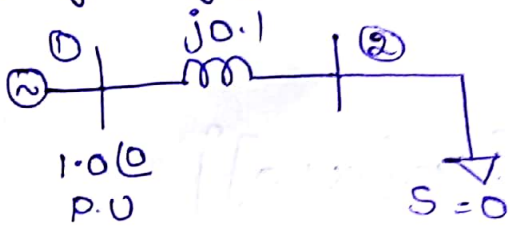
(A) $\Rightarrow S^* = P_K - JQ_K = V_K^* I_K$

$$I_K = \frac{P_K - JQ_K}{V_K^*}$$

$$Y_{KK} V_K = \frac{P_K - JQ_K}{V_K^*} - \sum_{\substack{i=1 \\ \neq K}}^{n} Y_{Ki} V_i$$

$$V_K = \frac{1}{Y_{KK}} \left[\frac{P_K - JQ_K}{V_K^*} - \sum_{\substack{i=1 \\ \neq K}}^{n} Y_{Ki} V_i \right]$$

Calculate the Voltage at buss2 for the given Single line diagram by using gauss Seidel method



Bus	V	δ	P	Q
1	1.0	0	—	—
2.	—	—	-0.8	-0.5j

$$V_K = \frac{1}{Y_{KK}} \left[\frac{P_K - JQ_K}{V_K^*} - \sum_{\substack{i=1 \\ \neq K}}^{n} Y_{Ki} V_i \right]$$

(i+1)

$$Y_{KK} = Y_{22} = \begin{bmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{bmatrix}$$

$$Y_{11} = y_{11} + y_{12} + \frac{y'_{12}}{2}$$

$$= 0 + \frac{1}{j0.1} + 0 = -10j$$

$$Y_{12} = -y_{12} = -(-10j) = 10j$$

$$Y_{21} = Y_{12} = 10j$$

www.Jntufastupdates.com Scanned by CamScanner

$$Y_{22} = Y_{21} + Y_{22} + \frac{Y_{21}}{2} = -10j$$

$$Y_{22} = \begin{bmatrix} -10j & 10j \\ 10j & -10j \end{bmatrix}$$

$$V_2^{(i+1)} = \frac{1}{Y_{22}} \left[\frac{P_2 - jQ_2}{V_2^*} - Y_{21} V_1 \right] \quad \text{Assume } V_2^* = 0.1$$

$$= \frac{1}{-10j} \left[\frac{-0.8 + 0.5j}{1.0} - (10j) \times 1.0 \right]$$

$$V_2^1 = 0.95 - 0.08j$$

$$V_2^1 = 0.95 \angle -4.81$$

2nd Iteration

$$V_2^2 = \frac{1}{Y_{22}} \left[\frac{P_2 - jQ_2}{0.95 \angle -4.81} - [(10j) \times 1.0] \right]$$

$$= \frac{1}{-10j} \left[\frac{-0.8 + 0.5}{0.95 \angle +4.81} - 10j \right]$$

$$V_2^2 = 0.94 \angle -4.83$$

3rd Iteration

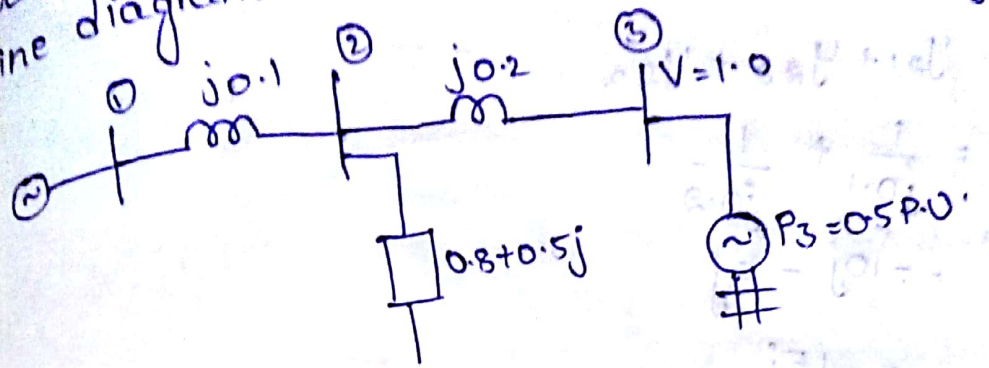
$$V_2^3 = \frac{1}{-10j} \left[\frac{-0.8 + 0.5j}{0.94 \angle 4.83} - 10j \right]$$

$$= 0.94 \angle -4.88$$

$$V_2^3 = 0.94 \angle -4.88$$

www.Jntufastupdates.com Scanned by CamScanner

By using gauss Siedal method Calculate the State Variables V_2, δ_2 and δ_3 for the following Single line diagram.



Bus	V	δ	P	Q	
1	1.0	0	–	–	– slack bus
2	–	–	-0.8	-0.5j	– load bus
3	1.0	–	0.5	–	– Generator bus.

$$V_2^{(i+1)} = \frac{1}{Y_{22}}\left[\frac{P_2 - jQ_2}{V_2^*} - \sum_{\substack{i=1 \\ \neq 2}}^{3} Y_{2i} V_i\right]$$

$$V_2^{(i+1)} = \frac{1}{Y_{22}}\left[\frac{P_2 - jQ_2}{V_2^{i*}} - Y_{21} V_1^i - Y_{23} V_3^i\right]$$

$$Y_{BUS} = \begin{bmatrix} -j10 & j10 & 0 \\ j10 & -j15 & 5j \\ 0 & .5j & -5j \end{bmatrix}$$

$$Y_{11} = y_{11} + y_{12} + y_{13}$$
$$= 0 + \frac{1}{j0.1} + 0$$
$$= -10j$$

$$Y_{12} = -y_{12} = +10j \qquad Y_{12} = Y_{21}$$

www.Jntufastupdates.com Scanned by CamScanner

$Y_{13} = 0$

$Y_{31} = 0$

$Y_{22} = y_{21} + y_{22} + y_{23}$

$= \frac{1}{j0.1} + \frac{1}{j0.2}$

$= -10j - 5j$

$= -15j$

$Y_{23} = -y_{23}$

$= 5j$

$Y_{33} = y_{31} + y_{32} + y_{33}$

$= 0 + \frac{1}{j0.2} + 0$

$= -5j$

$$V_2^1 = \frac{1}{-j15}\left[\frac{-0.8+0.5j}{1} - [j10 \times 1.0] - (5j \times 1.0)\right]$$

$$V_2^1 = \frac{1}{-j15}\left(-0.8 - 14.5j\right)$$

$$V_2^1 = 0.96\angle -3.15^\circ$$

$$V_3^1 = \frac{1}{Y_{33}}\left[\frac{P_3 - jQ_3}{V_3^*} - Y_{31}V_1^i - Y_{32}V_2^{(i+1}\right]$$

$$Q_3 = -\sum_{i=1}^{n} |V_k||Y_{ki}||V_i| \sin(\delta_i - \delta_k + \theta_{ki})$$

www.Jntufastupdates.com Scanned by CamScanner

$$Q_3 = -|V_3||Y_{31}||V_1| \sin(\delta_1 - \delta_3 + \theta_{31}) + -$$
$$|V_3||Y_{32}||V_2| \sin(\delta_2 - \delta_3 + \theta_{32}) -$$
$$|V_3||Y_{33}||V_3| \sin(\delta_3 - \delta_3 + \theta_{33})$$

$$Q_3 = (-|1||0|) - (1)(5)(0.96)\sin(-3.15 - 0 + 90)$$
$$-(1)(5)(1)\sin(0 - 0 + (-90))$$

