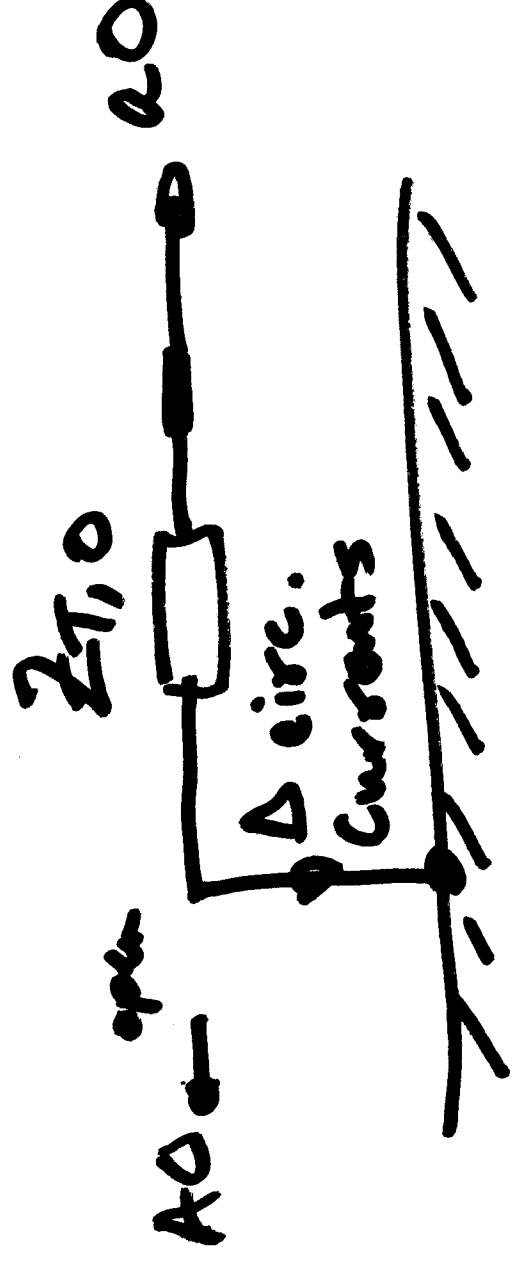
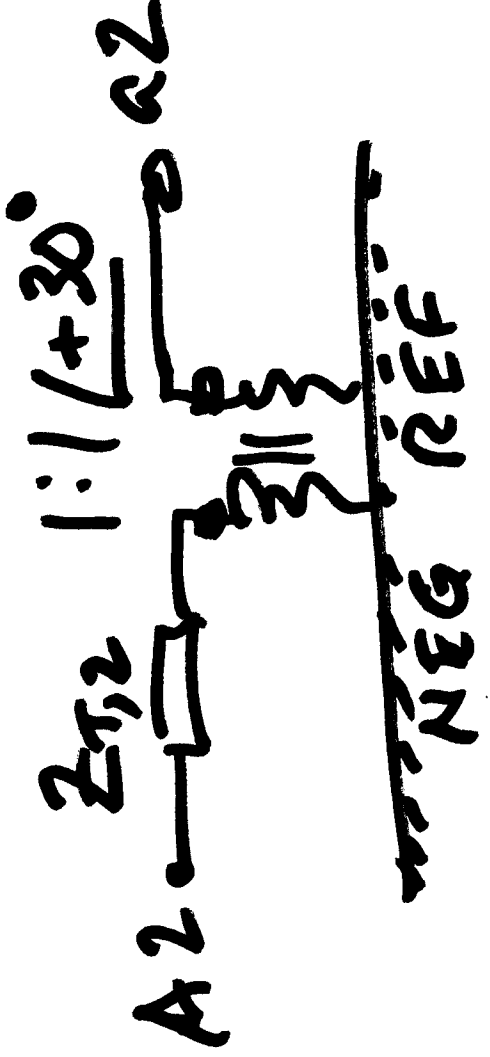
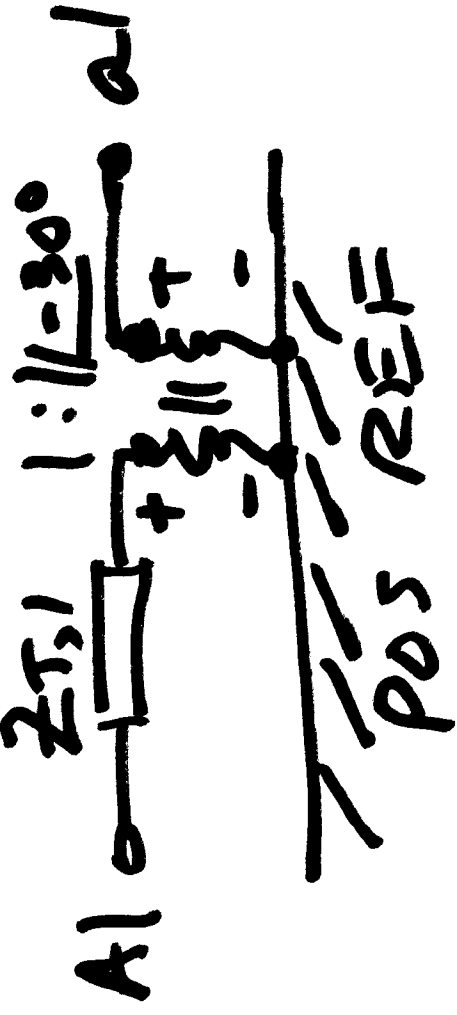


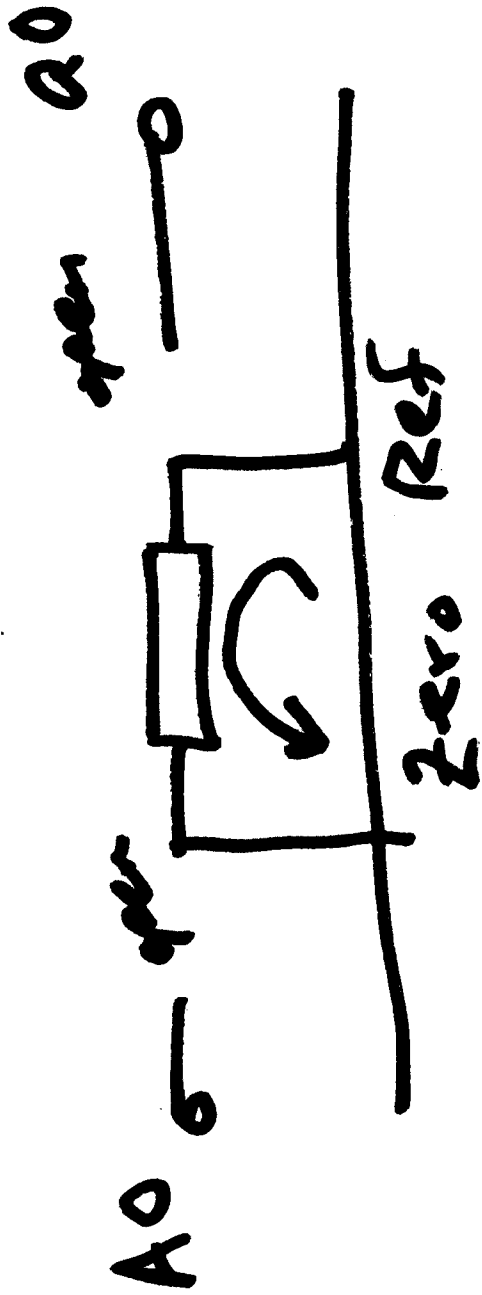
Topics for Today:

