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Department of Biomedical Engineering

Course Name: 23BMT201 & Circuit Analysis

II Year : III Semester

Unit III –THREE PHASE SYSTEM

Topic : Power Flow Analysis

Balanced Three-phase System

Possible Three-Phase Load Configurations:

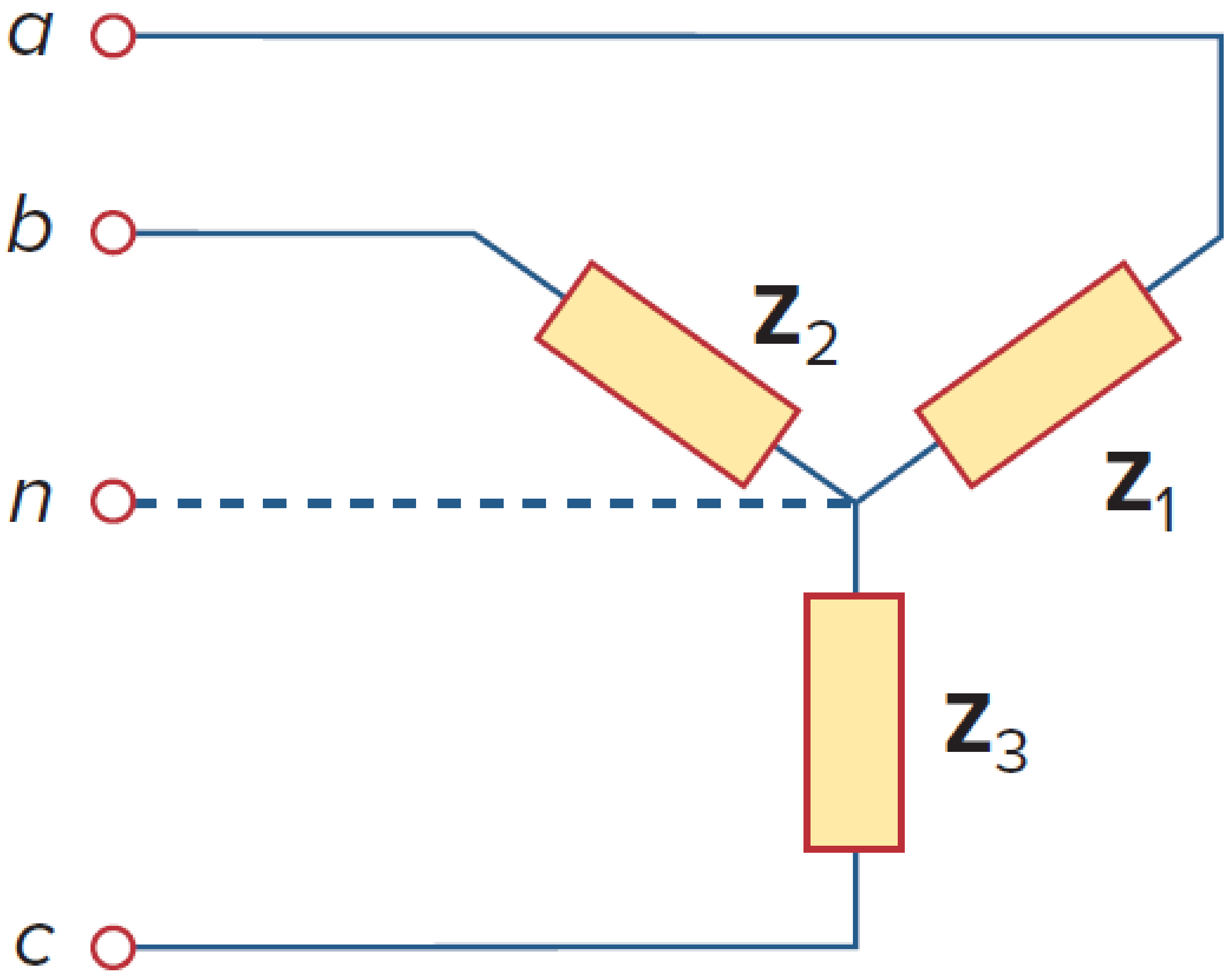
- Depending on the end application, a three-phase load can be either
  - Wye-connected (or)
  - Delta-connected.
- A balanced load is one in which the phase impedances are equal in magnitude and in phase.
- However, a wye- or delta-connected load is said to be unbalanced if the phase impedances are not equal in magnitude or phase.

Possible Three-Phase Load Configurations:

For a balanced wye-connected load,

$$\mathbf{Z}_1 = \mathbf{Z}_2 = \mathbf{Z}_3 = \mathbf{Z}_Y$$

where Z_Y is the load impedance per phase.



Balanced Three-phase System

Possible Three-Phase Load Configurations:

For a balanced delta-connected load,

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

where Z_Δ is the load impedance per phase.

Impedance relation between Y and Δ connected load:

$$Z_\Delta = 3 \times Z_Y \text{ or } Z_Y = \frac{1}{3} \times Z_\Delta$$

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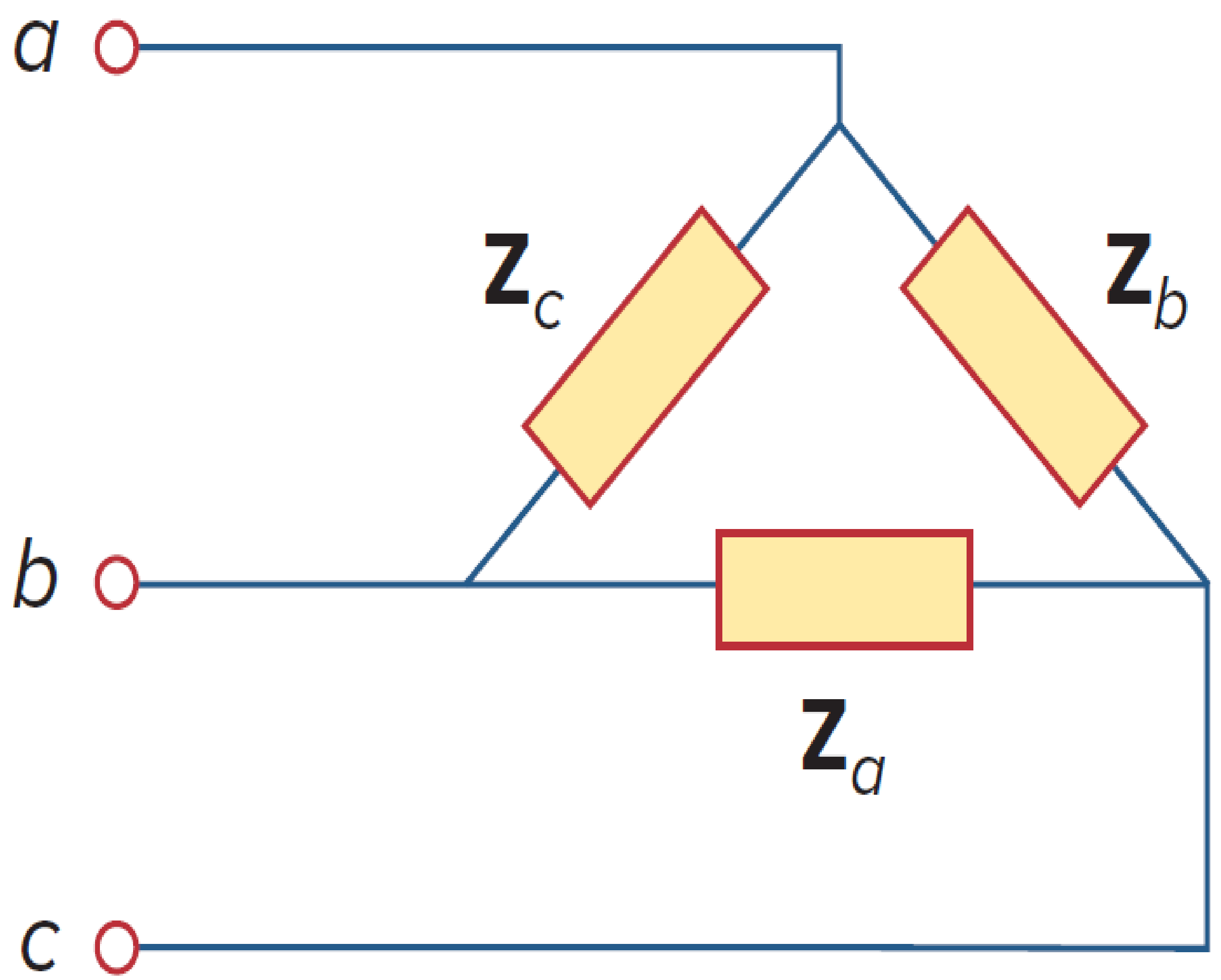