$$Q_3 = -4.079 + 5$$

$$Q_3 = 0.21$$

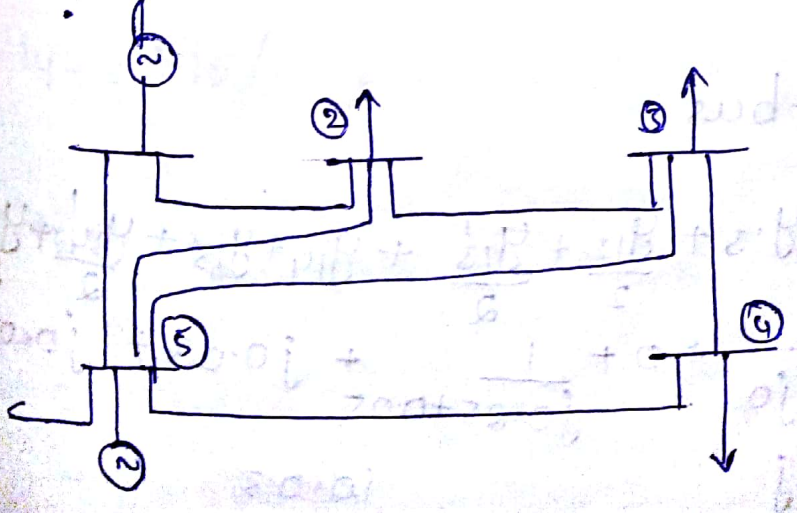
$$V_3^1 = \frac{1}{-5j}\left[\frac{0.5 - j0.21}{1.0} - (0) - \left((5j)(0.96\angle -3.15)\right)\right]$$

$$V_3^1 = \frac{1}{-5j}\left[\frac{0.5 - j0.21}{1} - (0) - \left[(5j)(0.95 - j0.05)\right]\right]$$

$$= \frac{1}{-5j}\left[0.5 - j0.21 - \left[4.75j + 0.25\right]\right]$$

$$V_3^1 = 0.99\angle 2.8^\circ \text{ V}$$

The following data denotes Y-bus matrix for the power system network shown in below



www.Jntufastupdates.com Scanned by CamScanner

line bus to bus	Impedance	line charge admittance $\frac{Y}{2}$
1-2	0.02+j0.1	j0.03
1-5	0.05+j0.25	j0.02
2-3	0.04+j0.2	j0.025
2-5	0.05+j0.25	j0.02
3-4	0.05+j0.25	j0.02
3-5	0.08+j0.4	j0.01
4-5	0.1+j0.5	j0.075

Bus Voltages (V, δ) power generated at load (initial data)

choose P and Q per unit values

Bus No	Bus Voltage		Power generation		load	
	mag	δ	P_G gen (MW)	Q_G gen (MVAR)	P_D (MW)	Q_D
slack 1	1.05	0				
load 2	1	0	0	0	96	62
load 3	1	0	0	0	35	14
load 4	1	0	0	0	16	8
PV 5	1.02	0	48	-	24	11

Calculate the State Variables at all the buses by using gauss Seidal method.

Calculation of 4-bus

$$Y_{11} = y_{11} + y_{12} + y_{13} + \frac{y'_{12}}{2} + \frac{y'_{13}}{2} + y_{14} + y_{15} + \frac{y'_{14}}{2} + \frac{y'_{15}}{2}$$

$$= 0 + \frac{1}{0.02+j0.1} + 0 + \frac{1}{j0.25+0.05} + j0.03 + j0.02$$

$$Y_{11} = 2.69 - 13.41j$$

j0.05

www.Jntufastupdates.com Scanned by CamScanner

$y_{12} = -y_{12}$

$= -\frac{1}{0.02+j0.1}$

$y_{22} = y_{21} + y_{22} + y_{23} + y_{24} + y_{25} + \frac{y_{21}'}{2} + \frac{y_{22}'}{2} + \frac{y_{23}'}{2} + \frac{y_{24}'}{2} +$

$= \frac{1}{0.02+j0.1} + \frac{1}{0.04+j0.2} + \frac{1}{0.05+j0.25} + j0.03 +$

$j0.025 + j0.02$

$= 2.22 - 8.76j$

$= 3.65 - 18.19j$

$y_{33} = y_{32} + y_{34} + y_{35} + \frac{y_{32}'}{2} + \frac{y_{34}'}{2} + \frac{y_{35}'}{2}$

$= \frac{1}{0.04+j0.2} + \frac{1}{0.05+j0.25} + \frac{1}{0.08+j0.4} + j0.025 +$

$j0.02 + j0.01$

$y_{33} = 2.21 - j11$

$y_{44} = y_{43} + y_{45} + \frac{y_{43}'}{2} + \frac{y_{45}'}{2}$

$y_{44} = \frac{1}{0.05+j0.25} + \frac{1}{0.1+j0.5} + j0.02 + j0.025$

$y_{44} = 1.15 - 4.99j$

$y_{55} = y_{51} + y_{52} + y_{53} + y_{54} + \frac{y_{51}'}{2} + \frac{y_{52}'}{2} + \frac{y_{53}'}{2} + \frac{y_{54}'}{2}$

$= \frac{1}{0.05+j0.25} + \frac{1}{0.05+j0.25} + \frac{1}{0.08+j0.4} + \frac{1}{0.1+j0.5}$

$+ j0.02 + j0.02 + j0.01 + j0.025$

www.Jntufastupdates.com Scanned by CamScanner

$Y_{55} = 2.40 - 11.81j$

$Y_{12} = -y_{12} = -\frac{1}{0.02 + j0.1} = Y_{21}$

$= -1.92 + 9.61j$

$Y_{15} = -y_{15} = -\frac{1}{0.05 + j0.25} = -0.76 + 3.8j$

$Y_{21} = -1.96 + 9.61j$

$Y_{23} = -y_{23} = -\frac{1}{j0.2 + 0.04} = -0.96j + 4.80j$

$Y_{23} = -0.96 + j4.8$

$Y_{24} = 0$

$Y_{25} = -y_{25} = -\frac{1}{0.05 + j0.25} =$

$Y_{31} = Y_{13} = 0$

$Y_{32} = -0.96 + j4.8$

$Y_{34} = -y_{34} = -\frac{1}{0.05 + j0.25} =$

$Y_{35} = -y_{35} = -\frac{1}{0.08 + j0.4} =$

$Y_{41} = Y_{14} = 0$

$Y_{42} = 0$

$Y_{43} = -y_{43} = -\frac{1}{0.05 + j0.25} =$

$Y_{45} = -y_{45} = -\frac{1}{0.1 + j0.5} =$

www.Jntufastupdates.com Scanned by CamScanner

$$Y_{BUS} = \begin{bmatrix} 2.69-j13.4 & -1.9+j9.61 & 0 & 0 & -0.76+j3.8 \\ -1.9+j9.61 & 3.65-j18.19 & -0.96+j4.8 & 0 & -0.76+j3.8 \\ 0 & -0.96+j4.8 & 2.21-j11 & -0.76+j3.8 & -0.48+j2.4 \\ 0 & 0 & -0.76+j3.84 & 1.15-j5.6 & -0.38+j1.9 \\ -0.76+j3.8 & -0.76+j3.8 & -0.48+j2.4 & -0.38+j1.9 & 2.4-j11.8 \end{bmatrix}$$

5×

Since bus① is a Slack bus all the State Variables are known there is no Calculations required at this bus.