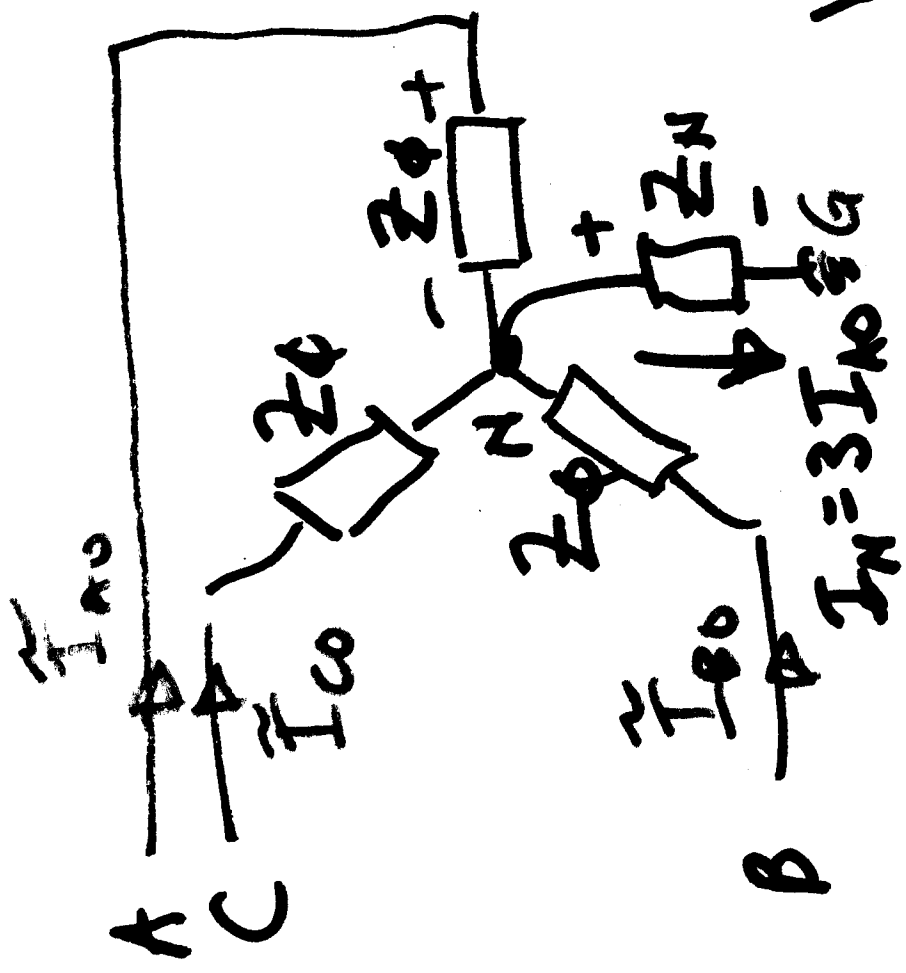
- Announcements
 - Matlab -- Off-campus use remote desktop: remote.mtu.edu
 - Learning Center hrs: TBD
 - Office: EERC 614. Phone: 906.487.2857
 - XFMR exercises due next Mon 9am.
 - Recommended problems from Ch.2, solutions posted
- XFMR, Chapter 2 - Transformers and circuits w/transformers
 - Pre-Req 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



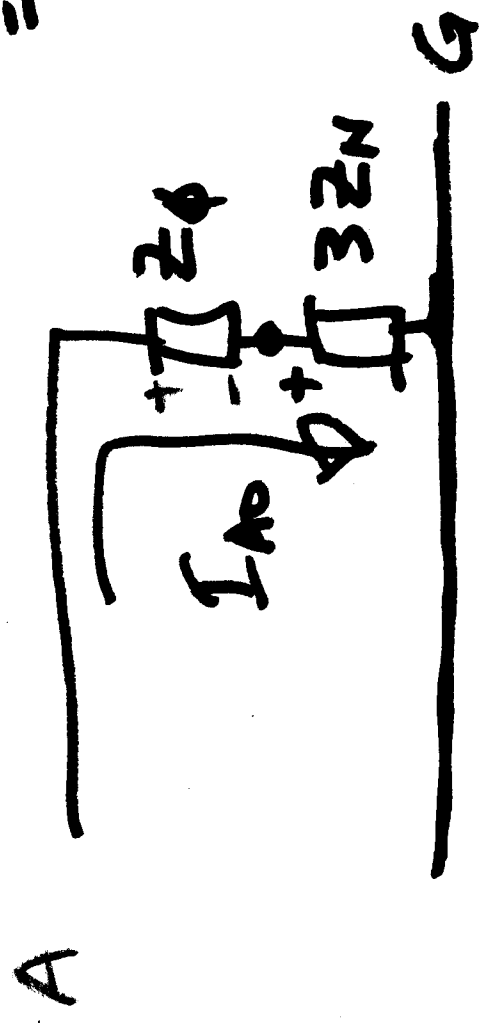
SS

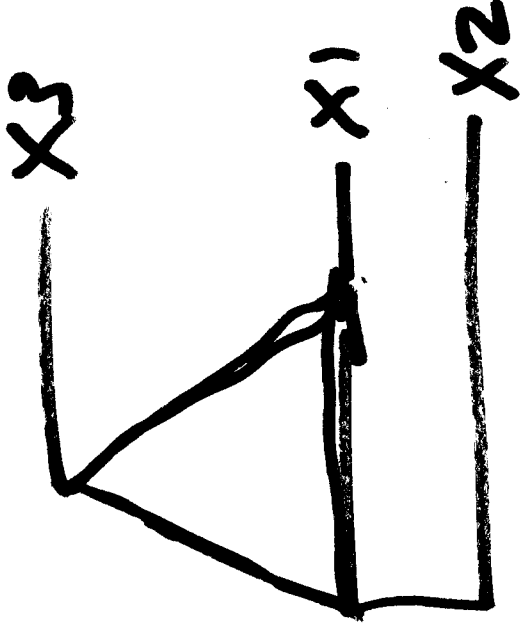
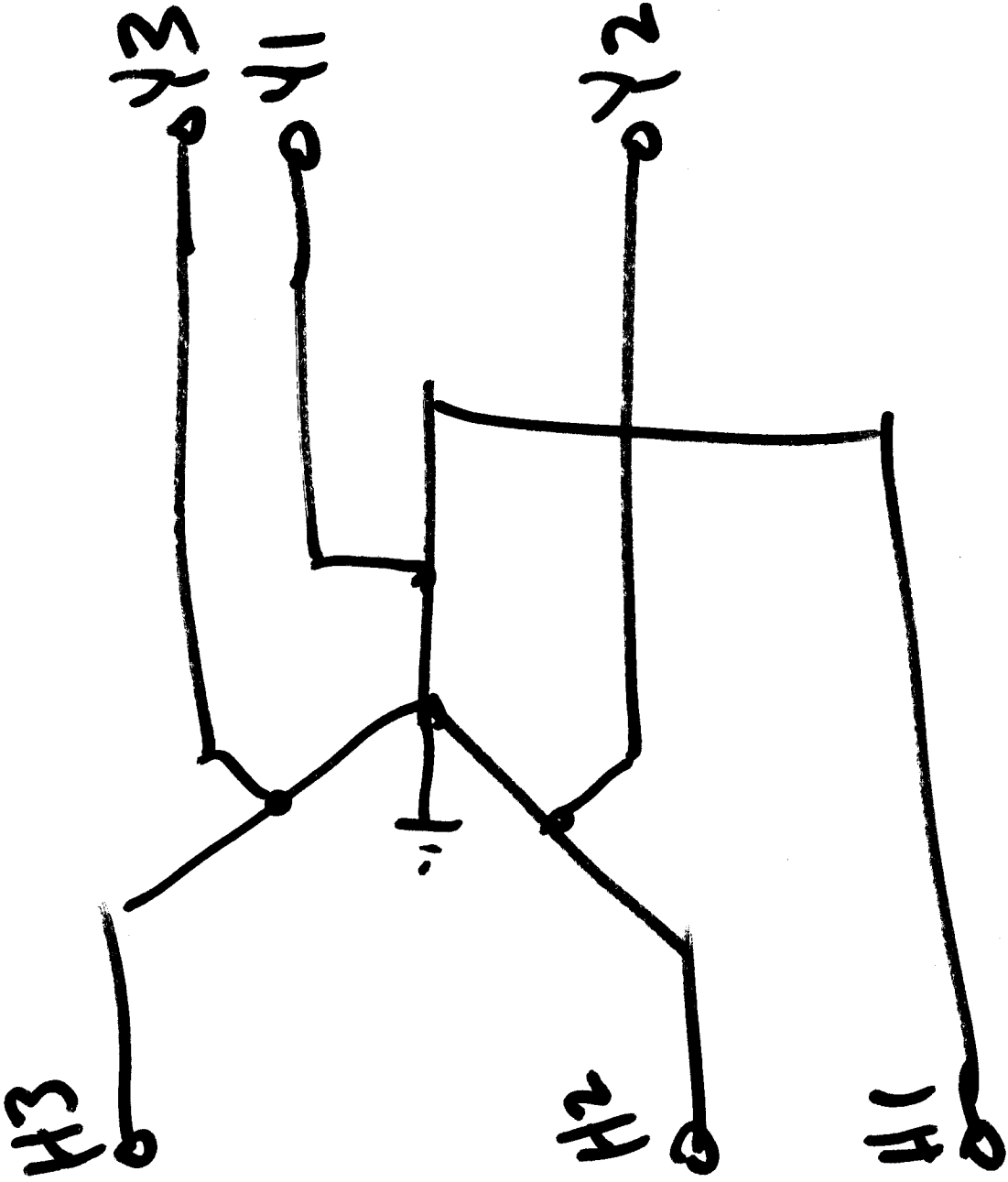
$\Delta \Delta$





