Vellore Institute of Technology

(Deemed to be University under section 3 of UGC Act, 1956)

SCHOOL OF ELECTRICAL ENGINEERING

BEEE101L

Basic Electrical Engineering

Three phase systems

By,

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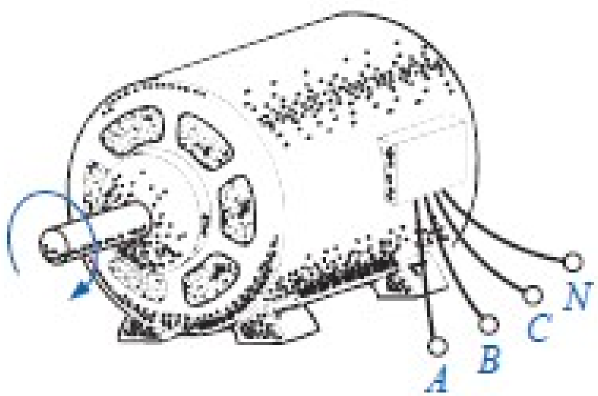
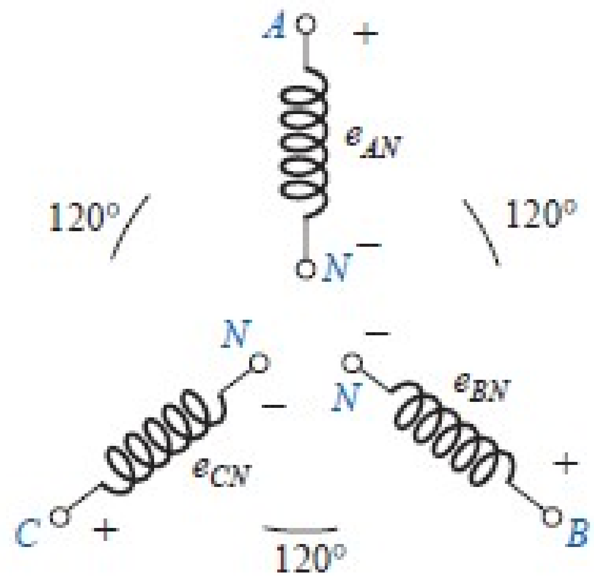
THE THREE-PHASE GENERATOR