Since bus 2 is load bus the State Variables V_2, δ_2 are Unknown and Calculated by Using load flow equation

$$V_k^{(it+1)} = \frac{1}{Y_{kk}}\left[\frac{P_k - jQ_k}{V_k^{i*}} - \sum_{\substack{i=1 \\ \neq k}}^{n} Y_{ki} V_i^{i}\right]$$

$$V_2^{1} = \frac{1}{Y_{22}}\left[\frac{P_k - jQ_k}{V_k^{0*}} - \sum_{\substack{i=1 \\ \neq 2}}^{5} Y_{ki} V_i^{i}\right]$$

$$V_2^{1} = \frac{1}{Y_{22}}\left[\frac{P_2 - jQ_2}{V_k^{*}} - Y_{21}V_1 - Y_{23}V_3 - Y_{24}V_4 - Y_{25}V_5\right]$$

$$V_2^{1} = \frac{1}{3.65-j18.19}\left[\frac{0.96+j0.62}{1.05\angle 0} - (1.9+j9.61)\underset{(1.05)}{*} - (0.96+j4.8)\underset{(1)}{*} - (0)(1) - (-0.76+j3.8)(1.02)\right]$$

$$V_2^{1} = 0.99\angle -2.59^{\circ} V$$

www.Jntufastupdates.com Scanned by CamScanner

Bus 3 is a load bus the State Variable V_3, δ_3 are Unknown and Calculated by Using load flow eqn

$$V_3^1 = \frac{1}{Y_{33}}\left[\frac{P_3 - jQ_3}{V_3^{0*}} - Y_{31}V_1 - Y_{32}V_2 - Y_{34}V_4 - Y_{35}V_5\right]$$

$$V_3^1 = \frac{1}{2.21-11j}\left[\frac{-0.35+j0.14}{1\angle 0} - ((0)(1.05)) - ((-0.96+j4.8)(0.99\angle -2.59)) - ((-0.76+j3.8)(1)) - ((0.48+j2.4)(1.02))\right]$$

$$V_3^1 = 0.988\angle -2.82V$$

Bus 4 is a load bus the State Variables V_4, δ_4 are Unknown and Calculated by Using load flow equation.

$$V_4^1 = \frac{1}{Y_{44}}\left[\frac{P_4 - jQ_4}{V_4^{0*}} - Y_{41}V_1 - Y_{42}V_2 - Y_{43}V_3 - Y_{45}V_5\right]$$

$$V_4^1 = \frac{1}{1.15\angle -j5.6}\left[\frac{-0.16+j0.08}{1\angle 0} - ((0)(1.05)) - ((0)(0.99\angle -2.59)) - ((-0.76+j3.84)(0.988\angle -2.82)) - ((-0.38+j1.9)\times(1.02))\right]$$

$$V_4^1 = 0.99\angle -3.48V$$

www.Jntufastupdates.com Scanned by CamScanner

Bus 5 is a PV bus Unknown Value is Q_g.

$$Q_k = \sum_{i=1}^{n} |V_k||Y_{ki}||V_i| \sin(\delta_i - \delta_k + \theta_{ki})$$

$$Q_5 = \sum_{i=1}^{5} |V_5||Y_{51}||V_1| \sin(\delta_1 - \delta_5 + \theta_{51}) -$$

$$|V_5||Y_{52}||V_2| \sin(\delta_2 - \delta_5 + \theta_{52}) -$$

$$|V_5||Y_{53}||V_3| \sin(\delta_3 - \delta_5 + \theta_{53}) -$$

$$|V_5||Y_{54}||V_4| \sin(\delta_4 - \delta_5 + \theta_{54}) -$$

$$|V_5||Y_{55}||V_5| \sin(\delta_5 - \delta_5 + \theta_{55})$$

$$Q_5 = |1.02||3.87||1.05| \sin(0 - 0 + (-78.6)) - |1.02||3.87|$$
$$|0.99| \sin(-2.59 + 0 + (-78.6)) - |1.02||2.44||0.988|$$
$$\sin(-2.82 + 0 + 78.6) - |1.02||1.93||0.99| \sin(-3.48 - 0$$
$$(-78.6) - |1.02||12.04||1.02| \sin(0 - 0 + 78.5)$$

$$Q_5 = -4.06 + 3.86 + 2.43 + 1.93 + 2.2$$

$$Q_5 = 16.36$$

$$V_5' = \frac{1}{Y_{55}}\left[\frac{P_5 - jQ_5}{V_5^*} - Y_{51}V_1 - Y_{52}V_2 - Y_{53}V_3 - Y_{54}V_4\right]$$

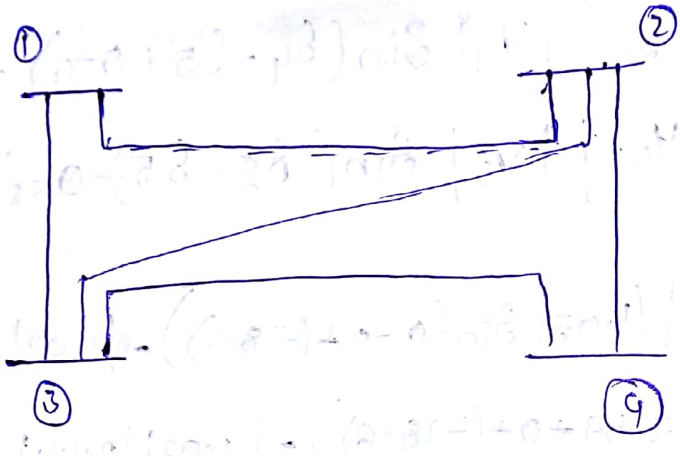
$$= \frac{1}{2.4 - j11.8}\left[\frac{0.24 - j0.05}{1.02} - \left[(-0.76 + j3.8)(1.05)\right] - \left[(-0.76 + j3.8)\right.\right.$$
$$\left.\left.(0.99\angle -2.59)\right] - \left[(-0.48 + j2.4)(0.988\angle -2.82)\right] - \left[(-0.38 + j1.9)(0.99\angle -3.48)\right]$$

$$V_5' = \frac{1}{2.4 - j11.8}\left[0.240\angle -11.76 - 4.06\angle 101.3 - 3.83\angle 98.71 - 2.41\angle 98.48\right]$$

$$V_5' = \frac{12.29\angle -79.5 - 1.91\angle 97.82}{2.4 - j11.8} \Rightarrow \frac{}{1.02\angle -0.9\,V}$$

www.Jntufastupdates.com Scanned by CamScanner

For the Sample System shown in below the generators are connected at all the 4 buses while loads are connected at buses 2 & 3. The Values of Real and reactive powers are listed in below by assuming flat Voltage start find the Voltages and bus angles at the three buses at the end of 1st Gauss Siedal iteration.



Bus to Bus	Resistance in P.U $\frac{1}{R}=G$	X P.U $\frac{1}{X}=B$
1-2	20	-6.66j
1-3	10	-3.3j
2-3	6.6	-2.2j
2-4	10	-3.3j
3-4	20	-6.6j

$$Y_{BUS} = \begin{bmatrix} 30-9.9j & -20+6.6j & -10+3.3j & 0 \\ -20+6.6j & 36.6-12.5j & -6.6+2.2j & -10+3.3j \\ -10+3.3j & -6.6+2.2j & 36.6-12j & -20+6.6j \\ 0 & -10+3.3j & -20+6.6j & 30-9.9j \end{bmatrix}$$

www.Jntufastupdates.com Scanned by CamScanner

Bus	P_i (p.u)	Q_i (p.u)	V	δ
1	-	-	1.04	0
2.	0.5	-0.2	-	-
3	-1	0.5	-	-
4.	0.3	-0.1	-	-

Since 1st bus is a slack bus then is no calculations required.

