Lecture Notes
ELEC B7

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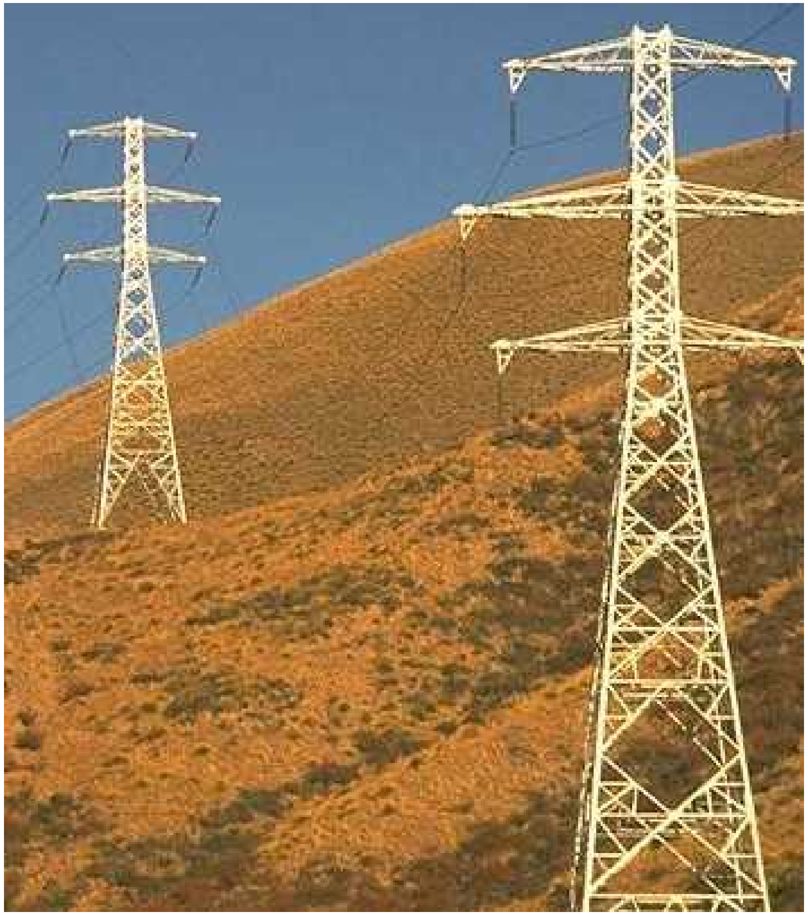
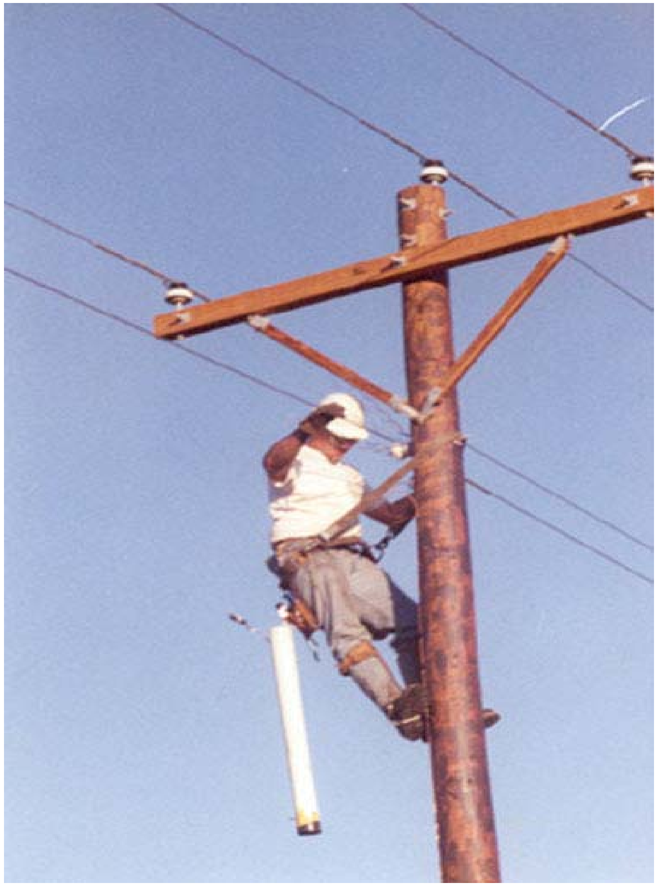
Three Phase circuits

Three-phase Circuits





Advantages of Three-phase Circuits

- Smooth flow of power (instantaneous power is constant).
- Constant torque (reduced vibrations).
- The power delivery capacity tripled (increased by 200%) by increasing the number of conductors from 2 to 3 (increased by 50%).