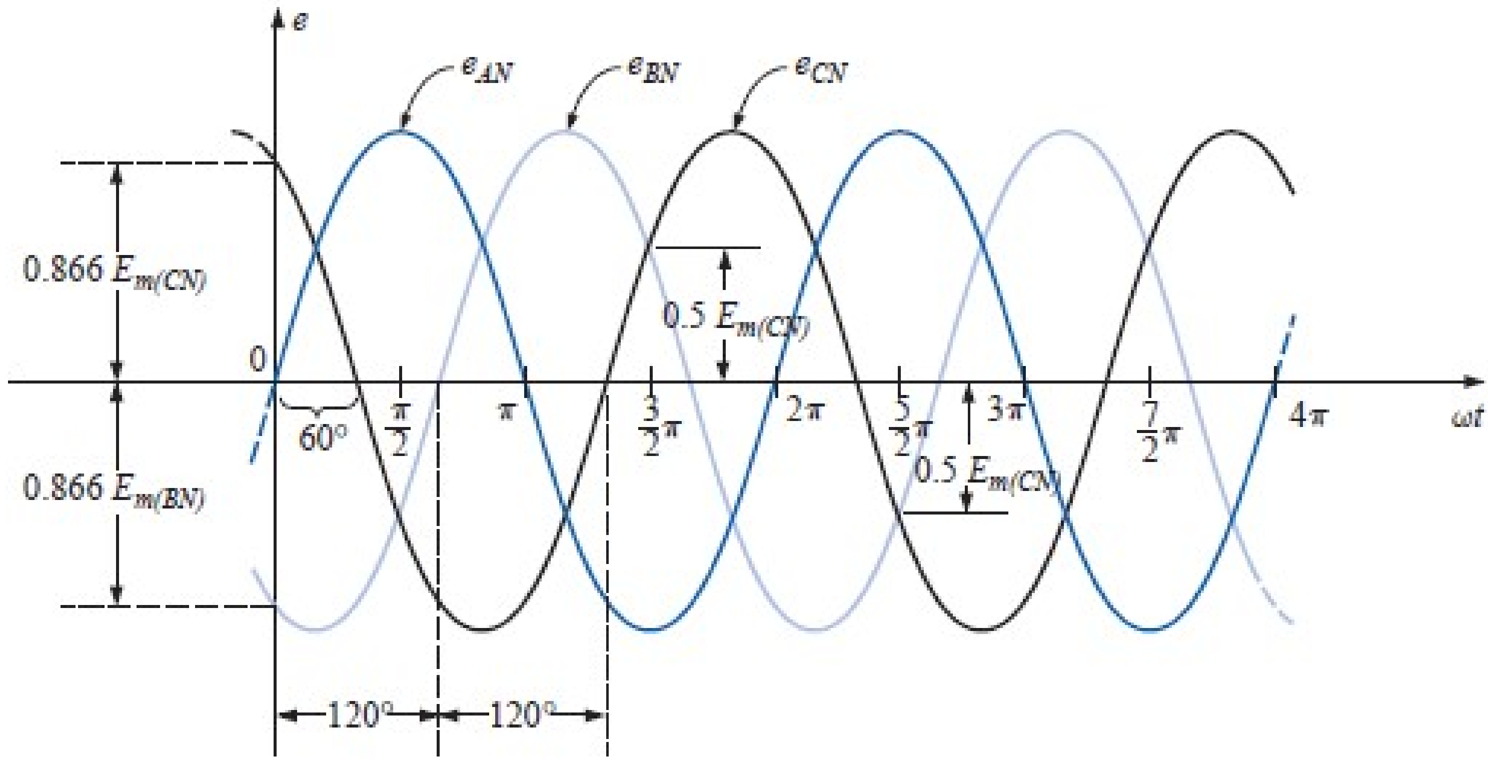




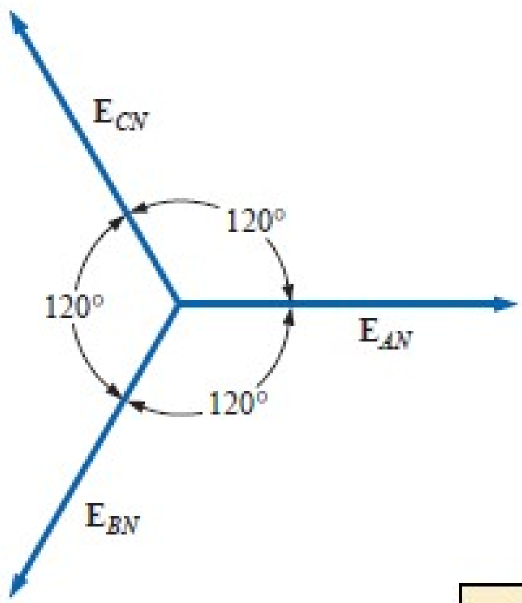
In particular, note that

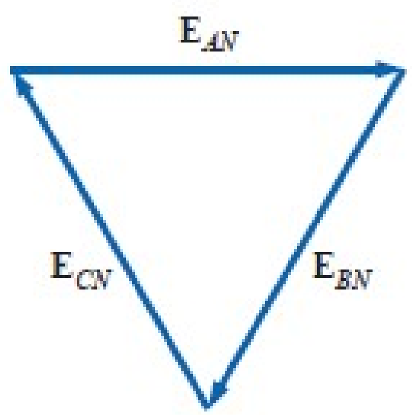
at any instant of time, the algebraic sum of the three phase voltages of a three-phase generator is zero.