At Bus 2

$$V_k = \frac{1}{Y_{kk}}\left[\frac{P_k - jQ_k}{V_k^*} - \sum_{\substack{i=1 \\ \neq k}}^{n} Y_{ki}V_i\right]$$

$$V_2^{i+1} = \frac{1}{Y_{22}}\left[\frac{P_2 - jQ_2}{V_2^*} - Y_{21}V_1^i - Y_{23}V_3^i - Y_{24}V_4^i\right]$$

$$= \frac{1}{36.6 - 12.1j}\left[\frac{0.5 + j0.2}{1\angle 0} - \left[(20 + 6.6j)(1.04)\right] - \left[(-6.6 + 2.2j)(1)\right] - \left[(-10 + 3.3j)(1)\right]\right]$$

$$= \frac{1}{36.6 - 12.1j}\left[0.5 + j0.2 + 20 - 6.6j + 6.6 - 2.2j + 10 - 3.3j\right]$$

$$= \frac{\left[37.1 - 12.1j\right]}{36.6 - 12.1j}$$

$$= 1.02\angle 0.23V$$

$$= \cancel{k\,0.2+c\alpha}$$

$$V_2 = 1.02\angle 0.23V$$

www.Jntufastupdates.com Scanned by CamScanner

Similarly V_3 at 1st iteration

$$V_3 = 1.028 - j0.087 = 1.03\angle -4.83$$

Similarly V_4 at 1st iteration

$$V_4 = \frac{1}{Y_{44}}\left[\frac{P_4 - jQ_4}{V_4^*} - Y_{41}V_1 - Y_{42}V_2 - Y_{43}V_3\right]$$

$$V_4 = \frac{1}{30 - 9.9j}\left[\frac{0.3 + j0.1}{1} - (0) - \left[(-10 + 3.3j)(1.02\angle 0)\right] - \left[(-20 + 6.6j)(1.028 - j0.087)\right]\right]$$

$V_4 =$

In example from above problem Let bus 2 be a PV bus Now with $|V_2| = 1.04$ P.U Assuming a flat Voltage Start find Q_2, δ_2, V_3, V_4 at the end of first gauss Siedal iteration given $0.2 \le Q_2 \le 1$ P.U

At bus 2 injected reactive power Q_2

$$Q_2 = -|V_2||Y_{21}||V_1|\sin(\delta_1 - \delta_2 + \theta_{21}) - |V_2||Y_{22}||V_2|\sin(\delta_2 - \delta_2 + \theta_{22}) - |V_2||Y_{23}||V_3|\sin(\delta_3 - \delta_2 + \theta_{23}) - |V_2||Y_{24}||V_4|\sin(\delta_4 - \delta_2 + \theta_{24})$$

$$Q_2 = -|1.04||21.06||1.04|\sin(0 - 0 + (+161.73)) - |1.04||38.54||1.04|\sin(0 - 0 - 18.29) - |1.04||6.25||1.03|\sin(-4.83 - 0 + 161.5)$$

www.Jntufastupdates.com Scanned by CamScanner

$= |1.04||10.5||1|\sin(0-0+161.7)$

$= -7.15 + 13.06 - 2.99 - 3.42$ ——— (1)

$Q_2 = 0.2$

$V_5 = \frac{1}{Y_{55}}\left[\frac{P_5 - jQ_5}{V_5^*} - Y_{51}V_1 - Y_{52}V_2 - Y_{53}V_3 - Y_{54}V_4\right]$

$= \frac{1}{30 - 9.9j}\left[\right]$

$V_2 = \frac{1}{Y_{22}}\left[\frac{P_2 - jQ_2}{V_2^*} - Y_{21}V_1 - Y_{23}V_3 - Y_{24}V_4\right]$

$= \frac{1}{36.6 - 12.1j}\left[\frac{0.5 + j0.2}{1.04} - \left[(21.06\angle 161.7)(1.04)\right] - \right.$

$\left.\left[(6.9\angle 161.5)(1)\right] - \left[(10.5\angle 161.7)(1)\right]\right]$

$(0.48 \mp 0.19j)$

$V_2 = \frac{1}{36.6 - 12.1j}\left[\left(\frac{0.5 \mp j0.2}{1.04}\right) + 20.79 - 6.87j + 6.5 - 2.18j + 9.96 - 3.29j\right]$

$= \frac{37.75 - 12.15j}{36.6 - 12.1j}$

$= 1.02 \angle 7.9 \times 10^{-3}j$

$V_2 = 1.03\angle -0.09$ V

$V_2 = 1.04\angle 0.9$ V

Since it is pv bus the voltage magnitude is always constant 1.04 when Q_2 is within the limits

www.Jntufastupdates.com Scanned by CamScanner

$$V_3^{(i+1)} = \frac{1}{Y_{33}}\left[\frac{P_3 - jQ_3}{V_3^*} - Y_{31}V_1^i - Y_{32}V_2^{i+1} - Y_{34}V_4^i\right]$$

$$= \frac{1}{36.6 - 12j}\left[\frac{-1 - 0.5j}{1} - \left[(-10 + 3.3j)(1.04)\right] - \left[(-6.6 + 2.2j)\right.\right.$$
$$\left.\left.(1.04\angle 0.9\right.\right.$$
$$- \left[(-20 + 6.6j)(1)\right]$$

$$= \qquad 1.031\angle$$
$$1.031 - j0.089$$

$$V_4^{(i+1)} = \frac{1}{Y_{44}}\left[\frac{P_4 - jQ_4}{V_4^*} - Y_{41}V_1 - Y_{42}V_2 - Y_{43}V_3\right]$$

$$= \frac{1}{30 - 9.9j}\left[\frac{0.3 + 0.1j}{\qquad}\right.$$

$$V_4^{(i+1)} =$$

$$0.99 - j0.003$$

Suppose the limits on Q_2 (reactive power injection) are revised as follows $0.25 \le Q_2 \le 1$ P.U.

The Calculated Q_2 Value from eqn (1) ($Q_2 = 0.2$)

Note: It is clear that the other data remaining the same but the Calculated Q_2 is now less than the Q_2 minimum. Hence the Q_2 is set equal to

www.Jntufastupdates.com

Q_2 minimum

i.e $Q_2 = 0.25$ P.U.

Also bus-2 becomes a PQ bus from a PV bus

∴ Magnitude of V_2 $|V_2|$ no longer remains fixed at 1.04 P.U.

The Value of V_2 at the end of the 1st iteration is calculated as follows.

$$V_2 = \frac{1}{Y_{22}}\left[\frac{P_2 - jQ_2}{V_2^*} - Y_{21}V_1 - Y_{23}V_3 - Y_{24}V_4\right]$$

$$= \frac{1}{36.6 - 12.5j}\left[\frac{0.5 - 0.25j}{1} - \left[(-20 + 6.6j)(1.04)\right] - \right.$$

$$\left.\left[\left(\frac{-6.6 + 2.2j}{36.6 - 12.5j}\right)(1)\right] - \left[\left((-10 + 3.3j)(1)\right)\right]\right]$$

$$= \frac{-5.3 + -1.59j \quad 37.9 - 12.61j}{36.6 - 12.5j}$$

$$= 1.03 + 8.17 \times 10^{-3} j$$

$$= 1.03 + 0.008j$$

$$= 1.03 \angle 0.4 \text{ V}$$

$1.05 + j0.05$

Similarly V_3 at 1st iteration

$V_3 = 1.034 - j0.089$ P.U

$V_4 = 1.077 + j0.092$

www.Jntufastupdates.com Scanned by CamScanner

Algorithm Or procedure for Siedal method:

Step-1

Construct ~~Ybus~~ Y_{bus} and assume initial Voltage at all the buses are flat Voltages i.e $V_k = 1 P.U$ except for Slack bus.

Step-2

Set the Convergent Criteria as $|\Delta V_K|_{max}$ is less than ε where ε is Set Value

Step-3

Initiate the iteration Count as $i = 0$.

Step-4

Initiate the bus Count as $k = 1$

Step-5

check. Is it Slack bus

Slack bus < Yes / No

If it is Yes go to Step-8

If it is No go to next Step

Step-6

check is it a generator bus

If it is No go to the next Step

If it is Yes Calculate $Q_k = -\sum_{i=1}^{n} |Y_{ki}||V_k||V_i| \sin(\delta_i - \delta_k + \theta_k)$

Calculate $V_k^{(i+1)} = \frac{1}{Y_{kk}}\left(\frac{P_k - jQ_k}{V_k^*} - \sum_{\substack{i=1 \\ \neq k}}^{n} Y_{ki} V_i\right)$

Based On the $V_K^{(i+1)}$ find Out the angle δ_k.

