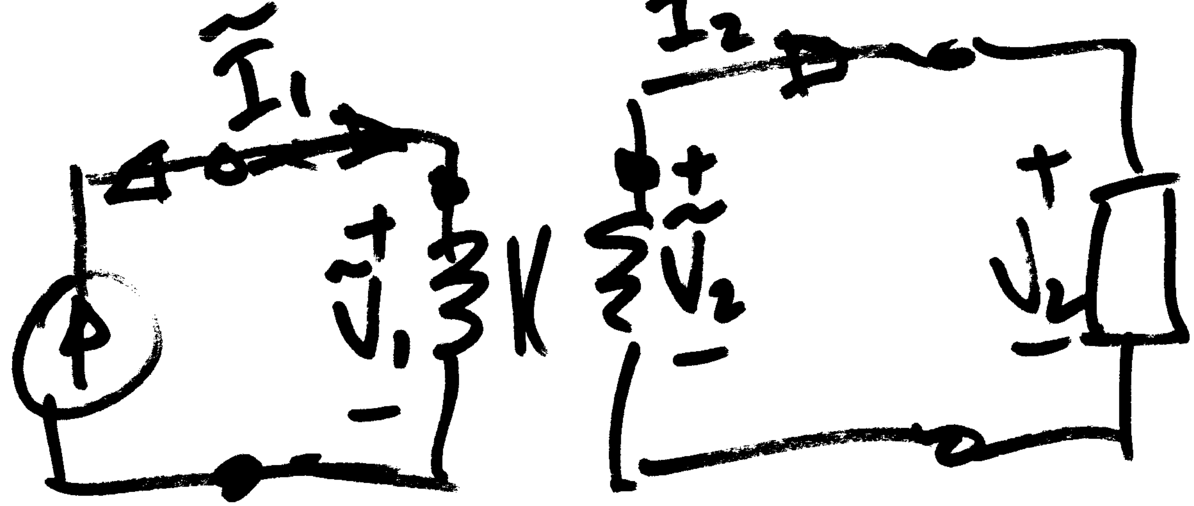
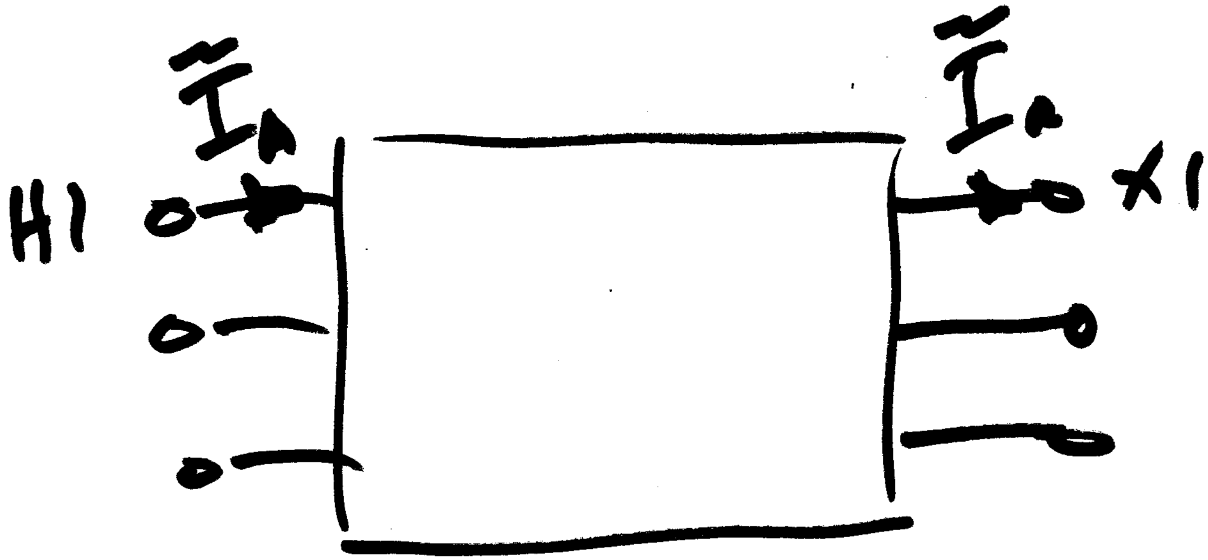
EE 5200 - Lecture 8 Wednesday Sep 18, 2019

Topics for Today:

- Announcements
  - Matlab -- Off-campus use remote desktop: remote.mtu.edu
  - Learning Center hrs: TBA
  - TA Office Hrs: EERC SB27 - to be confirmed..
  - Office: EERC 614. Phone: 906.487.2857
  - Matlab exercises to be posted on web page.
  - Recommended problems from Ch.2, solutions posted

- XFMR, Chapter 2 - Transformers and circuits w/transformers
  - Pre-Req Videos 3-6 - View them, study notes !
  - Single phase ideal transformer is building block - V, I, dot convention !
  - 3-phase transformer banks and phase shifts (ANSI/IEEE vs. IEC)
  - Standard 30°shift transformers, non-standard connections
  - Pos/neg sequence phase shifts, sequence networks.
  - Autotransformers
  - Load Tap Changing (LTC) transformers
  - Phase shifting transformers
  - Paralleling transformers with a) unlike impedances; b) unlike tap positions
  - Three-winding transformers

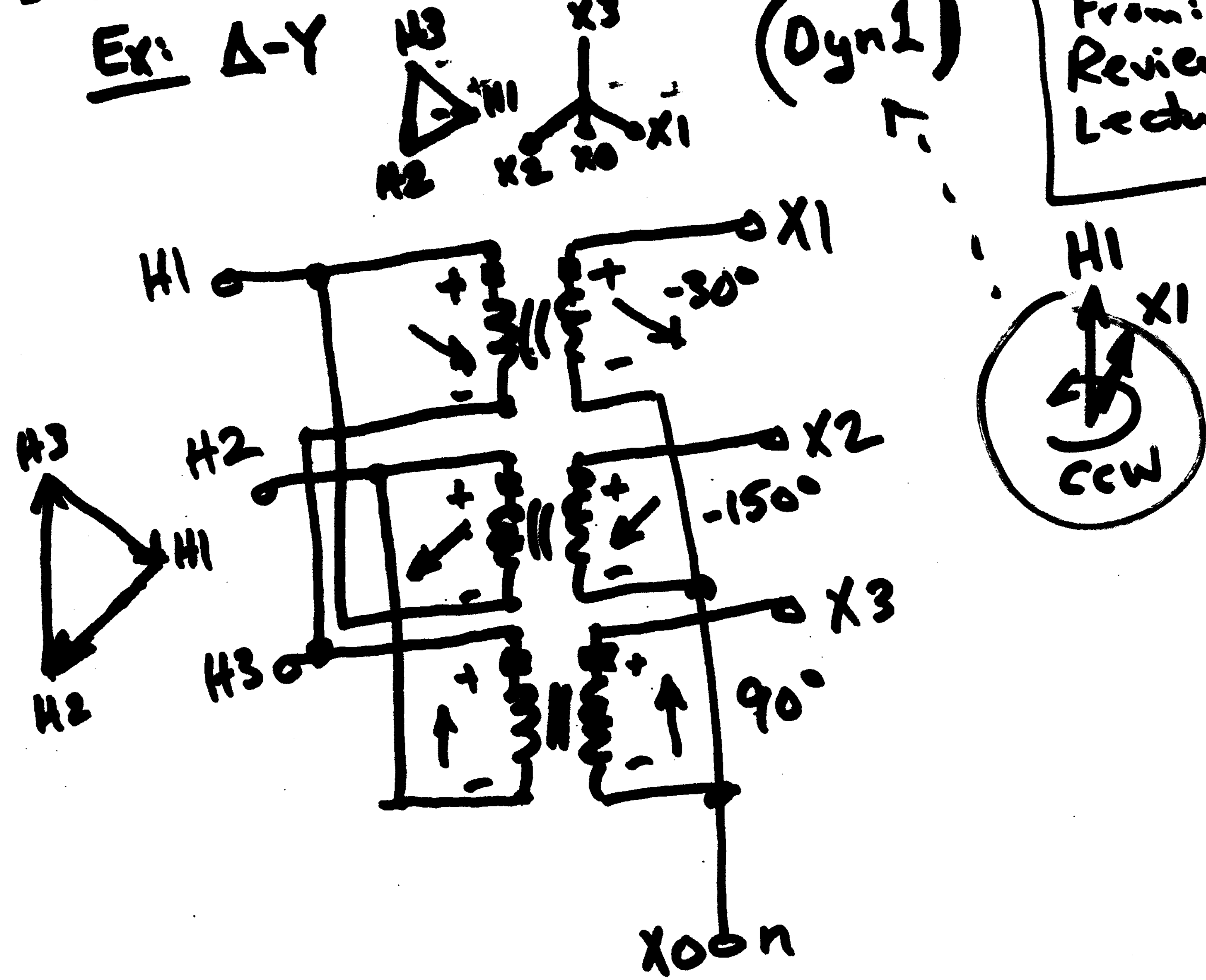
$$a_{eff} = \frac{|\tilde{V}_{LN}|_{PRI}}{|\tilde{V}_{LN}|_{SEC}} = \frac{|\tilde{V}_{LL}|_{PRI}}{|\tilde{V}_{LL}|_{SEC}}$$

