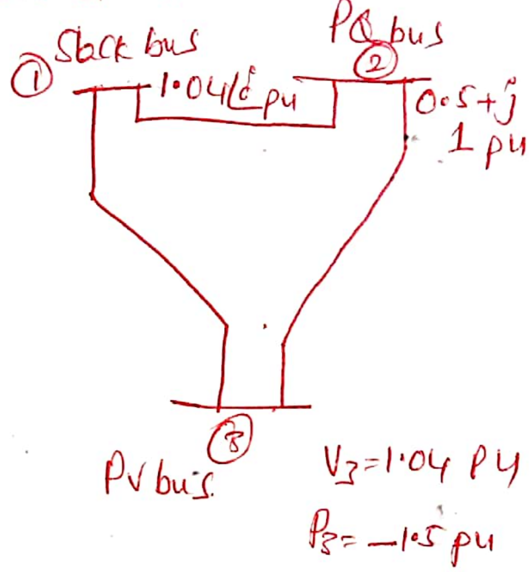
Problem on N-R method

Prob.:- For the system shown in the fig, the three lines have a series impedance of $0.02 + j0.08$ pu and a total shunt admittance $j0.02$ pu. Find the values of V_2, δ_2, Q_2 & δ_3 at the end of first iteration of N-R method of loadflow.



Sol:- $y_{series} = \dfrac{1}{0.02 + j0.08} = 2.941 - j11.764$

$= 12.13\angle -75.96°$

$\therefore$ Each off-diagonal elements of Y_{bus} (just -ve sign) $= -(2.941 - j11.764)$

$= 12.13\angle 104.04°$

& Each diagonal elements of Y_{bus} $= 2(2.941 - j11.764 + j0.01)$

$= 5.882 - j23.528$

$= 24.23\angle -75.95°$

Assuming nominal π model

0.02 is divided into 0.01 & 0.01.

① + ②

0.01 0.01

Assuming $V_2^0 = 1$ pu & $\delta_2^0 = 0 = \delta_3^0$

$$P_2 = V_2 \sum_{k=1}^{3} Y_{2k} V_k \cos(\theta_{2k} + \delta_k - \delta_2)$$

$$P_3 = V_3 \sum_{k=1}^{3} Y_{3k} V_k \cos(\theta_{3k} + \delta_k - \delta_3)$$

& $$Q_2 = -V_2 \sum_{k=1}^{3} Y_{2k} V_k \sin(\theta_{2k} + \delta_k - \delta_2)$$

Substituting given & assumed values of different quantities, we get

$P_2^0 = -0.23$ pu

$P_3^0 = 0.12$ pu

$Q_2^0 = -0.96$ pu.

$\therefore \Delta P_2^0 = P_2^s - P_2^{cal} = 0.5 - (-0.23) = 0.73$ pu

$\Delta P_3^0 = -1.5 - 0.12 = -1.62$ pu

$\Delta Q_2^0 = 1 - (-0.96) = 1.96$ pu.

(2) (1)

we have

$$\begin{bmatrix} \Delta P_2 \\ \Delta P_3 \\ \Delta Q_2 \end{bmatrix} = \begin{bmatrix} J_{11} & J_{12} \\ J_{21} & J_{22} \end{bmatrix} \begin{bmatrix} \Delta \delta_2 \\ \Delta \delta_3 \\ \Delta V_2 \end{bmatrix}$$

$$J^{0} = \begin{bmatrix} 24.47 & -12.23 & 5.64 \\ -12.23 & 24.95 & -3.05 \\ -6.11 & 3.05 & 22.54 \end{bmatrix}$$

$$\begin{bmatrix} \Delta \delta_2^0 \\ \Delta \delta_3^0 \\ \Delta V_2^0 \end{bmatrix} = \begin{bmatrix} J^0 \end{bmatrix}^{-1} \begin{bmatrix} \Delta P_2^0 \\ \Delta P_3^0 \\ \Delta Q_2^0 \end{bmatrix} = \begin{bmatrix} -0.23 \\ -0.0654 \\ 0.089 \end{bmatrix}$$

$$\begin{bmatrix} \delta_2^1 \\ \delta_3^1 \\ V_2^1 \end{bmatrix} = \begin{bmatrix} \delta_2^0 \\ \delta_3^0 \\ V_2^0 \end{bmatrix} + \begin{bmatrix} \Delta \delta_2^0 \\ \Delta \delta_3^0 \\ \Delta V_2^0 \end{bmatrix} = \begin{bmatrix} -0.023 \\ -0.065 \\ 1.089 \end{bmatrix} \rightarrow \text{Solution of the updated values.}$$

Using the updated values, we have $Q_3^1 = 0.4677$ pu.

... changes & we are ... here.

Decoupled Load flow Method

Adv's of N-R method

→ Faster than G-S method

→ It is a powerful method for solving non-linear algebraic eqns.

We have obtained by N-R method,

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_{11} & J_{12} \\ J_{21} & J_{22} \end{bmatrix} \begin{bmatrix} \Delta \delta \\ \Delta V \end{bmatrix} \longrightarrow (1)$$

→ We know $\bar{S}_i^* = P_i - jQ_i = V_i^* I_i = V_i^* \sum_{k=1}^{n} Y_{ik} \cdot V_k$

in polar form, $\bar{V}_i = V_i \angle \delta_i$, $\bar{V}_k = V_k \angle \delta_k$, $\bar{Y}_{ik} = Y_{ik} \angle \theta_{ik}$

and we know P_i & Q_i in terms of V_i, V_k & Y_{ik}.

$\Delta P = P_i^s - P_i^c(\delta, V)$

$\Delta Q = Q_i^s - Q_i^c(\delta, V)$

δ is variable for both PQ & PV buses

V is " PQ only.

→ Depending upon various combination of buses, the dimension of (δ, V) variables will change.

from (1), $J_{11} = \left[\frac{\partial P}{\partial \delta}\right]$ $J_{12} = \left[\frac{\partial P}{\partial V}\right]$ Already known.

$J_{21} = \left[\frac{\partial Q}{\partial \delta}\right]$ $J_{22} = \left[\frac{\partial Q}{\partial V}\right]$

ΔP is ~~de~~ mainly depends on $\Delta\delta$ in other words,

P is more dependent on δ than V.

Q is more " , V than δ.

$\delta \rightarrow$ phase angles of bus voltage

$V \rightarrow$ Mag.

$\Delta P = J_{11}\Delta\delta + \underbrace{J_{12}\Delta V}$ → should be zero or nearly = 0

$\Delta Q = \underbrace{J_{21}\Delta\delta}_{\text{should be zero}} + J_{22}\Delta V$

~~Measur~~ Major changes & we are decoupling here.

