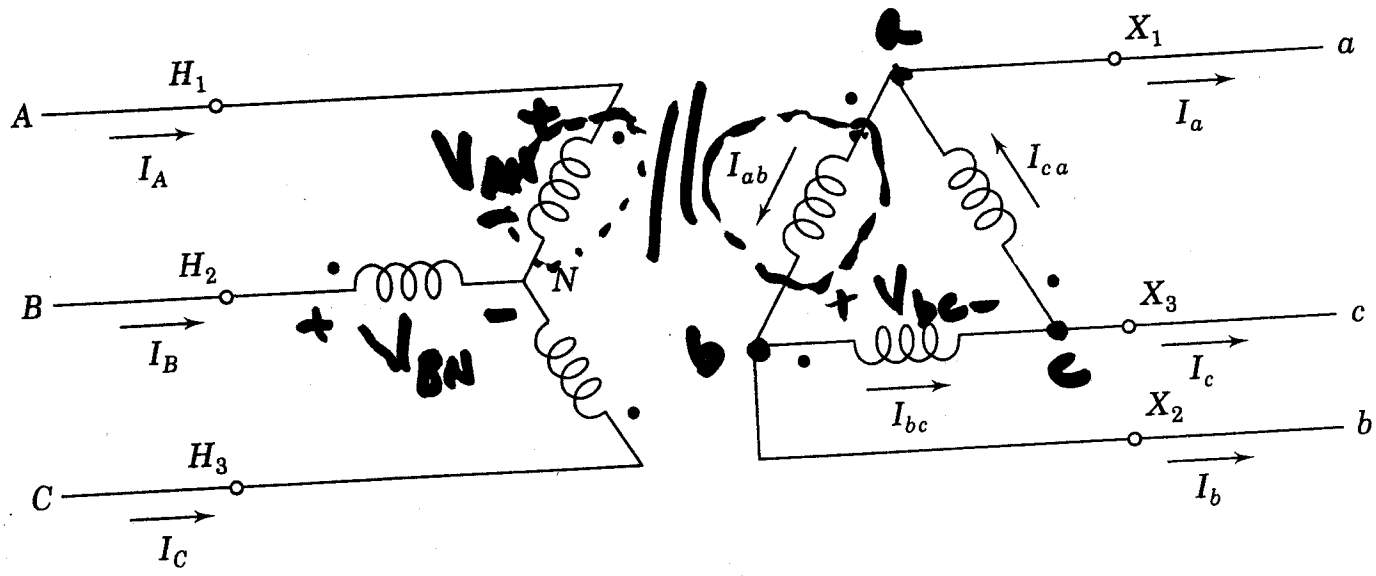
EE 5200 - Lecture 6 Tuesday Sep 11, 2003

Topics for Today:

- Announcements
  - Software: Matlab? Will begin using as early as next week.
  - Office hrs: 1:30-2:30pm, Mon, Wed, Fri
  - Office: EERC 623. Phone: 906.487.2857
  - Exercises posted on web page, check e-mail for details.
  - Collected problems, solutions posted after collecting.
  - Recommended problems from Ch.2, solutions posted

- Chapter 2 - Transformers and circuits w/transformers
  - 3-phase transformer banks and phase shifts (ANSI/IEEE vs. IEC)
  - Standard 30°shift transformers, non-standard connections
  - Pos/neg sequence phase shifts
  - Autotransformers
  - Load Tap Changing (LTC) transformers
  - Phase shifting transformers
  - Paralleling transformers with a) unlike impedances; b) unlike tap positions
  - Three-winding transformers

2



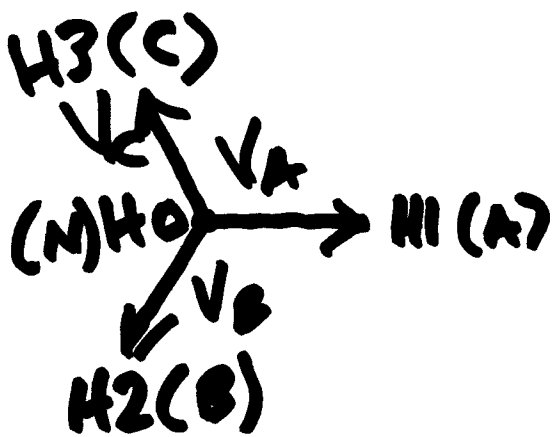
(*a*) Wiring diagram

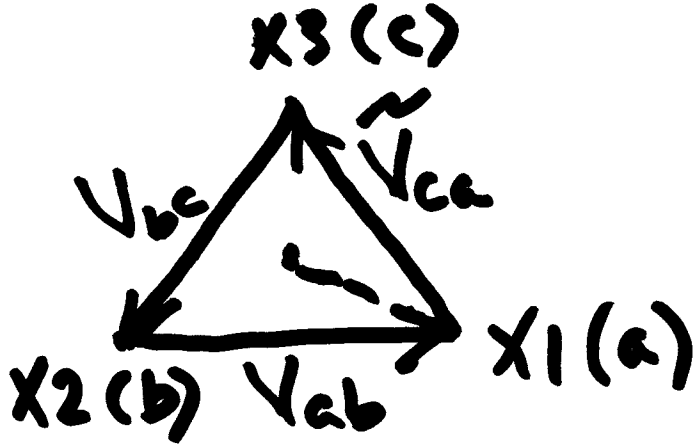
Note: Phasor diagrams in text do not follow common practice.

