

EE504 Boise Bench Cloverdale Section #712-02 Double Circuit

Define transformation

$$a := 1 \cdot e^{j \cdot \frac{2 \cdot \pi}{3}}$$

$$A1 := \begin{pmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{pmatrix}$$

Define Constants:

$$\rho := 100 \text{ohm} \cdot \text{m} \quad \text{freq} := 60 \text{Hz}$$

$$\mu_0 := 4 \cdot \pi \cdot 10^{-7} \frac{\text{H}}{\text{m}} \quad I_{\text{cons}} := \frac{\mu_0}{2 \cdot \pi}$$

$$\text{CarsonsResistConst} := 9.869 \times 10^{-7} \frac{\text{ohm}}{\text{m} \cdot \text{Hz}} \quad \text{De_const} := 2160 \cdot \frac{\text{ft} \cdot \text{Hz}^{0.5}}{(\text{ohm} \cdot \text{m})^{0.5}}$$

Compute the series impedance matrix for the line configuration of Tower V-30 where the conductor is 1272 MCM, 45/7 Strand ACSR (Bittern). Assume line is 3.2 miles long

Define heights relative to the earth

$$\text{Hgw} := (0.0) \cdot \text{ft}$$

$$\text{Ha1} := 55 \text{ft} \quad \text{Ha1} = 55 \text{ft} \quad \text{Ha2} := 55 \text{ft} \quad \text{Ha2} = 55 \text{ft}$$

$$\text{Hb1} := \text{Ha1} - 12.5 \text{ft} \quad \text{Hb1} = 42.5 \text{ft} \quad \text{Hb2} := \text{Ha1} - 12.5 \text{ft} \quad \text{Hb2} = 42.5 \text{ft}$$

$$\text{Hc1} := \text{Hb1} - 12.5 \text{ft} \quad \text{Hc1} = 30 \text{ft} \quad \text{Hc2} := \text{Hb2} - 12.5 \text{ft} \quad \text{Hc2} = 30 \text{ft}$$

Define horizontal position relative to center of the tower (some are negative).

$$\begin{aligned} X_{a1} &:= 8\text{ft} & X_{b1} &:= 8\text{ft} & X_{c1} &:= 8\text{ft} \\ X_{a2} &:= -8\text{ft} & X_{b2} &:= -8\text{ft} & X_{c2} &:= -8\text{ft} \end{aligned}$$

Now calculate distance between conductors (be careful of negative signs)

$$\begin{aligned} D_{ab11} &:= \sqrt{(H_{a1} - H_{b1})^2 + (X_{b1} - X_{a1})^2} & D_{ab22} &:= \sqrt{(H_{a2} - H_{b2})^2 + (X_{b2} - X_{a2})^2} \\ D_{ac11} &:= \sqrt{(H_{a1} - H_{c1})^2 + (X_{c1} - X_{a1})^2} & D_{ac22} &:= \sqrt{(H_{a2} - H_{c2})^2 + (X_{c2} - X_{a2})^2} \\ D_{bc11} &:= \sqrt{(H_{b1} - H_{c1})^2 + (X_{b1} - X_{c1})^2} & D_{bc22} &:= \sqrt{(H_{b2} - H_{c2})^2 + (X_{b2} - X_{c2})^2} \\ D_{ab12} &:= \sqrt{(H_{a1} - H_{b2})^2 + (X_{b1} - X_{a2})^2} & D_{aa12} &:= \sqrt{(H_{a1} - H_{a2})^2 + (X_{a1} - X_{a2})^2} \\ D_{ac12} &:= \sqrt{(H_{a1} - H_{c2})^2 + (X_{c1} - X_{a2})^2} & D_{bb12} &:= \sqrt{(H_{b1} - H_{b2})^2 + (X_{b1} - X_{b2})^2} \\ D_{bc12} &:= \sqrt{(H_{b1} - H_{c2})^2 + (X_{b1} - X_{c2})^2} & D_{cc12} &:= \sqrt{(H_{c1} - H_{c2})^2 + (X_{c1} - X_{c2})^2} \end{aligned}$$

