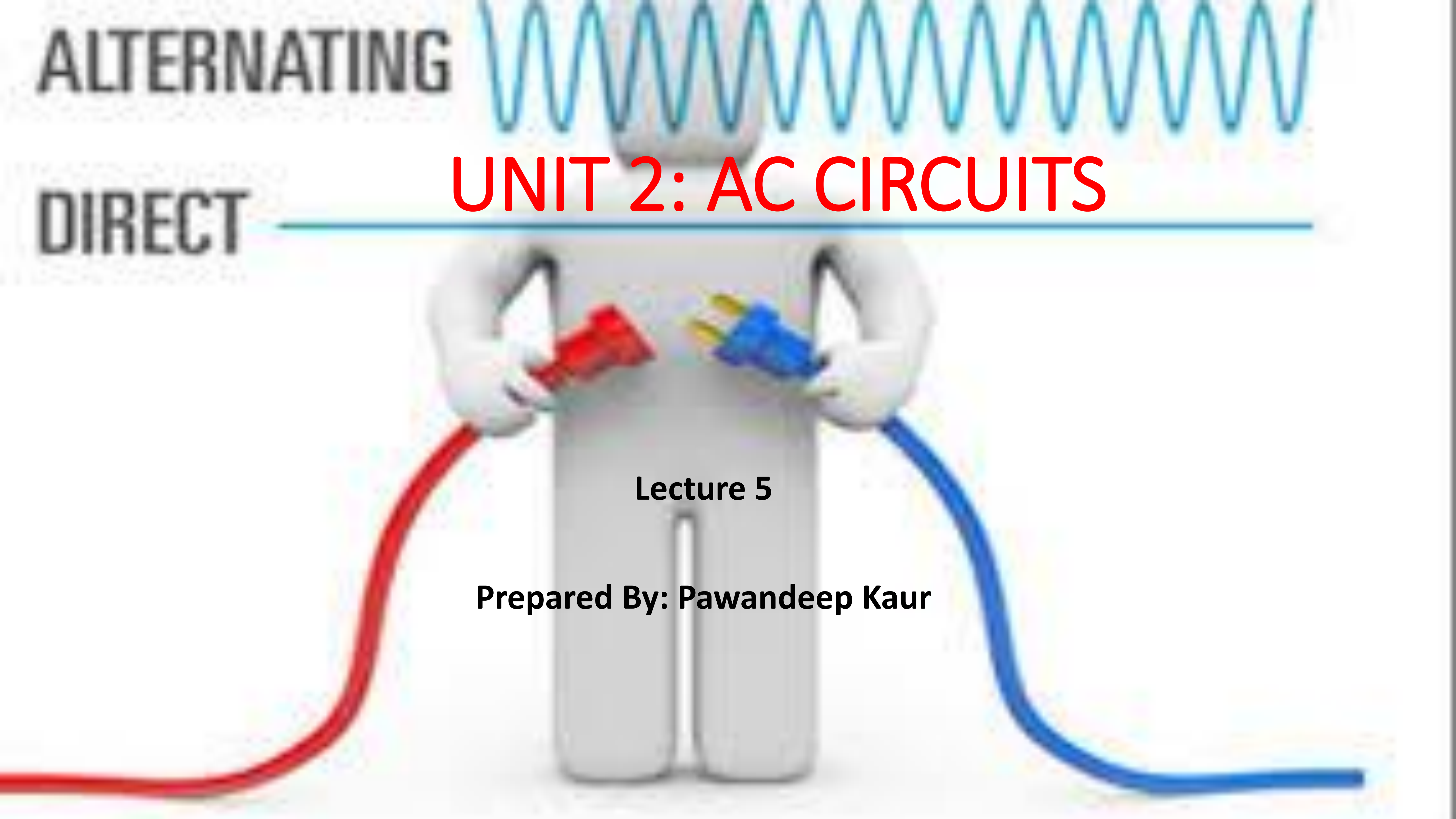


UNIT 2: AC CIRCUITS

Lecture 5

Prepared By: Pawandeep Kaur

Recap QUICK QUIZ (POLL)

The current _____ voltage by ____ in a capacitor when a sinusoidal supply applied.

A. Leads by 45°
B. Leads by 90°
C. Lags by 45°
D. Lags by 90°

Series RLC Circuit

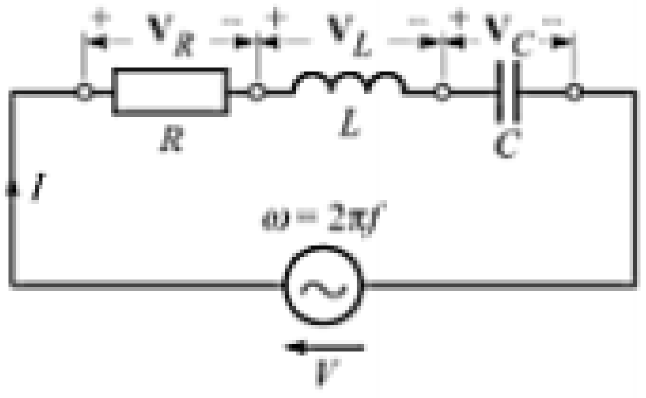
$$\mathit{In\ terms\ of\ Phasor}:$$
$$\boldsymbol{V} = \boldsymbol{V_R} + \boldsymbol{V_L} + \boldsymbol{V_c}$$

In terms of magnitude, we can write:

$$V = \sqrt{(V_R)^2 + (V_L - V_C)^2}$$

And , phase difference is given by:

$$\emptyset = \tan^{-1}\frac{X_L - X_C}{R}$$



$$I = \frac{V}{\sqrt{\left\{R^2 + \left(2\pi f L - \frac{1}{2\pi f C}\right)^2\right\}}} = \frac{V}{Z}$$

where Z = *impedance* of circuit in ohms

$$Z = \frac{V}{I} = \sqrt{\left\{R^2 + \left(2\pi f L - \frac{1}{2\pi f C}\right)^2\right\}}$$

Series RLC Circuit

In a series *RLC* circuit, one cannot definitely say whether the current lags or leads the applied voltage. It depends upon the relative values of the terms ωL and $1/\omega C$. There can be following three possibilities:

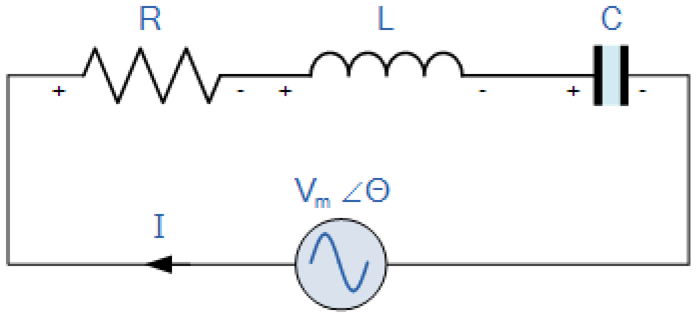
(1) *When* $\omega L > 1/\omega C$ The phase angle ϕ of the current phasor is negative (see Eq. 10.25). The current lags the voltage. The circuit behaves as an ***inductive circuit***.

(2) *When* $\omega L < 1/\omega C$ The phase angle ϕ of the current phasor is positive (see Eq. 10.25). The current leads the voltage. The circuit behaves as a ***capacitive circuit***.

(3) *When* $\omega L = 1/\omega C$ The phase angle $\phi = 0$. The current is in phase with voltage. The circuit behaves as a ***purely resistive circuit***. This is a special case, and is called ***resonance***.

Summary on RLC

Series RLC Circuit



Firstly, let us define what we already know about series RLC circuits.