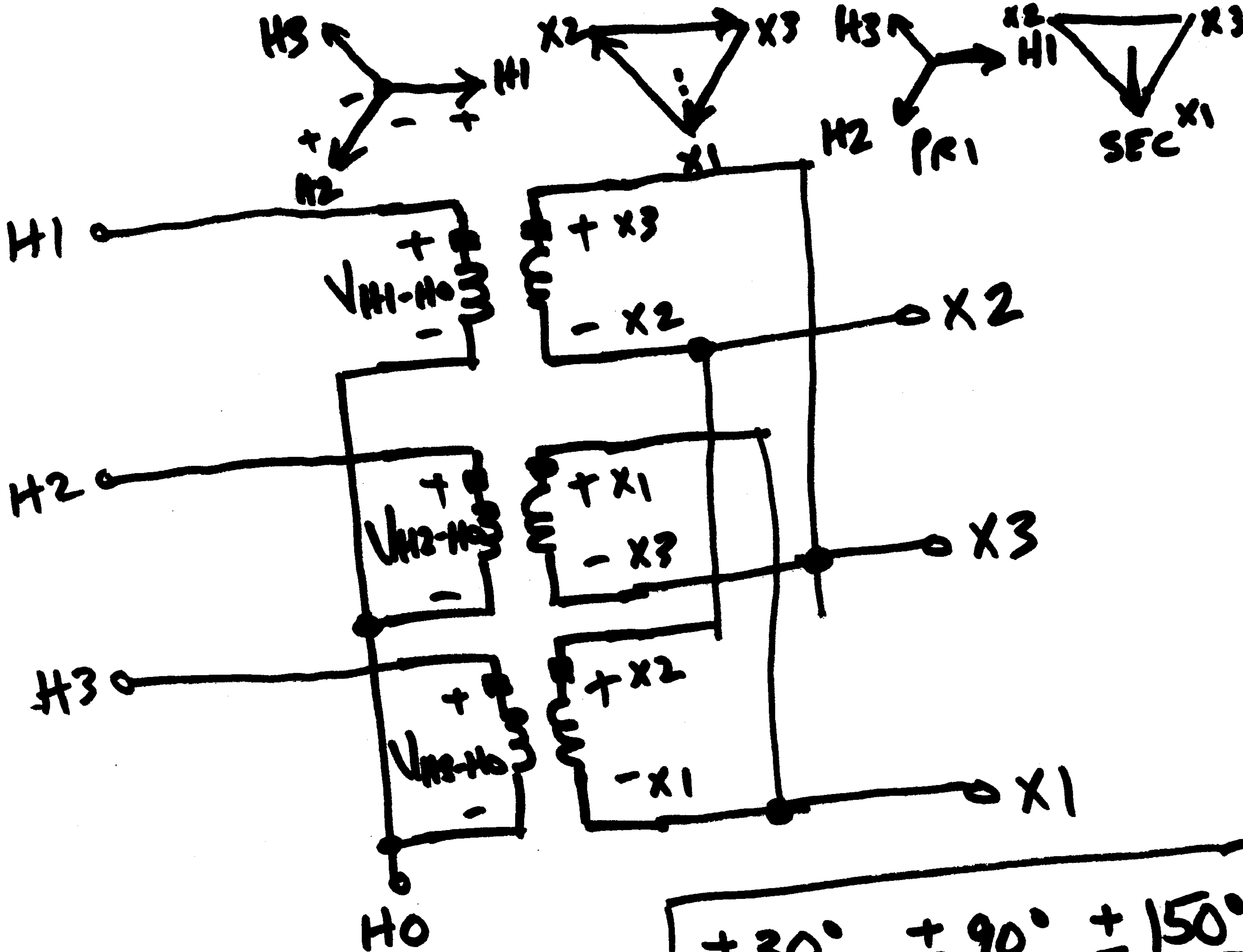

Ĩ1
Ṽ1
Ĩ2
Ṽ2
V2

ĨA
H1
ĨA
X1

3-PHASE XFMR BANKS

Ex: Δ-Y (Dyn1)

From: Review Lecture 5

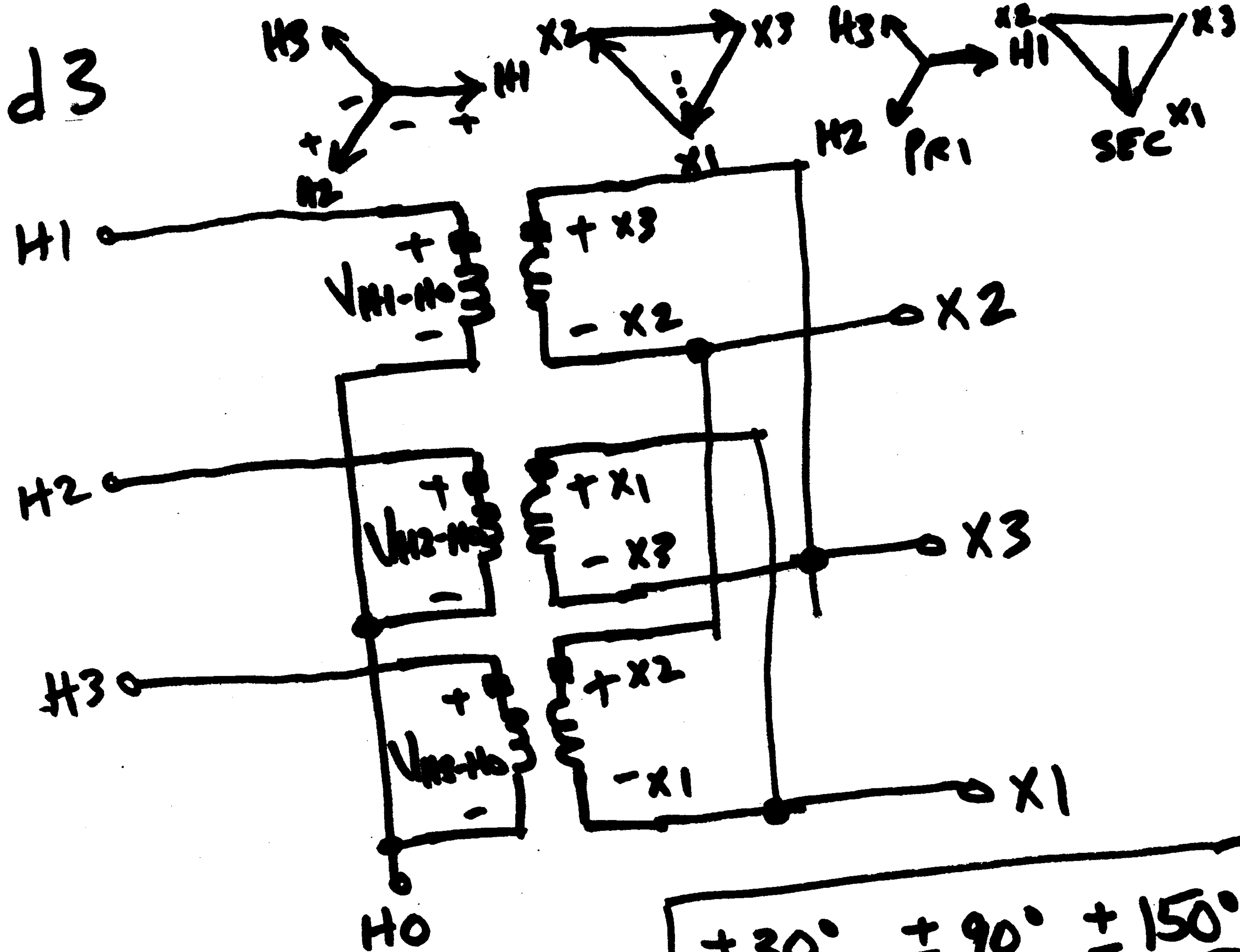




H3
H1
H2
+
-
X2
X3
X1
H3
H1
H2
PRI
X2
H1
X3
X1
SEC
H1
H2
H3
+
-
V_{H1-H0}
V_{H2-H0}
V_{H3-H0}
+ X3
- X2
+ X1
- X3
+ X2
- X1
X2
X3
X1
H0