Δ-connected load

Balanced Three-phase System

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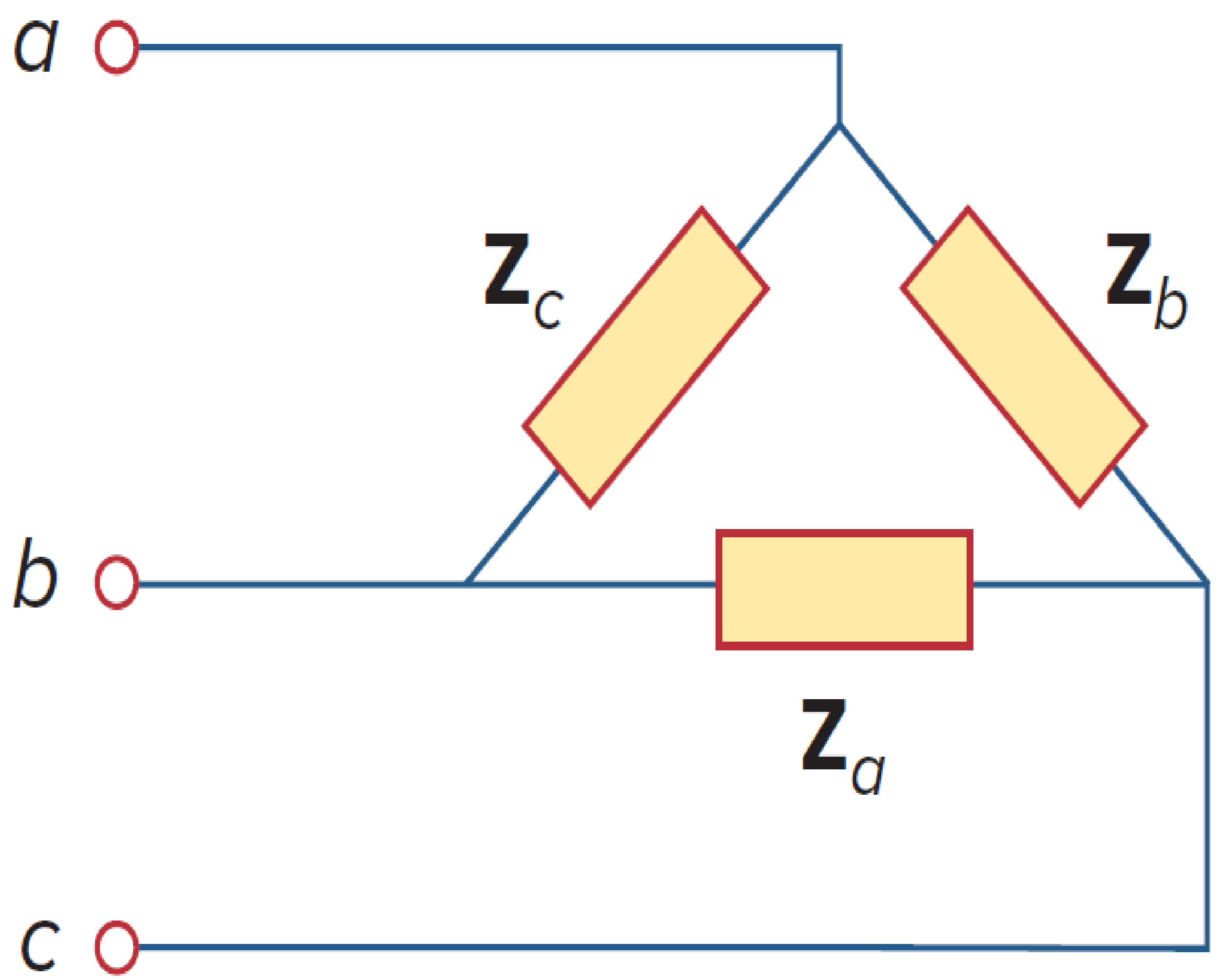
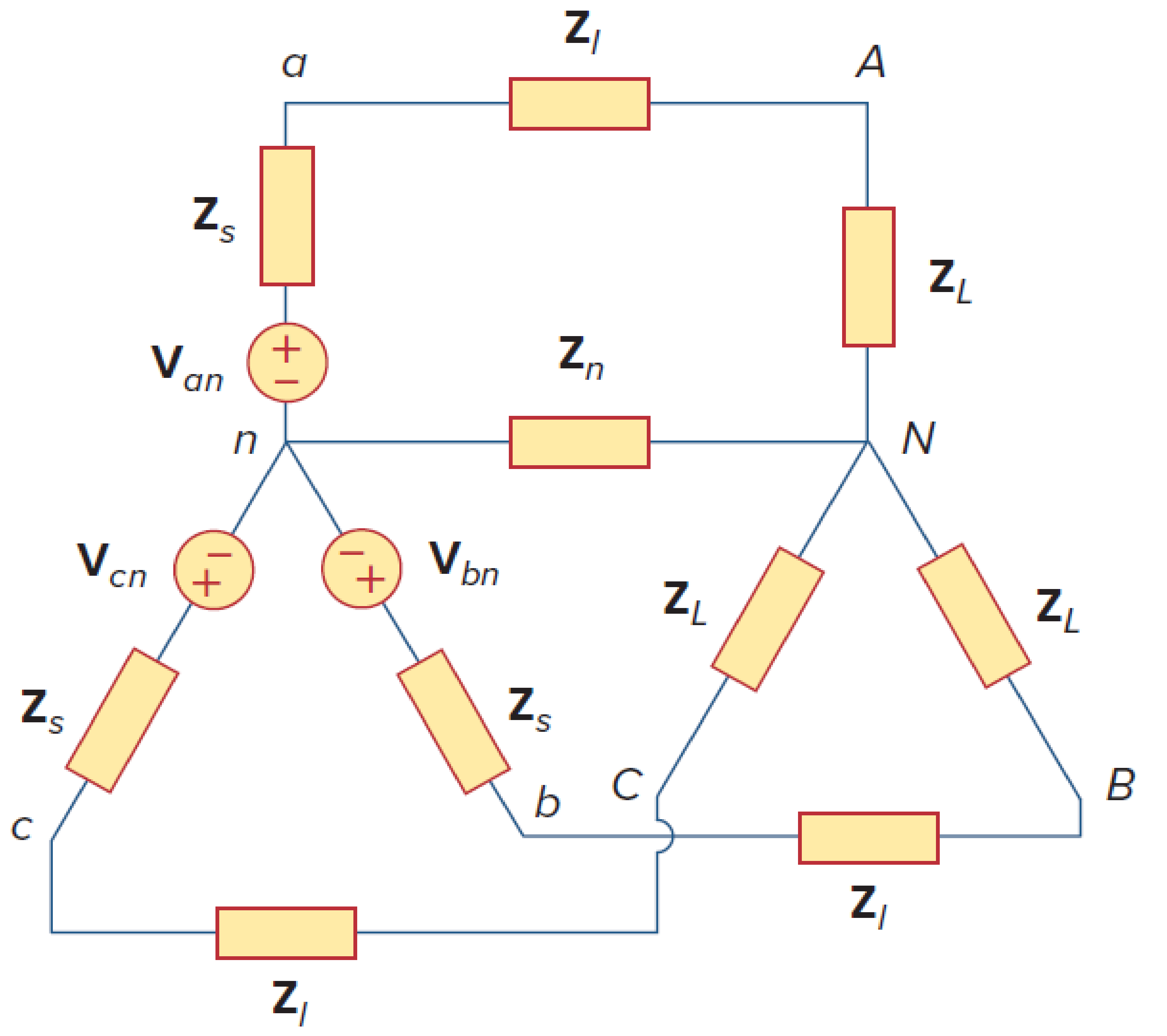


Δ-connected load

Balanced Three-phase System

Balanced Wye-Wye Connection:

A balanced Y-Y system is a three- phase system with a balanced Y- connected source and a balanced Y-connected load.