Go to Step 8

www.Jntufastupdates.com Scanned by CamScanner

Step 7
check if it is a load bus
calculate $V_k^{(i+1)} = \frac{1}{Y_{kk}}\left[\frac{P_k - jQ_k}{V_k^*} - \sum_{\substack{i=1 \\ \neq k}}^{n} Y_{ki}V_i\right]$
Based on $V_k^{(i+1)}$ calculate the angle δ_k
calculate $\Delta V_k = V_k^{(i+1)} - V_k^{(i)}$
Now replace V_k^i with by $V_k^{(i+1)}$ and go to next Step

Step 8
check is the bus Count $k = n$
If it is no increment bus Count $k = k+1$ and go to Step 5
If it is yes go to next Step.

Step 9
check $\Delta V_{k\,max} < \varepsilon$
If it is no the problem is divergent and increase the iteration Count $i = i+1$ and go to Step 4.
If it is yes the problem is Convergent now declare the reactive power and angle to a generator bus and magnitude of Voltage, angle to a load bus.

Note: In order to reduce the number of iterations an acceleration factor is considered which is indicated as α
By using acceleration factor,
$$V_k^{(i+1)} = V_k^i + \alpha\left[V_k^{i+1} - V_k^i\right]$$

www.Jntufastupdates.com Scanned by CamScanner

Newton Raphson method

1) NR method is much faster while compare with gauss Siedal method.
2) By Using Newton Raphson method the load flow Convergence is assured.
3) By Using NR method we can able to find out the Solution for a practical Systems [for large networks]
4) NR method requires more memory and Compact Storage Scheme.

NR method in Rectangular form:-

we know that

$$S_K^* = V_K^* I_K \quad - (2)$$

$$= V_K^* \sum_{i=1}^{n} Y_{Ki} V_i$$

$$S_K^* = \sum_{i=1}^{n} V_K^* Y_{Ki} V_i \quad - (1)$$

Let $V_K = e_K + jf_K$.

$$Y_{Ki} = G_{Ki} - jB_{Ki}$$

$$V_i = e_i + jf_i$$

Substitute in eqn (1)

$$S_K^* = P_K - JQ_K.$$

$$P_K - JQ_K = \sum_{i=1}^{n} (e_K - jf_K)(G_{Ki} - jB_{Ki})(e_i + jf_i)$$

$$= \sum_{i=1}^{n} (e_K - jf_K)(G_{Ki}e_i + jG_{Ki}f_i - jB_{Ki}e_i + B_{Ki}f_i)$$

$$P_K - \cdots = \sum_{i=1}^{n} e_K(G_{Ki}e_i + B_{Ki}f_i) + f_K(G_{Ki}f_i - e_iB_{Ki}) \quad - (2)$$

www.Jntufastupdates.com Scanned by CamScanner

$$\Delta P_k = \sum_{i=1}^{n} e_k \left[G_{ki} f_i - e_i B_{ki} \right] + f_k \left[-G_{ki} e_i - B_{ki} f_i \right]$$

$$\Delta Q_k = \sum_{i=1}^{n} f_k \left[G_{ki} e_i + f_i B_{ki} \right] - e_k \left[G_{ki} f_i - e_i B_{ki} \right] \quad -(2)$$

$$|V_k| = \sqrt{e_k^2 + f_k^2}$$

$$|V_k|^2 = e_k^2 + f_k^2 \quad -(4)$$

From eqn (2), (3) & (4)

In case of gauss Siedal method the Unknown electrical quantities of buses are expressed as non linear Simultaneous function of known. Values along with elements

for eqn (2) & (3), (4) in NR method the Specified electrical quantities of buses expressed a non-linear Simultaneous function of unknown electrical quantities of buses along with admittance of the network.

Out of three eqns (2,3,4) the eqn (2) & (3) are Used for load bus and (2) & (4) are Used for generator bus

Consider n equations which are function of a n Variable $x_1, x_2, \ldots x_n$

$$y_1 = f_1(x_1, x_2 \ldots x_n)$$

$$y_n = f_n(x_1, x_2 \ldots x_n)$$

$$y_1 = f_1(x_1^0 + \Delta x_1, x_2^0 + \Delta x_2 \ldots x_n^0 + \Delta x_n^0)$$

$$y_n = f_n(x_1^0 + \Delta x_1, x_2^0 + \Delta x_2 \ldots x_n^0 + \Delta x_n^0)$$

www.Jntufastupdates.com Scanned by CamScanner

where $x_1 = x_1^\circ + \Delta x_1$

x_1° = initial guess Value

Δx_1 is residual Value

x_1 is unknown Value

From Taylor Series expansion above eqn can be written as $y_1 = f_1(x_1^\circ + x_2^\circ + \cdots x_n^\circ) +$

$$\left(\frac{\partial f_1}{\partial x_1}\Big|_{x_1^\circ} \Delta x_1 + \frac{\partial f_1}{\partial x_2}\Big|_{x_2^\circ} \Delta x_2 \cdots \right.$$

$$\left. \frac{\partial f_n}{\partial x_n}\Big|_{x_n^\circ} \Delta x_n \right)$$

$$y_n = f_n(x_1^\circ + x_2^\circ + \cdots x_n^\circ) +$$

$$\left(\frac{\partial f_1}{\partial x_1}\Big|_{x_1^\circ} \Delta x_1 + \cdots \frac{\partial f_n}{\partial x_n}\Big|_{x_n^\circ} \Delta x_n\right)$$

calculated

$$= \begin{bmatrix} y_1 - f_1(x_1^\circ, x_2^\circ \cdots x_n^\circ) \\ \vdots \\ y_n - f_n(x_1^\circ, x_2^\circ \cdots x_n^\circ) \end{bmatrix} = \begin{bmatrix} \frac{\partial f_1}{\partial x_1}\Big|_{x_1^\circ} \cdots \frac{\partial f_n}{\partial x_n}\Big|_{x_n^\circ} \\ \vdots \\ \frac{\partial f_n}{\partial x_1}\Big|_{x_1^\circ} \cdots \frac{\partial f_n}{\partial x_n}\Big|_{x_n^\circ} \end{bmatrix} \begin{bmatrix} \Delta x_1 \\ \Delta x_2 \\ \vdots \\ \Delta x_n \end{bmatrix} \quad -(5)$$

specified.

$$\begin{bmatrix} \Delta y_1 \\ \vdots \\ \Delta y_n \end{bmatrix} = [J][C]$$

$$[B] = [J][C]$$

where B is residual matrix i.e known Value and J is Jacobian matrix and c is unknown residual matrix.