Three-phase Circuits

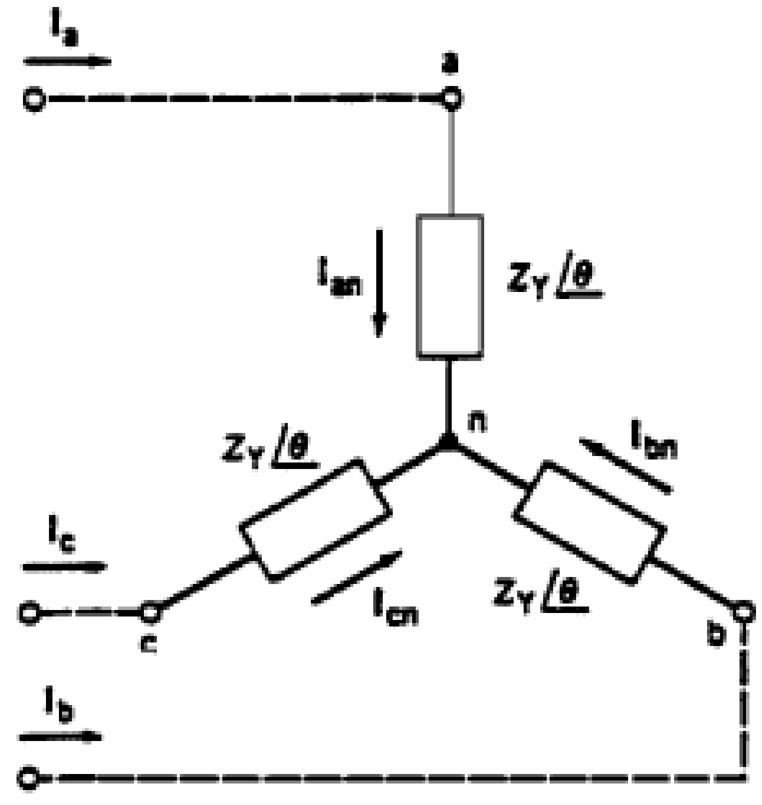
<u>Wye-Connected System</u>

- The neutral point is grounded
- The three-phase voltages have equal magnitude.
- The phase-shift between the voltages is 120 degrees.

