Given:
- phase V of ideal balanced 3-phase Y-source = 4.8kV
- source is connected to balanced Y-load by:
- distribution line with $z = 2 + j16\ \Omega$/phase
- load $z = 190 + j40\ \Omega/\phi$ (i.e. per phase)
- phase sequence is acb (for source)
- a-phase is reference

Specify:
a) the 3 line currents
b) " " " voltages at source
c) " " phase " " load
d) " " line " " "

ans:

a) $I_{aA} = 24\angle -16.3°$ A
$I_{bB} = 24\angle 103.7°$ A
$I_{cC} = 24\angle -136.3°$ A

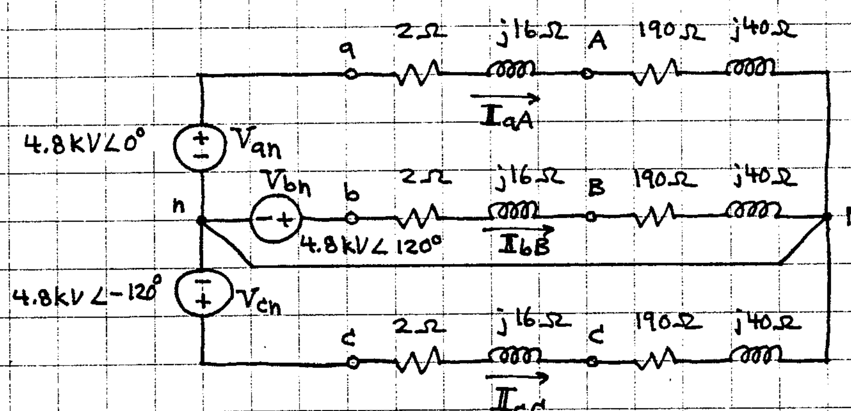
b) $V_{ab} = 4800\sqrt{3}\angle -30°$ V
$V_{bc} = 4800\sqrt{3}\angle 90°$ V
$V_{ca} = 4800\sqrt{3}\angle -150°$ V

c) $V_{AN} = 4660\angle -4.4°$ V
$V_{BN} = 4660\angle 115.6°$ V
$V_{CN} = 4660\angle -124.4°$ V

d) $V_{AB} = 8070\angle -34.4°$ V
$V_{BC} = 8070\angle 85.6°$ V
$V_{CA} = 8070\angle -154.4°$ V

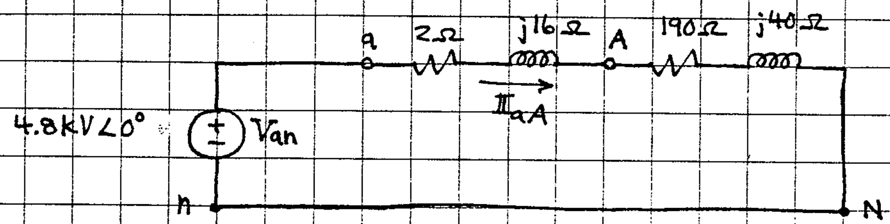
soln: a) acb $\Rightarrow$ negative phase sequence
$\therefore$ b or B signals are obtained from a or A signals by adding 120°
c or C signals " " " a or A
" " adding −120° (or subtracting +120°)

System diagram: (since a-phase is ref, use $\angle 0°$ for V_{an})



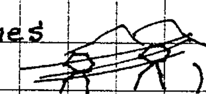
Note: No current flows in nN (gnd) connection for balanced 3-phase system.

We can solve for all the requested values by employing a single-phase model:



Now for definitions:

line ≡ distribution line connecting a to A. (In real life a high voltage line connecting a generator at Hoover Dam to (ultimately) a wall socket in your house. These are the high-voltage lines we see crossing the desert:

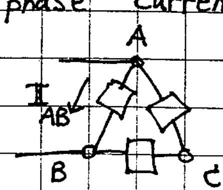


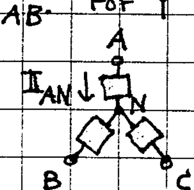
)

line current ≡ current flowing in the distribation line

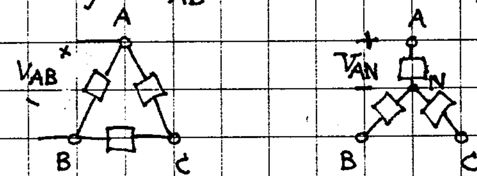
line voltage ≡ the voltage difference across a pair of distribution lines. (We can measure this at the source such as Hoover Dam or at the load such as a large motor in a factory)

phase current ≡ current flowing thru one leg of a Δ or Y configuration. For Δ config. we have, e.g. phase current $\mathbb{I}_{AB}$. For Y it's $\mathbb{I}_{AN}$.





phase voltage $\equiv$ voltage across on leg of a Δ or Y configuration. For Δ we have, e.g. difference voltage V_{AB}. For Y it's V_{AN}.



