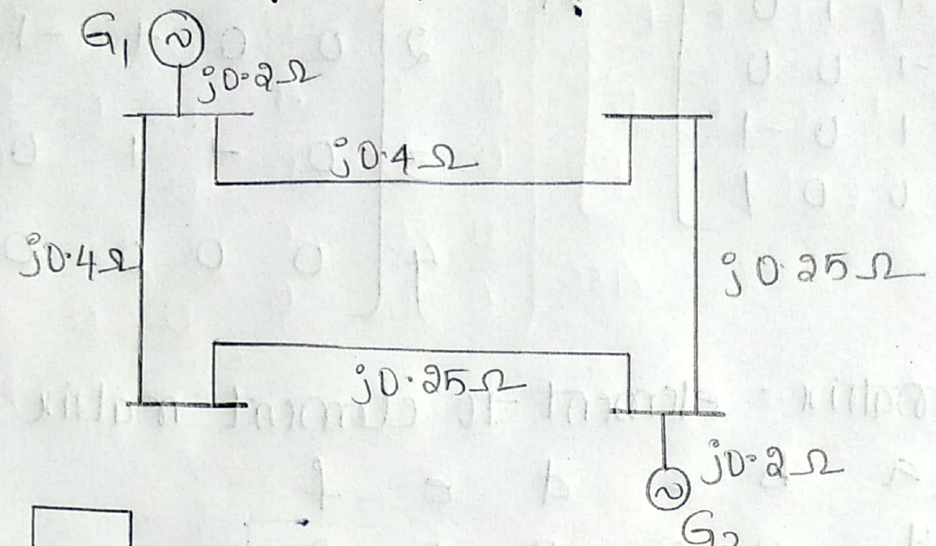
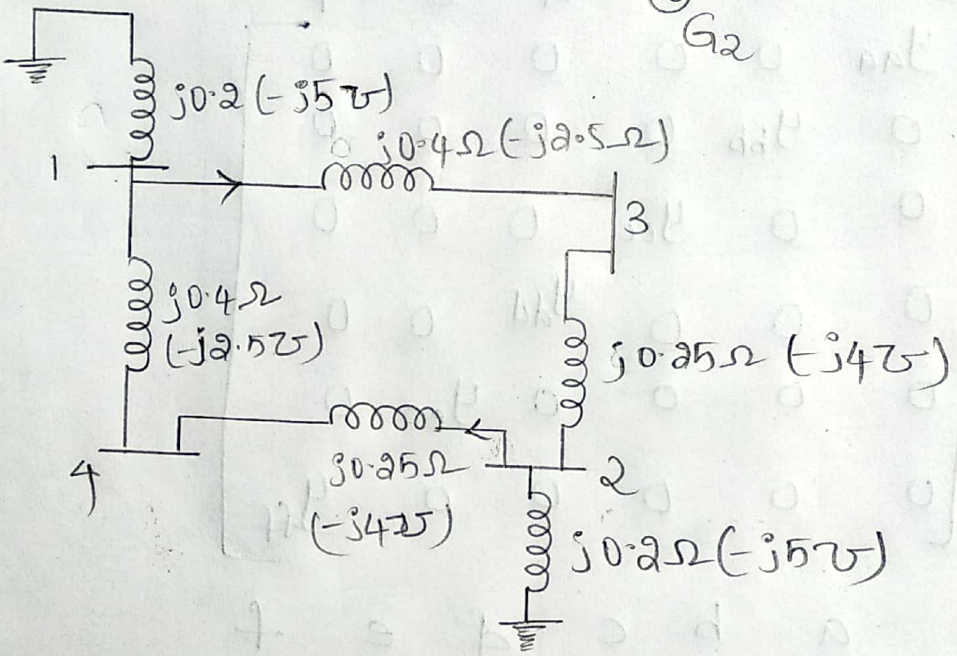
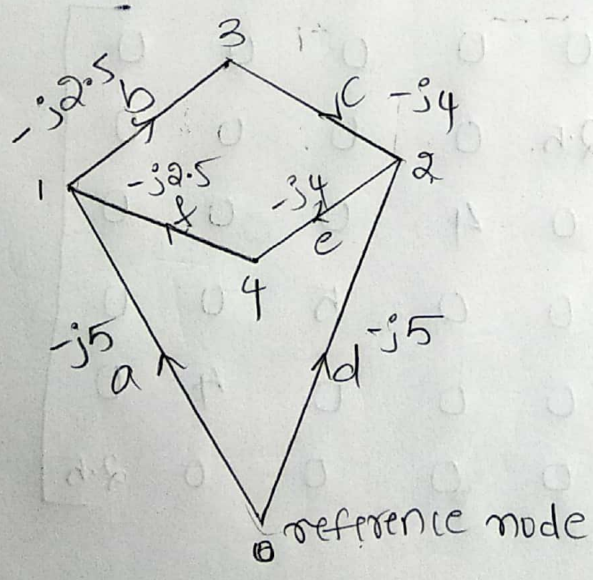
* Find Ybus for the following Power system as shown in fig by using singular transformation.



Sol.





$$A = \begin{array}{cc} & \begin{array}{cccc} 1 & 2 & 3 & 4 \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \\ f \end{array} & \begin{bmatrix} -1 & 0 & 0 & 0 \\ 1 & 0 & -1 & 0 \\ 0 & -1 & 1 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 1 & 0 & -1 \\ -1 & 0 & 0 & 1 \end{bmatrix} \end{array}$$

$$A^t = \begin{array}{cc} & \begin{array}{cccccc} a & b & c & d & e & f \end{array} \\ \begin{array}{c} 1 \\ 2 \\ 3 \\ 4 \end{array} & \begin{bmatrix} -1 & 1 & 0 & 0 & 0 & -1 \\ 0 & 0 & -1 & -1 & 1 & 0 \\ 0 & -1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 & 1 \end{bmatrix} \end{array}$$

