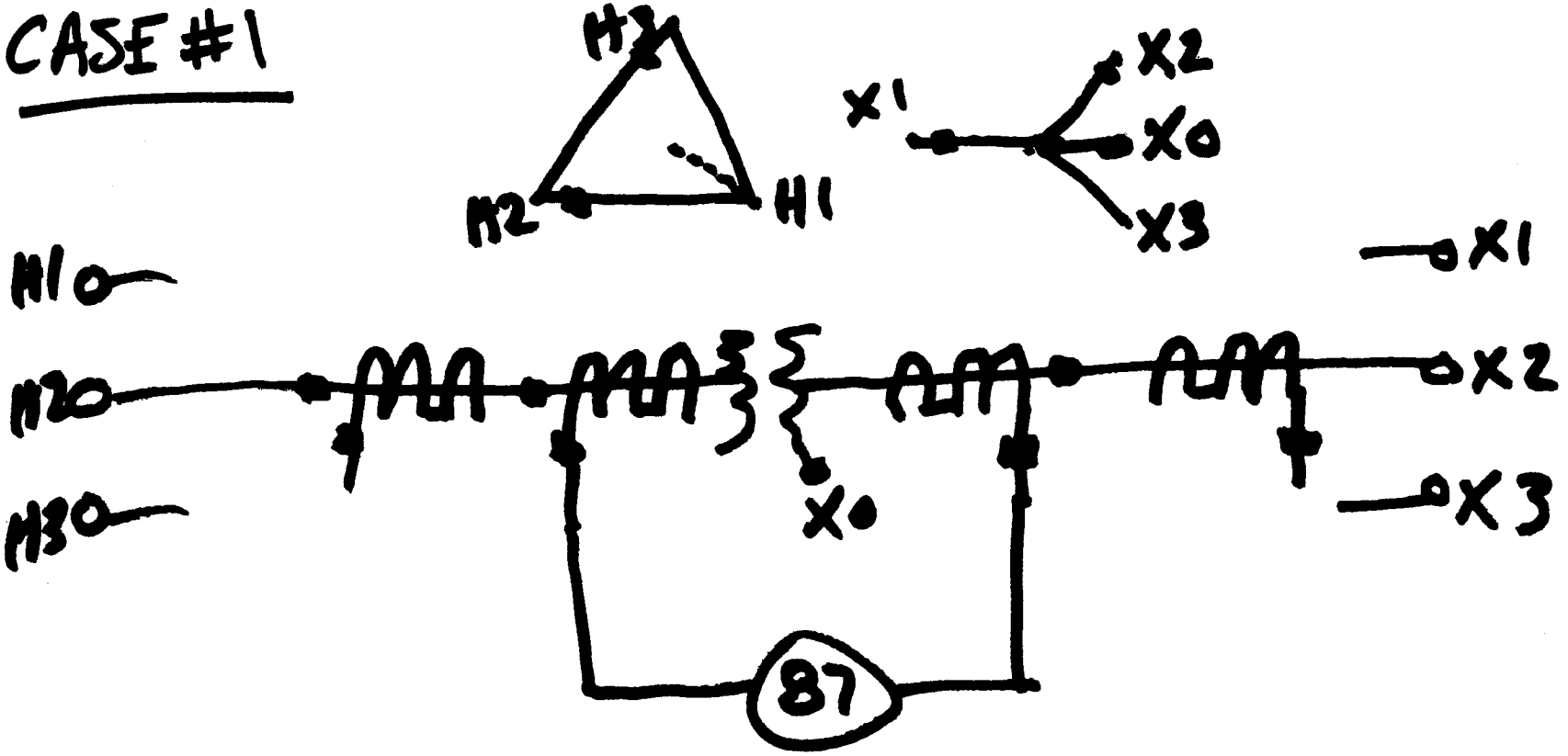
EE 5223 - Lecture 29 Wed Mar 22, 2023

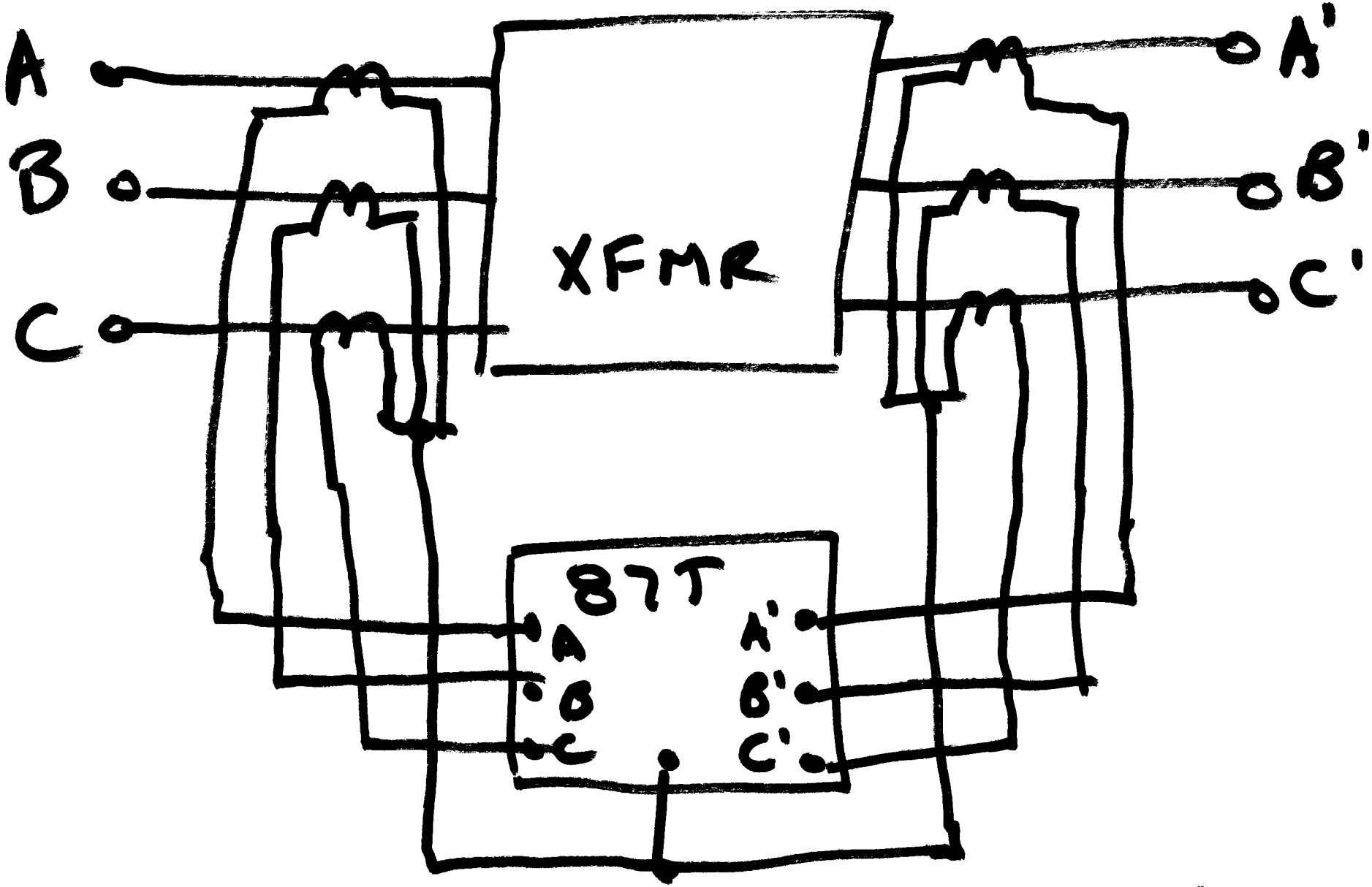
Ongoing List of Topics:

- URL: https://pages.mtu.edu/~bamork/EE5223/index.htm
- Term Project - Detailed outlines submitted, can resubmit after feedback.
  - Follow timeline, see posting on web page (posted in Week 5)
  - Formal outline w/complete references complete, get/keep cranking...
- Homework set 10 can be divided into two parts/efforts
  - Handout problem, Probs 4.2, 4.3 (a,b,c) - Complete by Tues 9am
  - Problem 4.4 - complete by Wed 9am (if help is needed).
- Protection fundamentals for 87T, ongoing
- Transformer protection/maintenance issues
    - Load Tap Changer - Voltage Reg
    - "Doble Test," Dissolved Gas in Oil
  - a) correct connection of CT secondaries to relays (Lectures 28,29)
  - b) relay settings, to compensate for pri voltage ratio and CT ratios.
  - c) Mismatch problems - due to being forced to use less than full CT ratio, having Pri and Sec CTs with different accuracy levels, LTC. Differential slope of trip characteristic can be 10%, 15%, 25%, etc, to allow for mismatch. Refer to XFMR.pdf !

