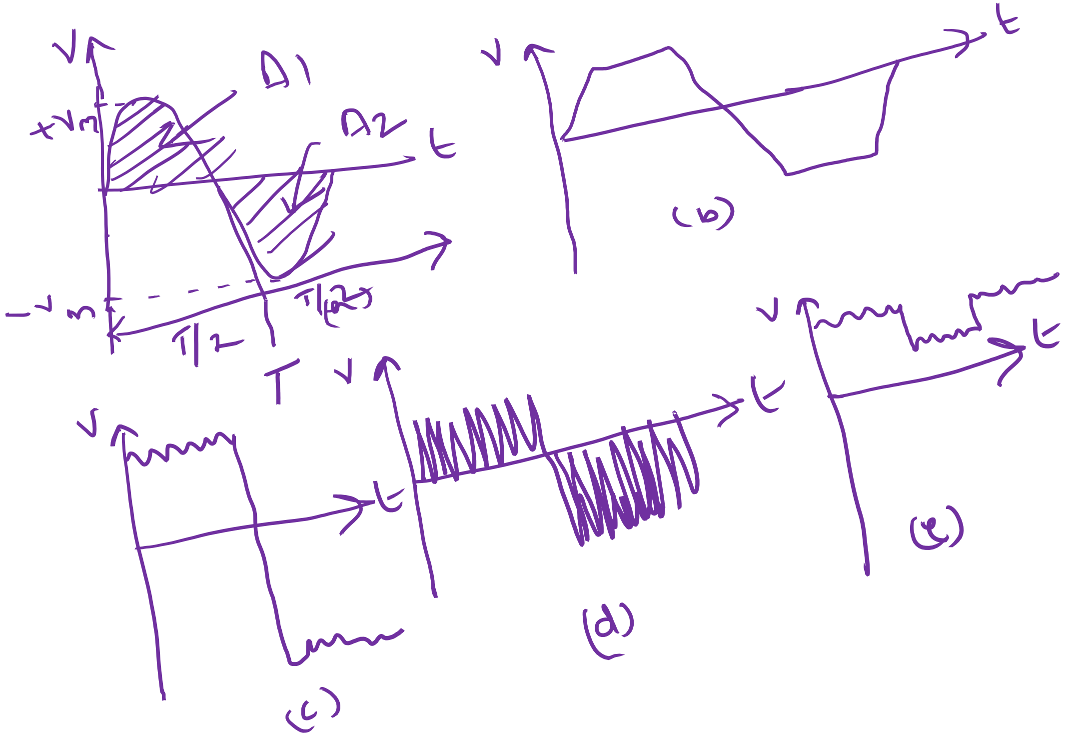
EEE1001
Basic Electrical and Electronics Engineering

Dr. M.A Inayathullaah,
Faculty, School of Electrical Engineering,
Vellore Institute of Technology, Chennai.

