worksheet 3.3 page 1

$l := 10 \quad \text{m}$

$X1 := 0 \quad \text{m}$ $\qquad X2 := 0.6\cdot 10^{-3} \quad \text{m}$ $\qquad X3 := -0.6\cdot 10^{-3} \quad \text{m}$

$Y1 := 0 \quad \text{m}$ $\qquad Y2 := 0 \quad \text{m}$ $\qquad Y3 := 0 \quad \text{m}$

$R1 := 1.5\cdot 10^{-3} \quad \Omega$ $\qquad R2 := 0.4\cdot 10^{-3} \quad \Omega$ $\qquad R3 := 0.4\cdot 10^{-3} \quad \Omega$

$n_1 := 30$ $\qquad n_2 := 12$ $\qquad n_3 := 12$

$N := n_1 + n_2 + n_3$

$i := 1 .. n_1 \qquad \theta_i := \frac{2\cdot\pi}{n_1}\cdot(i - 0.5) \quad \text{radian}$

$x_i := X1 + R1\cdot\cos(\theta_i) \qquad y_i := Y1 + R1\cdot\sin(\theta_i) \qquad r_i := \frac{R1}{n_1}$

$i := n_1 + 1 .. n_1 + n_2 \qquad \theta_i := \frac{2\cdot\pi}{n_2}\cdot(i - n_1 - 0.5)$

$x_i := X2 + R2\cdot\cos(\theta_i) \qquad y_i := Y2 + R2\cdot\sin(\theta_i) \qquad r_i := \frac{R2}{n_2}$

$i := n_1 + n_2 + 1 .. N \qquad \theta_i := \frac{2\cdot\pi}{n_2}\cdot(i - n_1 - n_2 - 0.5)$

$x_i := X3 + R3\cdot\cos(\theta_i) \qquad y_i := Y3 + R3\cdot\sin(\theta_i) \qquad r_i := \frac{R2}{n_3}$

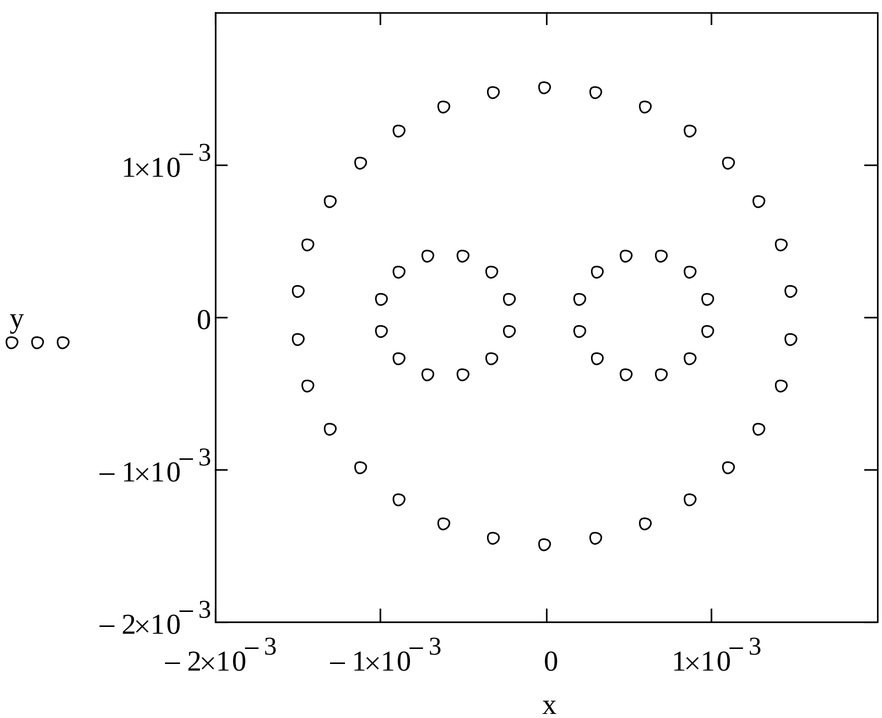

Fig 3.3.1 Definition of elemental conductors

worksheet 3.3 page 2

$\mu_o := 4\cdot\pi\cdot 10^{-7}$ H/m $\qquad \mu_r := 1 \qquad K := \dfrac{\mu_o\cdot\mu_r\cdot l}{2\cdot\pi} = 2\times 10^{-6}$ H

$$Zp := \left|\begin{array}{l} \text{for } i \in 1..N \\ \quad \text{for } j \in 1..N \\ \quad\quad \left|\begin{array}{l} h \leftarrow x_j - x_i \\ v \leftarrow y_j - y_i \\ rad \leftarrow \sqrt{h^2 + v^2} \\ rad \leftarrow r_i \ \text{ if } rad = 0 \\ Lp_{i,j} \leftarrow K\cdot\ln\left(\dfrac{l}{rad}\right) \end{array}\right. \\ Lp \end{array}\right.$$

$$Zloop := \left|\begin{array}{l} \text{for } i \in 1..N-1 \\ \quad \text{for } j \in 1..N-1 \\ \quad\quad Lloop_{i,j} \leftarrow Zp_{i,j} - Zp_{i,j+1} - Zp_{i+1,j} + Zp_{i+1,j+1} \\ Lloop \end{array}\right.$$

$$Vloop := \left|\begin{array}{l} \text{for } i \in 1..N-1 \\ \quad \left|\begin{array}{l} V_i \leftarrow 0 \\ V_i \leftarrow 1 \ \text{ if } i = n_1 \end{array}\right. \\ V \end{array}\right.$$

$$Iloop := \text{lsolve}(Zloop, Vloop)$$

$$Ip := \left|\begin{array}{l} I_1 \leftarrow Iloop_1 \\ \text{for } i \in 2..N-1 \\ \quad I_i \leftarrow Iloop_i - Iloop_{i-1} \\ I_N \leftarrow -Iloop_{N-1} \\ I \end{array}\right.$$

worksheet page 2: Calculating currents in elemental conductors worksheet 3.3 page 3. (worksheet 3.3 page 2 is identical to figure 3.2.6)

$$n = \begin{pmatrix} 30 \\ 12 \\ 12 \end{pmatrix}$$

number of elemental conductors in each composite.