CASE #1

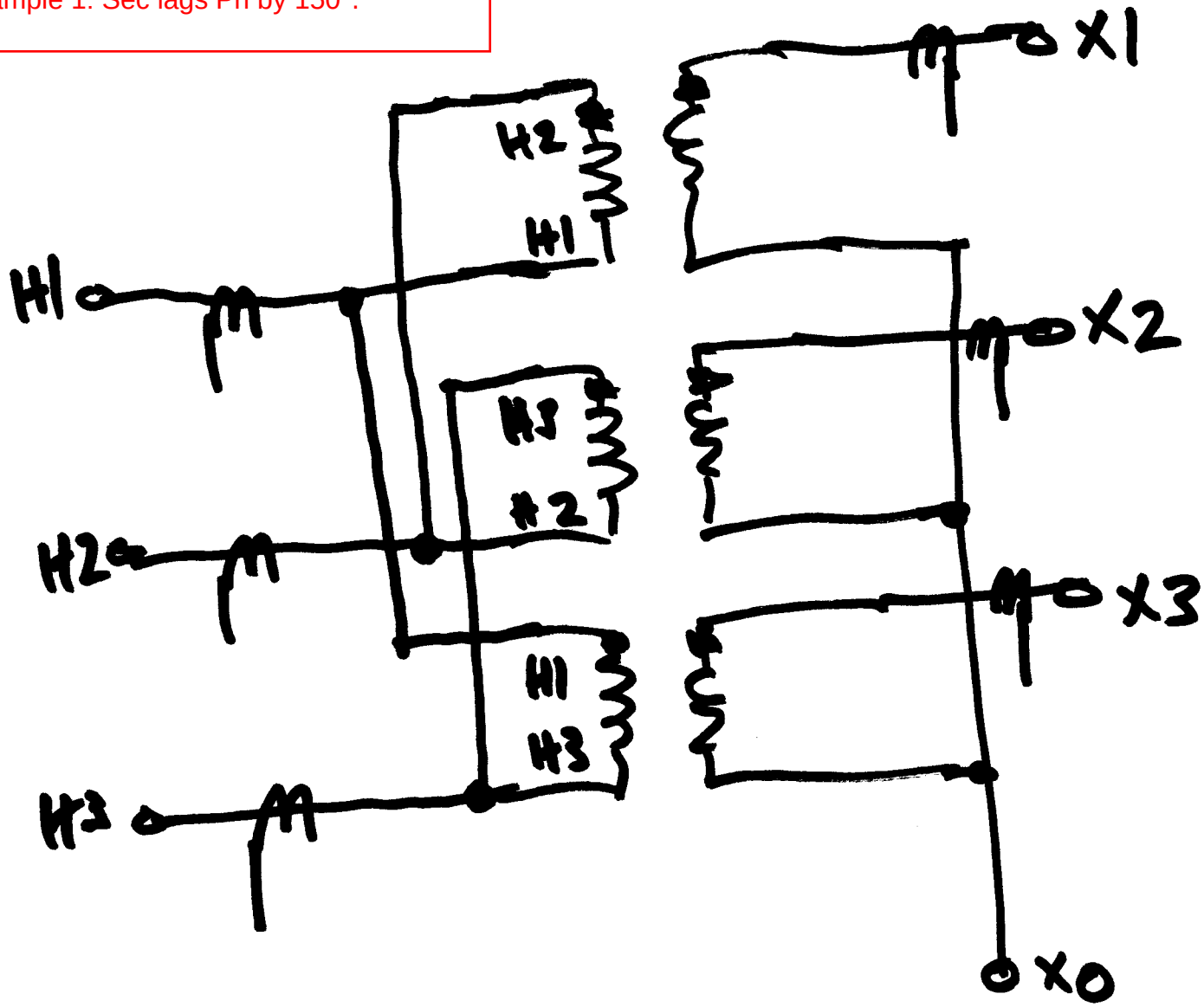


"Reconcile": Mag ✓ phase Ang ✓

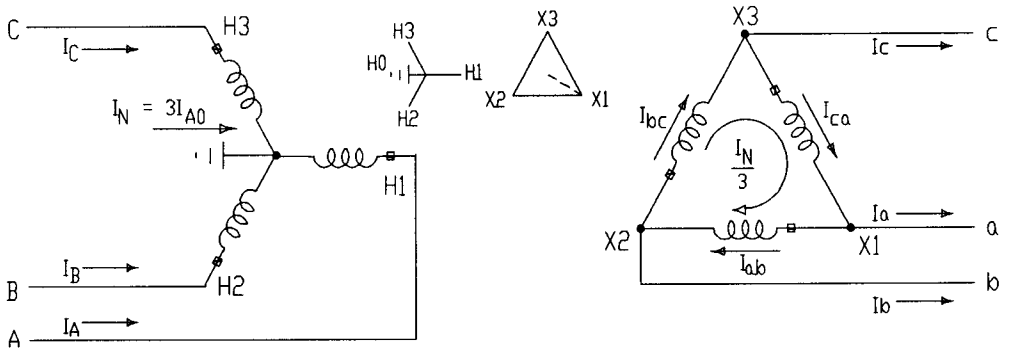


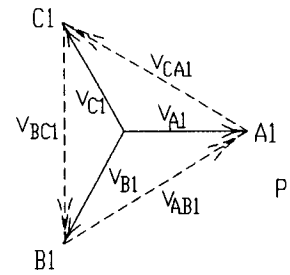
Ideally: for G3 relay, just connect line currents & provide settings.

Example 1: Sec lags Pri by 150°.