www.Jntufastupdates.com Scanned by CamScanner

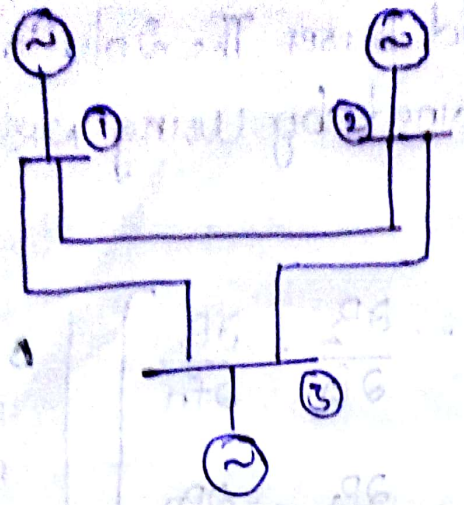
From eqn (5) for a power System network which consists of both generator and load buses The Solution of that network can be obtained by using NR method as follows

$$\begin{bmatrix} \Delta P_2 \\ \vdots \\ \Delta P_n \\ \Delta Q_2 \\ \vdots \\ \Delta Q_n \\ \Delta |V_2|^2 \\ \vdots \\ \Delta |V_n|^2 \end{bmatrix} = \begin{bmatrix} \frac{\partial P_2}{\partial e_2} & \cdots & \frac{\partial P_2}{\partial e_n} & \cdots & \frac{\partial P_2}{\partial f_2} & \cdots & \frac{\partial P_2}{\partial f_n} \\ \vdots & & & & & & \\ \frac{\partial P_n}{\partial e_2} & \cdots & \frac{\partial P_n}{\partial e_n} & \cdots & \frac{\partial P_2}{\partial f_2} & \cdots & \frac{\partial P_n}{\partial f_n} \\ \frac{\partial Q_2}{\partial e_2} & \cdots & \frac{\partial Q_2}{\partial e_n} & \cdots & \frac{\partial Q_2}{\partial f_2} & \cdots & \frac{\partial Q_2}{\partial f_n} \\ \frac{\partial Q_n}{\partial e_2} & \cdots & \frac{\partial Q_n}{\partial e_n} & \cdots & \frac{\partial Q_n}{\partial f_2} & \cdots & \frac{\partial Q_n}{\partial f_n} \\ \frac{\partial |V_2|^2}{\partial e_2} & \cdots & \frac{\partial |V_2|^2}{\partial e_n} & \cdots & \frac{\partial |V_2|^2}{\partial f_2} & \cdots & \frac{\partial |V_2|^2}{\partial f_n} \\ \frac{\partial |V_n|^2}{\partial e_2} & \cdots & \frac{\partial |V_n|^2}{\partial e_n} & \cdots & \frac{\partial |V_n|^2}{\partial f_2} & \cdots & \frac{\partial |V_n|^2}{\partial f_n} \end{bmatrix} \begin{bmatrix} \Delta e_2 \\ \vdots \\ \Delta e_n \\ \Delta f_2 \\ \vdots \\ \Delta f_n \end{bmatrix}$$

$$\begin{bmatrix} \Delta P_2 \\ \Delta P_n \\ \Delta Q_2 \\ \Delta Q_n \\ \Delta |V_2|^2 \\ \Delta |V_n|^2 \end{bmatrix} = \begin{bmatrix} J_1 & J_2 \\ J_3 & J_4 \\ J_5 & J_6 \end{bmatrix} \begin{bmatrix} \Delta e_2 \\ \vdots \\ \Delta e_n \\ \Delta f_2 \\ \vdots \\ \Delta f_n \end{bmatrix}$$

1) For the power System network shown in below each line has a series impedance of $0.02+j0.06$ and line admittance of 0.02.
The real and reactive powers are shown in following table and Controllable reactive power source is available at bus 3 with the Constraint $0 \le Q_{g3} \le 1.5$ P.U.
Find the load flow Solution using NR method.

www.Jntufastupdates.com Scanned by CamScanner



Bus No	Real load demand P_D	Q_D	P_g	Q_g	Voltage.
1	2	1	—	—	1.04 (Slac
2	0	0	0.5	1.0	- (PQ b
3	1.5	0.6	0	?	1.04 (PV b

$Z = 0.02 + j0.08 \quad \frac{y'}{2} = \frac{0.02}{2} = 0.01$

Calculation of 4-bus matrix

$$Y_{11} = y_{11} + y_{12} + y_{13} + \frac{y'_{12}}{2} + \frac{y'_{13}}{2}$$

$$= 0 + \frac{1}{0.02+j0.08} + \frac{1}{0.02+j0.08} + 0.01j + 0.01j$$

$$Y_{11} = 2.94 - 11.76j + 2.94 - 11.76j + 0.02j$$

$$= 5.9 - 23.52j = 24.9 \angle -75.91^\circ$$

$Y_{22} = 24.93 \angle -75.91$

$$Y_{12} = \frac{-1}{0.02+j0.08} = 12.12 \angle 104.03^\circ$$

$Y_{13} = 12.12 \angle 104.03^\circ$

www.Jntufastupdates.com Scanned by CamScanner

$Y_{22} = 24.93 \angle -75.91$

$Y_{33} = 24.93 \angle -75.91$

$Y_{21} = Y_{12}$

$Y_{13} = Y_{31}$

$$Y_{BUS} = \begin{bmatrix} 24.25\angle -75.91 & 12.12\angle 104.03 & 12.12\angle 104.03 \\ 12.12\angle 104.03 & 24.25\angle -75.91 & 12.12\angle 104.03 \\ 12.12\angle 104.03 & 12.12\angle 104.03 & 24.25\angle -75.91 \end{bmatrix}$$

we know that. Active power injected at bus k.

$$P_{k\,cal} = \sum_{i=1}^{3} |V_i||V_k||Y_{ki}| \cos(\delta_i - \delta_k + \theta_{ki})$$

$P_{2\,cal}^{(0)} = |V_1||V_2||Y_{21}| \cos(\delta_1 - \delta_2 + \theta_{21}) + |V_2||V_2||Y_{22}| \cos(\delta_2 - \delta_2 + \theta_{22}) + |V_3||V_2||Y_{23}| \cos(\delta_3 - \delta_2 + \theta_{23})$

$= |1.04||1||12.12| \cos(0 - 0 + 104.03) + |1||1||24.25| \cos(0 - 0 + (-75.91)) + |1.04||1||12.12| \cos(0 - 0 + 104.03)$

$= -3.057 + 5.903 - 3.057$

$\boxed{P_2^{(0)} = -0.21}$

$$P_{3\,cal} = \sum_{i=1}^{3} |V_j||V_k||Y_{ki}| \cos(\delta_i - \delta_k + \theta_{ki})$$

$= |V_1||V_3||Y_{31}| \cos(\delta_1 - \delta_3 + \theta_{31}) + |V_2||V_3||Y_{32}| \cos(\delta_2 - \delta_3 + \theta_{32}) + |V_3||V_3||Y_{33}| \cos(\delta_3 - \delta_3 + \theta_{33})$

www.Jntufastupdates.com

$= |1.04||1.04||12.126|(\cos(0-0+104.03) + |1||1.04|$
$|12.126|\cos(0-0+104.03) + |1.04||1.04||24.25|$
$\cos(0-0-75.91))$

$= -3.179 + -3.057 + 6.385$

$\boxed{P_3^{(0)} = 0.148}$

$Q_3 = -\sum_{j=1}^{n} |V_i||V_k||Y_{ki}| \sin(\delta_i - \delta_k + \theta_{ki})$

$= -\{|1.04||1.04||12.126|\sin(104.03)\} - \{|1||1.04||12.126|$
$\sin(104.03)\} + |1.04||1.04||24.25|\sin(-75.91)$

$= -12.724 - 12.234 + 25.439$

$\boxed{Q_3^{(0)} = 0.48}$

$Q_2 = -\sum_{j=1}^{n} |V_i||V_k||Y_{ki}| \sin(\delta_1 - \delta_k + \theta_{ki})$