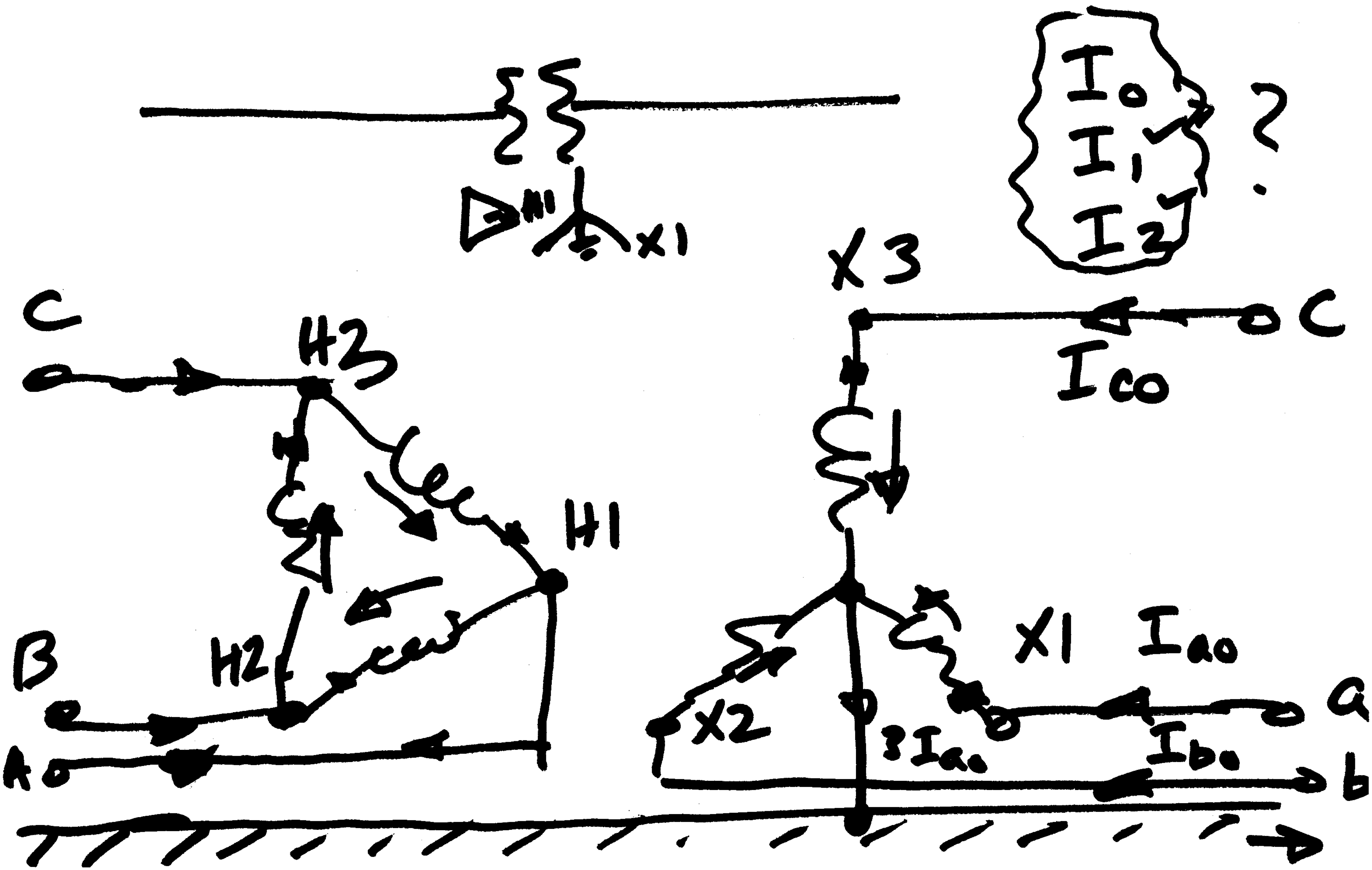
±30°, ±90° ±150°

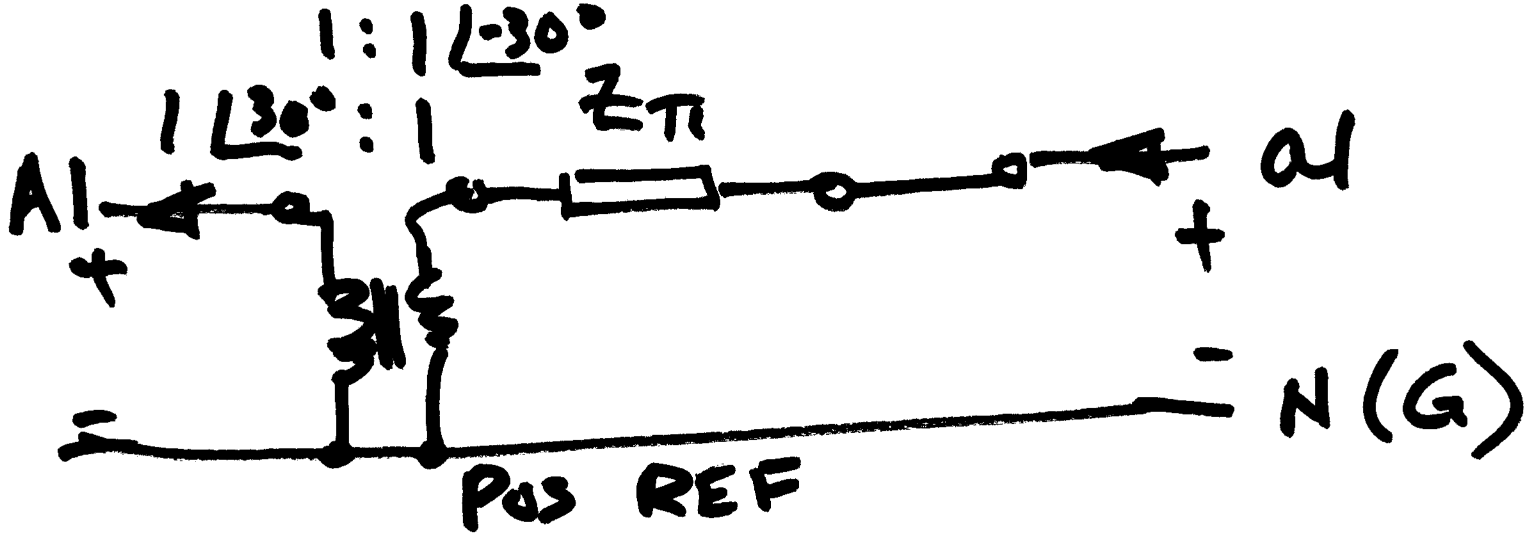
YNd3



±30°, ±90° ±150°

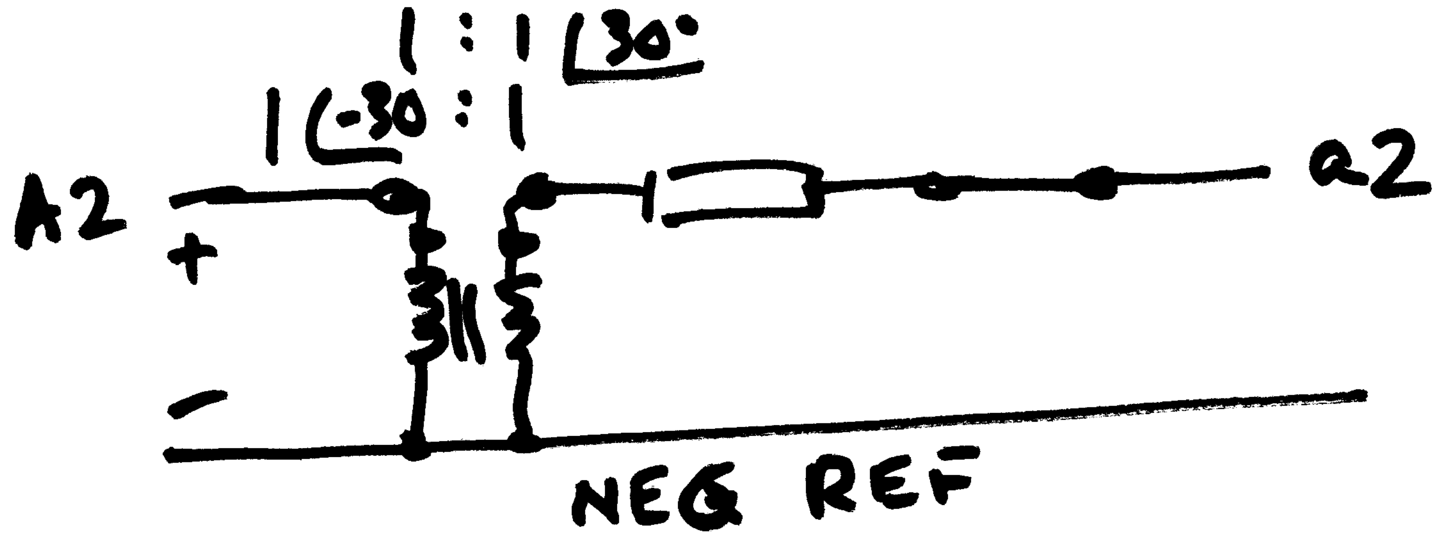
SEQUENCE NETWORKS FOR TRANSFORMERS





Per Phase Equiv :

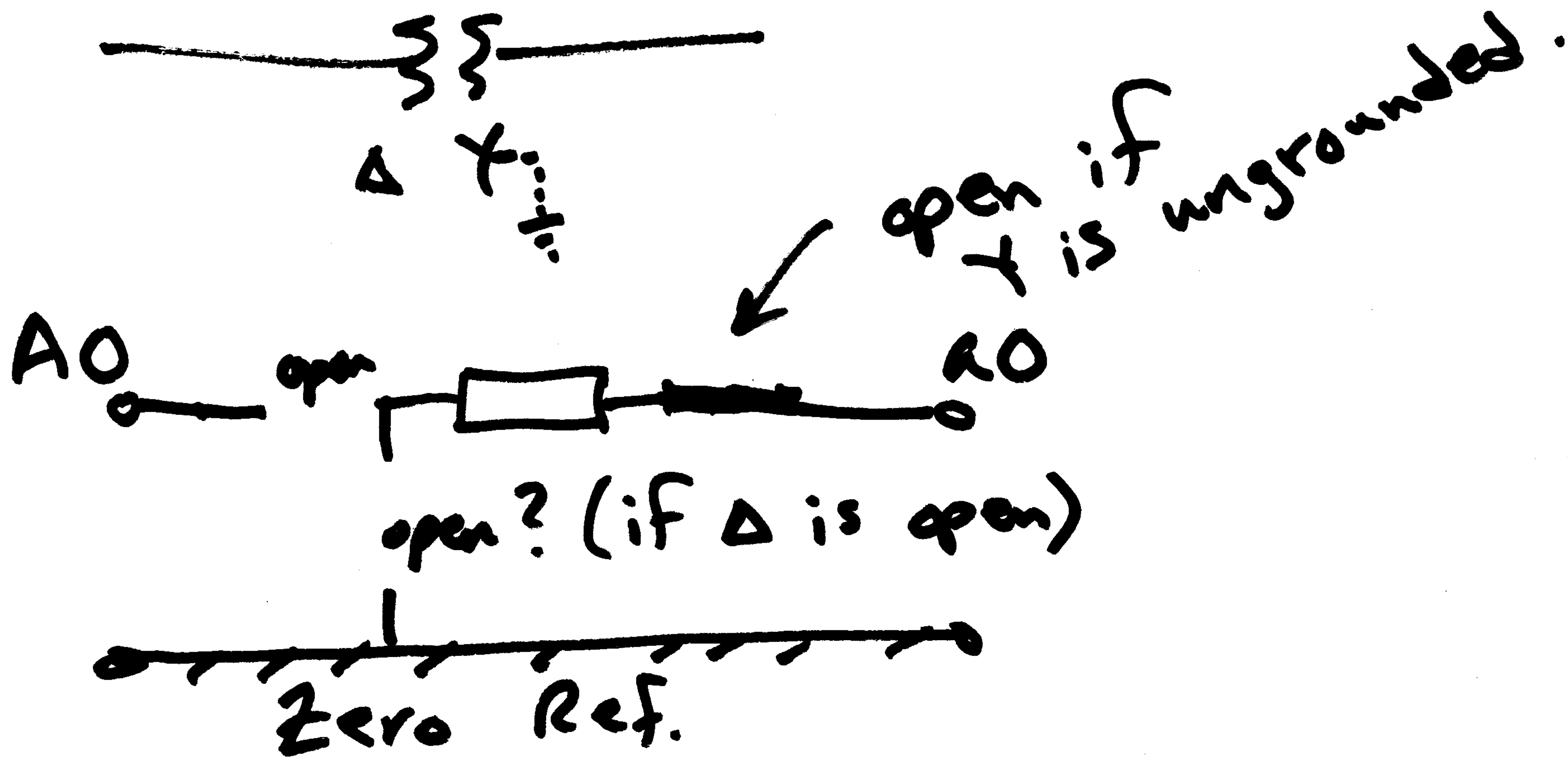
- V_{AN}
- L-N per phase equiv
- Per Unit Values:
  - V
  - I
  - Z
  - Y
  - P
  - Q
  - S



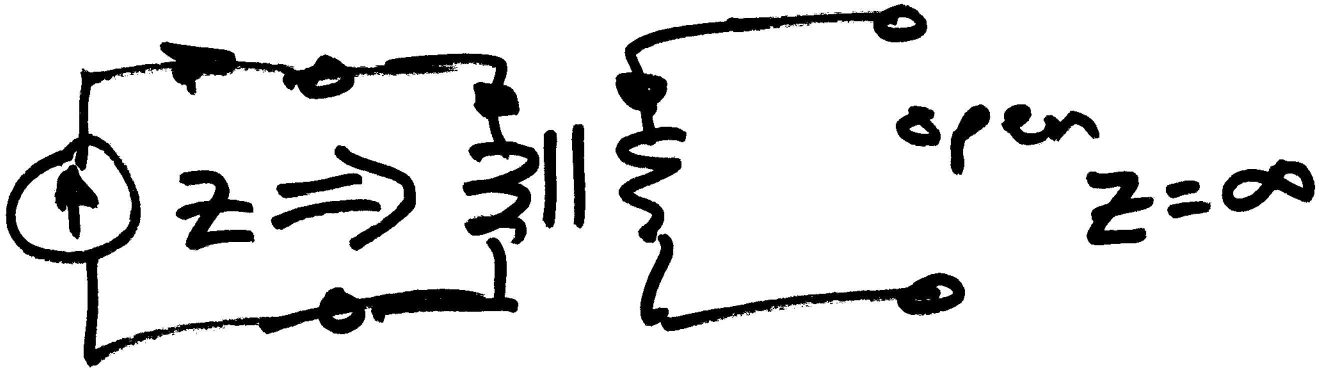
TRAP: Text books have "cook-book" eqns assuming that <u>all</u> transformers are std. 30°. WRONG!