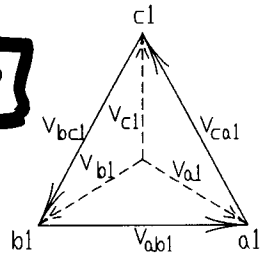
MORK



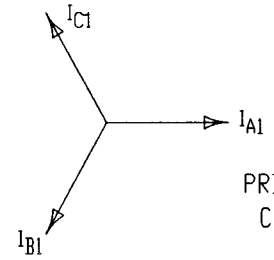


PRI POS SEQ VOLTAGES

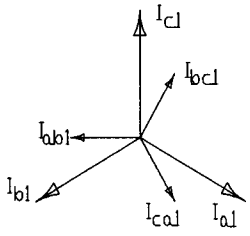
$V_{A1} = V_{a1} (1 \angle 30^\circ)$



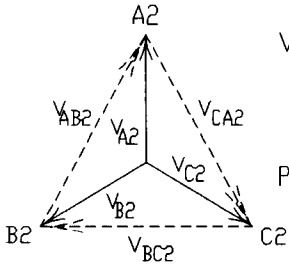
SEC POS SEQ VOLTAGES



PRI POS SEQ CURRENTS

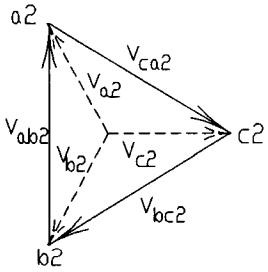


SEC POS SEQ CURRENTS

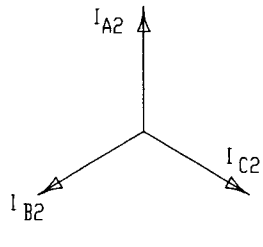


PRI NEG SEQ VOLTAGES