So, the name is Decoupled load flow

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

Assuming these sub-matrices ~~become~~ '0' as

So, $\Delta P = \underbrace{\begin{bmatrix}\frac{\partial P}{\partial \delta}\end{bmatrix}}_{J_{11}}[\Delta\delta]$ & $\longrightarrow$ (1)

$\Delta Q = \underbrace{\begin{bmatrix}\frac{\partial Q}{\partial V}\end{bmatrix}}_{J_{22}}[\Delta V]$ $\longrightarrow$ (2)

J_{11}, & J_{22} are non-zero.

T&n-lines are highly inductive in nature,

$\bar{Y}_{ik}$ $\longrightarrow$ i^{th} bus connected to k^{th} ~~other~~ bus.

in polar form $\bar{Y}_{ik} = Y_{ik}\angle\theta_{ik} = Y_{ik}\cos\theta_{ik} + j\,Y_{ik}\sin\theta_{ik}$

$= G_{ik} + j\,B_{ik}$

$G_{ik} \rightarrow$ Conductance

$B_{ik} \longrightarrow$ Susceptance. As the nature of the T&n-line is highly inductive in nature.

~~B_{ik} is ∞.~~

$G_{ik} << B_{ik}$, δ_i is phase angle of bus voltage at i^{th} bus

we can ignore G_{ik}. Suppose difference of two δ's, $\delta_i - \delta_j \simeq 0$

In stability analysis, we can see that difference of two δ's not very much high, its very less, $\simeq 0$ 2 assumptions here,

i) $G_{ik} << B_{ik}$ ii) $\delta_i - \delta_j \simeq 0$ (are within 10°) practically ≤ 10

With these two assumptions we will prove J_{12} & $J_{21} = 0$

first with $J_{11} = \begin{bmatrix}\frac{\partial P}{\partial \delta}\end{bmatrix}$ Depending upon no. of P, i.e PQ & PV buses the dimension may vary.

15×15 Suppose 10 PQ bus & 5 PV bus

Dimension, Total P is 15

δ is 15 (Variable for both)

may or may not equal i & j. (3)

$i = 1 \ldots 15$
$j = 1 \ldots 15$
$\frac{\partial P_7}{\partial \delta_3}$ n4

$$\left.\frac{\partial P_i}{\partial \delta_j}\right|_{i \neq j} =$$

first case.

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

for all remaining $k = 1, n$ → all are independent of j.

but $k = j$ then will get δ_j, only that term is depending on δ_j

for other values partial derivative will be Zero,

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

θ_{ij} is fixed
δ_j & δ_i variables
$\sin(A+B)$

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

$Y_{ij} \sin\theta_{ij} \to B_{ij}$ ← Img ~~Real~~ part

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

$\neq 0$ ($\because$ two assumptions)

So J_{11} elements will be non zero.

$B_{ij} \gg G_{ij}$ → can be ignored
$B_{ij} \neq 0$.
$\cos(0) = 1$
non-zero

next case.

When $i = j$, $\frac{\partial P_1}{\partial \delta_1} \ldots \frac{\partial P_5}{\partial \delta_5}$, it means

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

δ_i having in all terms except $k = i$ $(\delta_i - \delta_i)$

i^{th} term is Zero

other terms are non Zero.

-ve of sign   again +ve $-\sin(-)$ +ve

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

$\neq 0$.

$G_{ik} \simeq 0$
So $\cos\theta_{ik} = 0$
$\sin(\delta_k - \delta_i) = 0$

$J_{11} \neq 0$, & $J_{22} \neq 0$.

next $J_{12} = 0$ $\longrightarrow$ Sub the values of $G_{ik} = 0$

$J_{21} = 0$ we can get $(\delta_k - \delta_i) = 0$ $\sin(0) = 0$

$\cos(0) = 1$

you can check.

Now, the Jacobian Matrix of N-R method is simplified or modified, so less calculations are required.

Now, we have decoupled. remaining method is same.

$$\Delta P = J_{11} \Delta \delta + 0$$

$$\Delta Q = 0 + J_{22} \Delta V.$$ only.

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Fast Decoupled Load flow.

In D.L.F,

$$\left.\frac{\partial P_i}{\partial \delta_j}\right|_{i\neq j} = -V_i Y_{ij} V_j \sin(\theta_{ij}+\delta_j-\delta_i) = -V_i V_j B_{ij} + (0)$$

$$= -V_i V_j Y_{ij}\left[\sin\theta_{ij}\cdot \underbrace{\cos(\delta_j-\delta_i)}_{1} + \cos\theta_{ij}\sin\cancel{(\delta_j-\delta_i)}^{0}\right]$$

$$\left.\frac{\partial P_i}{\partial \delta_j}\right|_{i=j} = V_i \sum_{\substack{k=1\\k\neq i}}^{n} Y_{ik} V_k \sin(\theta_{ik}+\delta_k-\delta_i) = -Q_i - V_i^2 B_{ii} \approx -V_i^2 B_{ii}$$

Derived

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

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

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

(Q_i neglected)

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

$$= -V_i B_{ij}$$

Other elements — Home work.

In D.L.F, two assumptions were. $G_{ik} << B_{ik}$, $\delta_i - \delta_j \approx 0$ } Assumptions

Third assumption in F.D.L.F, $Q_i \leq V_i^2 B_{ii}$ → extended

$$\left.\frac{\partial P_i}{\partial \delta_j}\right|_{i=j} = -Q_i - \underbrace{V_i^2 B_{ij(ii)}}_{i=j} \approx -V_i B_{ij(ii)}$$

($\because$ Third assumption $Q_i = 0$) except i^{th} term.

— Q_i is except $k\neq i$, but if we add $k\neq i$, then if we put $k=i$, then.

$V_i \times V_i = V_i^2$ & $\sin\cancel{(\delta_i-\delta_i)}\to 0$ in $\sin(A+B)$ also Zero

$\sin\theta_{ij} Y_{ij} = B_{ij}$

$\left.\frac{\partial Q_i}{\partial V_j}\right|_{i=j}$ ⟶ Q_i formula we taken, here V_i is missing so Q_i/V_i

from D.L.F, we know.

$$[\Delta P] = \left[\frac{\partial P}{\partial \delta}\right][\Delta\delta] \quad \text{lly} \quad [\Delta Q] = \left[\frac{\partial Q}{\partial V}\right][\Delta V]$$

$(n-1)\times 1$ power mismatch vector; $(n-1)\times(n-1)$; $(n-1)\times 1$; $(m-1)\times 1$; $(m-1)\times(m-1)$; $(m-1)\times 1$

ΔP dimension depend upon no of a specified P. (both) total n, except slack bus $(n-1)\times 1$

ΔQ dimension specified for PQ only. Suppose PQ busses are upto m (i.e 2 to m) $\longrightarrow$ dimension $(m-1)\times(m-1)$

(multiplication rules in matrices)

ΔP_i is one element of ΔP vector,

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

Substitute $\left(\frac{\partial P_i}{\partial \delta_j}\right)$

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

we can write by taking all i^{th} bus Qty's together

$$\frac{\Delta P_i}{V_i} = \sum_{j=2}^{n} -V_j B_{ij}\,\Delta\delta_j$$

one more assumption is approximation

so, $V_j = 1$

bus voltage magnitudes = 1 pu. of all the buses (V_j; $j = 2\cdots n$)

also write

$$\frac{\Delta P_i}{V_i} = \sum_{j=2}^{n} -B_{ij}\,\Delta\delta_j$$

$B_{ij} \rightarrow$ const.

in general, $$\boxed{\left[\frac{\Delta P}{V}\right] = [-B_p]\cdot[\Delta\delta]}$$

↳ we have to evaluate once only, Same can be used in each iteration.

