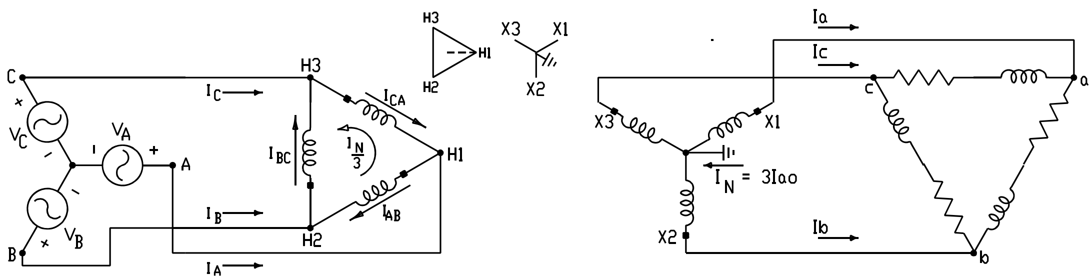
H5.5 This is a detailed example problem with solution. The basic situation is very similar to H5.4, continuing on to consider additional concepts. Go through this carefully. You are responsible for understanding the solution methods and concepts.

The following transformer is composed of 3 single phase transformers of pri:sec voltage ratio 480:120 volts. Each transformer is rated 4.5 kVA. For the load, R + jX = 8 + j6Ω. The voltage source is a balanced 3ϕ positive sequence source with $\mathbf{V}_A = 277.1\underline{/0^\circ}$ volts.



a) Find the effective 3ϕ turns ratio, a, of the 3ϕ transformer bank.

b) Calculate the magnitude of primary and secondary L-L and L-N voltages and construct closed phasor diagrams for these voltages (use separate diagrams for primary and secondary).

c) Calculate the magnitudes of the load phase currents, secondary line currents, primary line currents, and primary phase currents in the transformer's delta windings.

d) Construct phasor diagrams for all currents in the primary and secondary (use separate diagrams for primary and secondary).

e) In tabular form, list the phasor values of the following:

$\mathbf{V}_A$ $\mathbf{V}_{AB}$ $\mathbf{I}_A$ $\mathbf{I}_{AB}$ $\mathbf{V}_a$ $\mathbf{V}_{ab}$ $\mathbf{I}_a$ $\mathbf{I}_{ab}$

$\mathbf{V}_B$ $\mathbf{V}_{BC}$ $\mathbf{I}_B$ $\mathbf{I}_{BC}$ $\mathbf{V}_b$ $\mathbf{V}_{bc}$ $\mathbf{I}_b$ $\mathbf{I}_{bc}$

$\mathbf{V}_C$ $\mathbf{V}_{CA}$ $\mathbf{I}_C$ $\mathbf{I}_{CA}$ $\mathbf{V}_c$ $\mathbf{V}_{ca}$ $\mathbf{I}_c$ $\mathbf{I}_{ca}$

f) Has the VA rating for any of the 1ϕ transformers been exceeded?

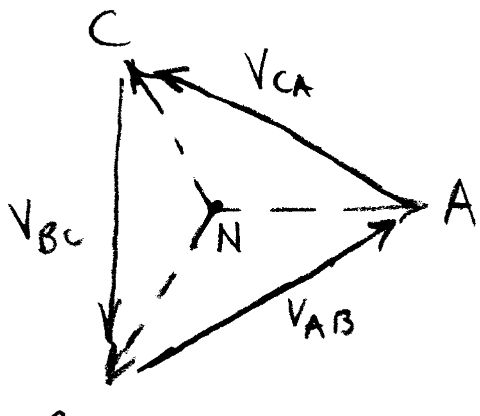
g) Construct a power triangle for the total 3ϕ complex power consumed by the load.

h) Concept/insight problem: If the short-circuit impedance ($R_{EQ} + jX_{EQ}$) of each of the single phase transformers referred to the 480V windings is 0.25 + j0.5 Ω, what is the equivalent per phase short-circuit impedance seen from the primary terminals of this 3ϕ transformer?

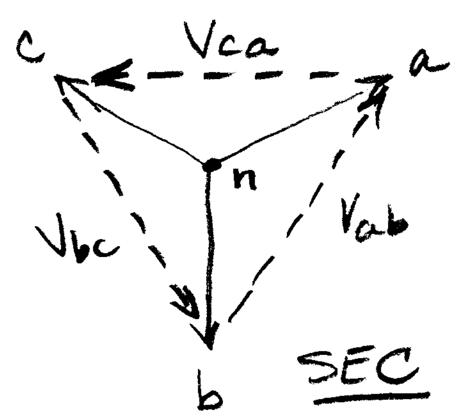
HANDOUT PROBLEM – SOLN

1) a) $a = \dfrac{|V_{LL}|_{pri}}{|V_{LL}|_{sec}} = \dfrac{|V_{LN}|_{pri}}{|V_{LN}|_{sec}} = \dfrac{480}{207.85} = \underline{\underline{2.309}}$

b) $|V_{LL}|_{pri} = 480V$ $|V_{LN}|_{pri} = 277.1$ $|V_{LL}|_{sec} = 207.9\ V$ $|V_{LN}|_{sec} = 120V$



PRI



SEC

c) $|I_{\phi,LOAD}| = \dfrac{207.9}{|8+j6|} = \underline{\underline{20.79\ A}}$

$|I_{L,sec}| = \sqrt{3}(20.79) = \underline{\underline{36\ A}} = |I_{\phi,sec}|$

$|I_{L,PRI}| = \frac{1}{a}|I_{L,sec}| = \dfrac{36}{2.31} = \underline{\underline{15.6\ A}} = |I_{\phi,sec}|$