- Inductive reactance : $X_L = 2\pi f L = \omega L$
- Capacitive reactance : $X_C = \dfrac{1}{2\pi f C} = \dfrac{1}{\omega C}$
- When $X_L > X_C$ the circuit is Inductive
- When $X_C > X_L$ the circuit is Capacitive
- Total circuit reactance = $X_T = X_L - X_C$ or $X_C - X_L$
- Total circuit impedance = $Z = \sqrt{R^2 + X_T^2} = R + jX$

QUICK QUIZ (POLL)

For a series RLC circuit: If $X_L = 12\Omega \; and \;\; X_C = 8\Omega$ and R= 15Ω , the circuit is:

A. Inductive, with Z=15.5 Ω

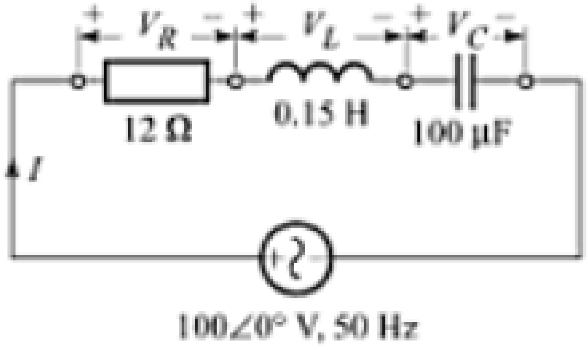
B. Inductive, with Z=17.5 Ω

C. Capacitive, with Z=15.5 Ω

D. Capacitive, with Z=17.5 Ω

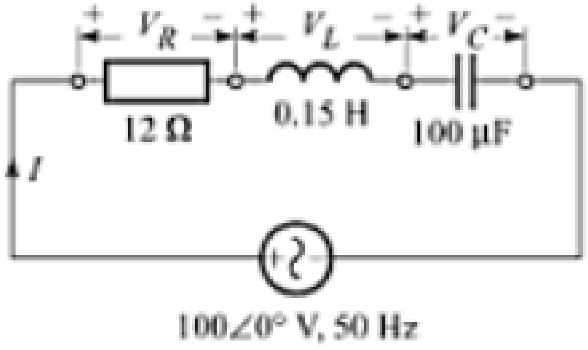
Practice Numerical:

For the circuit shown in Fig. 10.8*a* , calculate (*a*) the impedance, (*b*) the current, (*c*) the phase angle, (*d*) the voltage across each element, (*e*) the power factor, (*f*) the apparent power, and (*g*) the average power. Also, draw the phasor diagram for the circuit.



Practice Numerical:

For the circuit shown in Fig. 10.8*a* , calculate (*a*) the impedance, (*b*) the current, (*c*) the phase angle, (*d*) the voltage across each element, (*e*) the power factor, (*f*) the apparent power, and (*g*) the average power. Also, draw the phasor diagram for the circuit.



Resonance in Series RLC Circuits

The point of intersection where the inductive and capacitive reactance becomes equal i.e, $X_L = X_C$

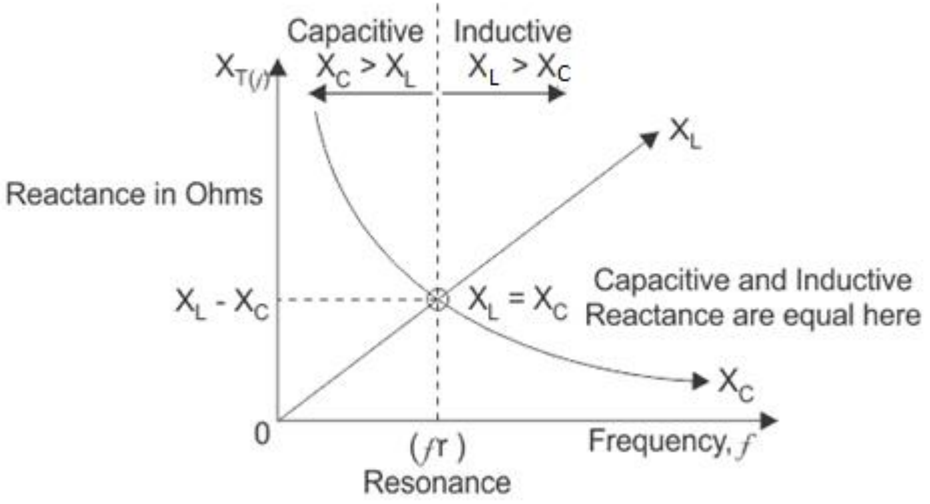
and the frequency at which these two reactances become equal, is called resonant frequency f_r.

$$X_L = X_C \quad \Rightarrow \quad 2\pi f L = \frac{1}{2\pi f C}$$

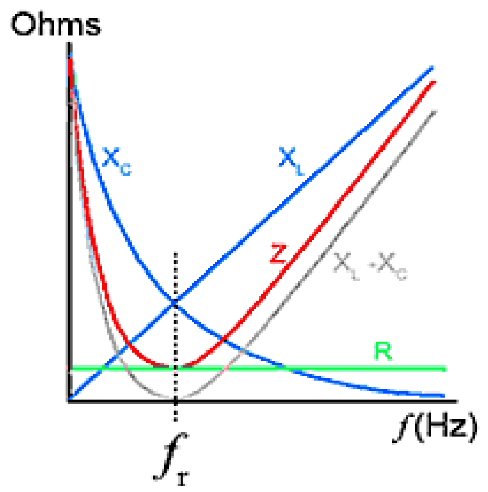
$$f^2 = \frac{1}{2\pi L \times 2\pi C} = \frac{1}{4\pi^2 LC}$$

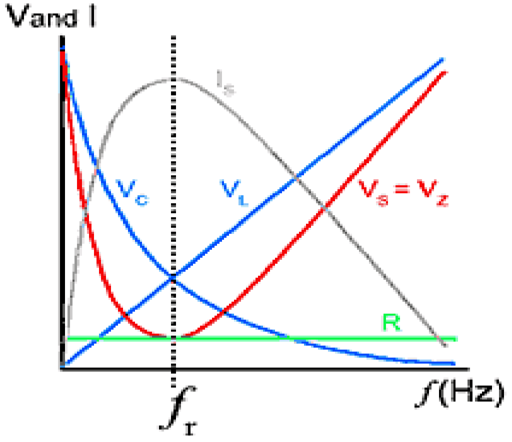
$$f = \sqrt{\frac{1}{4\pi^2 LC}}$$

$$\therefore \; f_r = \frac{1}{2\pi\sqrt{LC}} \text{(Hz)} \quad \text{or} \quad \omega_r = \frac{1}{\sqrt{LC}} \text{(rads)}$$



Resonance in Series RLC Circuits





Resonance in Series RLC Circuits

Quick Quiz Poll

- In a series RLC circuit, if the frequency of the source is below the resonance frequency (Fr),then

A) $X_C = X_L$

B) $X_C > X_L$

C) $X_C < X_L$

D)None of the above

Quality Factor

- The sharpness of the peak is measured quantitatively and is called the Quality factor, Q of the circuit.
- The Q, or quality, factor of a resonant circuit is a measure of the “goodness” or quality of a resonant circuit. A higher value for this figure of merit corresponds to a more narrow bandwidth, which is desirable in many applications. More formally, Q is the ratio of power stored to power dissipated in the circuit reactance and resistance, respectively:
- Mathematically,

$$Q = \frac{Power\ Stored}{Power\ Disspated} = \frac{I^2 X}{I^2 R} = \frac{X}{R}$$

Therefore, $Q = \frac{L\omega}{R} = \frac{1}{\omega RC} = \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{f_r}{BW}$

Quality Factor

QUICK QUIZ (POLL)

What is the value of resonant frequency if the value of C in a series RLC circuit is decreased?

A. Not affected

B. Increases

C. Reduces to zero

D. Decreases

QUICK QUIZ (POLL)

An inductor with a reactance of 120 Ω, a capacitor with a reactance of 120 Ω and a 24 Ω resistor are in series across a 60 V source. The circuit is at resonance. The voltage across the inductor is

A. 60 V

B. 660 V

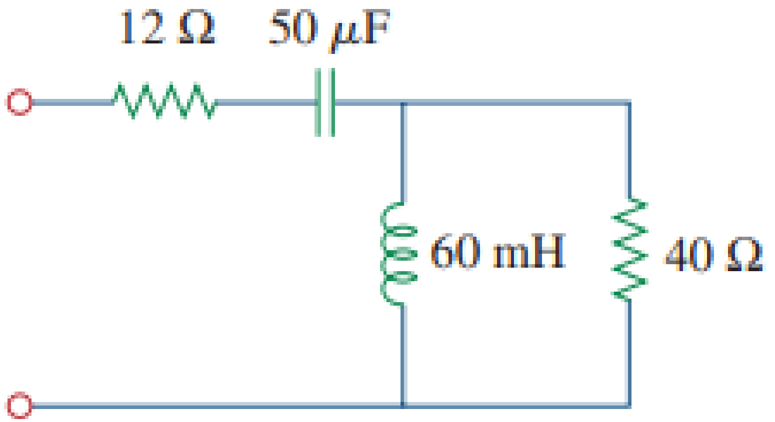
C. 30 V

D. 300 V

Practice Problem

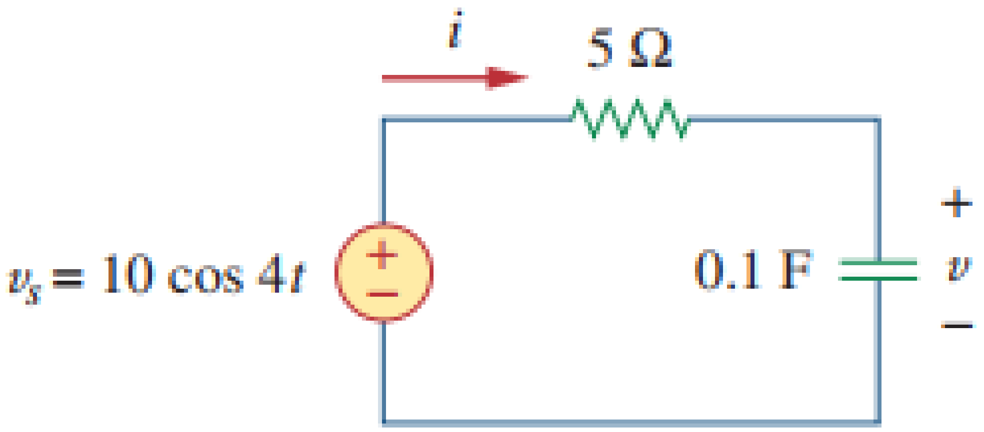
Find the input impedance of the given circuit:

Given that $\omega = 377\ rad/s$



Practice Problem 4

Find v(t) and i(t) in the circuit.