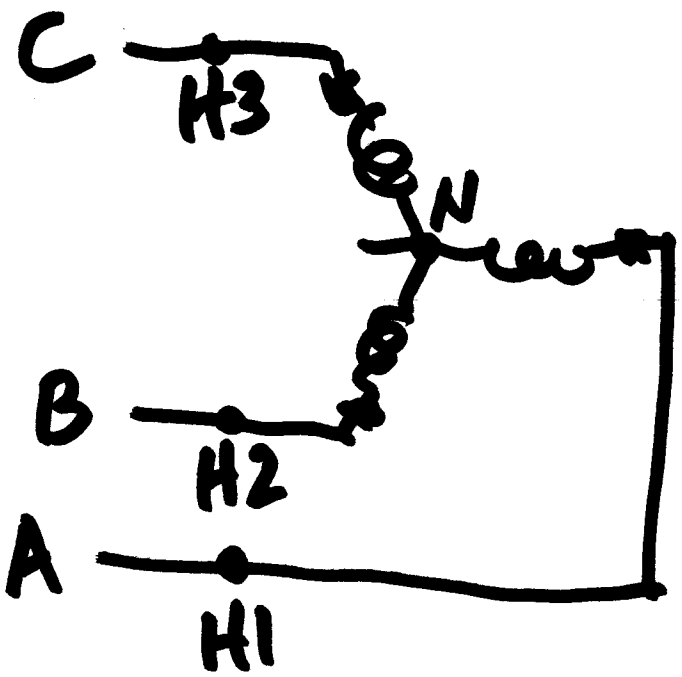
r by the per-unit
is not important
per unit with the

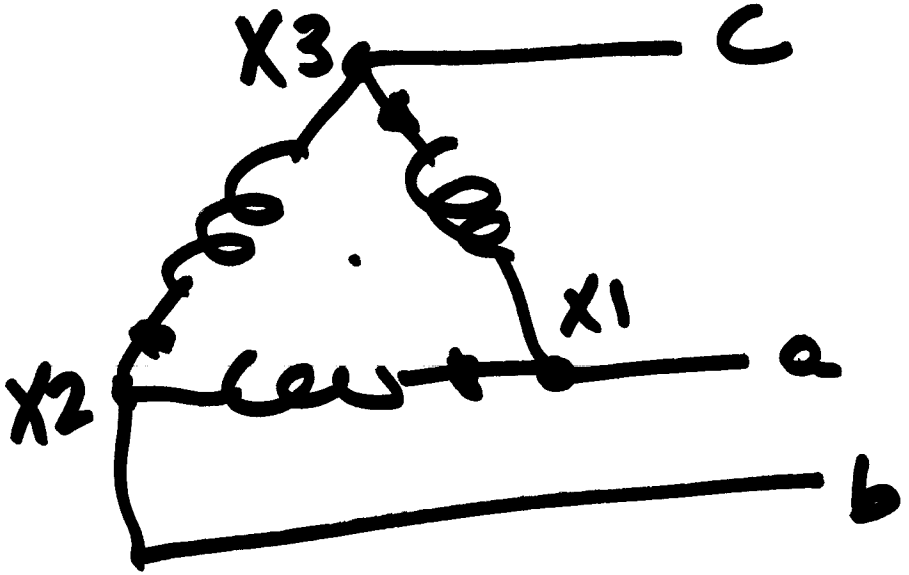
rmer impedances,
the resistance is

220 Y/22Δ kV. The
-voltage side of the
, this value may be
per-unit reactance of
nsformer in a system
) MVA, 230 kV.


H3(C)
Vc
VA
(N)H0
H1(A)
VB
H2(B)

