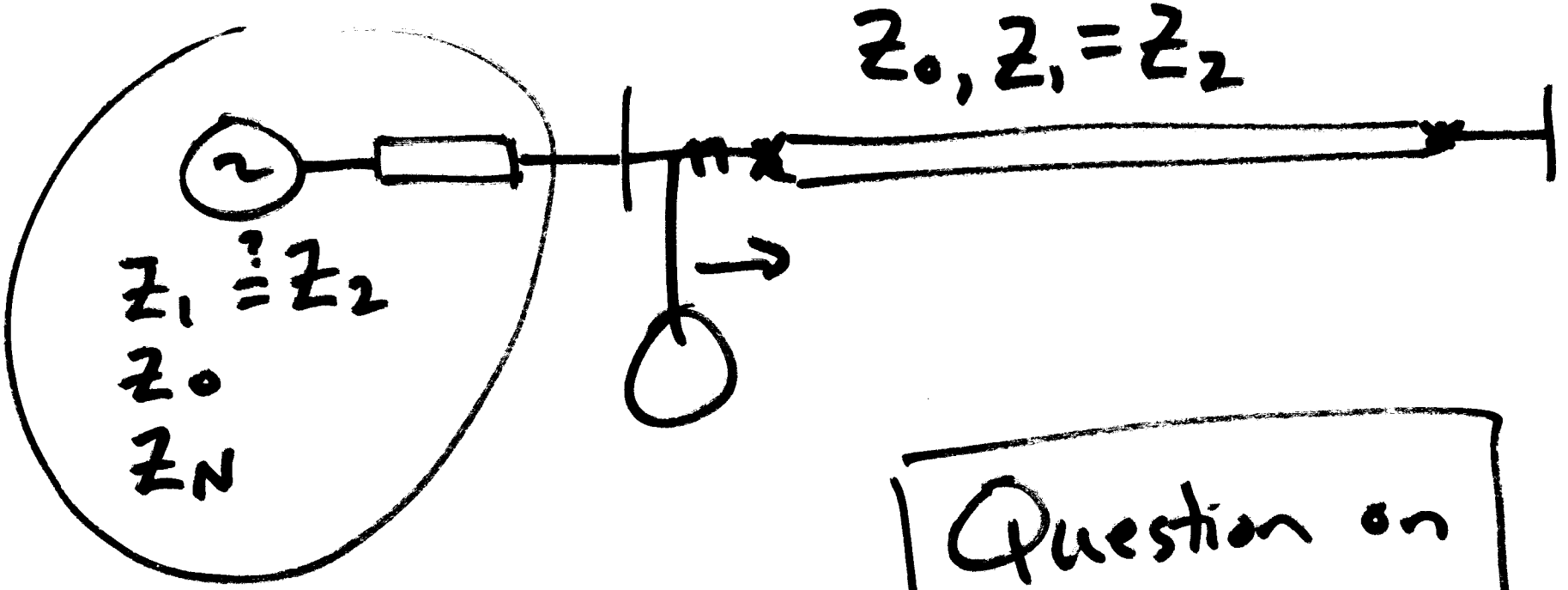
EE4223/5223

OFFICE HR 25 FEB '09

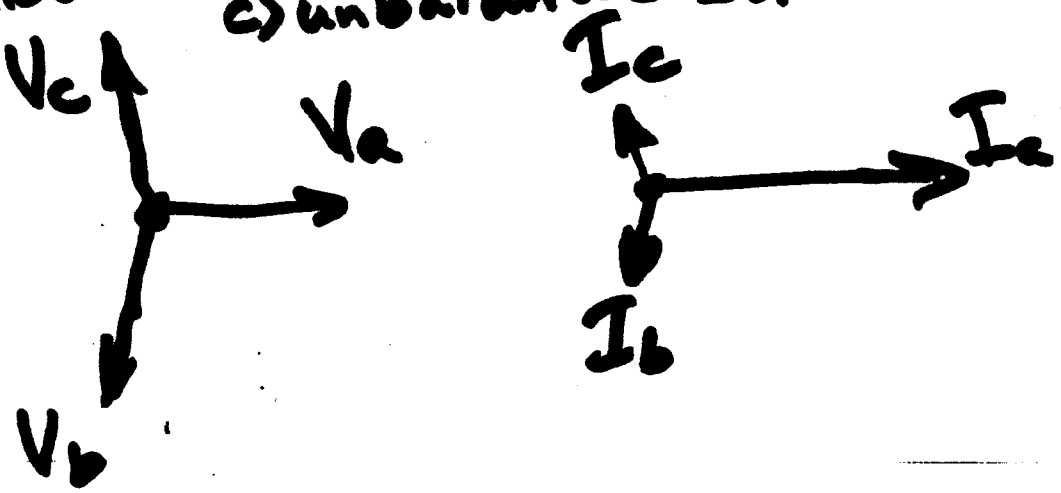


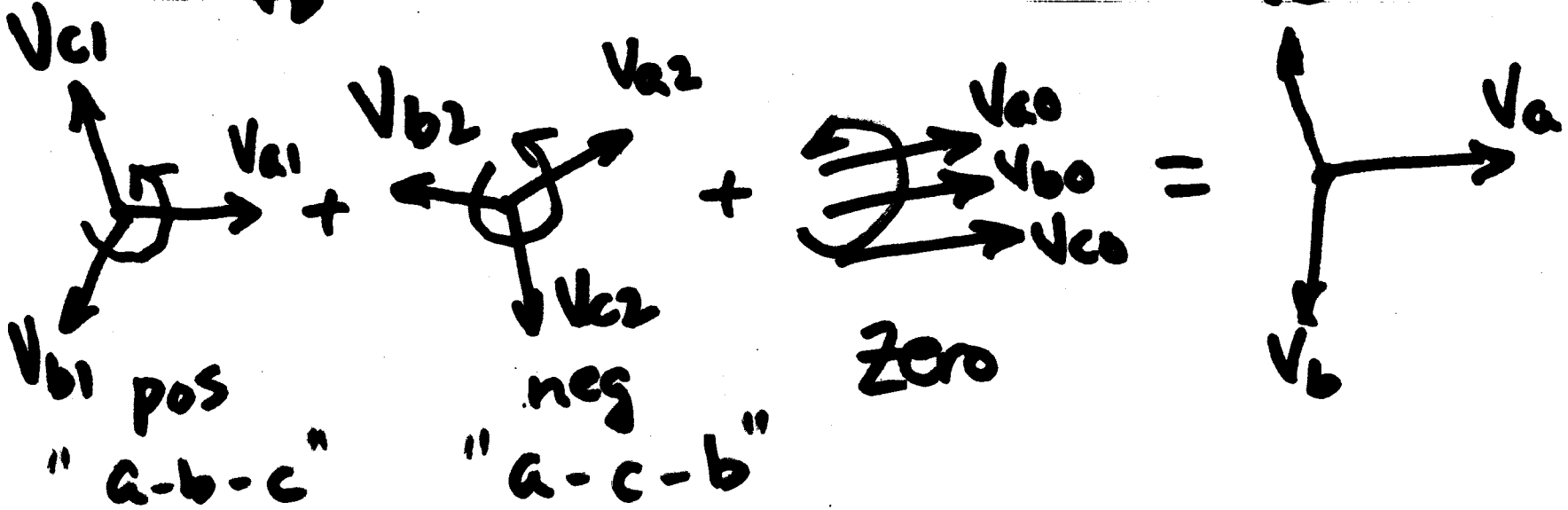
Question on Hwk 8

Symmetrical Components

- Deal w/ unbalanced 3φ situations.
- Real-world situation: a) unbalanced load currents flowing thru system,
  b) also unbalanced faults: L-G, L-L, L-L-G,
  c) unbalanced Zs.

Ex:





Per Phase Analysis is typical - no need to track ϕb & ϕc qty's if ϕa is known and each "group" (i.e. pos, neg, zero) is Symmetric/balanced.

Convenience to define "a":

$$\vec{a} = 1\angle 120^\circ$$

$$a = 1\angle 120^\circ$$

$$a^2 = 1\angle -120^\circ$$

$$\tilde{V}_{b1} = \tilde{V}_{a1}\,a^2 \qquad \tilde{V}_{b2} = \tilde{V}_{a2}\,a$$

$$\tilde{V}_{c1} = \tilde{V}_{a1}\,a \qquad \tilde{V}_{c2} = \tilde{V}_{a2}\,a^2$$

$$\begin{bmatrix} \tilde{V}_a \\ \tilde{V}_b \\ \tilde{V}_c \end{bmatrix} = \begin{bmatrix} \tilde{V}_{a0} + \tilde{V}_{a1} + \tilde{V}_{a2} \\ \tilde{V}_{b0} + \tilde{V}_{b1} + \tilde{V}_{b2} \\ \tilde{V}_{c0} + \tilde{V}_{c1} + \tilde{V}_{c2} \end{bmatrix} = \begin{bmatrix} \tilde{V}_{a0} + \tilde{V}_{a1} + \tilde{V}_{a2} \\ \tilde{V}_{a0} + a^2\tilde{V}_{a1} + a\tilde{V}_{a2} \\ \tilde{V}_{a0} + a\tilde{V}_{a1} + a^2\tilde{V}_{a2} \end{bmatrix}$$

