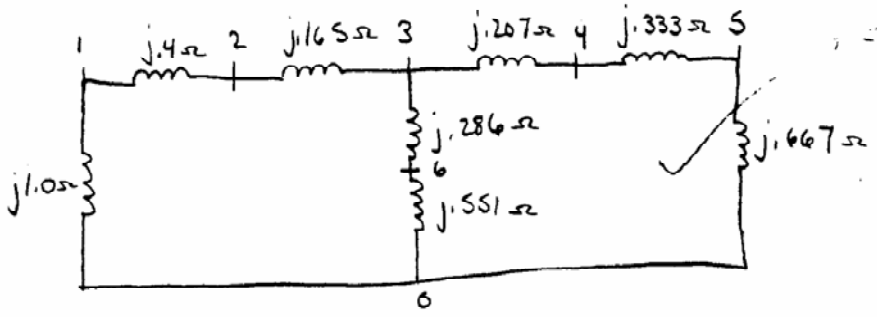
Homework set 4 Zbus

For the homework Problems of set 1 determine the Zbus models for short circuit studies. Assume generator reactance for Problems 2, 3 and 4 is equal to 10% at $S_b = 10$ MVA.

set #5 10

PROBLEM 1(a)



RADIAL LINE FROM ⓪ to ①

$Z_{BUS} = \begin{matrix} 1 \end{matrix}\begin{bmatrix} 1 \end{bmatrix}$ ✓

RADIAL LINE FROM ① TO ②

$$Z_{BUS} = \begin{matrix} & 1 & 2 \\ 1 \\ 2 \end{matrix}\begin{bmatrix} 1 & 1 \\ 1 & 1.4 \end{bmatrix}$$ ✓

RADIAL LINE FROM ② to ⑤

$$Z_{BUS} = \begin{matrix} & 1 & 2 & 3 \\ 1 \\ 2 \\ 3 \end{matrix}\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1.4 & 1.4 \\ 1 & 1.4 & 1.565 \end{bmatrix}$$ ✓

RADIAL LINE FROM ③ to ④

$$Z_{BUS} = \begin{matrix} & 1 & 2 & 3 & 4 \\ 1 \\ 2 \\ 3 \\ 4 \end{matrix}\begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & 1.4 & 1.4 & 1.4 \\ 1 & 1.4 & 1.565 & 1.565 \\ 1 & 1.4 & 1.565 & 1.772 \end{bmatrix}$$ ✓

RADIAL LINE FROM ④ to ⑤

$$Z_{BUS} = \begin{matrix} & 1 & 2 & 3 & 4 & 5 \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \end{matrix}\begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 1.4 & 1.4 & 1.4 & 1.4 \\ 1 & 1.4 & 1.565 & 1.565 & 1.565 \\ 1 & 1.4 & 1.565 & 1.772 & 1.772 \\ 1 & 1.4 & 1.565 & 1.772 & 2.105 \end{bmatrix}$$

RADIAL LINE FROM ③ to ⑥

$$Z_{BUS} = \begin{matrix} & 1 & 2 & 3 & 4 & 5 \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{matrix}\begin{bmatrix} & & 1 & & \\ & & 1.4 & & \\ & & 1.565 & & \\ & & 1.565 & & \\ & & 1.565 & & \\ 1 & 1.4 & 1.565 & 1.565 & 1.565 \end{bmatrix}$$

COMPLETE LOOP FROM ⓪ to ⑥

$$Z_{ll} = Z_{pp} + Z_{qq} - 2Z_{pq} + 3_{pq}$$

$$\therefore Z_{ll} = Z_{00} + Z_{66} - 2Z_{06} + 3_{06}$$
$$= 1.851 + .551 = 2.402$$

$$Z_{BUS} = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ \ell \end{array} \begin{array}{c} \begin{array}{cccccc} 1 & 2 & 3 & 4 & 5 & 6 \end{array} \ell \\ \left[\begin{array}{cccccc|c} & & & & & & 1 \\ & & & & & & 1.4 \\ & & & & & & 1.565 \\ & & & & & & 1.565 \\ & & & & & & 1.565 \\ & & & & & 1.851 & 1.851 \\ \hline 1 & 1.4 & 1.565 & 1.565 & 1.565 & 1.851 & 2.402 \end{array}\right] \end{array}$$