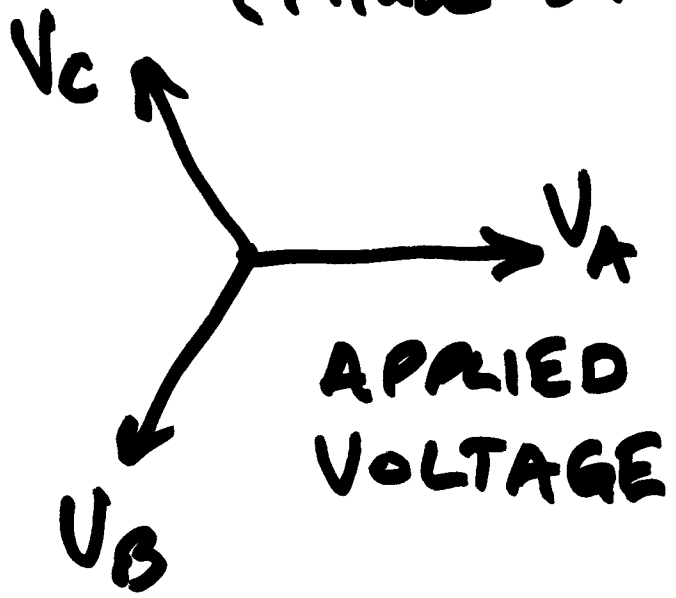

X3(c)
Vca
Vbc
X1(a)
X2(b)
Vab


C
H3
N
B
H2
A
H1

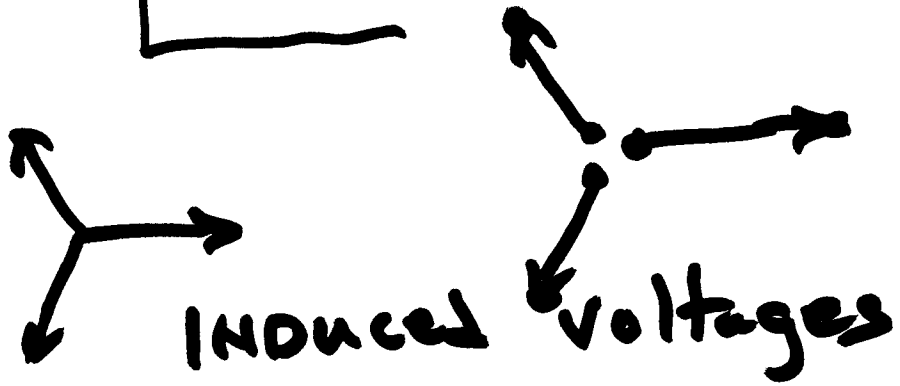

X3
C
X1
a
X2
b

Possible Connections for Δ-Y or YΔ XFMRS?

(Phase-Shifts)

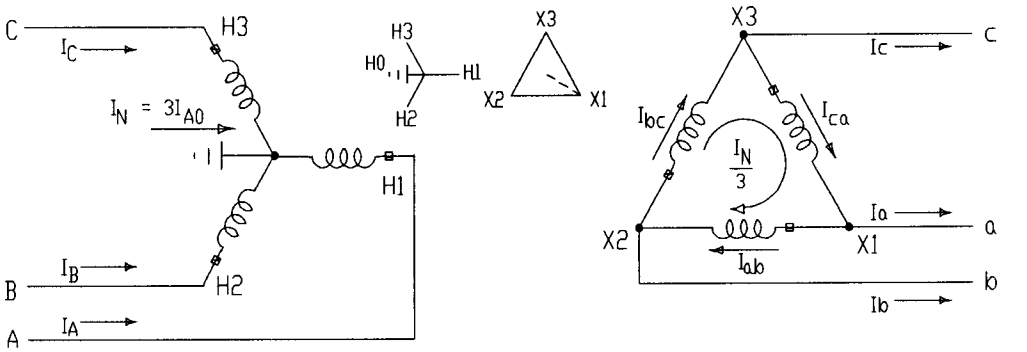


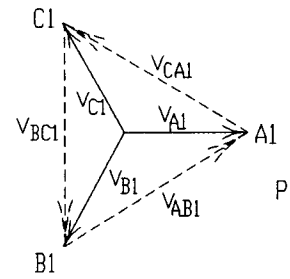
- ±30°
- ±90°
- ±150°



Note: Textbook "cookbook" eqns are set up to assume 30° phase shift.
But - many transformers are non-std phase shift, required by the grid tie requirements. ∴ learn to use phasor diagrams to figure out correct phase shifts!

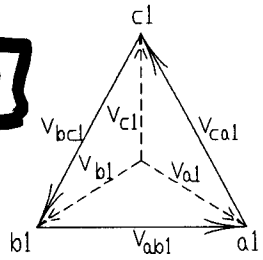
MORK



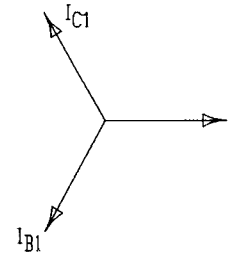


PRI POS SEQ VOLTAGES

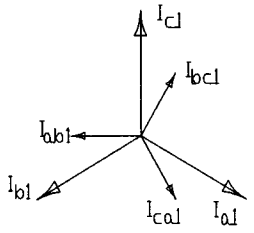
$$V_{A1} = V_{a1}\ (1\angle 30^\circ)$$



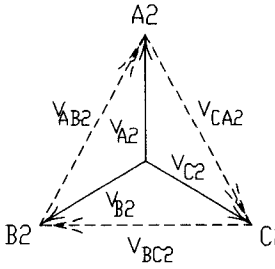
SEC POS SEQ VOLTAGES



PRI POS SEQ CURRENTS

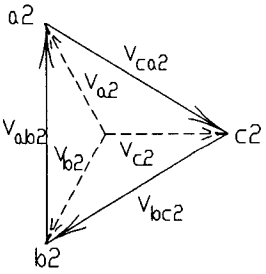


SEC POS SEQ CURRENTS

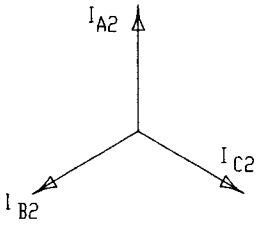


PRI NEG SEQ VOLTAGES

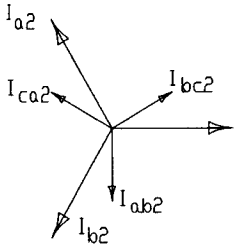
$$V_{A2} = V_{a2}\ (1\angle -30^\circ)$$