Note: $V_{a0} = V_{b0} = V_{c0}$

$$\begin{bmatrix} \tilde{V}_a \\ \tilde{V}_b \\ \tilde{V}_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} \tilde{V}_{a0} \\ \tilde{V}_{a1} \\ \tilde{V}_{a2} \end{bmatrix} = [A] \begin{bmatrix} \tilde{V}_{a0} \\ \tilde{V}_{a1} \\ \tilde{V}_{a2} \end{bmatrix}$$

$$[V_p] = [A][V_s]$$

$$[I_p] = [A][I_s]$$

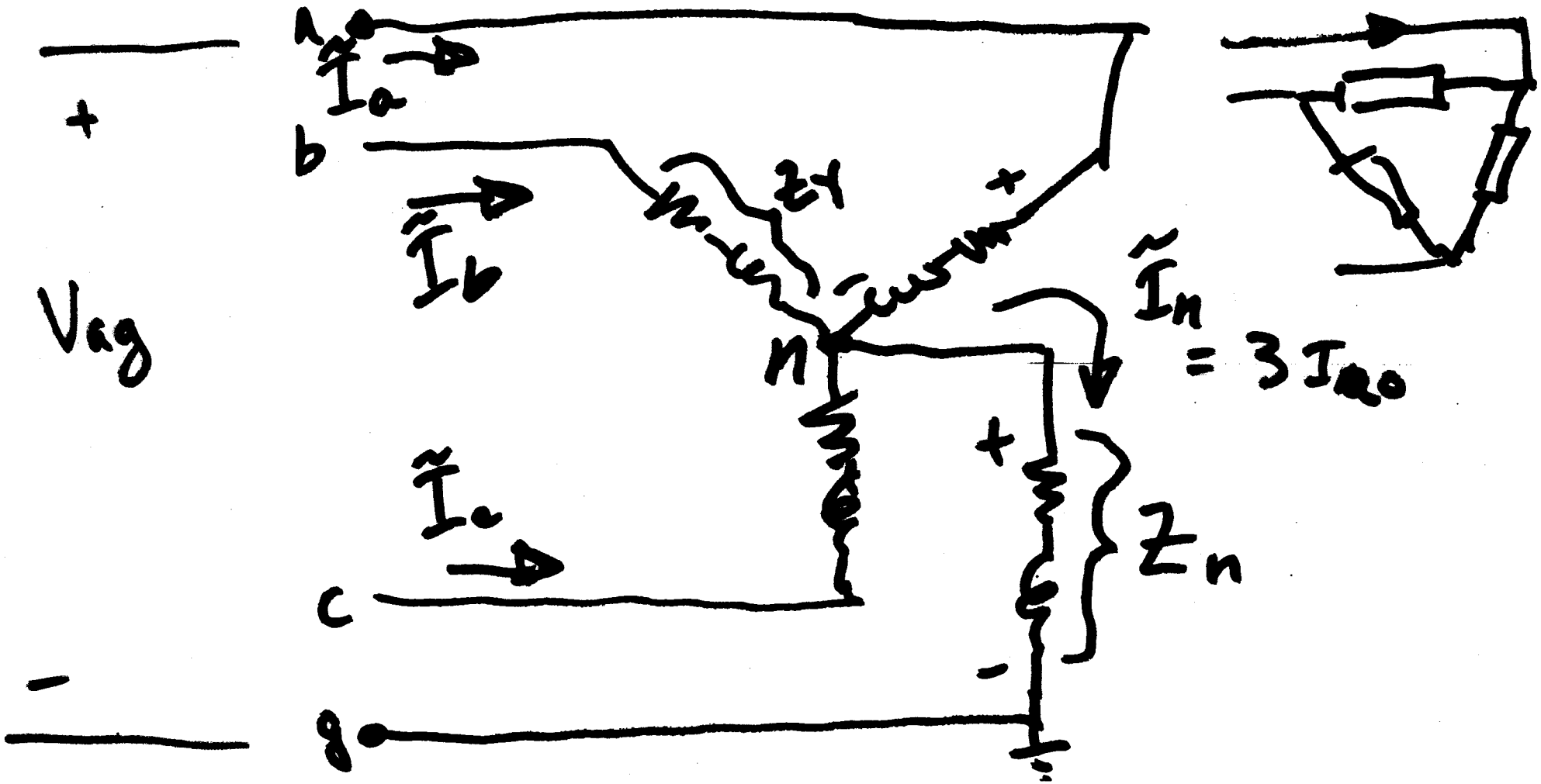
$$[A]^{-1}[V_p] = [A]^{-1}[A][V_s]$$

$$[V_s] = [A]^{-1}[V_p]$$

Z_p = "phase impedances"

Z_s = "seq impedances"

} §8.2 G&S



$$\tilde{V}_{ag} = Z_Y I_a + Z_n I_n$$

$$= Z_Y I_a + Z_n (I_a + I_b + I_c)$$

$$= (Z_Y + Z_n) I_a + Z_n I_b + Z_n I_c$$

$$\tilde{V}_{bg} = Z_n I_a + (Z_Y + Z_n) I_b + Z_n I_c$$

$$\tilde{V}_{cg} = Z_n I_a + Z_n I_b + (Z_n + Z_Y) I_c$$

$$\begin{bmatrix} V_{ag} \\ V_{bg} \\ V_{cg} \end{bmatrix} = \begin{bmatrix} (Z_Y + Z_n) & Z_n & Z_n \\ Z_n & (Z_Y + Z_n) & Z_n \\ Z_n & Z_n & (Z_Y + Z_n) \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix}$$

