D-Line Models Master

From paper: Radial Distribution Test Feeders, Distribution System Analysis Subcommittee Report by IEEE from http://ewh.ieee.org/soc/pes/dsacom/testfeeders.html

Line configurations:

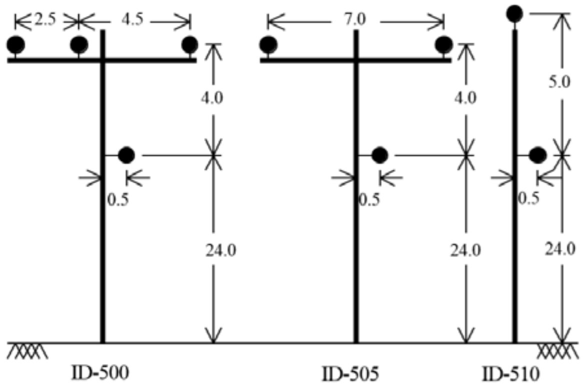

Figure 1 – Overhead Line Spacings

$$OHL\_cond := \begin{pmatrix} \text{"SIZE"} & \text{"TYPE"} & \text{"ohms/mile"} & \text{"O.D. in"} & \text{"GMR ft"} & \text{"AMPS @50dC"} \\ 1000 & \text{"AA"} & 0.105 & 1.15 & 0.0368 & 698 \\ 556.5 & \text{"ACSR"} & .1859 & 0.927 & .0313 & 730 \\ 500 & \text{"AA"} & 0.206 & 0.813 & 0.026 & 483 \\ 336.4 & \text{"ACSR"} & 0.306 & 0.721 & 0.0244 & 530 \\ 250 & \text{"AA"} & 0.410 & 0.567 & 0.0171 & 329 \\ 0000 & \text{"ACSR"} & 0.592 & 0.563 & 0.00814 & 340 \\ 00 & \text{"AA"} & 0.769 & 0.414 & 0.0125 & 230 \\ 0 & \text{"ACSR"} & 1.12 & 0.398 & 0.00446 & 230 \\ 0 & \text{"AA"} & 0.970 & 0.368 & 0.0111 & 310 \\ 2 & \text{"AA"} & 1.54 & 0.292 & 0.00883 & 156 \\ 2 & \text{"ACSR"} & 1.69 & 0.316 & 0.0418 & 180 \\ 4 & \text{"ACSR"} & 2.55 & 0.257 & 0.00452 & 140 \\ 10 & \text{"CU"} & 5.903 & 0.102 & 0.00331 & 80 \\ 12 & \text{"CU"} & 9.375 & 0.081 & 0.00262 & 75 \\ 14 & \text{"CU"} & 14.872 & 0.064 & 0.00208 & 20 \end{pmatrix}$$

Base Setting

$S_{base} := 10\text{MVA}$ $\qquad$ $U_{base} := 4.16\text{kV}$

$$I_{base} := \frac{S_{base}}{\sqrt{3}\cdot U_{base}} = 1.3879\cdot\text{kA} \qquad Z_{base} := \frac{\left(\frac{U_{base}}{\sqrt{3}}\right)^2}{\frac{S_{base}}{3}} = 1.7306\,\Omega \qquad Z_{base} := \frac{U_{base}^{\;2}}{S_{base}} = 1.7306\,\Omega \qquad Y_{base} := Z_{base}^{\;-1} = 0.5778\cdot\text{S}$$

Distribution Line Data Calculations for Spacing ID=500 with Line Conductors ID=601:

$cp_1 := (0.0 + j\cdot 28)\text{ft}$ $\qquad$ $cp_2 := (2.5 + j\cdot 28)\text{ft}$ $\qquad$ $cp_3 := (7.0 + j\cdot 28)\text{ft}$ $\qquad$ $cn_1 := (4.0 + j\cdot 24)\text{ft}$

