SNS COLLEGE OF TECHNOLOGY

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COIMBATORE-35
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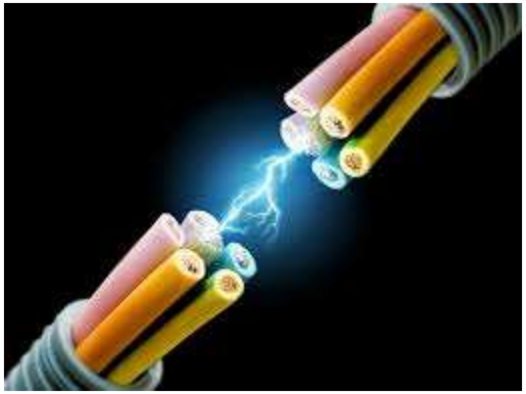
19EEB102 / ELECTRIC CIRCUIT ANALYSIS
I YEAR / II SEMESTER
UNIT-III: AC CIRCUITS

THREE PHASE CIRCUITS

TOPIC OUTLINE

- Objectives
- 3 phase circuits advantages
- Single and 3 phase configurations
- 3 phase generations
- Wye – Delta connections


OBJECTIVES

- What is three phase and advantages
- Be familiar with different three-phase configurations
- How to analyze them.
- Know the difference between balanced and unbalanced circuits
- Learn about power in a balanced three-phase system
- Know how to analyze unbalanced three-phase systems
- Apply what is learnt to three-phase measurement and residential wiring

Three phase Circuits

- An AC generator designed to develop a single sinusoidal voltage for each rotation of the shaft (rotor) is referred to as a **single-phase AC generator.**
- If the number of coils on the rotor is increased in a specified manner, the result is a **Polyphase AC generator**, which develops more than one AC phase voltage per rotation of the rotor
- In general, three-phase systems are preferred over single-phase systems for the transmission of power for many reasons.

  1. Single phase power touches zero 100 times per second (50 Hz), so pulsating waveform, so pulsating output. Three phase at any instant is always 1.5 times the maximum value.

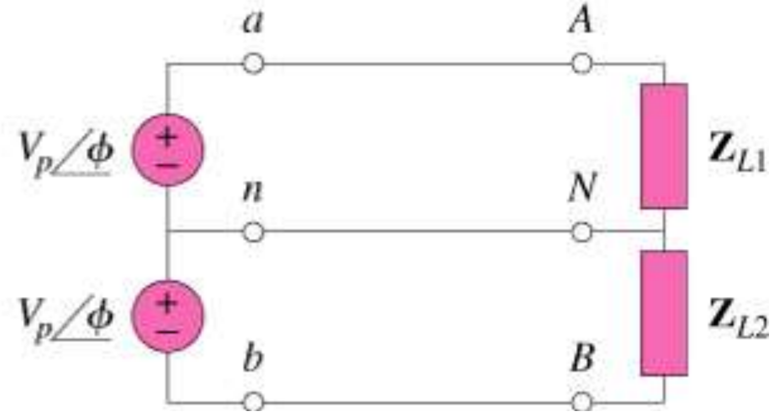
  2. Thinner conductors can be used to transmit the same kVA at the same voltage, which reduces the amount of copper required (typically about 25% less).

  3. The lighter lines are easier to install, and the supporting structures can be less massive and farther apart.

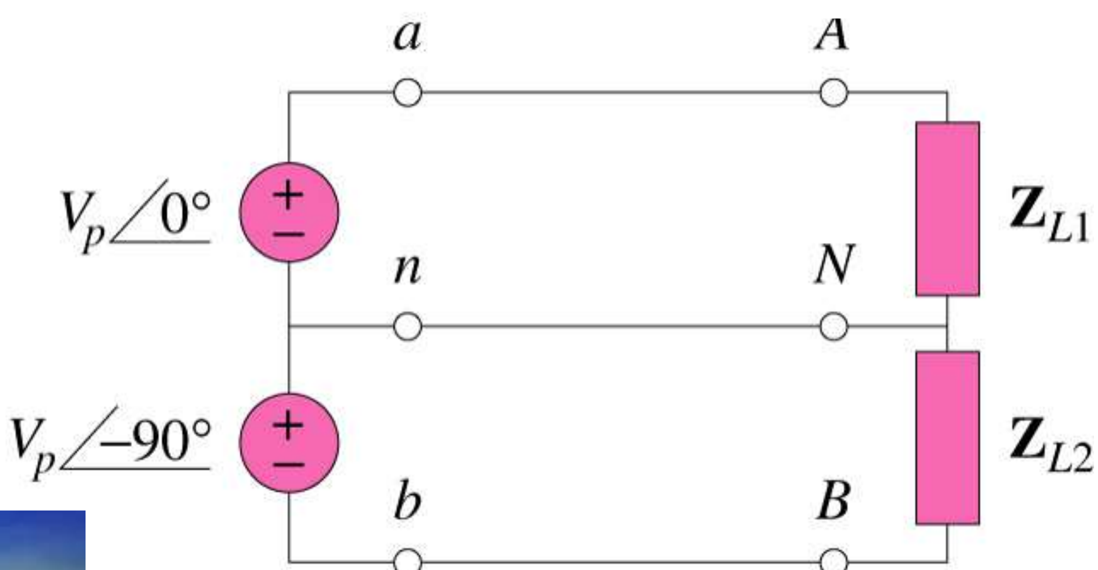
  4. Three-phase equipment and motors have preferred running and starting characteristics compared to single-phase systems because of a more even flow of power

Single Phase, Three phase Circuits

a) Single phase systems two-wire type



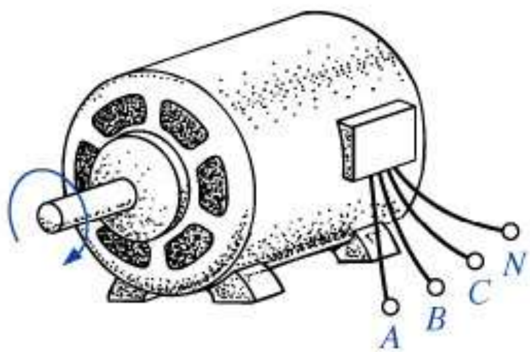
b) Single phase systems three-wire type. Allows connection to both 120 V and 240 V.