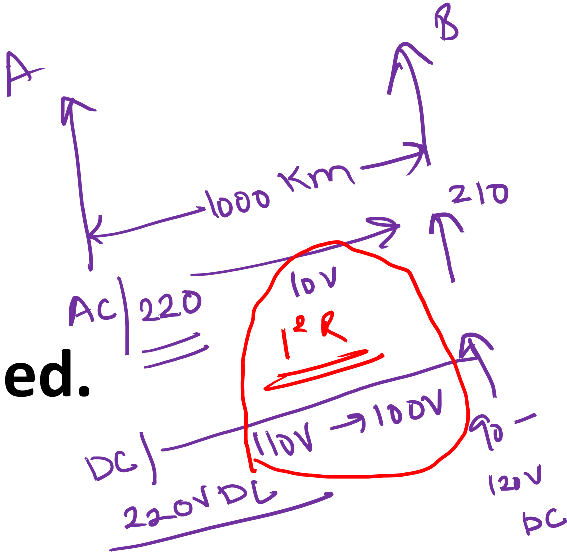
Module -2: AC circuits



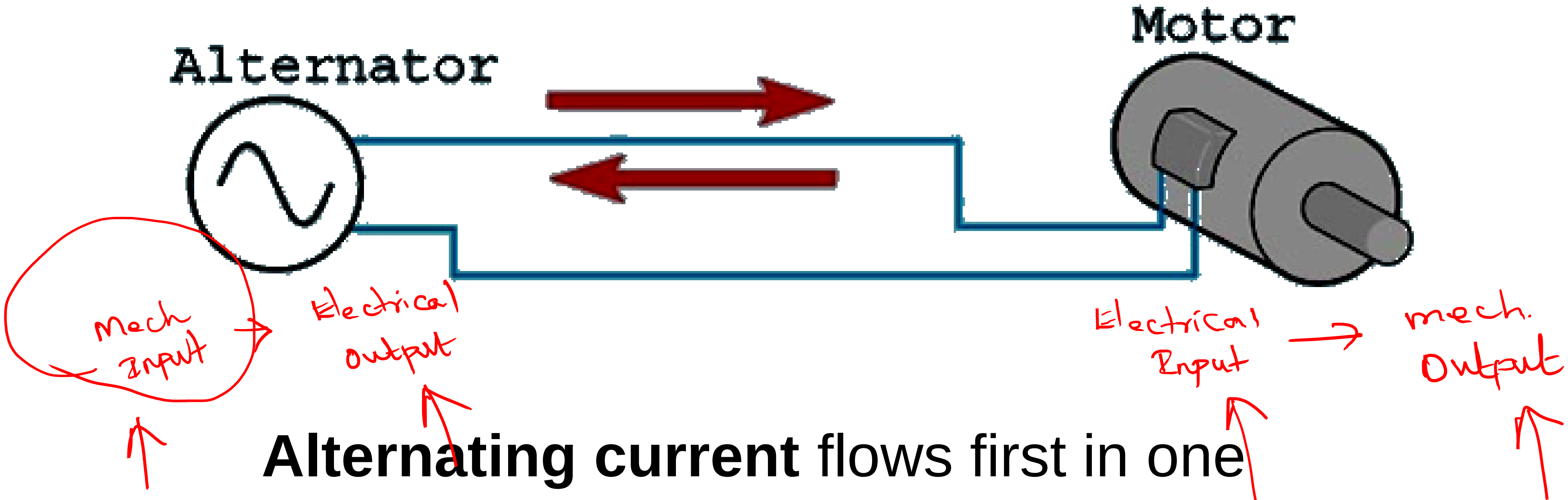
- Alternating voltages and currents,
- RMS,Average,Form factor, Peak Factor
- Single Phase RL, RC, RLC Series circuits,
- Single Phase RL, RC, RLC Parallel circuits,
- Power and Power Factor
- Balanced Three Phase Systems – Star and Delta Connection

Alternating Current

- The single greatest advantage of alternating current is that AC current can be transformed and DC current cannot be transformed.
- This allows high-voltage electrical power to be distributed with smaller wires and lower amperage.
- The electrical power is then transformed to a lower voltage where it is needed.