$D_{12} := |cp_1 - cp_2| = 2.5\cdot\text{ft}$ $\qquad$ $D_{23} := |cp_2 - cp_3| = 4.5\cdot\text{ft}$ $\qquad$ $D_{31} := |cp_3 - cp_1| = 7\cdot\text{ft}$

$D_{1n} := \left|cp_1 - cn_1\right| = 5.6569 \cdot ft$ $D_{2n} := \left|cp_2 - cn_1\right| = 4.272 \cdot ft$ $D_{3n} := \left|cp_3 - cn_1\right| = 5 \cdot ft$

$D_{11} := 0.0313ft$ $D_{22} := D_{11}$ $D_{33} := D_{11}$ $D_{nn} := 0.00814ft$

$r_{ph} := 0.1859 \frac{\Omega}{mile}$ $r_{np} := 0.5920 \frac{\Omega}{mile}$

Order of the conductor placemtn is 123n. Rotation to proper phase spacing is performed latter.

$$z_{ii}(f_n, \rho, r_i, GMR_i) := \left[r_i + 0.00158836 \cdot f_n + j \cdot 0.00202237 \cdot f_n \cdot \left(\ln\left(\frac{1}{GMR_i}\right) + 7.6786 + \frac{1}{2}\ln\left(\frac{\rho}{f_n}\right)\right)\right] \cdot \frac{\Omega}{mile}$$

For soil resitivity of $\rho := 100\Omega \cdot m$ and system frequency of $f_n := 60Hz$

$$z_{aa} := z_{ii}\left(f_n \cdot \frac{1}{Hz}, \rho \cdot \frac{1}{\Omega \cdot m}, r_{ph} \cdot \frac{mile}{\Omega}, D_{11} \cdot \frac{1}{ft}\right) = (0.2812 + 1.3831i) \cdot \frac{\Omega}{mile}$$

$$z_{bb} := z_{aa} = (0.2812 + 1.3831i) \cdot \frac{\Omega}{mile}$$

$$z_{cc} := z_{aa} = (0.2812 + 1.3831i) \cdot \frac{\Omega}{mile}$$

$$z_{nn} := z_{ii}\left(f_n \cdot \frac{1}{Hz}, \rho \cdot \frac{1}{\Omega \cdot m}, r_{np} \cdot \frac{mile}{\Omega}, D_{nn} \cdot \frac{1}{ft}\right) = (0.6873 + 1.5465i) \cdot \frac{\Omega}{mile}$$

$$z_{ij}(f_n, \rho, D_{ij}) := \left[0.00158836 \cdot f_n + j \cdot 0.00202237 \cdot f_n \cdot \left(\ln\left(\frac{1}{D_{ij}}\right) + 7.6786 + \frac{1}{2}\ln\left(\frac{\rho}{f_n}\right)\right)\right] \cdot \frac{\Omega}{mile}$$

For soil resitivity of $\rho := 100\Omega \cdot m$, system frequency of $f_n := 60Hz$ and distances between conductors calcualted above:

$z_{ab} := z_{ij}\left(f_n \cdot \frac{1}{Hz}, \rho \cdot \frac{1}{\Omega \cdot m}, D_{12} \cdot \frac{1}{ft}\right) = (0.0953 + 0.8515i) \cdot \frac{\Omega}{mile}$ $z_{ba} := z_{ab}$

$z_{ac} := z_{ij}\left(f_n \cdot \frac{1}{Hz}, \rho \cdot \frac{1}{\Omega \cdot m}, D_{31} \cdot \frac{1}{ft}\right) = (0.0953 + 0.7266i) \cdot \frac{\Omega}{mile}$ $z_{ca} := z_{ac}$

$z_{an} := z_{ij}\left(f_n \cdot \frac{1}{Hz}, \rho \cdot \frac{1}{\Omega \cdot m}, D_{1n} \cdot \frac{1}{ft}\right) = (0.0953 + 0.7525i) \cdot \frac{\Omega}{mile}$ $z_{na} := z_{an}$