THREE PHASE CIRCUITS

Lecture 6

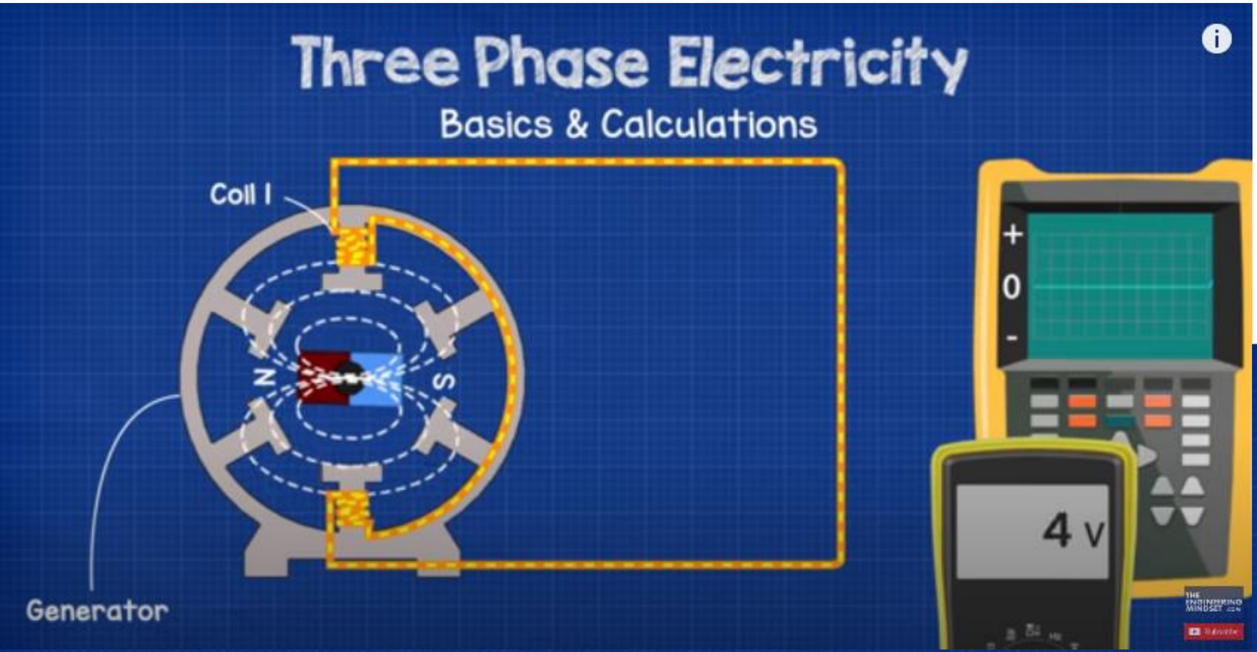
Three Phase Circuits

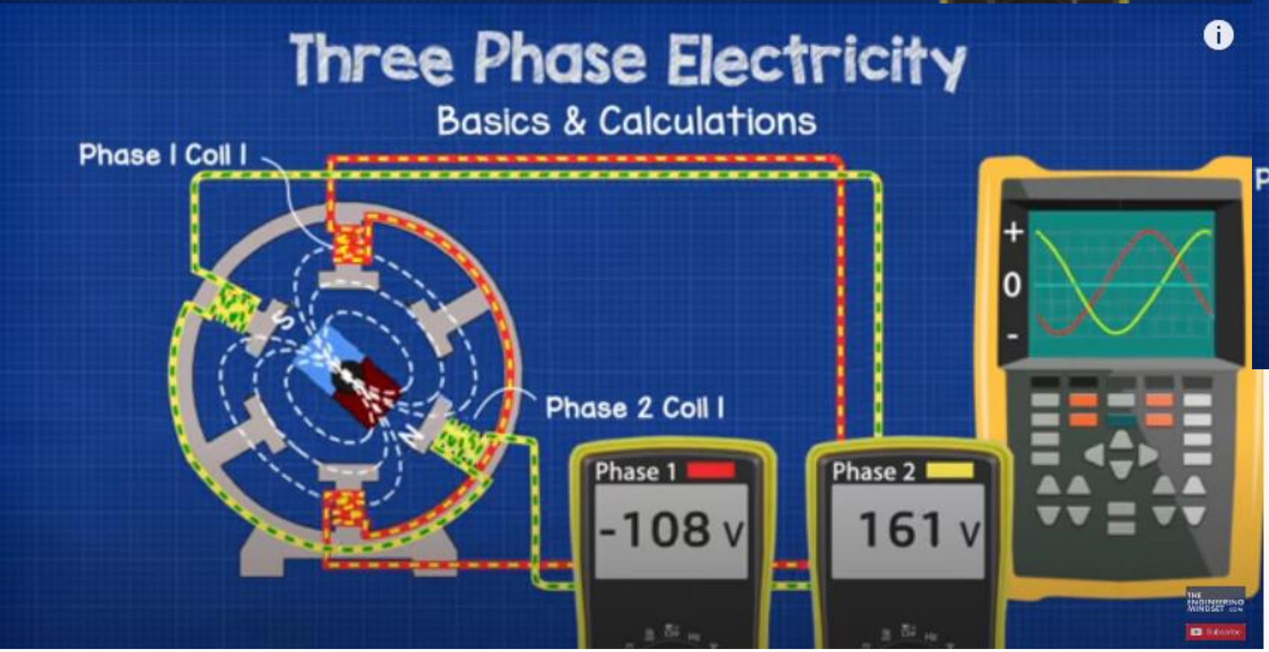
- Why?

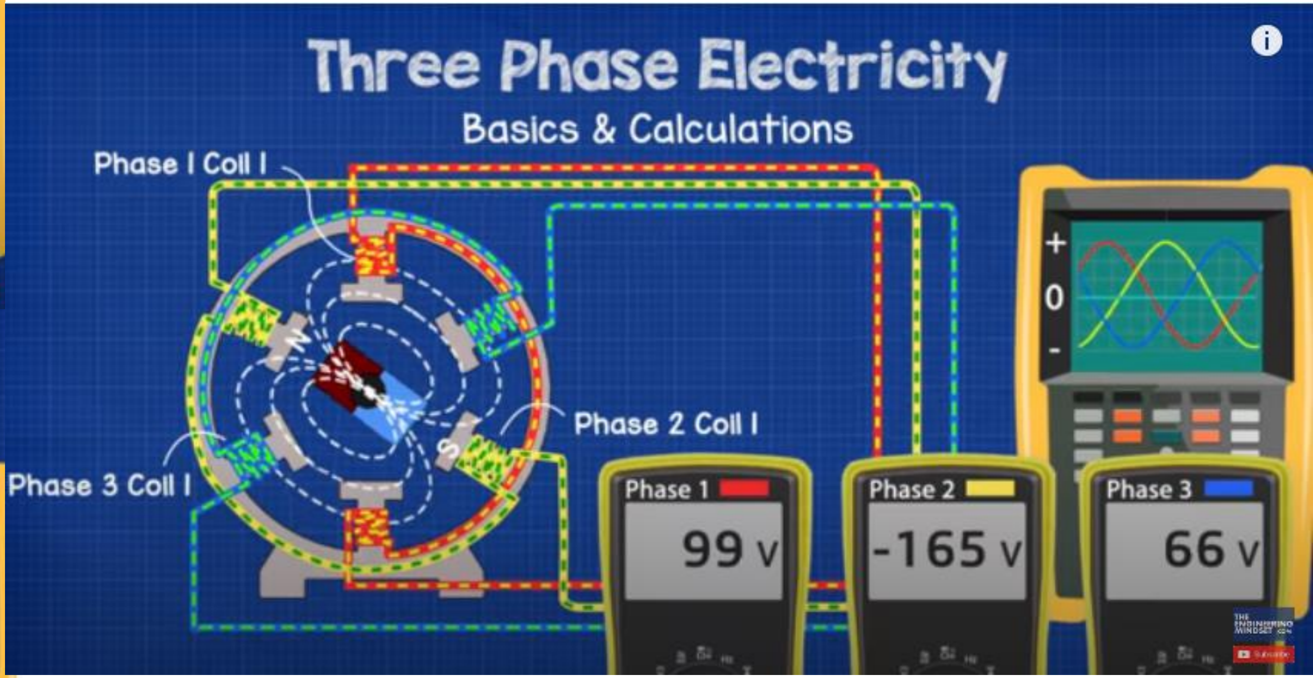
1. Requires lesser number of conductors
2. Power in a single phase circuit is pulsating, while as the power in the three phase circuit remains constant.
3. Due to the constant power, a uniform torque is generated in three phase motors.
4. Provides higher output voltage as compared to a 1-Phase.
5. Serves the purpose of domestic as well as industrial use.
6. Better Voltage Regulation.