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} Z_{aa} & Z_{ab} & Z_{ac} \\ Z_{ba} & Z_{bb} & Z_{bc} \\ Z_{ca} & Z_{cb} & Z_{cc} \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix}$$

$$[V_p] = [Z_p][I_p]$$

$$[V_p] = [Z_p][I_p]$$

$$Z_s = A^{-1} Z_p A$$

$$= \begin{bmatrix} Z_{00} & Z_{01} & Z_{02} \\ Z_{10} & Z_{11} & Z_{12} \\ Z_{20} & Z_{21} & Z_{22} \end{bmatrix}$$

$$\begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} = V_s = Z_s I_s$$

$$Z_p = A Z_s A^{-1}$$

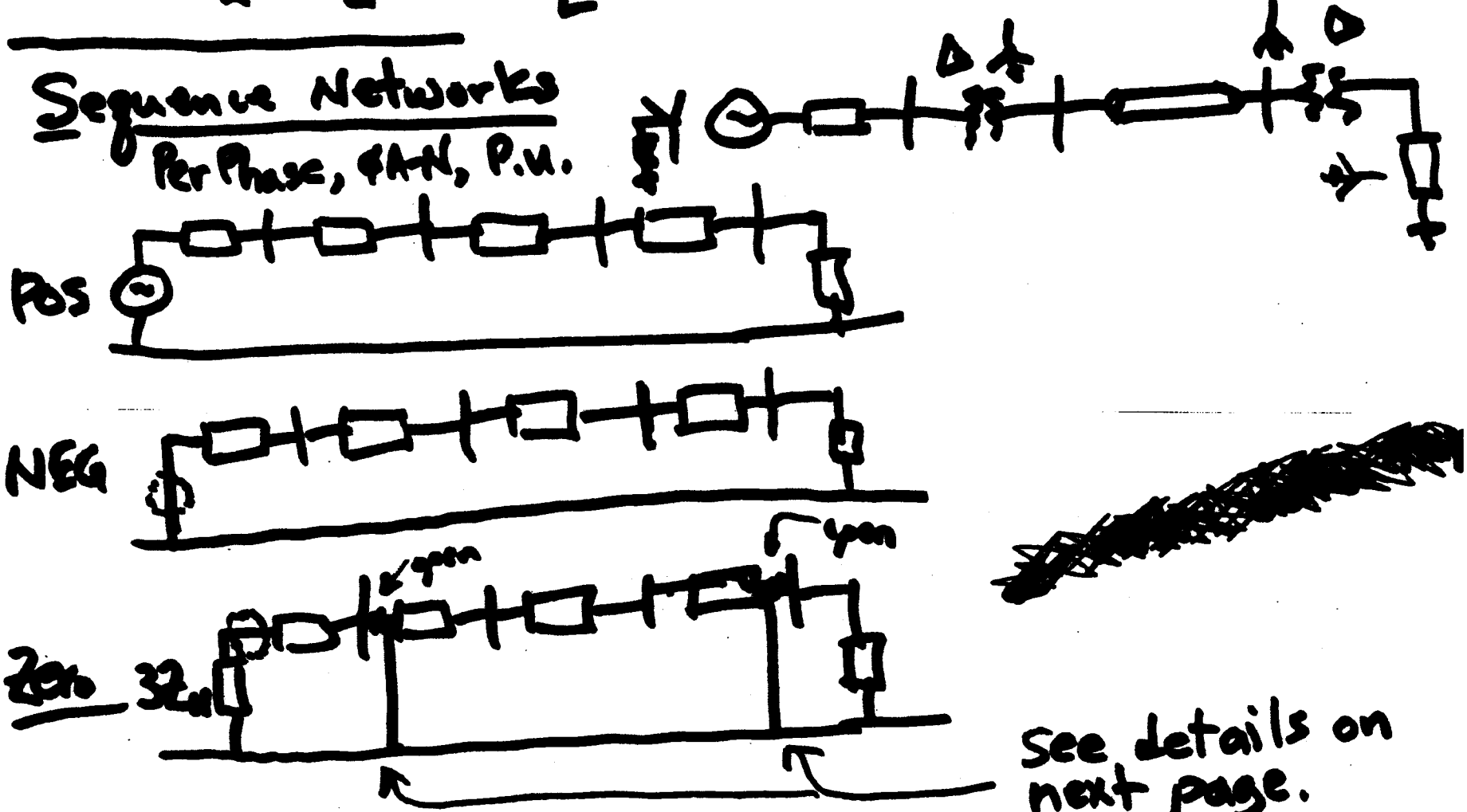
$$\begin{bmatrix} Z_{00} & 0 & 0 \\ 0 & Z_{11} & 0 \\ 0 & 0 & Z_{22} \end{bmatrix}$$

decoupled

$$\text{i.e. } \begin{bmatrix} \tilde{V}_{a0} \\ \tilde{V}_{a1} \\ \tilde{V}_{a2} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & a & a^2 \\ 1 & a^2 & a \end{bmatrix} \begin{bmatrix} \tilde{V}_a \\ \tilde{V}_b \\ \tilde{V}_c \end{bmatrix}$$