$z_{bc} := z_{ij}\left(f_n \cdot \frac{1}{Hz}, \rho \cdot \frac{1}{\Omega \cdot m}, D_{23} \cdot \frac{1}{ft}\right) = (0.0953 + 0.7802i) \cdot \frac{\Omega}{mile}$ $z_{cb} := z_{bc}$

$z_{bn} := z_{ij}\left(f_n \cdot \frac{1}{Hz}, \rho \cdot \frac{1}{\Omega \cdot m}, D_{2n} \cdot \frac{1}{ft}\right) = (0.0953 + 0.7865i) \cdot \frac{\Omega}{mile}$ $z_{nb} := z_{bn}$

$z_{cn} := z_{ij}\left(f_n \cdot \frac{1}{Hz}, \rho \cdot \frac{1}{\Omega \cdot m}, D_{3n} \cdot \frac{1}{ft}\right) = (0.0953 + 0.7674i) \cdot \frac{\Omega}{mile}$ $z_{nc} := z_{cn}$

The matrix describing distribution line is a "primitive" 4 x 4 type with elements as follows:

$$z := \begin{pmatrix} z_{aa} & z_{ab} & z_{ac} & z_{an} \\ z_{ba} & z_{bb} & z_{bc} & z_{bn} \\ z_{ca} & z_{cb} & z_{cc} & z_{cn} \\ z_{na} & z_{nb} & z_{nc} & z_{nn} \end{pmatrix} = \begin{pmatrix} 0.2812+1.3831i & 0.0953+0.8515i & 0.0953+0.7266i & 0.0953+0.7525i \\ 0.0953+0.8515i & 0.2812+1.3831i & 0.0953+0.7802i & 0.0953+0.7865i \\ 0.0953+0.7266i & 0.0953+0.7802i & 0.2812+1.3831i & 0.0953+0.7674i \\ 0.0953+0.7525i & 0.0953+0.7865i & 0.0953+0.7674i & 0.6873+1.5465i \end{pmatrix} \cdot \frac{\Omega}{\text{mile}}$$

not rotated

Rotation & twist

$$z := \begin{pmatrix} z_{bb} & z_{ba} & z_{bc} & z_{bn} \\ z_{ab} & z_{aa} & z_{ac} & z_{an} \\ z_{cb} & z_{ca} & z_{cc} & z_{cn} \\ z_{nb} & z_{na} & z_{nc} & z_{nn} \end{pmatrix} = \begin{pmatrix} 0.2812+1.3831i & 0.0953+0.8515i & 0.0953+0.7802i & 0.0953+0.7865i \\ 0.0953+0.8515i & 0.2812+1.3831i & 0.0953+0.7266i & 0.0953+0.7525i \\ 0.0953+0.7802i & 0.0953+0.7266i & 0.2812+1.3831i & 0.0953+0.7674i \\ 0.0953+0.7865i & 0.0953+0.7525i & 0.0953+0.7674i & 0.6873+1.5465i \end{pmatrix} \cdot \frac{\Omega}{\text{mile}}$$

rotated

Rotation & twist

Using Kron's reduction to 3-phase, phase quantities $z_{abc} = z_{ij} - z_{in} \cdot z_{nn}^{-1} \cdot z_{nj}$

$$z_{ij} := \text{submatrix}(z,0,2,0,2) = \begin{pmatrix} 0.2812+1.3831i & 0.0953+0.8515i & 0.0953+0.7802i \\ 0.0953+0.8515i & 0.2812+1.3831i & 0.0953+0.7266i \\ 0.0953+0.7802i & 0.0953+0.7266i & 0.2812+1.3831i \end{pmatrix} \cdot \frac{\Omega}{\text{mile}}$$

$$z_{in} := \text{submatrix}(z,0,2,3,3) = \begin{pmatrix} 0.0953+0.7865i \\ 0.0953+0.7525i \\ 0.0953+0.7674i \end{pmatrix} \cdot \frac{\Omega}{\text{mile}}$$