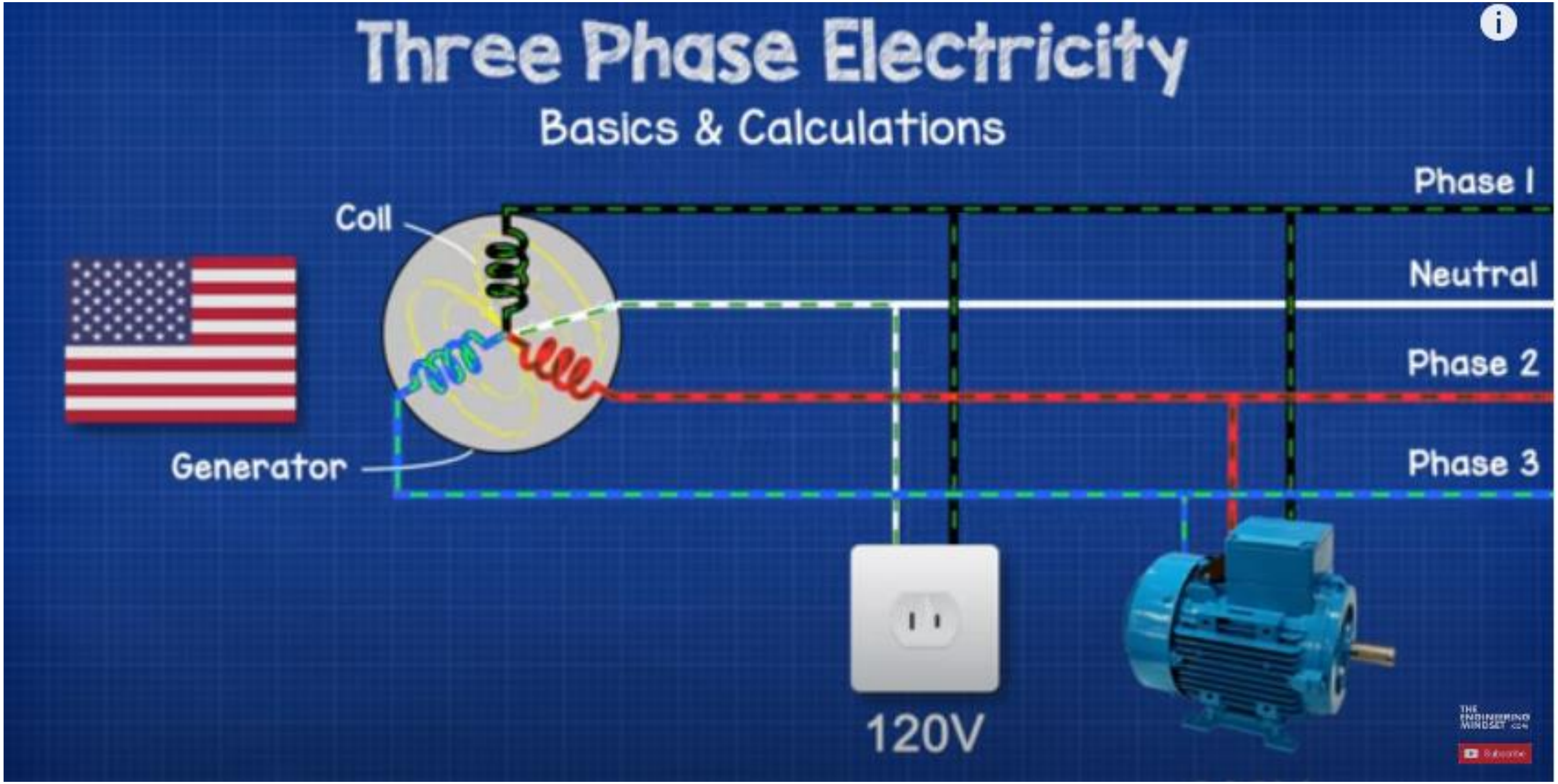
Explanation Slide

Explanation Slide


Three Phase Electricity
Basics & Calculations
Coil 1
N
S
Generator
+
0
-
4 V


Three Phase Electricity
Basics & Calculations
Phase 1 Coil 1
Phase 2 Coil 1
+
0
-
Phase 1
-108 V
Phase 2
161 V

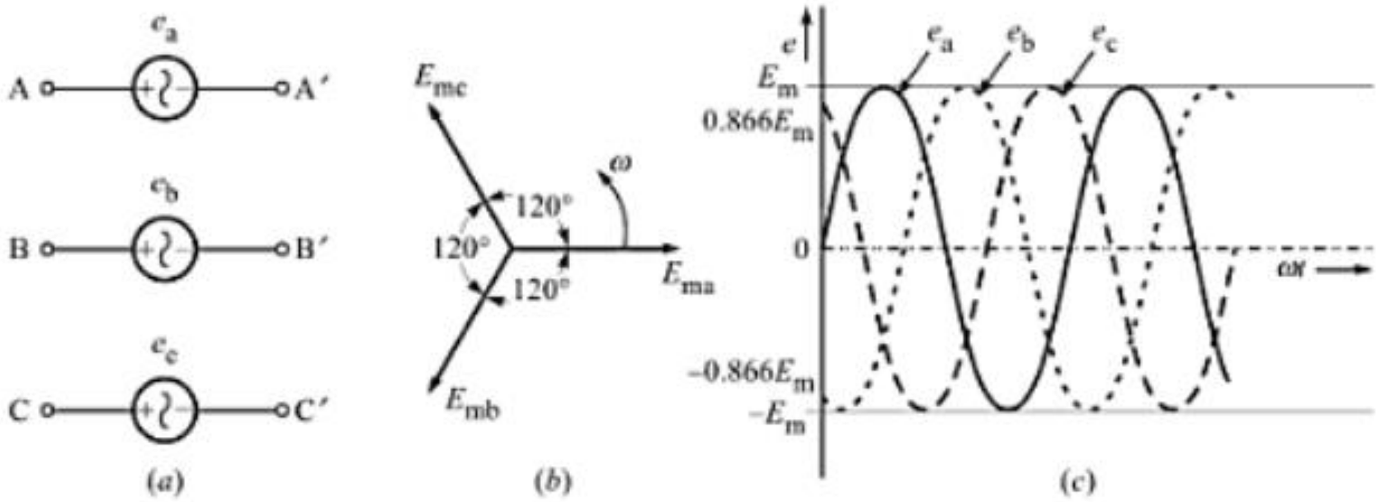

Three Phase Electricity
Basics & Calculations
Phase 1 Coil 1
Phase 2 Coil 1
Phase 3 Coil 1
+
0
-
Phase 1
99 V
Phase 2
-165 V
Phase 3
66 V



Three Phase Electricity
Basics & Calculations
Coil
Generator
Phase 1
Neutral
Phase 2
Phase 3
120V

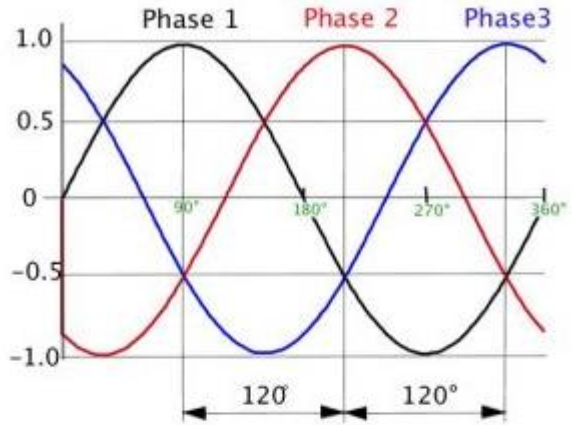
Three Phase Voltage

- Has three single phase emfs with same amplitude and frequency but phase displaced by 120.
- Considering Ea as the reference voltage, then (rotating anticlockwise) phase b lags phase a by 120 and phase c lags phase b by 120.