$$Z_{BUS\ \text{without } \ell} = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{array} \left[\begin{array}{cccccc} & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \end{array}\right] - \left[\begin{array}{c} 1 \\ 1.4 \\ 1.565 \\ 1.565 \\ 1.565 \\ 1.851 \end{array}\right] \left[\frac{1}{2.402}\right] \left[\begin{array}{cccccc} 1 & 1.4 & 1.565 & 1.565 & 1.5 \end{array}\right.$$

$$= \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{array} \begin{array}{c} \begin{array}{cccccc} 1 & 2 & 3 & 4 & 5 & 6 \end{array} \\ \left[\begin{array}{cccccc} 1 & 1 & 1 & 1 & 1 & 1 \\ 1 & 1.4 & 1.4 & 1.4 & 1.4 & 1.4 \\ 1 & 1.4 & 1.565 & 1.56 & 1.56 & 1.56 \\ 1 & 1.4 & 1.565 & 1.772 & 1.772 & 1.565 \\ 1 & 1.4 & 1.56 & 1.772 & 2.105 & 1.565 \\ 1 & 1.4 & 1.565 & 1.565 & 1.565 & 1.851 \end{array}\right] \end{array} - \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{array} \begin{array}{c} \begin{array}{cccccc} 1 & 2 & 3 & 4 & 5 & 6 \end{array} \\ \left[\begin{array}{cccccc} .42 & .58 & .65 & .65 & .65 & . \\ .58 & .82 & .91 & .91 & .91 & 1.0 \\ .65 & .91 & 1.01 & 1.01 & 1.01 & 1.2 \\ .65 & .91 & 1.01 & 1.01 & 1.01 & 1.2 \\ .65 & .91 & 1.01 & 1.01 & 1.01 & 1.2 \\ .77 & 1.07 & 1.21 & 1.21 & 1.21 & 1.43 \end{array}\right] \end{array}$$

$$= \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{array} \begin{array}{c} \begin{array}{cccccc} 1 & 2 & 3 & 4 & 5 & 6 \end{array} \\ \left[\begin{array}{cccccc} .58 & .42 & .35 & .35 & .35 & .23 \\ .42 & .58 & .49 & .49 & .49 & .33 \\ .35 & .49 & .555 & .555 & .555 & .355 \\ .35 & .49 & .555 & .762 & .762 & .355 \\ .35 & .49 & .555 & .762 & 1.095 & .355 \end{array}\right] \end{array}$$

LOOP FROM ⓪ to ⑤

$$Z_{BUS\ with\ \ell} = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ \ell \end{array} \begin{array}{c} \begin{array}{cccccc} 1 & 2 & 3 & 4 & 5 & 6 \end{array} \\ \left[\begin{array}{cccccc} & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ .35 & .49 & .555 & .762 & 1.09 & .355 \end{array}\right. \end{array} \begin{array}{c} \ell \\ .35 \\ .49 \\ .555 \\ .762 \\ 1.095 \\ .355 \\ \left.1.762\right] \end{array}$$

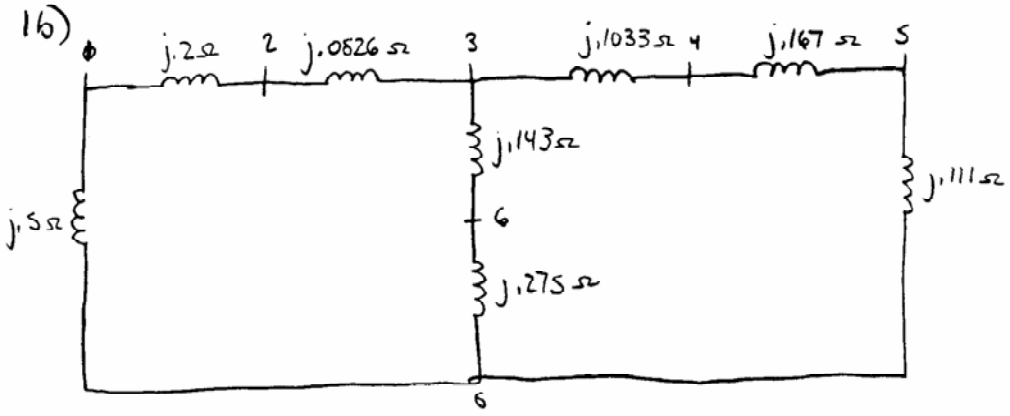
$$Z_{\ell\ell} = Z_{pp} + Z_{qq} - 2Z_{pq}$$