$$z_{nn} := \text{submatrix}(z,3,3,3,3) = (0.6873+1.5465i) \cdot \frac{\Omega}{\text{mile}}$$

$$z_{nj} := \text{submatrix}(z,3,3,0,2) = (0.0953+0.7865i \quad 0.0953+0.7525i \quad 0.0953+0.7674i) \cdot \frac{\Omega}{\text{mile}}$$

$$z_{ser\_abc} := z_{ij} - z_{in} \cdot z_{nn}^{-1} \cdot z_{nj} = \begin{pmatrix} 0.3465+1.018i & 0.156+0.5017i & 0.158+0.4237i \\ 0.156+0.5017i & 0.3375+1.0478i & 0.1535+0.3849i \\ 0.158+0.4237i & 0.1535+0.3849i & 0.3414+1.0349i \end{pmatrix} \cdot \frac{\Omega}{\text{mile}}$$

$$y_{ser\_abc} := z_{ser\_abc}^{-1} = \begin{pmatrix} 0.4338-1.2501i & -0.184+0.4621i & -0.1008+0.3456i \\ -0.184+0.4621i & 0.3798-1.1846i & -0.0478+0.2639i \\ -0.1008+0.3456i & -0.0478+0.2639i & 0.3358-1.1177i \end{pmatrix} \cdot \text{S} \cdot \text{mile}$$

$LF := 1000ft$

$baseMVA := \frac{10}{3} MVA = 3.3333 \cdot MVA$

$basekV := \frac{4.16}{\sqrt{3}} = 2.4018$

$baseZkv := \frac{(1000V)^2}{baseMVA} = 0.3\,\Omega$

$baseZ_{4.16kv} := baseZkv \cdot basekV^2 = 1.7306\,\Omega$

$baseY_{4.16kv} := \frac{1}{baseZkv} \cdot \frac{1}{basekV^2} = 0.5778 \cdot S$

$$Z_{601} := z_{ser\_abc} \cdot LF = \begin{pmatrix} 0.0656 + 0.1928i & 0.0295 + 0.095i & 0.0299 + 0.0802i \\ 0.0295 + 0.095i & 0.0639 + 0.1985i & 0.0291 + 0.0729i \\ 0.0299 + 0.0802i & 0.0291 + 0.0729i & 0.0647 + 0.196i \end{pmatrix} \Omega$$

$$Y_{601} := Z_{601}^{-1} = \begin{pmatrix} 2.2902 - 6.6005i & -0.9717 + 2.4398i & -0.5321 + 1.8246i \\ -0.9717 + 2.4398i & 2.0051 - 6.2549i & -0.2526 + 1.3935i \\ -0.5321 + 1.8246i & -0.2526 + 1.3935i & 1.7732 - 5.9013i \end{pmatrix} \frac{1}{\Omega}$$

$$Y_{601\_1} := \frac{y_{ser\_abc}}{LF} = \begin{pmatrix} 2.2902 - 6.6005i & -0.9717 + 2.4398i & -0.5321 + 1.8246i \\ -0.9717 + 2.4398i & 2.0051 - 6.2549i & -0.2526 + 1.3935i \\ -0.5321 + 1.8246i & -0.2526 + 1.3935i & 1.7732 - 5.9013i \end{pmatrix} \frac{1}{\Omega}$$

$$Z_{601.pu} := \frac{Z_{601}}{baseZ_{4.16kv}} = \begin{pmatrix} 0.0379 + 0.1114i & 0.0171 + 0.0549i & 0.0173 + 0.0464i \\ 0.0171 + 0.0549i & 0.0369 + 0.1147i & 0.0168 + 0.0421i \\ 0.0173 + 0.0464i & 0.0168 + 0.0421i & 0.0374 + 0.1133i \end{pmatrix}$$

$$Y_{601.pu} := \frac{Y_{601}}{baseY_{4.16kv}} = \begin{pmatrix} 3.9634 - 11.4225i & -1.6816 + 4.2223i & -0.9208 + 3.1576i \\ -1.6816 + 4.2223i & 3.47 - 10.8245i & -0.4371 + 2.4116i \\ -0.9208 + 3.1576i & -0.4371 + 2.4116i & 3.0686 - 10.2125i \end{pmatrix}$$