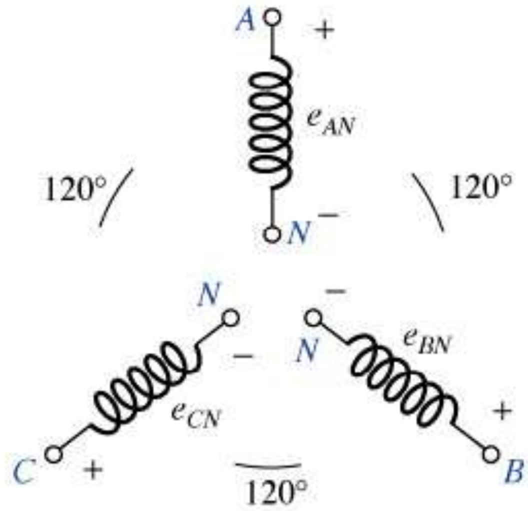


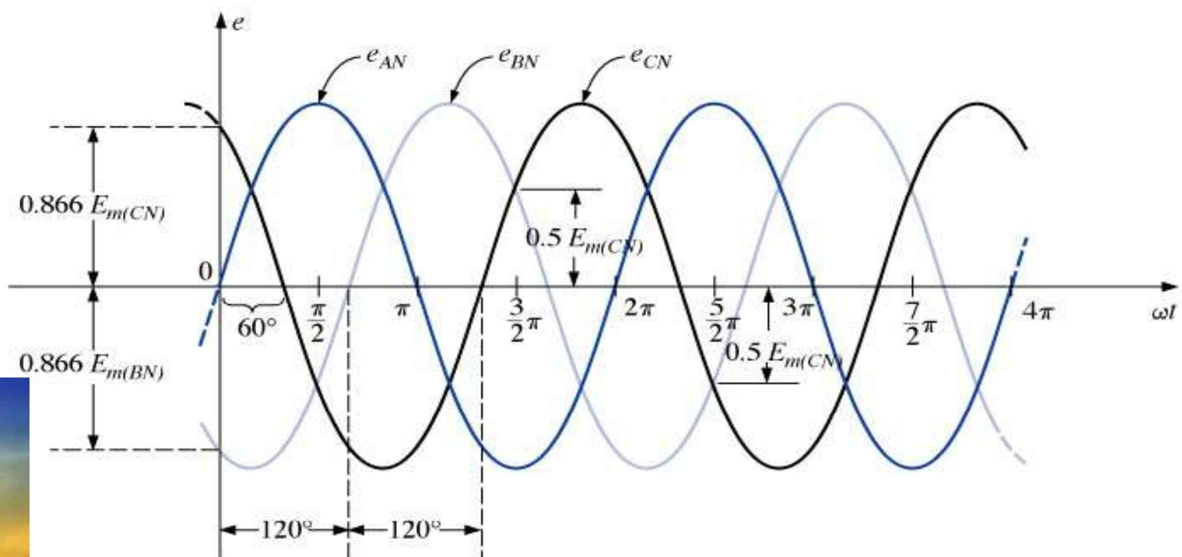
c) Two-phase three-wire system. The AC sources operate at different phases.

Three-phase Generator

- The three-phase generator has three induction coils placed 120° apart on the stator.
- The three coils have an equal number of turns, the voltage induced across each coil will have the same peak value, shape and frequency.