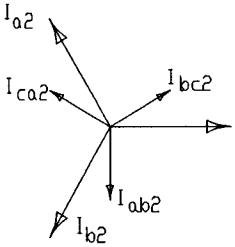
$V_{A2} = V_{a2} (1 \angle -30^\circ)$



SEC NEG SEQ VOLTAGES



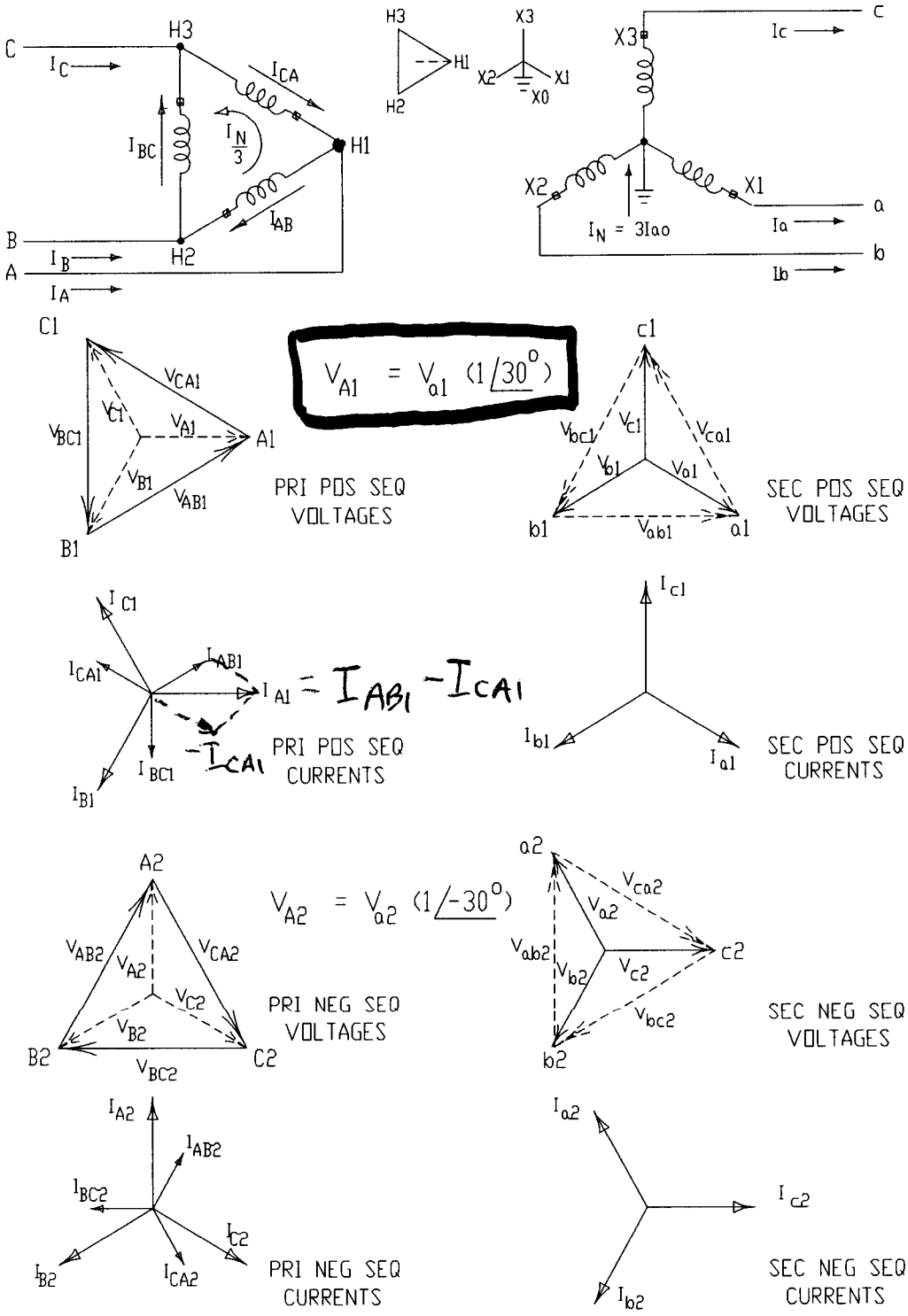
PRI NEG SEQ CURRENTS



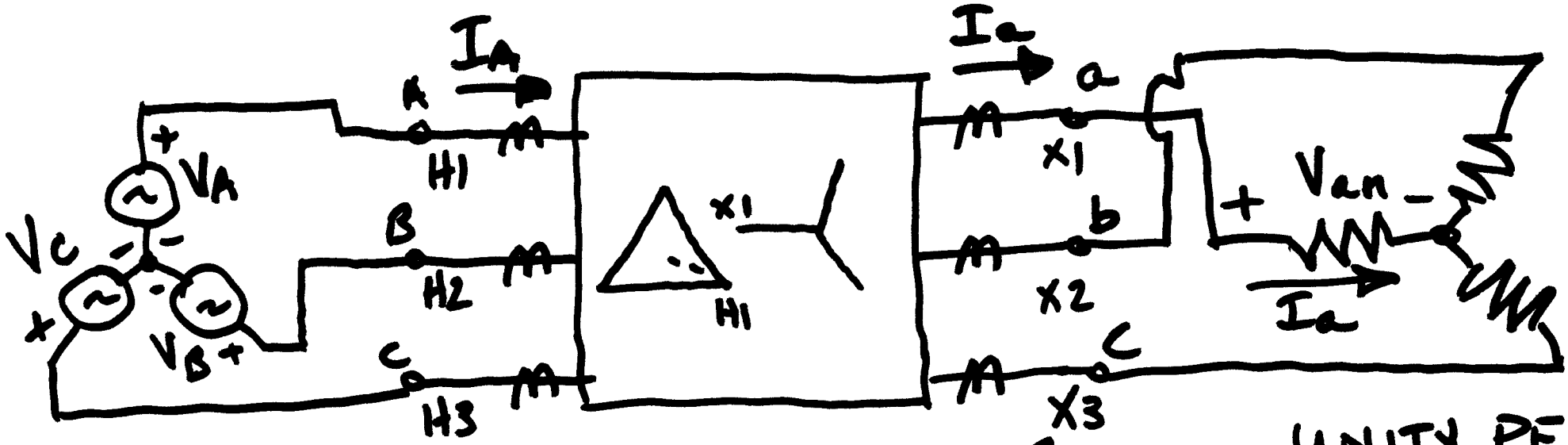
SEC NEG SEQ CURRENTS

ANSI STANDARD 30-DEGREE SHIFT WYE-DELTA

MARK

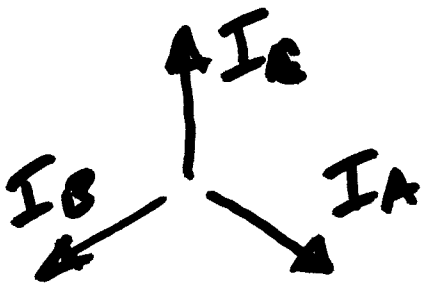


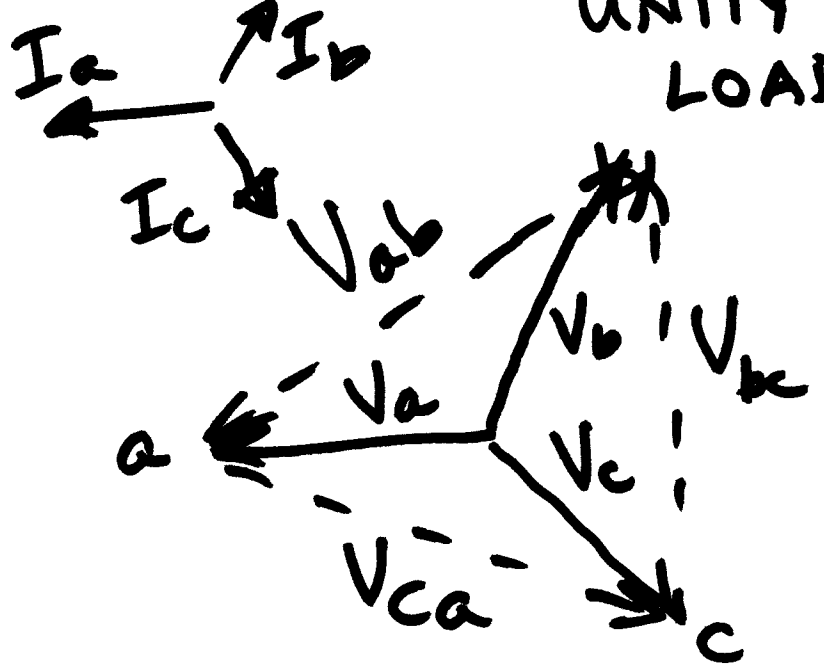
ANSI STANDARD 30-DEGREE SHIFT DELTA-WYE