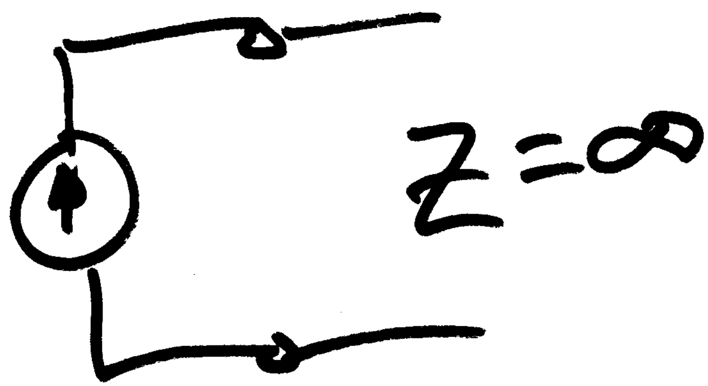
MANY OTHER OPTIONS

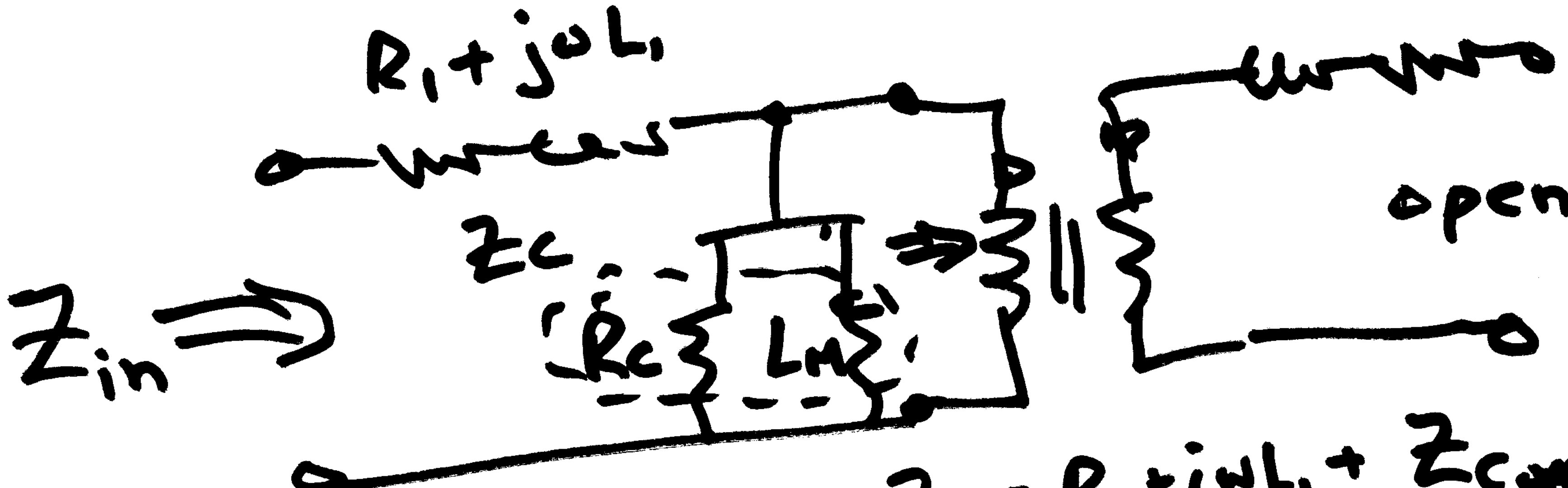
$\pm 30°$, $\pm 90°$, $\pm 150°$ Δ-Y, Y-Δ



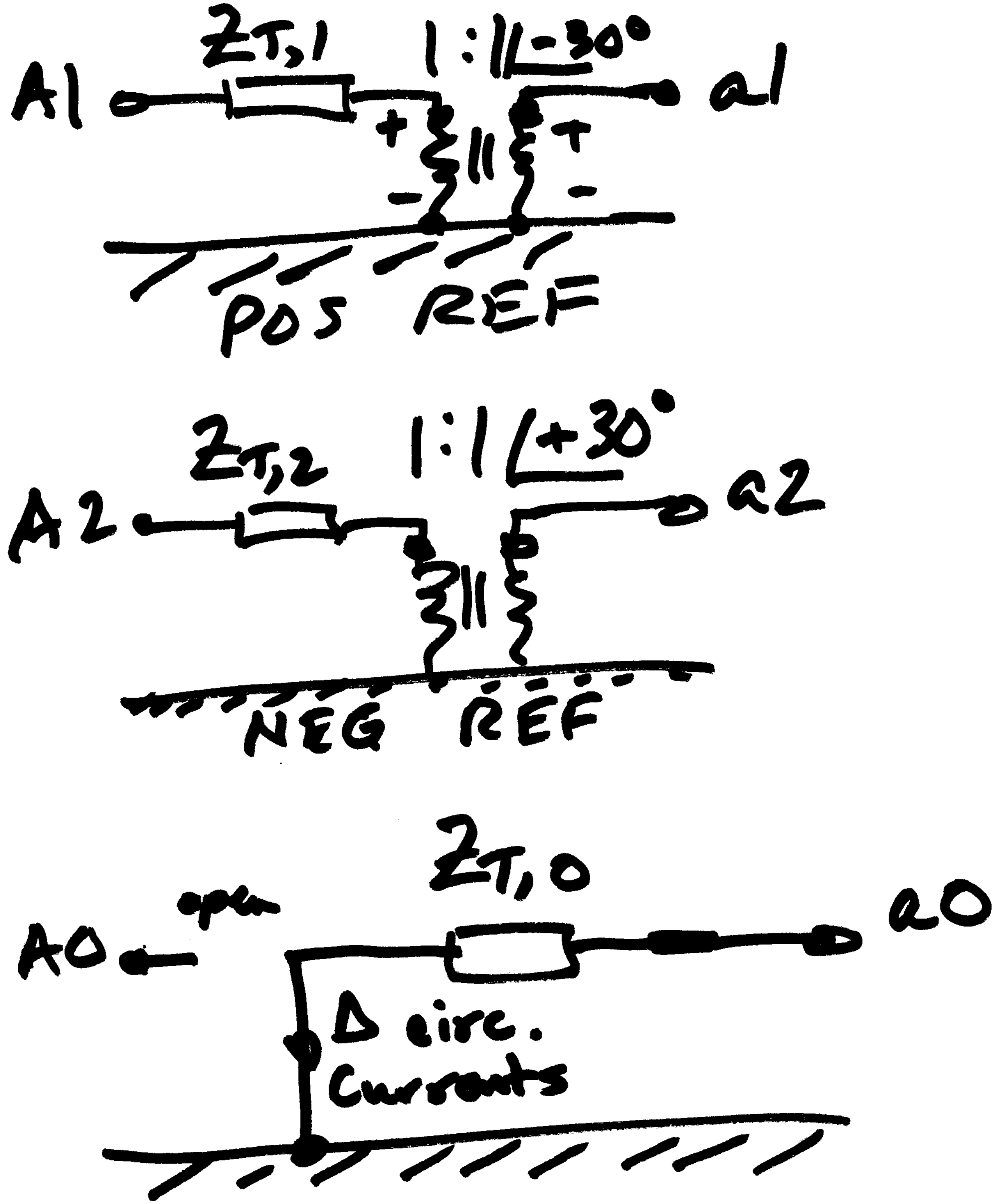
Δ
Y
AO
open
aO
open if Y is ungrounded.
open? (if Δ is open)
Zero Ref.



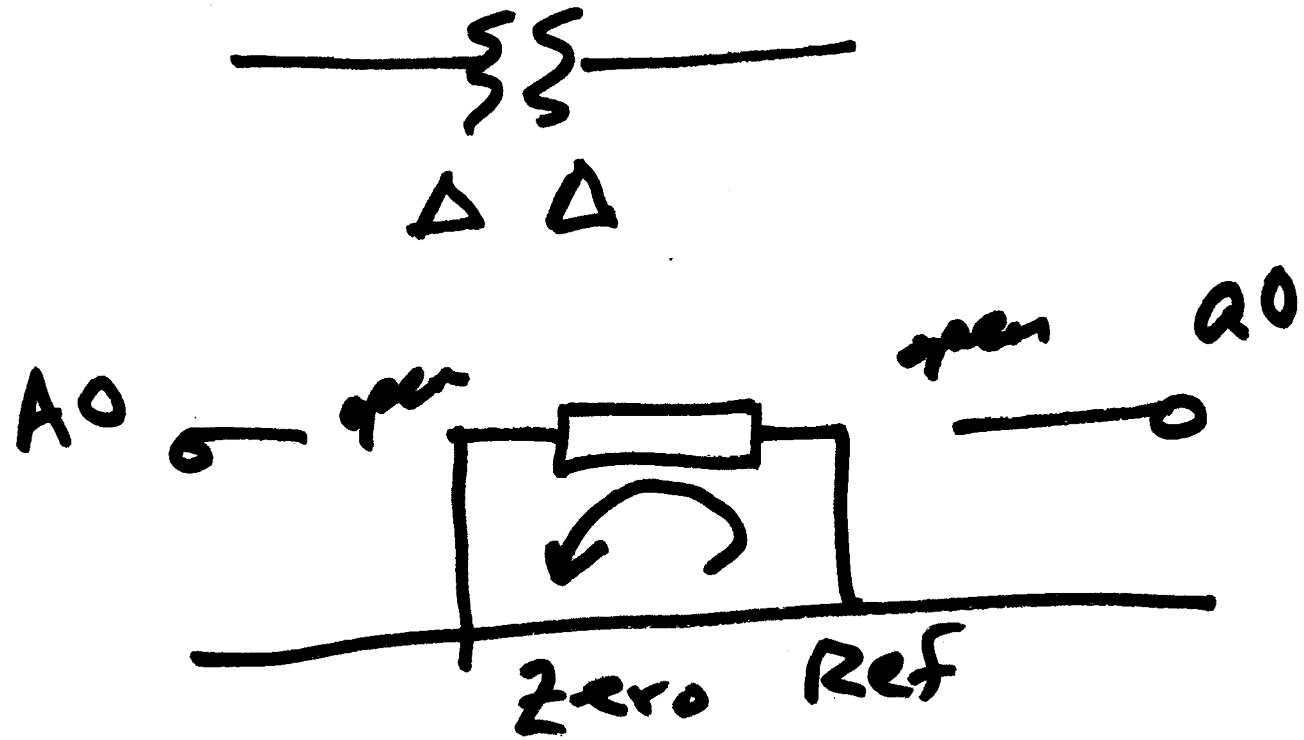




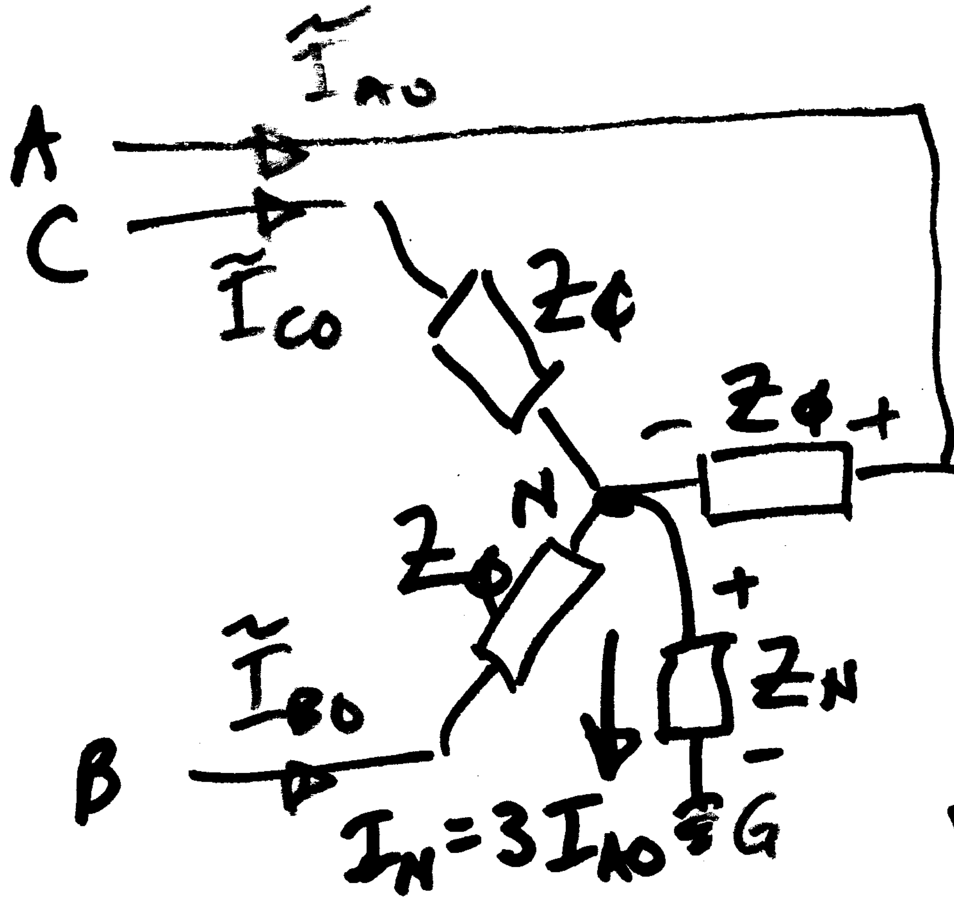
$Z_{in} = R_1 + j\omega L_1 + Z_{core}$



A1
Z T,1
1:1 ∠-30°
a1
+
-
+
-
POS REF
A2
Z T,2
1:1 ∠+30°
a2
NEG REF
A0
open
Z T,0
a0
Δ circ.
Currents