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

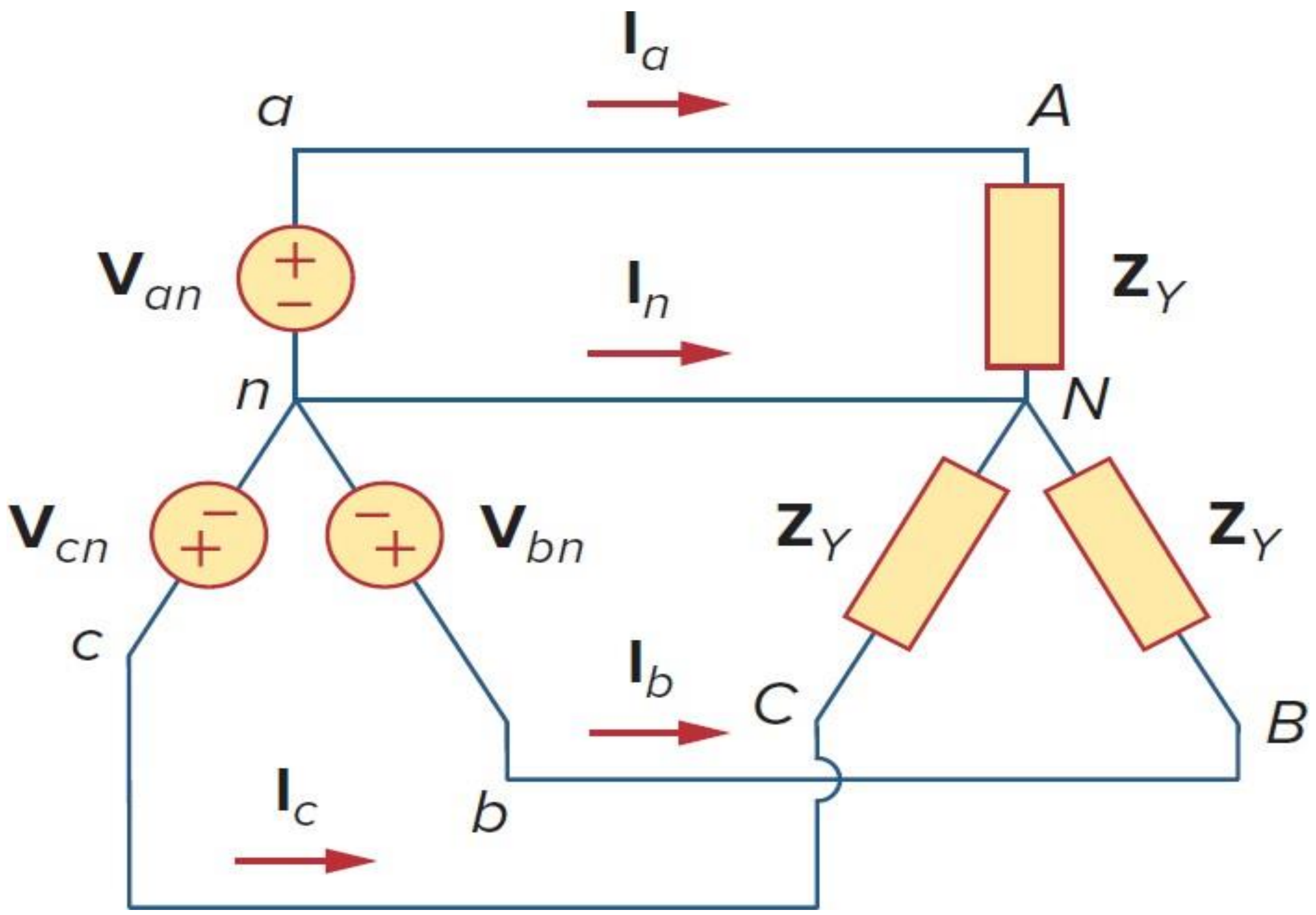
Balanced Three-phase System

Balanced Wye-Wye Connection:

- By lumping the impedances together,

  $Z_Y = Z_S + Z_l + Z_L$

- Z_s and Z_l are often very small compared with Z_L, so one can assume that $Z_Y = Z_L$ if no source or line impedance is given.