Symmetrical Components

$l_{line\_12} := 2000ft$ Distance of D-line between points "1" and "2"

$$Z_{abc\_12} := l_{line\_12} z_{ser\_abc} = \begin{pmatrix} 0.1313 + 0.3856i & 0.0591 + 0.19i & 0.0599 + 0.1605i \\ 0.0591 + 0.19i & 0.1278 + 0.3969i & 0.0581 + 0.1458i \\ 0.0599 + 0.1605i & 0.0581 + 0.1458i & 0.1293 + 0.392i \end{pmatrix} \Omega$$

$$Y_{line\_12\_pu} := \frac{Z_{abc\_12}}{Z_{base}} = \begin{pmatrix} 0.0758 + 0.2228i & 0.0341 + 0.1098i & 0.0346 + 0.0927i \\ 0.0341 + 0.1098i & 0.0739 + 0.2294i & 0.0336 + 0.0843i \\ 0.0346 + 0.0927i & 0.0336 + 0.0843i & 0.0747 + 0.2265i \end{pmatrix} \cdot pu$$

Transformation to symetrical components can be achieved by applying

$$A_s := \begin{pmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{pmatrix} = \begin{pmatrix} 1 & 1 & 1 \\ 1 & -0.5 - 0.866i & -0.5 + 0.866i \\ 1 & -0.5 + 0.866i & -0.5 - 0.866i \end{pmatrix}$$

or

$$A_s^{-1} = \frac{1}{3}\cdot\begin{pmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{pmatrix} \qquad A_s^{-1} = \begin{pmatrix} 0.3333 & 0.3333 & 0.3333 \\ 0.3333 & -0.1667+0.2887i & -0.1667-0.2887i \\ 0.3333 & -0.1667-0.2887i & -0.1667+0.2887i \end{pmatrix}$$

$$z_{012} := A_s^{-1}\cdot z_{ser\_abc}\cdot A_s = \begin{pmatrix} 0.6534+1.9071i & 0.0298+0.0198i & -0.0227+0.0164i \\ -0.0227+0.0164i & 0.186+0.5968i & -0.0413-0.0597i \\ 0.0298+0.0198i & 0.0413-0.0596i & 0.186+0.5968i \end{pmatrix}\cdot\frac{\Omega}{mile}$$

$$Z_{L\_4W\_pos} := z_{012_{1,1}} = (0.186+0.5968i)\cdot\frac{\Omega}{mile}$$

$$Z_{L\_4W\_zero} := z_{012_{0,0}} = (0.6534+1.9071i)\cdot\frac{\Omega}{mile}$$

Unbalanced or untransposed symmetrical components impedance matrix for D-Line is

$$z_{012\_34} := A_s^{-1}\cdot Z_{abc\_12}\cdot A_s = \begin{pmatrix} 0.2475+0.7224i & 0.0113+0.0075i & -0.0086+0.0062i \\ -0.0086+0.0062i & 0.0704+0.2261i & -0.0156-0.0226i \\ 0.0113+0.0075i & 0.0157-0.0226i & 0.0704+0.2261i \end{pmatrix}\Omega$$

Symmetrical Components

Susceptance calculations:

Susceptance Calculations

Distances between conductors and images are in below matrix and distances between conductors above ground or image are calcualted before:

$$s := \begin{pmatrix} |cp_1-\overline{cp_1}| & |cp_1-\overline{cp_2}| & |cp_1-\overline{cp_3}| & |cp_1-\overline{cn_1}| \\ |cp_2-\overline{cp_1}| & |cp_2-\overline{cp_2}| & |cp_2-\overline{cp_3}| & |cp_2-\overline{cn_1}| \\ |cp_3-\overline{cp_1}| & |cp_3-\overline{cp_2}| & |cp_3-\overline{cp_3}| & |cp_3-\overline{cn_1}| \\ |cn_1-\overline{cp_1}| & |cn_1-\overline{cp_2}| & |cn_1-\overline{cp_3}| & |cn_1-\overline{cn_1}| \end{pmatrix}\cdot\frac{1}{ft} = \begin{pmatrix} 56 & 56.0558 & 56.4358 & 52.1536 \\ 56.0558 & 56 & 56.1805 & 52.0216 \\ 56.4358 & 56.1805 & 56 & 52.0865 \\ 52.1536 & 52.0216 & 52.0865 & 48 \end{pmatrix}$$

$OD_{ph} := 0.927in$ $\quad OD_{np} := 0.563in$ $\quad RD_{ph} := \frac{OD_{ph}}{2} = 0.038625 \cdot ft$ $\quad RD_n := \frac{OD_{np}}{2} = 0.023458 \cdot ft$

$\varepsilon_{air\_si} = 8.85 \cdot 10^{-12} \cdot \frac{F}{m}$

$\varepsilon_{air\_en} := 1.4240 \cdot 10^{-2} \cdot \frac{\mu F}{mile}$

$p_{ii}(s_{ii}, r_{ii}) := 11.17689 \cdot \ln\left(\frac{s_{ii}}{r_{ii}}\right) \frac{mile}{\mu F}$

$p_{ij}(s_{ij}, D_{ij}) := 11.17689 \cdot \ln\left(\frac{s_{ij}}{D_{ij}}\right) \frac{mile}{\mu F}$

$P_{11} := p_{ii}\left(s_{0,0}, RD_{ph} \cdot \frac{1}{ft}\right) = 81.3589 \cdot \frac{mile}{\mu F}$ $\quad P_{22} := P_{11}$ $\quad P_{33} := P_{11}$

$P_{nn} := p_{ii}\left(s_{3,3}, RD_n \cdot \frac{1}{ft}\right) = 85.2096 \cdot \frac{mile}{\mu F}$

$P_{12} := p_{ij}\left(s_{0,1}, D_{12} \cdot \frac{1}{ft}\right) = 34.7608 \cdot \frac{mile}{\mu F}$ $\quad P_{21} := P_{12}$

$P_{13} := p_{ij}\left(s_{0,2}, D_{31} \cdot \frac{1}{ft}\right) = 23.3283 \cdot \frac{mile}{\mu F}$ $\quad P_{31} := P_{13}$

$P_{1n} := p_{ij}\left(s_{0,3}, D_{1n} \cdot \frac{1}{ft}\right) = 24.8275 \cdot \frac{mile}{\mu F}$ $\quad P_{n1} := P_{1n}$

$P_{23} := p_{ij}\left(s_{1,2}, D_{23} \cdot \frac{1}{ft}\right) = 28.216 \cdot \frac{mile}{\mu F}$ $\quad P_{32} := P_{23}$

$P_{2n} := p_{ij}\left(s_{1,3}, D_{2n} \cdot \frac{1}{ft}\right) = 27.9375 \cdot \frac{mile}{\mu F}$ $\quad P_{n2} := P_{2n}$

$P_{3n} := p_{ij}\left(s_{2,3}, D_{3n} \cdot \frac{1}{ft}\right) = 26.1927 \cdot \frac{mile}{\mu F}$ $\quad P_{n3} := P_{3n}$

$$P_{p.nrot} := \begin{pmatrix} P_{11} & P_{12} & P_{13} & P_{1n} \\ P_{21} & P_{22} & P_{23} & P_{2n} \\ P_{31} & P_{32} & P_{33} & P_{3n} \\ P_{n1} & P_{n2} & P_{n3} & P_{nn} \end{pmatrix} = \begin{pmatrix} 81.3589 & 34.7608 & 23.3283 & 24.8275 \\ 34.7608 & 81.3589 & 28.216 & 27.9375 \\ 23.3283 & 28.216 & 81.3589 & 26.1927 \\ 24.8275 & 27.9375 & 26.1927 & 85.2096 \end{pmatrix} \cdot \frac{mile}{\mu F}$$