GMR, diameter, and R_{ac} from table for Bittern

$$\text{GMR} := 0.0445\text{ft} \quad \text{diameter} := 1.345\text{in}$$

$$\text{Rac} := 0.0759 \frac{\text{ohm}}{\text{mi}} \quad \text{at } 25\text{C and } 60\text{Hz}$$

$$R_d := \text{CarsonsResistConst} \cdot \text{freq}$$

$$R_{\text{perlength}} := \begin{pmatrix} R_{ac} + R_d & R_d & R_d & R_d & R_d & R_d \\ R_d & R_{ac} + R_d & R_d & R_d & R_d & R_d \\ R_d & R_d & R_{ac} + R_d & R_d & R_d & R_d \\ R_d & R_d & R_d & R_{ac} + R_d & R_d & R_d \\ R_d & R_d & R_d & R_d & R_{ac} + R_d & R_d \\ R_d & R_d & R_d & R_d & R_d & R_{ac} + R_d \end{pmatrix}$$

$$De := De_const \cdot \sqrt{\frac{\rho}{freq}} \quad De = 2788.55 \text{ ft}$$

$$L_{perlength} := \begin{pmatrix} \text{Icons} \cdot \ln\left(\frac{De}{GMR}\right) & \text{Icons} \cdot \ln\left(\frac{De}{Dab11}\right) & \text{Icons} \cdot \ln\left(\frac{De}{Dac11}\right) & \text{Icons} \cdot \ln\left(\frac{De}{Daa12}\right) & \text{Icons} \cdot \ln\left(\frac{De}{Dab12}\right) & \text{Icons} \cdot \ln\left(\frac{De}{Dac12}\right) \\ \text{Icons} \cdot \ln\left(\frac{De}{Dab11}\right) & \text{Icons} \cdot \ln\left(\frac{De}{GMR}\right) & \text{Icons} \cdot \ln\left(\frac{De}{Dbc11}\right) & \text{Icons} \cdot \ln\left(\frac{De}{Dab12}\right) & \text{Icons} \cdot \ln\left(\frac{De}{Dbb12}\right) & \text{Icons} \cdot \ln\left(\frac{De}{Dbc12}\right) \\ \text{Icons} \cdot \ln\left(\frac{De}{Dac11}\right) & \text{Icons} \cdot \ln\left(\frac{De}{Dbc11}\right) & \text{Icons} \cdot \ln\left(\frac{De}{GMR}\right) & \text{Icons} \cdot \ln\left(\frac{De}{Dac12}\right) & \text{Icons} \cdot \ln\left(\frac{De}{Dbc12}\right) & \text{Icons} \cdot \ln\left(\frac{De}{Dcc12}\right) \\ \text{Icons} \cdot \ln\left(\frac{De}{Daa12}\right) & \text{Icons} \cdot \ln\left(\frac{De}{Dab12}\right) & \text{Icons} \cdot \ln\left(\frac{De}{Dac12}\right) & \text{Icons} \cdot \ln\left(\frac{De}{GMR}\right) & \text{Icons} \cdot \ln\left(\frac{De}{Dab22}\right) & \text{Icons} \cdot \ln\left(\frac{De}{Dac22}\right) \\ \text{Icons} \cdot \ln\left(\frac{De}{Dab12}\right) & \text{Icons} \cdot \ln\left(\frac{De}{Dbb12}\right) & \text{Icons} \cdot \ln\left(\frac{De}{Dbc12}\right) & \text{Icons} \cdot \ln\left(\frac{De}{Dab22}\right) & \text{Icons} \cdot \ln\left(\frac{De}{GMR}\right) & \text{Icons} \cdot \ln\left(\frac{De}{Dbc22}\right) \\ \text{Icons} \cdot \ln\left(\frac{De}{Dac12}\right) & \text{Icons} \cdot \ln\left(\frac{De}{Dbc12}\right) & \text{Icons} \cdot \ln\left(\frac{De}{Dcc12}\right) & \text{Icons} \cdot \ln\left(\frac{De}{Dac12}\right) & \text{Icons} \cdot \ln\left(\frac{De}{Dbc22}\right) & \text{Icons} \cdot \ln\left(\frac{De}{GMR}\right) \end{pmatrix}$$