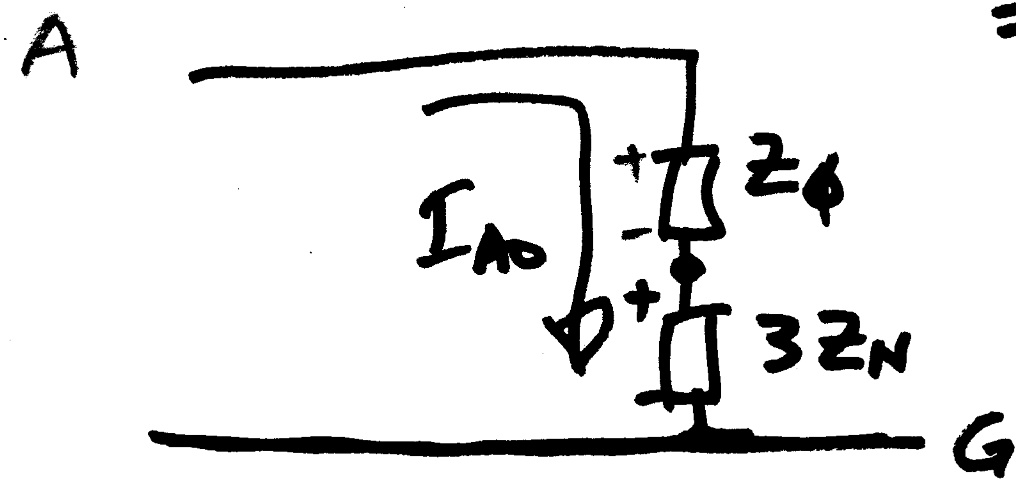


AO
open
open
QO
Zero Ref



$V_{DROP} = 3I_{A0}Z_N$

$= V_{NG}$



triplen harmonics

buried tertiary

buried delta

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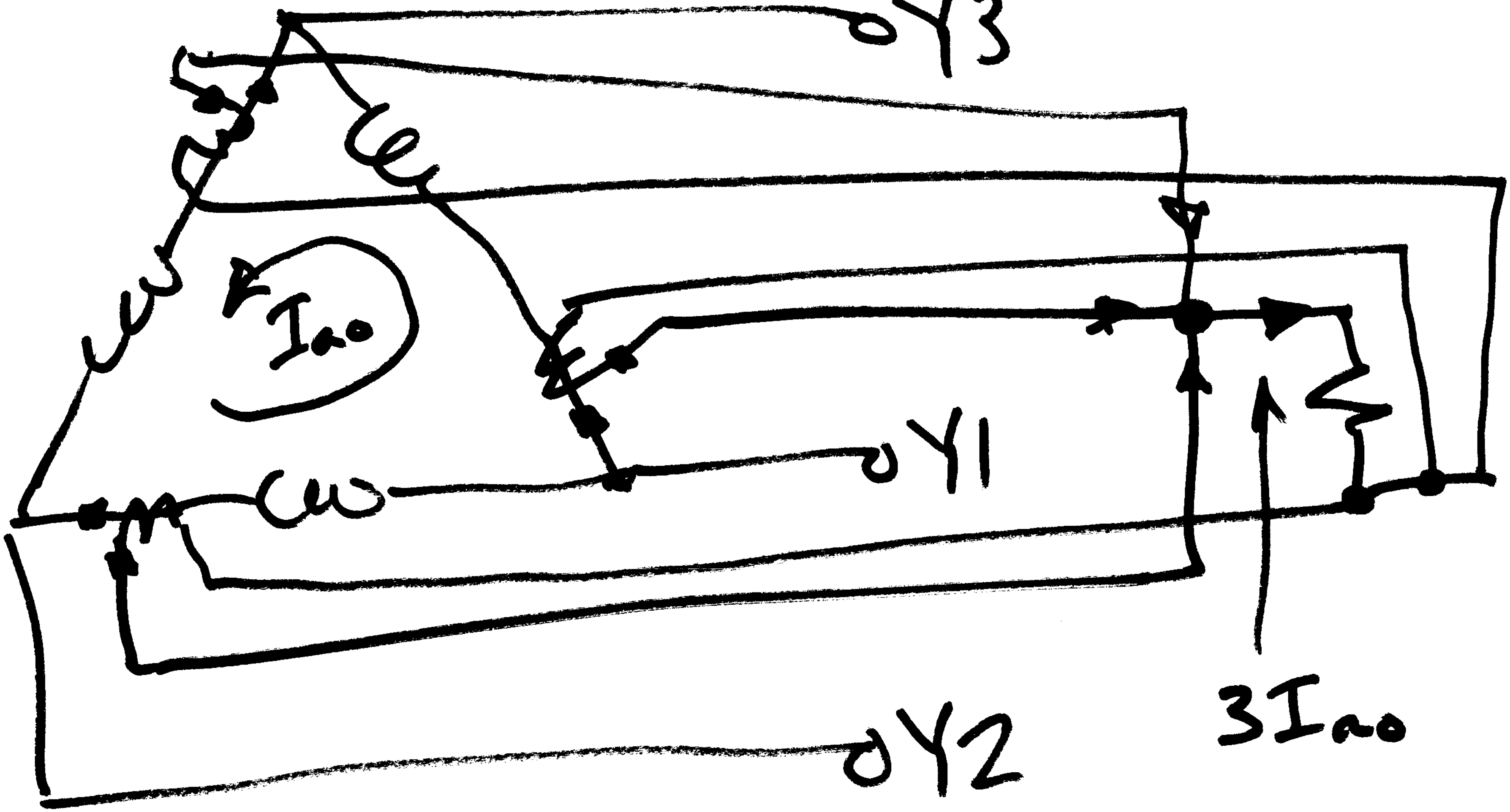
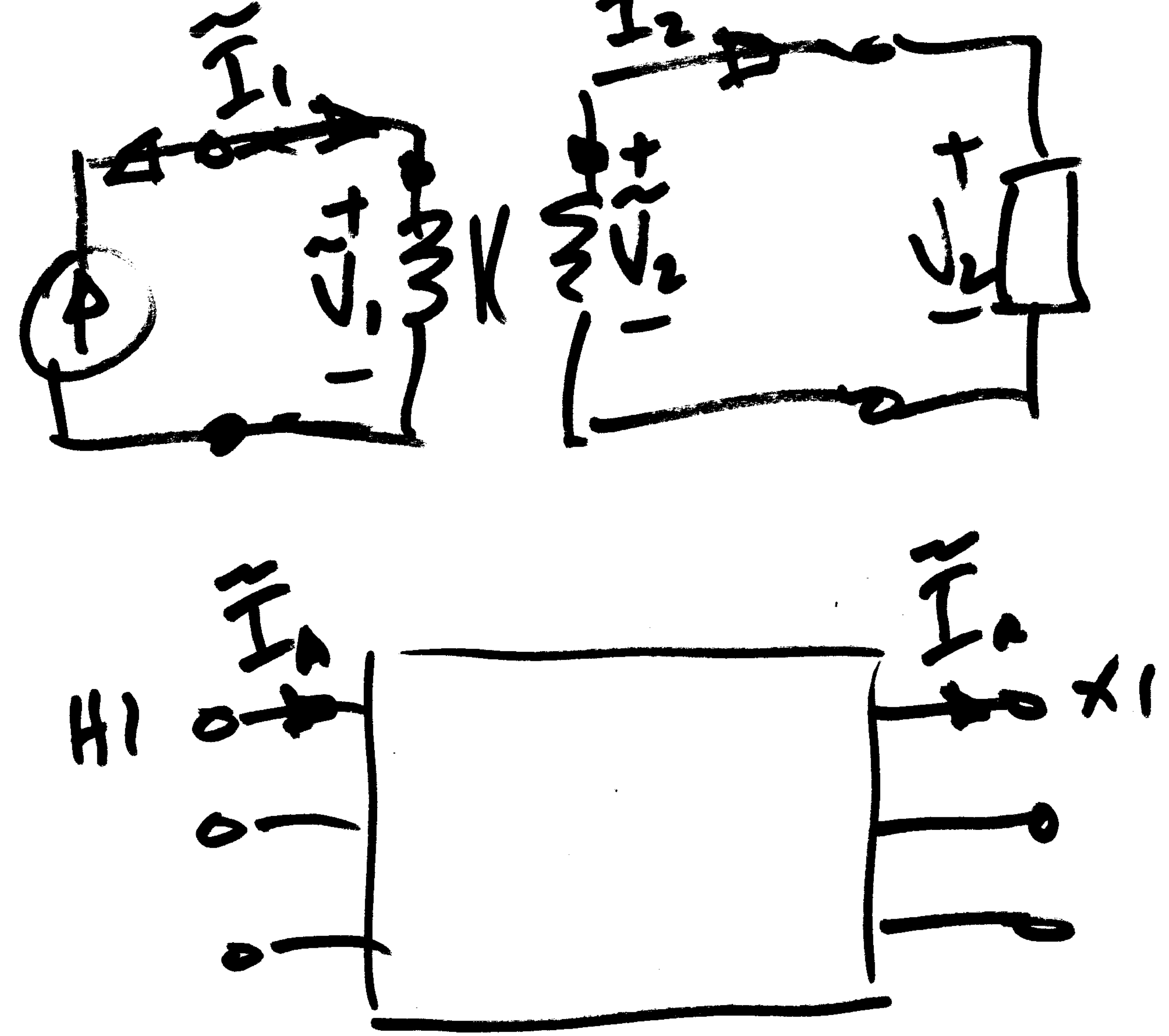
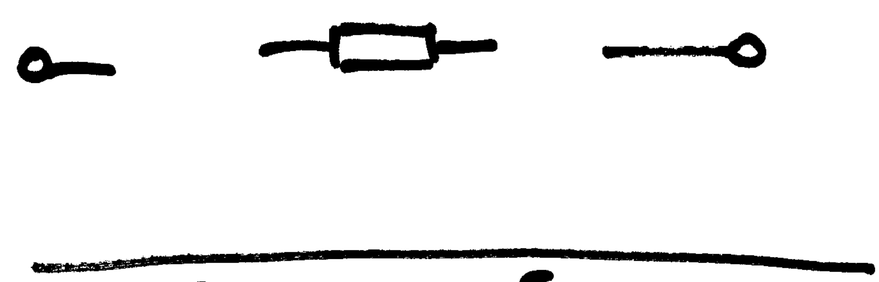
delta:
- trap triplen harmonics
- zero seq circ path
- Aux power (station service)
- Protection
  - CTs