not rotated

$$P_p := \begin{pmatrix} P_{22} & P_{21} & P_{23} & P_{2n} \\ P_{12} & P_{11} & P_{13} & P_{1n} \\ P_{32} & P_{31} & P_{33} & P_{3n} \\ P_{n2} & P_{n1} & P_{n3} & P_{nn} \end{pmatrix} = \begin{pmatrix} 81.3589 & 34.7608 & 28.216 & 27.9375 \\ 34.7608 & 81.3589 & 23.3283 & 24.8275 \\ 28.216 & 23.3283 & 81.3589 & 26.1927 \\ 27.9375 & 24.8275 & 26.1927 & 85.2096 \end{pmatrix} \cdot \frac{mile}{\mu F}$$

rotated

Using Kron's reduction to 3-phase, phase quantities $P_{abc} = p_{ij} - p_{in} \cdot p_{nn}^{-1} \cdot p_{nj}$

$\mu S \equiv 10^{-6} \cdot S$

$$p_{ij} := \mathrm{submatrix}(P_p, 0, 2, 0, 2) = \begin{pmatrix} 81.3589 & 34.7608 & 28.216 \\ 34.7608 & 81.3589 & 23.3283 \\ 28.216 & 23.3283 & 81.3589 \end{pmatrix} \cdot \frac{mile}{\mu F}$$

$$p_{in} := \mathrm{submatrix}(P_p, 0, 2, 3, 3) = \begin{pmatrix} 27.9375 \\ 24.8275 \\ 26.1927 \end{pmatrix} \cdot \frac{mile}{\mu F}$$

$$p_{nn} := \mathrm{submatrix}(P_p, 3, 3, 3, 3) = (85.2096) \cdot \frac{mile}{\mu F}$$

$$p_{nj} := \mathrm{submatrix}(P_p, 3, 3, 0, 2) = (27.9375 \quad 24.8275 \quad 26.1927) \cdot \frac{mile}{\mu F}$$

$$P_{abc} := p_{ij} - p_{in} \cdot p_{nn}^{-1} \cdot p_{nj} = \begin{pmatrix} 72.199088 & 26.620613 & 19.628236 \\ 26.620613 & 74.124909 & 15.696576 \\ 19.628236 & 15.696576 & 73.307502 \end{pmatrix} \cdot \frac{mile}{\mu F}$$

$$C_{abc} := P_{abc}^{-1} = \begin{pmatrix} 0.0167 & -0.0053 & -0.0033 \\ -0.0053 & 0.0158 & -0.002 \\ -0.0033 & -0.002 & 0.015 \end{pmatrix} \cdot \frac{\mu F}{mile}$$

$$\boxed{y_{sht\_abc} := j \cdot 2 \cdot \pi \cdot f_n \cdot C_{abc} = \begin{pmatrix} 6.299808i & -1.995761i & -1.259455i \\ -1.995761i & 5.959696i & -0.741719i \\ -1.259455i & -0.741719i & 5.638638i \end{pmatrix} \cdot 10^{-6} \cdot \frac{S}{mile}}$$

$$baseY_{4.16kv} = 0.5778 \cdot S$$

$$LF = 1000 \cdot ft$$

$$Y_{sht.601} := \frac{y_{sht\_abc} \cdot LF}{baseY_{4.16kv}} = \begin{pmatrix} 2.0648i \times 10^{-6} & -6.5413i \times 10^{-7} & -4.128i \times 10^{-7} \\ -6.5413i \times 10^{-7} & 1.9533i \times 10^{-6} & -2.431i \times 10^{-7} \\ -4.128i \times 10^{-7} & -2.431i \times 10^{-7} & 1.8481i \times 10^{-6} \end{pmatrix}$$

Susceptance Calculations