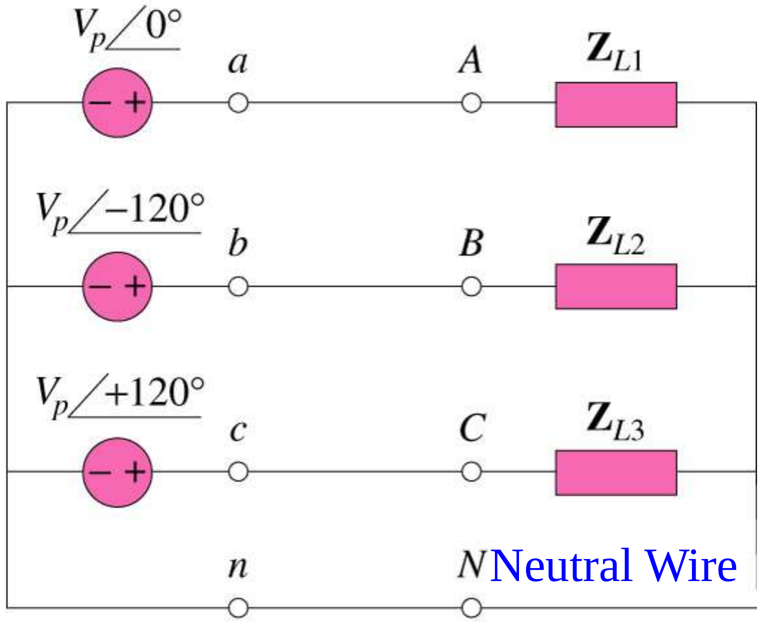




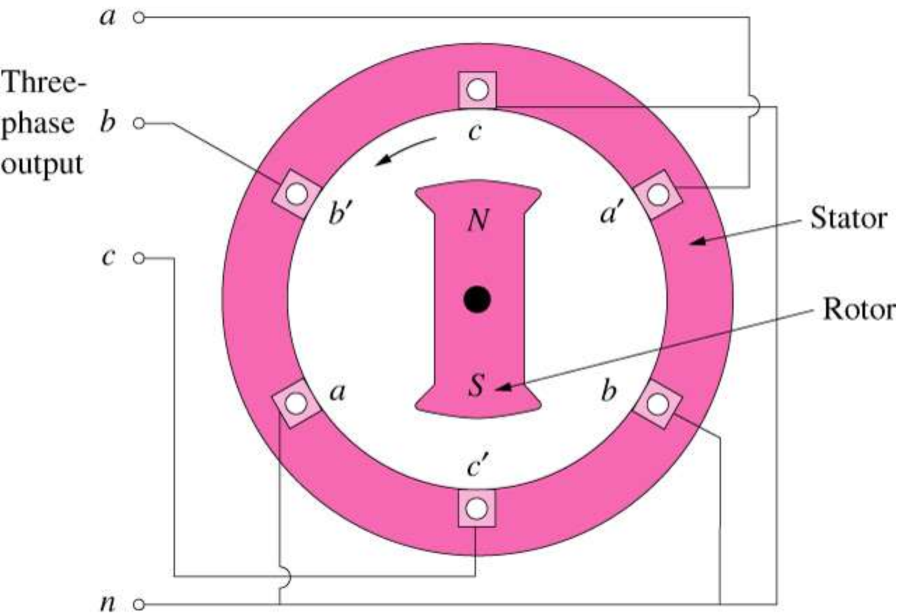


Balanced Three-phase Voltages

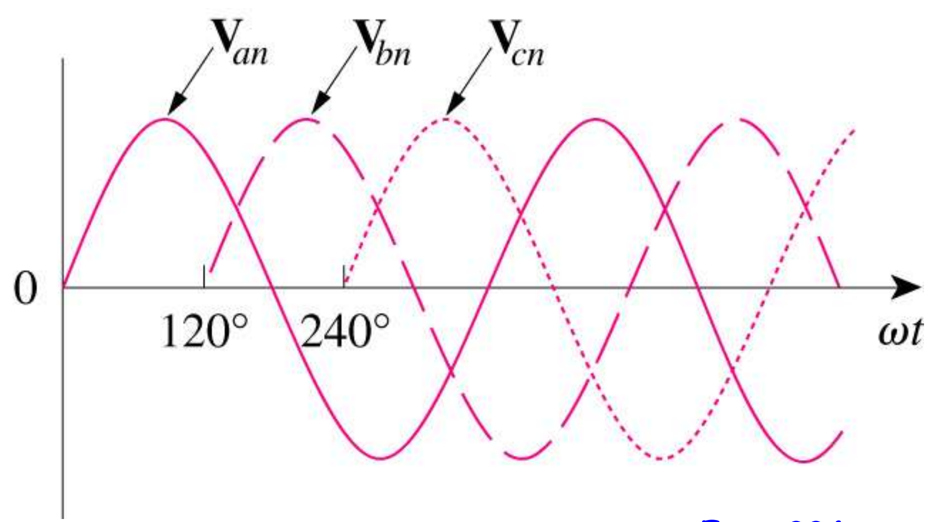
Three-phase four-wire system



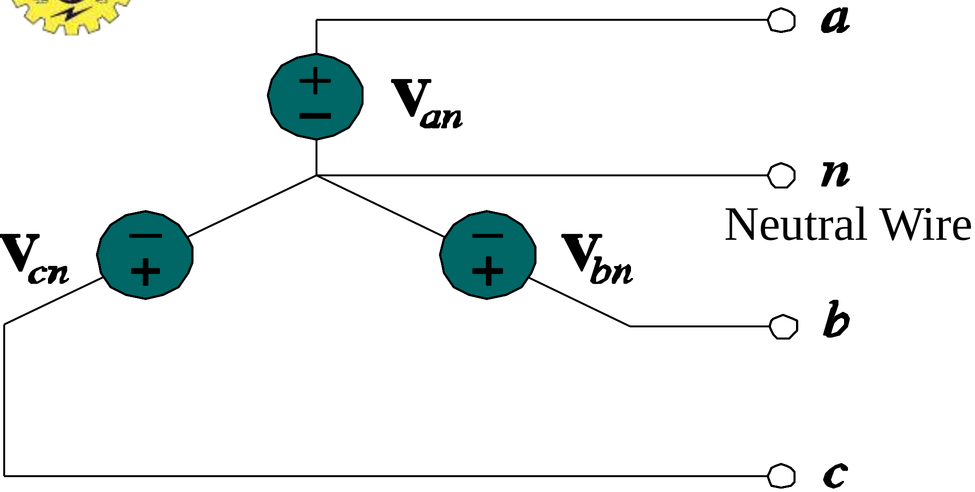
A Three-phase Generator



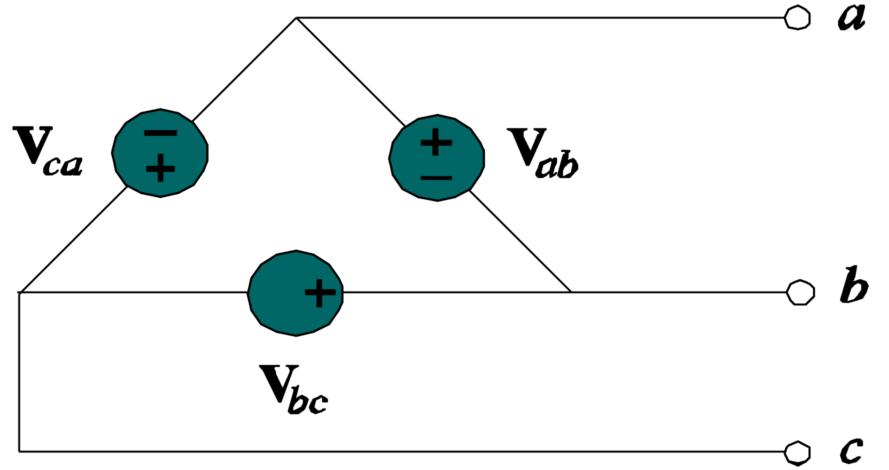
Voltages having 120° phase difference



Balanced Three phase Voltages

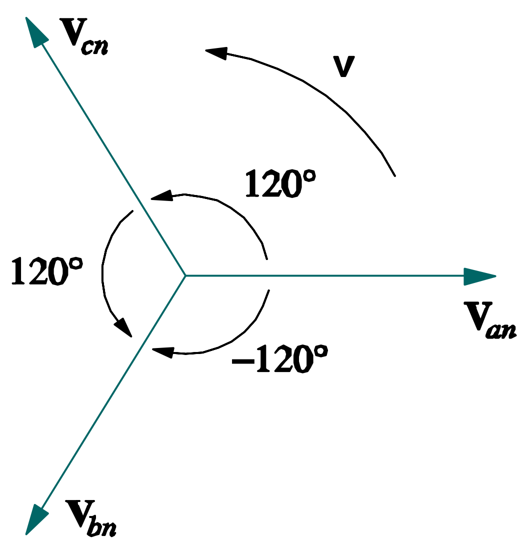


a) Wye Connected Source

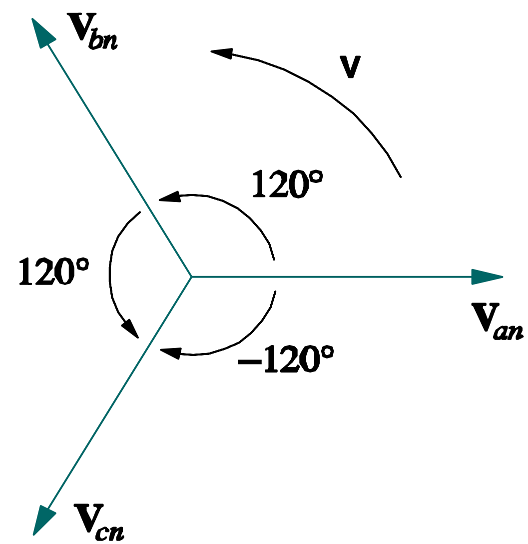


b) Delta Connected Source

$$V_{an} = V_p \angle 0^\circ$$
$$V_{bn} = V_p \angle -120^\circ$$
$$V_{cn} = V_p \angle -240^\circ$$



a) abc or positive sequence

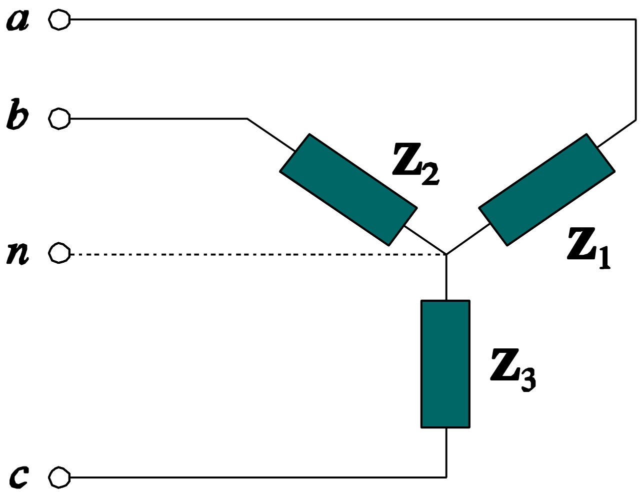


b) acb or negative sequence

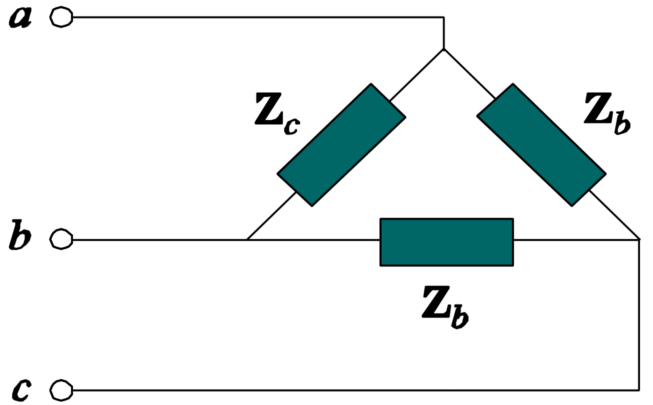
$$V_{an} = V_p \angle 0^\circ$$
$$V_{bn} = V_p \angle +120^\circ$$
$$V_{cn} = V_p \angle +240^\circ$$

Balanced Three phase Loads

- A Balanced load has equal impedances on all the phases



a) Wye-connected load



b) Delta-connected load

Balanced Impedance Conversion:

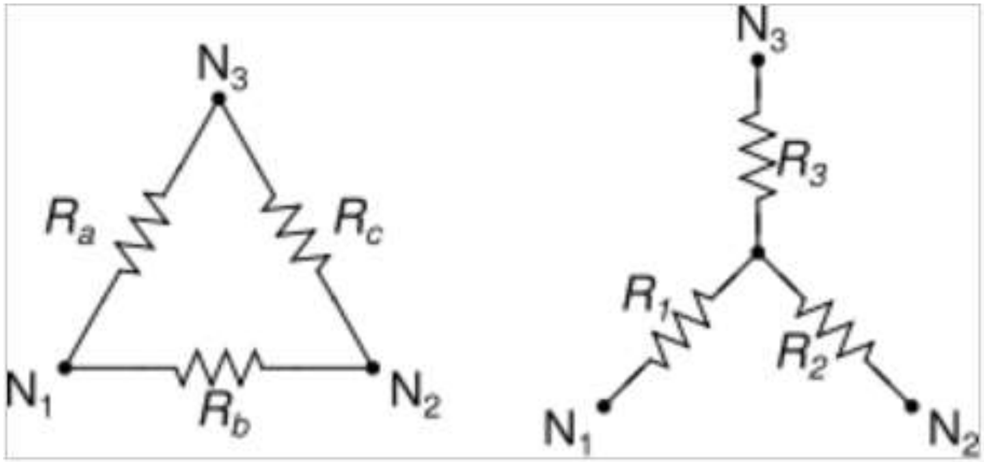
Conversion of Delta circuit to Wye or Wye to Delta.

$$Z_Y = Z_1 = Z_2 = Z_3$$

$$Z_\Delta = Z_a = Z_b = Z_c$$

$$Z_\Delta = 3Z_Y \qquad Z_Y = \frac{1}{3} Z_\Delta$$

General Delta to Wye conversion



Delta to Wye

$$R_1 = \frac{R_a R_b}{R_a + R_b + R_c}$$

$$R_2 = \frac{R_b R_c}{R_a + R_b + R_c}$$

$$R_3 = \frac{R_a R_c}{R_a + R_b + R_c}$$

Wye to Delta

$$R_1 = \frac{R_b R_a}{R_T}$$

$$R_2 = \frac{R_b R_c}{R_T}$$

$$R_3 = \frac{R_a R_c}{R_T}$$

where $R_T = R_a + R_b + R_c$

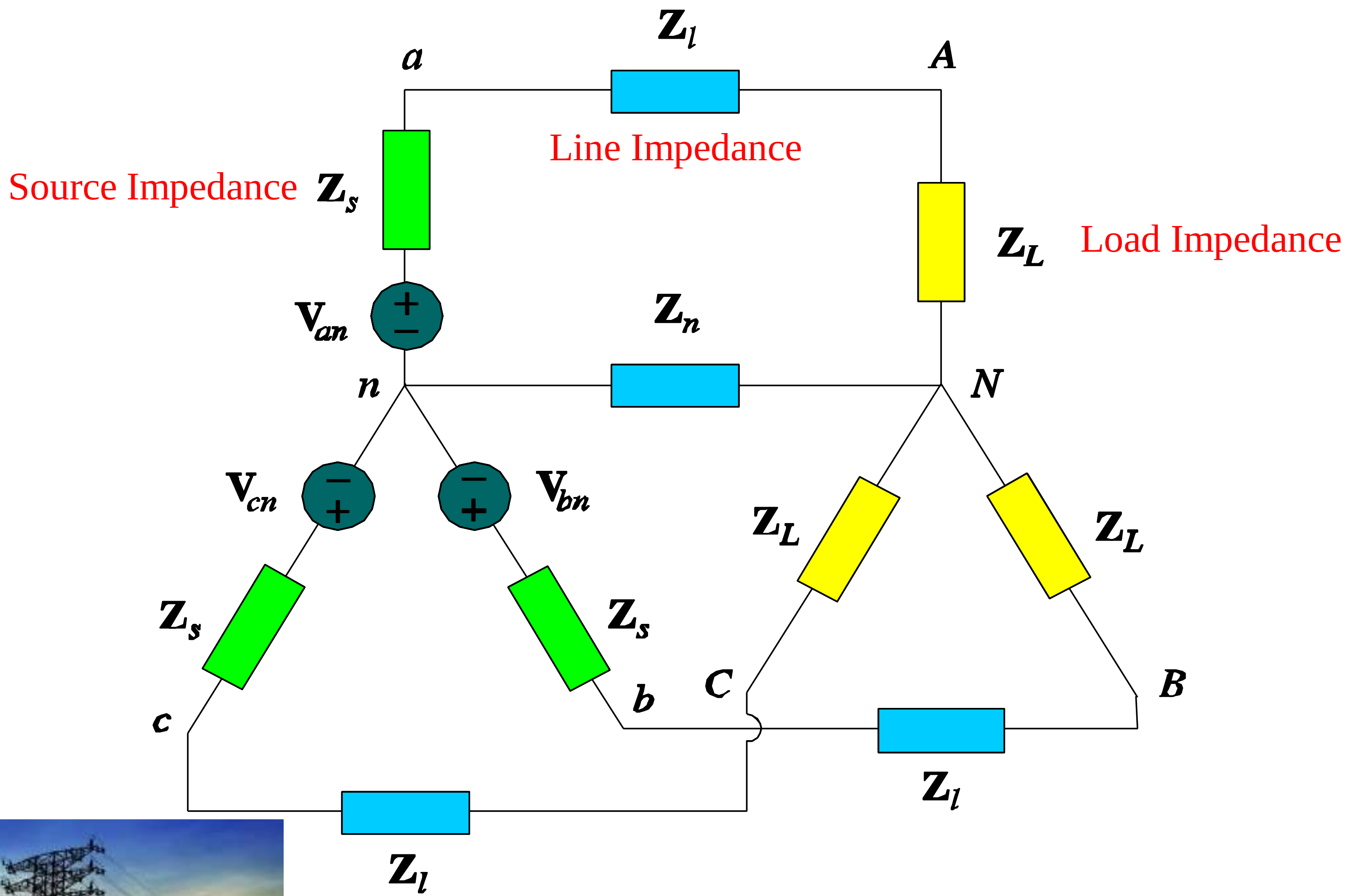
works the same way for complex impedances

Three phase Connections

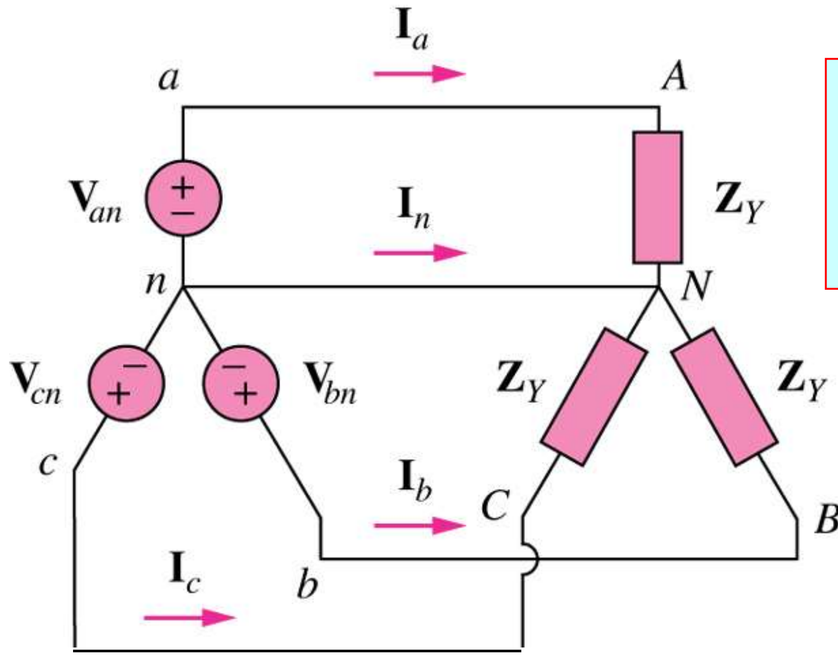
- Both the three phase source and the three phase load can be connected either Wye or DELTA.
- We have 4 possible connection types.
  - Y-Y connection
  - Y-Δ connection
  - Δ-Δ connection
  - Δ-Y connection
- Balanced Δ connected load is more common.
- Y connected sources are more common.