SEC NEG SEQ VOLTAGES



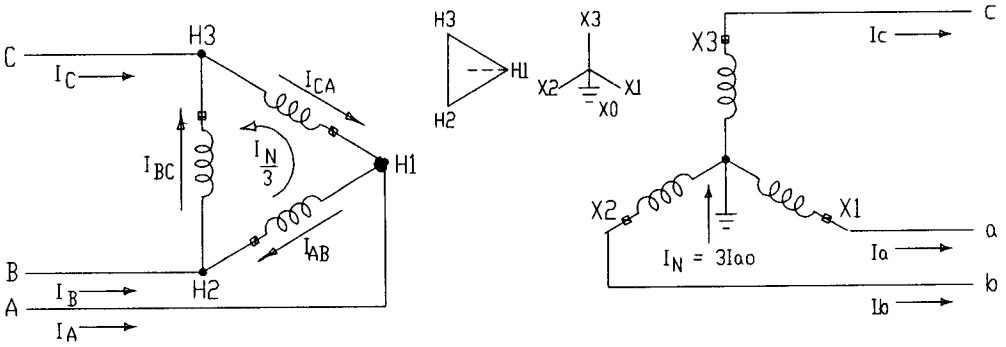
PRI NEG SEQ CURRENTS

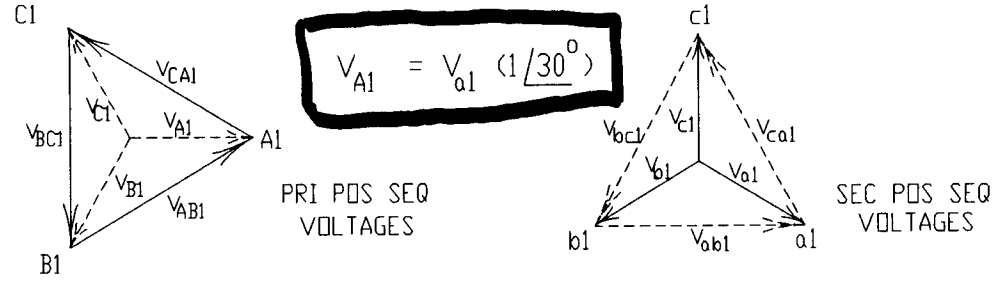


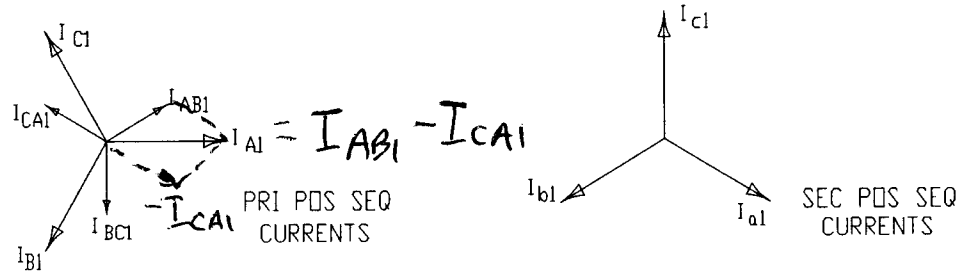
SEC NEG SEQ CURRENTS

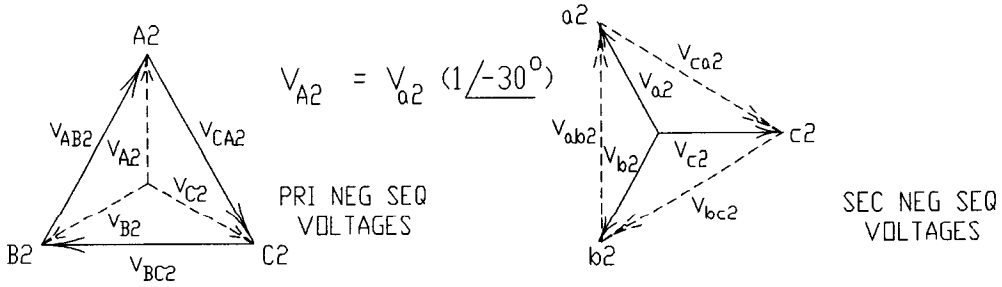
ANSI STANDARD 30-DEGREE SHIFT WYE-DELTA

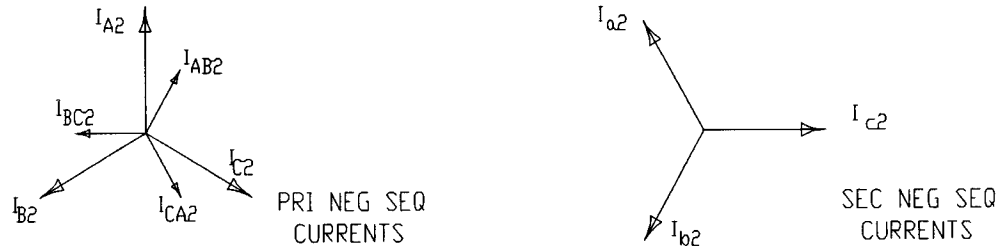
MARK