$$Z_{BUS\ without\ \ell} = \begin{bmatrix} & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \end{bmatrix} - \begin{bmatrix} .35 \\ .49 \\ .555 \\ .762 \\ 1.09 \\ .355 \end{bmatrix} \left[\frac{1}{1.762}\right] \begin{bmatrix} .35 & .49 & .555 & .762 & 1.09 \end{bmatrix}$$

$$= \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{array} \begin{array}{c} \begin{array}{cccccc} 1 & 2 & 3 & 4 & 5 & 6 \end{array} \\ \left[\begin{array}{cccccc} .58 & .42 & .35 & .35 & .35 & .23 \\ .42 & .58 & .49 & .49 & .49 & .33 \\ .35 & .49 & .555 & .555 & .555 & .355 \\ .35 & .49 & .555 & .762 & .762 & .355 \\ .35 & .49 & .555 & .762 & 1.095 & .355 \\ .23 & .49 & .355 & .355 & .355 & .421 \end{array}\right. \end{array} - \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{array} \begin{array}{c} \begin{array}{cccccc} 1 & 2 & 3 & 4 & 5 & 6 \end{array} \\ \left[\begin{array}{cccccc} .07 & .097 & .11 & .15 & .22 & .07 \\ .097 & .14 & .15 & .21 & .303 & .099 \\ .11 & .15 & .17 & .24 & .343 & .112 \\ .15 & .21 & .24 & .33 & .47 & .154 \\ .22 & .303 & .343 & .47 & .67 & .21 \\ .07 & .099 & .112 & .154 & .21 & .07 \end{array}\right. \end{array}$$

$$Z_{BUS} = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \end{array} \begin{array}{c} \begin{array}{cccccc} & 2 & 3 & 4 & 5 & 6 \end{array} \\ \left[\begin{array}{cccccc} .51 & .323 & .24 & .20 & .13 & .16 \\ .323 & .44 & .34 & .28 & .187 & .231 \\ .24 & .34 & .385 & .315 & .212 & .243 \\ .20 & .28 & .315 & .432 & .292 & .201 \end{array}\right. \end{array}$$

PROBLEM 16)



RADIAL LINE FROM ⓪ to ①

$$Z_{BUS} = \begin{matrix} \\ 1 \end{matrix} \begin{matrix} 1 \\ \begin{bmatrix} .5 \end{bmatrix} \end{matrix}$$

RADIAL LINE FROM ① TO ②

$$Z_{BUS} = \begin{matrix} \\ 1 \\ 2 \end{matrix} \begin{matrix} 1 & 2 \\ \begin{bmatrix} .5 & .5 \\ .5 & .7 \end{bmatrix} \end{matrix}$$

RADIAL LINE FROM ② to ③

$$Z_{BUS} = \begin{matrix} \\ 1 \\ 2 \\ 3 \end{matrix} \begin{matrix} 1 & 2 & 3 \\ \begin{bmatrix} .5 & .5 & .5 \\ .5 & .7 & .7 \\ .5 & .7 & .78 \end{bmatrix} \end{matrix}$$

RADIAL LINE FROM ③ to ④

$$Z_{BUS} = \begin{matrix} \\ 1 \\ 2 \\ 3 \\ 4 \end{matrix} \begin{matrix} 1 & 2 & 3 & 4 \\ \begin{bmatrix} & & & .5 \\ & & & .7 \\ & & & .78 \\ .5 & .7 & .78 & .88 \end{bmatrix} \end{matrix}$$

RADIAL LINE FROM ④ to ⑤

$$Z_{BUS} = \begin{matrix} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \end{matrix} \begin{matrix} 1 & 2 & 3 & 4 & 5 \\ \begin{bmatrix} & & & & .5 \\ & & & & .7 \\ & & & & .78 \\ & & & & .88 \\ .5 & .7 & .78 & .88 & 1.047 \end{bmatrix} \end{matrix}$$

RADIAL LINE FROM ⑤ to ⑥

$$Z_{BUS} = \begin{matrix} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{matrix} \begin{matrix} 1 & 2 & 3 & 4 & 5 \\ \begin{bmatrix} & & .5 & & \\ & & .7 & & \\ & & .78 & & \\ & & .78 & & \\ & & .78 & & \\ .5 & .7 & .78 & .78 & .78 \end{bmatrix} \end{matrix}$$