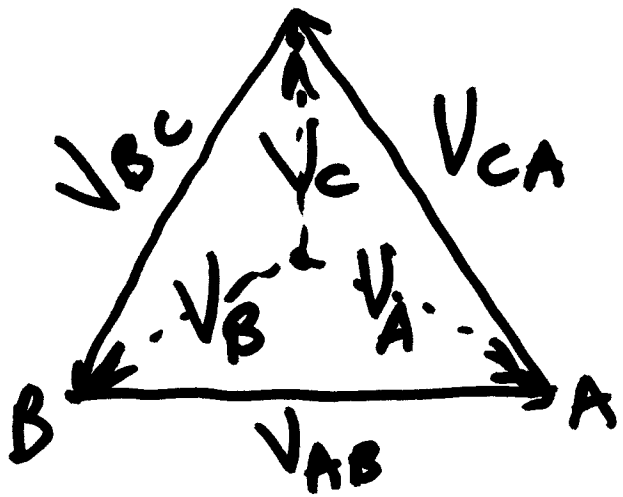


POS SEQ SOURCE

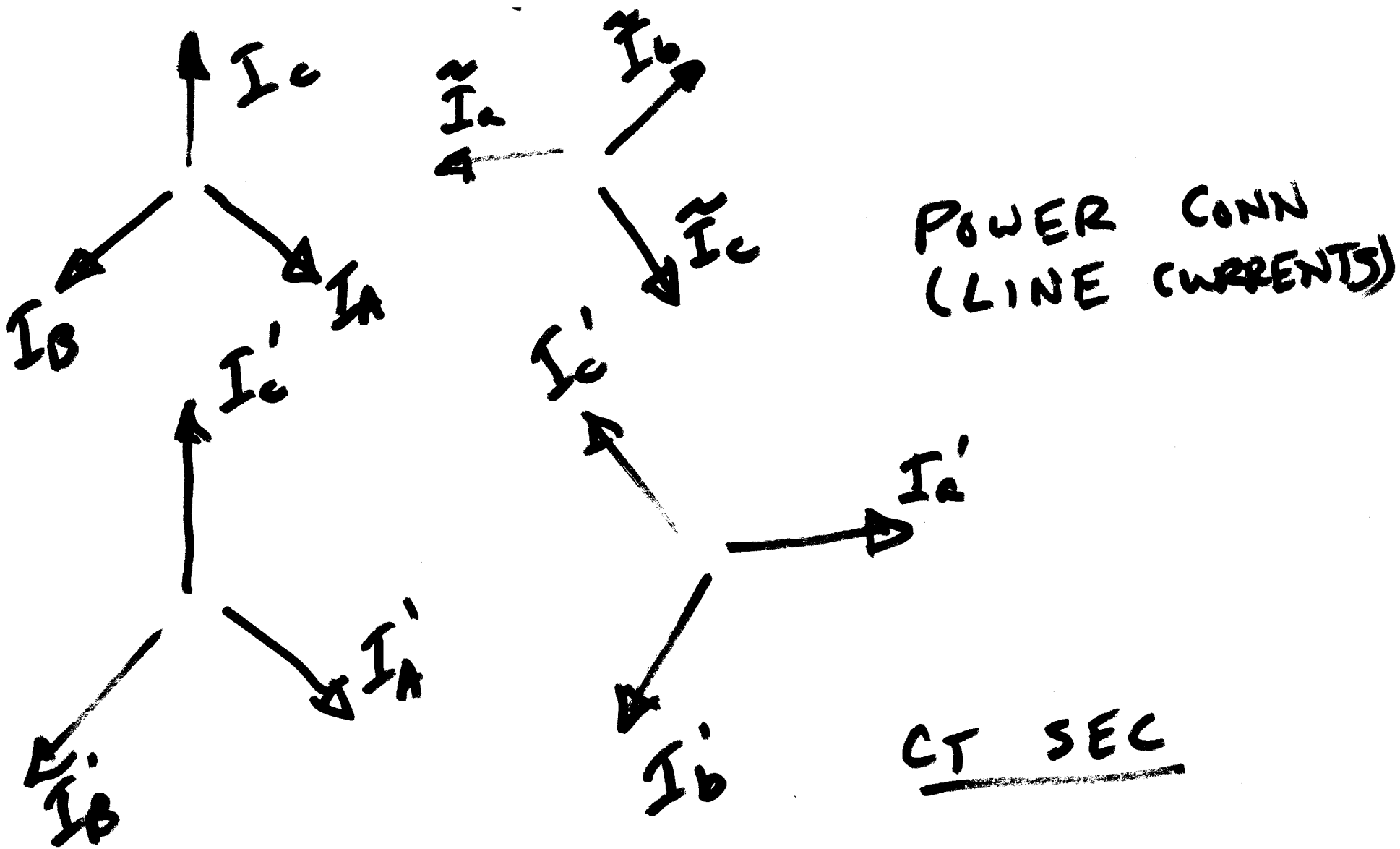
UNITY PF LOAD





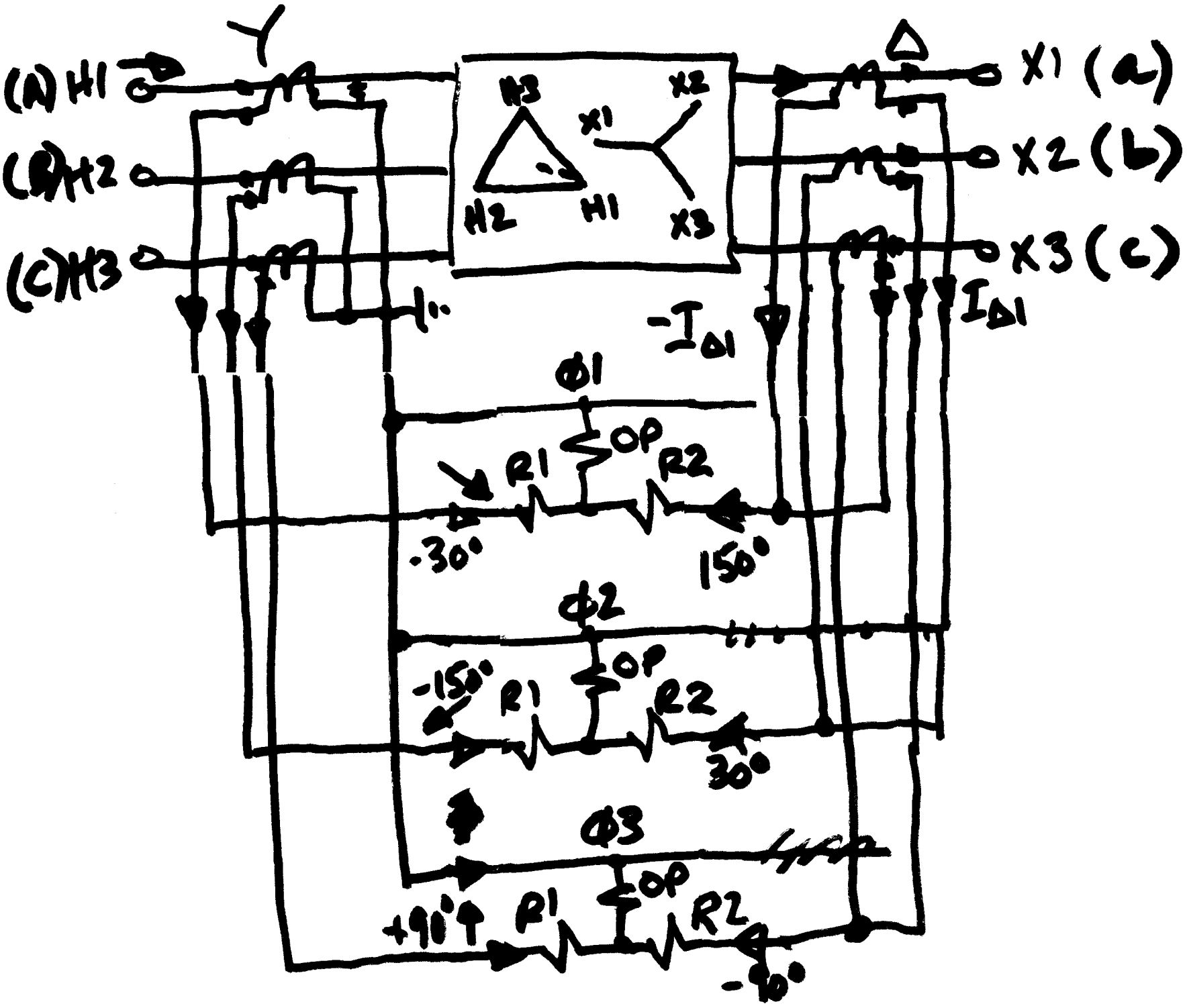


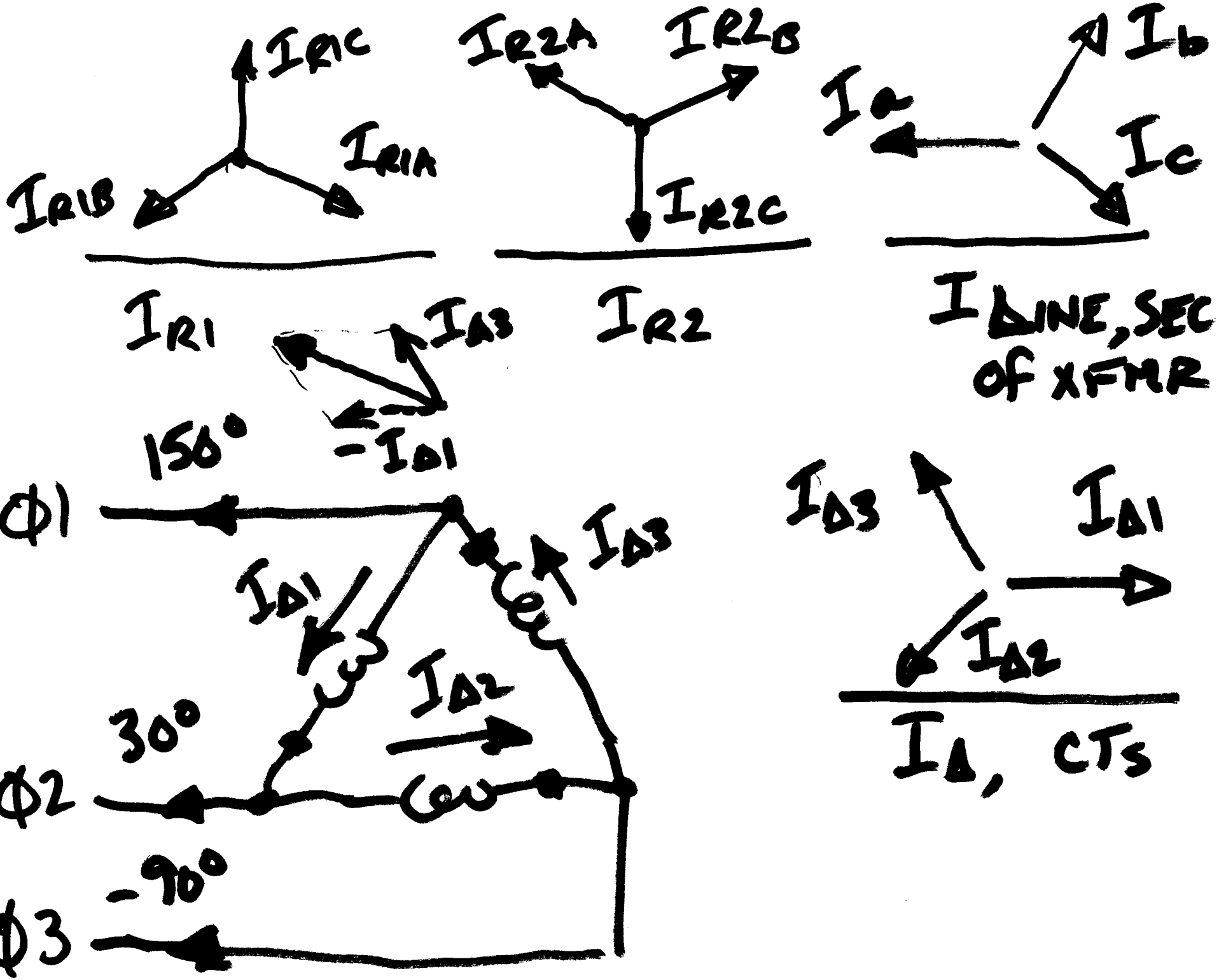
Notes: 1) Source is not drawn/oriented to match voltage phasor diagram (pos seq).
2) Load is oriented to match pos seq V's.

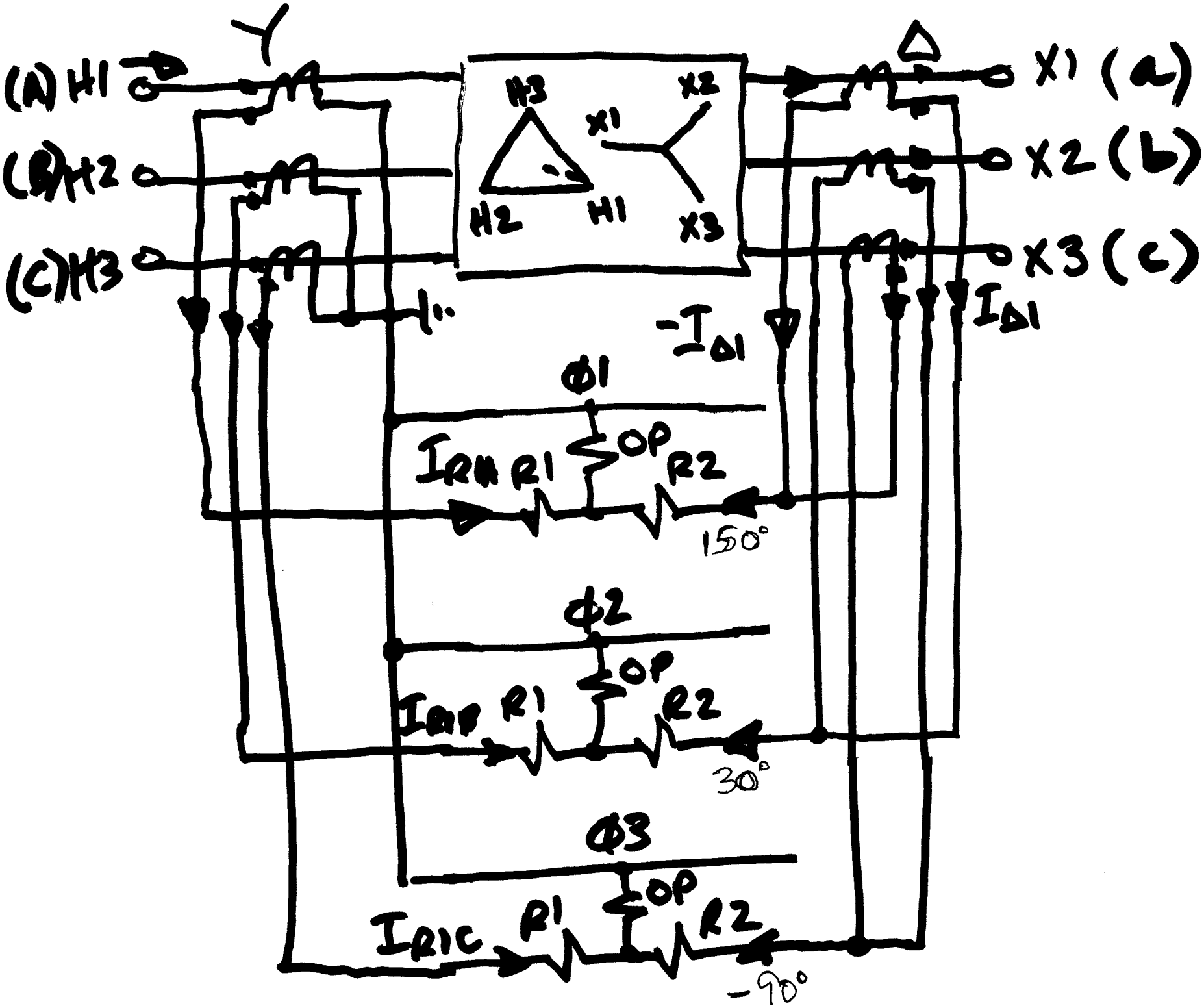


POWER CONN
(LINE CURRENTS)