Three phase voltage



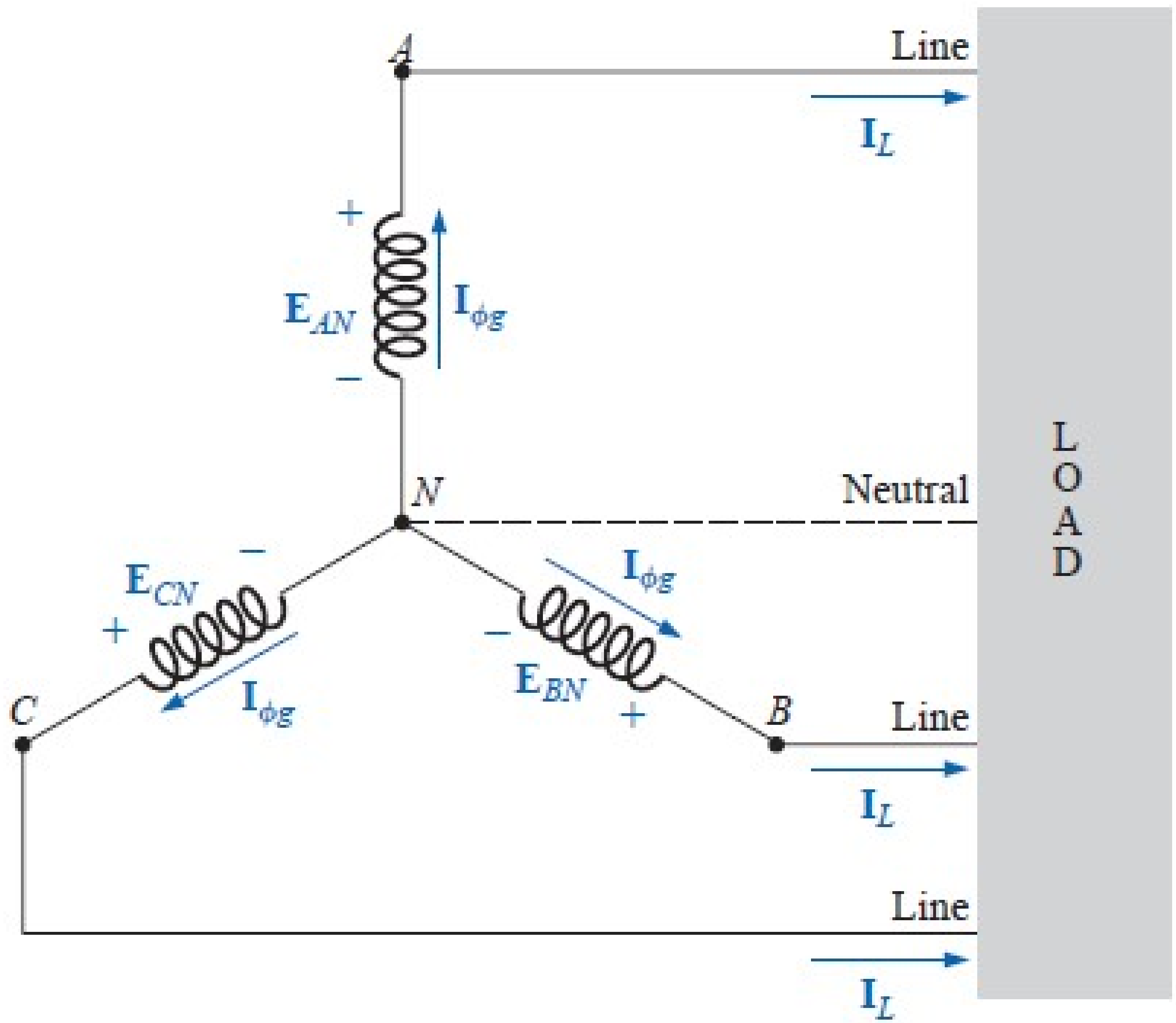
$$e_{AN} = E_{m(AN)} \sin \omega t$$
$$e_{BN} = E_{m(BN)} \sin(\omega t - 120°)$$
$$e_{CN} = E_{m(CN)} \sin(\omega t - 240°) = E_{m(CN)} \sin(\omega t + 120°)$$