LOOP FROM ⓪ to ⑥

$$Z_{BUS} = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ \ell \end{array} \begin{array}{c} \begin{array}{ccccccc} 1 & 2 & 3 & 4 & 5 & 6 & \ell \end{array} \\ \begin{bmatrix} .5 & .5 & .5 & .5 & .5 & .5 & .5 \\ .5 & .7 & .7 & .7 & .7 & .7 & .7 \\ .5 & .7 & .78 & .78 & .78 & .78 & .78 \\ .5 & .7 & .78 & .88 & .88 & .78 & .78 \\ .5 & .7 & .78 & .88 & 1.047 & .78 & .78 \\ .5 & .7 & .78 & .78 & .78 & .92 & .92 \\ .5 & .7 & .78 & .78 & .78 & .92 & 1.195 \end{bmatrix} \end{array}$$

$Z_{\ell\ell} = Z_{pp} + Z_{qq} - 2Z_{pq} + Z_{pq}$

$Z_{\ell\ell} = .92 + .275$

$$Z_{BUS\ \text{without}\ \ell} = \begin{bmatrix} \\ \\ \\ \\ \\ \\ \end{bmatrix} - \begin{bmatrix} .5 \\ .7 \\ .78 \\ .78 \\ .78 \\ .92 \end{bmatrix} \left[\frac{1}{1.195}\right] \begin{bmatrix} .5 & .7 & .78 & .78 & .78 & .92 \end{bmatrix}$$

$$Z_{BUS} = \begin{bmatrix} \\ \\ \\ \\ \\ \\ \end{bmatrix} - \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{array} \begin{array}{c} \begin{array}{cccccc} 1 & 2 & 3 & 4 & 5 & 6 \end{array} \\ \begin{bmatrix} .209 & .29 & .33 & .33 & .33 & .38 \\ .29 & .41 & .46 & .46 & .46 & .53 \\ .33 & .46 & .51 & .51 & .51 & .6 \\ .33 & .46 & .51 & .51 & .51 & .6 \\ .33 & .46 & .51 & .51 & .51 & .6 \\ .38 & .53 & .6 & .6 & .6 & .71 \end{bmatrix} \end{array}$$

$$Z_{BUS} = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{array} \begin{array}{c} \begin{array}{cccccc} 1 & 2 & 3 & 4 & 5 & 6 \end{array} \\ \begin{bmatrix} .291 & .21 & .17 & .17 & .17 & .12 \\ .21 & .29 & .24 & .24 & .24 & .17 \\ .17 & .24 & .27 & .27 & .27 & .18 \\ .17 & .24 & .27 & .37 & .37 & .18 \\ .17 & .24 & .27 & .37 & .537 & .18 \\ .12 & .17 & .18 & .18 & .18 & .21 \end{bmatrix} \end{array}$$

LOOP FROM ⓪ to ⑤

$$Z_{BUS} = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \\ \ell \end{array} \begin{array}{c} \begin{array}{ccccccc} 1 & 2 & 3 & 4 & 5 & 6 & \ell \end{array} \\ \begin{bmatrix} .291 & .21 & .17 & .17 & .17 & .12 & .17 \\ .21 & .29 & .24 & .24 & .24 & .17 & .24 \\ .17 & .24 & .27 & .27 & .27 & .18 & .27 \\ .17 & .24 & .27 & .37 & .37 & .18 & .37 \\ .17 & .24 & .27 & .37 & .537 & .18 & .537 \\ .12 & .17 & .18 & .18 & .18 & .21 & .18 \\ .17 & .24 & .27 & .37 & .537 & .18 & .648 \end{bmatrix} \end{array}$$

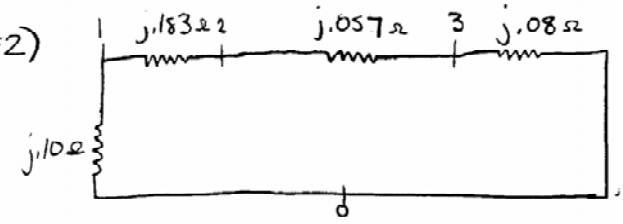
$Z_{\ell\ell} = .537 + .111 = .648$

$$Z_{BUS\ without\ \ell} = \begin{bmatrix} & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \end{bmatrix} - \begin{bmatrix} .17 \\ .24 \\ .27 \\ .37 \\ .537 \\ .18 \end{bmatrix} \left[\frac{1}{.648}\right] \begin{bmatrix} .17 & .24 & .27 & .37 & .537 & .18 \end{bmatrix}$$