Illy for Q_i, $\Delta Q = \left[\frac{\partial Q}{\partial V}\right]\left[\Delta V\right]$ → from decoupled Load flow

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

PQ only Q is specified. So PQ buses are 2....m only

↳ Substitute $-V_i B_{ij}$

for i^{th} PQ bus,

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

$$\frac{\Delta Q_i}{V_i} = \sum_{j=2}^{m} \underbrace{(-B_{ij})}_{\text{const}} \Delta V_j$$

Also write

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

modified Power mismatch eqns for F.D.L.F after Certain assumptions.

Now it becomes easy & fast to evaluate, but procedure will be same as NR method.

If no of iterations will be ↑, but time is more per iteration.

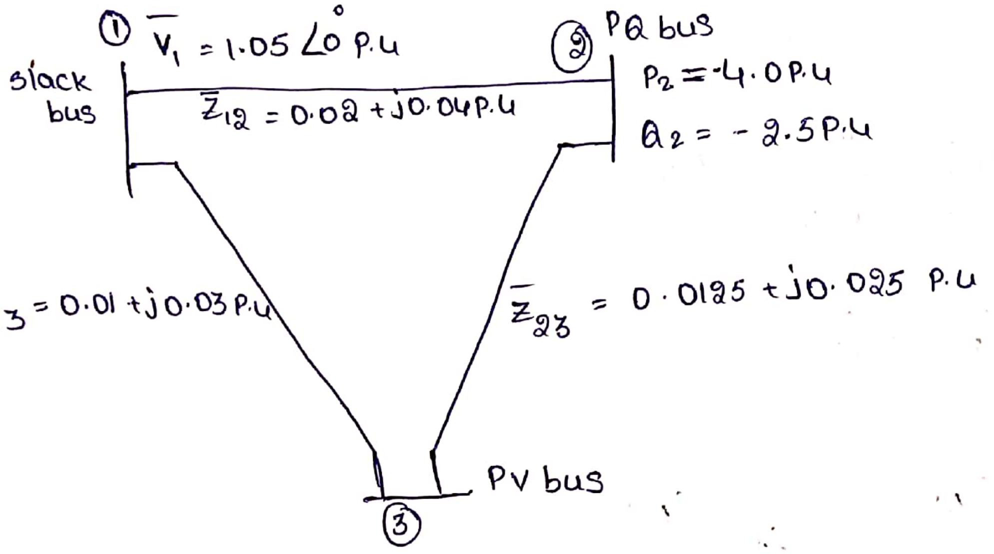
In this modified method, you may not get accuracy but, speed will be faster, If you want that level of accuracy should be go for more iterations..

Here $[-B_P]$ & $[-B_Q]$ are Constant in F.D.L.F. (After 3^{rd} assumption)

but $\left[\frac{\partial P}{\partial \delta}\right]$ & $\left[\frac{\partial Q}{\partial V}\right]$ are not Constant in D.L.F

FAST DECOUPLED LOAD FLOW METHOD.

* For the 3-bus s/m shown in fig. use fast decoupled load flow method to obtain one iteration of the load flow solution.



$P_3 = 2.0$ pu

$V_3 = 1.04$ p.u

$1.0\text{ pu} \le Q_3 \le 1.5$ p.u

Sol: Find out Y_{bus} :-

$$\bar{Y}_{bus} = \begin{bmatrix} 20-j50 & -10+j20 & -10+j30 \\ -10+j20 & 26-j52 & -16+j32 \\ -10+j30 & -16+j32 & 26-j62 \end{bmatrix}$$

Assume initial values :-

$$V_2^0 = 1.0 \text{ p.u}, \quad \delta_2^0 = \delta_3^0 = 0^\circ$$

Note :

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

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

$$\Rightarrow \begin{bmatrix} \dfrac{\Delta P_2}{V_2} \\ \dfrac{\Delta P_3}{V_3} \end{bmatrix} = -\underbrace{[B_P]}_{\text{(const)}} \begin{bmatrix} \Delta\delta_2 \\ \Delta\delta_3 \end{bmatrix}$$

$$\frac{\Delta P_i}{V_i} = -\sum_{k=2}^{n} B_{ik}\, \Delta \delta_k$$

$$[B_p] = \begin{bmatrix} -52 & 32 \\ 32 & -62 \end{bmatrix}$$

$$\frac{\Delta Q_i}{V_i} = -\sum_{k=2}^{m} B''_{ik}\, \Delta V_k$$

$$[B_Q] = [-52]$$

$$\begin{bmatrix} \frac{\Delta P_2^{\circ}}{V_2^{\circ}} \\ \frac{\Delta P_3^{\circ}}{V_3} \end{bmatrix} = -[B_p] \begin{bmatrix} \Delta \delta_2 \\ \Delta \delta_3 \end{bmatrix}$$

$$\Delta P_2^{\circ} = P_2^{\circ} - \left(V_2^{\circ} \sum_{k=1}^{3} Y_{2k} V_k \cos\left(\theta_2 k + \delta_k - \delta_2^{\circ}\right)\right)$$

$$\begin{bmatrix} \Delta \delta_2^{\circ} \\ \Delta \delta_3^{\circ} \end{bmatrix} = [-B_p]^{-1} \begin{bmatrix} \frac{\Delta P_2^{\circ}}{V_2^{\circ}} \\ \frac{\Delta P_3^{\circ}}{V_3} \end{bmatrix}$$

$$[-B_p] = \begin{bmatrix} +52 & -32 \\ -32 & 62 \end{bmatrix}$$

$$[-B_p]^{-1} = \frac{1}{2200} \begin{bmatrix} 62 & 32 \\ 32 & 52 \end{bmatrix}$$