$$\mathbf{E}_{AN} + \mathbf{E}_{BN} + \mathbf{E}_{CN} = 0$$

THE Y-CONNECTED GENERATOR

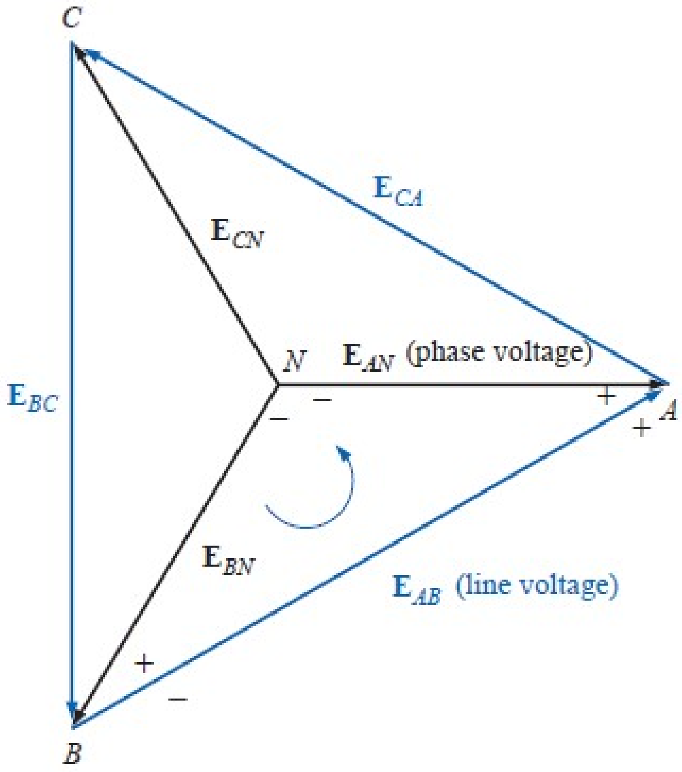


Y-CONNECTION

- The line current equals the phase current for each phase.

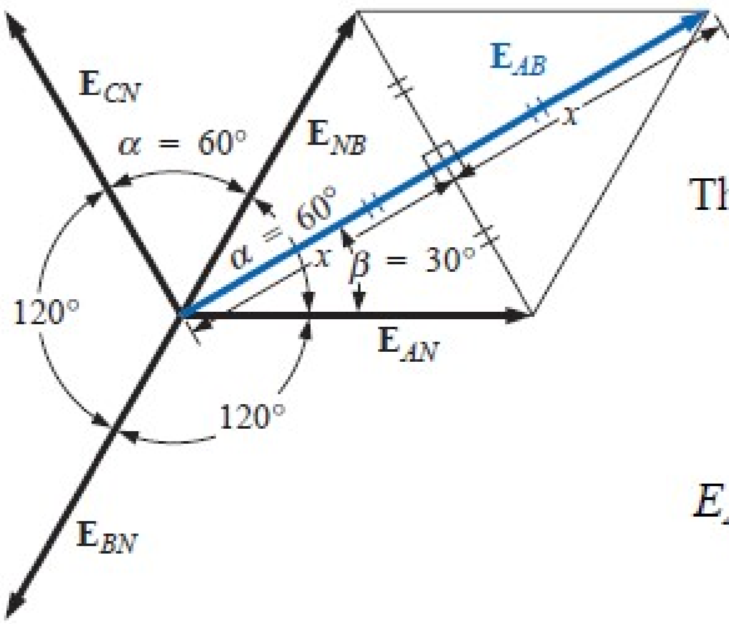
$$\boxed{\mathbf{I}_L = \mathbf{I}_{\phi g}}$$

- The voltage from one line to another is called a line voltage.



$$\mathbf{E}_{AB} - \mathbf{E}_{AN} + \mathbf{E}_{BN} = 0$$

$$\mathbf{E}_{AB} = \mathbf{E}_{AN} - \mathbf{E}_{BN} = \mathbf{E}_{AN} + \mathbf{E}_{NB}$$



The length x is

$$x = E_{AN} \cos 30° = \frac{\sqrt{3}}{2} E_{AN}$$

$$E_{AB} = 2x = (2) \frac{\sqrt{3}}{2} E_{AN} = \sqrt{3} E_{AN}$$

Noting from the phasor diagram that θ of $\mathbf{E}_{AB} = \beta = 30°$, the result is