Primitive matrix = element to element matrix

$$y = \begin{array}{cc} & \begin{array}{cccccc} a & b & c & d & e & f \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \\ f \end{array} & \begin{bmatrix} y_{aa} & 0 & 0 & 0 & 0 & 0 \\ 0 & y_{bb} & 0 & 0 & 0 & 0 \\ 0 & 0 & y_{cc} & 0 & 0 & 0 \\ 0 & 0 & 0 & y_{dd} & 0 & 0 \\ 0 & 0 & 0 & 0 & y_{ec} & 0 \\ 0 & 0 & 0 & 0 & 0 & y_{ff} \end{bmatrix} \end{array}$$

$$y = -j \begin{array}{cc} & \begin{array}{cccccc} a & b & c & d & e & f \end{array} \\ \begin{array}{c} a \\ b \\ c \\ d \\ e \\ f \end{array} & \begin{bmatrix} 5 & 0 & 0 & 0 & 0 & 0 \\ 0 & 2.5 & 0 & 0 & 0 & 0 \\ 0 & 0 & 4 & 0 & 0 & 0 \\ 0 & 0 & 0 & 5 & 0 & 0 \\ 0 & 0 & 0 & 0 & 4 & 0 \\ 0 & 0 & 0 & 0 & 0 & 2.5 \end{bmatrix} \end{array}$$

$$Y_{BUS} = [A^t][y][A]$$

$$= -j \begin{bmatrix} -1 & 1 & 0 & 0 & 0 & -1 \\ 0 & 0 & -1 & -1 & 1 & 0 \\ 0 & -1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 & 1 \end{bmatrix}_{4\times6} \begin{bmatrix} 5 & 0 & 0 & 0 & 0 & 0 \\ 0 & 2.5 & 0 & 0 & 0 & 0 \\ 0 & 0 & 4 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 4 & 0 \\ 0 & 0 & 0 & 0 & 0 & 2.5 \end{bmatrix}_{6\times6}$$

$$\begin{bmatrix} -1 & 0 & 0 & 0 \\ 1 & 0 & -1 & 0 \\ 0 & -1 & 1 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 1 & 0 & -1 \\ -1 & 0 & 0 & 1 \end{bmatrix}_{6\times4}$$

$\Rightarrow [y][A]$

$$= \begin{bmatrix} 5\times-1+0 & 0 & 0 & 0 \\ 0+2.5 & 0 & -2.5 & 0 \\ 0 & -4 & 4 & 0 \\ 0 & -5 & 0 & 0 \\ 0 & 4 & 0 & -4 \\ -2.5 & 0 & 0 & 2.5 \end{bmatrix} = \begin{bmatrix} -5 & 0 & 0 & 0 \\ 2.5 & 0 & -2.5 & 0 \\ 0 & -4 & 4 & 0 \\ 0 & -5 & 0 & 0 \\ 0 & 4 & 0 & -4 \\ -2.5 & 0 & 0 & 2.5 \end{bmatrix}$$

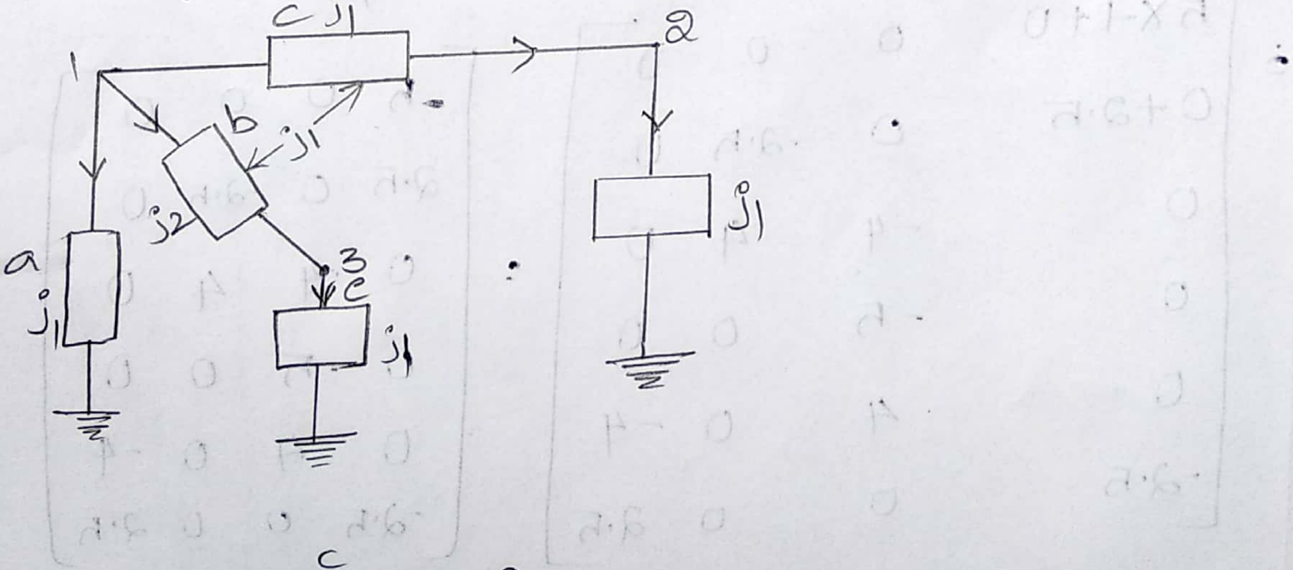
$\Rightarrow [A^t][y][A]$

$$= -j \begin{bmatrix} -1 & 1 & 0 & 0 & 0 & -1 \\ 0 & 0 & -1 & -1 & 1 & 0 \\ 0 & -1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -1 & 1 \end{bmatrix} \begin{bmatrix} -5 & 0 & 0 & 0 \\ 2.5 & 0 & -2.5 & 0 \\ 0 & -4 & 4 & 0 \\ 0 & -5 & 0 & 0 \\ 0 & 4 & 0 & -4 \\ -2.5 & 0 & 0 & 2.5 \end{bmatrix}$$

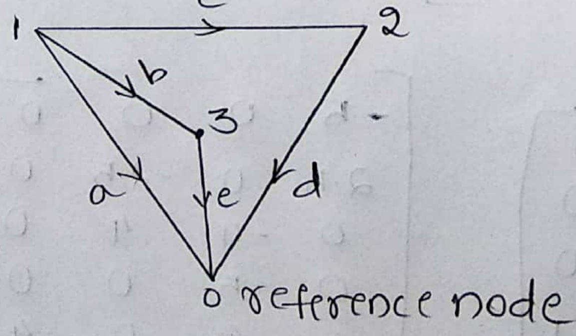
$$= -j \begin{bmatrix} 5+2.5+2.5 & 0 & -2.5 & -2.5 \\ 0 & 4+5+4 & -4+2.5 & -4 \\ -2.5 & -4 & 2.5+4 & 0 \\ -2.5 & -4 & 0 & 4+2.5 \end{bmatrix}$$

$$Y_{BUS} = -j \begin{bmatrix} 10 & 0 & -2.5 & -2.5 \\ 0 & 13 & -1.5 & -4 \\ 2.5 & -4 & 6.5 & 0 \\ -2.5 & -4 & 0 & 6.5 \end{bmatrix}$$

* Determination primitive impedance, primitive admittance and Ybus of the following interconnected system given By considering line reactances.