Y3
Y1
Y2
I_ao
3I_ao

$$a_{eff} = \frac{|\tilde{V}_{LN}|_{PRI}}{|\tilde{V}_{LN}|_{SEC}} = \frac{|\tilde{V}_{LL}|_{PRI}}{|\tilde{V}_{LL}|_{SEC}}$$



$\tilde{I}_1$
$\tilde{V}_1$
$\tilde{I}_2$
$\tilde{V}_2$
$\tilde{I}_A$
H1
$\tilde{I}_a$
X1



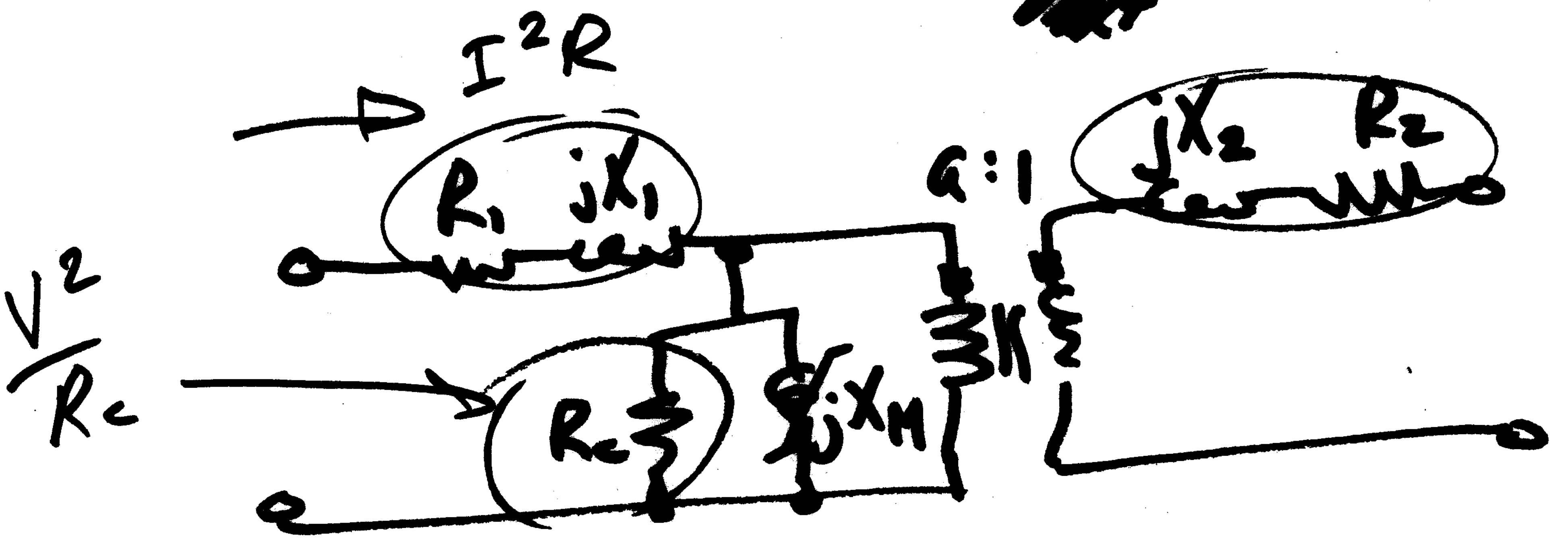
Zero ref.

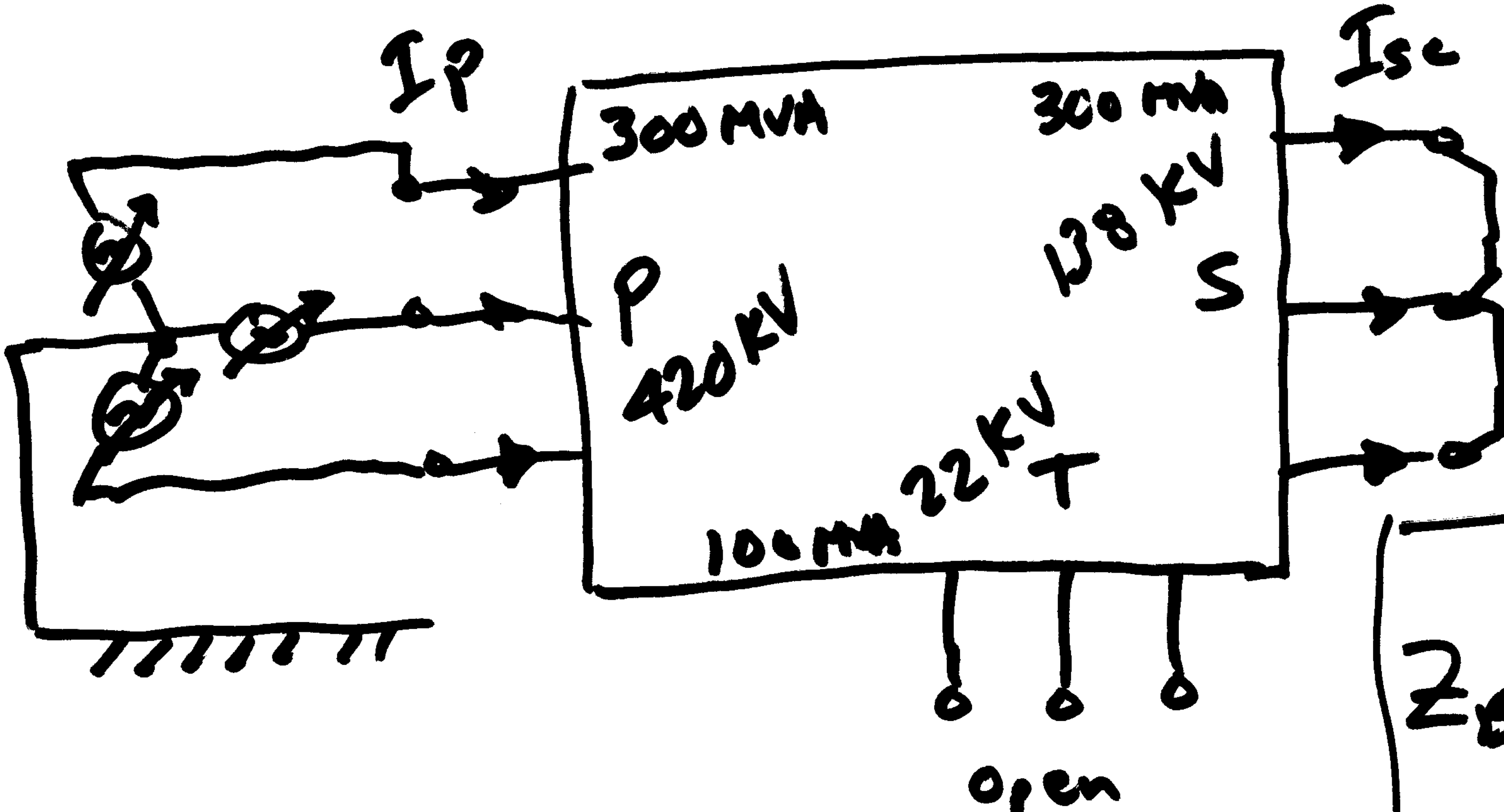
Harmonics:	SEQ
3, 6, 9 ...	0
1, 4, 7 ...	1
2, 5, 8 ...	2

↑ xfmr inrush

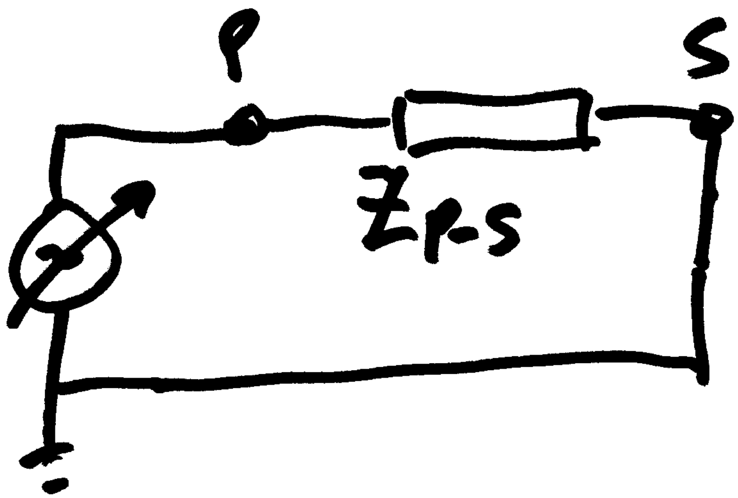
Factory Test Report

- S.C. Impedance (VR, S.C. Studies)
- Loss Evaluations
  - No-load Losses (core) R_c
  - Load Losses $R_1 + R_2 a^2$