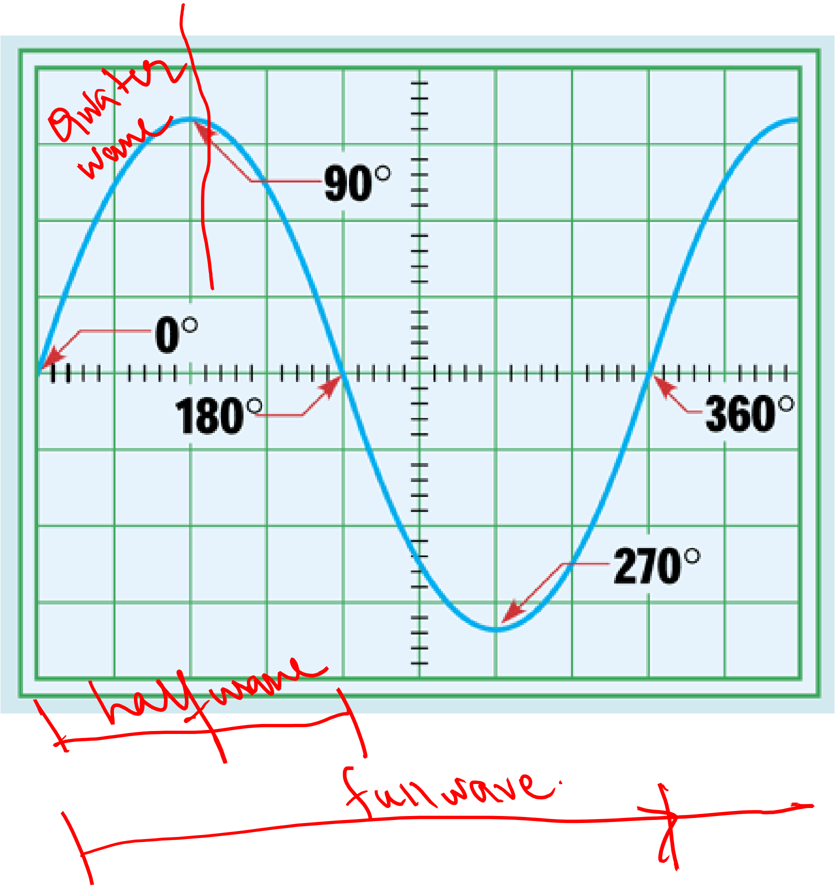


Alternating Current

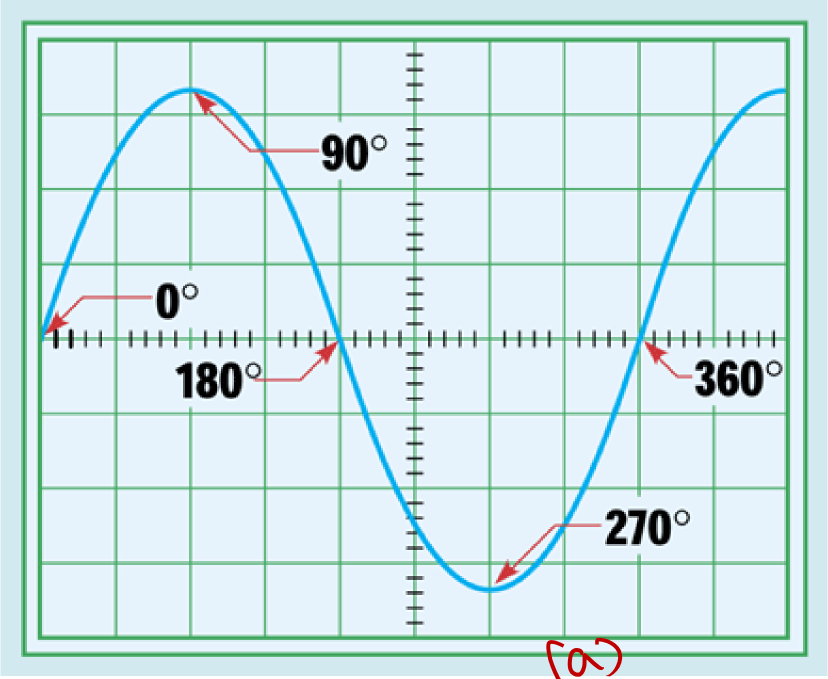


Alternating current flows first in one direction and then in the other direction.

Alternating Current



- The sine wave is the most common of all the AC wave forms.
- One sine wave is 360 electrical degrees.



(a)

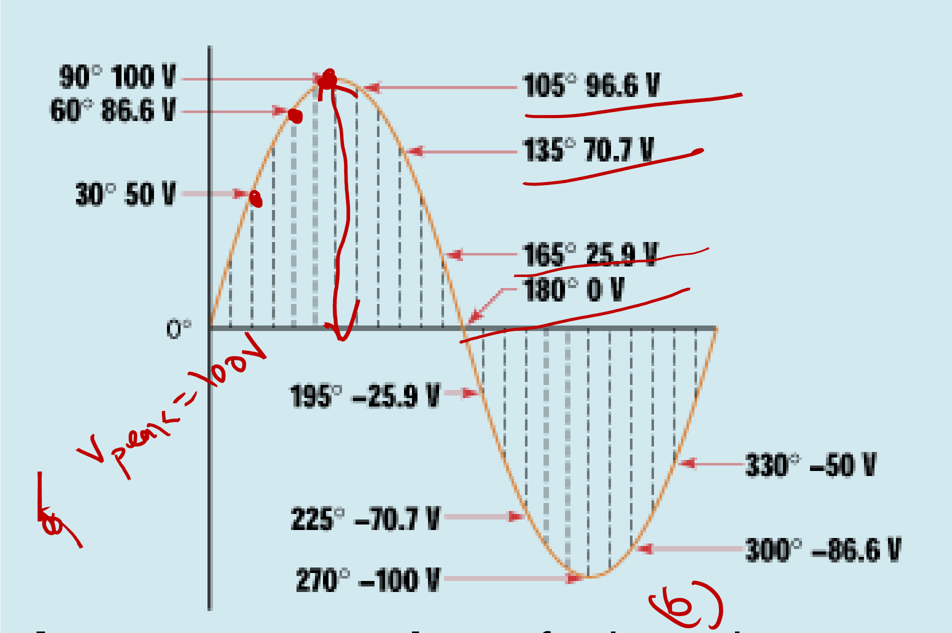
Alternating Current

- The voltage at any point along the **sine wave** is equal to the maximum, or **peak,** value times the **sine of the angle of rotation**.

$E_{inst} = E_m \sin\theta$ | $E_{inst} = E_m \cos(90-\theta)$

$$E_{(INST)} = E_{(MAX)} \times \text{SINE } \theta$$

$E_{(INST)}$ = the voltage at any point on the wave form
$E_{(MAX)}$ = the maximum, or peak, voltage
SINE θ = the sine of angle theta, the angle of rotation