$$e_a = E_m \sin \omega t$$
$$e_b = E_m \sin(\omega t - 120°)$$
$$e_c = E_m \sin(\omega t - 240°) = E_m \sin(\omega t + 120°)$$

$$e_a = E_m \sin \omega t$$
$$e_b = E_m \sin(\omega t - 120°)$$
$$e_c = E_m \sin(\omega t - 240°) = E_m \sin(\omega t + 120°)$$



$$e_a = 0,\ e_b = E_m \sin(-120°) = -0.866 E_m \qquad \text{and} \qquad e_b = E_m \sin 120° = +0.866 E_m$$

Thus, at $t = 0$, we have

$$e_a + e_b + e_c = 0 + (-0.866 E_m) + 0.866 E_m = 0$$

QUICK QUIZ (POLL)

In a three phase AC circuit, the sum of all three generated voltages is:

A. 1

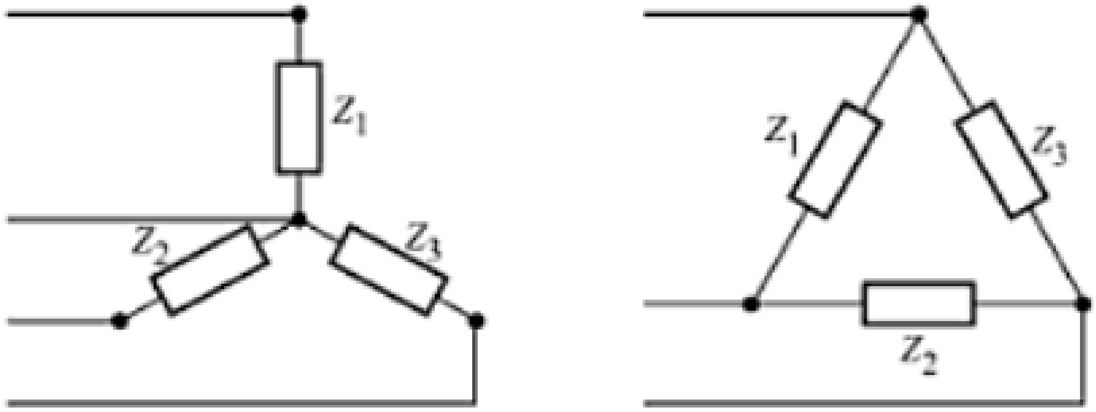
B. Infinite

C. ZERO

Types of Load

4 wire voltage system is
A)Star connection
B) Delta Connection

1. Star Connection
2. Delta Connection

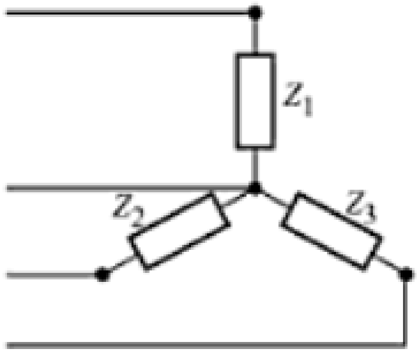


(a) Star (Y) connected. (b) Delta (Δ) connected.

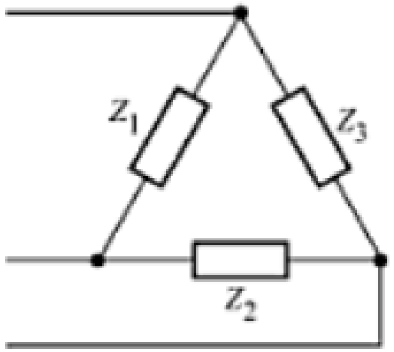
$if\ Z_1 = Z_2 = Z_3$, then the load is said to be **BALANCED**.

Before we Begin!

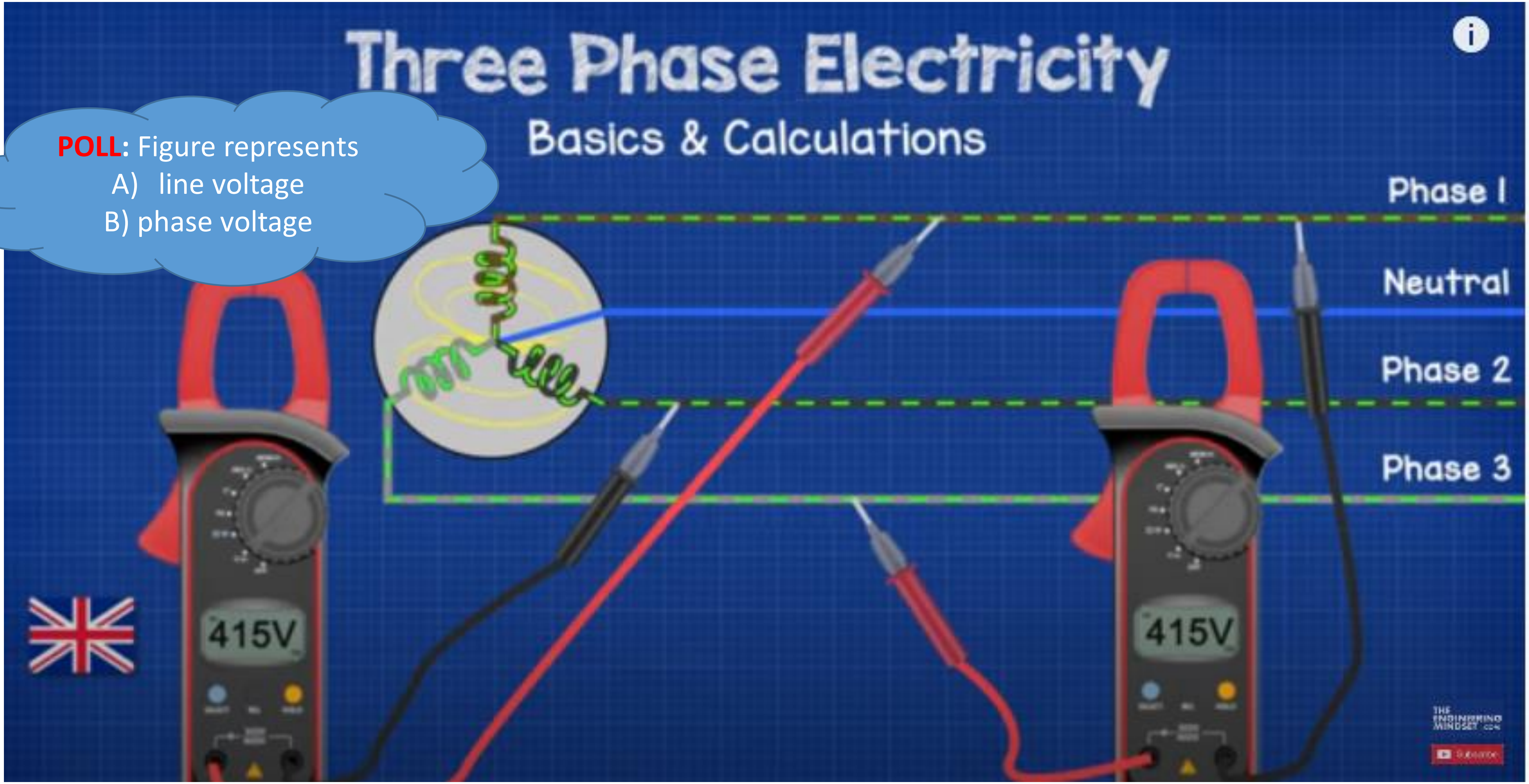
The current flowing through each phase is called **Phase current I_{ph}**, and the current flowing through each line conductor is called **Line Current I_L**. Similarly, the voltage across each phase is called **Phase Voltage E_{ph}**, and the voltage across two line conductors is known as the **Line Voltage E_L.**



(*a*) Star (Y) connected.



(*b*) Delta (Δ) connected.