$$\mathbf{V}_{\mathbf{an}} = |V| \angle 0° = V$$

$$\mathbf{V}_{\mathbf{bn}} = |V| \angle -120°$$

$$\mathbf{V}_{\mathbf{cn}} = |V| \angle -240°$$



Three-phase Circuits

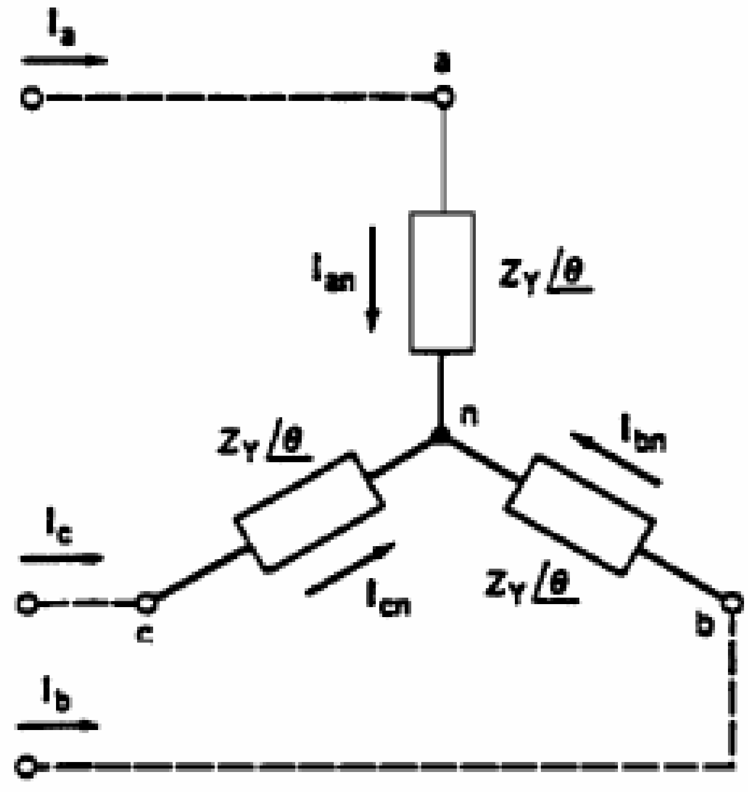
<u>Wye-Connected System</u>

- Line-to-line voltages are the difference of the phase voltages

$$\mathbf{V}_{ab} = \mathbf{V}_{an} - \mathbf{V}_{bn} = \sqrt{3}\,\mathrm{V}\,\angle 30$$

$$\mathbf{V}_{bc} = \mathbf{V}_{bn} - \mathbf{V}_{cn} = \sqrt{3}\,\mathrm{V}\,\angle -90$$

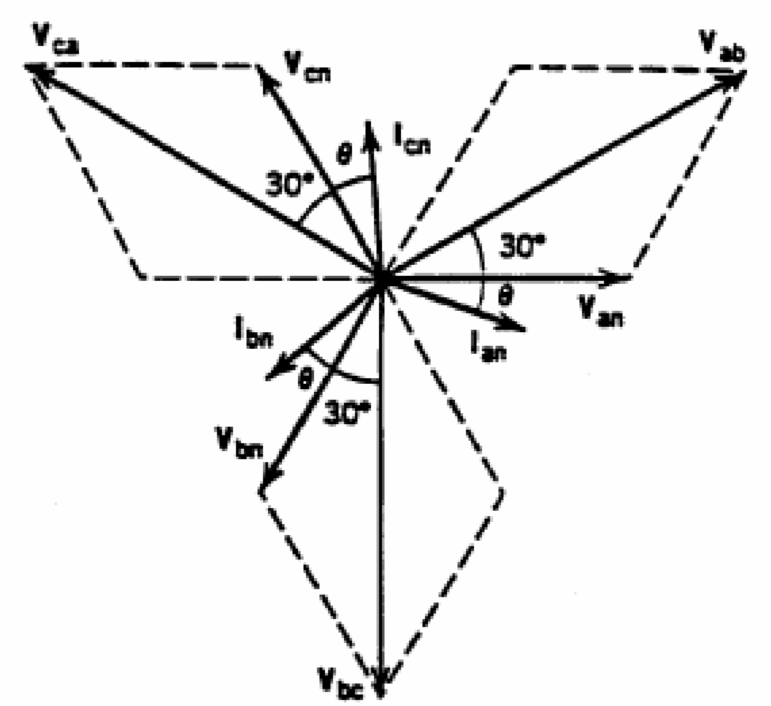
$$\mathbf{V}_{ca} = \mathbf{V}_{cn} - \mathbf{V}_{an} = \sqrt{3}\,\mathrm{V}\angle 150$$



Three-phase Circuits

Wye-Connected System

- Phasor diagram is used to visualize the system voltages
- Wye system has two type of voltages: Line-to-neutral, and line-to-line.
- The line-to-neutral voltages are shifted with 120^o
- The line-to-line voltage leads the line to neutral voltage with 30^o
- The line-to-line voltage is $\sqrt{3}$ times the line-to-neutral voltage