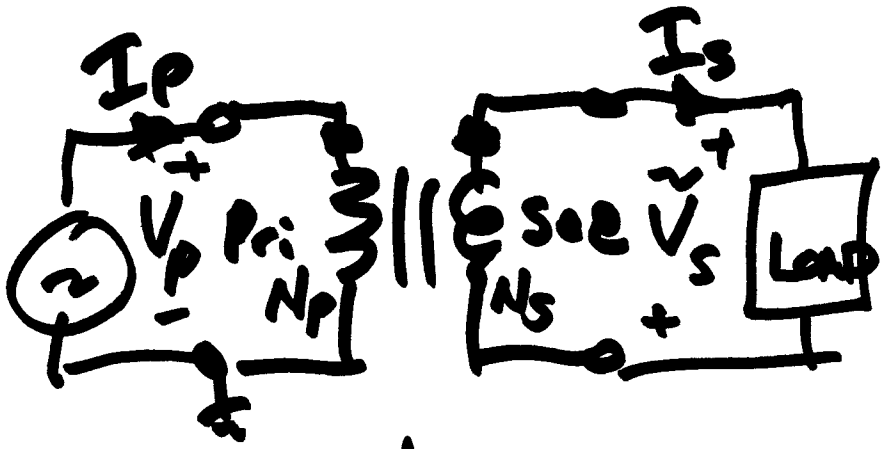






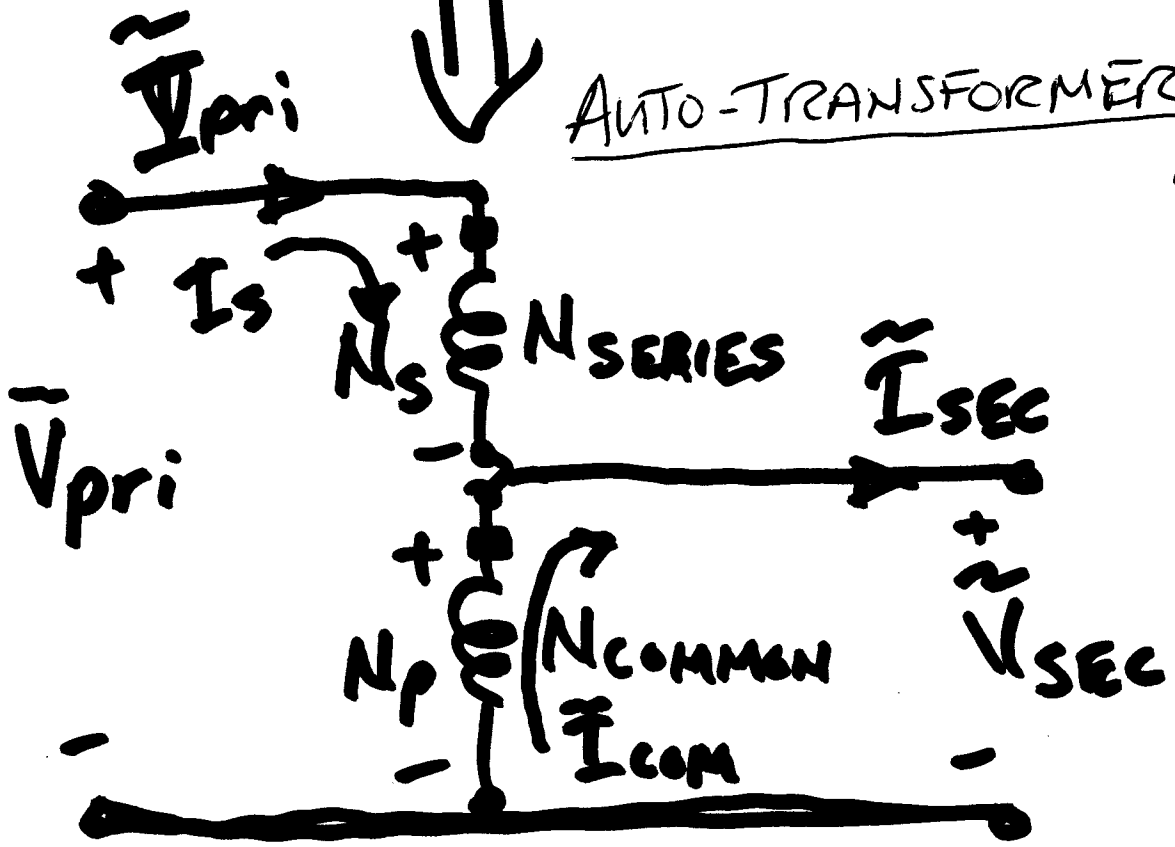


ANSI STANDARD 30-DEGREE SHIFT DELTA-WYE



$$\tilde{V}_p \tilde{I}_p^* = \tilde{V}_s \tilde{I}_s^*$$

AUTO-TRANSFORMERS



$$\tilde{V}_{PRI} \tilde{I}_{PRI}^* = \tilde{V}_{SEC} \tilde{I}_{SEC}^*$$

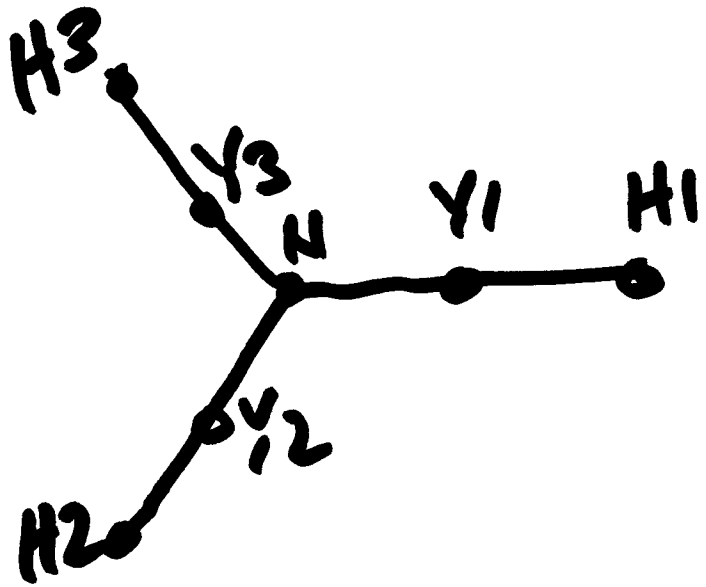