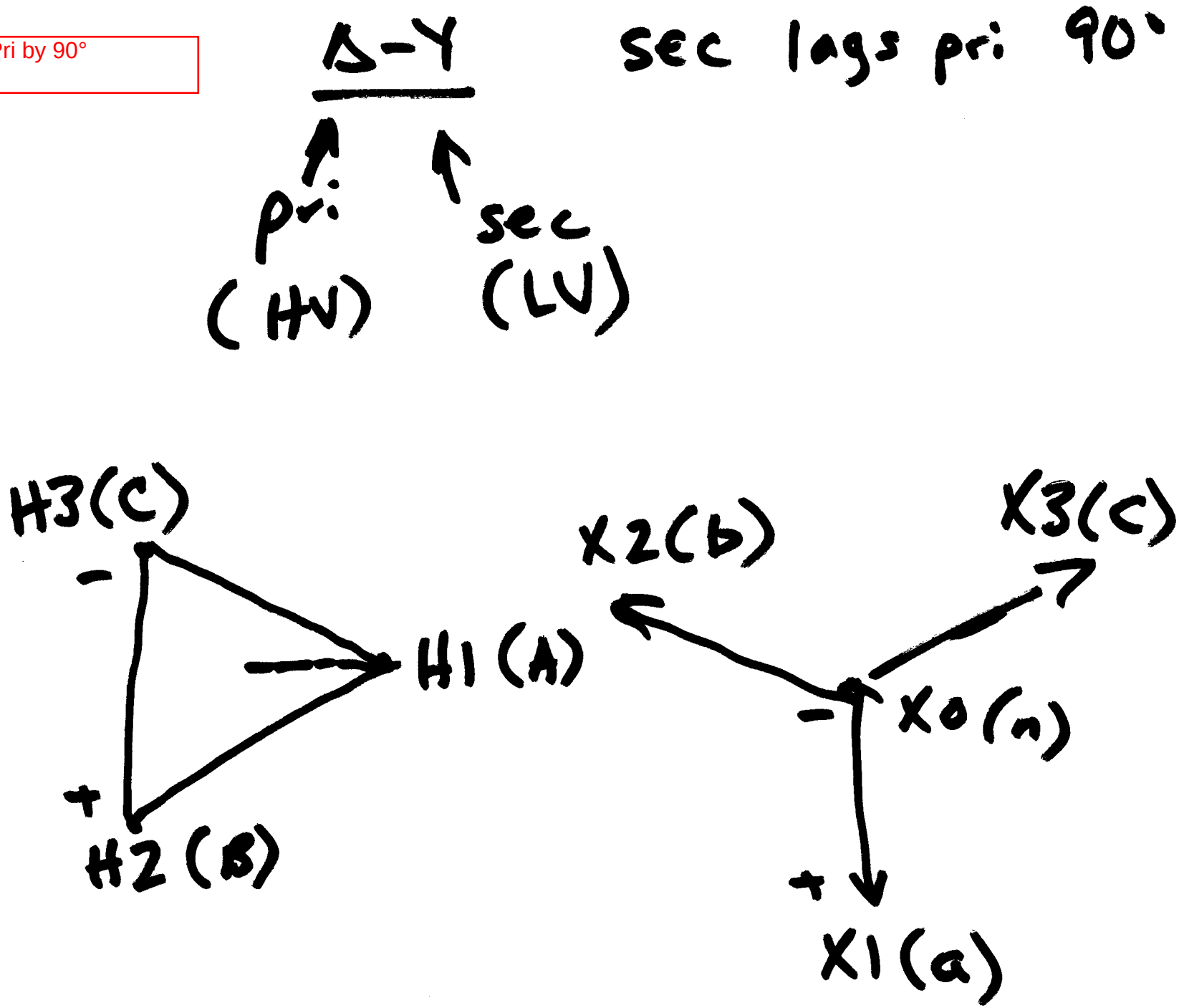
CT SEC

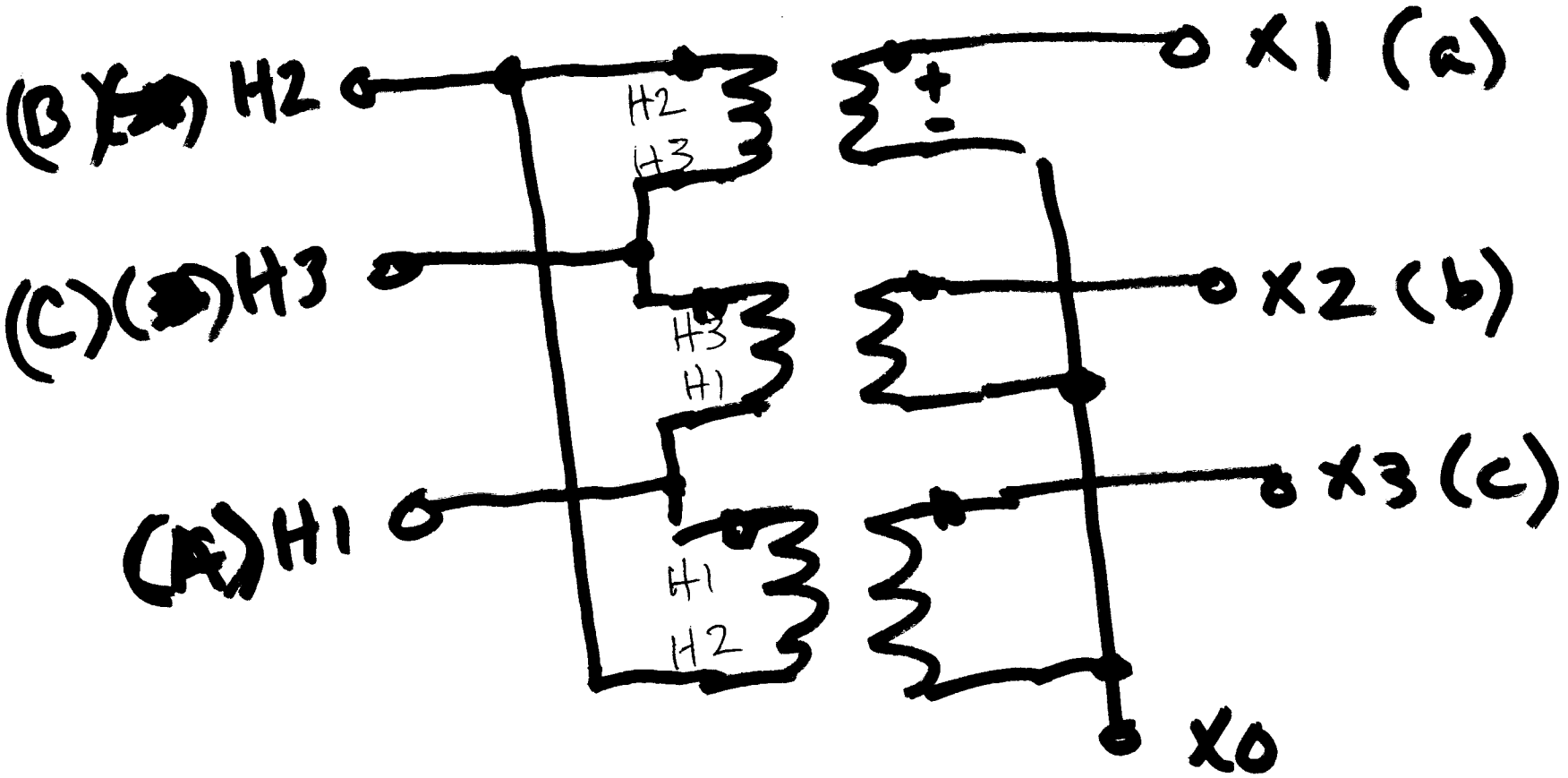

(A) H1
(B) H2
(C) H3
Y
H3
X2
X1
H2
H1
X3
Δ
X1 (a)
X2 (b)
X3 (c)
$I_{\Delta 1}$
$-I_{\Delta 1}$
Φ1
OP
R1
R2
-30°
150°
Φ2
-150°
30°
Φ3
+90°
-90°


I_{R1C}
I_{R1A}
I_{R1B}
I_{R1}
I_{R2A}
I_{R2B}
I_{R2C}
I_{R2}
I_a
I_b
I_c
$I_{\Delta LINE,SEC}$ of XFMR
$I_{\Delta 3}$
$-I_{\Delta 1}$
150°
$\phi 1$
$I_{\Delta 1}$
$I_{\Delta 3}$
$I_{\Delta 2}$
30°
$\phi 2$
-90°
$\phi 3$
$I_{\Delta 3}$
$I_{\Delta 1}$
$I_{\Delta 2}$
I_Δ, CTs