$= V_{NG}$





triplex harmonics

buried tertiary

buried delta

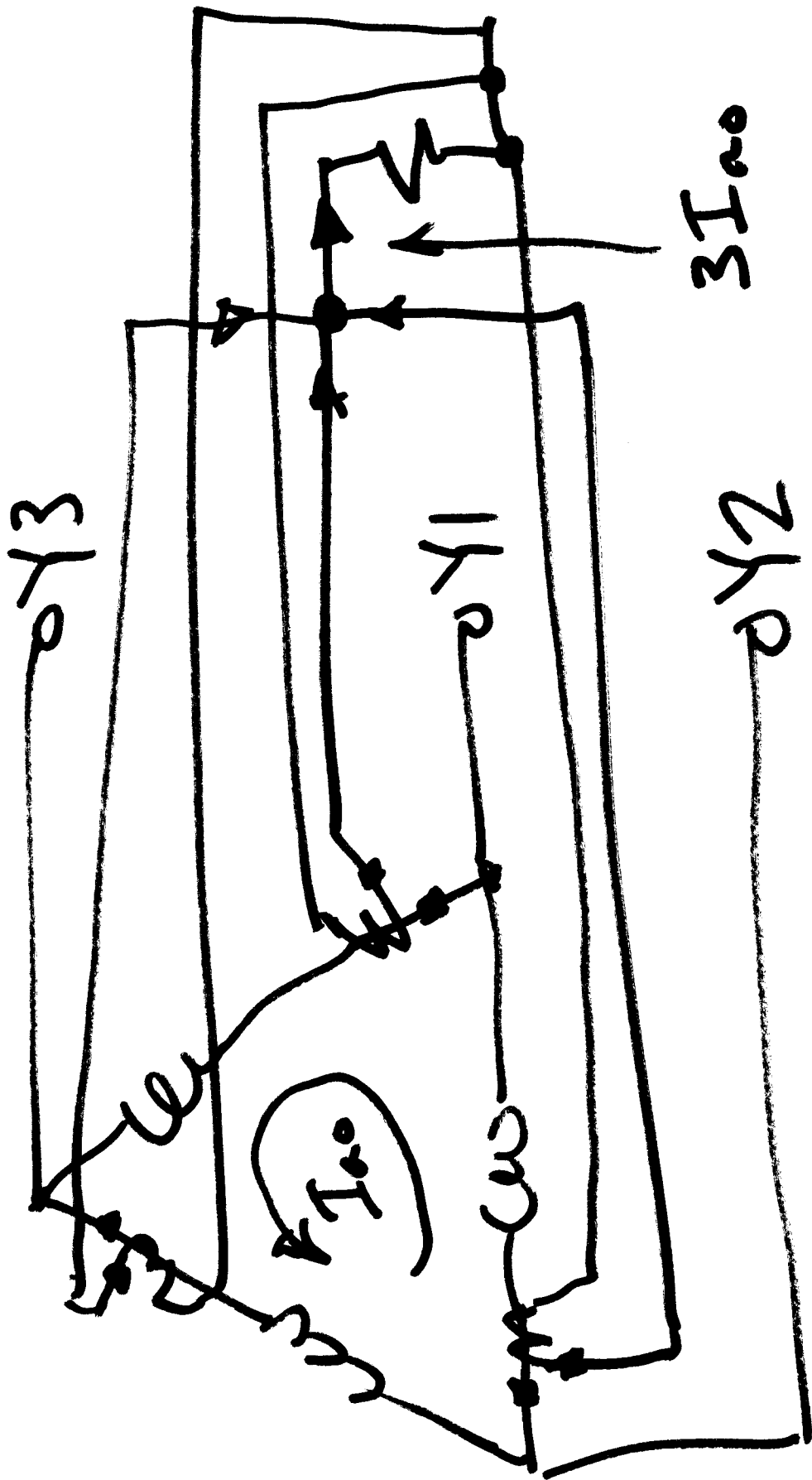
delta: - trap triplen harmonics

- zero seq circ path

- Aux power (station service)

- Protection

- CTS





Zero ref.

Harmonics:

3, 6, 9...

1, 4, 7...

2, 5, 8...