Sequence Networks

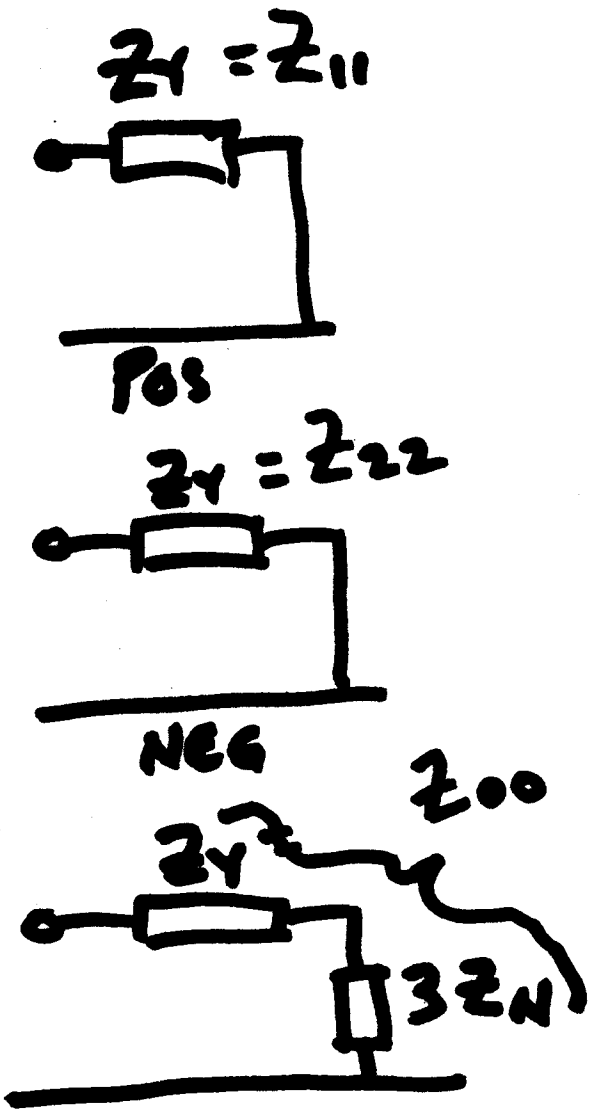
Per Phase, ϕ-N, P.U.



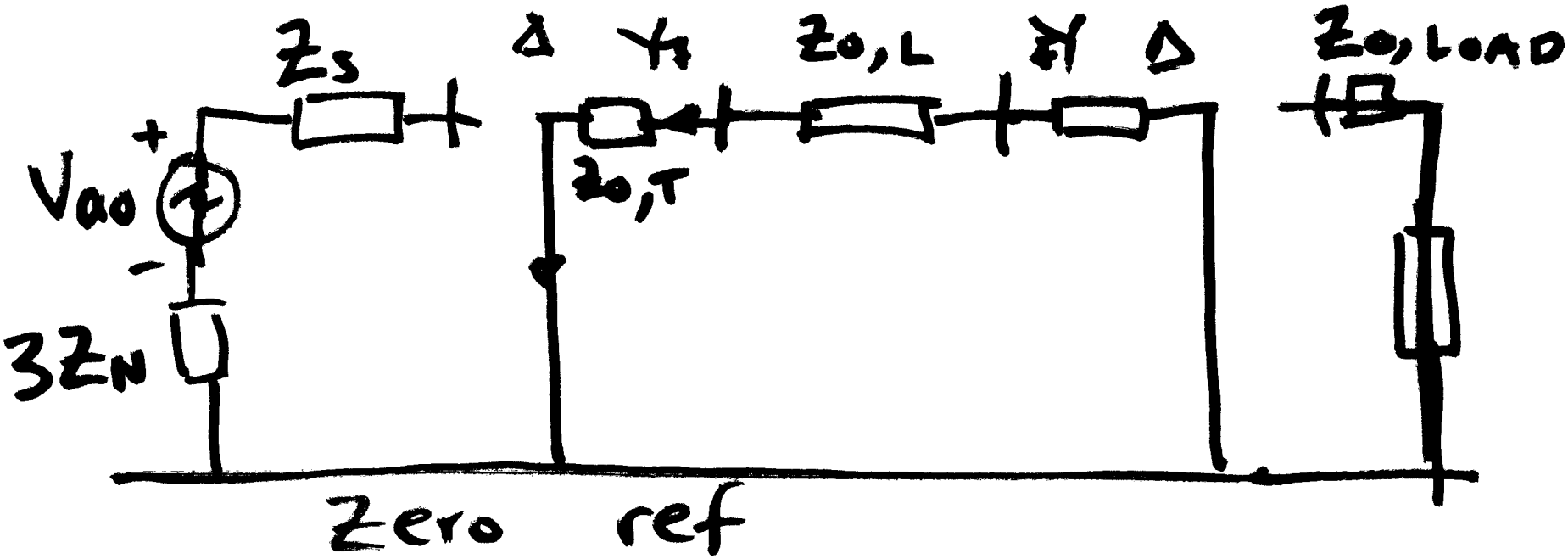
For our simple GY load, see p.1 of these notes,

$$Z_s = A^{-1} Z_p A \Rightarrow$$

$$Z_s = \begin{bmatrix} Z_Y + 3Z_N & 0 & 0 \\ 0 & Z_Y & 0 \\ 0 & 0 & Z_Y \end{bmatrix}$$



