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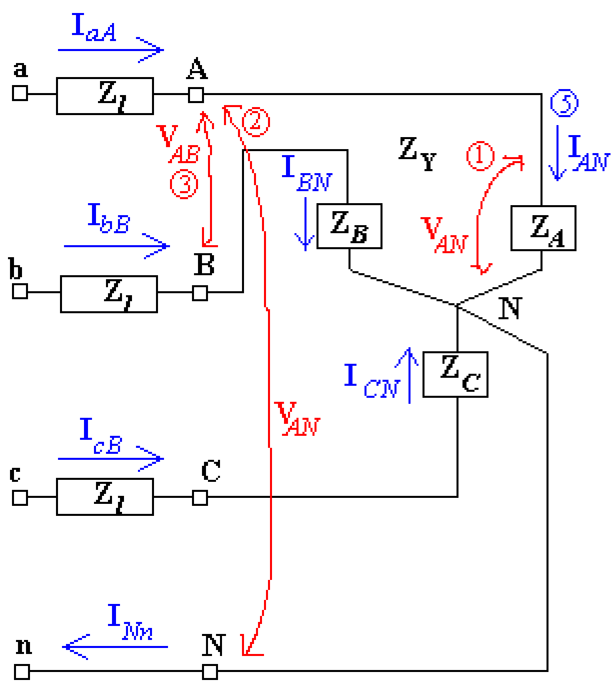
EECE 301 NETWORK ANALYSIS II Dr. Charles Kim

Note 15: 3-phase system -- SUMMARY

1. Balanced 3-ϕ system is characterized by:
   - 3 voltages are with same magnitude and 120° phase shift
   - 3 load impedances are same
   - Therefore, the currents are balanced with same magnitude and 120° apart
2. There are two types of voltages and two types of currents:
   - Phase Voltage (V_ϕ)= "voltage across a phase impedance"
   - Line Voltage (V_l)= "voltage between a (phase) line and another (phase) line"
   - Phase Current (I_ϕ)= "current through a phase impedance"
   - Line Current (I_l) = "current through a (phase) line"
3. Above definitions have different meaning at different load formation, Y or Δ

Y-load case: As shown below, the three phase impedances (Z_A, Z_B, Z_C) form the letter "Y". In the figure, the line connecting 3-phase source to the Y-load is represented by a line impedance, Z_l.



$V_\phi = V_{AN}$, V_{BN}, and V_{CN} (1)

i.e., phase voltage is same as the voltage between a (phase) line and the neutral (marked as "N") (2)

$V_l = V_{AB}$, V_{BC}, and V_{CA} (3)

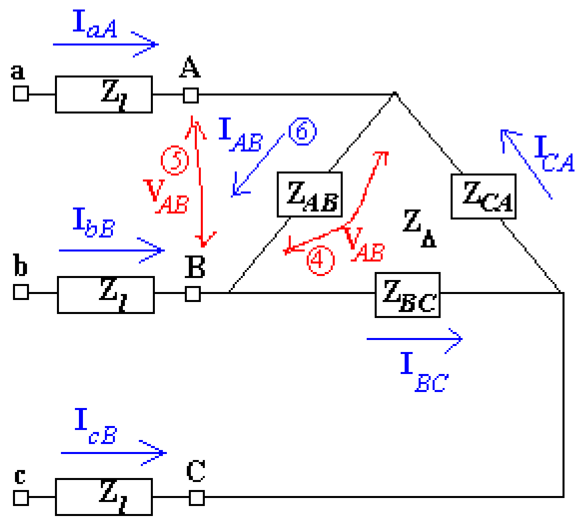
$I_\phi = I_{AN}$, I_{NN}, and i_{CN}

$I_l = I_{aA}$, I_{bB}, and i_{cC} (also, $I_{AN}=I_{aA}$,etc)

Conclusion of Y-load:

(i) $I_\phi = I_l$ (ii) $V_\phi \neq V_l$ (instead, $V_l = \sqrt{3} V_\phi \angle 30^\circ$)

Δ Load Case: As shown below, the 3 phase loads (Z_{AB}, Z_{BC}, and Z_{CA}) form a Delta shape. As in Y-load, the line connecting 3-phase source to the Y-load is represented by a line impedance, Z_l. Note that there is no neutral point.