$$\begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{array} \begin{array}{c} \begin{array}{cccccc} 1 & 2 & 3 & 4 & 5 & 6 \end{array} \\ \begin{bmatrix} .291 & .21 & .17 & .17 & .17 & .12 \\ & .29 & .24 & .24 & .24 & .17 \\ & & .27 & .27 & .27 & .18 \\ & & & .37 & .37 & .18 \\ & & & & .537 & .18 \\ & & & & & .21 \end{bmatrix} \end{array} - \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{array} \begin{array}{c} \begin{array}{cccccc} 1 & 2 & 3 & 4 & 5 & 6 \end{array} \\ \begin{bmatrix} .04 & .06 & .07 & .097 & .14 & .047 \\ & .089 & .1 & .13 & .199 & .067 \\ & & .113 & .154 & .22 & .075 \\ & & & .21 & .31 & .103 \\ & & & & .45 & .15 \\ & & & & & .05 \end{bmatrix} \end{array}$$

$$Z_{BUS} = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ 6 \end{array} \begin{array}{c} \begin{array}{cccccc} 1 & 2 & 3 & 4 & 5 & 6 \end{array} \\ \begin{bmatrix} .251 & .15 & .1 & .073 & .03 & .073 \\ .15 & .201 & .14 & .11 & .041 & .103 \\ .1 & .14 & .157 & .116 & .05 & .105 \\ .073 & .11 & .116 & .16 & .06 & .077 \\ .03 & .041 & .05 & .06 & .087 & .03 \\ .073 & .103 & .105 & .077 & .03 & .16 \end{bmatrix} \end{array}$$

PROB #2)



RADIAL LINE FROM ⓪ to ①

$$Z_{BUS} = \begin{matrix} \\ 1 \end{matrix}\begin{matrix} 1 \\ \left[.10\right] \end{matrix}$$

RADIAL LINE FROM ① to ②

$$Z_{BUS} = \begin{matrix} & 1 & 2 \\ 1 & .1 & .1 \\ 2 & .1 & .283 \end{matrix}$$

RADIAL LINE FROM ② to ③

$$Z_{BUS} = \begin{matrix} & 1 & 2 & 3 \\ 1 & .1 & .1 & .1 \\ 2 & .1 & .283 & .283 \\ 3 & .1 & .283 & .34 \end{matrix}$$

COMPLETE LOOP FROM ③ to ⓪

$$Z_{BUS} \text{ with } \ell = \begin{matrix} & 1 & 2 & 3 & \ell \\ 1 & .1 & .1 & .1 & .1 \\ 2 & .1 & .283 & .283 & .283 \\ 3 & .1 & .283 & .34 & .34 \\ \ell & .1 & .283 & .34 & .42 \end{matrix}$$

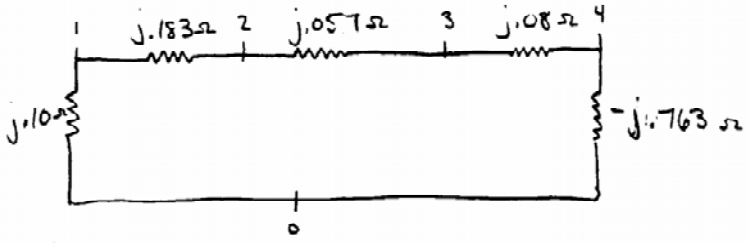
$Z_{\ell\ell} = .336 + .08 = .416$

$$Z_{BUS \text{ without } \ell} = \begin{bmatrix} & & \\ & & \\ & & \end{bmatrix} - \begin{bmatrix} .1 \\ .283 \\ .336 \end{bmatrix}\left[\frac{1}{.42}\right]\begin{bmatrix} .1 & .283 & .336 \end{bmatrix}$$

$$Z_{BUS} = \begin{bmatrix} .1 & .1 & .1 \\ .1 & .283 & .283 \\ .1 & .283 & .336 \end{bmatrix} - \begin{bmatrix} .02 & .068 & .081 \\ .068 & .19 & .23 \\ .081 & .23 & .27 \end{bmatrix}$$

$$\boxed{Z_{BUS} = \begin{bmatrix} .08 & .032 & .019 \\ .032 & .093 & .053 \\ .019 & .053 & .066 \end{bmatrix}}$$