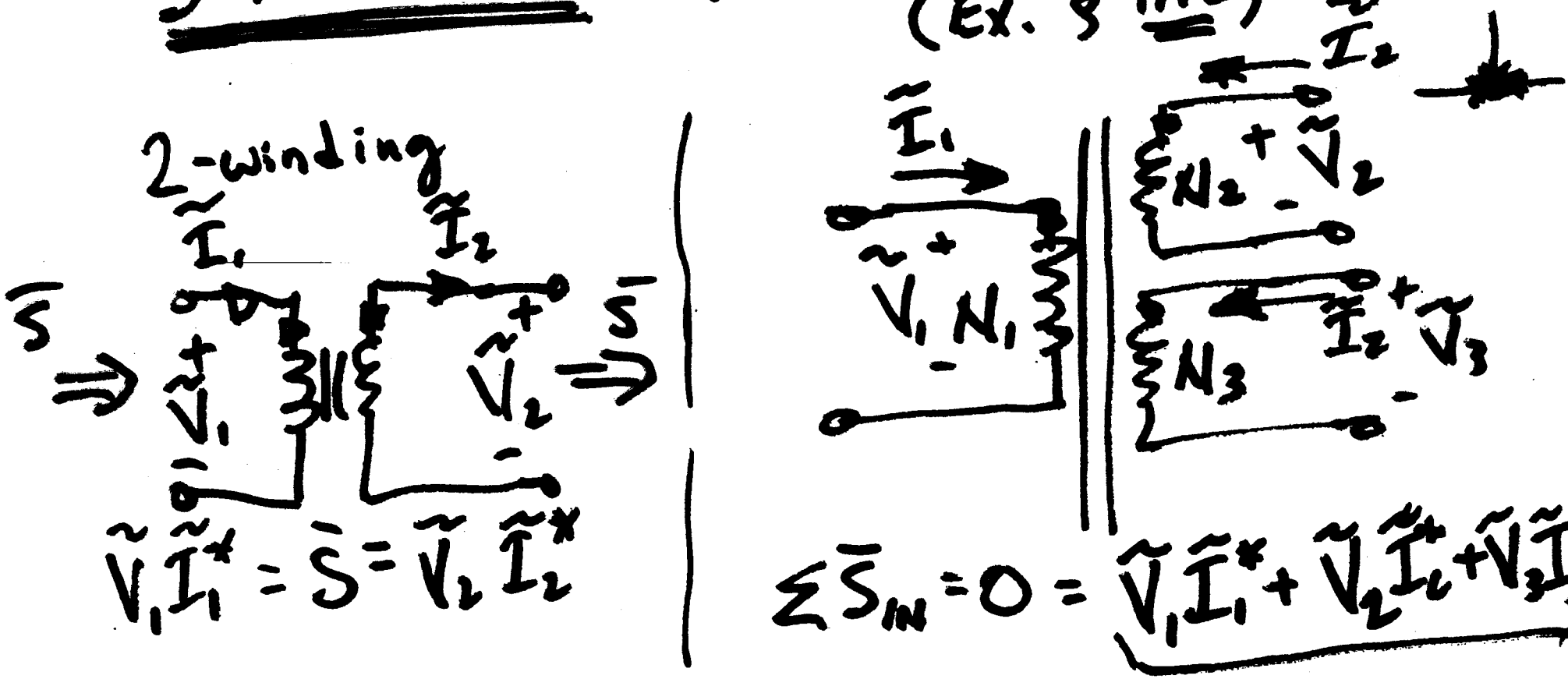
∴ Can work with this either in phase qtys or in sequence qtys!