Balanced Wye-wye Connection

- A balanced Y-Y system, showing the source, line and load impedances.



Balanced Wye-wye Connection



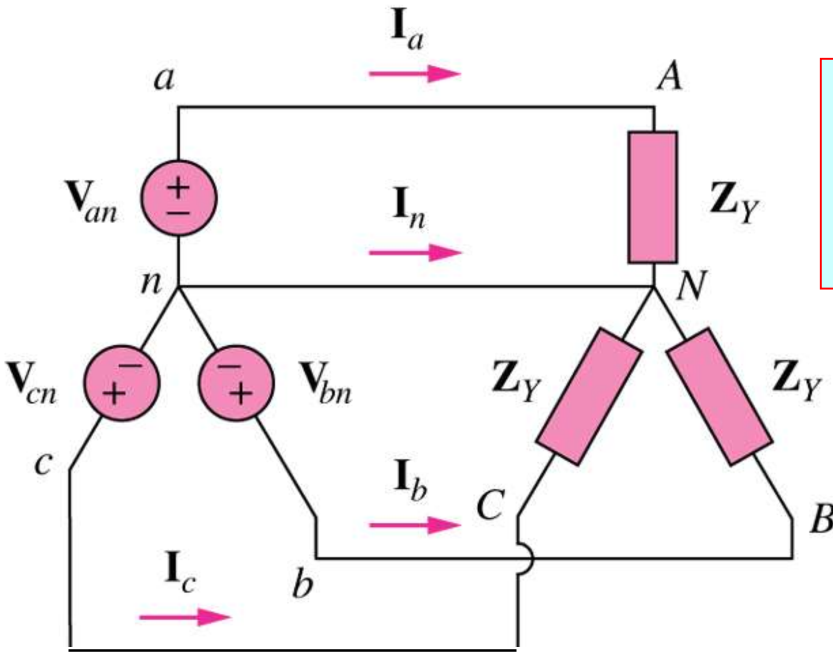
Line current I_n add up to zero.
Neutral current is zero:

$$I_n = -(I_a + I_b + I_c) = 0$$

- Phase voltages are: V_{an}, V_{bn} and V_{cn}.
- The three conductors connected from a to A, b to B and c to C are called LINES.
- The voltage from one line to another is called a **LINE voltage**
- Line voltages are: V_{ab}, V_{bc} and V_{ca}
- Magnitude of line voltages is √3 times the magnitude of phase voltages. $V_L = \sqrt{3}\ V_p$

Current: $I_L = I_p$

Balanced Wye-wye Connection



Line current I_n add up to zero.
Neutral current is zero:

$$I_n = -(I_a + I_b + I_c) = 0$$

- Magnitude of line voltages is √3 times the magnitude of phase voltages. $V_L = \sqrt{3}\, V_p$

$$V_{an} = V_p\angle 0°,\quad V_{bn} = V_p\angle -120°,\quad V_{cn} = V_p\angle +120°$$

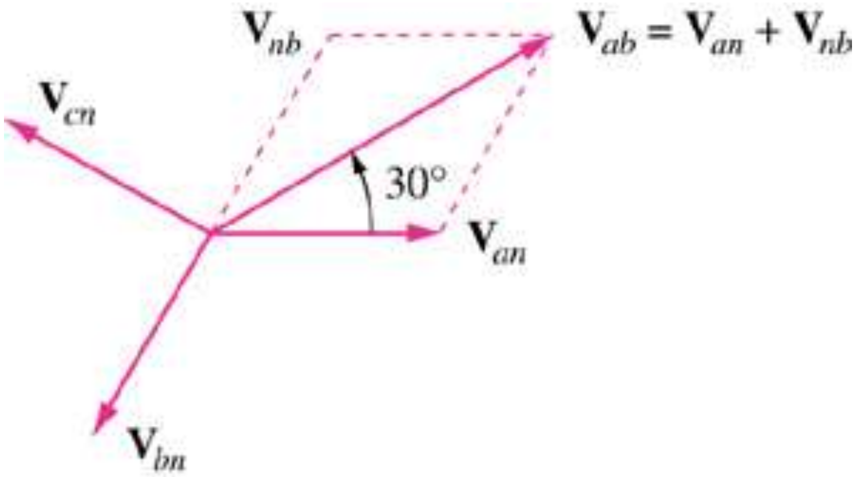
$$V_{ab} = V_{an} + V_{nb} = V_{an} - V_{bn} = \sqrt{3}V_p\angle 30°$$

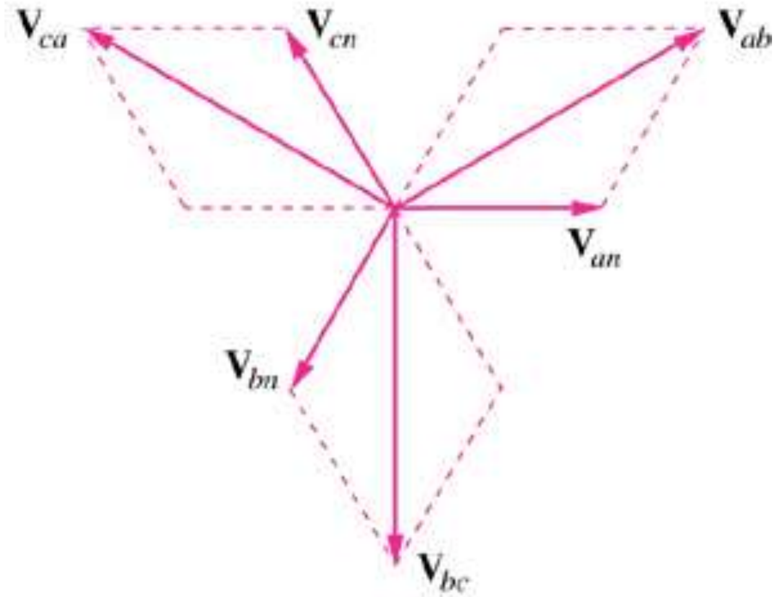
$$V_{bc} = V_{bn} - V_{cn} = \sqrt{3}V_p\angle -90°$$