Sol:



$$A = \begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccc} 1 & 2 & 3 \end{array} \\ \begin{bmatrix} 1 & 0 & 0 \\ 1 & 0 & -1 \\ 1 & -1 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \end{array} \qquad A^t = \begin{bmatrix} 1 & 1 & 1 & 0 & 0 \\ 0 & 0 & -1 & 1 & 0 \\ 0 & -1 & 0 & 0 & 1 \end{bmatrix}$$

$$|Z| = \begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{bmatrix} Z_{aa} & 0 & 0 & 0 & 0 \\ 0 & Z_{bb} & Z_{bc}^* & 0 & 0 \\ 0 & Z_{cb}^* & Z_{cc} & 0 & 0 \\ 0 & 0 & 0 & Z_{dd} & 0 \\ 0 & 0 & 0 & 0 & Z_{ee} \end{bmatrix} \end{array}$$

$$Z = j \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 2 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} \quad Z^{-1} = y = -j \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 1 & 0.5 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix}$$

$$Y_{Bus} = [A^t]\,[y]\,[A]$$

$$[y][A] = -j \begin{bmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 0.5 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 1 & 0 & -1 \\ 1 & -1 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$Y_{Bus} = [A^t][y][A]$$

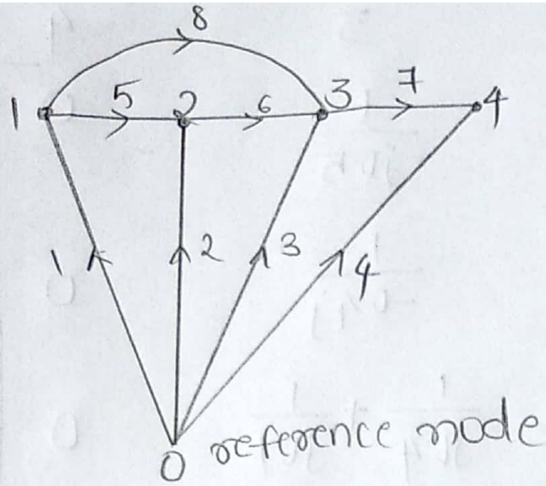
$$= -j\begin{bmatrix} 1 & 0 & 0 \\ 0.5+1 & -1 & 0.5 \\ 1+1 & -1 & -1 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} 1 & 1 & 1 & 0 & 0 \\ 0 & 0 & -1 & 1 & 0 \\ 0 & -1 & 0 & 0 & 1 \end{bmatrix}$$

$$= -j\begin{bmatrix} 1 & 1 & 1 & 0 & 0 \\ 1.5 & 0 & 2.5 & -1 & 0.5 \\ 2 & 3 & 3 & -1 & -1 \\ 0 & 0 & -1 & 1 & 0 \\ 0 & -1 & 0 & 0 & 1 \end{bmatrix}$$

* Form Y_{Bus} for the following system as shown in below diagram

Element	Bus code	Self impedance in per unit
1	0-1	0.1
2	0-2	0.2
3.	0-3	0.3
4	0-4	0.35
5	1-2	0.4
6.	2-3	0.1
7	3-4	0.2
8	1-3	0.15

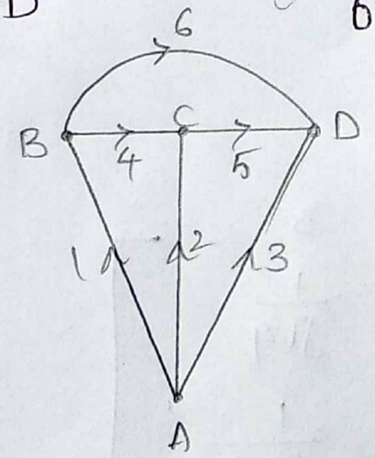
Sol



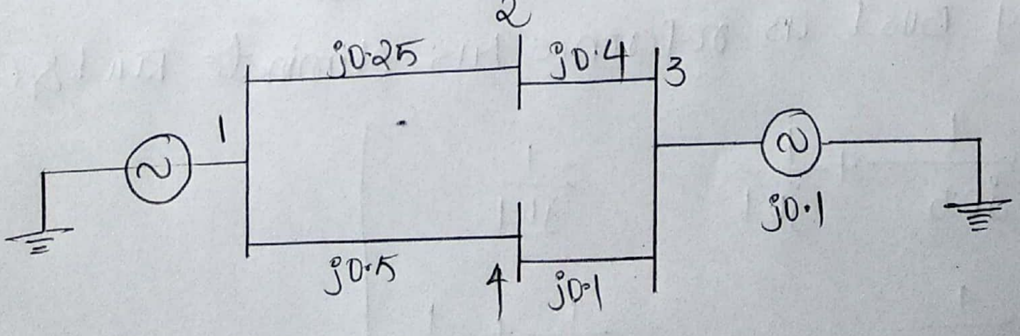
* Form Y-Bus for the following system :

Element	line reactance (impedance)
A-B	0.1 Ω
A-C	0.2 Ω
A-D	0.3 Ω
B-C	0.4 Ω
C-D	0.45 Ω
B-D	0.35 Ω

Sol

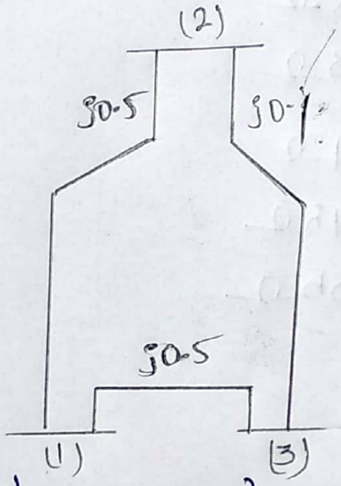


* Form Y bus for the following system given below. Considered line reactance are in per unit. By direct inspection method.



$$
Y_{BUS} = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \end{array}
\begin{array}{c}
\begin{array}{cccc} \quad 1 \quad & \quad 2 \quad & \quad 3 \quad & \quad 4 \quad \end{array} \\
\begin{bmatrix}
\frac{1}{j0.25} + \frac{1}{j0.5} & \frac{1}{-j0.25} & \frac{1}{-j0.5} & 0 \\
\frac{1}{-0.25} & \frac{1}{0.25} + \frac{1}{j0.4} & \frac{1}{-0.4j} & 0 \\
\frac{1}{-j0.4} & \frac{1}{-j0.1} & \frac{1}{j0.4} + \frac{1}{j0.1} & 0 \\
 & & &
\end{bmatrix}
\end{array}
$$

* Obtain Y-bus by direct inspection method for the following given n/w take bus 1 as a reference bus and the impedance mark in per unit.