$$\mathbf{E}_{AB} = E_{AB} \angle 30° = \sqrt{3} E_{AN} \angle 30°$$

and

$$\mathbf{E}_{CA} = \sqrt{3} E_{CN} \angle 150°$$

$$\mathbf{E}_{BC} = \sqrt{3} E_{BN} \angle 270°$$

$$\boxed{E_L = \sqrt{3} E_\phi}$$

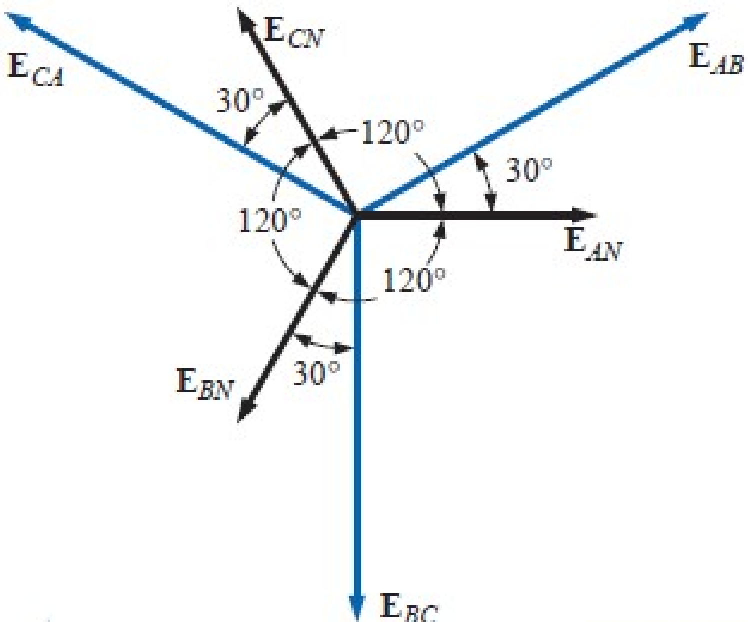
In sinusoidal notation,

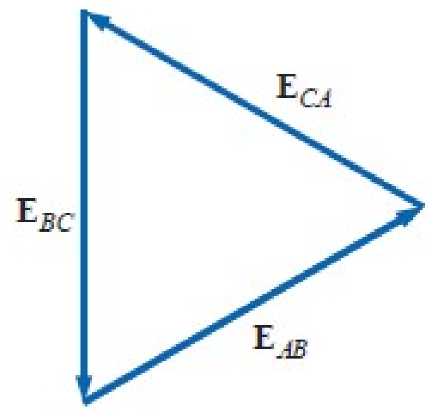
$$e_{AB} = \sqrt{2}E_{AB}\sin(\omega t + 30^\circ)$$