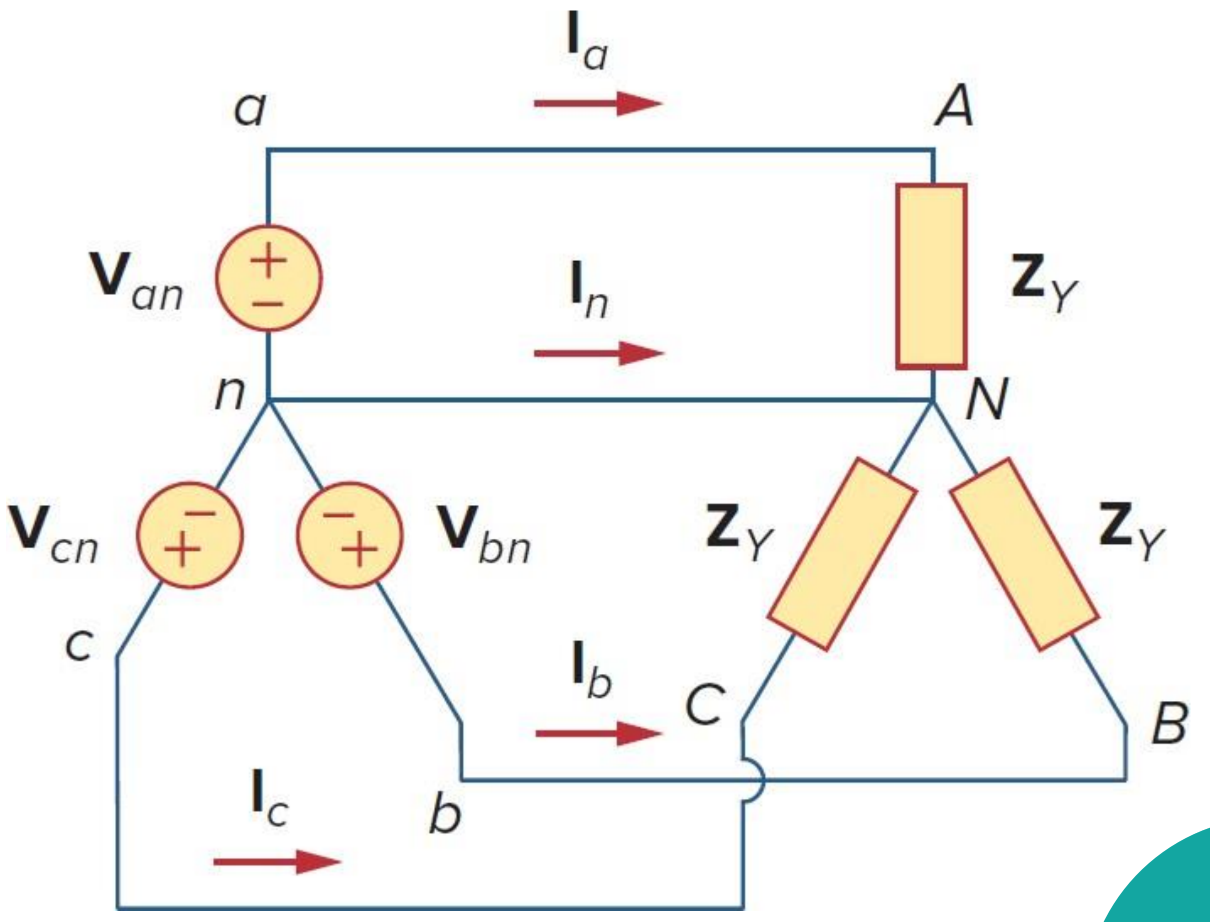
Balanced Y-Y connection with $Z_Y = Z_s + Z_l + Z_L$

Balanced Three-phase System

Balanced Wye-Wye Connection:

Assuming the positive sequence, the phase voltages (or line-to neutral voltages) are,

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



The line-to-line voltages or simply line voltages

V_{ab}, V_{bc}, and V_{ca} are related to the phase voltages as,

$$V_{ab} = V_{an} + V_{nb} = V_{an} - V_{bn} = V_p\angle 0^\circ - V_p\angle -120^\circ$$

$$= V_p\left(1 + \frac{1}{2} + j\frac{\sqrt{3}}{2}\right) = \sqrt{3}V_p\angle 30^\circ$$

Balanced Wye-Wye Connection:

Similarly, one can obtain:

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

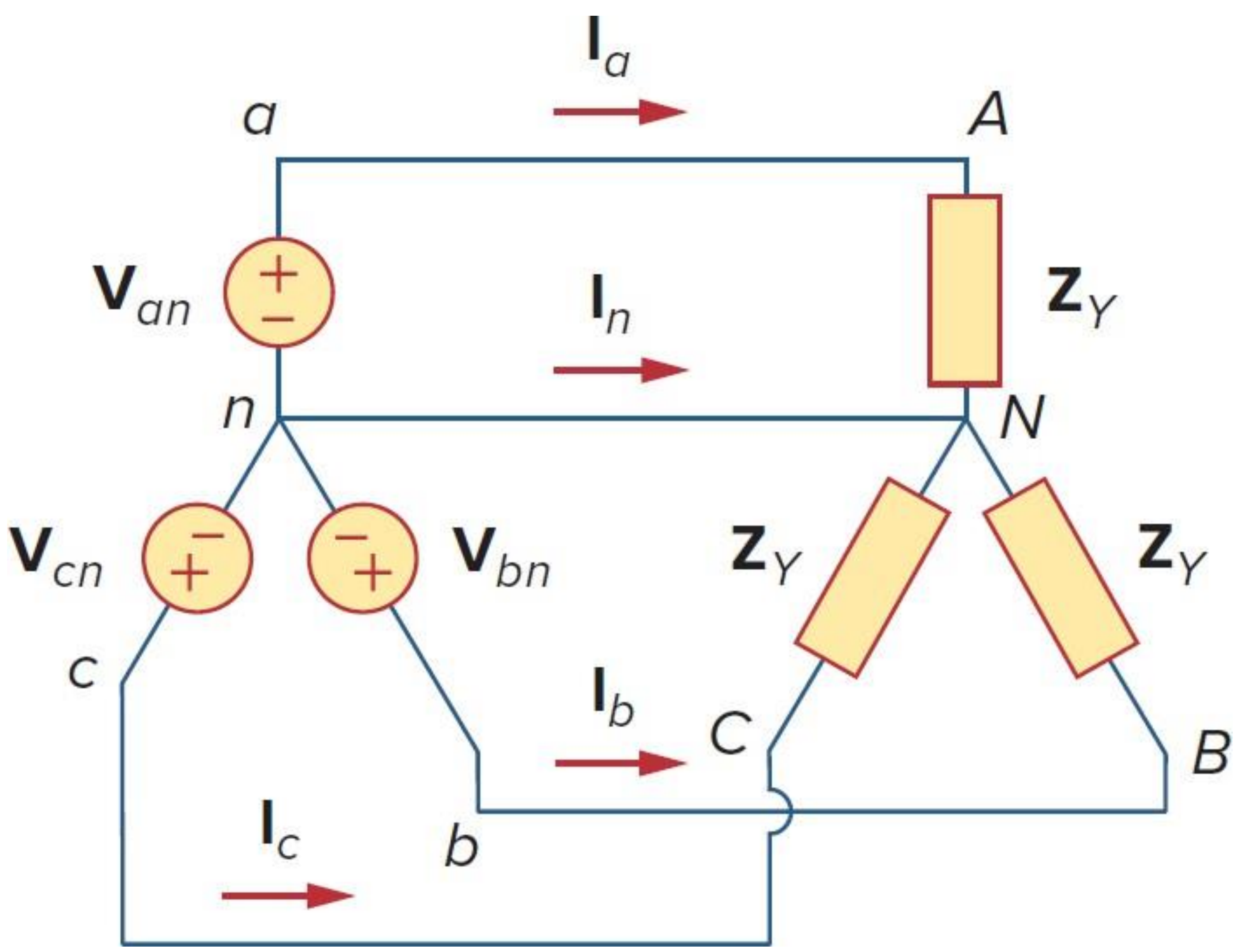
$$V_{ca} = V_{cn} - V_{an} = \sqrt{3}V_p \angle -210^\circ$$