PROBLEM #3)
PROBLEM #4)



RADIAL LINE FROM ⓪ to ①

$$Z_{BUS} = \begin{matrix} \\ 1 \end{matrix}\begin{matrix} \begin{bmatrix} 1 \\ .1 \end{bmatrix} \end{matrix}$$

RADIAL LINE FROM ① to ②

$$Z_{BUS} = \begin{matrix} \\ 1 \\ 2 \end{matrix}\begin{matrix} \begin{bmatrix} 1 & 2 \\ .1 & .1 \\ .1 & .283 \end{bmatrix} \end{matrix}$$

RADIAL LINE FROM ② to ③

$$Z_{BUS} = \begin{matrix} \\ 1 \\ 2 \\ 3 \end{matrix}\begin{matrix} \begin{bmatrix} 1 & 2 & 3 \\ .1 & .1 & .1 \\ .1 & .283 & .283 \\ .1 & .283 & .34 \end{bmatrix} \end{matrix}$$

RADIAL LINE FROM ③ to ④

$$Z_{BUS} = \begin{matrix} \\ 1 \\ 2 \\ 3 \\ 4 \end{matrix}\begin{matrix} \begin{bmatrix} 1 & 2 & 3 & 4 \\ & & .1 & .1 \\ & & .283 & .283 \\ & & .34 & .34 \\ .1 & .283 & .34 & .42 \end{bmatrix} \end{matrix}$$

COMPLETE LOOP FROM ④ to ⓪

$$Z_{BUS} = \begin{matrix} \\ 1 \\ 2 \\ 3 \\ 4 \\ \ell \end{matrix}\begin{matrix} \begin{bmatrix} 1 & 2 & 3 & 4 & \ell \\ & & & .1 & .1 \\ & & & .283 & .283 \\ & & & .34 & .34 \\ & & & .42 & .42 \\ .1 & .283 & .34 & .42 & -.343 \end{bmatrix} \end{matrix}$$

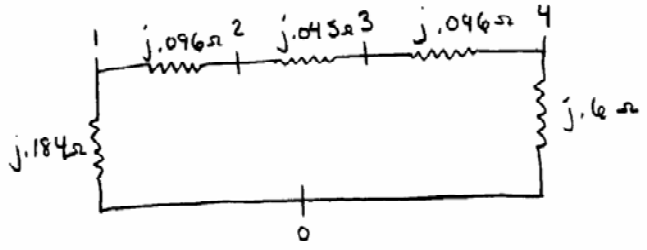
$$Z_{\ell\ell} = Z_{44} + Z_{40} = .42 + -.763$$

$$Z_{BUS\ \text{without}\ \ell} = \begin{bmatrix} & & \\ & & \\ & & \end{bmatrix} - \begin{bmatrix} .1 \\ .283 \\ .34 \\ .42 \end{bmatrix} \left[\frac{1}{-.343}\right] \begin{bmatrix} .1 & .283 & .34 & .42 \end{bmatrix}$$

$$Z_{BUS} = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \end{array} \begin{array}{c} \begin{array}{cccc} 1 & 2 & 3 & 4 \end{array} \\ \begin{bmatrix} .1 & .1 & .1 & .1 \\ .1 & .283 & .283 & .283 \\ .1 & .283 & .34 & .34 \\ .1 & .283 & .34 & .42 \end{bmatrix} \end{array} + \begin{bmatrix} .003 & .008 & .01 & .012 \\ & .023 & .028 & .03 \\ & & .034 & .04 \\ & & & .05 \end{bmatrix}$$

$$Z_{BUS} = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \end{array} \begin{array}{c} \begin{array}{cccc} 1 & 2 & 3 & 4 \end{array} \\ \begin{bmatrix} .103 & .108 & .11 & .1012 \\ .108 & .306 & .311 & .313 \\ .11 & .311 & .374 & .38 \\ .1012 & .313 & .38 & .47 \end{bmatrix} \end{array}$$

PROBLEM #5)



RADIAL LINE FROM ⓪ to ①

$$Z_{BUS} = \begin{matrix} \\ 1 \end{matrix} \begin{matrix} 1 \\ \left[.184 \right] \end{matrix}$$

RADIAL LINE FROM ① to ②

$$Z_{BUS} = \begin{matrix} \\ 1 \\ 2 \end{matrix} \begin{matrix} 1 & 2 \\ \left[\begin{matrix} .184 & .184 \\ .184 & .28 \end{matrix} \right] \end{matrix}$$