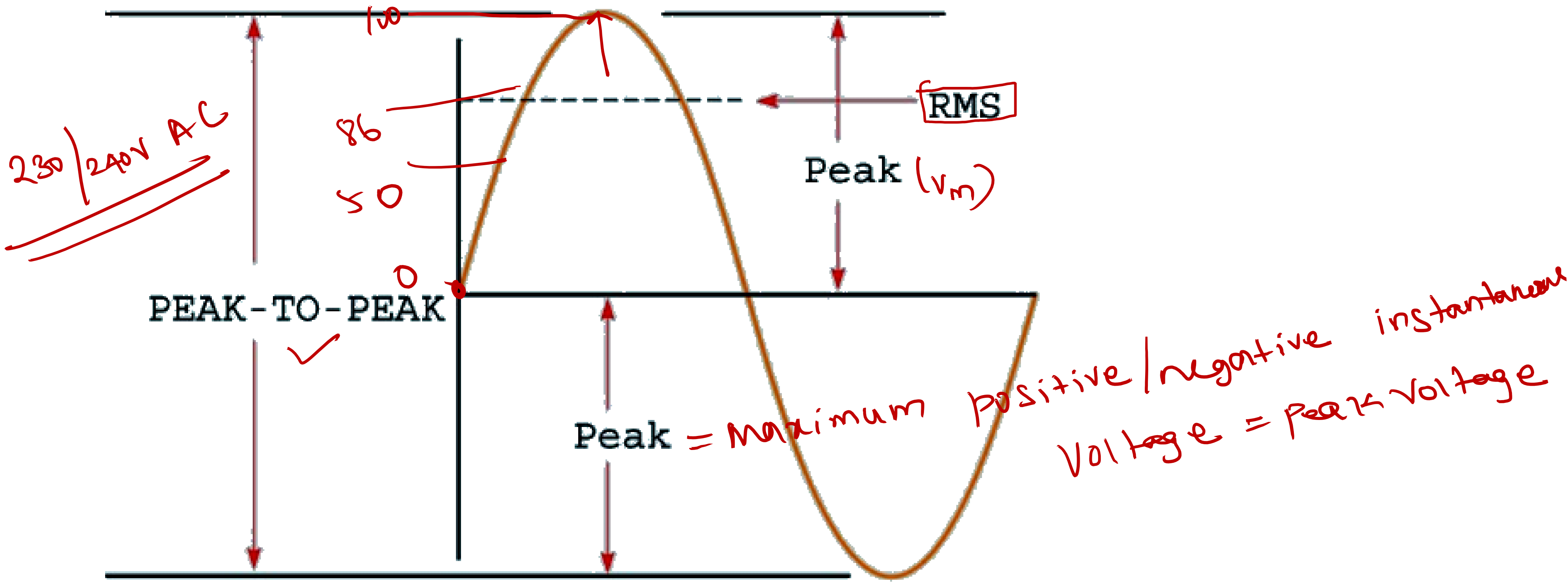
$V_{peak} = 100V$

(b)

Instantaneous values of voltage along a sine wave.

Instantaneous values are the values of the alternating quantities at any instant of time. They are represented by small letters, i, v, e

Alternating Current

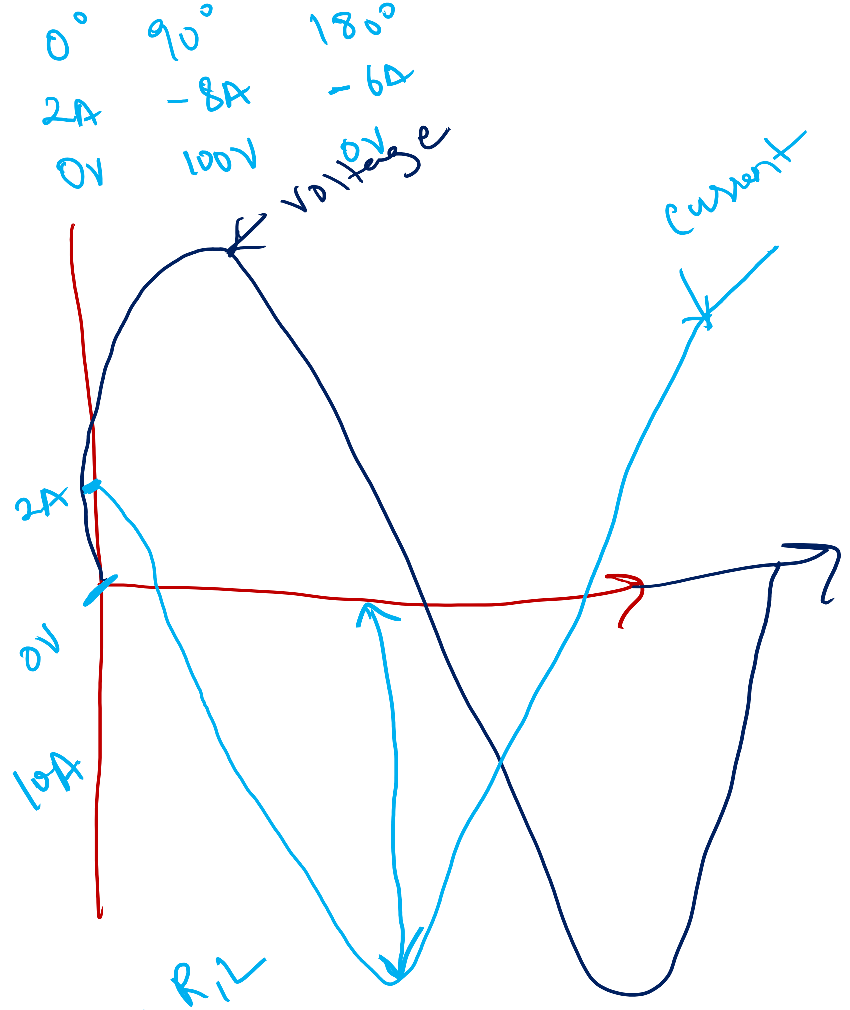


Peak, Peak-to-Peak, and RMS values along a sine wave.