POLL: Figure represents

A) line voltage

B) phase voltage

Star Connected Three Phase System

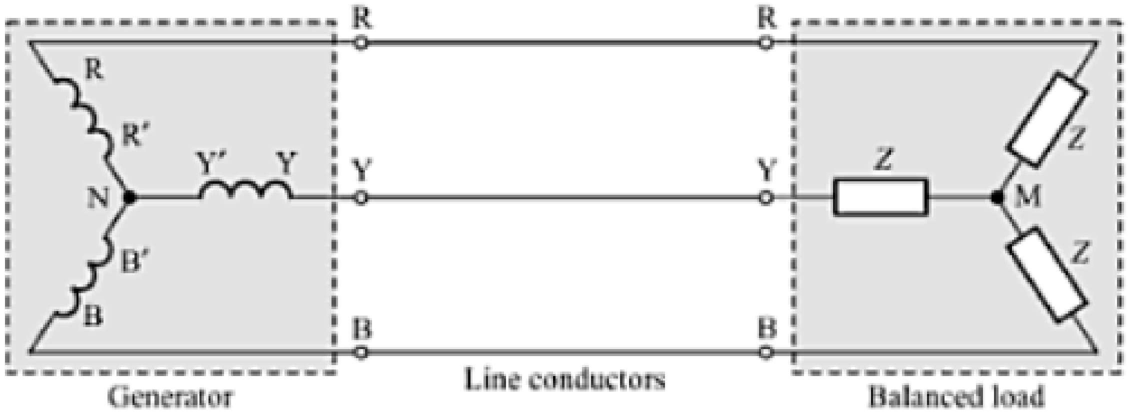


Fig. 12.7 *Three-wire star-connected voltage system with balance load.*

Star Connected Three Phase System

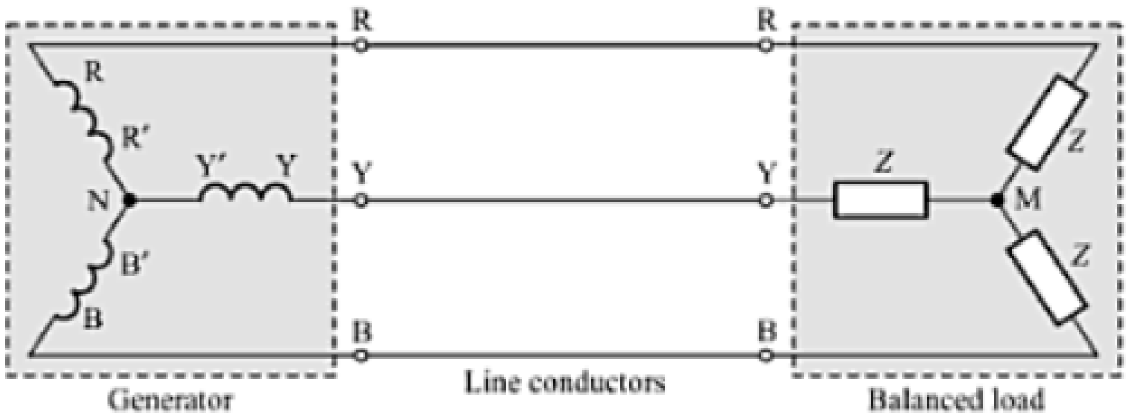
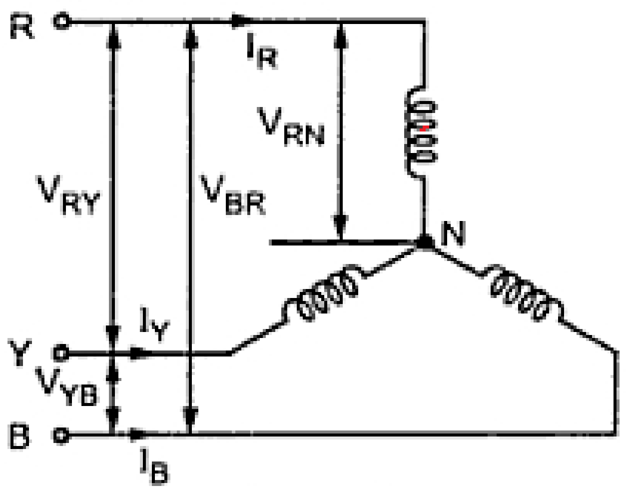


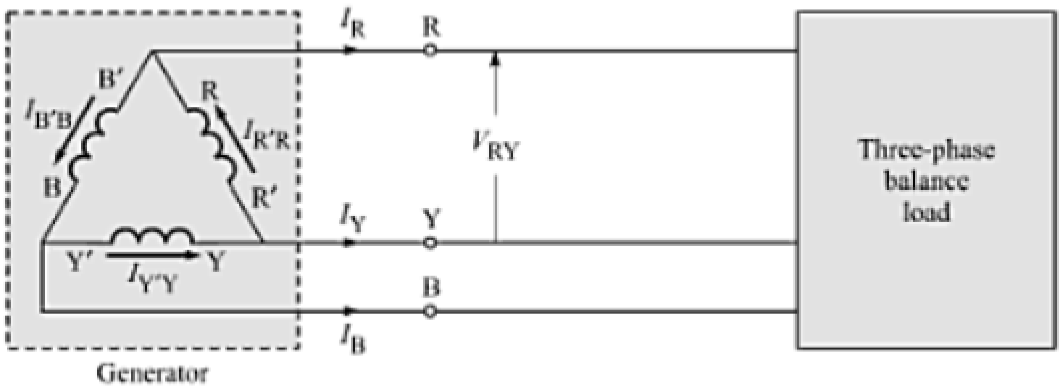
Fig. 12.7 *Three-wire star-connected voltage system with balance load.*

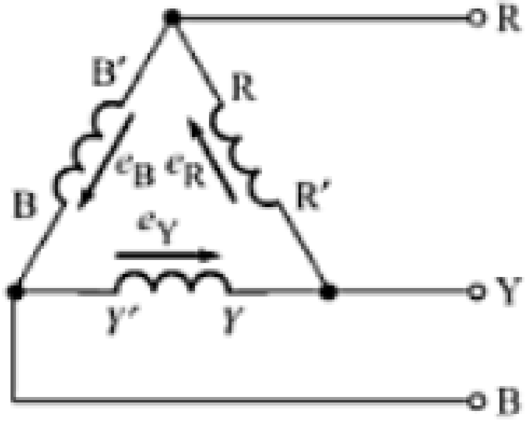
Summary (Star Connection)

- $I_L = I_{ph}$
- $V_L = \sqrt{3}V_{ph}$
- $P = 3V_{ph}I_{ph}\cos\emptyset = \sqrt{3}V_L I_L \cos\emptyset$

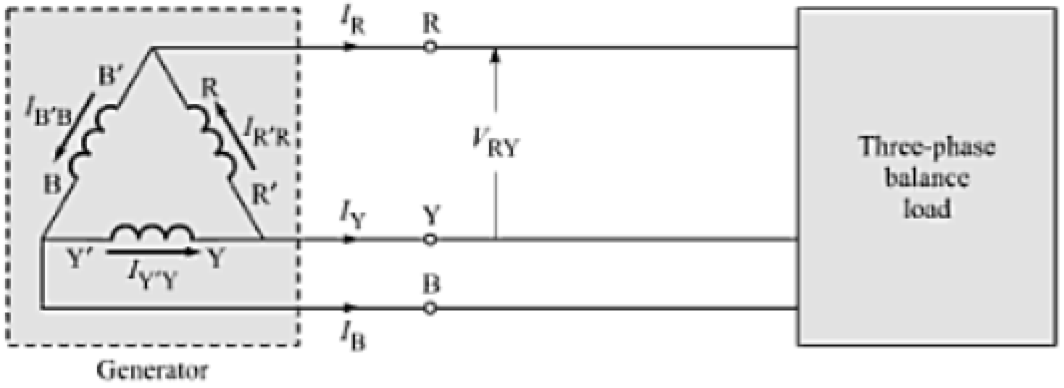


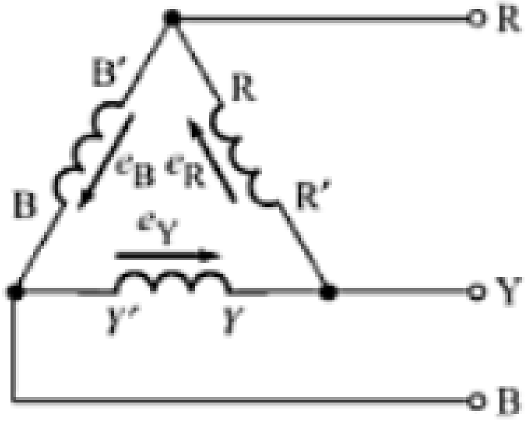
Delta Connected Three Phase System





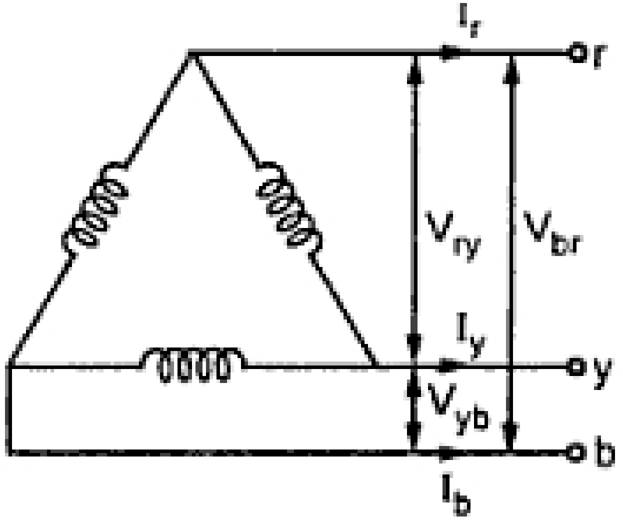
Delta Connected Three Phase System





Summary (Delta Connection)