$$V_{ca} = V_{cn} - V_{an} = V_{an} + V_{bn} = \sqrt{3}V_p\angle -210°$$

Balanced Wye-wye Connection

- Phasor diagram of phase and line voltages





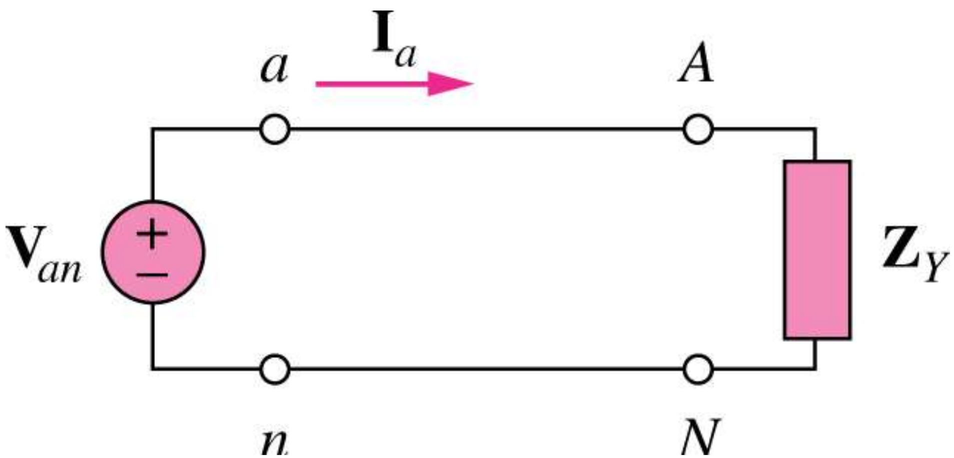
$$V_L = |V_{ab}| = |V_{bc}| = |V_{ca}|$$

$$= \sqrt{3}|V_{an}| = \sqrt{3}|V_{bn}| = \sqrt{3}|V_{cn}| = \sqrt{3}V_p$$

$$V_p = |V_{an}| = |V_{bn}| = |V_{cn}|$$

Single Phase Equivalent of Balanced Y-Y Connection

- Balanced three phase circuits can be analyzed on "per phase " basis.
- We look at one phase, say phase *a* and analyze the single phase equivalent circuit.
- Because the circuit is balanced, we can easily obtain other phase values using their phase relationships.



$$I_a = \frac{V_{an}}{Z_Y}$$

P.P.12.2 Calculate the line voltages and line currents of a Y-Y connection.

$$Z_{Source} = (0.4 + j0.3),\quad Z_{Line} = (0.6 + j0.7),\quad Z_{Load} = (24 + j19)$$

(a) $\mathbf{V}_{ab} = \mathbf{V}_{an} - \mathbf{V}_{bn} = 120\angle 30^\circ - 120\angle -90^\circ$

$\mathbf{V}_{ab} = (103.92 + j60) + j120 \qquad \mathbf{V}_{ab} = \underline{\mathbf{207.85\angle 60^\circ\ V}}$

Alternatively, using the fact that $\mathbf{V}_{ab}$ leads $\mathbf{V}_{an}$ by 30° and has a magnitude of $\sqrt{3}$ times that of $\mathbf{V}_{an}$,

$$\mathbf{V}_{ab} = \sqrt{3}(120)\angle(30^\circ + 30^\circ) = 207.85\angle 60^\circ$$

Following the abc sequence,

$$\mathbf{V}_{bc} = \underline{\mathbf{207.85\angle -60^\circ\ V}} \qquad \mathbf{V}_{ca} = \underline{\mathbf{207.85\angle -180^\circ\ V}}$$

(b) $\mathbf{I}_a = \dfrac{\mathbf{V}_{an}}{\mathbf{Z}}$

$\mathbf{Z} = Z_{Source} + Z_{Line} + Z_{Load} = (0.4 + j0.3) + (24 + j19) + (0.6 + j0.7)$

$\mathbf{Z} = 25 + j20 = 32\angle 38.66^\circ$

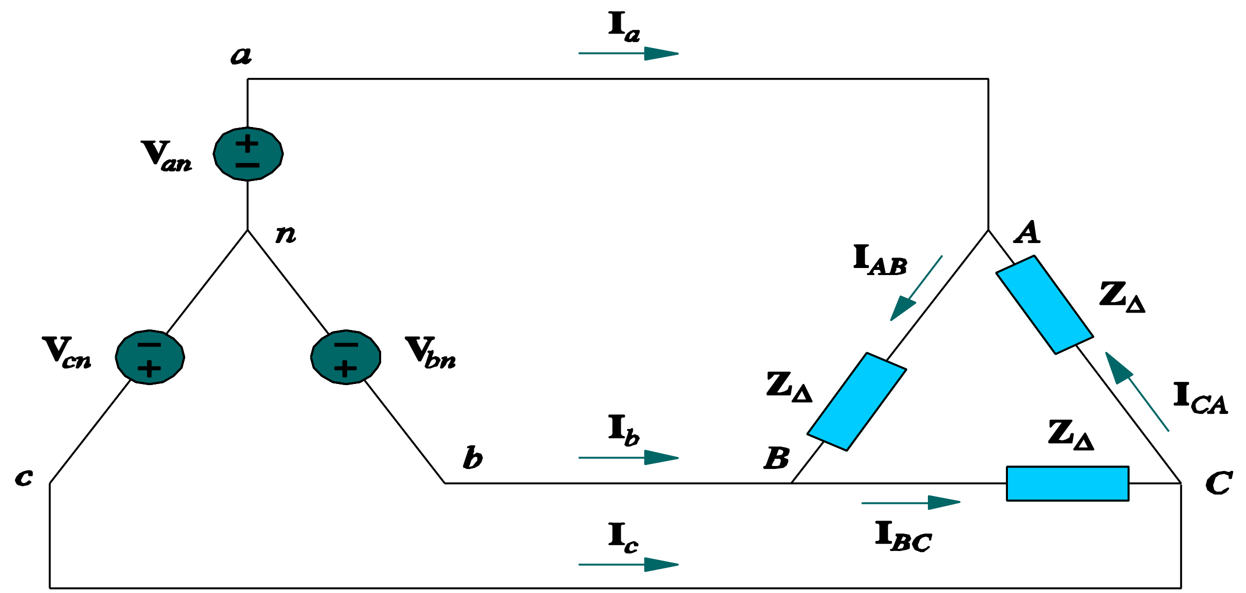
$$\mathbf{I}_a = \frac{120\angle 30^\circ}{32\angle 38.66^\circ} = \underline{\mathbf{3.75\angle -8.66^\circ\ A}}$$

Following the abc sequence, $\mathbf{I}_b = \mathbf{I}_a\angle -120^\circ = \underline{\mathbf{3.75\angle -128.66^\circ\ A}}$

$\mathbf{I}_c = \mathbf{I}_a\angle -240^\circ = \underline{\mathbf{3.75\angle -248.66^\circ\ A}}$

Balanced Wye-delta Connection

- Three phase sources are usually Wye connected and three phase loads are Delta connected.
- There is no neutral connection for the Y-Δ system.