↑ x four increase

SEQ

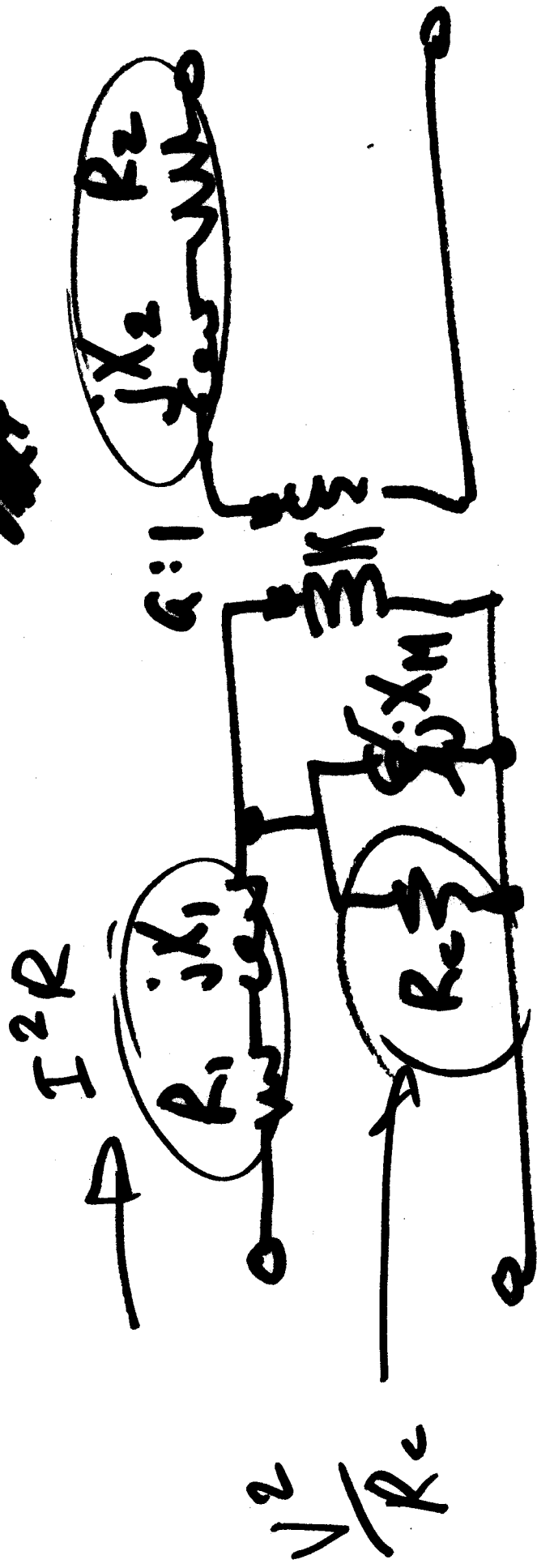
0

1

2

Factory Test Report

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



APPENDIX C: TRANSFORMER FACTORY TEST REPORT

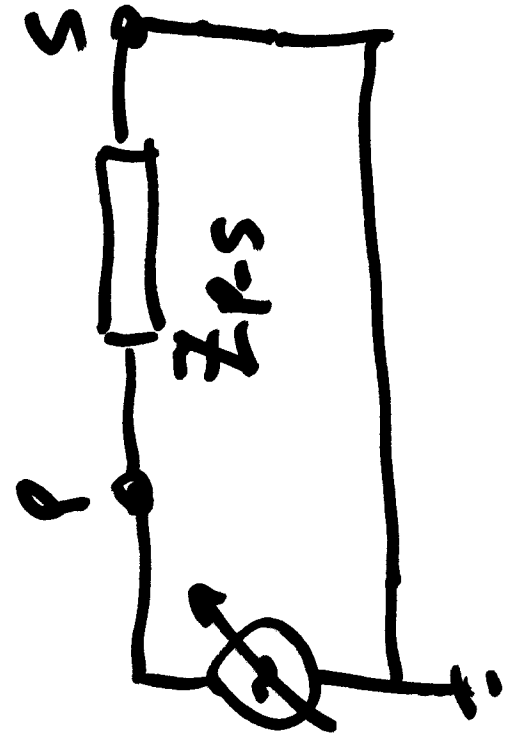
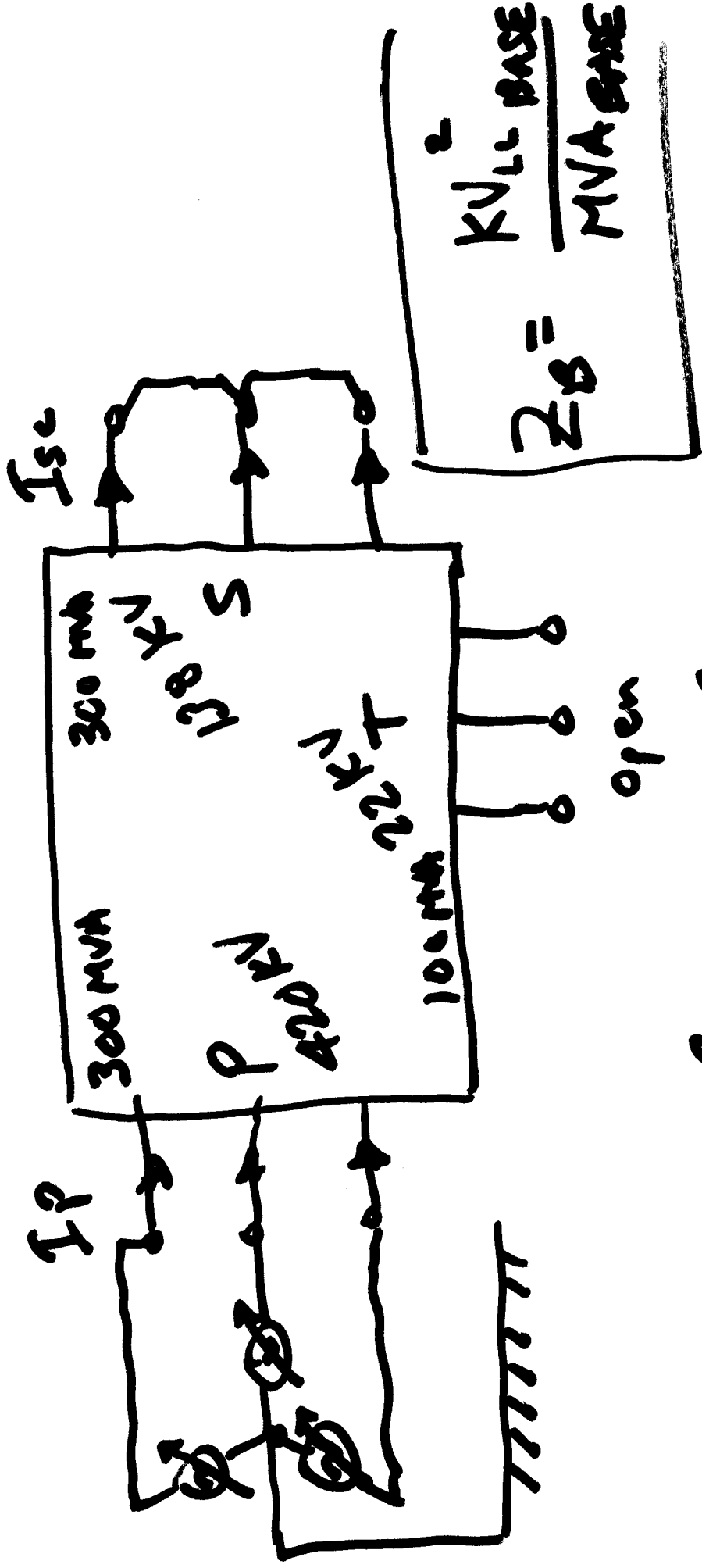
TRANSFORMER TEST REPORT

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 13800A
 KVA 296000/394000/490000 * KVA 296000/294000/490000 * KVA 77000/102667/128333 *

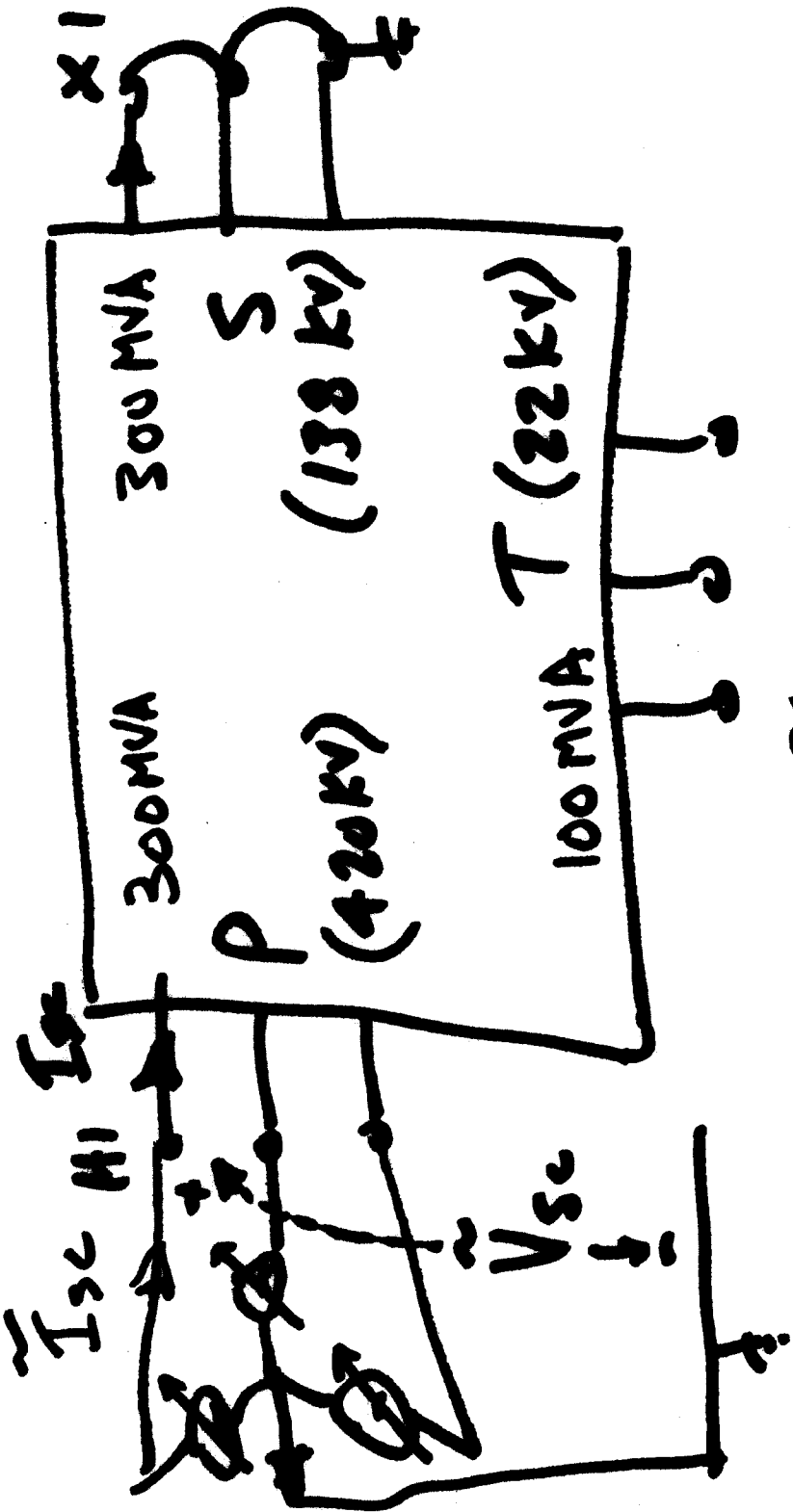
Serial Number			C-04070-5-1	Guarantees
Polarity See <u>N.P. Dwg. #307256</u>	Transf. Conn.:	345000-118000	Volts @ 296 MVA	
W.M. Copper Loss @ Full Load 75°C			376940	
Core Loss @ 100% Voltage			✓ 297600	310000
Total Loss @ Full Load 100% Voltage			676540	605000
Core Loss @ 110% Voltage			** 402240	390000
% Exciting Current @ 100% Voltage			✓ 0.77	1.00
% Exciting Current @ 110% Voltage			1.71	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
Efficiency @ Full Load 100% P.F.			99.77	99.76
Efficiency @ ¾ Load 100% P.F.			99.77	99.75
Efficiency @ 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")			0.6756	
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 (345000-118000 Volts) 296 MVA		Zpt	55.9	55.0
% Impedance @ 75°C (118000-138000 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				
Connected: 362000-118000 Volts	MVA	296	394	490
Copper Rise Corrected to Shutdown °C	Series Wdg.	42.4	43.5	47.9
	Common Wdg.	43.3	43.3	47.5
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.
 This transformer satisfactorily withstood Impulse Tests. See Impulse Test Report.
 This transformer satisfactorily withstood Switching Surge Tests. See Switching Surge Test Report.
 See Page #2 for additional test performance data.