$$e_{CA} = \sqrt{2}E_{CA}\sin(\omega t + 150^\circ)$$

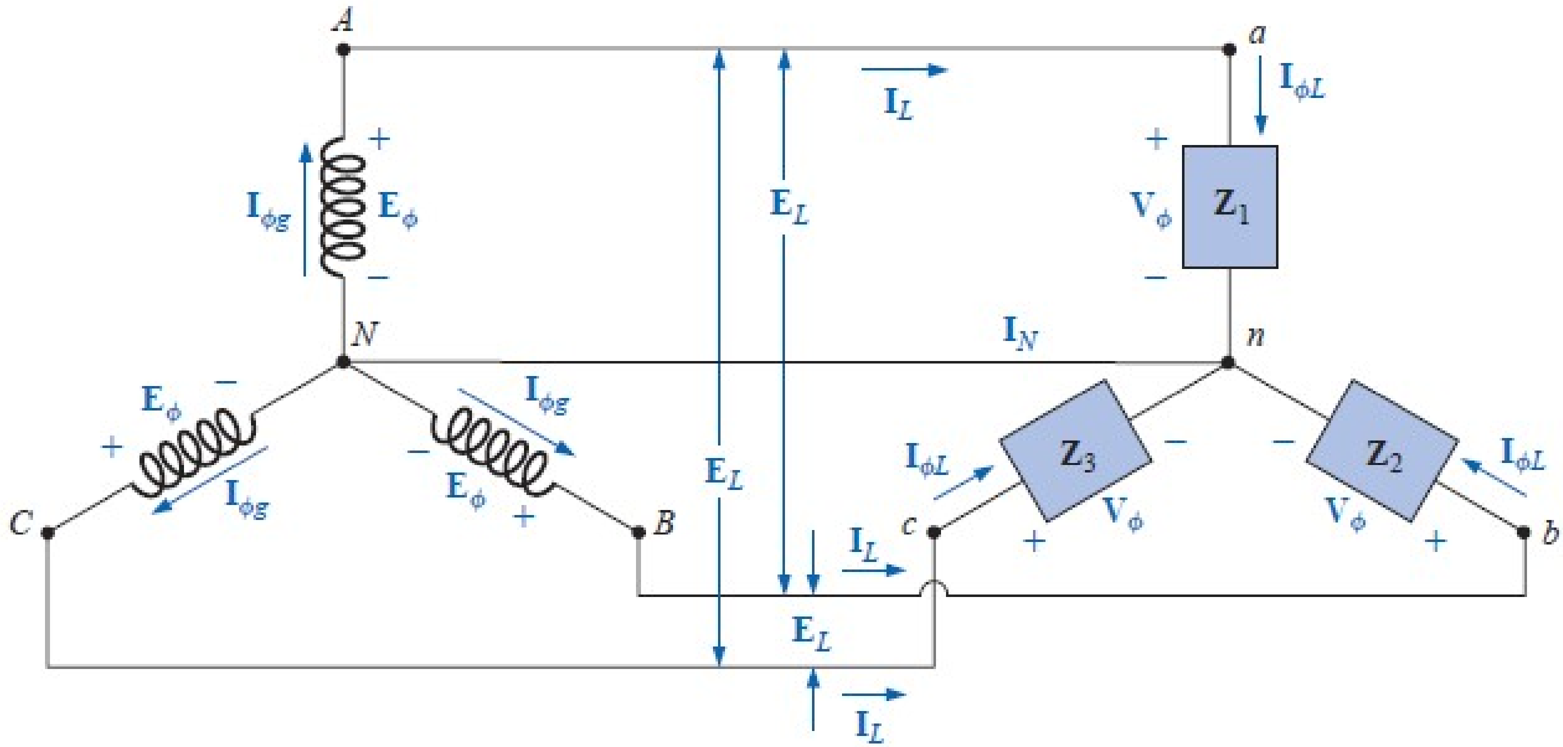
and

$$e_{BC} = \sqrt{2}E_{BC}\sin(\omega t + 270^\circ)$$



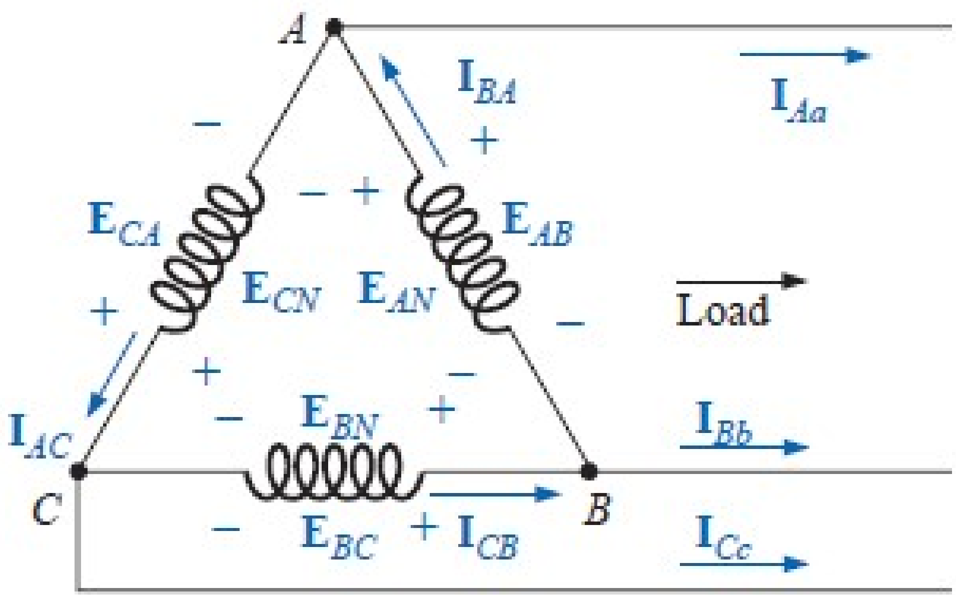


$$\boxed{\mathbf{E}_{AB} + \mathbf{E}_{CA} + \mathbf{E}_{BC} = 0}$$



Y-connected generator with a Y-connected load.