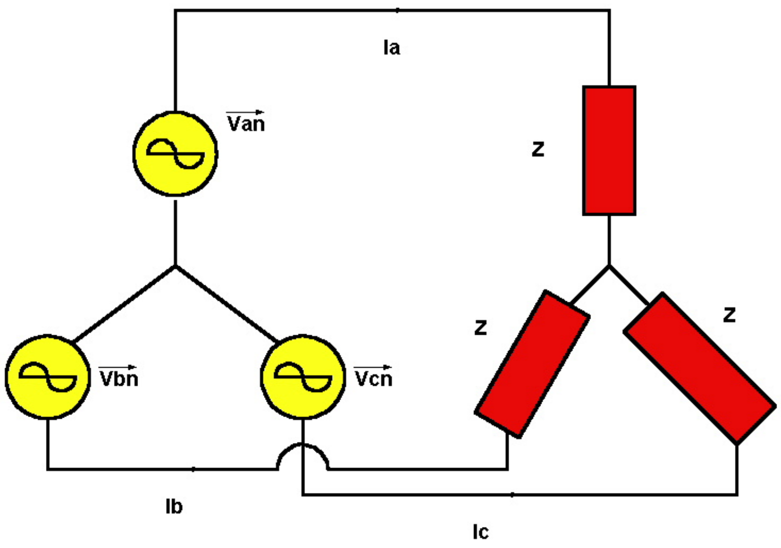


Three-phase Circuits

Wye-Connected Loaded System

- **The load is a balanced load and each one = Z**
- **Each phase voltage drives current through the load.**
- **The phase current expressions are:**

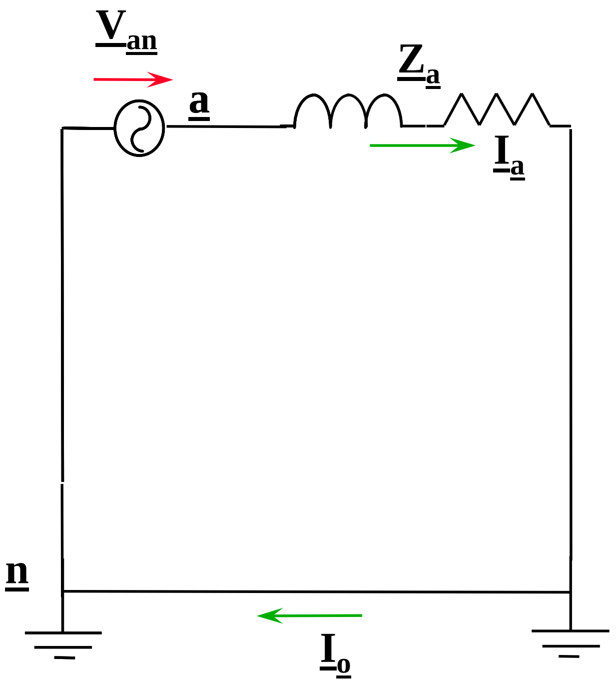
$$I_a = \frac{V_{an}}{Z}, \quad I_b = \frac{V_{bn}}{Z}, \quad I_c = \frac{V_{cn}}{Z}$$



Three-phase Circuits

Wye-Connected Loaded System

- **Since the load is balanced ($Z_a = Z_b = Z_c$) then: Neutral current = 0**

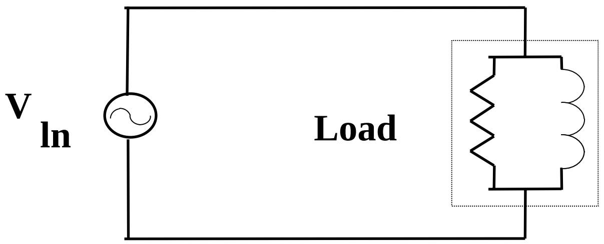


- **This case single phase equivalent circuit can be used (phase a, for instance, only)**
- **Phase b and c are eliminated**

Three-phase Circuits

Wye-Connected System with balanced load

- A single-phase equivalent circuit is used
- Only phase **a** is drawn, because the magnitude of currents and voltages are the same in each phase. Only the phase angles are different (-120^{o} phase shift)
- The supply voltage is the **line to neutral voltage.**
- The single phase loads are connected to neutral or ground.