$$\mathrm{Start} := \begin{pmatrix} 1 \\ n_1 + 1 \\ n_1 + n_2 + 1 \end{pmatrix} \qquad \mathrm{End} := \begin{pmatrix} n_1 \\ n_1 + n_2 \\ N \end{pmatrix}$$

Pointers to nine sub-matrices.

$h := 1..3 \qquad k := 1..3$

control variables

$$vq_{h,k} := \left| \begin{array}{l} v \leftarrow 0 \\ \text{for } \ i \in \mathrm{Start}_h .. \mathrm{End}_h \\ \quad \text{for } \ j \in \mathrm{Start}_k .. \mathrm{End}_k \\ \qquad v \leftarrow v + Zp_{i,j} \cdot Ip_j \\ \dfrac{v}{n_h} \end{array} \right.$$

voltage components of sub-matrices

$$vq = \begin{pmatrix} 12.667 & -6.334 & -6.334 \\ 12.694 & -7.284 & -6.41 \\ 12.694 & -6.41 & -7.284 \end{pmatrix}$$

$$Vq_h := \left| \begin{array}{l} v \leftarrow 0 \\ \text{for } \ k \in 1..3 \\ \quad v \leftarrow v + vq_{h,k} \\ v \end{array} \right.$$

Voltage along composite conductors:-

$$Vq = \begin{pmatrix} -5.874 \times 10^{-8} \\ -1 \\ -1 \end{pmatrix}$$

$$Iq_h := \left| \begin{array}{l} I \leftarrow 0 \\ \text{for } \ i \in \mathrm{Start}_h .. \mathrm{End}_h \\ \quad I \leftarrow I + Ip_i \\ I \end{array} \right.$$

Current in composite conductors:-

$$Iq = \begin{pmatrix} 7.193 \times 10^{5} \\ -3.597 \times 10^{5} \\ -3.597 \times 10^{5} \end{pmatrix}$$

$\mathrm{Itotal} := Iq_1 + Iq_2 + Iq_3 = 0$

Sum of currents in conductors

Figure 3.3.2 Computing values for voltages and currents in composite conductors.

worksheet 3.3 page 4

$$Lq_{h,k} := \frac{vq_{h,k}}{Iq_k}$$

Deriving primitive inductance values from current and voltage data. See equation (3.2.15)

$$Lq = \begin{pmatrix} 1.761 \times 10^{-5} & 1.761 \times 10^{-5} & 1.761 \times 10^{-5} \\ 1.765 \times 10^{-5} & 2.025 \times 10^{-5} & 1.782 \times 10^{-5} \\ 1.765 \times 10^{-5} & 1.782 \times 10^{-5} & 2.025 \times 10^{-5} \end{pmatrix}$$

Deriving loop inductance values for three-conductor assembly. See equation (3.2.3)

$$L\_loop := \left| \begin{array}{l} \text{for } h \in 1..2 \\ \quad \text{for } k \in 1..2 \\ \quad\quad \mathbf{L}_{h,k} \leftarrow Lq_{h,k} - Lq_{h,k+1} - Lq_{h+1,k} + Lq_{h+1,k+1} \\ \mathbf{L} \end{array} \right.$$

$$L\_loop = \begin{pmatrix} 2.606 \times 10^{-6} & -2.432 \times 10^{-6} \\ -2.432 \times 10^{-6} & 4.864 \times 10^{-6} \end{pmatrix}$$

$$Lc_1 := L\_loop_{1,1} + L\_loop_{1,2}$$

$$Lc_2 := -L\_loop_{1,2}$$

$$Lc_3 := L\_loop_{2,2} + L\_loop_{2,1}$$

Deriving circuit inductors for three-conductor assembly. See equation (2.7.10).

$$\frac{Lc}{2} = \begin{pmatrix} 8.711 \times 10^{-8} \\ 1.216 \times 10^{-6} \\ 1.216 \times 10^{-6} \end{pmatrix} \quad \text{H}$$

Deriving capacitor values. See equation (2.3.3)

$$\varepsilon_o := 8.854 \cdot 10^{-12} \quad \text{F/m}$$

$$\varepsilon_r := 1$$

$$Cc := \frac{\mu_o \cdot \mu_r \cdot \varepsilon_o \cdot \varepsilon_r \cdot l^2}{Lc}$$

$$Cc = \begin{pmatrix} 6.386 \times 10^{-9} \\ 4.575 \times 10^{-10} \\ 4.575 \times 10^{-10} \end{pmatrix} \quad \text{F}$$

Figure 3.3.3 Calculating values of circuit components

$i := 1 .. N$ $\qquad A_{i,1} := \mathbf{x}_i \cdot 10^3$ $\qquad A_{i,2} := \mathbf{y}_i \cdot 10^3$ $\qquad A_{i,3} := \left|\mathbf{Ip}_i\right| \cdot 10^{-3}$

rem WRITEPRN("sect3-4ws.prn") $:= A$