- $V_L = V_{ph}$
- $I_L = \sqrt{3} I_{ph}$
- $P = 3 V_{ph} I_{ph} \cos \emptyset = \sqrt{3} V_L I_L \cos \emptyset$



Comparison Table

Star Connected System	Delta Connected System
Speed of star connected motors is Slow	Speed of delta connected motors is fast
Lesser number of turns are required	More turns are required
Savings in copper	More copper wire
Low insulation is required	Heavy insulation is required
Typically used in power transmission	Used in power distribution and industries

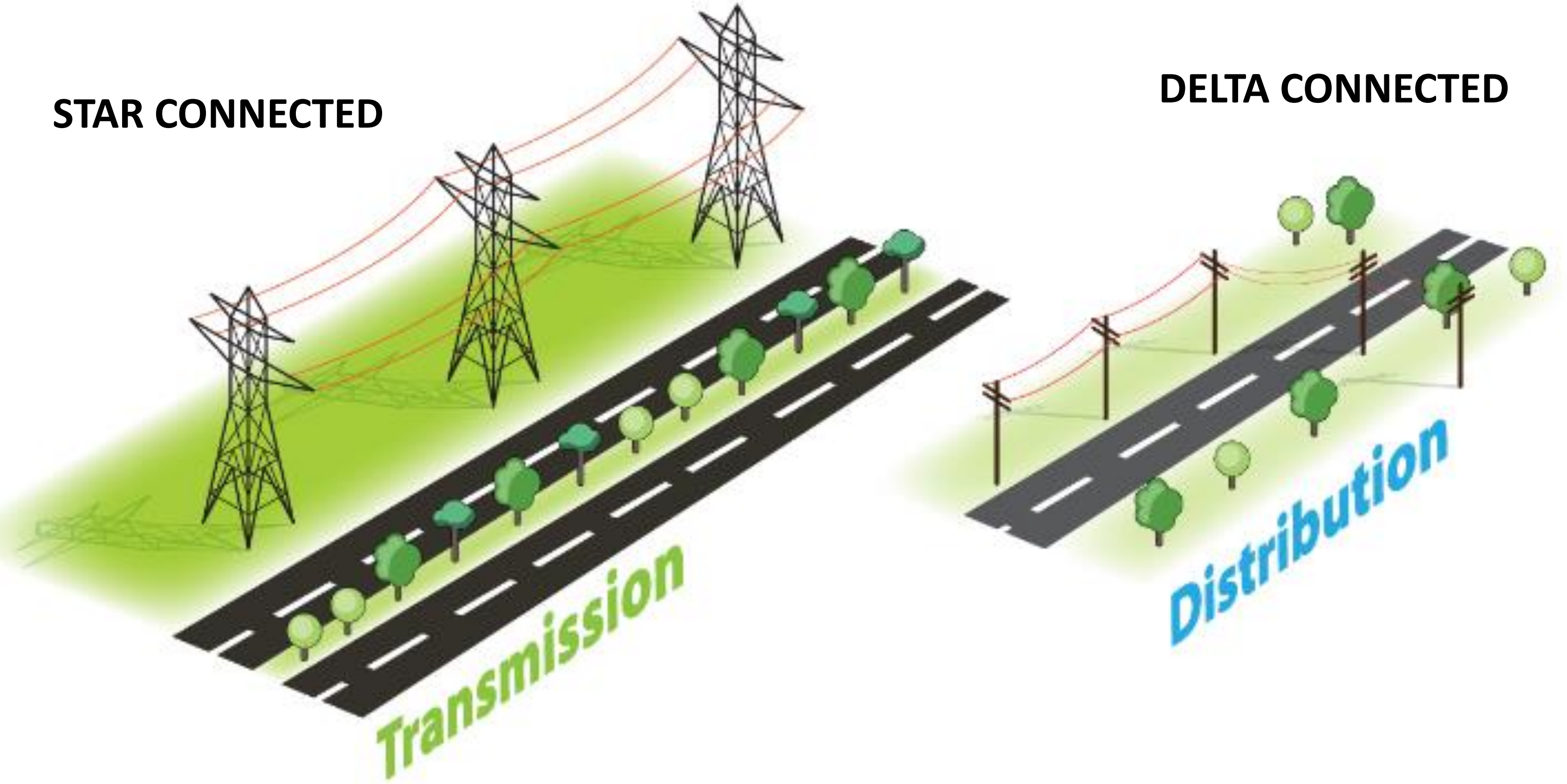
Comparison Table

S. No.	Star-Connected System	Delta-Connected System
1.	Similar ends are joined together.	Dissimilar ends are joined.
2.	$V_L = \sqrt{3}\, V_{ph}$ and $I_L = I_{ph}$	$V_L = V_{ph}$ and $I_L = \sqrt{3}\, I_{ph}$
3.	Neutral wire is available.	Neutral wire is not available.
4.	4-wire, 3-ϕ system is possible.	4-wire, 3-ϕ system is not possible.
5.	Both domestic and industrial loads can be handled.	Only industrial loads can be handled.
6.	By earthing the neutral wire, relays and protective devices can be provided in alternators for safety.	Due to absence of neutral wire, it is not possible.