$= -|1.04||1||12.126|\sin(104.03) - |1||1||24.25|\sin\cos(-$

$-|1.04||1||12.126|\sin(104.03)$

$= -12.234 + 423.520 - 12.234$

$Q_2^{(0)} = -0.96$

$\Delta P_2^{\circ} = P_{2\,spe} - P_{2\,cal} = 0.5 + 0.24 = 0.74$ P.U

$\Delta P_3^{\circ} = P_{3\,spe} - P_{3\,cal} = -1.5 - 0.14 = -1.64$ P.U

$\Delta Q_2^{\circ} = Q_{2\,spe} - Q_{2\,cal} = -1.0 + 0.96 = 1.96$ P.U

www.Jntufastupdates.com Scanned by CamScanner

$$\begin{bmatrix} \Delta P_2^0 \\ \Delta P_3^0 \\ \Delta Q_2^0 \end{bmatrix} = \begin{bmatrix} \frac{\partial P_2}{\partial \delta_2} & \frac{\partial P_2}{\partial \delta_3} & \frac{\partial P_2}{\partial V_2} \\ \frac{\partial P_3}{\partial \delta_2} & \frac{\partial P_3}{\partial \delta_3} & \frac{\partial P_3}{\partial V_2} \\ \frac{\partial Q_2}{\partial \delta_2} & \frac{\partial Q_2}{\partial \delta_3} & \frac{\partial Q_2}{\partial V_2} \end{bmatrix} \begin{bmatrix} \Delta\delta_2 \\ \Delta\delta_3 \\ \Delta V_2 \end{bmatrix}$$

$$\frac{\partial P_2}{\partial \delta_2} = |V_1||V_2||Y_{21}| \overset{-\sin}{\cos}(\delta_1 - \delta_2 + \theta_{21})(-1) + |V_2||V_2||Y_{22}| - \sin(\delta_2 - \delta_2 + \theta_{22})(0) + |V_3||V_2||Y_{23}| - \overset{\sin}{\cos}(\delta_3 - \delta_2 + \theta_{23})(-1)$$

$$= |V_1||V_2||Y_{21}| \sin(\delta_1 - \delta_2 + \theta_{21}) + |V_2||V_2||Y_{22}|(0) + |V_3||V_2||Y_{23}| \sin(\delta_3 - \delta_2 + \theta_{23})$$

$$(1.04)(1)(12.126)\sin(104.04) + (1.04)(1)(12.126)\sin(104.04)$$

$$= 12.234 + 12.234$$

$$= 24.46 \text{ P.U.}$$

$$\frac{\partial P_2}{\partial \delta_3} = -|V_3||V_2||Y_{23}| \sin(\delta_3 - \delta_2 + \theta_{23})$$

$$= (1.04)(12.126)\sin(104.04)$$

$$= -12.23.$$

$$\frac{\partial P_2}{\partial V_2} = |V_1||Y_{21}|\cos(\theta_{21}) + 2V_2 Y_{22}\cos(\theta_{22}) + |V_3||Y_{23}|\cos(\theta_{23})$$

$$\frac{\partial P_2}{\partial V_2} = -3.05 + 11.90 - 3.05$$

$$= 5.80.$$

$$\frac{\partial P_3}{\partial \delta_2} = -|V_2||V_3||Y_{32}| \sin(\delta_2 - \delta_3 + \theta_{32})$$

$$= -12.234 \text{ P.U}$$

www.Jntufastupdates.com Scanned by CamScanner

$$\frac{\partial P_3}{\partial \delta_3} = |V_1||V_3||Y_{31}|\sin(\delta_1 - \delta_3 + \theta_{31}) + |V_2||V_3||Y_{31}|$$
$$\sin(\delta_2 - \delta_3 + \theta_{32})$$
$$= 12.72 + 12.23$$
$$= 24.95 \text{ P.U}$$

$$\frac{\partial P_3}{\partial V_2} = |V_3||Y_{32}|\cos(\theta_{32})$$
$$= -3.06$$

$$\frac{\partial Q_2}{\partial \delta_2} = +|V_1||Y_{21}||V_2|\cos(\delta_1 - \delta_2 + \theta_{21}) - |V_2|^2|Y_{22}|$$
$$\cos(\theta_{22}) + |V_3||V_2||Y_{23}|\cos(\delta_3 - \delta_2 + \theta_{23})$$
$$= |1.04||12.126||1|\cos(0 - 0 + 104.03) +$$
$$|1.04||1||12.126|\cos(104.03)$$
$$= -3.05 - 3.05 = -6.1 \text{ P.U}$$

$$\frac{\partial Q_2}{\partial \delta_3} = -|V_3||V_2||Y_{23}|\cos(\delta_3 - \delta_2 + \theta_{23})$$
$$= -|1.04||1||12.126|\cos(0 - 0 + 104.03)$$
$$= 3.05 \text{ P.U}$$

www.Jntufastupdates.com Scanned by CamScanner

$$\frac{\partial Q_2}{\partial V_2} = |V_3||Y_{31}|\sin(\delta_2-\delta_3+\theta_{32}) + |V_3||Y_{23}|\sin(\delta_3-\delta_2+\theta_{23})$$

$$\frac{\partial Q_2}{\partial V_2} = 22.54$$

$$= \begin{bmatrix} 24.46 & -12.23 & 5.8 \\ -12.234 & 24.95 & -3.06 \\ -6.11 & +3.05 & 22.54 \end{bmatrix}$$

$$\begin{bmatrix} \Delta\delta_2 \\ \Delta\delta_3 \\ \Delta V_2 \end{bmatrix} = \begin{bmatrix} 24.46 & -12.23 & 5.8 \\ -12.234 & 24.95 & -3.06 \\ -6.11 & +3.05 & 22.54 \end{bmatrix}^{-1} \begin{bmatrix} \Delta P_2 \\ \Delta P_3 \\ \Delta Q_2 \end{bmatrix}$$

$$\begin{bmatrix} \Delta\delta_2 \\ \Delta\delta_3 \\ \Delta V_2 \end{bmatrix} = \begin{bmatrix} 0.05 & 0.02 & -9.97\times10^{-3} \\ 0.02 & 0.05 & -1.77\times10^{-4} \\ 0.01 & 1.13\times10^{-5} & 0.04 \end{bmatrix} \begin{bmatrix} 0.7 \\ -1.64 \\ 1.96 \end{bmatrix}$$

$$\begin{bmatrix} \Delta\delta_2 \\ \Delta\delta_3 \\ \Delta V_2 \end{bmatrix} = \begin{bmatrix} -0.02 \\ -0.06 \\ 0.08 \end{bmatrix}$$

www.Jntufastupdates.com Scanned by CamScanner

Algorithm for Newton Raphson method

Step1 Find out the Y-bus matrix and assume initial Voltages and flat Voltages except for Slack bus

Step2 Set the Convergent Criteria is less than ε

Step3 Set the iteration Count i=0

Step4 Initiate the bus Count k=1

Step5 check it is a Slack bus. If it is yes go to Step8

If it is no go to the next Step.

Step6 check is it a generator bus.

If it is no go to next Step

If it is yes Calculate $\Delta P = P_{spe} - P_{cal}$.

Similarly $\Delta V_p^2 = V_{spe}^2 - V_{cal}^2$.

Go to Step8

Step7 If it is a load bus

Calculate $\Delta P = P_{spe} - P_{cal}$

$\Delta Q = Q_{spe} - Q_{cal}$.

Go to the next Step.

Step8 check is the bus Count k=N

If it is no increment the bus Count as k=k+1 and go to Step5

If it is Yes go to next Step.

Step9 check is the maximum Value is less than ε.

If it is No go to 8 next Step

www.Jntufastupdates.com Scanned by CamScanner

If it is Yes the problem is Convergent Stop the iteration

$[C] = [J]^{-1}[B]$

where C is residual Unknown matrix.

J is Jacobian matrix

B is residual known matrix

Then Calculate $V_2^{i+1} = V_2^i + \Delta V_2$

Use above Values are the initial Values increment the iteration count as i = i+1 and go the Step+4.

Decoupled Newton Raphson method.