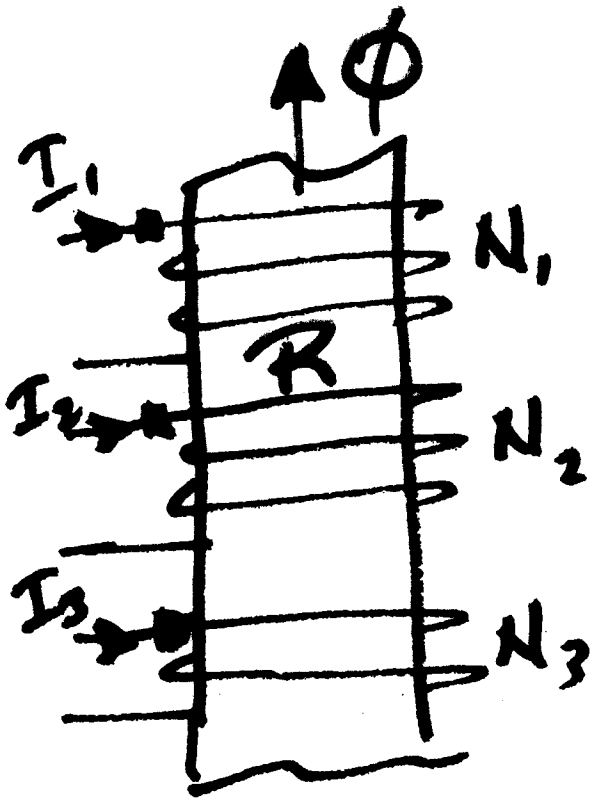

Z_S
Δ
Y_T
$Z_{0,L}$
Δ
$Z_{0,LOAD}$
V_{A0}
+
−
$3Z_N$
$Z_{0,T}$
Zero ref

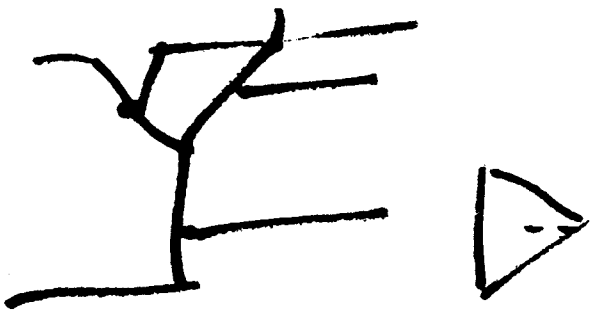
Ch.6 - Overview "relay fundamentals"

§6.5.6, 6.5.7 – 3-4 pages - R-X

3-Wind Xfmrs (ref. Hewitt 4.4 (p.505) (Ex. § 4.12)







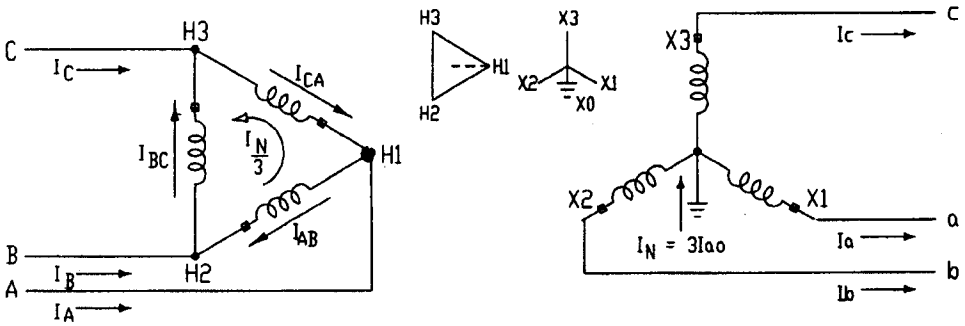
Prob 4.4

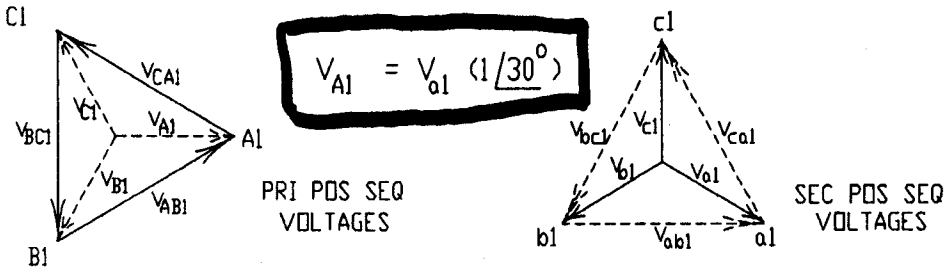
$$\Sigma MMF_s = 0$$

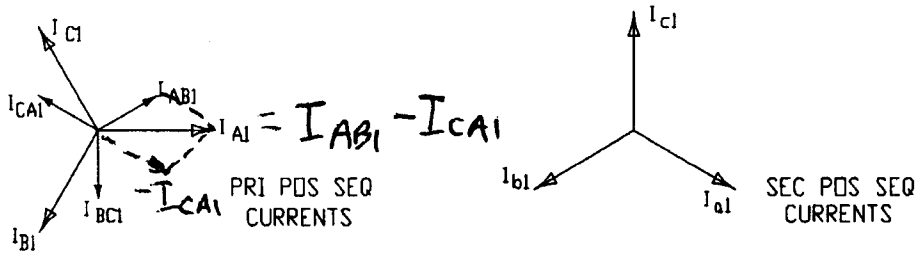
$$= \underline{\tilde{I}_1 N_1 + \tilde{I}_2 N_2 + \tilde{I}_3 N_3}$$