Thus, the magnitude of the line voltages is,

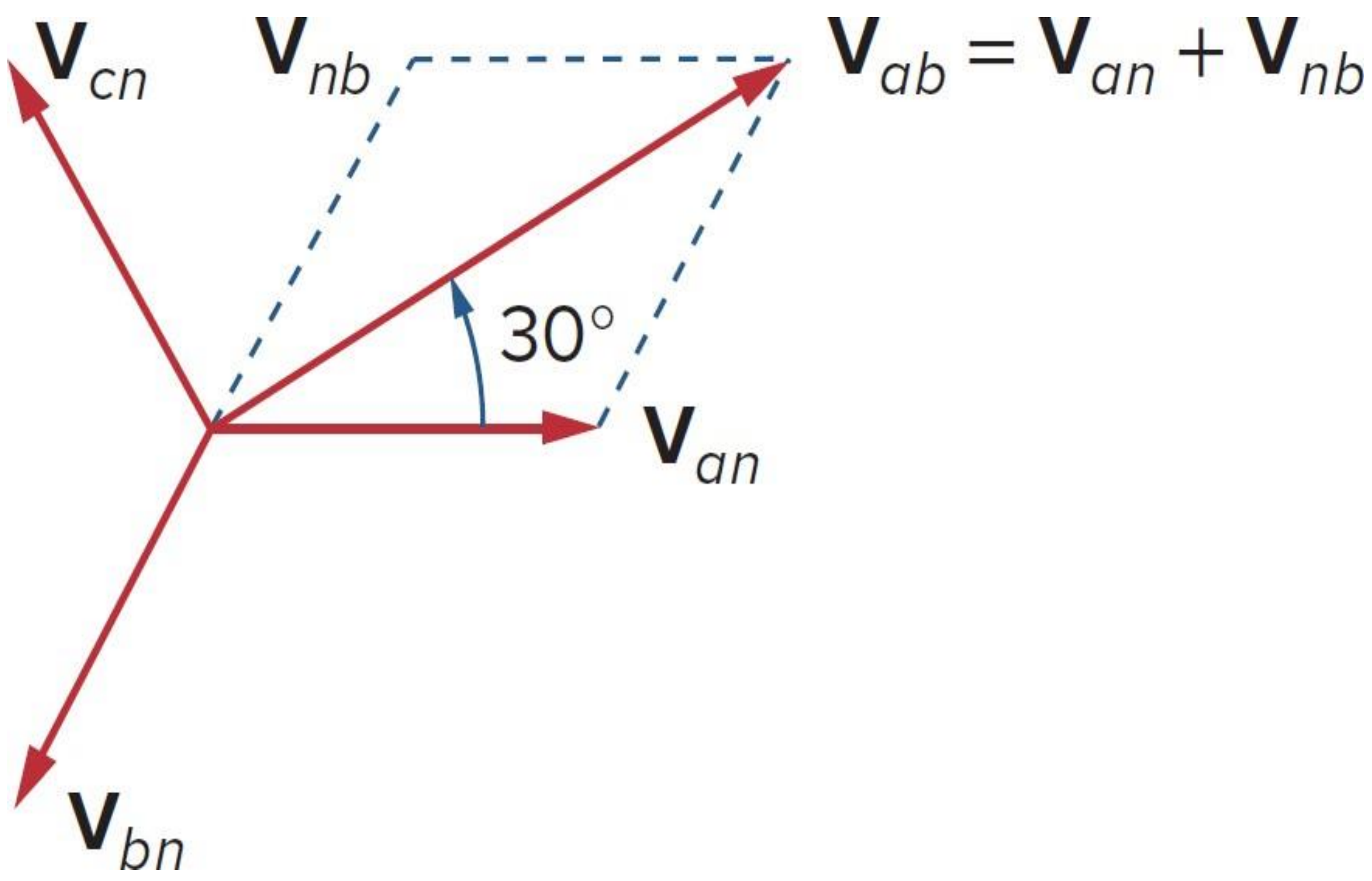
$$V_L = \sqrt{3}V_p$$

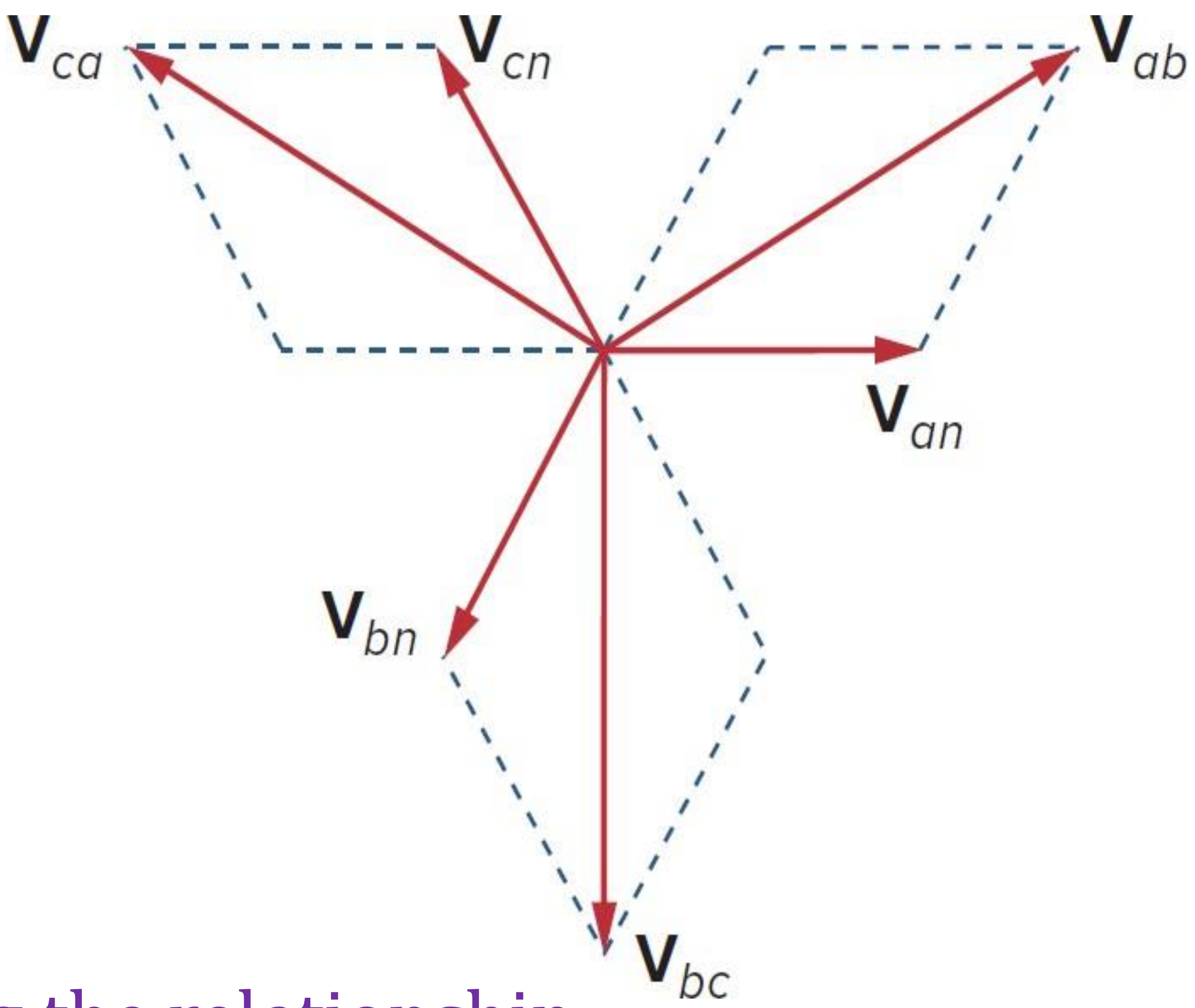
where $V_p = |V_{an}| = |V_{bn}| = |V_{cn}|$ and

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