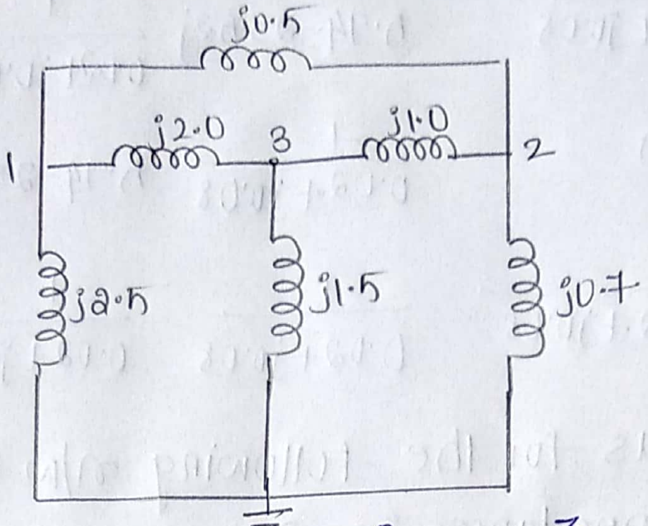


$$
Y_{Bus} = \begin{array}{c} \\ 1 \\ 2 \\ 3 \end{array}
\begin{array}{c}
\begin{array}{ccc} \quad 1 \quad & \quad 2 \quad & \quad 3 \quad \end{array} \\
\begin{bmatrix}
\frac{1}{j0.3} + \frac{1}{j0.4} & -\frac{1}{j0.5} & -\frac{1}{j0.4} \\
-\frac{1}{j0.5} & \frac{1}{j0.5} + \frac{1}{j0.1} & -\frac{1}{j0.1} \\
-\frac{1}{j0.4} & -\frac{1}{j0.1} & \frac{1}{0.4j} + \frac{1}{j0.1}
\end{bmatrix}
\end{array}
$$

By considering Bus 1 as reference bus eliminate Row 1 & Column.

$$
Y_{Bus} = \begin{array}{c} 2 \\ 3 \end{array}
\begin{bmatrix}
\frac{1}{j0.5} + \frac{1}{j0.1} & -\frac{1}{j0.1} \\
-\frac{1}{j0.1} & \frac{1}{j0.4} + \frac{1}{j0.1}
\end{bmatrix}
$$

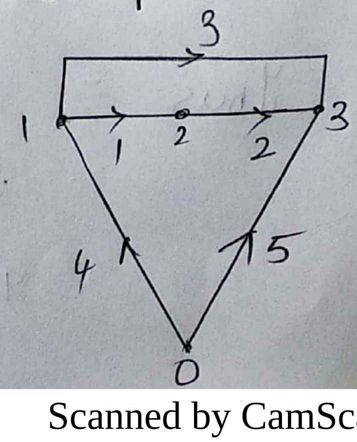
* Determine Y_{Bus} by direct inspection method for the (5) following method as shown in below diagram. Given values are in per unit admittance.



$$Y_{Bus} = \begin{array}{c} \\ 0 \\ 1 \\ 2 \\ 3 \end{array} \begin{array}{c} \begin{array}{cccc} 0 & 1 & 2 & 3 \end{array} \\ \begin{bmatrix} j4.7 & -j2.5 & -j0.7 & -j1.5 \\ -j2.5 & j5 & -j0.5 & -j2.0 \\ -j0.7 & -j0.5 & j2.2 & -j1.0 \\ -j1.5 & -j2.0 & -j1.0 & j4.5 \end{bmatrix} \end{array}$$

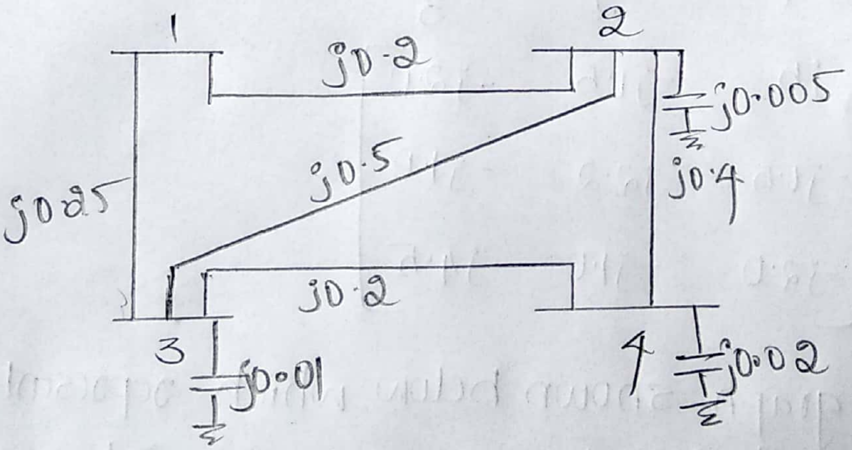
$$Y_{Bus} = \begin{array}{c} \\ 1 \\ 2 \\ 3 \end{array} \begin{array}{c} \begin{array}{ccc} 1 & 2 & 3 \end{array} \\ \begin{bmatrix} j5 & -j0.5 & -j2.0 \\ -j0.5 & j2.2 & -j1.0 \\ -j2.0 & -j1.0 & j4.5 \end{bmatrix} \end{array}$$

* Consider the graph shown below which represents a four bus t/m s/m each line has a series impedance of $0.02 + j0.08$ and line charging admittance of $j0.02$. Compute Y-bus by direct inspection method.



$$
Y_{Bus} = \begin{array}{c|cccc}
 & 0 & 1 & 2 & 3 \\
\hline
0 & 5.94-23.52j & \frac{-1}{0.02+j0.08} & 0 & \frac{-1}{0.02+j0.08} \\
1 & \frac{-1}{0.02+j0.08} & 5.94-23.52j & \frac{-1}{0.02+j0.08} & \frac{-1}{0.02+j0.08} \\
2 & 0 & \frac{-1}{0.02+j0.08} & 5.94-23.52j & \frac{-1}{0.02+j0.08} \\
3 & \frac{-1}{0.02+j0.08} & \frac{-1}{0.02+j0.08} & \frac{-1}{0.02+j0.08} & 5.94-j23.52
\end{array}
$$

* Compute Y-bus for the following n/w by direct inspectio[n] method. Line impedances in P.U are given in the n/w. Consi-der half line charging admittance at bus 2 is j0.005 and at bus 3 is j0.01 shunt capacitor admittance at bus 4 is j0.0[…] Compute Y-bus by singular transformation without consi-dering half line charging admittance and shunt capacitor admittance.