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$$= \begin{bmatrix} 0.0282 & 0.0146 \\ 0.0146 & 0.0236 \end{bmatrix} \begin{bmatrix} \frac{-2.8601}{1.0} \\ \frac{1.4384}{1.04} \end{bmatrix}$$

$$= \begin{bmatrix} -0.0605 \\ -0.0091 \end{bmatrix}$$

$$\begin{bmatrix} \delta_2' \\ \delta_3' \end{bmatrix} = \begin{bmatrix} 0^\circ \\ 0^\circ \end{bmatrix} + \begin{bmatrix} -0.0605 \times \frac{180^\circ}{\pi} \\ -0.0091 \times \frac{180^\circ}{\pi} \end{bmatrix} = \begin{bmatrix} -3.4664^\circ \\ -0.5214^\circ \end{bmatrix}$$

$$\left[\frac{\Delta Q_3^\circ}{V_3} \right] = -[B_Q][\Delta V_2^\circ]$$

$$\Rightarrow \left[\frac{-0.2201}{1.0} \right] = +52 \, \Delta V_2^\circ$$

$$\Rightarrow \Delta V_2^\circ = -0.0042$$

$$V_2' = V_2^\circ + \Delta V_2^\circ$$

$$= 1 - 0.0042$$

$$= 0.9958 \text{ P.u}$$

Now,

$$Q_3' = -V_3 Y_{31} V_1 \sin(\theta_{31} + \delta_1 - \delta_3')$$

$$- V_3 Y_{32} V_2' \sin(\theta_{32} + \delta_2' - \delta_3')$$

$$- V_3 Y_{33} V_3 \sin(\theta_{33} + \delta_3' - \delta_3')$$

$$= -1.04 \times 31.6228 \times 1.05 \times \sin(108.4349^\circ + 0^\circ - (-0.5214))$$

$$= -1.04 \times 35.7771 \times 0.9958 \times \sin(116.5651^\circ + (-3.4664^\circ) - (-0.5214^\circ))$$

$$= -(1.04)^2 \times 67.2309 \times \sin(-67.2490^\circ + 0^\circ)$$

$$= -32.6593 - 33.9478 + 67.0591$$

$$= 0.4520 \text{ P.u}$$

$$\begin{bmatrix} \frac{\Delta Q_2^0}{V_2^0} \\ \frac{\Delta Q_3^0}{V_3^0} \end{bmatrix} = -[BQ]_{new} \begin{bmatrix} \Delta V_2^0 \\ \Delta V_3^0 \end{bmatrix}$$

V_3^0

$$Q_3^S = Q_{3,min} = 1.0 \text{P.u}$$

$$V_3' = V_3^0 + \Delta V_3^0$$

$$=$$

* Develop Algorithm and flow chart for the following load flow Method 1) FDLF 2) DLF

fast - decoupled flow Method :-

Step1: Read the given Load flow data and form Y Bus

Step2: from the matrix [B'] & [B''] [Susceptance]

Step3: Assume flat voltage profile (initial guess)

$$V_p^0 = 1 \text{ p.u} \quad \delta_p^0 = 0^\circ$$

where $p \neq$ Slack bus. Slack bus (data|voltage) is specified

$\therefore$ $P = 2, 3, 4 \text{-----} n$

Step4: Set iteration count $K=0$

Step5: set bus count $P=1$

Step6: Set convergence condition 'ε'

Step7: Calculate ΔP, ΔQ by using the following equation

$$\Delta P = P_{p\,spec} - P_{p\,cal}$$

$$\Delta Q = Q_{p\,spec} - Q_{p\,cal}$$

$$P_{p\,cal} = \sum_{q=1}^{n} V_p V_q Y_{pq} \cos(\delta_p - \delta_q - \theta_{pq})$$

$$Q_{p\,cal} = \sum_{q=1}^{n} V_p V_q Y_{pq} \sin(\delta_p - \delta_q - \theta_{pq})$$

Step8: check for convergence condition

$\Delta P_p \leq \varepsilon$, $Q_p \leq \varepsilon$, If it is true go to

Step [10] Otherwise go to next Step [9]

Step 9: Advance iteration count $K = K+1$ and go to step 7

Step 10: Calculate $\Delta\delta_p$, ΔV_p by using the following eq^n

$$\boxed{\frac{\Delta P_p}{V} = [B'][\Delta\delta_p]} \qquad \boxed{\Delta\delta_p = \left[\frac{\Delta P_p}{V}\right][B']^{-1}}$$

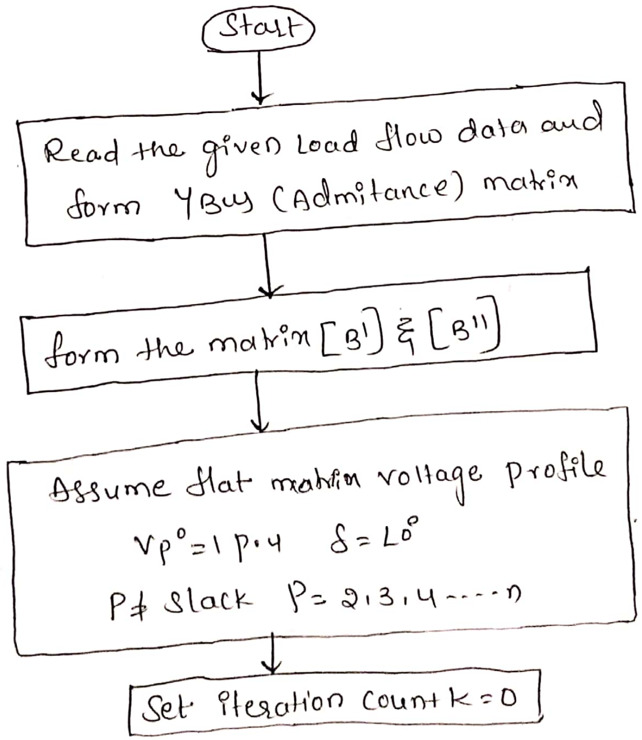
$$\boxed{\frac{\Delta\delta_p}{V} = B''[\Delta V_p]} \qquad \boxed{\Delta V_p = \left[\frac{\Delta Q_p}{V}\right][B'']^{-1}}$$