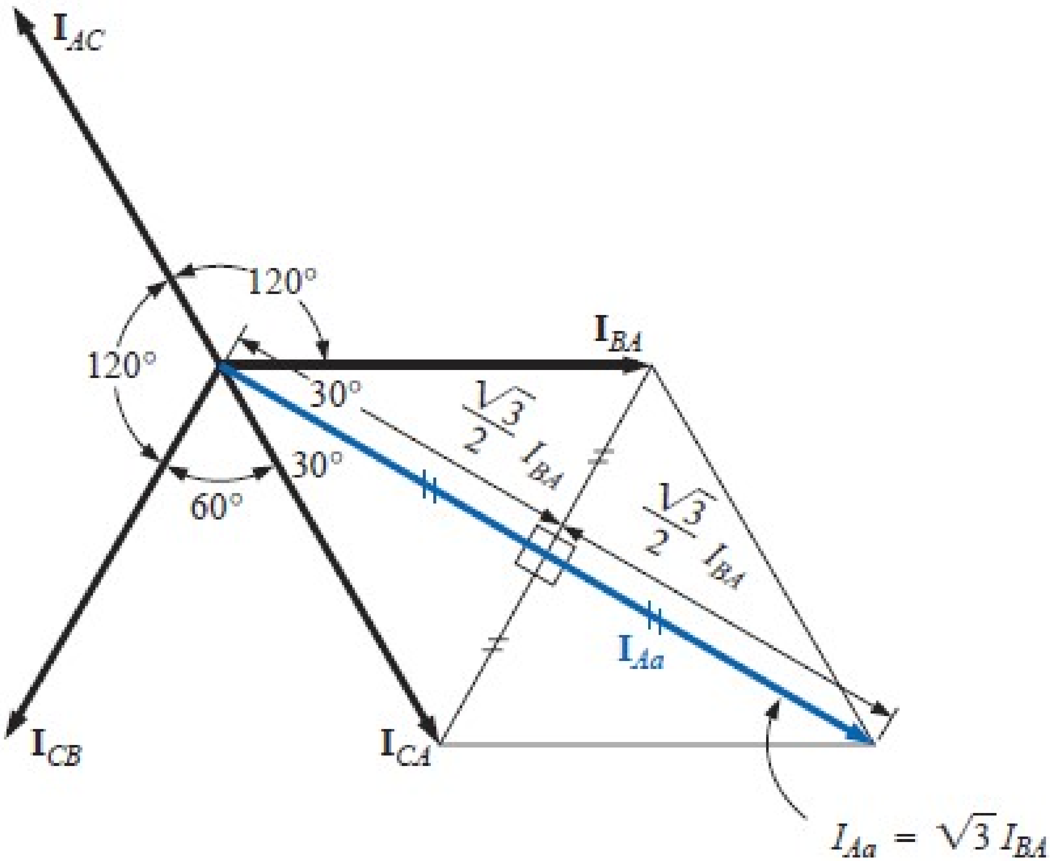
DELTA CONNECTION



The phase and line voltages are equivalent

$$\mathbf{E}_L = \mathbf{E}_{\phi g}$$

DELTA CONNECTION



$$\boxed{I_L = \sqrt{3} I_{\phi g}}$$

Problem 1. Three loads, each of resistance 30 Ω, are connected in star to a 415 V, 3-phase supply. Determine (a) the system phase voltage, (b) the phase current and (c) the line current.

For a star connection, $V_L = \sqrt{3}V_p$

Hence phase voltage, $V_p = \dfrac{V_L}{\sqrt{3}} = \dfrac{415}{\sqrt{3}} = \mathbf{239.6\ V\ or\ 240\ V}$

Phase current, $I_p = \dfrac{V_p}{R_p} = \dfrac{240}{30} = \mathbf{8\ A}$

For a star connection, $I_p = I_L$

Hence the line current, $I_L = \mathbf{8\ A}$

Problem 2. A star-connected load consists of three identical coils each of resistance 30 Ω and inductance 127.3 mH. If the line current is 5.08 A, calculate the line voltage if the supply frequency is 50 Hz

Inductive reactance $X_L = 2\pi f L = 2\pi(50)(127.3 \times 10^{-3}) = 40\ \Omega$

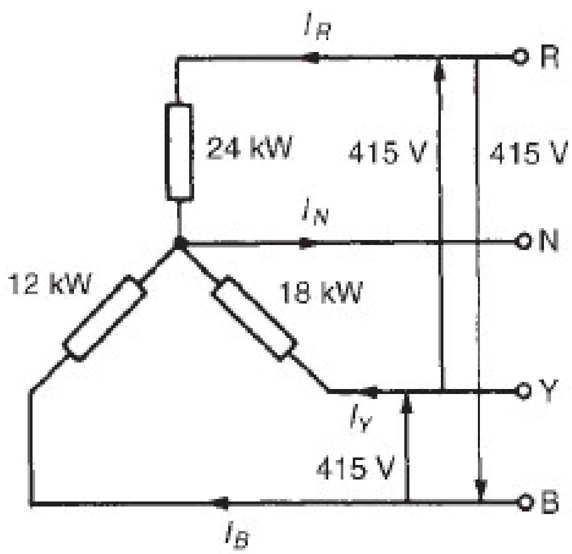
Impedance of each phase $Z_p = \sqrt{(R^2 + X_L{}^2)} = \sqrt{(30^2 + 40^2)} = 50\ \Omega$