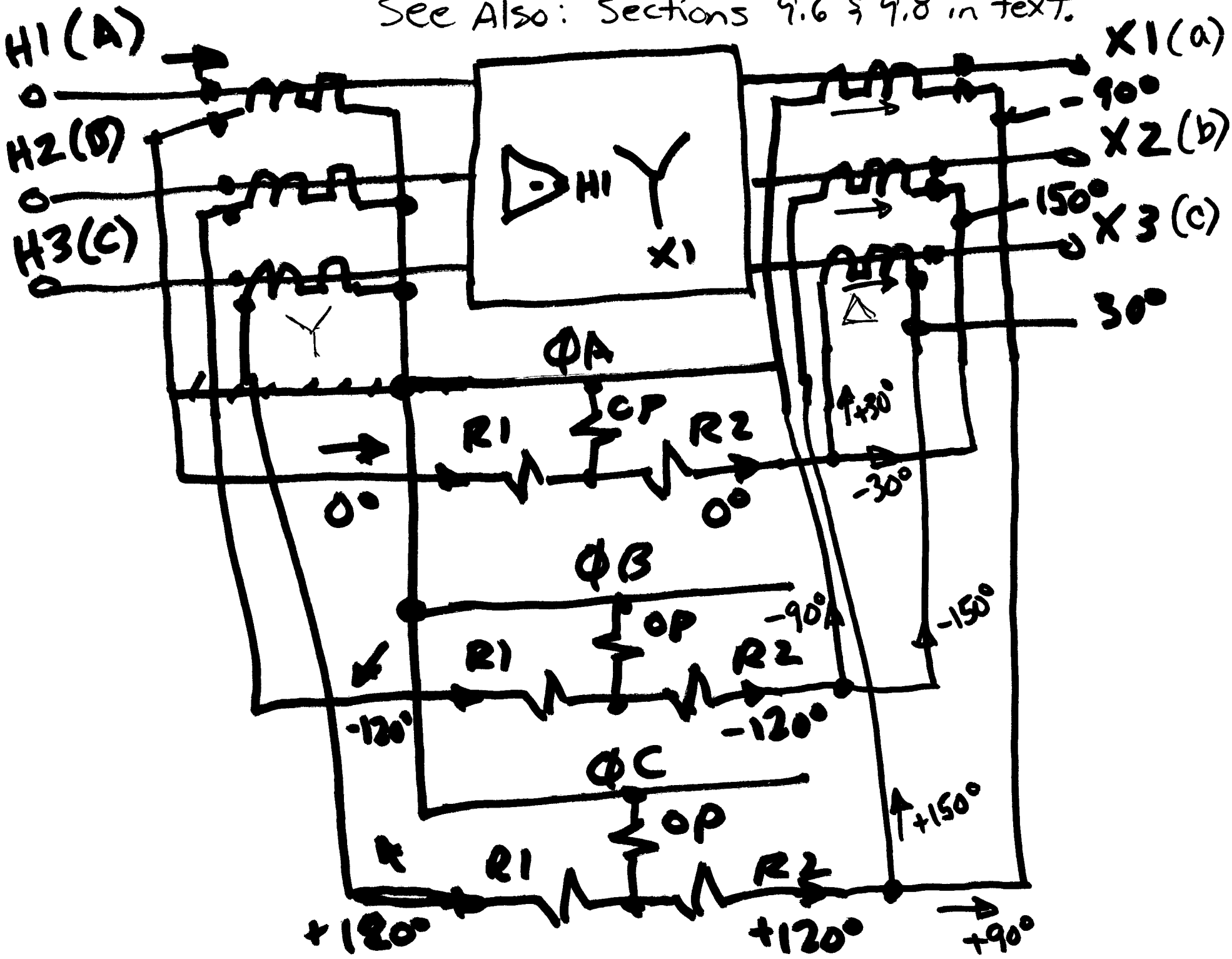

(A) H1
(B) H2
(C) H3
Y
H3
X2
X1
H2
H1
X3
X1 (a)
X2 (b)
X3 (c)
$I_{\Delta 1}$
$-I_{\Delta 1}$
$\phi 1$
I_{R1A}
R1
OP
R2
150°
$\phi 2$
I_{R1B}
R1
OP
R2
30°
$\phi 3$
I_{R1C}
R1
OP
R2
-90°