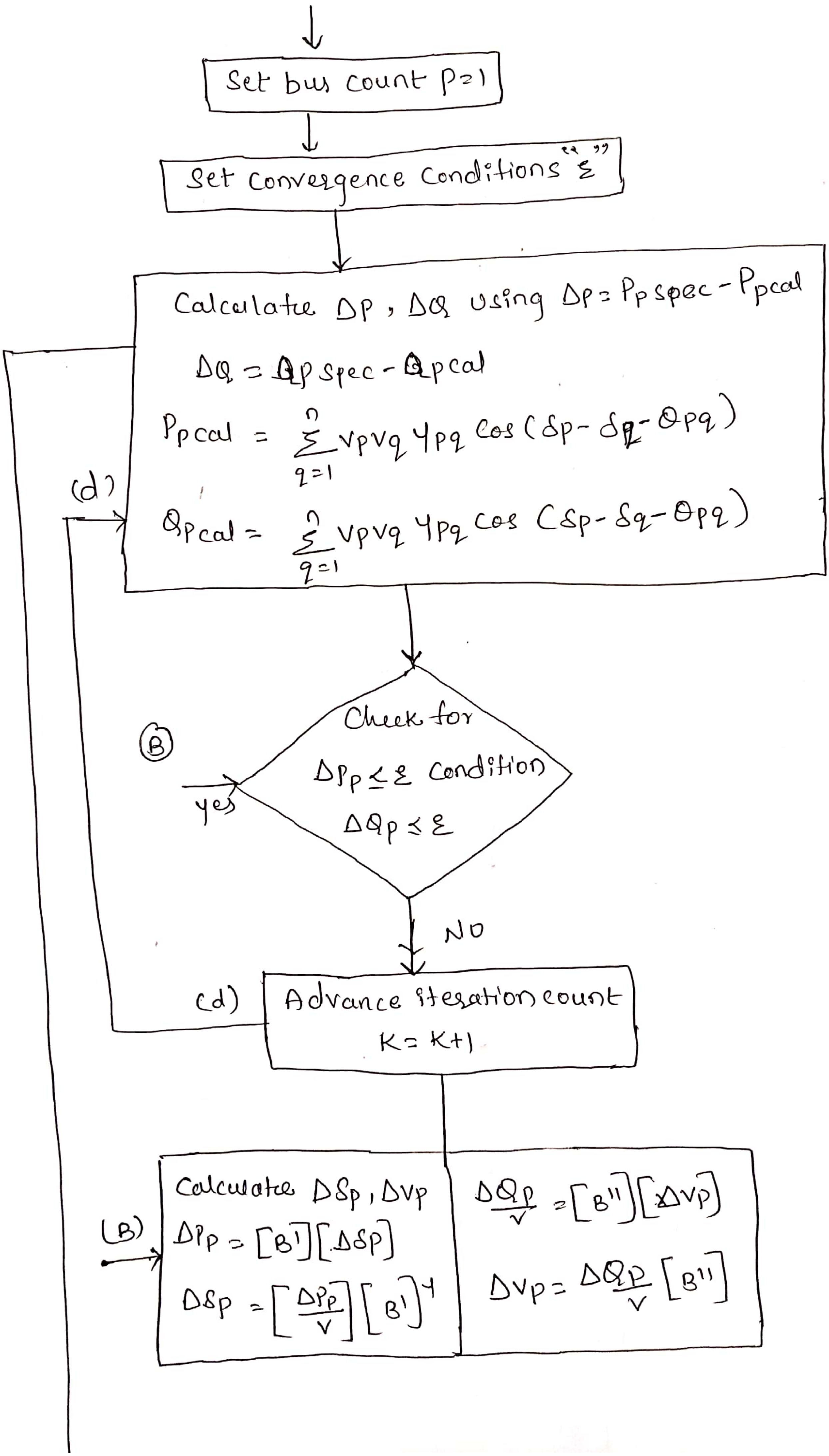
Step 11: check whether all the buses are connected if not go to next step. if yes go to step 13

Step 12: Advance bus count by $P = P+1$ and goto step 7

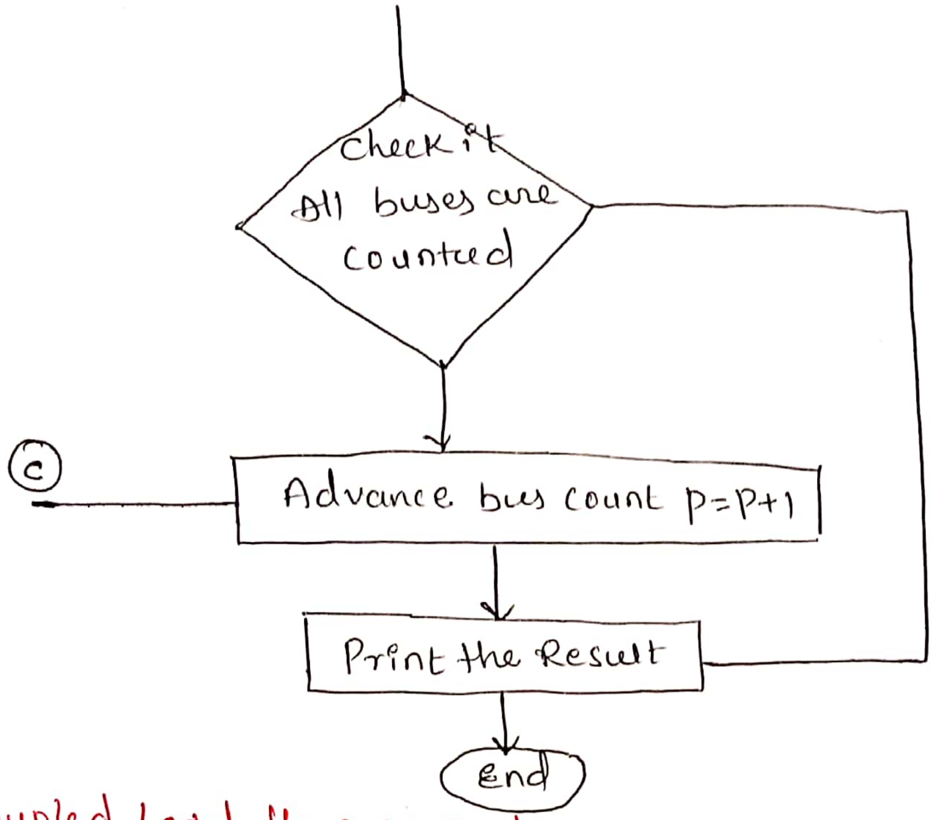
Step 13: Print the Result

flow chart:





Set bus count p=1
Set convergence conditions "ε"
Calculate ΔP, ΔQ using ΔP = Pp spec − Pp cal
ΔQ = Qp spec − Qp cal
Pp cal = Σ (q=1 to n) Vp Vq Ypq cos (δp − δq − θpq)
Qp cal = Σ (q=1 to n) Vp Vq Ypq cos (δp − δq − θpq)
(d)
(B)
Check for
ΔPp ≤ ε condition
ΔQp ≤ ε
yes
NO
(d)
Advance iteration count
K = K+1
(B)
Calculate Δδp, ΔVp
ΔPp = [B'][Δδp]
Δδp = [ΔPp/V][B']^-1
ΔQp/V = [B''][ΔVp]
ΔVp = ΔQp/V [B'']



Decoupled Load flow Method:

Step 1: Read the given Load flow data, and form Y_{Bus}

Step 2: Assume flat voltage profile (initial guess)

$V_p^0 = 1\,p.u \quad \delta_p^0 = \angle 0^\circ$

where $p \neq$ Slack bus

Step 3: Set iteration count $k=0$

Step 4: Set step bus count $p=1$

Step 5: Set convergence condition = 'ε'

Step 6: Calculate ΔP, ΔQ by using the following eqn's

$$\Delta P_p = P_{p\,spec} - P_{p\,cal}$$

$$\Delta Q_p = Q_{p\,spec} - Q_{p\,cal}.$$

$$P_{p\,cal} = \sum_{q=1}^{n} V_p V_q Y_{pq} \cos(\delta_p - \delta_q - \theta_{pq})$$

$$Q_{p\,cal} = \sum_{q=1}^{n} V_p V_q Y_{pq} \sin(\delta_p - \delta_q - \theta_{pq})$$