$$
Y_{bus} = \begin{array}{c|cccc}
 & 1 & 2 & 3 & 4 \\
\hline
1 & Y_{11} & Y_{12} & Y_{13} & Y_{14} \\
2 & Y_{21} & Y_{22} & Y_{23} & Y_{24} \\
3 & Y_{31} & Y_{32} & Y_{33} & Y_{34} \\
4 & Y_{41} & Y_{42} & Y_{43} & Y_{44}
\end{array}
$$

$$y_{11} = j0.2 + j0.25 = y_{12} + y_{13} = \frac{1}{j0.2} + \frac{1}{j0.25} = -j5 - j4 = -j9$$

$$y_{12} = -\left(\frac{1}{j0.2}\right) = j5$$

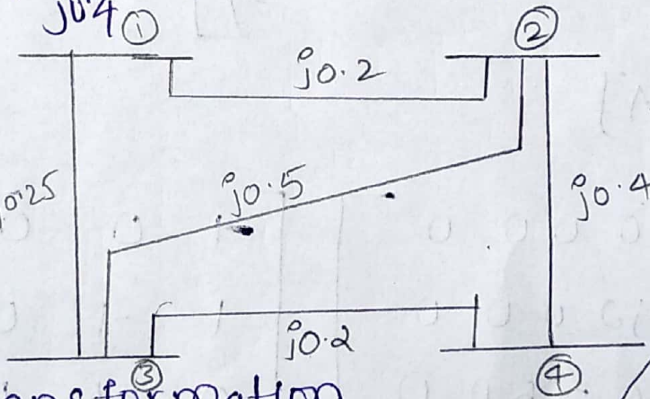
$$y_{13} = -\left(\frac{1}{0.25}\right) = j4 \qquad y_{22} = 5 + 2.5 + 2$$

$$y_{14} = 0.$$

$$Y_{bus} = \begin{bmatrix} -j9 & j5 & j4 & 0 \\ j5 & -j9.495 & j2 & j2.5 \\ j4 & j2 & -j10.99 & j5 \\ 0 & j2.5 & j5 & -j7.48 \end{bmatrix}$$

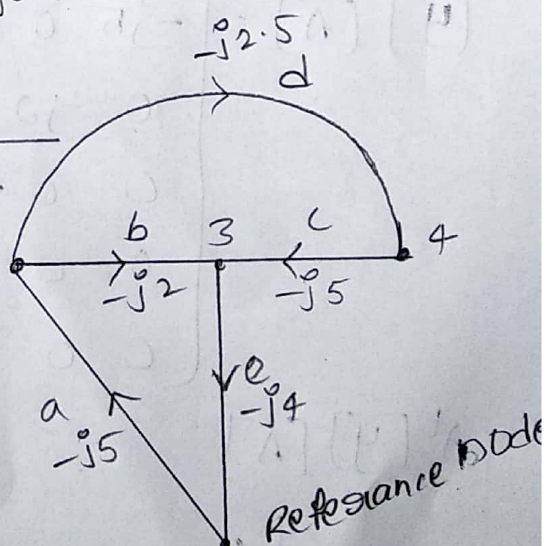
$$y_{33} = \frac{1}{j0.25} + \frac{1}{j0.5} + \frac{1}{j0.2} + j0.01 = -j10.99$$

$$y_{44} = \frac{1}{j0.2} + \frac{1}{j0.4} + j0.02 = -j7.48$$



singular transformation

$$Y_{Bus} = A^t [y] A$$



$$A = \begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccc} 2 & 3 & 4 \end{array} \\ \begin{bmatrix} -1 & 0 & 0 \\ 1 & -1 & 0 \\ 0 & -1 & 1 \\ 1 & 0 & -1 \\ 0 & +1 & 0 \end{bmatrix} \end{array} \Rightarrow A^t = \begin{array}{c} \\ 2 \\ 3 \\ 4 \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{bmatrix} -1 & 1 & 0 & 1 & 0 \\ 0 & -1 & -1 & 0 & 1 \\ 0 & 0 & 1 & -1 & 0 \end{bmatrix} \end{array}$$

$$y = \begin{array}{c} \\ a \\ b \\ c \\ d \\ e \end{array} \begin{array}{c} \begin{array}{ccccc} a & b & c & d & e \end{array} \\ \begin{bmatrix} y_{aa} & 0 & 0 & 0 & 0 \\ 0 & y_{bb} & 0 & 0 & 0 \\ 0 & 0 & y_{cc} & 0 & 0 \\ 0 & 0 & 0 & y_{dd} & 0 \\ 0 & 0 & 0 & 0 & y_{ee} \end{bmatrix} \end{array}$$

$$y = \begin{bmatrix} -j5 & 0 & 0 & 0 & 0 \\ 0 & -j2 & 0 & 0 & 0 \\ 0 & 0 & -j5 & 0 & 0 \\ 0 & 0 & 0 & -j2.5 & 0 \\ 0 & 0 & 0 & 0 & -j4 \end{bmatrix}$$

$$Y_{Bus} = A^t [y] [A]$$

$$[y][A] = \begin{bmatrix} -j5 & 0 & 0 & 0 & 0 \\ 0 & -j2 & 0 & 0 & 0 \\ 0 & 0 & -j5 & 0 & 0 \\ 0 & 0 & 0 & -j2.5 & 0 \\ 0 & 0 & 0 & 0 & -j4 \end{bmatrix} \begin{bmatrix} -1 & 0 & 0 \\ 1 & -1 & 0 \\ 0 & -1 & 1 \\ 1 & 0 & -1 \\ 0 & 1 & 1 \end{bmatrix}$$

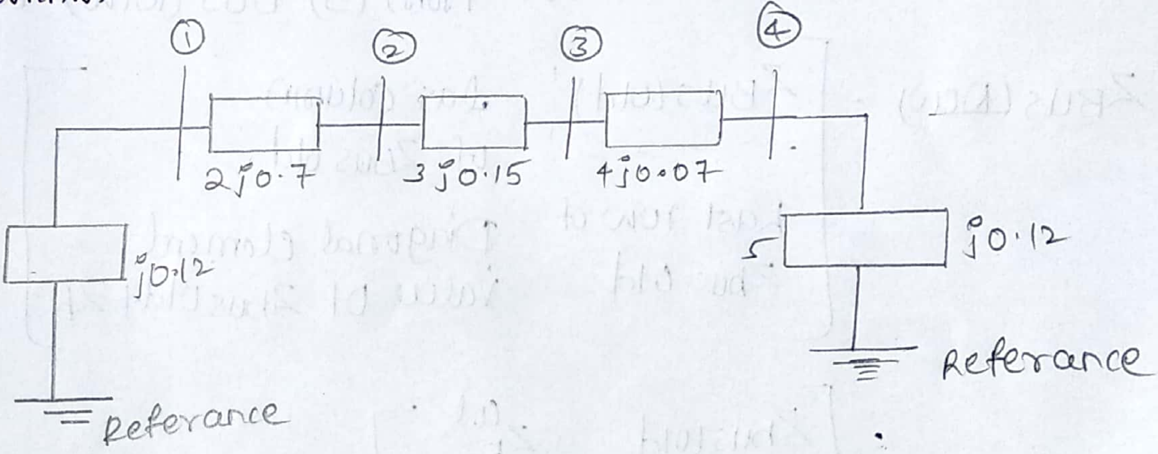
$A^t [y] [A]$

$$= \begin{bmatrix} j5 & 0 & 0 \\ -j2 & j2 & 0 \\ 0 & j5 & -j5 \\ -j2.5 & 0 & j2.5 \\ 0 & -j4 & -j4 \end{bmatrix} \begin{bmatrix} -1 & 1 & 0 & 1 & 0 \\ 0 & -1 & -1 & 0 & 1 \\ 0 & 0 & 1 & -1 & 0 \end{bmatrix}$$