For a star connection $I_L = I_p = \dfrac{V_p}{Z_p}$

Hence phase voltage $V_p = I_p Z_p = (5.08)(50) = 254\ \text{V}$

Line voltage $V_L = \sqrt{3} V_p = \sqrt{3}(254) = \mathbf{440\ V}$

Problem . A 415 V, 3-phase, 4 wire, star-connected system supplies three resistive loads as shown in Figure 19.7. Determine (a) the current in each line and (b) the current in the neutral conductor.



For a star-connected system $V_L = \sqrt{3} V_p$

Hence $$V_p = \frac{V_L}{\sqrt{3}} = \frac{415}{\sqrt{3}} = 240 \text{ V}$$

Since current $I = \dfrac{\text{Power } P}{\text{Voltage } V}$ for a resistive load

then $$I_R = \frac{P_R}{V_R} = \frac{24\,000}{240} = \mathbf{100\ A}$$

$$I_Y = \frac{P_Y}{V_Y} = \frac{18\,000}{240} = \mathbf{75\ A}$$

$$I_B = \frac{P_B}{V_B} = \frac{12\,000}{240} = \mathbf{50\ A}$$

Alternatively, by calculation, considering I_R at 90°, I_B at 210° and I_Y at 330°:

$$\begin{aligned}\text{Total horizontal component} &= 100\cos 90^\circ + 75\cos 330^\circ + 50\cos 210^\circ \\ &= 21.65\end{aligned}$$

$$\begin{aligned}\text{Total vertical component} &= 100\sin 90^\circ + 75\sin 330^\circ + 50\sin 210^\circ \\ &= 37.50\end{aligned}$$

$$\text{Hence magnitude of } I_N = \sqrt{(21.65^2 + 37.50^2)} = \mathbf{43.3\ A}$$

Problem . Three identical coils each of resistance 30 Ω and inductance 127.3 mH are connected in delta to a 440 V, 50 Hz, 3-phase supply. Determine (a) the phase current, and (b) the line current.

Phase impedance, $Z_p = 50\ \Omega$

Phase current, $$I_p = \frac{V_p}{Z_p} = \frac{V_L}{Z_p} = \frac{440}{50} = \mathbf{8.8\ A}$$

For a delta connection, $I_L = \sqrt{3} I_p = \sqrt{3}(8.8) = \mathbf{15.24\ A}$

Problem . Three coils each having resistance 3 Ω and inductive reactance 4 Ω are connected (i) in star and (ii) in delta to a 415 V, 3-phase supply. Calculate for each connection (a) the line and phase voltages and (b) the phase and line currents.

For a star connection: $I_L = I_p$ and $V_L = \sqrt{3} V_p$

A 415 V, 3-phase supply means that the

line voltage, $V_L = \mathbf{415\ V}$

$$\text{Phase voltage, } V_p = \frac{V_L}{\sqrt{3}} = \frac{415}{\sqrt{3}} = \mathbf{240\ V}$$

$$\text{Impedance per phase, } Z_p = \sqrt{(R^2 + X_L{}^2)} = \sqrt{(3^2 + 4^2)}$$

$$= 5\ \Omega$$

$$\text{Phase current, } I_p = \frac{V_p}{Z_p} = \frac{240}{5} = \mathbf{48\ A}$$

$$\text{Line current, } I_L = I_p = \mathbf{48\ A}$$

For a delta connection: $V_L = V_p$ and $I_L = \sqrt{3} I_p$

$$\text{Line voltage, } V_L = 415\ \text{V}$$

$$\text{Phase voltage, } V_p = V_L = \mathbf{415\ V}$$

$$\text{Phase current, } I_p = \frac{V_p}{Z_p} = \frac{415}{5} = \mathbf{83\ A}$$

$$\text{Line current, } I_L = \sqrt{3} I_p = \sqrt{3}(83) = \mathbf{144\ A}$$