$|I_{\phi,PRI}| = \dfrac{|I_{L,PRI}|}{\sqrt{3}} = \dfrac{(15.6)}{\sqrt{3}} = \underline{\underline{9\ A}}$

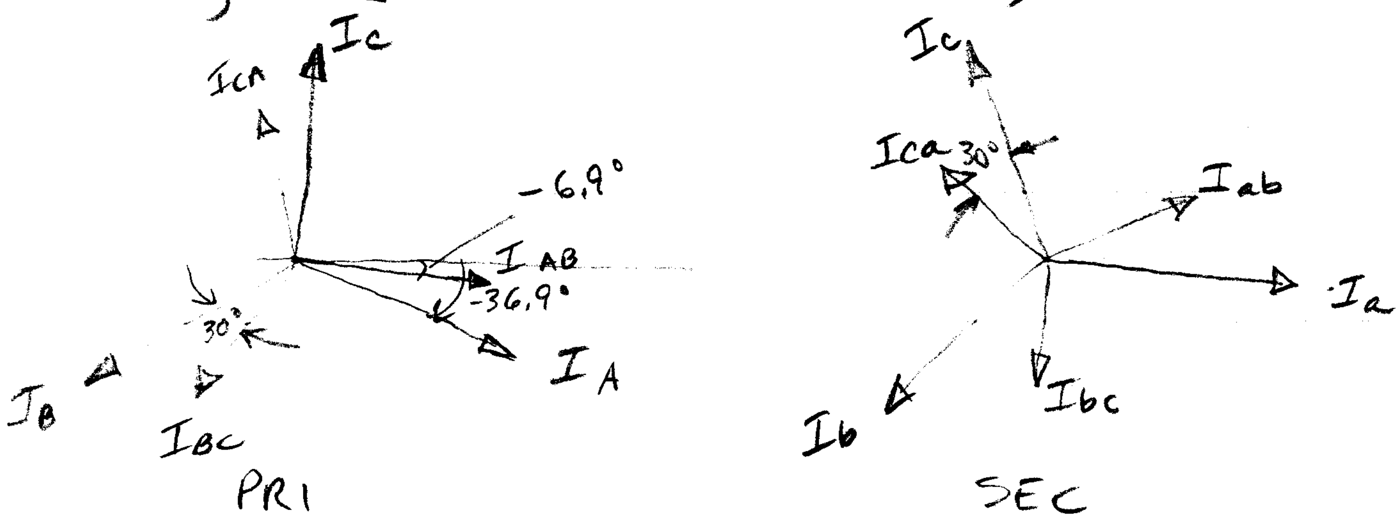
Constant VA check

$\underbrace{3(15.6)(277)}_{\text{SOURCE}} \stackrel{?}{=} \underbrace{3(9)(480)}_{\text{PRI}} \stackrel{?}{=} \underbrace{3(36)(120)}_{\text{SEC}} \stackrel{?}{=} \underbrace{3(20.79)(207.9)}_{\text{LOAD}}$

= 12,960 VA in each case

d) The angle of the load impedance is
$\tan^{-1}(6/8) = 36.9°$

All currents in the system must therefore lag their corresponding voltages by 36.9°. Using $\angle V_{AN} = 0°$ as reference,



Note: I_{AB} is in phase with I_a
I_{BC} — " — I_b
I_{CA} — " — I_c

e)

$V_A = 277.1\angle 0°$	$V_{AB} = 480\angle 30°$	$V_a = 120\angle 30°$	$V_{ab} = 207.9\angle 60°$
$V_B = 277.1\angle -120°$	$V_{BC} = 480\angle -90°$	$V_b = 120\angle -90$	$V_{bc} = 207.9\angle -60°$
$V_C = 277.1\angle 120°$	$V_{CA} = 480\angle 150°$	$V_c = 120\angle 150°$	$V_{ca} = 207.9\angle 180°$

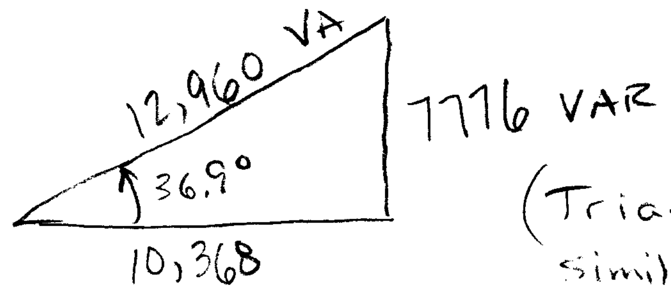
$I_A = 15.6\angle -36.9°$	$I_{AB} = 9\angle -6.9°$	$I_a = 36\angle -6.9°$	$I_{ab} = 20.8\angle 23.1°$
$I_B = 15.6\angle -156.9°$	$I_{BC} = 9\angle -126.9$	$I_b = 36\angle -126.9°$	$I_{bc} = 20.8\angle -96.9°$
$I_C = 15.6\angle 83.1°$	$I_{CA} = 9\angle 113.1°$	$I_c = 36\angle 113.1°$	$I_{ca} = 20.8\angle 143.1°$

f) As calculated in part c,

$$VA = 12{,}960/3 = 4320\ VA$$

$\therefore$ VA rating is not exceeded.

g)



(Triangle is similar to impedance triangle)

h) Moving $R_{EQ} + jX_{EQ}$ from the Δ windings to the line current path would require

$$(0.25 + j0.5)\left(\frac{277.1}{480}\right)^2 = \underline{0.083 + j0.167\,\Omega}$$

- This is like transforming from $\Delta \to Y$

or,

- This results in same total $I^2 R_{EQ}$ loss whether $R_{EQ} + jX_{EQ}$ is referred to Δ windings or to line.