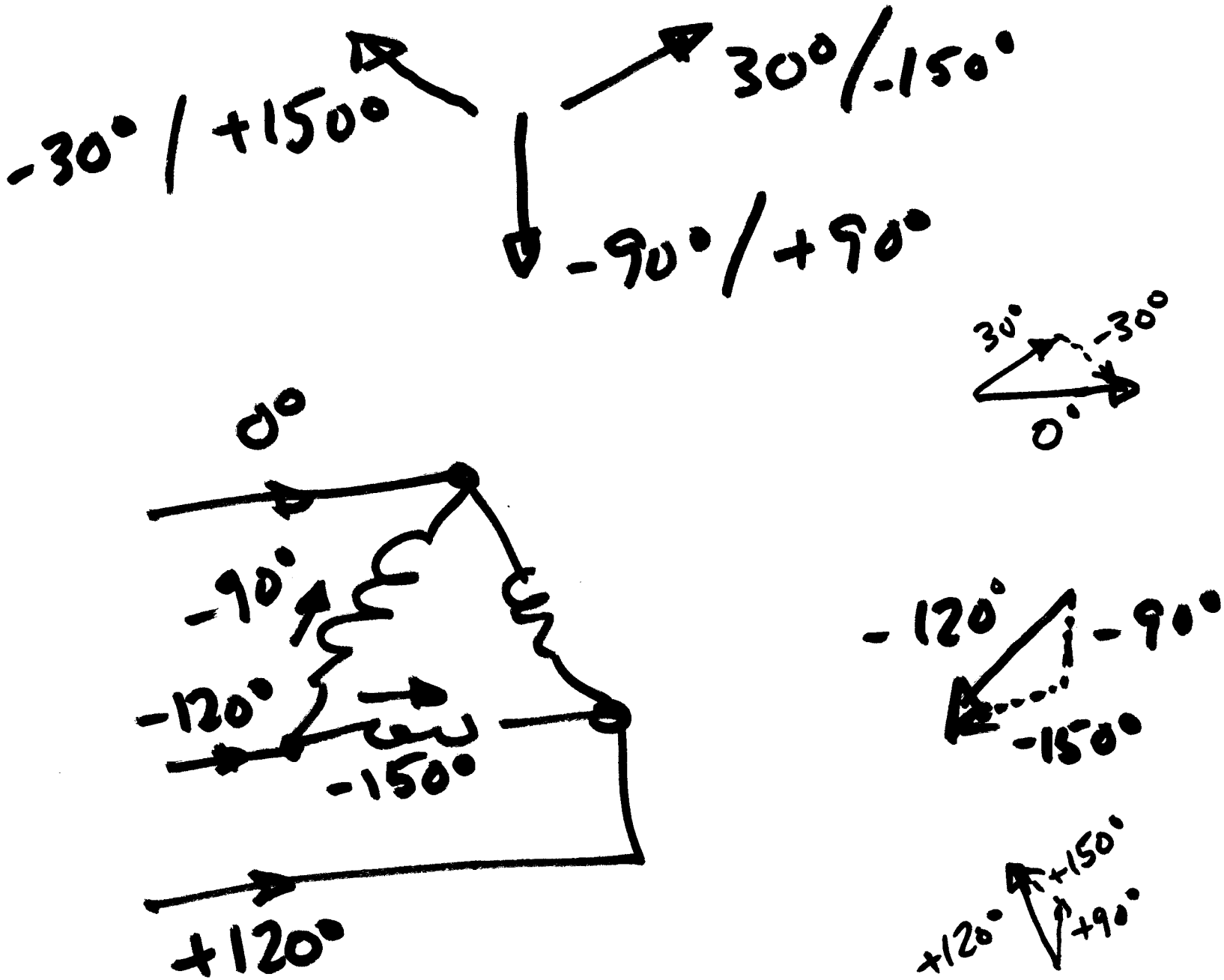
Example 2: Sec lags Pri by 90°

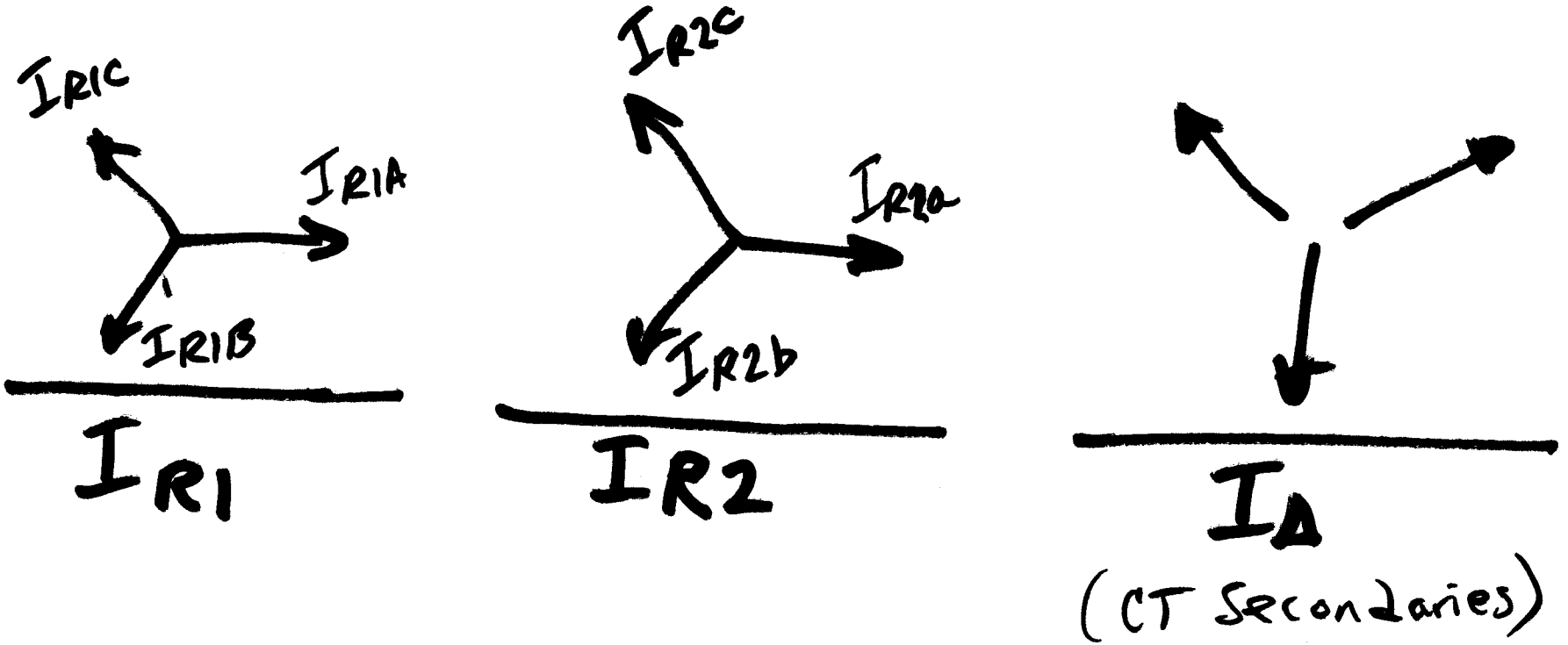



(B) H2
(C) H3
(A) H1
H2
H3
H3
H1
H1
H2
+
-
X1 (a)
X2 (b)
X3 (c)
X0

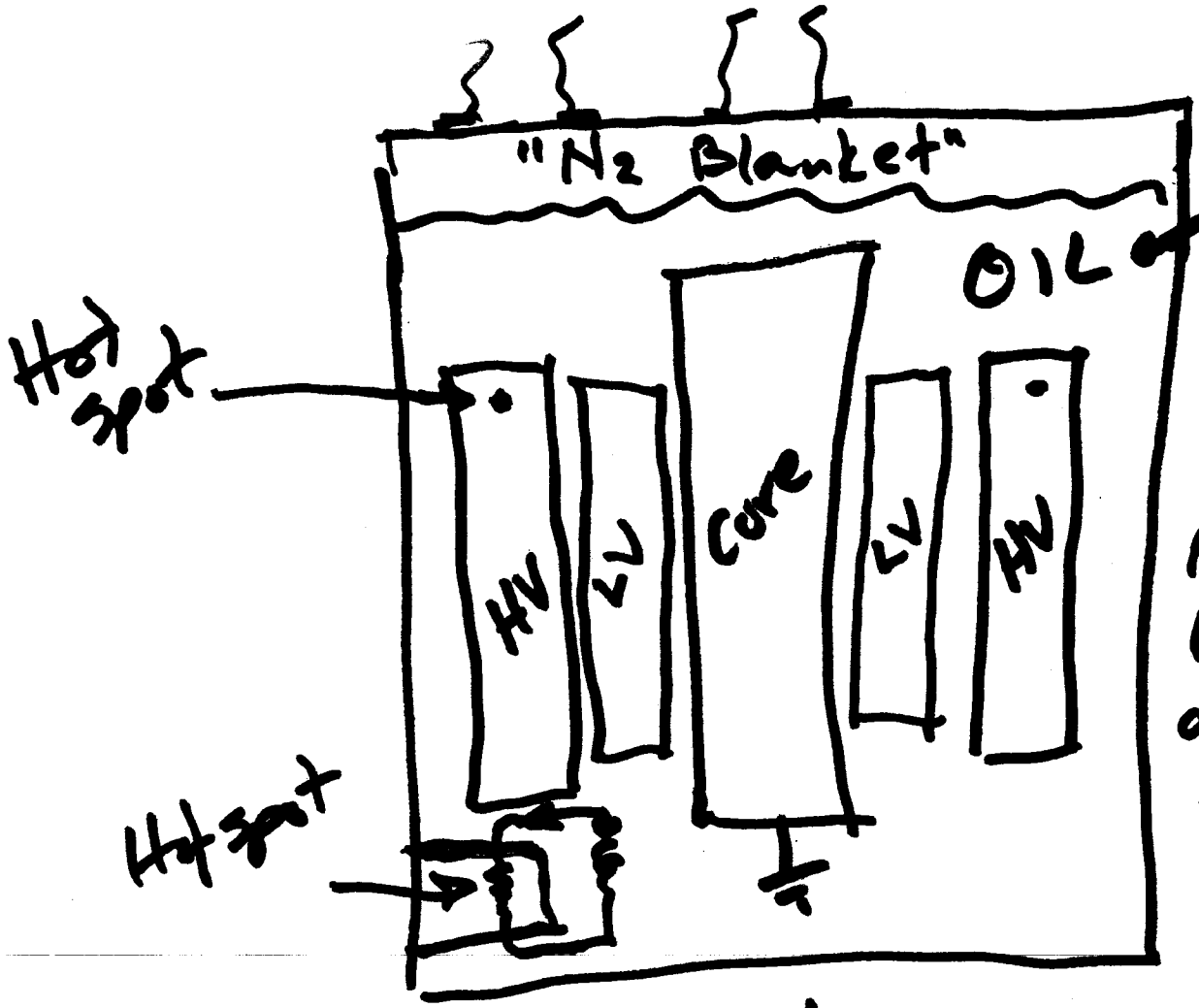
See Also: Sections 9.6 & 9.8 in text.




-30° / +150°
300°/-150°
-90°/+90°
30°
-30°
0°
0°
-90°
-120°
-150°
+120°
-120°
-90°
-150°
+150°
+120°
+90°



Another way to do "book keeping"



$= P_{NL}$

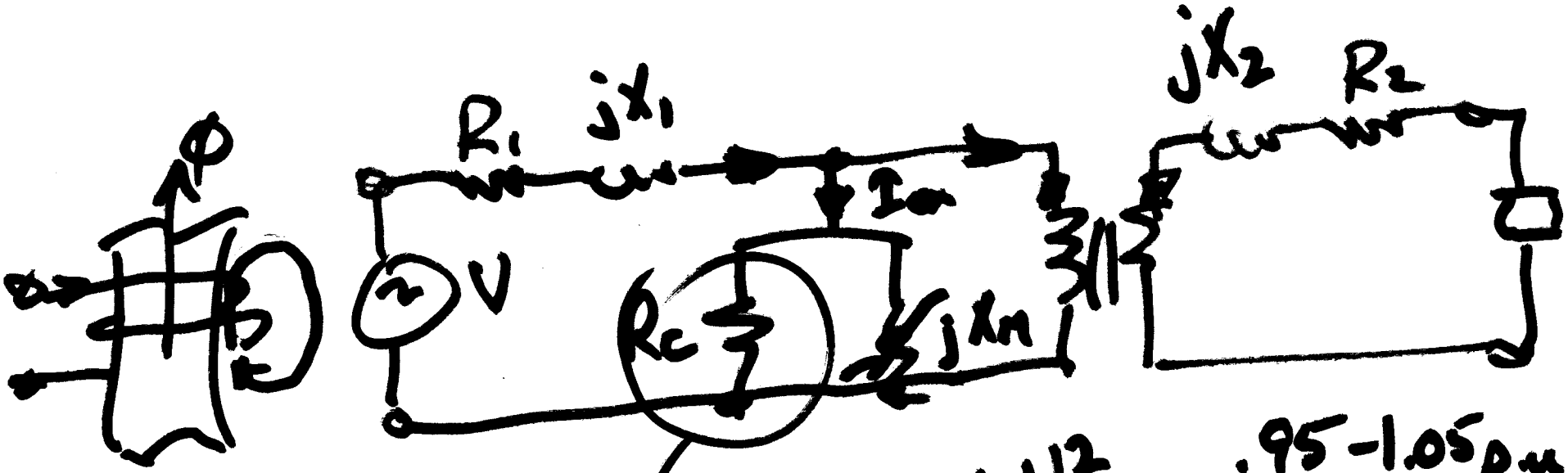
$P_{core} \propto \frac{V^2}{R_c}$

Heat: Core: R_c I_m

Coils: R_1 R_2 R_{EQ}

$P_{coil} \propto I^2 R_{EQ}$

$= P_{LOAD}$



$P_{NL} = P_{core} \propto V^2$

.95 - 1.05 pu

$\Rightarrow \pm 10\%$