RADIAL LINE FROM ② to ③

$$Z_{BUS} = \begin{matrix} \\ 1 \\ 2 \\ 3 \end{matrix} \begin{matrix} 1 & 2 & 3 \\ \left[\begin{matrix} .184 & .184 & .184 \\ .184 & .28 & .28 \\ .184 & .28 & .325 \end{matrix} \right] \end{matrix}$$

RADIAL LINE FROM ③ to ④

$$Z_{BUS} = \begin{matrix} \\ 1 \\ 2 \\ 3 \\ 4 \end{matrix} \begin{matrix} 1 & 2 & 3 & 4 \\ \left[\begin{matrix} & & .184 & .184 \\ & & .28 & .28 \\ & & .325 & .325 \\ .184 & .28 & .325 & .421 \end{matrix} \right] \end{matrix}$$

COMPLETE LOOP FROM ④ to ⓪

$$Z_{BUS} = \begin{matrix} \\ 1 \\ 2 \\ 3 \\ 4 \\ \ell \end{matrix} \begin{matrix} 1 & 2 & 3 & 4 & \ell \\ \left[\begin{matrix} & & & .184 & .184 \\ & & & .28 & .28 \\ & & & .325 & .325 \\ & & & .421 & .421 \\ .184 & .28 & .325 & .421 & 1.021 \end{matrix} \right] \end{matrix}$$

$$Z_{\ell\ell} = Z_{44} + Z_{40} = .421 + .6$$

$$Z_{BUS\ without\ \ell} = \left[\quad \right] - \begin{bmatrix} .184 \\ .28 \\ .325 \\ .421 \end{bmatrix} \left[\frac{1}{1.021} \right] \begin{bmatrix} .184 & .28 & .325 & .421 \end{bmatrix}$$

$$Z_{BUS} = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \end{array} \begin{array}{c} \begin{array}{cccc} 1 & 2 & 3 & 4 \end{array} \\ \begin{bmatrix} .184 & .184 & .184 & .184 \\ . & .28 & .28 & .28 \\ & & .325 & .325 \\ & & & .421 \end{bmatrix} \end{array} - \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \end{array} \begin{array}{c} \begin{array}{cccc} 1 & 2 & 3 & 4 \end{array} \\ \begin{bmatrix} .033 & .05 & .06 & .075 \\ & .076 & .091 & .116 \\ & & .103 & .134 \\ & & & .174 \end{bmatrix} \end{array}$$

$$Z_{BUS} = \begin{array}{c} \\ 1 \\ 2 \\ 3 \\ 4 \end{array} \begin{array}{c} \begin{array}{cccc} 1 & 2 & 3 & 4 \end{array} \\ \begin{bmatrix} .151 & .134 & .124 & .109 \\ .134 & .204 & .189 & .164 \\ .124 & .189 & .222 & .191 \\ .109 & .164 & .191 & .247 \end{bmatrix} \end{array}$$

RADIAL LINE FROM FROM ⑤ to ⑧

Z_{BUS} =

	7	1	2	9	6	5	8
7						.34	.34
1						.59	.59
2						.695	.695
9						.945	.94
6						1.225	1.225
5						1.278	1.278
8	.34	.59	.695	.945	1.225	1.278	1.611

RADIAL LINE FROM ⑦ to ④

Z_{BUS} =

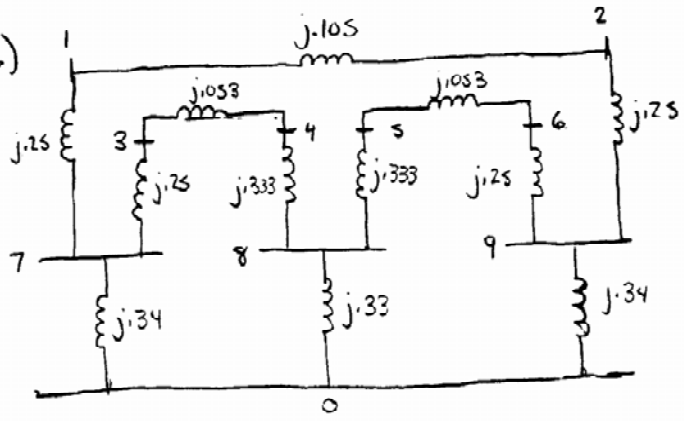
	7	1	2	9	6	5	8	4
7							.34	.34
1							.59	.59
2							.695	.695
9							.94	.94
6							1.225	1.225
5							1.278	1.278
8							1.611	1.611
4	.34	.59	.695	.94	1.225	1.278	1.611	1.944