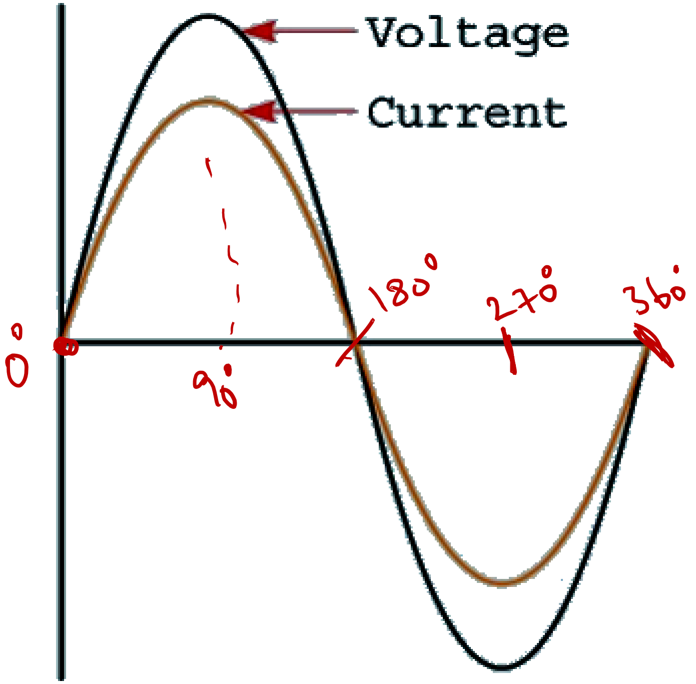
RMS = Peak x 0.707

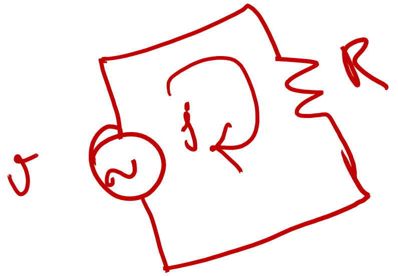
Peak = RMS x 1.414 $= \sqrt{2}$

Alternating Current



Load → R, L
→ R, C
→ R, L, C
out of phase





$v = V_m \sin \omega t$

In a pure resistive circuit, the voltage and current are **in phase.**

Alternating Current

1. Most of the electrical power generated in the world is alternating current.
2. Alternating current can be transformed and direct current cannot.
3. Alternating current reverses its direction of flow at periodic intervals.
4. The most common AC wave form is the sine wave.
5. There are 360 degrees in one complete sine wave.
6. Sine waves are produced by rotating machines.
7. The instantaneous voltage at any point on a sine wave is equal to the peak, or maximum, voltage times the sine of the angle of rotation.
8. The peak-to-peak voltage is the amount of voltage attained by the wave form.
9. The peak value is the maximum amount of voltage attained by the wave form.
10. The current and voltage in a pure resistive circuit are in phase with each other.

Alternating Current

$$T = \frac{1}{f} \text{ or } f = \frac{1}{T}$$

Problem 1. Determine the periodic time for frequencies of (a) 50 Hz and (b) 20 kHz

(a) Periodic time $T = \frac{1}{f} = \frac{1}{50} = \mathbf{0.02\ s\ or\ 20\ ms}$

(b) Periodic time $T = \frac{1}{f} = \frac{1}{20\,000} = \mathbf{0.000\ 05\ s\ or\ 50\ \mu s}$

Problem 2. Determine the frequencies for periodic times of (a) 4 ms, (b) 4 μs

(a) Frequency $f = \frac{1}{T} = \frac{1}{4 \times 10^{-3}} = \frac{1000}{4} = \mathbf{250\ Hz}$

(b) Frequency $f = \frac{1}{T} = \frac{1}{4 \times 10^{-6}} = \frac{1\,000\,000}{4}$

$= \mathbf{250\ 000\ Hz}$ or $\mathbf{250\ kHz}$ or $\mathbf{0.25\ MHz}$

Problem 3. An alternating current completes 5 cycles in 8 ms. What is its frequency?