Scanned by CamScanner

$$Y_{bus} = \begin{bmatrix} -j5 & j5 & 0 & j5 & 0 \\ j2 & -j4 & -j2 & -j2 & j2 \\ 0 & -j5 & -j10 & j5 & j5 \\ j2.5 & -j2.5 & j2.5 & -j5 & 0 \\ 0 & j4 & 0 & j4 & -j4 \end{bmatrix}$$

* Find ~~Ibus~~ coincidence matrix for the following interconnected PS line impedances are in P.U By applying complete Zbus algorithm.

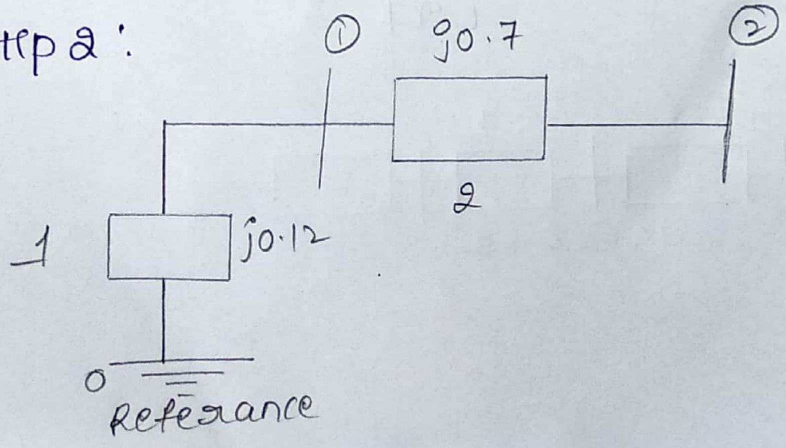


Step 1: Element '1' is connected from Bus ① (New BUS) to reference

$$Z_{BUS}(new) = \begin{array}{c|cc} & 0 & 1 \\ \hline 0 & Z_{old} & 0 \\ 1 & 0 & 0 \end{array} = \begin{bmatrix} 0 & 0 \\ 0 & j0.12 \end{bmatrix}$$

$$= j0.12$$

Step 2:

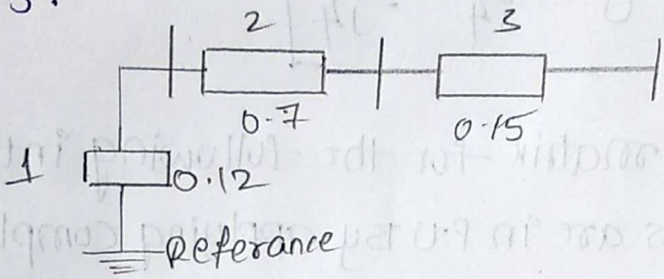


Element '2' is added from bus(2) to bus(1)

$$Z_{BUS(NEW)} = \begin{bmatrix} j0.12 & j0.12 \\ j0.12 & j0.12 + j0.7 \end{bmatrix}$$

$$Z_{BUS(NEW)} = j\begin{bmatrix} 0.12 & 0.12 \\ 0.12 & 0.82 \end{bmatrix}$$

Step 3:



Element '3' is added to from (3) BUS (New) to (2)

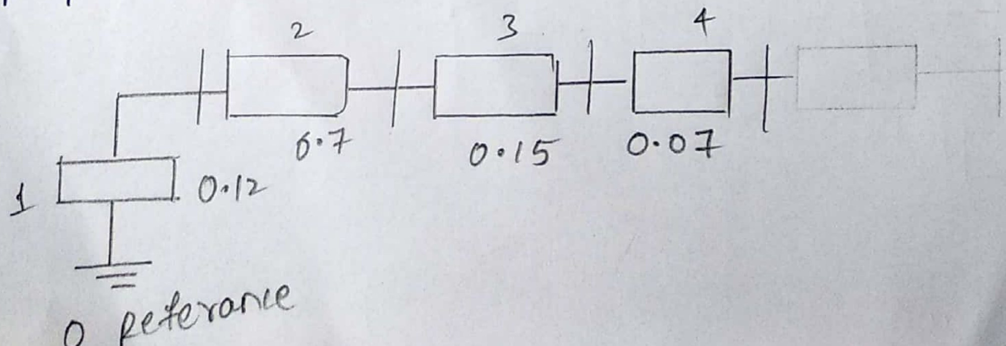
$$Z_{BUS(NEW)} = \begin{bmatrix} Z_{BUS(old)} & \text{las column of } Z_{bus} \text{ old} \\ \text{Last row of } Z_{bus} \text{ old} & \text{Diagonal element value of } Z_{bus} \text{ old} + Z_b \end{bmatrix}$$

$$= \begin{bmatrix} Z_{bus(old)} & Z_k^{col} \\ Z_k^{row} & Z_b + Z_k \end{bmatrix}$$

$$= j \begin{array}{c c} & \begin{array}{ccc} 1 & 2 & 3 \end{array} \\ \begin{array}{c} 1 \\ 2 \\ 3 \end{array} & \left[\begin{array}{cc|c} 0.12 & 0.12 & 0.12 \\ 0.12 & 0.82 & 0.82 \\ \hline 0.12 & 0.82 & \boxed{0.82+0.15} \end{array}\right] \end{array}$$

