ECE 523

SYMMETRICAL COMPONENTS

SESSION no. 30

4 Consider the line configuration shown in Figure 2. Instead of using a single conductor of 336,400 CM ACSR in each phase, with current carrying capacity of 530 amperes, suppose that each phase consists of a two-conductor bundle of two 3/0 ACSR conductors with capacity of 300 amperes/conductor. Let the two conductors of each bundle be seperated by 1.0ft vertically.

(a) Compute the phase impedance matrix Zabc for the bundled conductor configuration and compare with the previous solution (problem 2). • 6x6 matrix

→ reduce to 3x3

$\text{Rac3} := 0.560 \dfrac{\text{ohm}}{\text{mi}}$ from table B.8 at 25C and 60Hz

$\text{GMR3} := 0.006\text{ft}$ diameter3 := 0.502in

(b) Calculate geometric mean radius of the bundle and use the 3x3 matrix method. The is an approximation of the 6x6 matrix approach. Compare the results to part (a). • Geometric mean distance

(c) Compute the sequence impedance matrix for part (a) and compare to problem 2.

5. Consider an untransposed line described in problem 2. Let the ground wire be 1/0 ACSR and recalculate the phase impedance matrix Zabc, the sequence impedance matrix Z012, and the unbalance factors. Compare with previous results from problem 2 for the same line without the grou wire.

RAC, GMR of GW

6. Repeat problem 5 with the transposition of problem 3, part (d).

→ Do the transpositions before matrix reduction to 3x3 equiv.

First transposed case:

$$Y0121 := Z0121^{-1}$$

$$Y0121 = \begin{pmatrix} 1.76473 - 8.66714i & -0.05715 - 0.05228i & 0.07389 + 0.02557i \\ 0.07389 + 0.02557i & 9.6082 - 27.77506i & 0.33557 + 0.38762i \\ -0.05715 - 0.05228i & -0.45617 - 0.2345i & 9.6082 - 27.77506i \end{pmatrix} \text{mS}$$

Second transposed case:

$$Y0123 := Z0123^{-1}$$

$$Y0123 = \begin{pmatrix} 1.76552 - 8.66803i & 0.02348 + 0.14835i & -0.14356 + 0.0535i \\ -0.14356 + 0.0535i & 9.63221 - 27.79083i & -0.04638 - 1.02282i \\ 0.02348 + 0.14835i & 1.00575 - 0.19655i & 9.63221 - 27.79083i \end{pmatrix} \text{mS}$$

Fully Transposed Case

$$Y0126 := Z0126^{-1}$$

$$Y0126 = \begin{pmatrix} 1.7645 - 8.6668i & 0 & 0 \\ 0 & 9.6002 - 27.7698i & 0 \\ 0 & 0 & 9.6002 - 27.7698i \end{pmatrix} \text{mS}$$

$$\begin{bmatrix} I_0 \\ I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} y_{00} & y_{01} & y_{02} \\ y_{10} & y_{11} & y_{12} \\ y_{20} & y_{21} & y_{22} \end{bmatrix} \begin{bmatrix} 0 \\ V_1 \\ 0 \end{bmatrix}$$

$$m_0 = \frac{I_0}{I_1} = \frac{V_1 \cdot y_{01}}{V_1\, y_{11}} = \frac{y_{01}}{y_{11}}$$