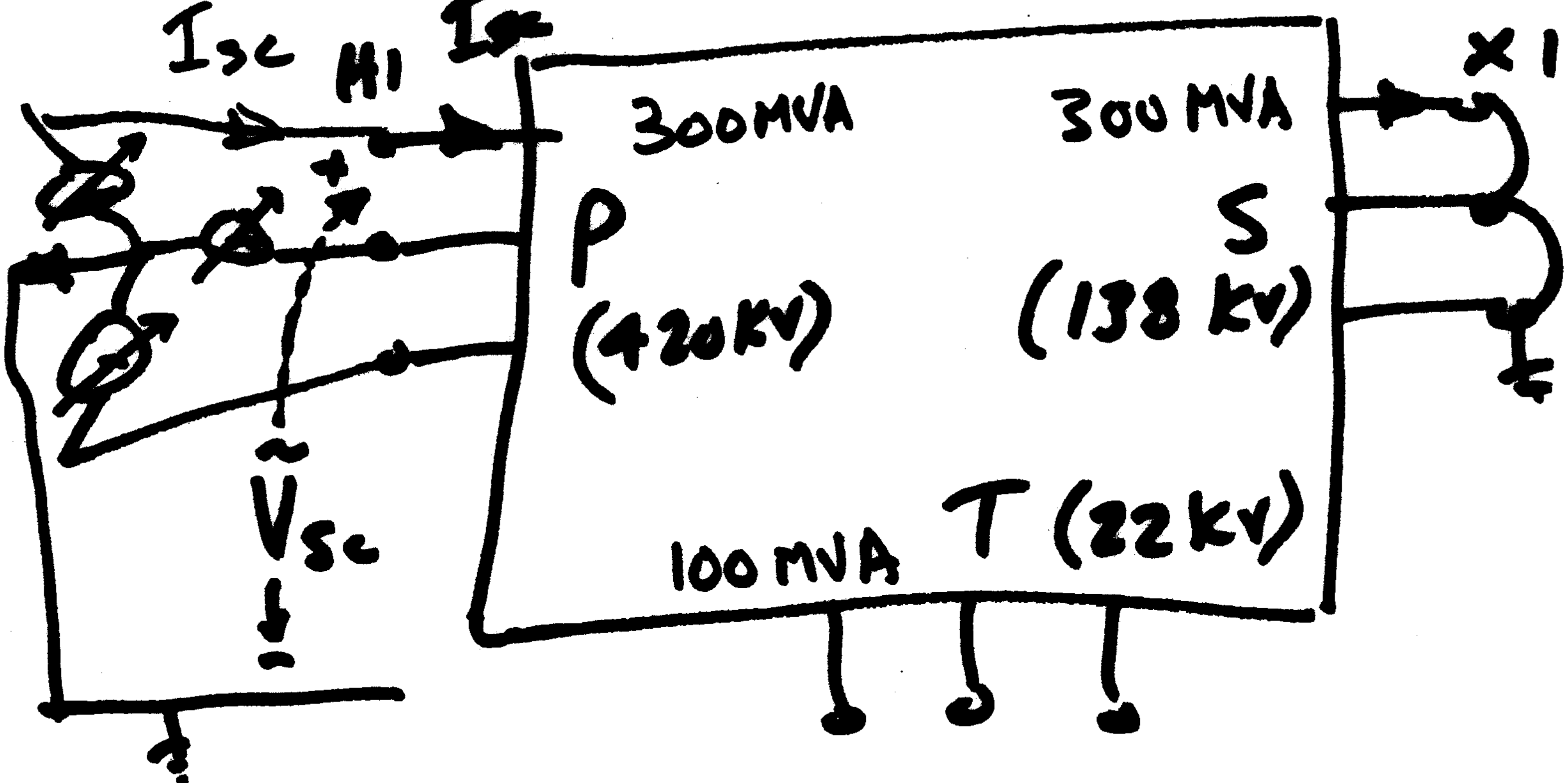




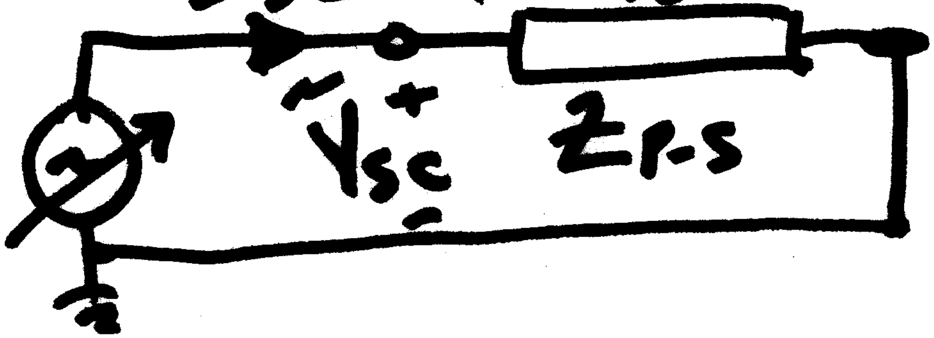
$$Z_B = \frac{KV_{LL\,BASE}^2}{MVA_{BASE}}$$



3



$$\bar{Z}_{sc,P-S} = \frac{\tilde{V}_{sc}}{\bar{I}_{sc}} \Omega$$



$$\frac{V_{LL}^2(KV)}{MVA}$$

$$Z_{BASE} = \frac{420^2}{300}$$

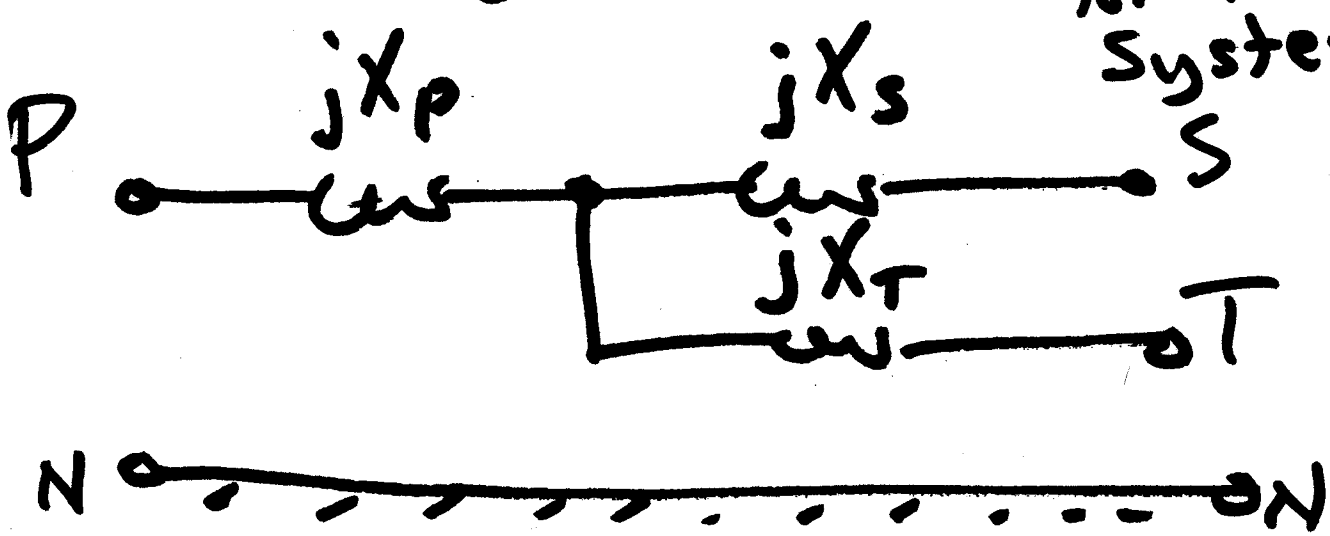
$$= \_\_\_$$

Binary S.C. Tests

	Meas	Reactance	Ω
P-S	300 MVA	15.95%	93.8Ω
P-T	100 MVA	8.70%	153.8
S-T	100 MVA	2.61%	4.97

⇓

"Star Equiv" [for 100 MVA System Base]



Convert to 100 MVA Base

$$Z_{pu} = \frac{Z_{\Omega}}{Z_{BASE}} = \frac{Z_{\Omega}\ VA_{Base}}{V_{BASE}^{2}}$$

① $Z_{\Omega} = Z_{pu} \times Z_{BASE,OLD}$

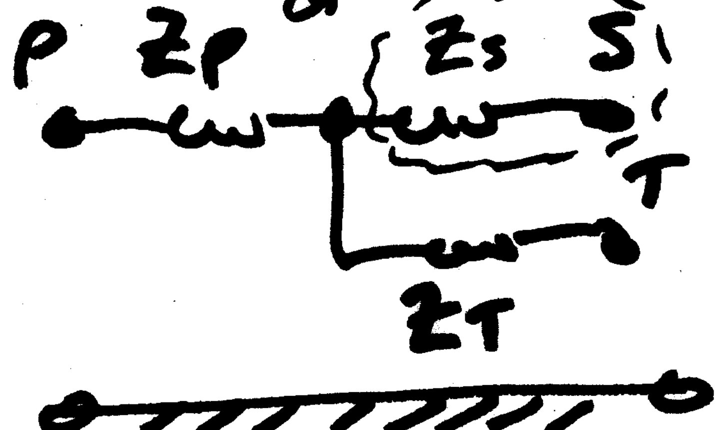
② $Z_{pu,100} = \dfrac{Z_{\Omega}}{Z_{BASE,NEW}} = \dfrac{Z_{\Omega}\ 100}{420^2}$

$$Z_{BASE} = \frac{420^2}{100}$$

$$\bar{Z}_{PS} = \bar{Z}_P + \bar{Z}_S$$
$$\bar{Z}_{PT} = \bar{Z}_P + \bar{Z}_T$$
$$Z_{ST} = \bar{Z}_S + Z_T$$

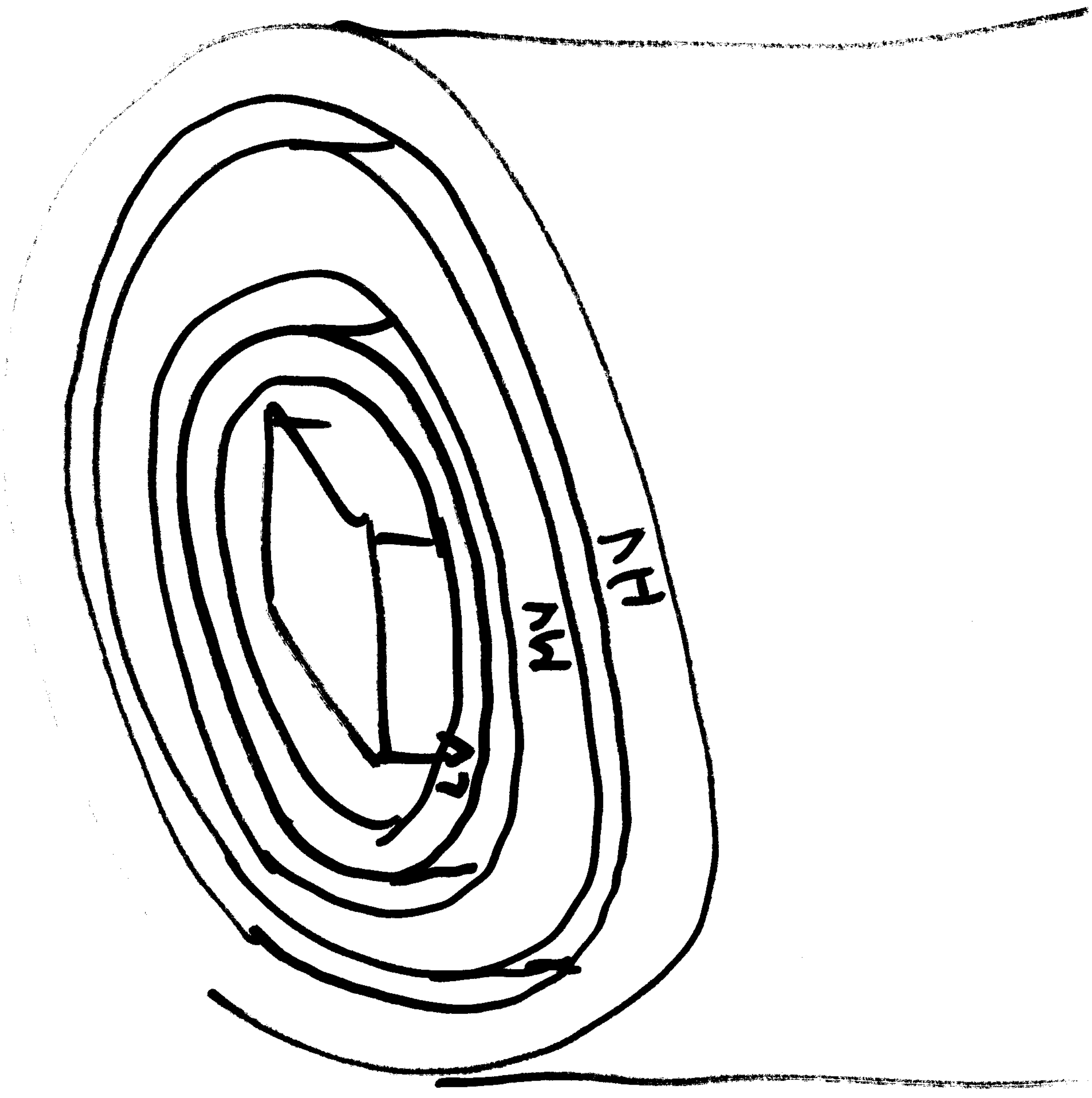
Solve for Z_P, Z_S, Z_T

often neg for Auto-Δ



Y-Δ Transform

⇒


HV
MV
LV

APPENDIX C: TRANSFORMER FACTORY TEST REPORT

TRANSFORMER TEST REPORT

Date of Test 6/3/71 Customer's Order C-67899 Our Order C-04070-5

Type OA/FOA/FOA Phase 3 Cycles 60 Rise 55°/65°C Taps See N.P. Dwg. #307256 Spec. 13018