Step 7: Calculate H & L matrix by following equation

$M = N = 0$

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} H & 0 \\ 0 & L \end{bmatrix} \begin{bmatrix} \Delta \delta \\ \frac{\Delta V}{V} \end{bmatrix}$$

$$\Delta P = [H][\delta\Delta]$$

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

$$H_{pp} = -Q_p - V_p^2 Y_{pp} \sin\theta_{pp}$$

$$L_{pp} = Q_p - V_p^2 Y_{pp} \sin\theta_{pp}$$

$$H_{pq} = L_{pq} = V_p V_q Y_{pq} \sin(\delta_p - \delta_q - \theta_{pq})$$

Step 8: Check for Convergence conditions

$\Delta P_p \leq \varepsilon$, $\Delta Q_p \leq \varepsilon$ if it is true goto Step 10 otherwise go to next step [step 9]

Step 9: Advance interation count $K = K+1$ and go to step-(6)

Step 10: Calculate $\Delta \delta_p$, ΔV_p by using the following eqn's

$$\frac{\Delta P_p}{V} = [H]\,\Delta\delta_p \qquad \frac{\Delta Q_p}{V} = [L][\Delta V_p]$$

$$\Delta\delta_p = \frac{\Delta P_p}{V}[H]^{-1} \qquad \Delta V_p = \left[\frac{\Delta Q_p}{V}\right][L]^{-1}$$

Step 11: Check whether all the buses are counted if not go to next step if yes go to Step 13

Step 12: Advance bus count by $P = P+1$ and go to step 6

Step 13: Print the Result

Flow chart:-

Start

Read the given load flow data & form YBUS

Assume flat voltage profile $V = 1\,p.u$, $\delta = \angle 0$ p ≠ slack bus $p = 2, 3, \ldots n$

Set iteration count

Set bus count $p = 1$

Set convergence condition $= \varepsilon$

Calculate $\Delta P, \Delta Q$ $\Delta P = P_{p\,spec} - P_{pcal}$

$\Delta Q = Q_{p\,spec} - Q_{pcal}$

$$P_{pcal} = \sum_{q=1}^{n} V_p V_q Y_{pq} \cos(\delta_p - \delta_q - \theta_{pq})$$

$$Q_{pcal} = \sum_{q=1}^{n} V_p V_q Y_{pq} \sin(\delta_p - \delta_q - \theta_{pq})$$

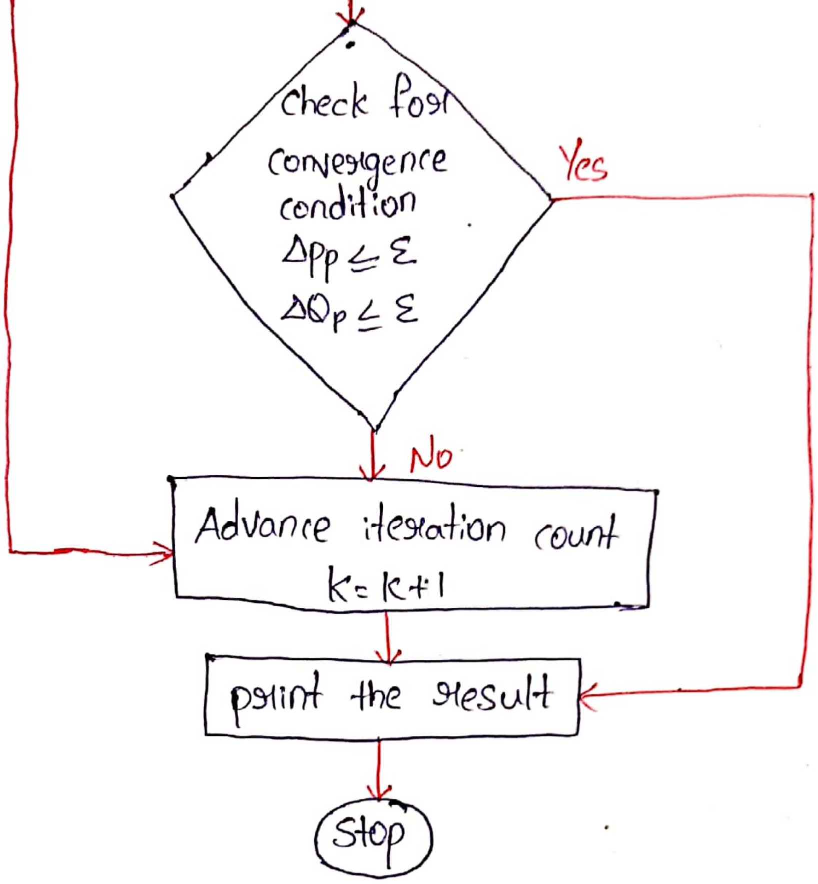
Calculate $\Delta P = [H][\Delta \delta]$

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

$$H_{pp} = -Q_p - V_p^2 \cdot Y_{pp} \sin \theta_{pp}$$

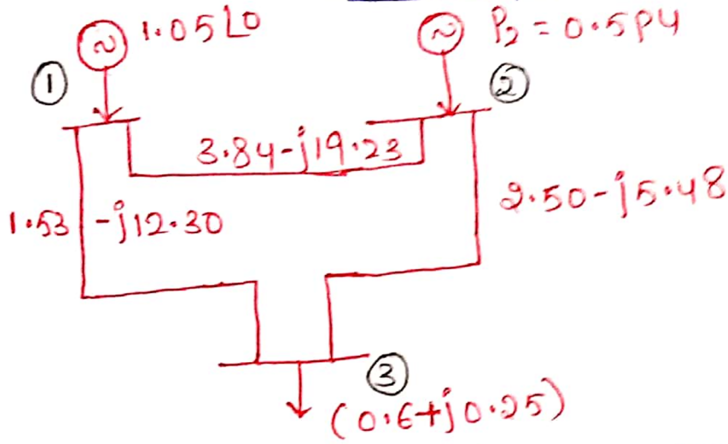
$$L_{pp} = Q_p - V_p^2 Y_{pp} \sin \theta_{pp}$$

$$H_{pq} = L_{pq} = V_p V_q Y_{pq} \sin(\delta_p - \delta_q - \theta_{pq})$$


Check for convergence condition
$\Delta P_p \leq \varepsilon$
$\Delta Q_p \leq \varepsilon$
Yes
No
Advance iteration count
$k = k+1$
print the result
Stop

DLF & FDLF   Load Flow problems ①

Problems :-



A Three bus p.s is given in above diagram with line Admittance. Calculate voltage angle at second bus and third bus along with voltage at third bus by considering following load flow solution method. All the calculations are for 1^{st} iteration