$$I_{AB} = \frac{V_{AB}}{Z_{\Delta}}$$

$$I_{BC} = \frac{V_{BC}}{Z_{\Delta}}$$

$$I_{CA} = \frac{V_{CA}}{Z_{\Delta}}$$

- Line currents are obtained from the phase currents I_{AB}, I_{BC} and I_{CA}

$$I_a = I_{AB} - I_{CA} = I_{AB}\sqrt{3}\angle -30°$$

$$I_b = I_{BC} - I_{AB} = I_{BC}\sqrt{3}\angle -30°$$

$$I_c = I_{CA} - I_{BC} = I_{CA}\sqrt{3}\angle -30°$$

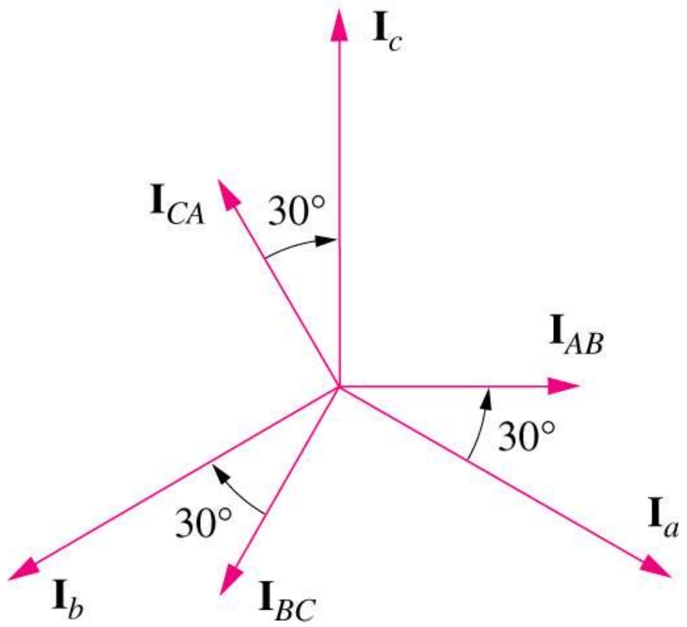
$$I_L = |I_a| = |I_b| = |I_c|$$

$$I_p = |I_{AB}| = |I_{BC}| = |I_{CA}|$$

$$I_L = \sqrt{3} I_p$$

Balanced Wye-delta Connection

- Phasor diagram of phase and line currents

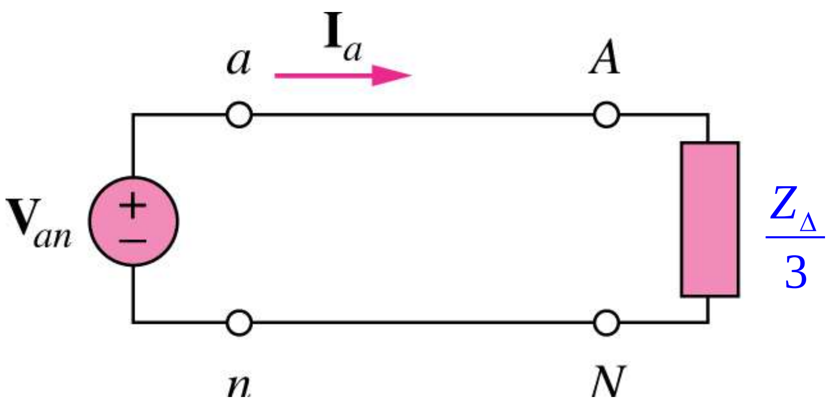


$$I_L = |I_a| = |I_b| = |I_c|$$

$$I_p = |I_{AB}| = |I_{BC}| = |I_{CA}|$$

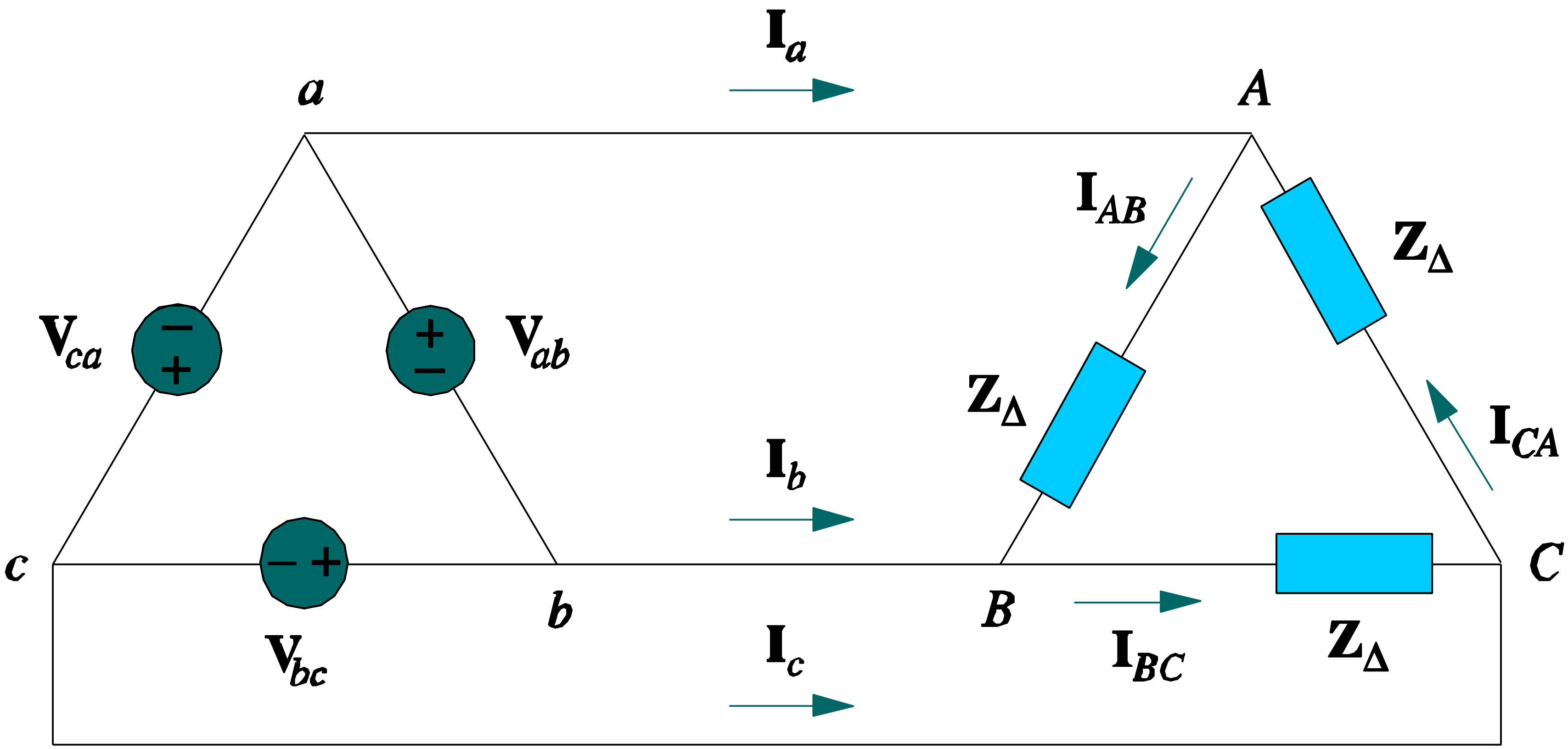
