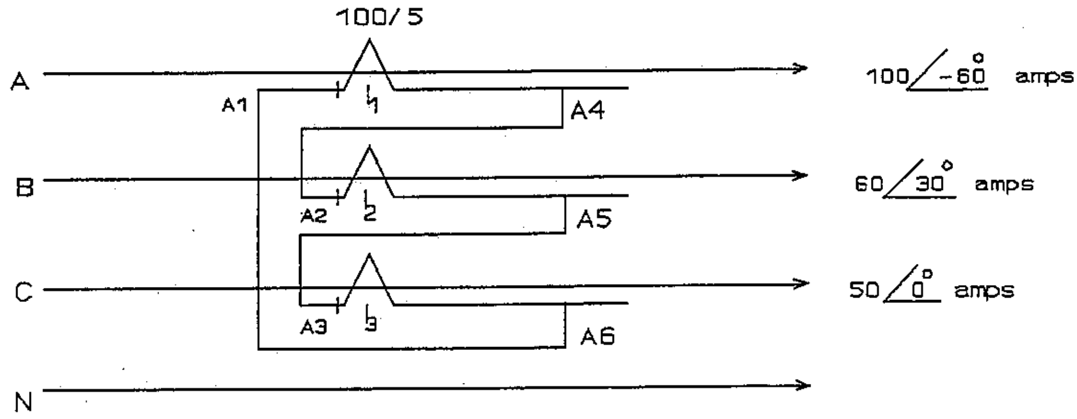
4kV METERING WITH UNBALANCED LOAD

This is a comparison of how a two-element meter registers watts on a 4kV, four-wire system with unbalanced load, to the calculated valued, using the single phase method of calculation. For simplification, the voltages are assumed to remain equal and symmetrical. The currents are at various magnitudes and power factors as follows:



Potential ratio = 20-1 Ø-N. Primary volts are 2400V. Ø-N or 4160V. Ø-Ø.

First the primary kW is calculated one phase at a time and added together for total 3Ø kW.

AØ = 100 amps x 2.4 kV x cos -60°		= 120 kW
BØ = 60 amps x 2.4 kV x cos 30°		= 124.7 kW
CØ = 50 amps x 2.4 kV x cos 0°		= <u>120 kW</u>
	Total 3Ø kw	= 364.7 kW
	3Ø primary watts	= 364,700 watts

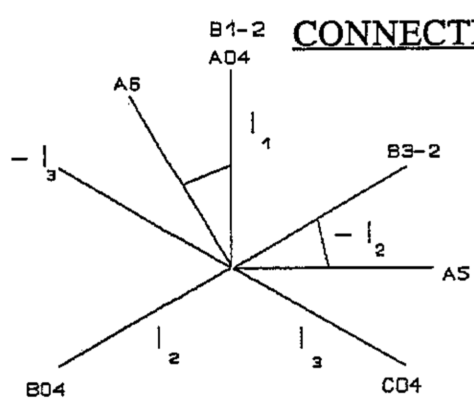
Next it is converted to secondary watts:
Multiplier = CT x PT

$$= \frac{100}{5} \times \frac{20}{1} = 400$$

$$\textit{Secondary watts} = \frac{364700}{400}$$

= <u>911.7 watts</u>

<u>CONNECTION</u>



Now, as the meter sees it, one element registers A6 current with reference to B1-2 voltage and A5 current with reference to B3-2 voltage, so those currents must first be calculated.

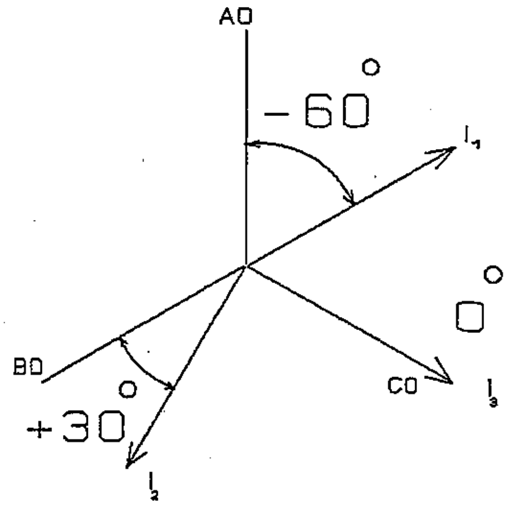
The secondary currents are:

$$I_1 = \frac{100}{20} = 5\angle{-60°}$$

$$I_2 = \frac{60}{20} = 3\angle 30°$$

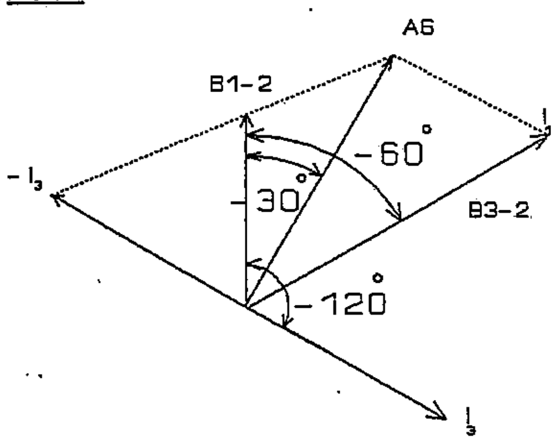
$$I_3 = \frac{50}{20} = 2.5\angle 0°$$

$$Secondary\ volts = \frac{2400}{20} = 120V.$$

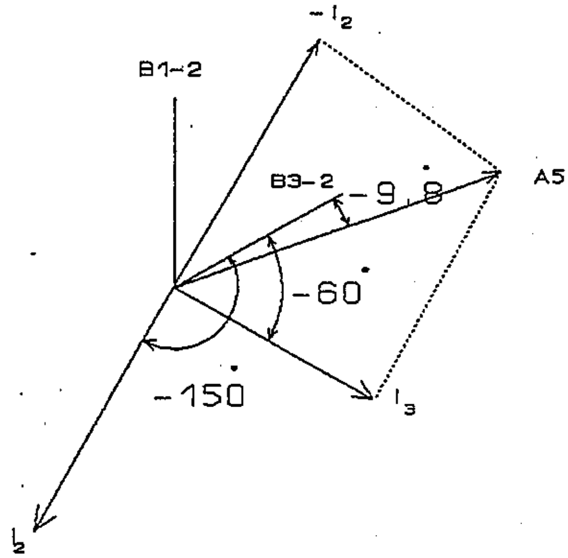


A6 will be equal to the phasor sum of I_1 + ($-I_3$) with B1-2 as reference, and A5 will be equal to the phasor sum of I_3 + ($-I_2$) with B3-2 as reference:

$$A6 = I_1 - I_3 = 5\underline{/-60°} - 2.5\underline{/-120°} = 4.33\underline{/-30°}$$
(B1-2 reference)



$A5 = I_3 - I_2 = 2.5\underline{/-60°} - 3\underline{/-150°} = 3.9\underline{/-9.8°}$
(B3-2 reference)



The two element meter registers the following:

A6-element watts = 4.33 x 120 x cos -30° = 450 watts
A5-element watts = 3.91 x 120 x cos -9.8° = 461.7 watts

Total watts in the meter = <u>911.7 watts</u>

This answer corresponds to the one obtained by the single phase calculations.

PROOF OF 4 WIRE 4kV 2 ELEMENT METERING

Can we prove that $P = A_6 \times B_{1-2} + A_5 \times B_{3-2}$ in a 4 wire 4 kv system where load is connected phase to ground?

Let us use E_1 , E_2 and E_3 as our phase to ground line potentials.

We will also let I_1 , I_2 and I_3 represent our phase to ground line currents.

Refer to 4 kv metering, Page 3, Figure 6 for a pictorial representation.

$P = I_1E_1 + I_2E_2 + I_3E_3$ and $E_1 + E_2 + E_3 = 0$

Re-arrange voltage equation so $E_3 = -E_2 -E_1$
Substitute into power equation to obtain

$P = I_1E_1 + I_2E_2 + I_3 (-E_2 -E_1)$ and expand to
$P = I_1E_1 + I_2E_2 - I_3E_2 - I_3E_1$

combining like E terms gives us

$P = E_1 (I_1 -I_3) + (-E_2)(I_3 -I_2)$

$I_1 -I_3$ graphically is shown to be A_6
$I_3 -I_2$ graphically is shown to be A_5

E_1 is a phase to ground voltage that lies in the same place as the A_0 current phasor which due to standard Edison 4 kv station light and power pot connection is the same as B_{1-2}

$-E_2$ is a phase to ground voltage that is 180^0 out (or pushed through the wheel) from the E_2 voltage which lies the same as the B_0 phase current phasor which is a B_{2-3} (note opposite polarity marks) so pushed through, or 180^0 out becomee B_{3-2}

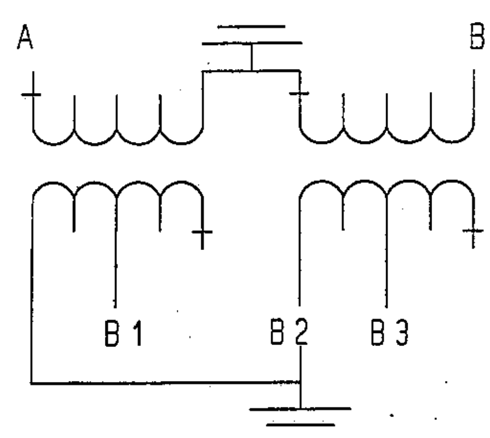


FIGURE 1

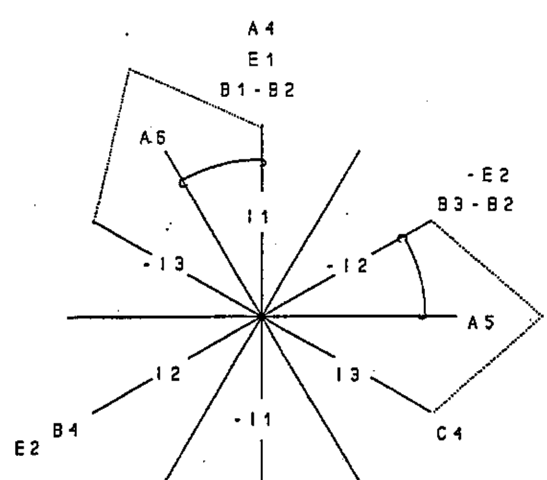


FIGURE 2