$$\tilde{I}_{SEC} = \tilde{I}_s + \tilde{I}_{COM}$$

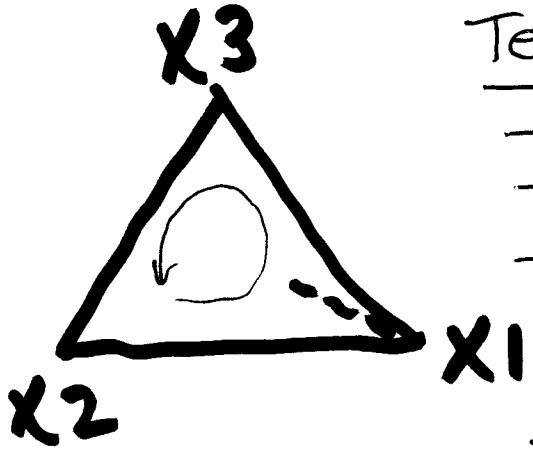
- Auto: transform more VA for same coil ratings (i.e. cheaper than 2-winding)

- 2-Winding provides isolation between pri-sec.

- Auto doesn't.

- Auto transformer: no phase shift for 3-ph applications.

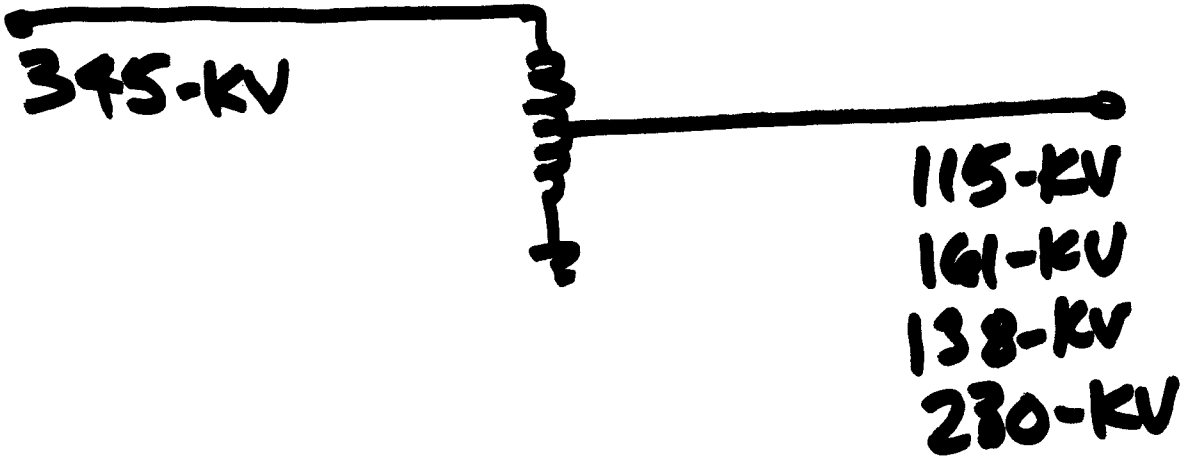




Tertiary:

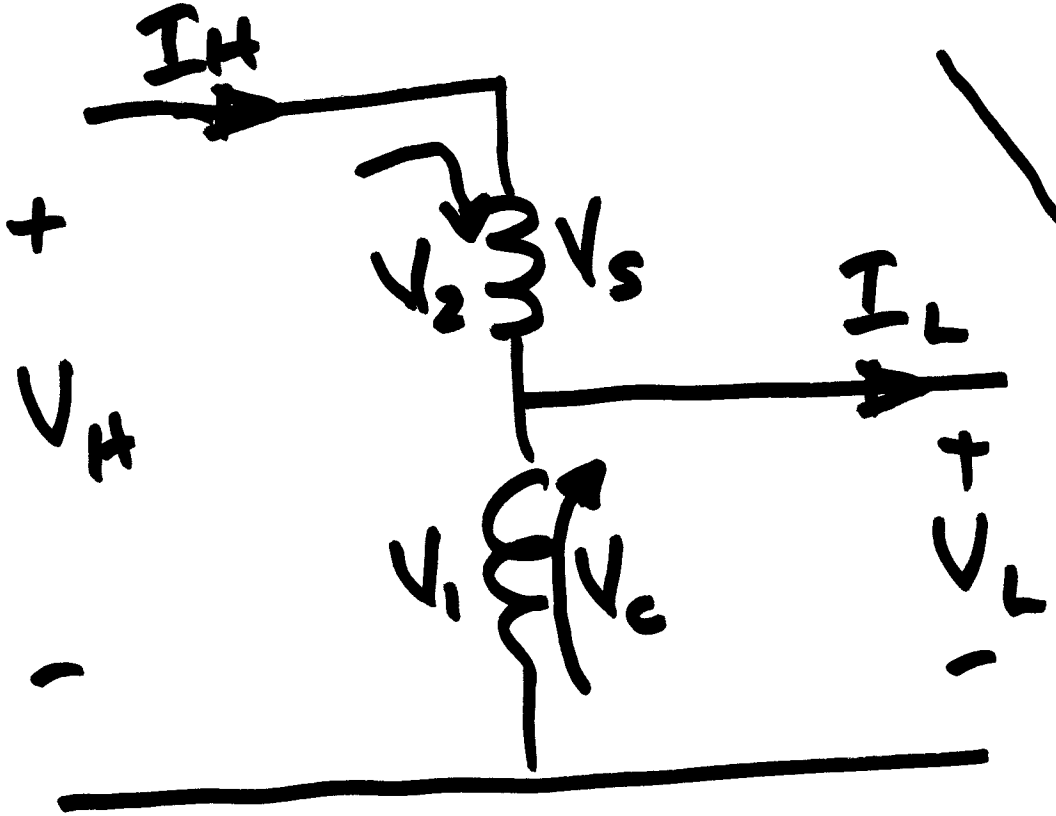
- Station Service
- Local Distribution
- Reactors or Caps
- Relaying CTs
- Harmonic Containment Tri-plen Circulation.

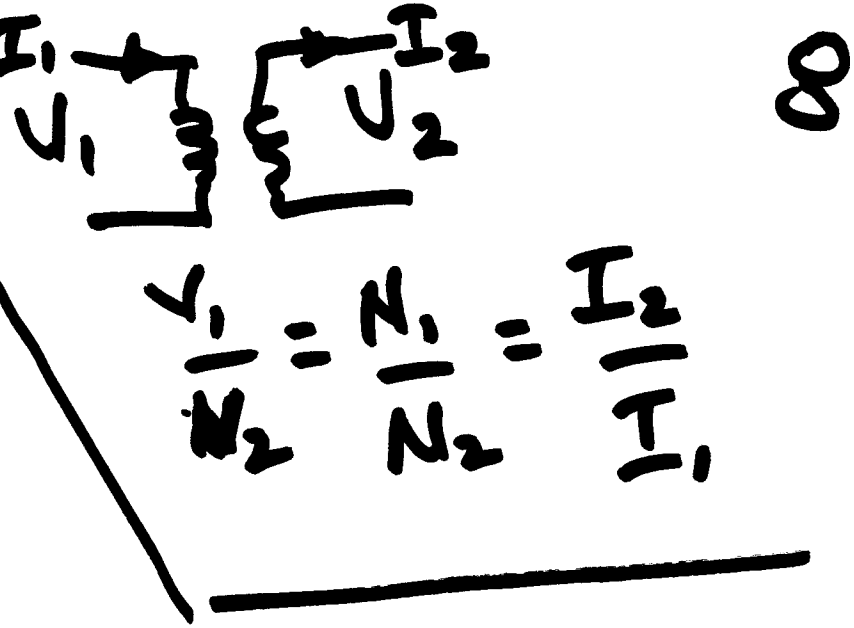
- Autotransformers usually limited to $\leq 3:1$ voltage ratio. (Leakage impedance)



- "VOLT-AMP ADVANTAGE"