(i) FDLF Method   (ii) DLF Method

(iii) Determine DC load flow model for 2^{nd} & 3^{rd} bus

Sol

	Bus type	P	Q	V	δ
1.	Slack bus	–	–	1.05	0°
2.	PV	0.5	–	–	–
3.	PQ	-0.6	-0.25	–	–

$$Y_{Bus} = \begin{vmatrix} Y_{11} & Y_{12} & Y_{13} \\ Y_{21} & Y_{22} & Y_{23} \\ Y_{31} & Y_{32} & Y_{33} \end{vmatrix}$$

$$= \begin{vmatrix} 5.37 - j31.53 & -3.84 + j19.23 & -1.53 + j12.30 \\ -3.84 + j19.23 & 5.89 - j24.71 & -2.50 + j5.48 \\ -1.53 + j12.30 & -2.05 + j5.48 & 3.58 + j17.78 \end{vmatrix}$$

$$= \begin{vmatrix} 31.98\angle -80.33 & 19.60\angle 101.29 & 12.39\angle 97.09 \\ 19.60\angle 101.29 & 25.40\angle -76.59 & 6.02\angle 114.52 \\ 12.39\angle 97.09 & 5.85\angle 110.5 & 18.13\angle -78.61 \end{vmatrix}$$

from y bus

$B_{22} = -24.71$

$B_{23} = 5.48$

$B_{32} = 5.48$

$B_{33} = -17.78$

form polar form

$Y_{21} = 19.60$ $\theta_{21} = 101.29$

$Y_{22} = 25.40$ $\theta_{22} = -76.59$

$Y_{23} = 6.02$ $\theta_{23} = 114.52$

$Y_{31} = 12.39$ $\theta_{31} = 97.09$

(i) FDLF Method :- Slag bus voltage profile is Assumed

$\therefore V_2^0 = 1.0\angle 0°$

$V_3^0 = 1.0\angle 0°$

$$\left[\frac{\Delta P}{V}\right] = [B'][\Delta\delta] \quad -(1)$$

$$\left[\frac{\Delta Q}{V}\right] = [B''][\Delta V] \quad -(2)$$

$B' = \cancel{-[B_{33}]}$ $B' = -\begin{bmatrix} B_{22} & B_{23} \\ B_{32} & B_{33} \end{bmatrix}$ Eliminate slack bus i.e 1st row & first column

$B'' = -[B_{33}]$ Eliminate PV bus i.e, 2nd row & 2nd column

$$B' = -\begin{bmatrix} -24.71 & 5.48 \\ 5.48 & -17.78 \end{bmatrix}$$

$$B'' = -[-17.78] = [17.78]$$

from (1)

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

Scanned with CamScanner

$$\frac{\Delta P_2}{V_2} = [B'][\Delta\delta_2]$$

$$\frac{\Delta P_3}{V_3} = [B'][\Delta\delta_3]$$

$$\Delta P_2 = P_2\ Spec - P_2\ cal$$

$$\Delta P_3 = P_3\ Sepc - P_3\ cal$$

$$P_2'\ cal = \sum_{q=1}^{n} V_q V_p Y_{pq} \cos(\delta_p - \delta_q - \theta_{pq})$$

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

$$= 1 \times 1.05 \times 19.20 (\cos 101.29) + 25.40 \cos(76^\circ) + 6.02 \cos(114.53$$

$$P_2\ cal = 0.37\ p.u$$

$$P_3\ cat = \sum_{q=1}^{n} V_p V_q V_{pq} \cos(\delta_p - \delta_q - \theta_{pq})$$

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

$$= 1 \times 1.05 \times 12.39 \cos(97) + 1 \times 1 \times 6.62 \cos(114.52)$$
$$+ 1 \times 1 \times 18.13 \cos(78.61)$$

$$P_3'\ cal = -0.46\ pu$$

$$\Delta P_2 = P_2\ Spec - P_2\ cal$$

$$= 0.5 + 0.37$$

$$= 0.87\ pu$$

$\Delta P_3 = P_3\,\text{Spec} - P_3\,\text{cal}$

$= -0.16 + 0.46 = -0.14$ p.u

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

$= -1.05 \times 12.39 \sin(97) - 6.02 \sin(114.52) +$
$18.33 \sin(78.61)$

$Q_3'\,\text{cal} = -0.42$

$\Delta Q_3 = Q_3\,\text{Spec} - Q_3\,\text{cal} \Rightarrow -0.25 + 0.42 = 0.17$ p.u

$$\frac{\Delta P_2}{V_2^0} = [B'][\Delta\delta_2]$$

$$\Delta\delta_2 = \frac{\Delta P_2}{V_2^0}[B']^{-1}$$

$$= \frac{0.87}{1}\begin{bmatrix} -24.71 & 5.48 \\ 5.48 & -17.78 \end{bmatrix}^{-1}$$

$$= 0.87\begin{bmatrix} -0.043 & -0.013 \\ -0.013 & -0.06 \end{bmatrix}$$

$$\Rightarrow \begin{bmatrix} -0.0348 & -0.01131 \\ -0.01131 & -0.0522 \end{bmatrix}$$

$\Delta\delta_2 = \delta_2\,\text{Spec} - \delta_2\,\text{cal}$

$\delta_2\,\text{cal} = \delta_2\,\text{Spec} - \Delta\delta_2$

$$\delta_2\,\text{cal} = \begin{bmatrix} 0.034 & 0.01 \\ 0.01 & 0.05 \end{bmatrix}$$

$\delta_2\,\text{cal} = 0.016$ p.u

$$\frac{\Delta P_3}{V_3^0} = [B'][\Delta\delta_3]$$

$$\Delta\delta_3 = \frac{\Delta P_3}{V_3^0}\left[[B']^{-1}\right]$$

$$= \frac{-0.14}{1}\begin{bmatrix} -24.71 & 5.48 \\ 5.48 & -17.78 \end{bmatrix}^{-1}$$

$$= -0.14\begin{bmatrix} -0.043 & -0.013 \\ -0.013 & -0.06 \end{bmatrix}$$

$$\Delta\delta_3 = \begin{bmatrix} 0.056 & 0.018 \\ 0.018 & 0.084 \end{bmatrix}$$

$$\Delta\delta_3 = \delta_3^0 spec - \delta_3 cal.$$

$$\delta cal = \delta spec - \Delta\delta_3$$

$$= \begin{bmatrix} -0.056 & -0.018 \\ -0.018 & -0.084 \end{bmatrix} = 0.0438 \text{ p.u}$$

$$\frac{\Delta Q_3}{V_3^0} = [B''][\Delta V_3]$$

$$\Delta V_3 = \frac{\Delta Q_3}{V_3^0}[B'']^{-1}$$

$$\Delta V_3 = \frac{0.17}{1}[17.18]^{-1}$$

$$\Delta V_3 = 0.085 \text{ p.u}$$

$$V_3 = V_3^0 spec - \Delta V_3$$

$$= 1 - 0.085$$

$$V_3 = 0.915V$$

JNTUH PEQ from 2 & 3rd units Previous Exams

1) What is the necessity of load flow studies [2M]