$$m_2 = \frac{I_2}{I_1} = \frac{y_{21}}{y_{11}}$$

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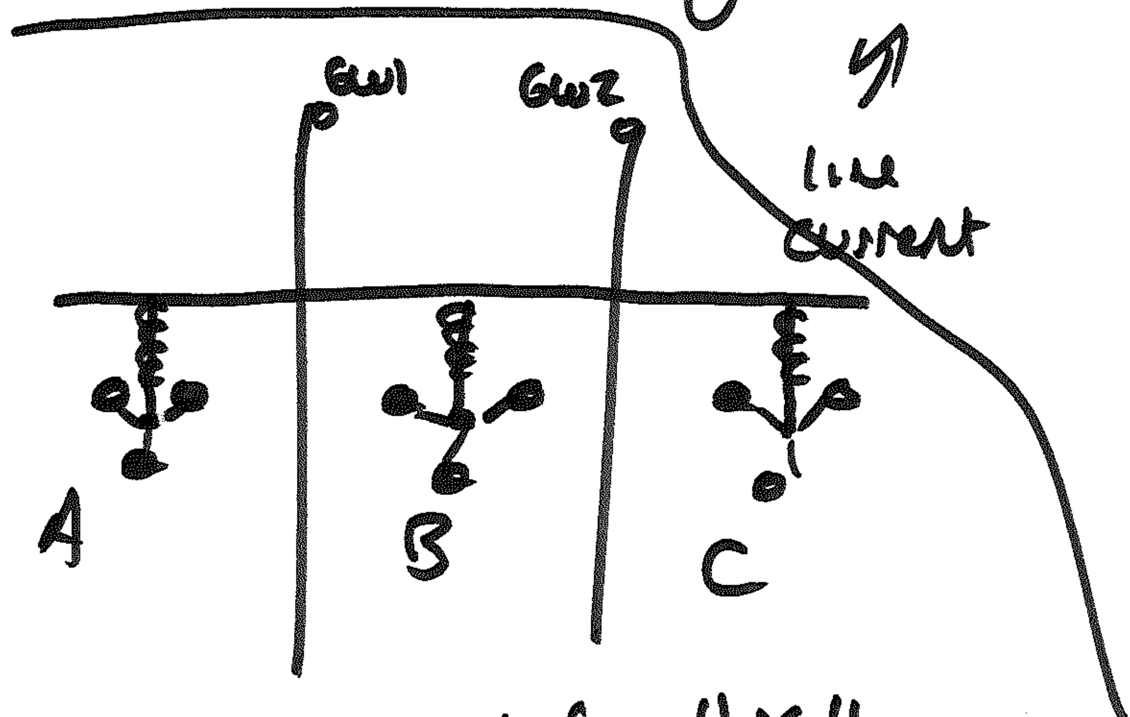
Bundled Conductors and/or Static Wires

→ we're interested in relating I_{ABC} to V_{ABC}

I_{ABC} ↑ line current

V_{ABC} ↑ voltage drop across the line



Z_{ABC} will be 11×11

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- reduce this larger matrix to a smaller, equivalent 3X3 matrix
  - then find Z_{012} of the smaller matrix
  - Transpotion should be applied to the unreduced matrix <u>then</u> the reduction is applied
    → GW's are not transposed with phases

$$V_1 = A I_1 + B I_2$$

$$V_2 = C I_1 + D I_2$$

Let $V_2 = 0$ $\quad -D I_2 = C I_1 \Rightarrow I_2 = -\frac{C}{D} I_1$

$$V_1 = \left(A - \frac{B \cdot C}{D}\right) I_1$$

Kron Reduction

Matrix Equation → No bundles, just 1 GW

$$\begin{bmatrix} V_A \\ V_B \\ V_C \\ \hline V_{GW} \end{bmatrix} = \left[\begin{array}{ccc|c} Z_{AA} & Z_{AB} & Z_{AC} & Z_{AGW} \\ Z_{BA} & Z_{BB} & Z_{BC} & Z_{BGW} \\ Z_{CA} & Z_{CB} & Z_{CC} & Z_{CGW} \\ \hline Z_{GWA} & Z_{GWB} & Z_{GWC} & Z_{GWGW} \end{array}\right] \begin{bmatrix} I_A \\ I_B \\ I_C \\ \hline I_{GW} \end{bmatrix}$$

Z_1 Z_2 Z_3 Z_4

partition matrix into submatrices

$Z_2 = Z_3^T$

$$\begin{bmatrix} \underline{V}_{ABC} \\ \hdashline \underline{V}_{GW} \end{bmatrix} = \begin{bmatrix} Z_1 & Z_2 \\ Z_3 & Z_4 \end{bmatrix} \begin{bmatrix} \underline{I}_{ABC} \\ \hdashline \underline{I}_{GW} \end{bmatrix}$$

$\underline{V}_{GW} \rightarrow 0$

$$\underline{V}_{ABC} = Z_1 \underline{I}_{ABC} + Z_2 \underline{I}_{GW}$$

$$\underline{0} = Z_3 \underline{I}_{ABC} + Z_4 I_{GW}$$

$$-Z_4 \underline{I}_{GW} = Z_3 \underline{I}_{ABC}$$

$$(-Z_4)^{-1}(-Z_4) I_{GW} = -Z_4^{-1} Z_3 I_{ABC}$$

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$$\underline{I}_{GW} = -Z_4^{-1} Z_3 I_{ABC}$$

substitute & collect terms

$$\underline{V}_{ABC} = Z_1 \underline{I}_{ABC} + Z_2 \left(-Z_4^{-1}\right) Z_3 \underline{I}_{ABC}$$

$$= \underbrace{\left(Z_1 - Z_2 Z_4^{-1} Z_3\right)}_{Z_{ABC_{eq}} \;\to 3\times 3} \underline{I}_{ABC}$$