Time for 1 cycle $= \frac{8}{5}$ ms $= 1.6$ ms $=$ periodic time T

Frequency $f = \frac{1}{T} = \frac{1}{1.6 \times 10^{-3}} = \frac{1000}{1.6} = \frac{10000}{16} = \mathbf{625\ Hz}$

Alternating Current

$(I_{dc}^2 R) = (I_{ac}^2 R)$

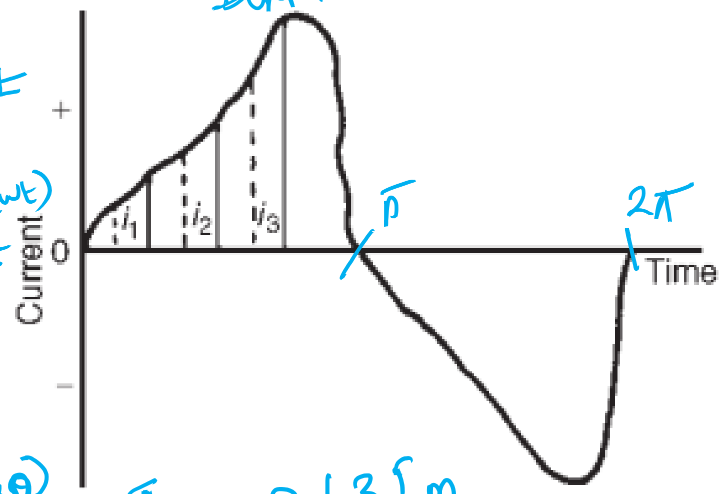
4A DC → 100 Ω, P=1.6kW

$I_{ac\,rms}$

The **average** or **mean value** of a symmetrical alternating quantity, (such as a sine wave), is the average value measured over a half cycle, (since over a complete cycle the average value is zero).

$$\text{Average or mean value} = \frac{\text{area under the curve}}{\text{length of base}}$$

$$I_{avg} = \frac{1}{\pi}\int_0^{\pi} I_m \sin\omega t \, d(\omega t) = \frac{I_m}{\pi}\left(-\cos\omega t\right)_0^{\pi} = \frac{I_m}{\pi}(\cos\pi - \cos 0) = -\frac{I_m}{\pi}(-1-1) = \frac{2I_m}{\pi} = 0.63\, I_m$$



Rms

The effective value of an alternating current is that current which will produce the same heating effect as an equivalent direct current. The effective value is called the root mean square (rms) value and whenever an alternating quantity is given, it is assumed to be the rms value.

$$I = \sqrt{\left(\frac{i_1^2 + i_2^2 + \dots + i_n^2}{n}\right)}$$

where n is the number of intervals used.

$$I_{rms} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi} (I_m \sin\omega t)^2 \, d(\omega t)}$$

root, mean, square

$$\text{Form factor} = \frac{\text{rms value}\ (I_{rms})}{\text{average value}\ (I_{avg})}$$

For a sine wave,
form factor = 1.11

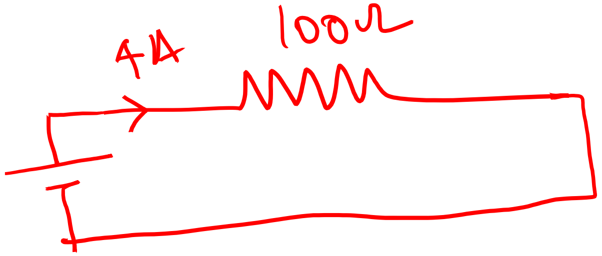
$$\text{Peak factor} = \frac{\text{maximum value}\ (I_m)}{\text{rms value}\ (I_{rms})}$$

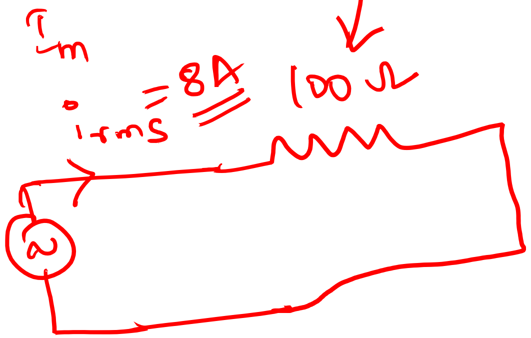
For a sine wave,
peak factor = 1.41

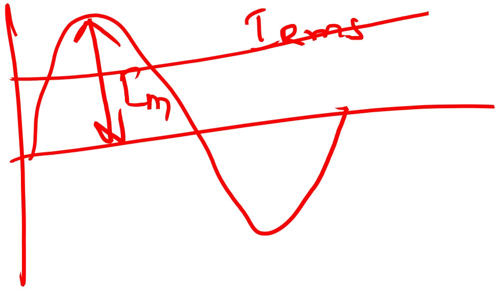
Dr. M.A Inayathullaah, AP/SELECT, VIT-Chennai