$$I_L = \sqrt{3} I_p$$

- Single phase equivalent circuit of the balanced Wye-delta connection



Balanced Delta-delta Connection

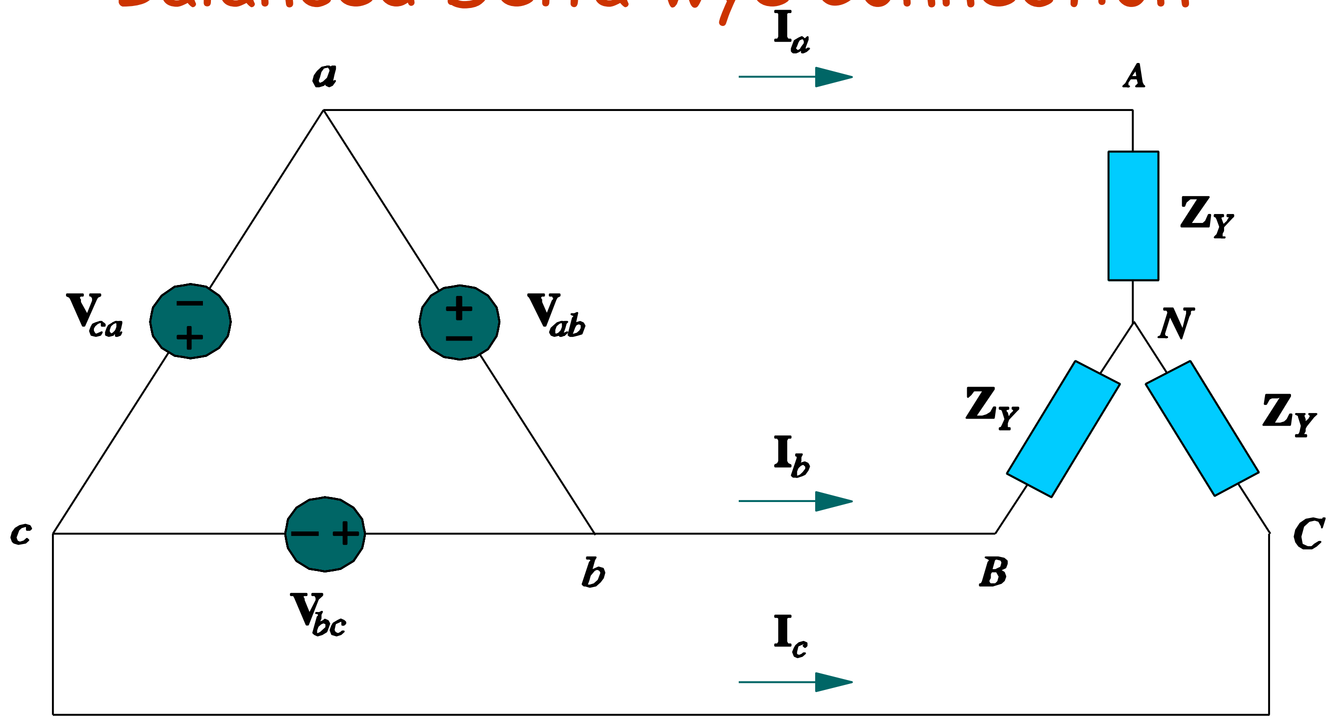
- Both the source and load are Delta connected and balanced.



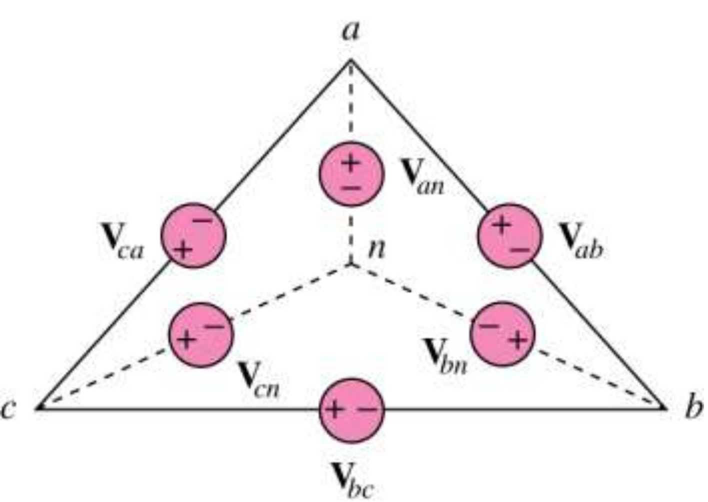
$$I_{AB} = \frac{V_{AB}}{Z_\Delta}, \quad I_{BC} = \frac{V_{BC}}{Z_\Delta}, \quad I_{CA} = \frac{V_{CA}}{Z_\Delta}$$

$$I_a = I_{AB} - I_{CA}, \quad I_b = I_{BC} - I_{AB}, \quad I_c = I_{CA} - I_{BC}$$

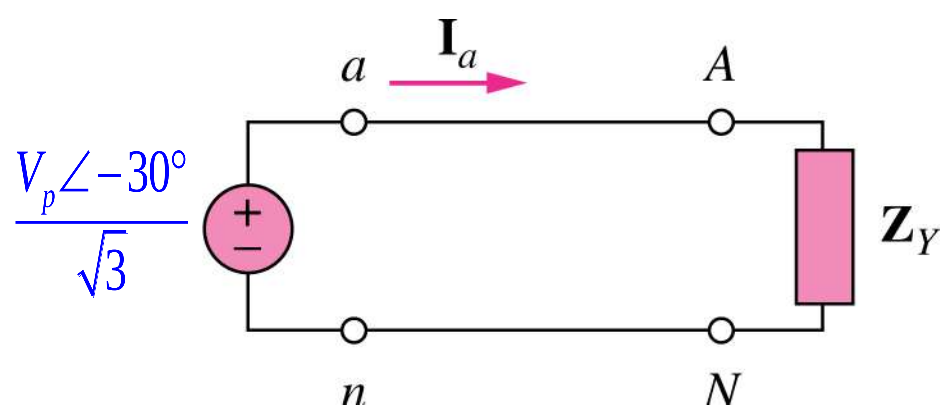
Balanced Delta-wye Connection



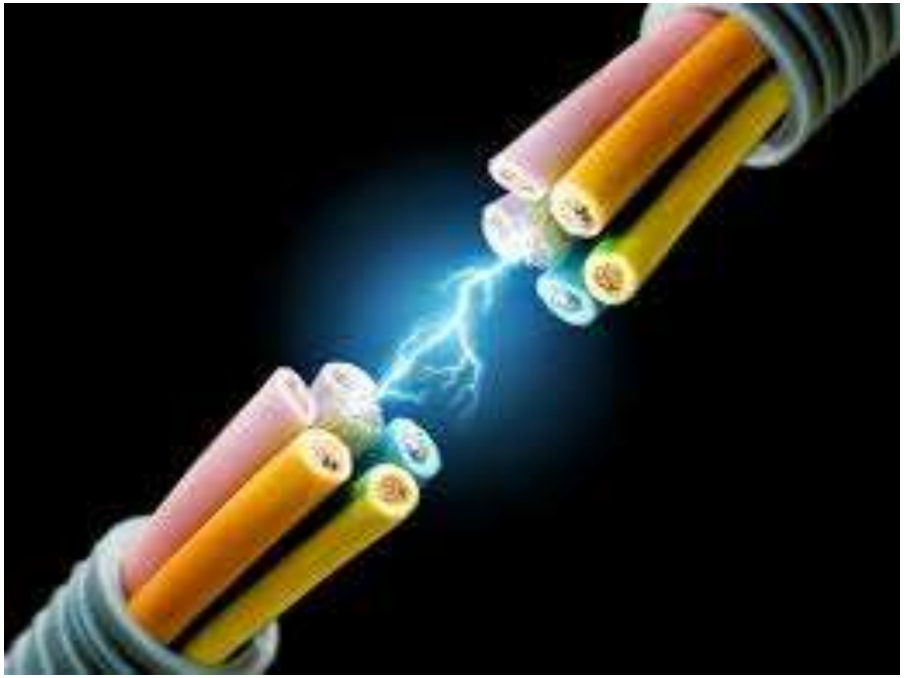
Transforming a Delta connected source to an equivalent Wye connection



Single phase equivalent of Delta Wye connection



RECAP….



…THANK YOU