3



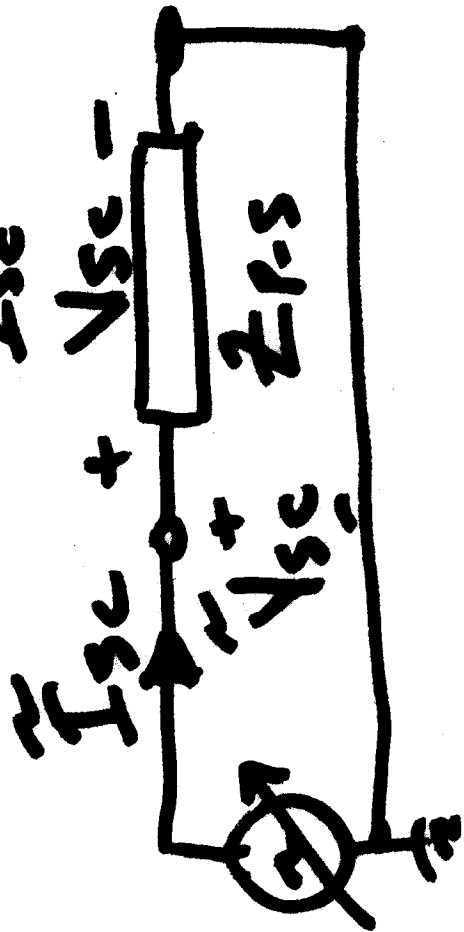
$$\frac{V_{Lc}^2 (kV)}{MVA}$$

$$\frac{420^2}{300}$$

$$Z_{base} =$$


$$=$$

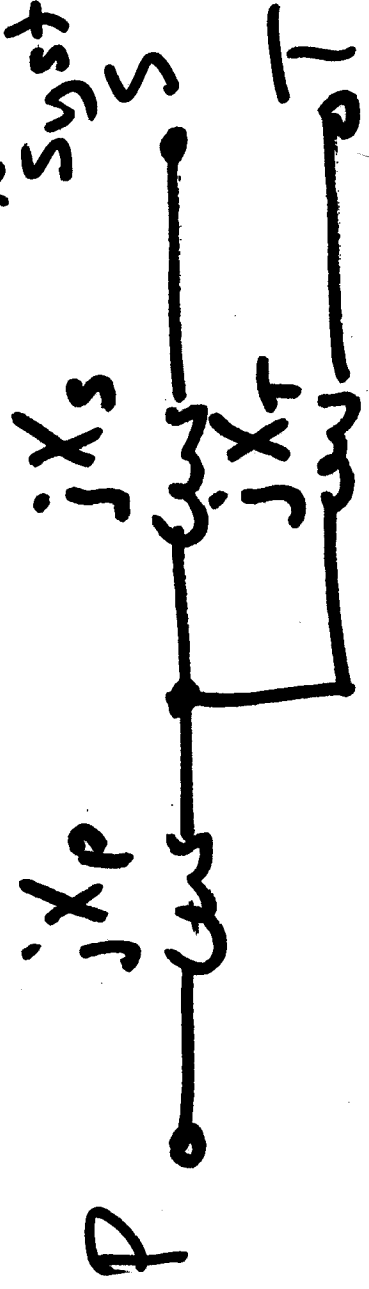
$$Z_{sc, P-S} = \frac{V_{sc}}{I_{sc}} \Omega$$



Binary S.C. Tests

	<u>MVA</u>	<u>Reactance</u>	<u>Ω</u>
P-S	300 MVA	15.95%	93.8 Ω
P-T	100 MVA	8.70%	153.8
S-T	100 MVA	2.61%	4.97


 "Star Equiv"
 for 100 MVA
 System Base



NO CONNECTION

4

Convert to 100 MVA Base

$$Z_{pu} = \frac{Z_r}{Z_{BASE}} = \frac{Z_r \cdot V_{BASE}}{V_{BASE}^2}$$

$$\textcircled{1} Z_r = Z_{pu} \times Z_{BASE, old}$$

$$Z_r = \frac{100}{420^2}$$

$$\textcircled{2} Z_{pu, 100} = \frac{Z_r}{Z_{BASE, NEW}}$$

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

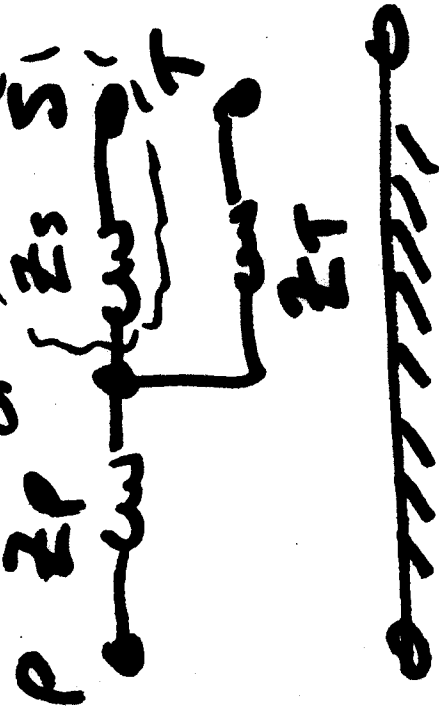
$$\bar{Z}_{PS} = \bar{Z}_P + \bar{Z}_S$$