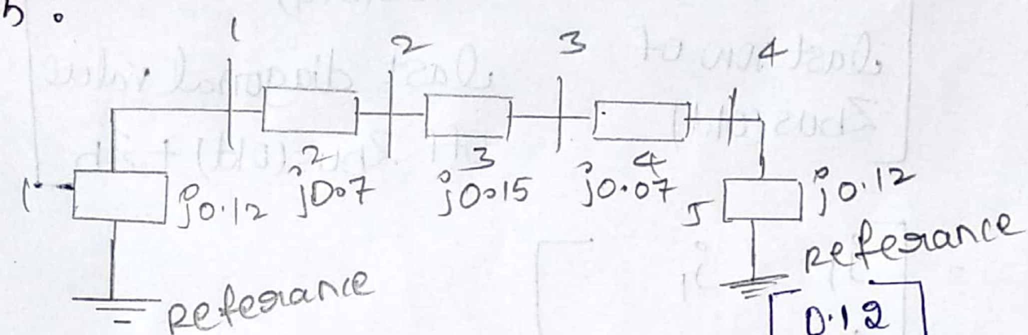
0.97

Step 4:



$$= j\begin{bmatrix} 0.12 & 0.12 & 0.12 & 0.12 \\ 0.12 & 0.82 & 0.82 & 0.82 \\ 0.12 & 0.82 & 0.97 & 0.97 \\ 0.12 & 0.82 & 0.97 & 0.97+0.07 \end{bmatrix}$$

Step 5 :

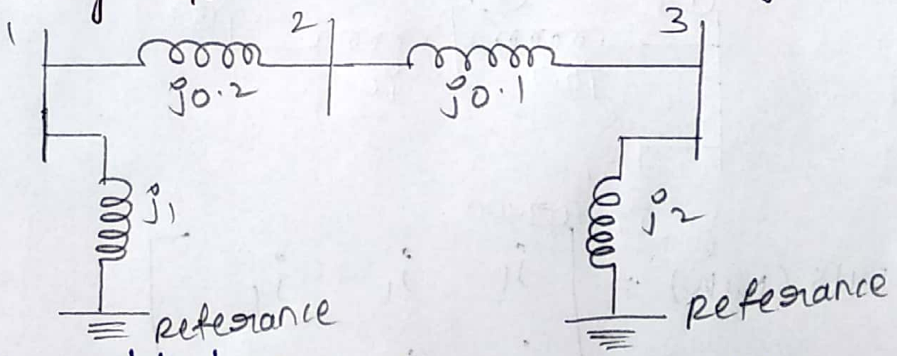


$$Z_{Bus\,(New)} = Z_{Bus(old)} - \frac{1}{1.04+0.12}\begin{bmatrix} 0.12 \\ 0.82 \\ 0.97 \end{bmatrix}\begin{bmatrix} 0.12 & 0.82 & 0.97 \end{bmatrix}$$

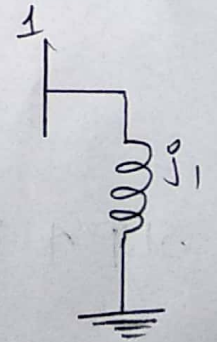
* Compute Zbus by a) Zbus algorithm method

b) Inversion of YBus

For the following n/w line reactances are given in per unit



Step 1 : J_1 is added from bus(1) to ref bus(1) is new bus

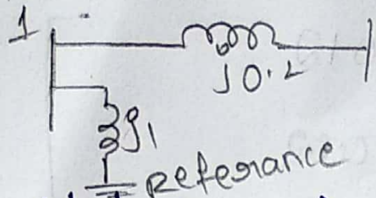


$$Z_{Bus\,(new)} = \begin{array}{c c} & \begin{array}{cc} 0 & 1 \end{array} \\ \begin{array}{c} 0 \\ 1 \end{array} & \begin{bmatrix} Z_{bus\,(old)} & 0 \\ 0 & 0 \end{bmatrix} \end{array}$$

$$= \begin{array}{c c} & \begin{array}{cc} 0 & 1 \end{array} \\ \begin{array}{c} 0 \\ 1 \end{array} & \begin{bmatrix} 0 & 0 \\ 0 & j_1 \end{bmatrix} \end{array}$$

$$Z_{Bus\,(new)} = [j_1]$$

Step 2 :



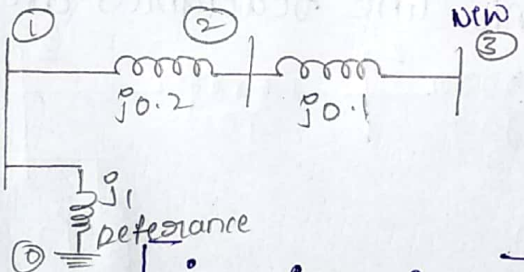
j0.2 is added from from bus 2 (new) to bus 1 (old)

$$Z_{BUS}(new) = \begin{bmatrix} Z_{BUS}(old) & \text{last column of } Z_{bus}(old) \\ \text{last row of } Z_{bus}(old) & \text{last diagonal value off } Z_{bus}(old) + Z_b \end{bmatrix}$$

$$= \begin{bmatrix} j1 & j1 \\ j1 & j1 + j0.2 \end{bmatrix}$$

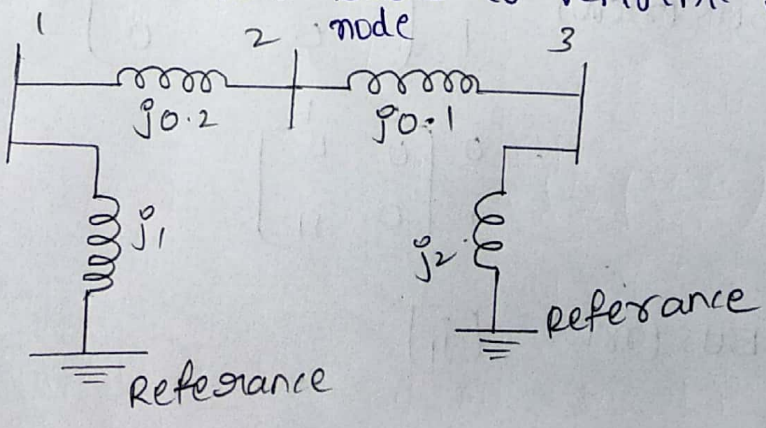
$$= \begin{bmatrix} j1 & j1 \\ j1 & j1.2 \end{bmatrix}$$

Step 3 : j0.1 is added from bus 3 to bus 2 (old)



$$Z_{BUS}(New) = \begin{bmatrix} j1 & j1 & j1 \\ j1 & j1.2 & j1.2 \\ j1 & j1.2 & j1.3 \end{bmatrix}$$

Step 4 : j2 is added from bus 3 to refrerence Bus 3 is old bus



(9)

$$Z_{bus}(new) = Z_{Bus}(old) - \frac{1}{\text{last diagonal value}} \begin{bmatrix} \text{last} \\ \text{column} \\ \text{of } Z_{Bus}\text{ old} \end{bmatrix} \begin{bmatrix} \text{last row of } Z_{bus} \text{ old} \end{bmatrix}$$

$$= \begin{bmatrix} j1 & j1 & j1 \\ j1 & j1.2 & j0.2 \\ j1 & j1.2 & j1.3 \end{bmatrix} - \frac{1}{j1.3+j2} \begin{bmatrix} j1 \\ j1.2 \\ j1.3 \end{bmatrix} \begin{bmatrix} j1 & j1.2 & j1.3 \end{bmatrix}$$