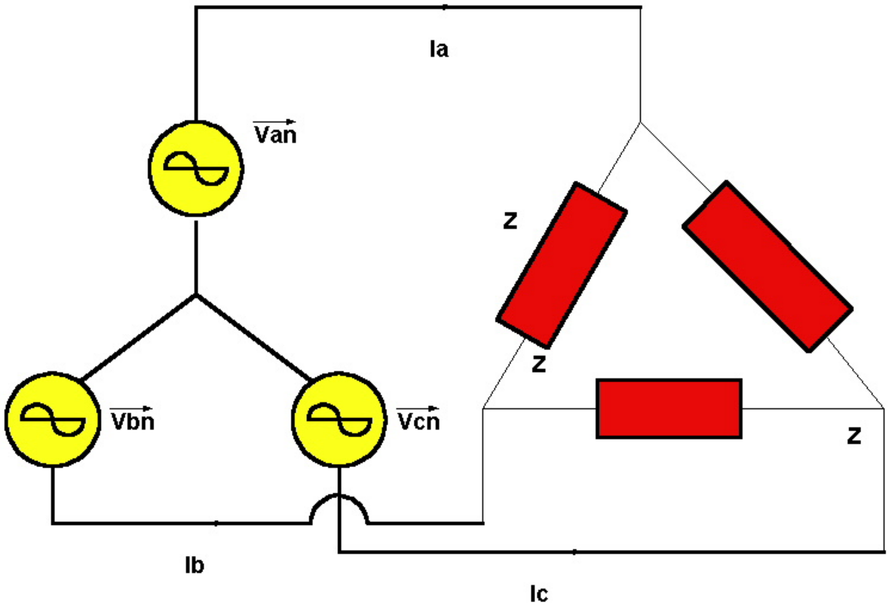


Three-phase Circuits

Balanced Delta-Connected System

- **The system has only one voltage : the line-to-line voltage (V_{LL})**
- **The system has two currents**
  - **line current**
  - **phase current**
- **The phase currents are:**

$$I_a = \frac{V_{ab}}{z}$$



Three-phase Circuits

<u>Delta-Connected System</u>

The line currents are:

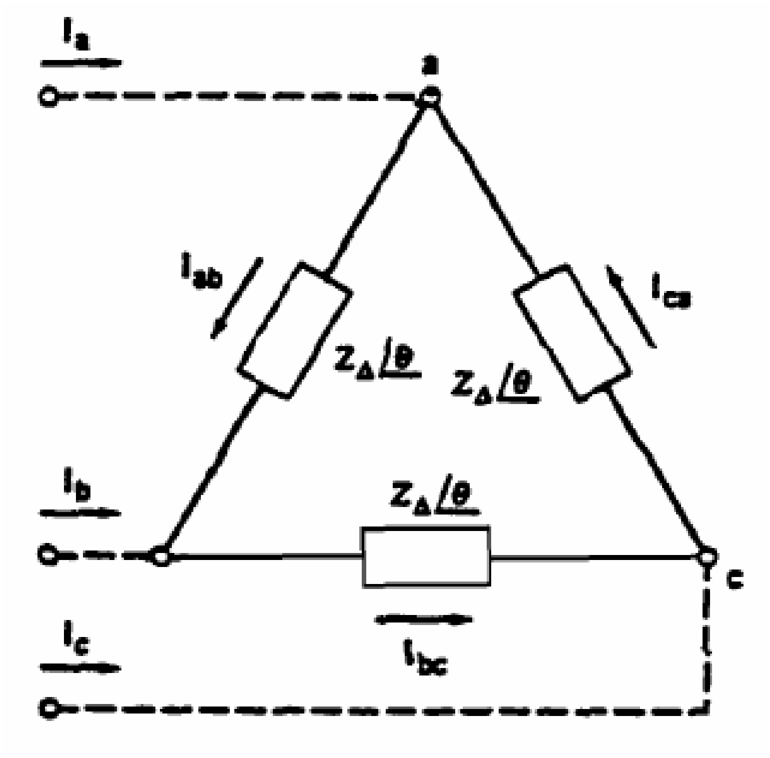
$$\mathbf{I_a = I_{ab} - I_{ca}}$$

$$\mathbf{I_b = I_{bc} - I_{ab}}$$

$$\mathbf{I_c = I_{ca} - I_{bc}}$$

- **In a balanced case the line currents are:**

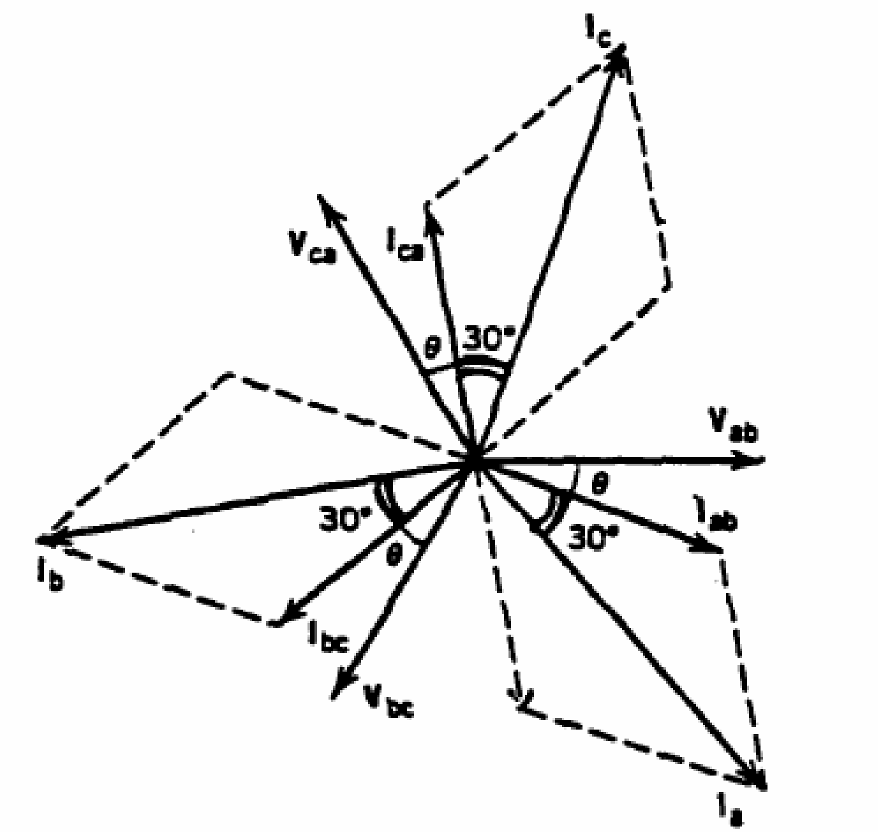
$$I_{line} = \sqrt{3} I_{phase} \angle -30$$



Three-phase Circuit

Delta-Connected System

- **The phasor diagram is used to visualize the system currents**
- **The system has two type of currents: line and phase currents.**
- **The delta system has only line-to-line voltages, that are shifted by**
- **The phase currents lead the line currents by 30°**
- **The line current is $\sqrt{3}$ times the phase current and shifted by 30 degree.**



Three-phase Circuit

- **Circuit conversions**
  - A delta circuit can be converted to an equivalent wye circuit. The equation for phase a is:

$$\mathbf{Z_a} = \frac{\mathbf{Z}_{\text{ab}}\,\mathbf{Z_{ca}}}{\mathbf{Z}_{\text{ab}} + \mathbf{Z_{bc}} + \mathbf{Z_{ca}}}$$

  - Conversion equation for a balanced system is:

$$\mathbf{Z_a} = \frac{\mathbf{Z}_{\text{ab}}}{3}$$

Three-phase Circuit

Power Calculation

- **The three phase power is equal the sum of the phase powers**

$$\mathbf{P = P_a + P_b + P_c}$$

- **If the load is balanced:**

$$\mathbf{P = 3\,P_{phase} = 3\,V_{phase} I_{phase}\,\cos(\phi)}$$

- **Wye system:** $\mathbf{V_{phase} = V_{LN}}$ $\mathbf{I_{phase} = I_L}$ $\mathbf{V_{LL} = \sqrt{3}\,V_{LN}}$

$$\mathbf{P = 3\,V_{phase} I_{phase}\,\cos(\phi) = \sqrt{3}\,V_{LL} I_L\,\cos(\phi)}$$

- **Delta system:** $\mathbf{I_{Line} = \sqrt{3}\,I_{phase}}$ $\mathbf{V_{LL} = V_{phase}}$

$$\mathbf{P = 3\,V_{phase} I_{phase}\,\cos(\phi) = \sqrt{3}\,V_{LL} I_L\,\cos(\phi)}$$