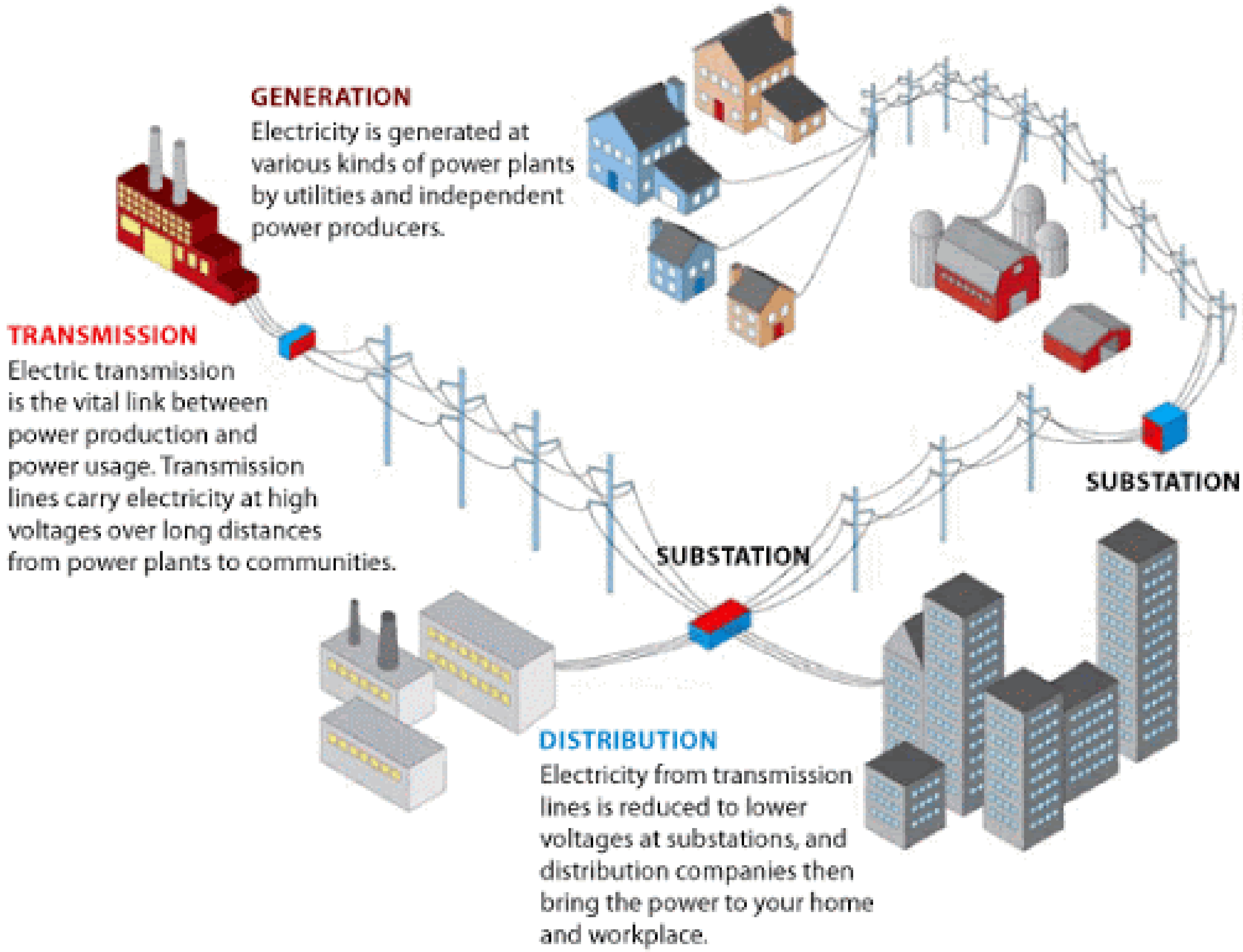
Applications

STAR CONNECTED

DELTA CONNECTED



The Big Picture



Syllabus

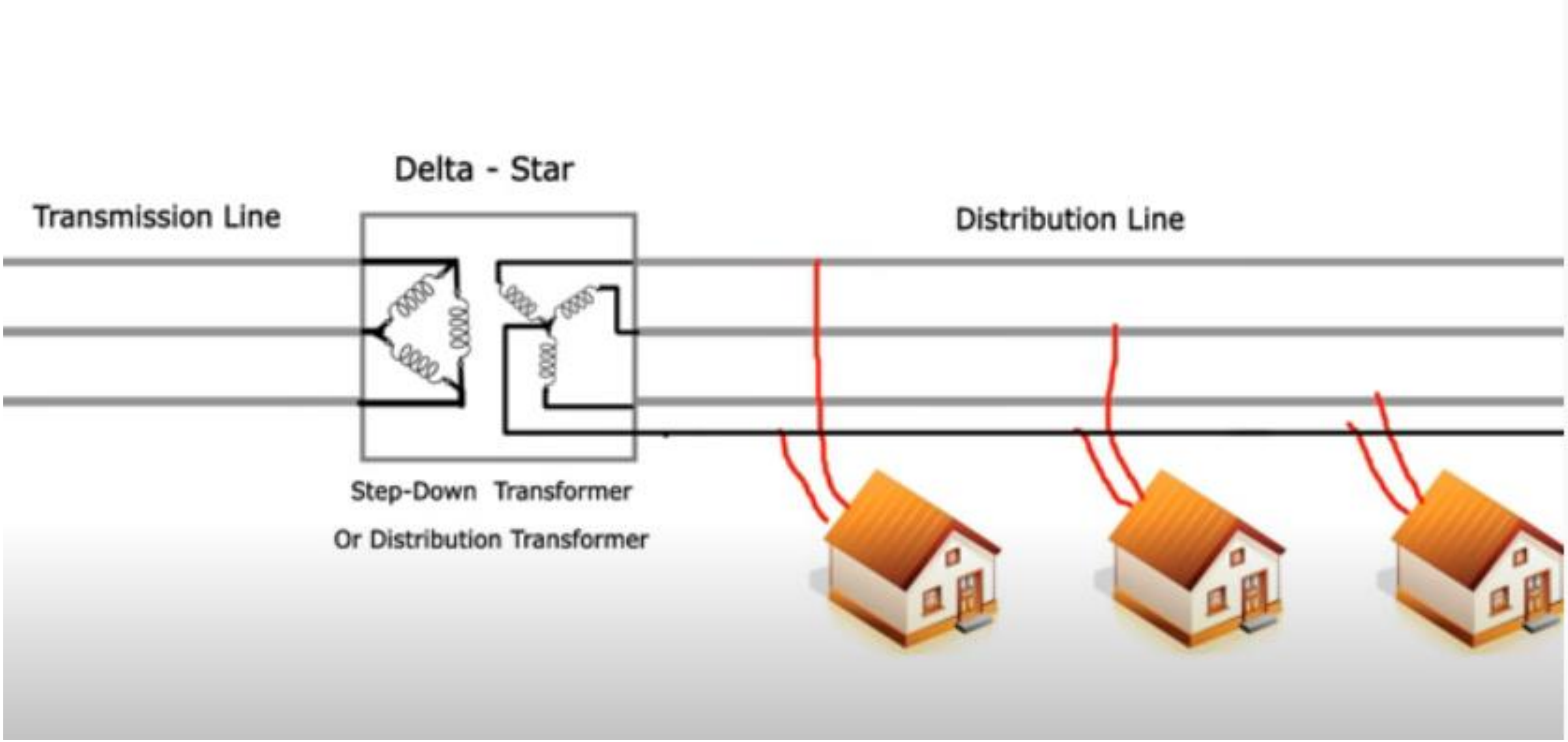
Have an Overview!

Unit I

Fundamentals of D.C. circuits : resistance, inductance, capacitance, voltage, current, power and energy concepts, ohm's law, Kirchhoff's laws, basic method of circuit analysis, intuitive method of circuit analysis- series and parallel simplification, voltage division rule, current division rule, star–delta transformation, mesh and nodal analysis, introduction to dependent and independent sources, network theorems- superposition theorem, Thevenin's theorem, Norton's theorem, maximum power transfer theorem

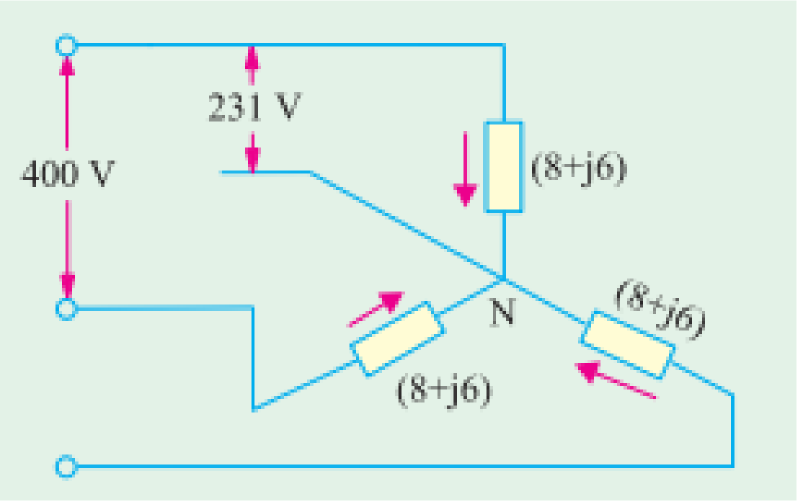
Unit II

Fundamentals of A.C. circuits : alternating current and voltage, concept of notations (i, v, I, V), definitions of amplitude, phase, phase difference, RMS value and average value of an AC signal, complex representation of impedance, steady state analysis of ac circuits consisting of RL, RC and RLC (series), resonance in series RLC circuit, power factor and power calculation in RL, RC and RLC circuits, three-phase circuits- numbering and interconnection (delta or mesh connection) of three phases, relations in line and phase voltages and currents in star and delta


Delta - Star
Transmission Line
Distribution Line
Step-Down Transformer
Or Distribution Transformer

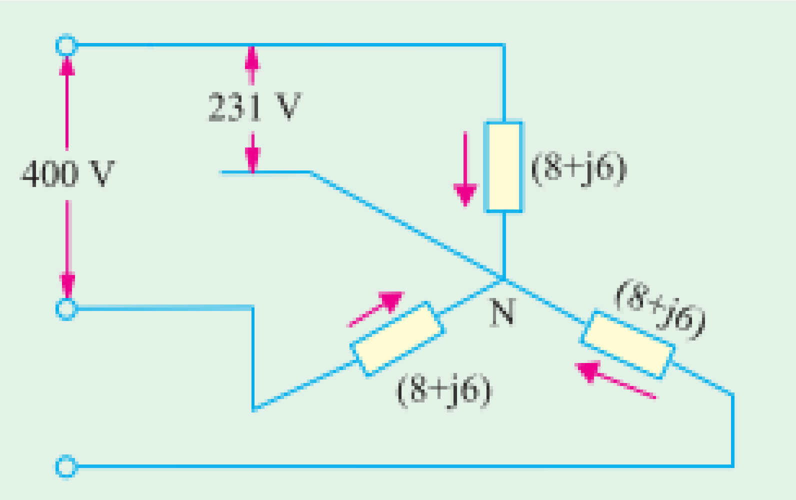
Practice Problem

A balanced star-connected load of (8 + j6) Ω per phase is connected to a balanced 3-phase 400-V supply. Find the line current, power factor, and power.



Practice Problem

A balanced star-connected load of (8 + j6) Ω per phase is connected to a balanced 3-phase 400-V supply. Find the line current, power factor, and power.



Practice Problem

Given a balanced 3− ϕ, 3-wire system with Y-connected load for which line voltage is 230 V and impedance of each phase is (6 + J8) ohm. Find the line current and power absorbed by each phase.

Practice Problem

A star-connected alternator supplies a delta connected load. The impedance of the load branch is (8 + j6) ohm/phase. The line voltage is 230 V. Determine (a) current in the load branch, (b) power consumed by the load, (c) power factor of load, (d) reactive power of the load