$$L_{perlength} = \begin{pmatrix} 3.555 & 1.741 & 1.517 & 1.661 & 1.584 & 1.462 \\ 1.741 & 3.555 & 1.741 & 1.584 & 1.661 & 1.584 \\ 1.517 & 1.741 & 3.555 & 1.462 & 1.584 & 1.661 \\ 1.661 & 1.584 & 1.462 & 3.555 & 1.741 & 1.517 \\ 1.584 & 1.661 & 1.584 & 1.741 & 3.555 & 1.741 \\ 1.462 & 1.584 & 1.661 & 1.462 & 1.741 & 3.555 \end{pmatrix} \begin{matrix} \text{mH} \\ \text{mi} \end{matrix} \quad \text{Length} := 3.2\text{mi}$$

$$Z_{abc_perlength} := R_{perlength} + j \cdot 2 \cdot \pi \cdot freq \cdot L_{perlength} \quad Z_{abc} := Z_{abc_perlength} \cdot \text{Length}$$

$$Z_{abc} = \begin{pmatrix} 0.548 + 4.289i & 0.305 + 2.1i & 0.305 + 1.831i & 0.305 + 2.004i & 0.305 + 1.911i & 0.305 + 1.764i \\ 0.305 + 2.1i & 0.548 + 4.289i & 0.305 + 2.1i & 0.305 + 1.911i & 0.305 + 2.004i & 0.305 + 1.911i \\ 0.305 + 1.831i & 0.305 + 2.1i & 0.548 + 4.289i & 0.305 + 1.764i & 0.305 + 1.911i & 0.305 + 2.004i \\ 0.305 + 2.004i & 0.305 + 1.911i & 0.305 + 1.764i & 0.548 + 4.289i & 0.305 + 2.1i & 0.305 + 1.831i \\ 0.305 + 1.911i & 0.305 + 2.004i & 0.305 + 1.911i & 0.305 + 2.1i & 0.548 + 4.289i & 0.305 + 2.1i \\ 0.305 + 1.764i & 0.305 + 1.911i & 0.305 + 2.004i & 0.305 + 1.764i & 0.305 + 2.1i & 0.548 + 4.289i \end{pmatrix} \Omega$$

$$Z_m := \frac{(Z_{abc0,1} + Z_{abc0,2} + Z_{abc0,3} + Z_{abc0,4} + Z_{abc0,5} + Z_{abc1,2} + Z_{abc1,3} + Z_{abc1,4} + Z_{abc1,5} + Z_{abc2,3} + Z_{abc2,4} + Z_{abc2,5} + Z_{abc3,4} + Z_{abc3,5} + Z_{abc4,5})}{15}$$

$$Z_m = 0.305 + 1.95i \Omega$$

$$Z_s := \frac{(Z_{abc0,0} + Z_{abc1,1} + Z_{abc2,2} + Z_{abc3,3} + Z_{abc4,4} + Z_{abc5,5})}{6}$$

$$Z_s = 0.548 + 4.289i \Omega$$

$$Z_0 := Z_s + 2 \cdot Z_m \quad Z_0 = 1.158 + 8.188i \Omega$$

$$Z_1 := Z_s - Z_m \quad Z_1 = 0.243 + 2.339i \Omega$$

3, 4 + Zabc3, 5 + Zabc4, 5)