H. V. Volts 345000 Grd.Y/199200 L. V. Volts 118000 Grd.Y/68200 T.V. Volts 13800Δ

KVA 296000/394000/490000 * KVA 296000/294000/490000 * KVA 77000/102667/128333 *

							Guarantees
Serial Number					C-04070-5-1		
Polarity See N.P. Dwg. #307256		Transf. Conn.: 345000-118000			Volts @ 296 MVA		
W.M. Copper Loss @ Full Load 75°C					376940		
Core Loss @ 100% Voltage					✓ 297600		310000
Total Loss @ Full Load 100% Voltage					676540		695000
Core Loss @ 110% Voltage				**	402240		390000
% Exciting Current @ 100% Voltage					✓ 0.7[illegible]		1.00
% Exciting Current @ 110% Voltage					1.[illegible]		2.00
% Impedance @ 75°C				Zps	6.21		6.30
% Resistance @ 75°C					0.128		
% Reactance @ 75°C					6.20		
% Regulation @ 100% P.F. Full Load					0.32		0.33
% Regulation @ 80% P.F. Full Load					3.94		4.05
ficiency @ Full Load 100% P.F.					99.77		99.76
ciency @ ¾ Load 100% P.F.					99.77		99.75
% ciency @ ½ Load 100% P.F.					99.73		99.71
% Efficiency @ ¼ Load 100% P.F.					99.56		99.55
Total H.V. Resistance in Ohms @ 75°C (Series Wdg.	- Tap "A")				0.6766		
Total L.V. Resistance in Ohms @ 75°C (Common Wdg.)					0.1635		
Total T.V. Resistance in Ohms @ 75°C					0.01748		
% Impedance @ 75°C (345000-13800 Volts)	[illegible] MVA			Zpt	55.9		55.0
% Impedance @ 75°C (118000-13800 Volts)	@ 296 MVA			Zst	42.1		40.0
INSULATION TESTS							
and to T.V.							
H.V. & L.V/and Core Volts for 1 Min.					50000		50000
T.V. to Core Volts for 1 Min.					34000		34000
Induced Voltage in H.V. Winding Line to	Ground				460000		460000
Induced Voltage in H.V. Winding Line to Line					575000		575000
TEMPERATURE RISE		MVA		296	394	490	
Connected: 362000-118000 Volts		Series Wdg.		42.4	43.5	47.9	
Copper Rise Corrected to Shutdown °C		Common Wdg.		43.3	43.3	47.5	55
Oil Rise °C				51.4	33.7	33.2	

Unless otherwise specified the above Tests are in accordance with the latest A. S. A. and N. E. M. A. Standards.

Remarks:

	@ 77000 KVA	@ 102667 KVA	@ 128333 KVA
T.V. Gradient °C:	10.9	15.5	19.0

* KVA @ 65°C Rise: H.V. and L.V. 330000/440000/550000; T.V. - 86240/114987/143733.

** The Core Loss Value Exceeding Guarantee was submitted to and accepted by the customer.

…s transformer satisfactorily withstood Impulse Tests. See Impulse Test Report.

… transformer satisfactorily withstood Switching Surge Tests. See Switching Surge Test Repor…

See Page #2 for additional test performance data.

	MVA		on 100-MVA Base
Z_{ps}	296	6.21%	
Z_{pt}	77	55.9%	
Z_{st}	77	42.1%	

<u>Note:</u>

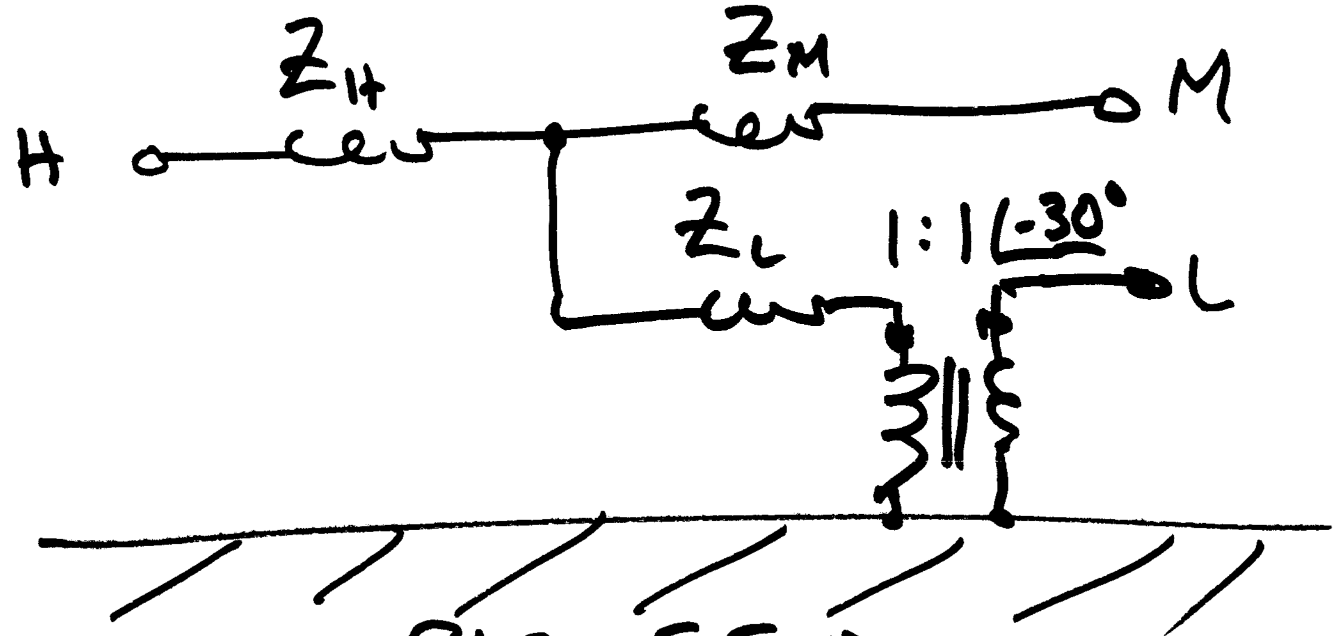
p: 296 MVA

s: 296 MVA

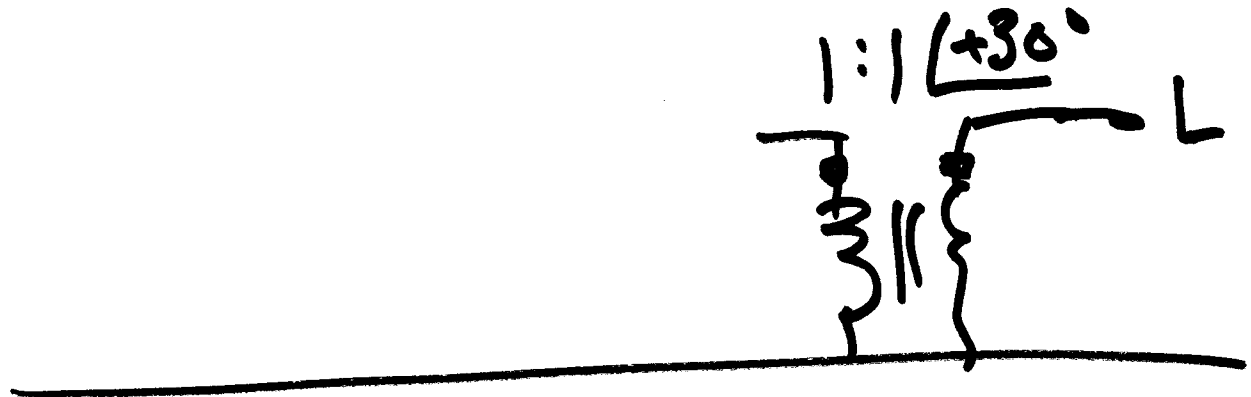
t: 77 MVA

ON PER-PHASE BASIS:

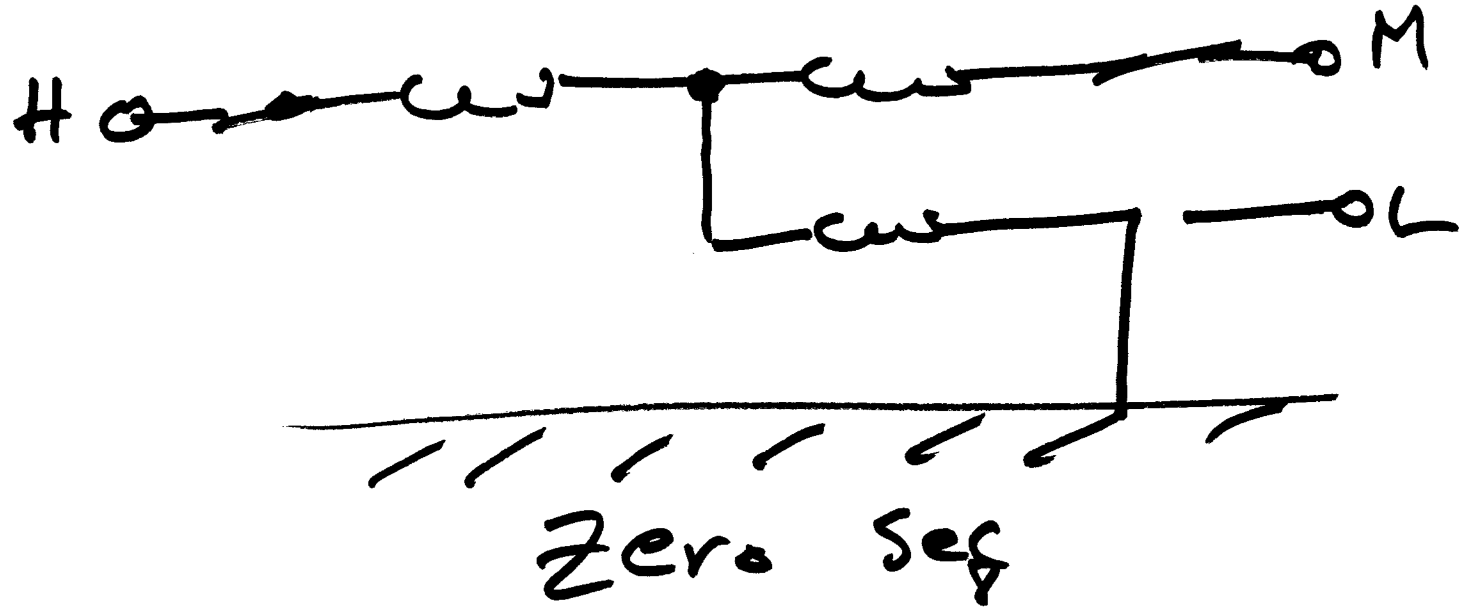
Auto - Δ



POS SEQ



NEG SEQ


H
M
L
Zero seq