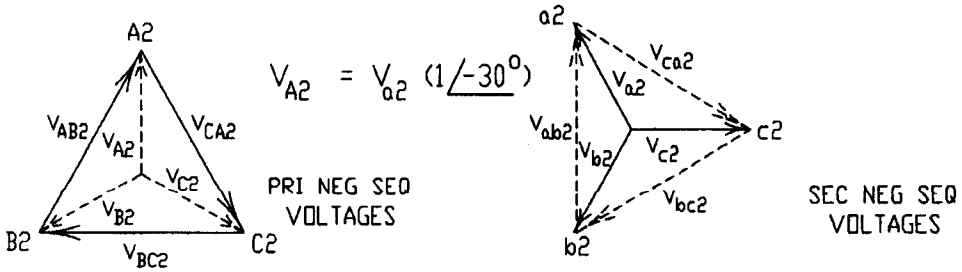
$$= I_1 V_1 + I_2 V_2 + I_3 V_3$$

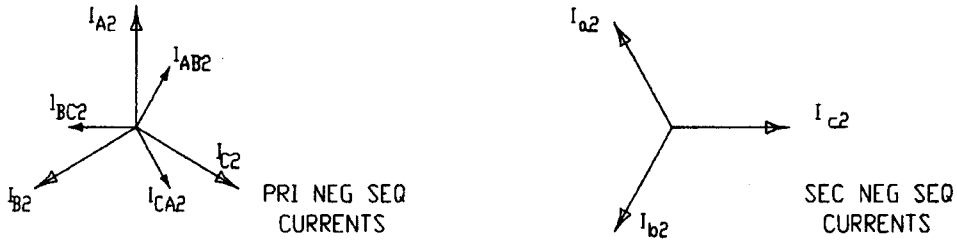
MARK





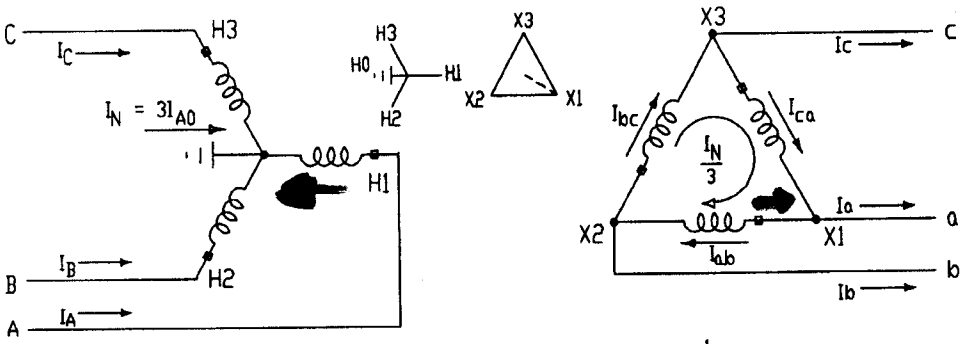


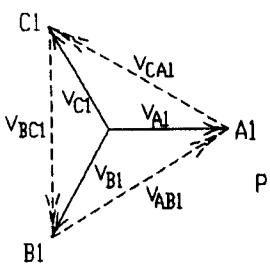




ANSI STANDARD 30-DEGREE SHIFT DELTA-WYE

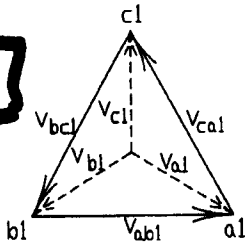
MORK



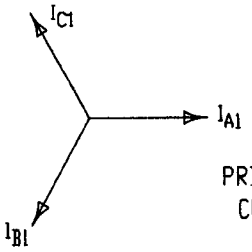


PRI POS SEQ VOLTAGES

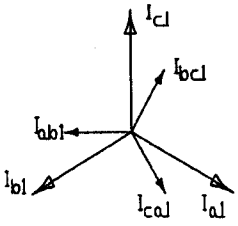
$V_{A1} = V_{a1}\ (1\angle 30^\circ)$



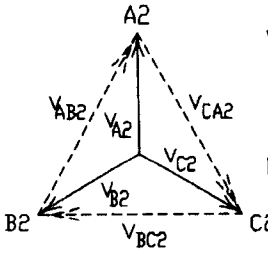
SEC POS SEQ VOLTAGES



PRI POS SEQ CURRENTS

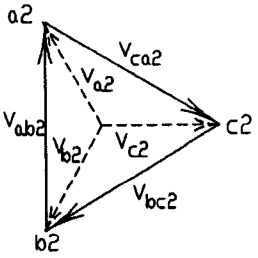


SEC POS SEQ CURRENTS

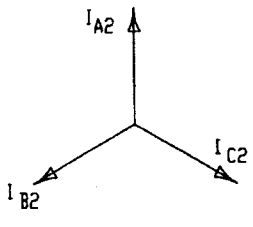


PRI NEG SEQ VOLTAGES

$V_{A2} = V_{a2}\ (1\angle -30^\circ)$



SEC NEG SEQ VOLTAGES



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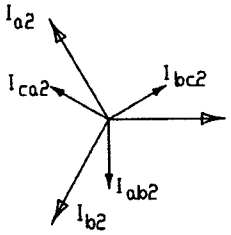

SEC NEG SEQ CURRENTS

ANSI STANDARD 30-DEGREE SHIFT WYE-DELTA