$$\bar{Z}_{PT} = \bar{Z}_P + \bar{Z}_T$$

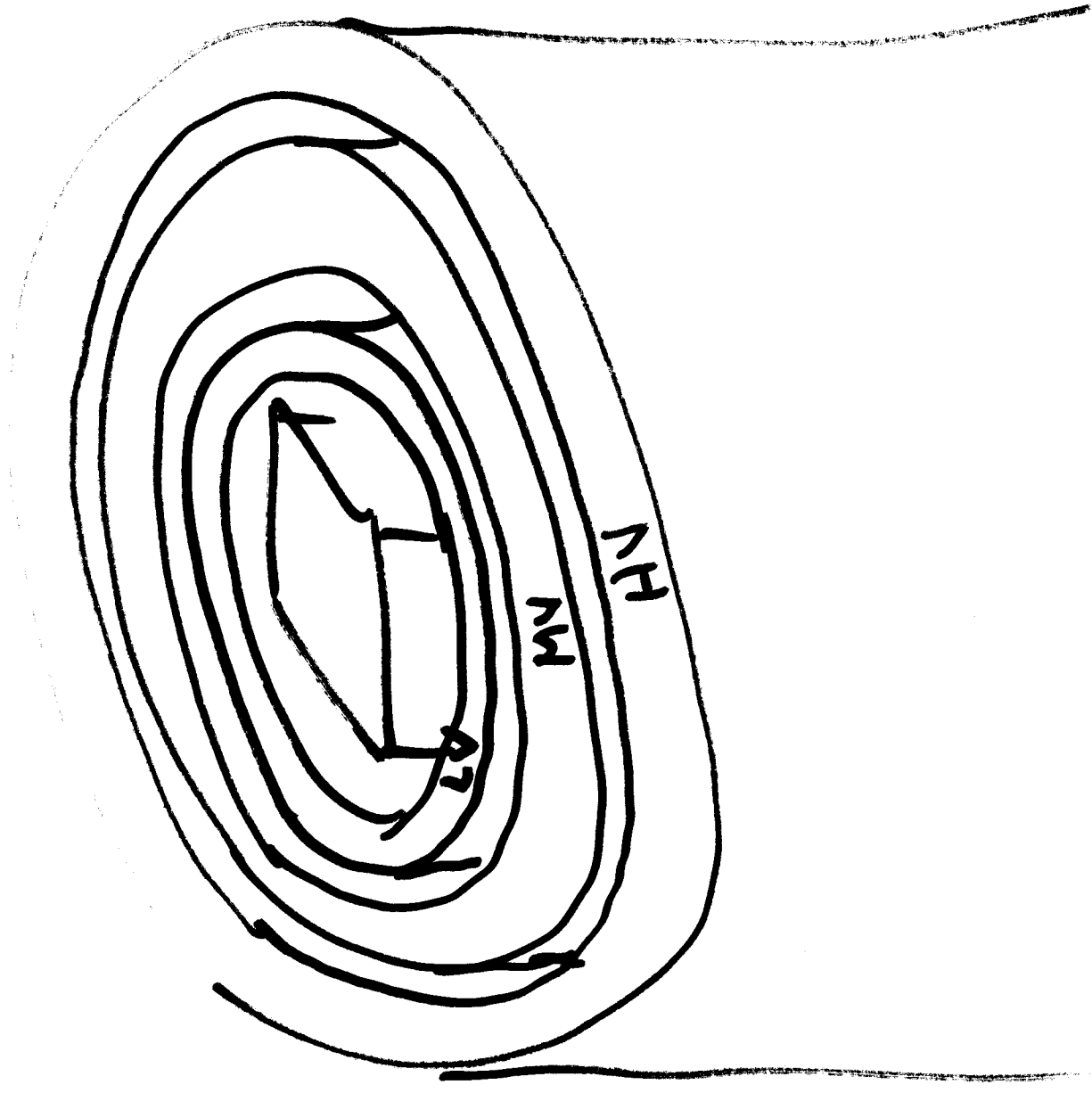
$$\bar{Z}_{ST} = \bar{Z}_S + \bar{Z}_T$$

Solve for Z_P, Z_S, Z_T

Changing for Auto- Δ Y- Δ Transform



EE 5240



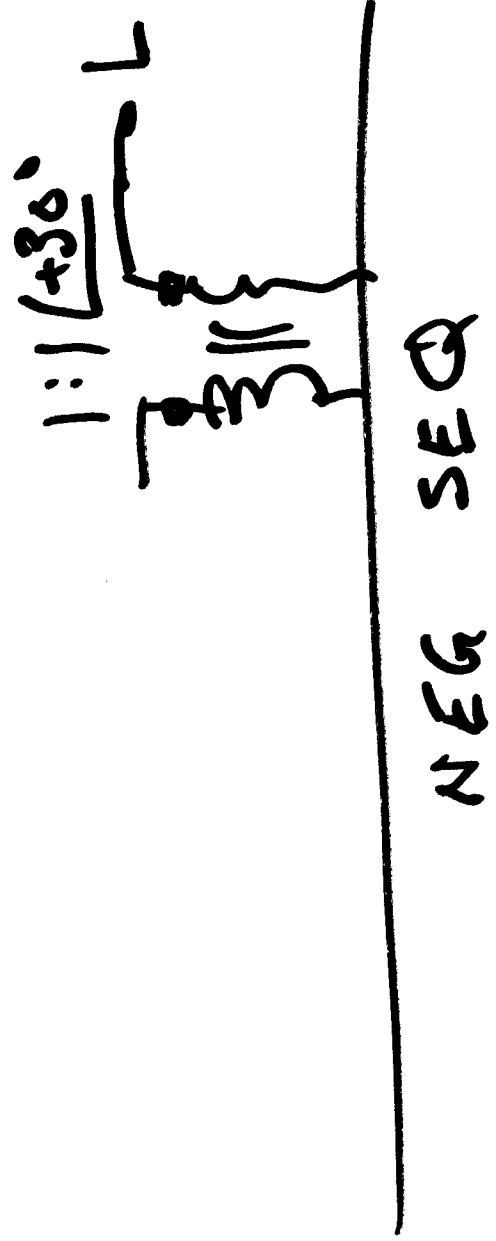
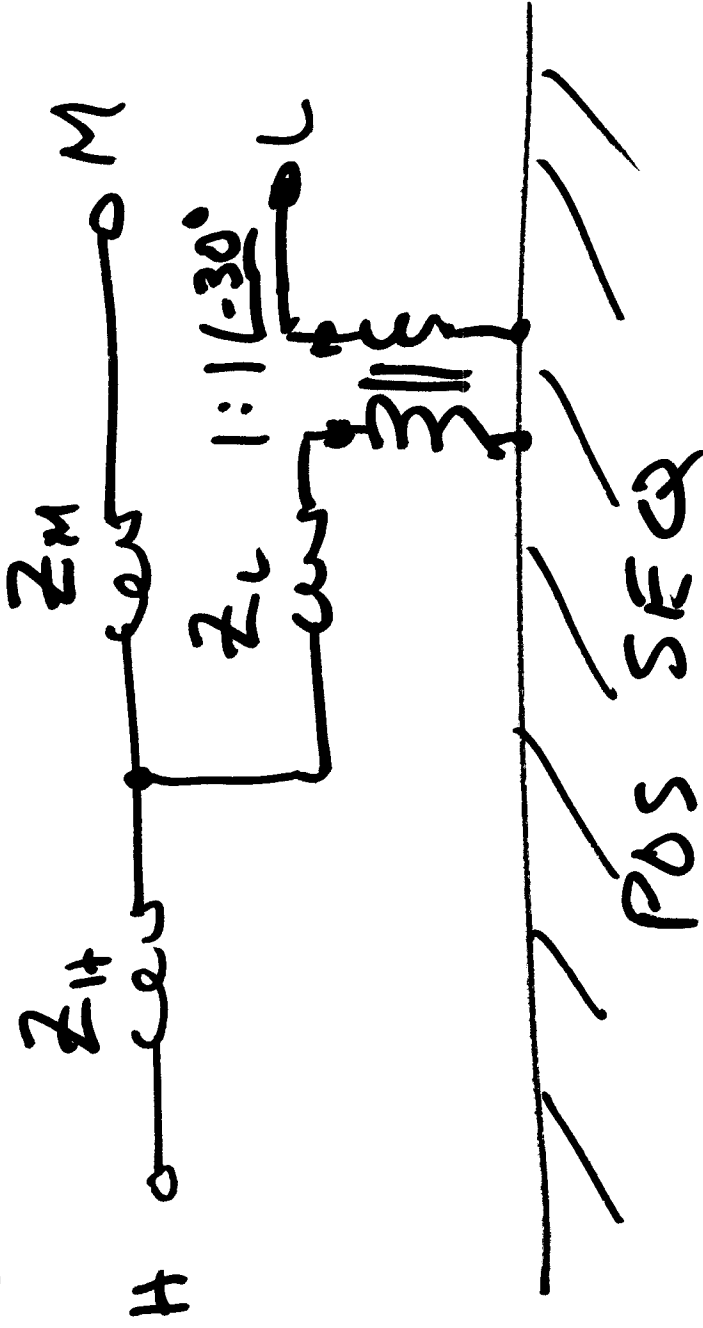
on 100-MVA Basis