2) Compare all the load flow methods [3M] ①

(i) No. of iterations

(ii) Memory

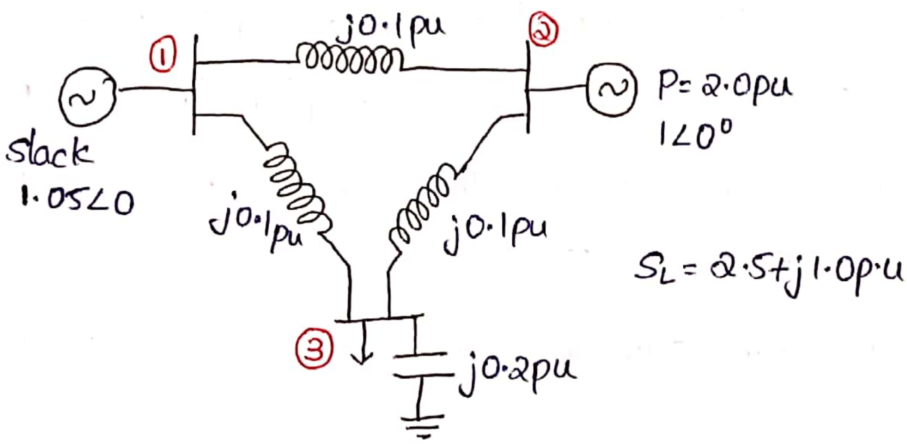
(iii) commutation time

(iv) Suitable for

(v) programming easy (or) difficult.

3) a) Describe briefly about the classification of load flow methods & their applications in real world [5M]

b) For the 3 bus system shown in below fig perform 2 iterations of G.S load flow method the values shown in fig. Line reactances in per unit of substance j0.2 pu [5M]



[OR]

4) Explain N-R load method in polar force & derive the equation to compute the Jacobian matrix elements [10M]

5) What is the need of DC load flow [2M]

6) What data is necessary for power flow studies [2M]

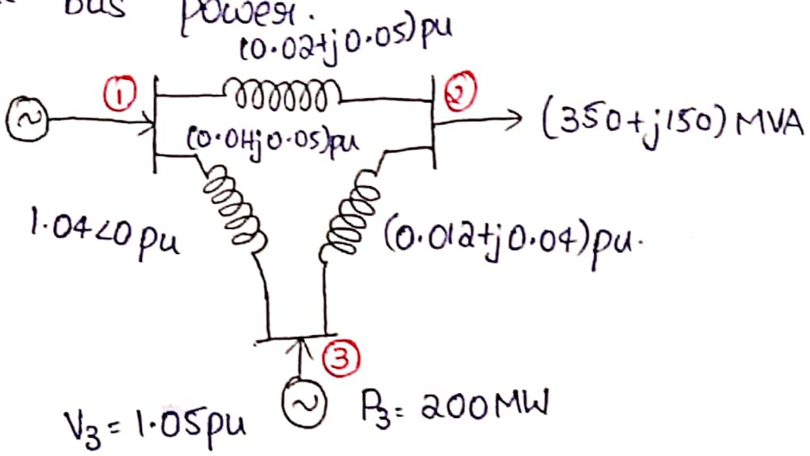
7) Write an algorithm of GS load flow method by considering all buses [7M]

8) single diagram of a simple p.s with generators ① & ③ shown in below fig. The necessary data are given diagram, line impedances are marked in p.u are 100MVA based.

Determine the following using FDLF method at the end of 1^{st} iteration.

(i) Voltage at buses ② & ③ [10M]

(ii) slack bus power.



$$\text{Slack bus power} = \frac{(V_1-V_2)^2}{Z_{12}} + \frac{(V_1-V_3)^2}{Z_{13}} + \frac{(V_2-V_3)^2}{Z_{23}}$$

9) What are the limitations of NR method [2M]

10) What is the advantage of acceleration factor in GS load flow method [3M]

11) Develop the power flow model using decoupled method & explain the assumptions to arrive at the fast Decoupled load flow method [10M]

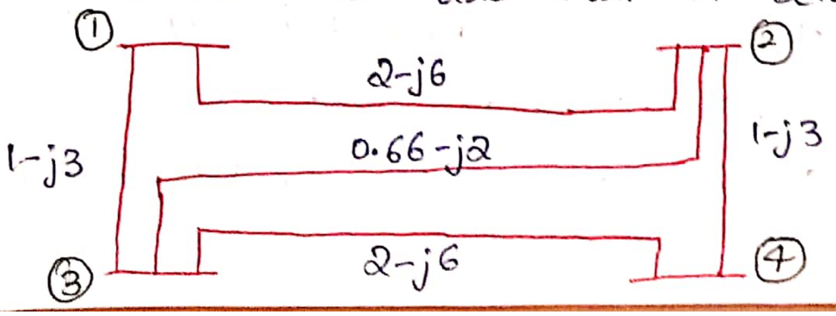
12) Define load flow problem. classify the various buses in p.s & discuss the importance of slack bus [4M]

13) Newton Raphson method solution for power flow solution by deriving necessary eqn.

14) Advantages of NR method over GS method.

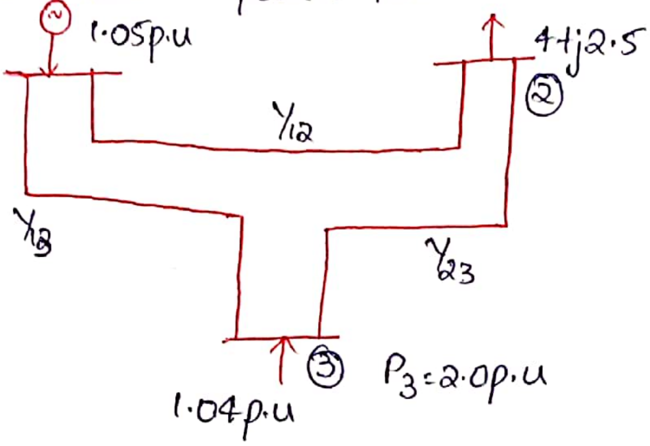
15) For the system shown in below fig $P_2 = 0.5$ pu, $Q_2 = -0.2$ pu, $P_3 = -1$ pu, $Q_3 = 0.5$ pu, $P_4 = 0.3$ p.u, $Q_4 = -0.1$ pu, $V_1 = 1.04\angle 0°$

Determine the value of V_2 after the first iteration by GS method. Line admittances are shown in below fig.



16) What are the assumptions made in reducing Decoupled method to fast decoupled method of power flow solution & derive FDLF load flow eqn.

17) The magnitude of voltage at bus ① is adjusted to 1.05 p.u, voltage magnitude at bus ③ is fixed at 1.04 p.u with a real power generation of 2 p.u. A load consisting of $P_{d_2} = 4$ pu. $Q_{d_2} = 2.5$ p.u is taken from bus ② & the line admittances are $Y_{12} = (10-j20)$ pu & $Y_{13} = (10-j30)$ p.u, $Y_{23} = (16-j32)$ p.u. Obtain power flow solution using FDLF method.



(12)