$I_{ac} = 1.6\,kW = I_{rms}$

$P = 1.6\,kW$





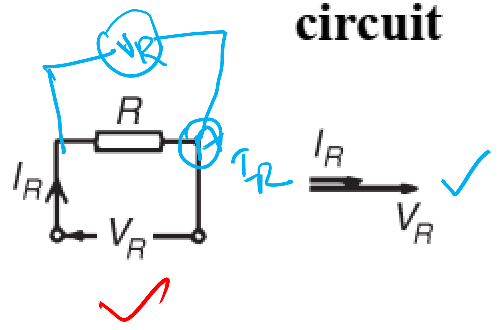


I_{rms}

I_{dc}

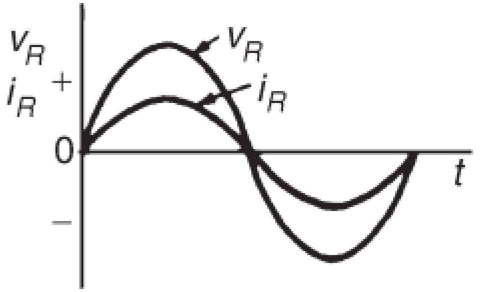
Alternating Current

Purely resistive a.c. circuit



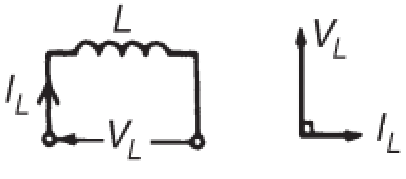
CIRCUIT DIAGRAM

PHASOR DIAGRAM



CURRENT AND VOLTAGE WAVEFORMS

Purely inductive a.c. circuit

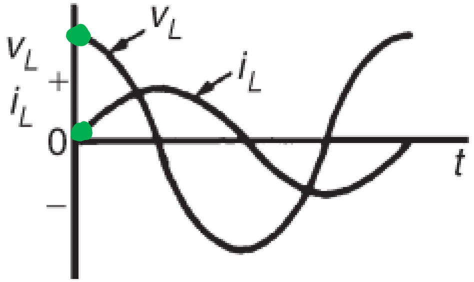


0 – 90°

I_L lags V_L by 90°

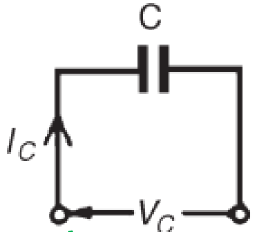
CIRCUIT DIAGRAM

PHASOR DIAGRAM

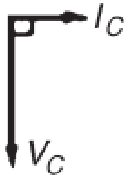


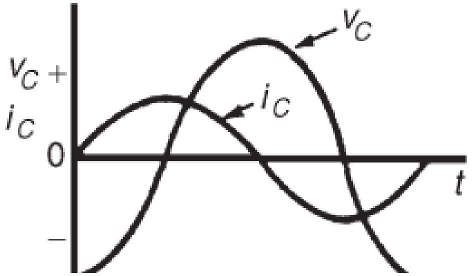
$$X_L = \frac{V_L}{I_L} = 2\pi f L \ \Omega$$

Purely capacitive a.c. circuit

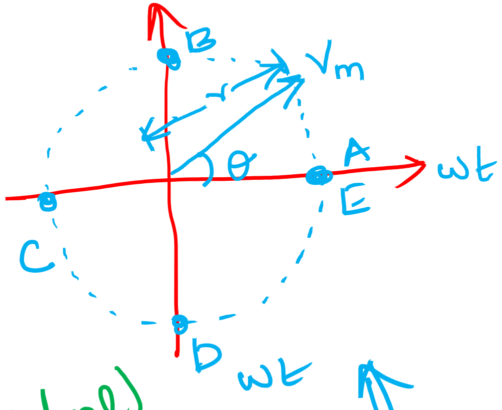


I_c leads V_c by 90° (ideal)

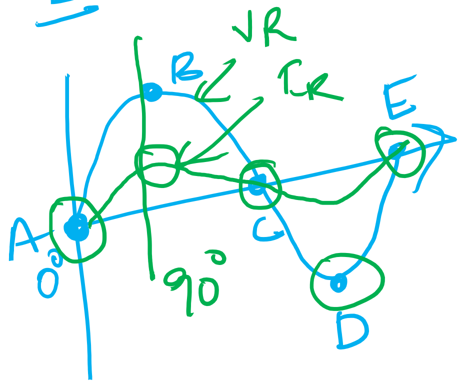




$$X_C = \frac{V_C}{I_C} = \frac{1}{2\pi f C} \Omega$$



$V_s = V_m \sin \omega t$



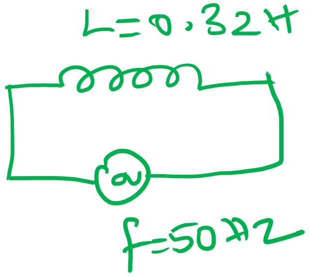
In a purely inductive circuit the opposition to the flow of alternating current is called the **inductive reactance, X_L**

In a purely capacitive circuit the opposition to the flow of alternating current is called the **capacitive reactance**, X_c

Alternating Current

X_L

(a) Calculate the reactance of a coil of inductance 0.32 H when it is connected to a 50 Hz supply. (b) A coil has a reactance of 124 Ω in a circuit with a supply of frequency 5 kHz. Determine the inductance of the coil.