Here we know that

$$P_K = \sum_{i=1}^{n} |V_i||V_K||Y_{Ki}| \cos(\delta_i - \delta_K + \theta_{Ki}) \quad -(1)$$

$$Q_K = -\sum_{i=1}^{n} |V_i||V_K||Y_{Ki}| \sin(\delta_i - \delta_K + \theta_{Ki}) \quad -(2)$$

from above equation Says that the Specified electrical quantities of the buses are expressed a non linear function of Unknown electrical quantities

from eqn (1) & (2).

$$\begin{bmatrix} \Delta P_K \\ \Delta Q_K \end{bmatrix} = \begin{bmatrix} J_1 & J_2 \\ J_3 & J_4 \end{bmatrix} \begin{bmatrix} \Delta\delta_K \\ \Delta V_K \end{bmatrix} =$$

for an Ac System the amount of real power flow depends upon difference of angle on both Sides and amount of reactive power flow depends upon magnitude of Voltage

www.Jntufastupdates.com Scanned by CamScanner

Hence the change in Voltage at the bus doesn't influence the active power change ΔP and Similarly the change in angle at the bus is not influence the reactive power ΔQ

Hence from the above matrix becomes Zero

$$\begin{bmatrix} \Delta P_k \\ \Delta Q_k \end{bmatrix} = \begin{bmatrix} J_1 & 0 \\ 0 & J_4 \end{bmatrix} \begin{bmatrix} \Delta \delta_k \\ \Delta V_k \end{bmatrix}$$

$\Delta P_k = J_1 \Delta \delta_k$.

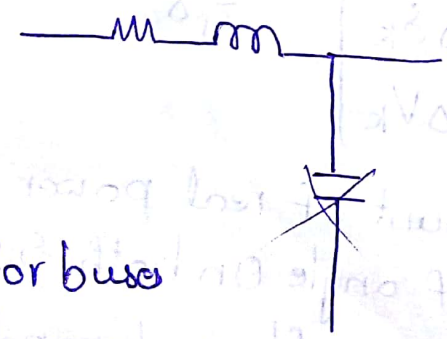
$\Delta Q_k = J_4 \Delta V_k$.

Fast decoupled NR method.

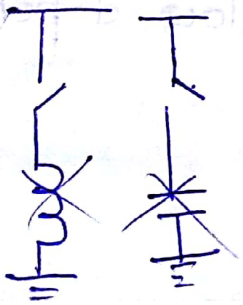
It is proposed to make the elements of J_1 and J_4 should remains Same in all iterations. So that J^{-1} will also Same hence the time taken will be reduced.

Assumptions:

1) The line Shunt Capacitance and also any external Shunt element at the buses Can be ignored. For Transmission line.



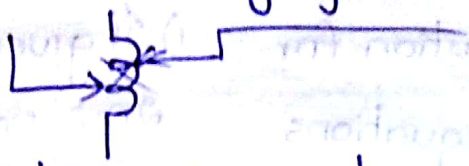
For buses



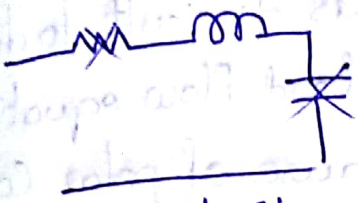
www.Jntufastupdates.com Scanned by CamScanner

ie construct the Ybus with only series elements

2) The tap settings of tap changing transformer can also be ignored.



3) The resistance of transmission line can be ignored



4) The phase shifting of phase shifting transformer i.e ΔY or $Y\Delta$ can be ignored.

5) Now we know that the active power injected at Bus k.

$$P_k = \sum_{i=1}^{n} |V_i||V_k||Y_{ki}| \cos(\delta_i - \delta_k + \theta_{ki})$$

$$Q_k = \sum_{i=1}^{n} |V_i||V_k||Y_{ki}| \sin(\delta_i - \delta_k + \theta_{ki})$$

$$\begin{bmatrix} \Delta P_k \\ \Delta Q_k \end{bmatrix} = \begin{bmatrix} J_1 & 0 \\ 0 & J_4 \end{bmatrix} \begin{bmatrix} \Delta \delta_k \\ \Delta V_k \end{bmatrix}$$

$$\Delta P_k = J_1 \Delta \delta_k.$$

$$\Delta Q_k = J_4 \Delta V_k.$$

Comparision of Gauss Siedal and Newto

www.Jntufastupdates.com Scanned by CamScanner

Comparision of Gauss Siedal and Newton Raphson method

Gauss Siedal	Newton Raphson
1) It gives the Solution for n-1 non linear equations	1) It gives the Solution for 2n-2 non linear Simultaneous equation.
2) It is easy to program the load flow equations because of rectangular Coordinates	2) It is difficult to develop the load flow equations because of polar Coordinates
3) The time taken for each iteration is less in Gauss Siedal method because not involvement of Jacobian matrix	3) The time taken for each iteration is high
4) No of iterations required to get the Convergent Criteria is more	4) No of iterations to get the Convergent Criteria is limited.
5) The total time taken to get the Convergent Criteria is high.	5) The total time taken to get the Convergenf Criter is less
6) Acceleration factor is proposed to reduce the iterations	6) No need of acceleration factor.
7) Less accurate and less efficient	7) More accurate and more efficient
8) This is recommended for Small Size of power System networks	8) These are recommended for large Size of power System networks (practical networks

www.Jntufastupdates.com Scanned by CamScanner

Previous problem by using decoupled NR method.

Step1 No changes in calculation of Ybus.

$$Y_{bus} = \begin{bmatrix} 24.25\angle -75.91 & 12.126\angle 104.03 & 12.126\angle 104.03 \\ 12.126\angle 104.03 & 24.25\angle -75.91 & 12.126\angle 104.03 \\ 12.126\angle 104.03 & 12.126\angle 104.03 & 24.25\angle -75.91 \end{bmatrix}$$

$\Delta P_2^0 = 0.74$ P.U

$\Delta P_3^0 = -1.64$ P.U

$\Delta Q_2^0 = 1.96$ P.U

$$\begin{bmatrix} \Delta P_2^0 \\ \Delta P_3^0 \\ \Delta Q_2^0 \end{bmatrix} = \begin{bmatrix} \frac{\partial P_2}{\partial \delta_2} & \frac{\partial P_2}{\partial \delta_3} & \frac{\partial P_2}{\partial V_2} \\ \frac{\partial P_3}{\partial \delta_2} & \frac{\partial P_3}{\partial \delta_3} & \frac{\partial P_3}{\partial V_2} \\ \frac{\partial Q_2}{\partial \delta_2} & \frac{\partial Q_2}{\partial \delta_3} & \frac{\partial Q_3}{\partial V_2} \end{bmatrix} \begin{bmatrix} \Delta\delta_2 \\ \Delta\delta_3 \\ \Delta V_2 \end{bmatrix}$$

In decoupled NR method the jacobian matrix can be rewritten as

$$\begin{bmatrix} \Delta P_2^0 \\ \Delta P_3^0 \\ \Delta Q_2^0 \end{bmatrix} = \begin{bmatrix} 24.46 & -12.23 & 0 \\ -12.23 & 24.95 & 0 \\ 0 & 0 & 22.54 \end{bmatrix}$$

$$\begin{bmatrix} \Delta\delta_2 \\ \Delta\delta_3 \\ \Delta V_2 \end{bmatrix} = \begin{bmatrix} 24.46 & -12.23 & 0 \\ -12.23 & 24.95 & 0 \\ 0 & 0 & 22.54 \end{bmatrix}^{-1} \begin{bmatrix} 0.74 \\ -1.64 \\ 1.96 \end{bmatrix}$$

$$\begin{bmatrix} \Delta\delta_2 \\ \Delta\delta_3 \\ \Delta V_2 \end{bmatrix} = \begin{bmatrix} 0.054 & 0.026 & 0 \\ 0.026 & 0.053 & 0 \\ 0 & 0 & 0.044 \end{bmatrix} \begin{bmatrix} 0.74 \\ -1.64 \\ 1.96 \end{bmatrix}$$

$$\begin{bmatrix} \Delta\delta_2 \\ \Delta\delta_3 \\ \Delta V_2 \end{bmatrix} = \begin{bmatrix} -2.68\times10^{-3} \\ -0.06 \\ 0.08 \end{bmatrix}$$

www.Jntufastupdates.com Scanned by CamScanner