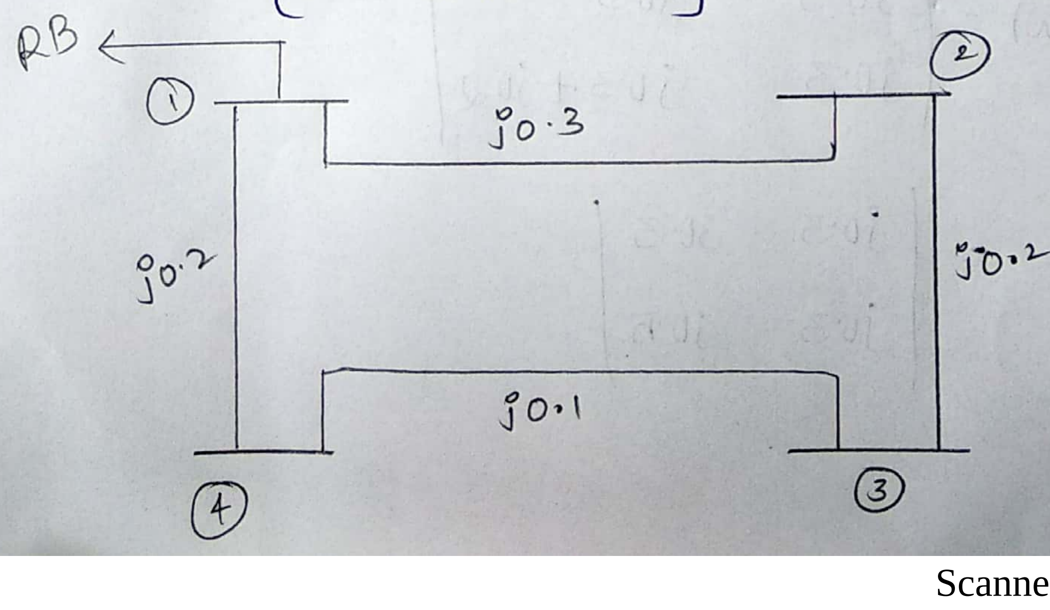
$$= \begin{bmatrix} j1 & j1 & j1 \\ j1 & j1.2 & j1.2 \\ j1 & j1.2 & j1.3 \end{bmatrix} - \frac{1}{j3.3} \begin{bmatrix} -1 & -1.2 & -1.3 \\ -1.2 & -1.44 & -1.56 \\ -1.3 & -1.36 & -1.69 \end{bmatrix}$$

$$= \begin{bmatrix} j1 & j1 & j1 \\ j1 & j1.2 & j1.2 \\ j1 & j1.2 & j1.3 \end{bmatrix} - \frac{1}{j} \begin{bmatrix} -0.3 & -0.36 & -0.39 \\ -0.36 & -0.43 & -0.47 \\ -0.39 & -0.47 & -0.51 \end{bmatrix}$$

$$= j \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1.2 & 1.2 \\ 1 & 1.2 & 1.3 \end{bmatrix} - j \begin{bmatrix} 0.3 & 0.36 & 0.39 \\ 0.36 & 0.43 & 0.47 \\ 0.39 & 0.47 & 0.51 \end{bmatrix}$$

$$= j \begin{bmatrix} 0.7 & 0.64 & 0.61 \\ 0.64 & 0.57 & 0.53 \\ 0.61 & 0.53 & 0.49 \end{bmatrix}$$

b)



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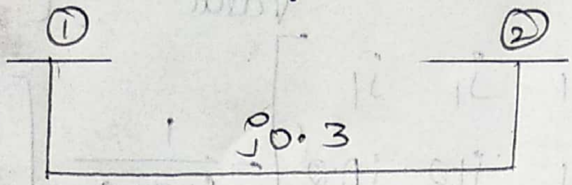
Step 1: Add j0·3 from Bus ② to Reference bus(1)

Let us consider bus(1) as reference bus

Reference bus



$$Z_{bus(New)} = \begin{array}{c|cc} & 1 & 2 \\ \hline 1 & Z_{bus(old)} & 0 \\ 2 & 0 & Z_b \end{array} = \begin{array}{c|cc} & 1 & 2 \\ \hline 1 & 0 & 0 \\ 2 & 0 & j0{\cdot}3 \end{array}$$

$= j|0{\cdot}3|$

Step 2: Add j0·2 from Bus old (2) to bus New (3)

$$Z_{Bus(New)} = \begin{vmatrix} Z_{Bus(old)} & Z_K^{column} \\ Z_K^{row} & Z_{KK} + Z_b \end{vmatrix}$$

where

Z_K^{row} = last row of Zold (except last diagonal of Zold)

Z_K^{col} = last col of Zold (Except last diagonal of Zold)

Z^{KK} = last diagonal of Zold

Z_b = element Impedance

$$Z_{Bus(New)} = \begin{vmatrix} j0{\cdot}3 & j0{\cdot}3 \\ j0{\cdot}3 & j0{\cdot}3 + j0{\cdot}2 \end{vmatrix}$$

$$= \begin{vmatrix} j0{\cdot}3 & j0{\cdot}3 \\ j0{\cdot}3 & j0{\cdot}5 \end{vmatrix}$$

Step 3: Add j0.1 from Bus(3) old to reference bus(4) new (10)

$$Z_{Bus(New)} = \begin{vmatrix} Z_{Bus(old)} & Z_k^{col} \\ Z_k^{row} & Z_{kk}+Z_b \end{vmatrix}$$

$$= \begin{vmatrix} j0.3 & j0.3 & j0.3 \\ j0.3 & j0.5 & j0.5 \\ j0.3 & j0.5 & j0.6 \end{vmatrix}$$

Step 4:

$$Z_{Bus(New)} = Z_{Bus(old)} - \frac{1}{Z_{kk}+Z_b}\left[Z_k^{col}\right]\left[Z_k^{row}\right]$$

$$= \begin{bmatrix} j0.3 & j0.3 & j0.3 \\ j0.3 & j0.5 & j0.5 \\ j0.5 & j0.5 & j0.6 \end{bmatrix} - \frac{1}{j0.5}\begin{bmatrix} j0.3 \\ j0.5 \end{bmatrix}\begin{bmatrix} j0.3 & j0.5 \end{bmatrix}$$

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