Thus, line current is I_{aA} for 1st phase, (i.e. 'a' phase).

Using single-phase model, we just apply standard circuit eq'ns:

$$I_{aA} = \frac{V_{an}}{Z_{tot}} = \frac{4.8\text{kV}\angle 0^\circ}{2 + j16 + 190 + j40}\text{ A} = \frac{4.8\text{kV}\angle 0^\circ}{192 + j56}\text{ A}$$

$$" = \frac{4.8\text{kV}\angle 0^\circ}{200\angle 16.3^\circ}\text{ A} = 24\angle -16.3^\circ\text{ A}$$

We obtain the other line currents by shifting $\pm 120^\circ$:

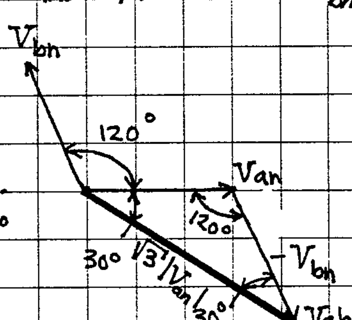
$$I_{bB} = I_{aA} \cdot 1\angle +120^\circ = 24\angle 103.7^\circ\text{ A}$$

$$I_{cC} = I_{aA} \cdot 1\angle -120^\circ = 24\angle -136.3^\circ\text{ A}$$

b) Line voltage at source is $V_{ab} \equiv V_{an} - V_{bn}$.

Use phasor diagram and fact that $V_{bn} = V_{an} \cdot 1\angle 120^\circ$:

$V_{ab} \equiv V_{an} - V_{bn}$ gives V_{ab} = long side of isosceles triangle.
$\angle$ relative $V_{an} = -30^\circ$
$|V_{ab}| = \sqrt{3}\,|V_{an}|$



Note: for positive phase sequence we would get $+30^\circ$ for $\angle V_{ab}$ relative to $\angle V_{an}$.

From diagram, we have $V_{ab} = V_{an} \cdot \sqrt{3} \angle -30°$.

Using this result and $\pm 120°$ phase shifts gives:

$$V_{ab} = 4.8\text{kV} \angle 0° \cdot \sqrt{3} \angle -30° = 4800\sqrt{3} \angle -30° \text{ V}$$
$$V_{bc} = 4800\sqrt{3} \angle -30° + 120° = 4800\sqrt{3} \angle 90° \text{ V}$$
$$V_{ca} = 4800\sqrt{3} \angle -30° - 120° = 4800\sqrt{3} \angle -150° \text{ V}$$

c) Since we have a Y load, the phase voltages at the load are V_{AN}, V_{BN}, V_{CN}.

To find V_{AN}, we use V_{an} and V-divider:

$$V_{AN} = V_{an} \cdot \frac{190 + j40}{2 + j16 + 190 + j40} = V_{an} \frac{190 + j40}{192 + j56}$$

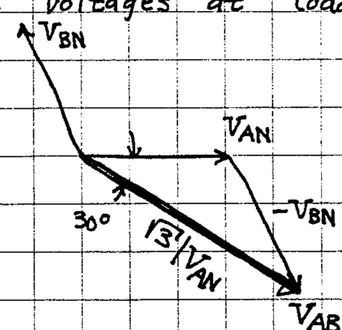
$$'' = 4800 \angle 0° \cdot \frac{194 \angle 11.9°}{200 \angle 16.3°} = 4800 \cdot \frac{194}{200} \angle 0° + 11.9° - 16.3° \text{ V}$$

$$'' = 4.66 \text{ kV} \angle -4.4°$$

$$V_{BN} = V_{AN} \cdot 1 \angle 120° = 4.66 \text{ kV} \angle 115.6°$$

$$V_{CN} = V_{AN} \cdot 1 \angle -120° = 4.66 \text{ kV} \angle -124.4°$$

d) Line voltages at load are $V_{AB} = V_{AN} - V_{BN}, V_{BC}, V_{CA}$.



As with V_{ab} vs V_{an}, we have $V_{AN} = V_{AN} \cdot \sqrt{3} \angle -30°$.

$$\therefore V_{AB} = 4.66\text{kV} \angle -4.4° \cdot \sqrt{3} \angle -30°$$
$$'' = 8070 \angle -34.4° \text{ V}$$

$$V_{BC} = 8070 \angle -34.4° + 120° = 8070 \angle 85.6° \text{ V}$$
$$V_{CA} = 8070 \angle -154.4° \text{ V}$$