RADIAL LINE FROM ④ to ③

Z_{BUS} =

	7	1	2	9	6	5	8	4	3
7								.34	.34
1								.59	.59
2								.695	.695
9								.94	.94
6								1.225	1.225
5								1.278	1.278
8								1.611	1.611
4								1.944	1.944
3	.34								1.997

PROBLEM #6)



RADIAL LINE FROM (0) to (7)

$$Z_{BUS} = \begin{matrix} \\ 7 \end{matrix}\begin{matrix} 7 \\ \left[.34 \right] \end{matrix}$$

RADIAL LINE FROM (7) to (1)

$$Z_{BUS} = \begin{matrix} \\ 1 \\ 7 \end{matrix}\begin{matrix} 7 & 1 \\ \left[.34 & .34 \right. \\ \left. .34 & .59 \right] \end{matrix}$$

RADIAL LINE FROM (1) to (2)

$$Z_{BUS} = \begin{matrix} \\ 7 \\ 1 \\ 2 \end{matrix}\begin{matrix} 7 & 1 & 2 \\ \left[.34 & .34 & .34 \right. \\ .34 & .59 & .59 \\ \left. .34 & .59 & .695 \right] \end{matrix}$$

RADIAL LINE FROM (2) to (9)

$$Z_{BUS} = \begin{matrix} \\ 7 \\ 1 \\ 2 \\ 9 \end{matrix}\begin{matrix} 7 & 1 & 2 & 9 \\ \left[.34 & .34 & .34 & .34 \right. \\ .34 & .59 & .59 & .59 \\ .34 & .59 & .695 & .695 \\ \left. .34 & .59 & .695 & .945 \right] \end{matrix}$$

RADIAL LINE FROM (9) to (6)

$$Z_{BUS} = \begin{matrix} \\ 7 \\ 1 \\ 2 \\ 9 \\ 6 \end{matrix}\begin{matrix} 7 & 1 & 2 & 9 & 6 \\ \left[\right. & & & .34 & .34 \\ & & & .59 & .59 \\ & & & .695 & .695 \\ & & & .945 & .945 \\ \left. .34 & .59 & .695 & .945 & 1.225 \right] \end{matrix}$$

RADIAL LINE FROM (6) to (5)

$$Z_{BUS} = \begin{matrix} \\ 7 \\ 1 \\ 2 \\ 9 \\ 6 \\ 5 \end{matrix}\begin{matrix} 7 & 1 & & & 6 & 5 \\ \left[\right. & & & & .34 & .34 \\ & & & & .59 & .59 \\ & & & & .695 & .695 \\ & & & & .945 & .945 \\ & & & & 1.225 & 1.225 \\ \left. .34 \right. & .59 & .695 & .945 & 1.225 & 1.225 \end{matrix}$$

COMPLETE LOOP FROM ③ to ⑦

Z_{BUS} with ℓ =

	7	1	2	9	6	5	8	4	3	ℓ
7	.34								.34	0
1	.34								.59	.25
2	.34								.695	.355
9	.34								.94	.6
6	.34								1.225	.885
5	.34								1.278	.938
8	.34								1.611	1.271
4	.34								1.944	1.604
3	.34								1.997	1.657
ℓ	0	.25	.355	.6	.885	.938	1.271	1.604	1.657	1.907

$Z_{11} = Z_{77} + Z_{33} - 2Z_{37}$

$Z_{11} = .34 + 1.997 - 2(.34) + .25$

$Z_{1\ell} =$

$Z_{BUS\ without\ \ell} =$ [ ] $-$ [0 .25 .355 .6 .885 .938 1.271 1.604 1.657] $\left[\frac{1}{1.907}\right]$ [0 .25 .355 .6 .885 .938...

0	0	0	0	0	0	0	0	0	
	.633	.046	.079	.116	.123	.167	.21	.22	
		.066	.11	.165	.175	.237	.299	.31	
			.189	.278	.295	.399	.504	.52	
				.411	.44	.59	.744	.769	
					.461	.63	.79	.82	
						.847	1.07	1.1	
							1.35	1.39	
								1.44	