Ratio of $\dfrac{VA_{AUTO}}{VA_{2\text{-winding}}}$ = VA Advantage





$$\frac{V_1}{N_1} = \frac{N_1}{N_2} = \frac{I_2}{I_1}$$

$$VA_{2-w} = V_1 I_1 = V_2 I_2$$

$$VA = V_H I_H = V_L I_L$$

$$VA_{ADV} = \frac{V_H I_H}{V_1 I_1} = \frac{(V_1 + V_2) I_2}{V_1 I_1}$$

$$I_H = I_2$$

$$V_L = V_1$$

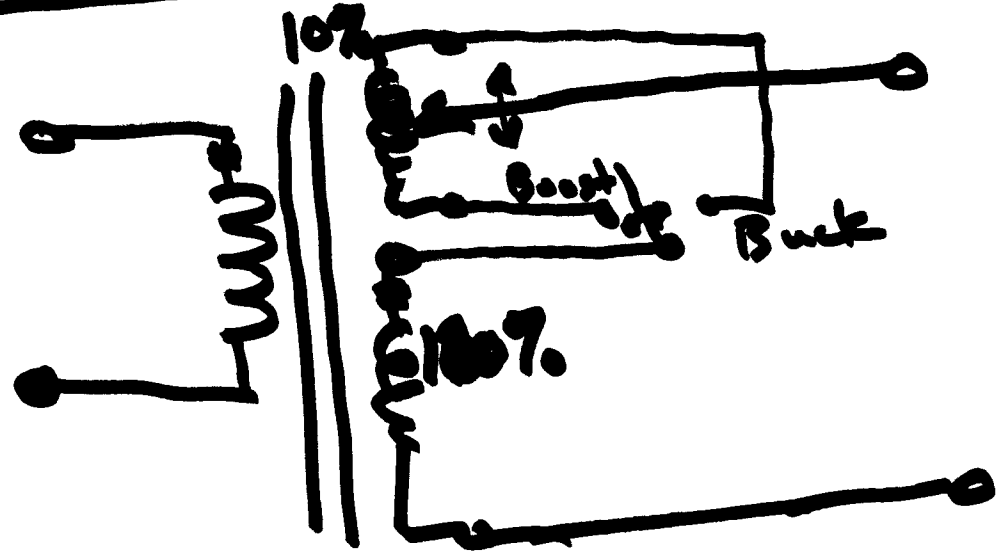
$$V_H = V_1 + V_2$$

$$I_L = I_1 + I_2$$

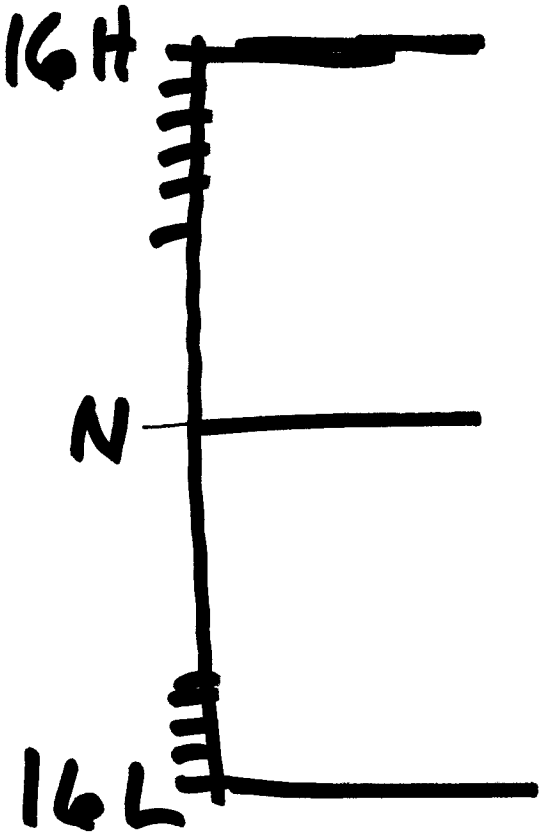
$$= \frac{(V_1 + V_2)\, I_1 \left(\frac{V_1}{V_2}\right)}{V_1 I_1} = \boxed{\frac{(V_1 + V_2)}{V_2}}$$

VOLT-AMP ADVANTAGE

TAP-CHANGERS (LTC)



→ boost or "buck" Nominal Voltage by 10%.



Thus: $V_{nominal} \pm 10\%$

16 tap positions

33 total positions

5/8% each step.

APPENDIX A

From EE 5200 text

TABLE A.1
Typical range of transformer reactances†
Power transformers 25,000 kVA and larger

Nominal system voltage, kV	Forced-air-cooled, %	Forced-oil-cooled, %
34.5	5–8	9–14
69	6–10	10–16
115	6–11	10–20
138	6–13	10–22
161	6–14	11–25
230	7–16	12–27
345	8–17	13–28
500	10–20	16–34
700	11–21	19–35

† Percent on rated kilovoltampere base. Typical transformers are now designed for the minimum reactance value shown. Distribution transformers have considerably lower reactance. Resistances of transformers are usually lower than 1%.