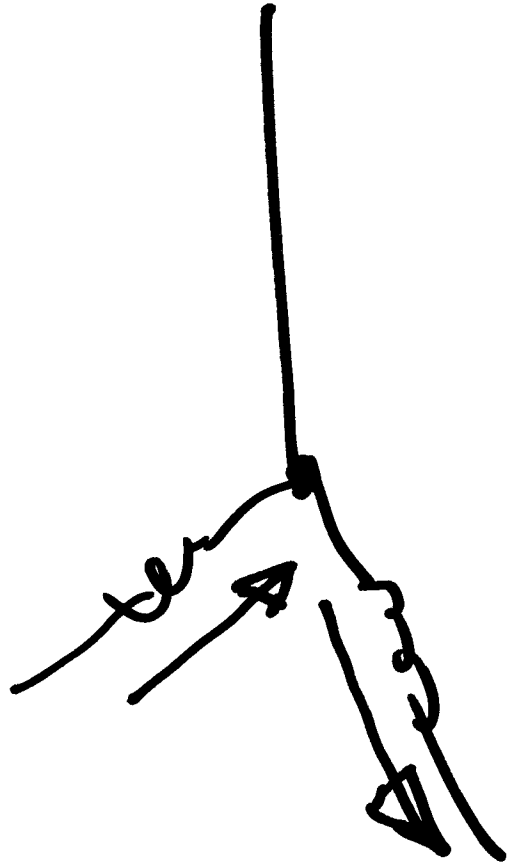
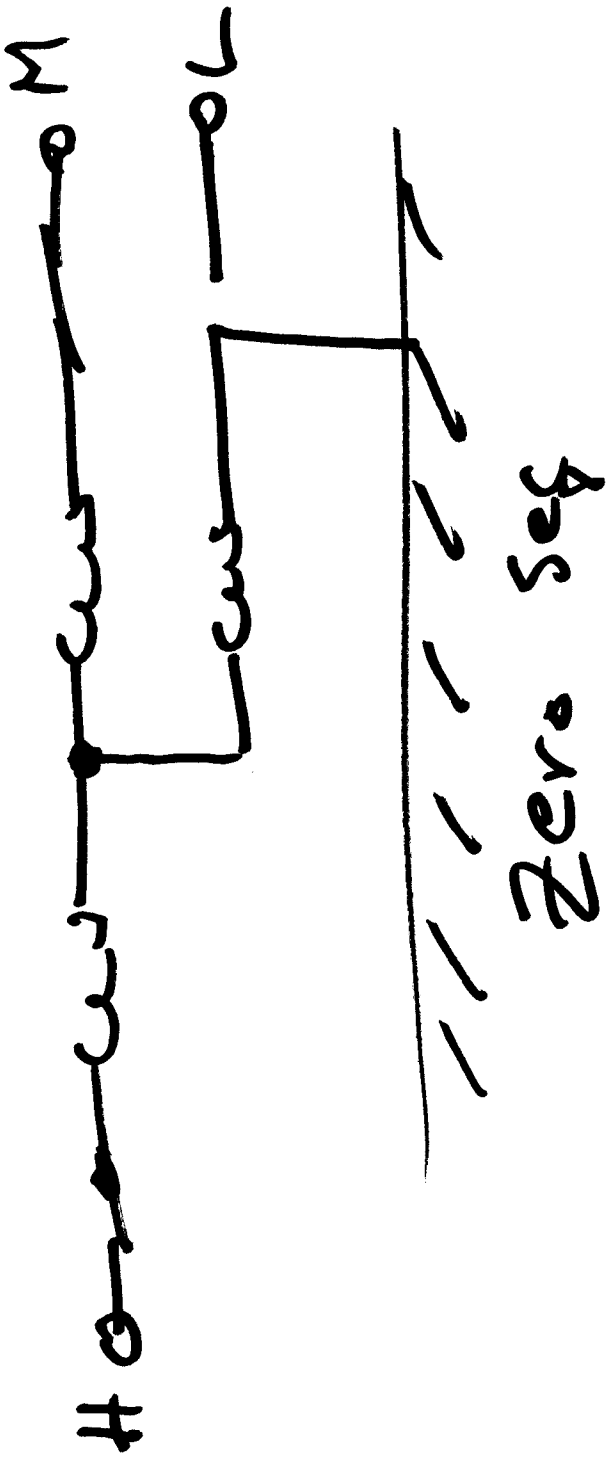
Z_{ps}	$\frac{MVA}{296}$	6.21%
Z_{pt}	77	55.9%
Z_{st}	77	42.1%

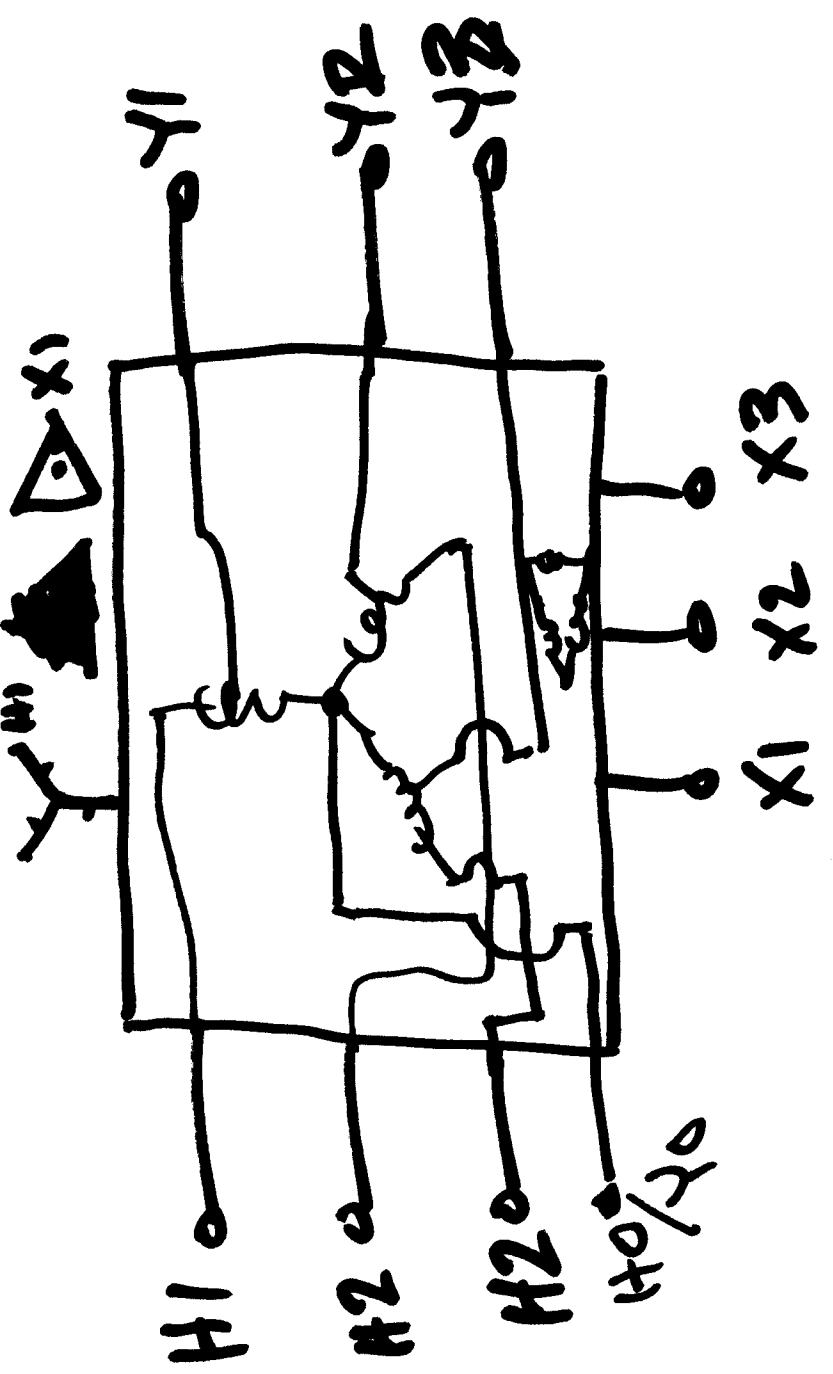
Note:
P: 296 MVA
S: 296 MVA
t: 77 MVA

ON PER-PHASE BASIS:

Auto-Δ





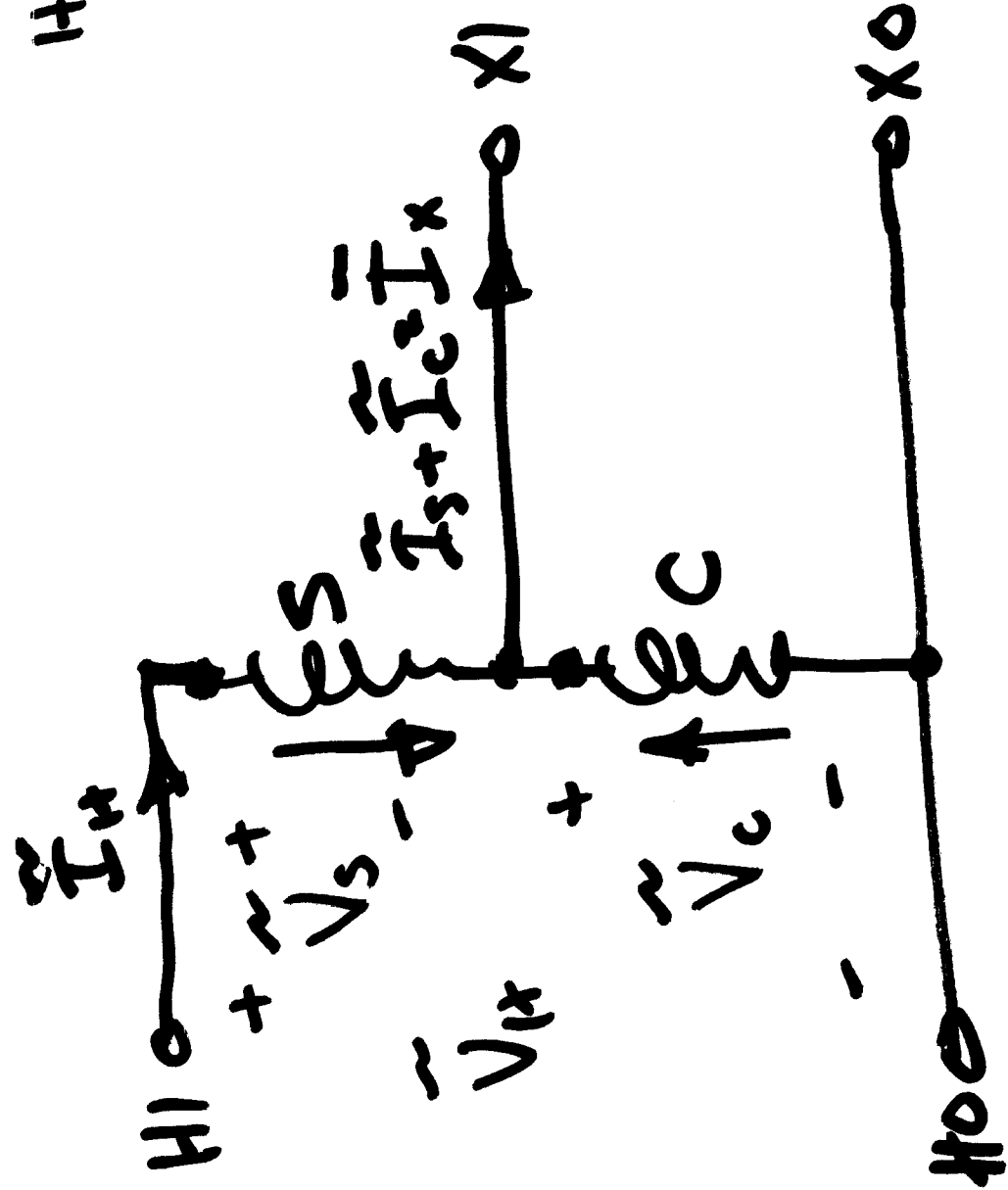
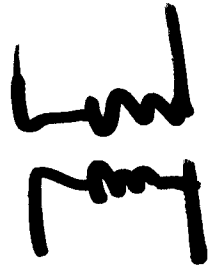
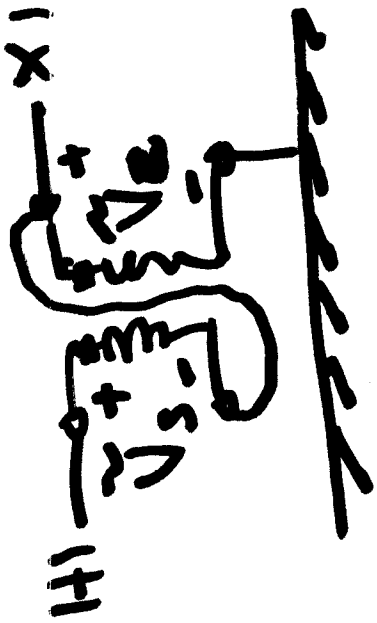


Rules of Thumb:

VA Advantage

$-\frac{V_H}{V_M} \leq 3$

- Above 3 {
- leakage, Zsc too high
 - Poor VR

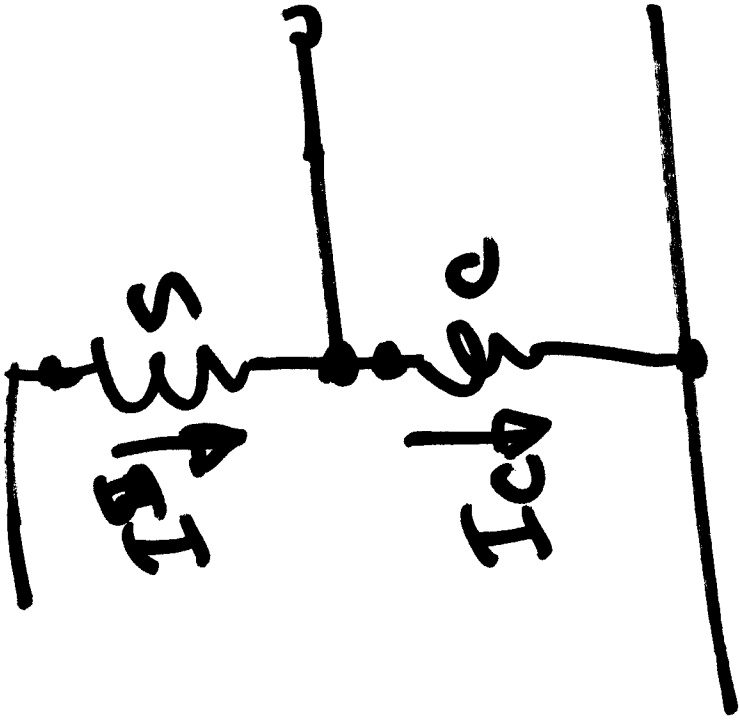


$$\frac{VA - Auto}{VA - 2w} = \frac{(V_s + V_c) I_H}{V_s I_H}$$

VA ADVANTAGE =

$$= \frac{V_s + V_c}{V_s} =$$

$$\boxed{\frac{V_H}{V_x}}$$



$$\begin{aligned} \sum MMF_s &= 0 \\ &= \tilde{I}_s N_s + \tilde{I}_c N_c \\ &\quad + \tilde{I}_\Delta N_\Delta \end{aligned}$$

$$\begin{aligned} \sum VA &= 0 \\ &= \tilde{V}_s \tilde{I}_s^* + \tilde{V}_c \tilde{I}_c^* + \tilde{V}_\Delta \tilde{I}_\Delta^* \\ &= 0 \end{aligned}$$