Balanced Wye-Wye Connection:





Phasor diagrams illustrating the relationship between line voltages and phase voltages

Balanced Three-phase System

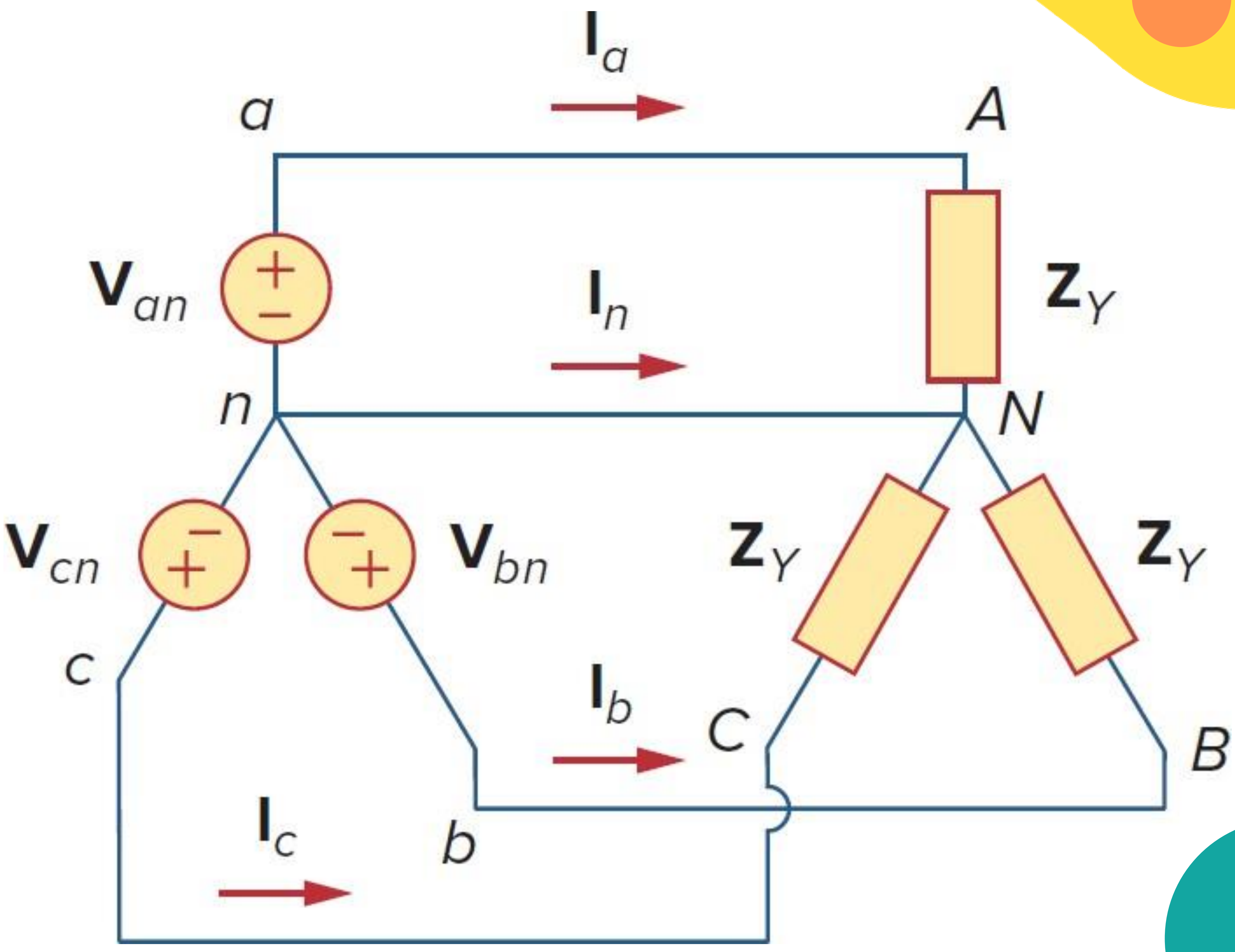
Balanced Wye-Wye Connection:

By applying KVL to each phase, line currents are obtained:

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

$$I_b = \frac{V_{bn}}{Z_Y} = \frac{V_{an}\angle -120^\circ}{Z_Y} = I_a\angle -120^\circ$$

$$I_c = \frac{V_{cn}}{Z_Y} = \frac{V_{an}\angle -240^\circ}{Z_Y} = I_a\angle -240^\circ$$



Balanced Y-Y connection

Balanced Wye-Wye Connection:

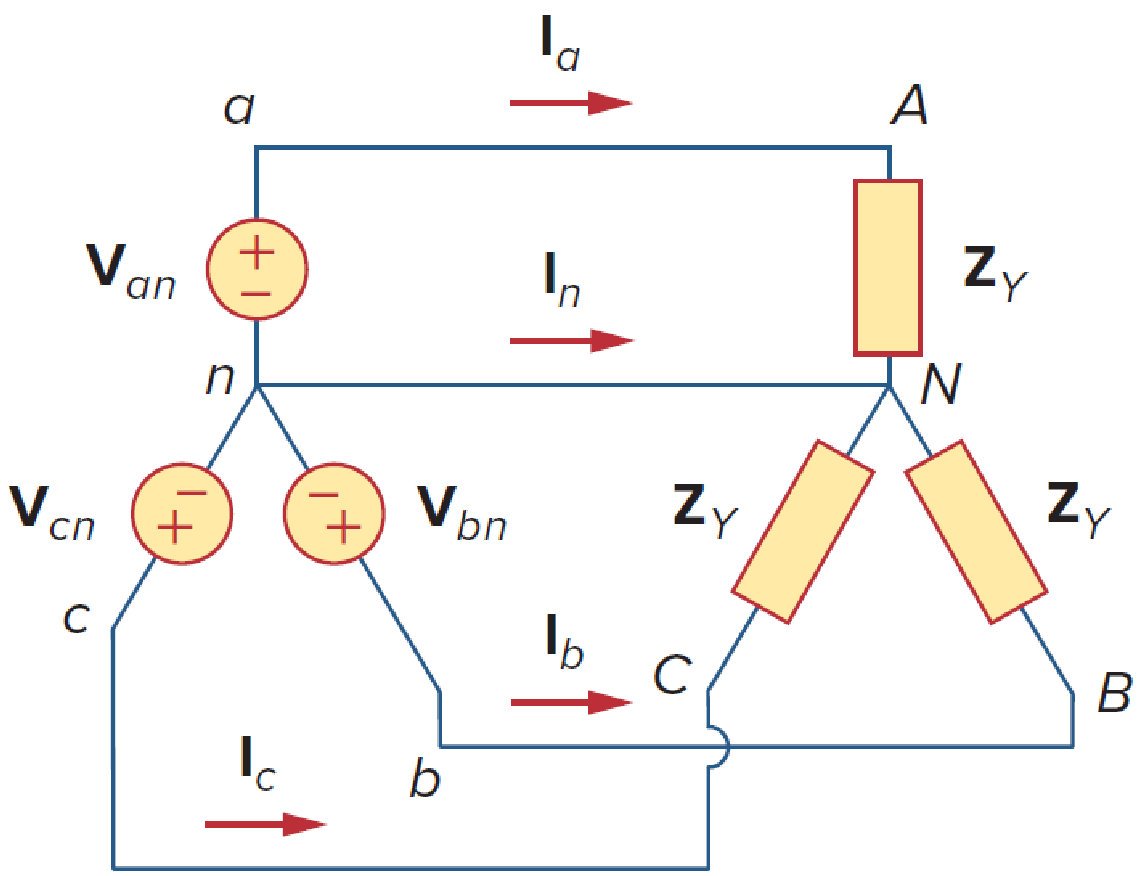
Now, one can readily infer that the line currents add up to zero,

$$I_a + I_b + I_c = 0$$

Therefore,

$$I_n = -(I_a + I_b + I_c) = 0 \qquad \text{(or)}$$

$$V_{nN} = Z_n I_n = 0$$



- The line current is the current in each line, the phase current is the current in each phase of the source or load.
- In the Y-Y system, the line current is the same as the phase current.