$V_\phi = V_{AB}$, V_{BC}, and V_{CA} (4)
$V_l = V_{AB}$, V_{BC}, and V_{CA} (5)
$I_\phi = I_{AB}$, I_{BC}, and i_{CA}
$I_l = I_{aA}$, I_{bB}, and i_{cC}

Conclusion of Δ-load:

(i) $I_\phi \neq I_l$ (instead $I_l = \sqrt{3} I_\phi \angle -30^\circ$) (ii) $V_\phi = V_l$

4. 3-Phase Power Calculations

Y-Load Case:

$$P_{3\phi} = 3V_\phi I_\phi \cos\theta_\phi = 3\left(V_l \big/ \sqrt{3}\right) I_l \cos\theta_\phi = \sqrt{3} V_l I_l \cos\theta_\phi$$

$$Q_{3\phi} = 3V_\phi I_\phi \sin\theta_\phi = \sqrt{3} V_l I_l \sin\theta_\phi$$

Δ Load Case:

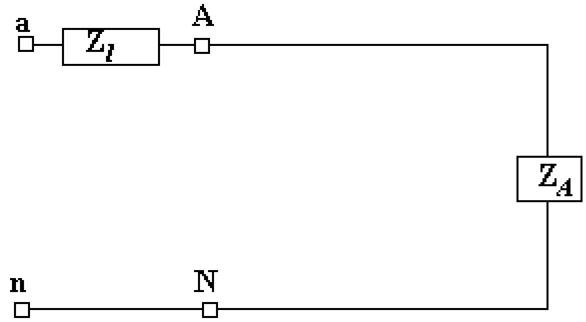
$$P_{3\phi} = 3V_\phi I_\phi \cos\theta_\phi = 3V_l \left(I_l \big/ \sqrt{3}\right) \cos\theta_\phi = \sqrt{3} V_l I_l \cos\theta_\phi$$

$$Q_{3\phi} = 3V_\phi I_\phi \sin\theta_\phi = \sqrt{3} V_l I_l \sin\theta_\phi$$

5. Single-Phase Equivalent Circuit

- In a balanced 3-phase system, voltage and current magnitudes are same.
- In a balanced 3-phase system, voltage and current are 120° apart from each other
- Therefore, once a phase value is known, the other two are also known
- **NOTE**: Single-phase equivalent circuit is formed so that a phase impedance is connected *between a phase (line) and the neutral*.

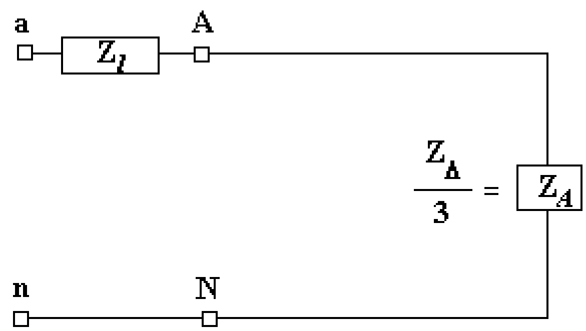
Y-load case: From the Y-load figure, let's delete two phases (B, and C), then the remaining circuit looks like below:



Note: $V_\phi = V_{AN}$, and

$I_\phi = I_{aA}$

Δ-Load Case: There is a slight problem here, since there is no neutral point. So we have to convert the load to Y-load equivalent. By the usual Δ-Y Transformation, we could get the Y impedance, in terms of Delta-load, as $Z_Y = \frac{Z_\Delta}{3}$. Then the single-phase circuit looks like this:



NOTE: The voltage across the impedance in this single-phase circuit is **not** the actual phase voltage across the impedance. V_{AB} is the actual voltage across a impedance. So we have to convert the voltage, after your calculation of V_{AN}, to V_{AB} for a delta-load phase voltage.

$V_\phi = V_{AB} = \sqrt{3} V_{AN} \angle 30^\circ$ and,

$I_\phi = I_{AB} = \frac{I_{aA}}{\sqrt{3}} \angle 30^\circ$