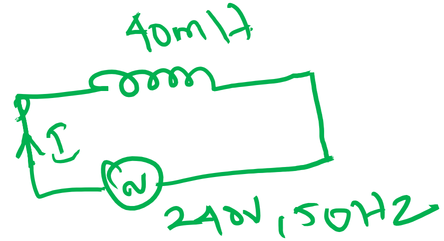


a) $X_L = \omega L = 2\pi f L = 2\pi \times 50 \times 0.32 = 100.48\Omega$

b) $L = \frac{X_L}{2\pi f} = \frac{124}{2\pi \times 5 \times 10^3} = \underline{3.94 mH}$

A coil has an inductance of 40 mH and negligible resistance. Calculate its inductive reactance and the resulting current if connected to (a) a 240 V, 50 Hz supply, and (b) a 100 V, 1 kHz supply.

a)



$L = 40 \times 10^{-3}$ H

$X_L = 2\pi f L = 2\pi \times 50 \times 40 \times 10^{-3} =$

$I = \frac{V}{X_L} =$

Alternating Current

Determine the capacitive reactance of a capacitor of 10 µF when connected to a circuit of frequency (a) 50 Hz (b) 20 kHz

A capacitor has a reactance of 40 Ω when operated on a 50 Hz supply. Determine the value of its capacitance.

Alternating Current

Calculate the current taken by a 23 μF capacitor when connected to a 240 V, 50 Hz supply.

Alternating Current

(a) Calculate the reactance of a coil of inductance 0.32 H when it is connected to a 50 Hz supply. (b) A coil has a reactance of 124 Ω in a circuit with a supply of frequency 5 kHz. Determine the inductance of the coil.

(a) Inductive reactance, $X_L = 2\pi f L = 2\pi(50)(0.32) = \mathbf{100.5\ \Omega}$

(b) Since $X_L = 2\pi f L$, inductance $L = \dfrac{X_L}{2\pi f} = \dfrac{124}{2\pi(5000)}\text{H} = \mathbf{3.95\ mH}$

A coil has an inductance of 40 mH and negligible resistance. Calculate its inductive reactance and the resulting current if connected to (a) a 240 V, 50 Hz supply, and (b) a 100 V, 1 kHz supply.

(a) Inductive reactance, $X_L = 2\pi f L = 2\pi(50)(40 \times 10^{-3}) = \mathbf{12.57\ \Omega}$

$$\text{Current, } I = \frac{V}{X_L} = \frac{240}{12.57} = \mathbf{19.09\ A}$$

(b) Inductive reactance, $X_L = 2\pi(1000)(40 \times 10^{-3}) = \mathbf{251.3\ \Omega}$

$$\text{Current, } I = \frac{V}{X_L} = \frac{100}{251.3} = \mathbf{0.398\ A}$$

Alternating Current

(a) Calculate the reactance of a coil of inductance 0.32 H when it is connected to a 50 Hz supply. (b) A coil has a reactance of 124 Ω in a circuit with a supply of frequency 5 kHz. Determine the inductance of the coil.

Required

a) Reactance (X_L)

b) ~~Reactance~~ Self Inductance (L)

Given

a) Self Inductance (L) = 0.32 H

frequency (f) = 50 Hz

b) Reactance = 124 Ω

frequency = 5 kHz

Solution

a) $X_L = 2\pi f L = 2 \times \pi \times 50 \times 0.32 = 100.53\Omega$

b) $L = \frac{X_L}{2\pi f} = \frac{124}{2 \times \pi \times 5 \times 10^3} = 39.5 \times 10^{-4} H$

$= 3.95 mH$

A coil has an inductance of 40 mH and negligible resistance. Calculate its inductive reactance and the resulting current if connected to (a) a 240 V, 50 Hz supply, and (b) a 100 V, 1 kHz supply.

Given

Supply voltage (V) = 240 V

frequency (f) = 50 Hz

Inductance (L) = 40×10^{-3} H.

Required data

1) Inductive Reactance (X_L)

2) Inductive current (I_L)

a) $X_L = 2\pi f L = 2 \times \pi \times 50 \times 40 \times 10^{-3}$

$= 12.56\ \Omega$

$I_L = \frac{V}{X_L} = \frac{240}{12.56} = 19.1 A$

Dr. M.A Inayathullaah, AP/SELECT, VIT-Chennai

Alternating Current

Determine the capacitive reactance of a capacitor of 10 µF when connected to a circuit of frequency (a) 50 Hz (b) 20 kHz

Required data

$X_C = ?$

Given data

$C = 10\mu F$

Solution

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

a) 50 Hz

$X_{C(50Hz)} = \frac{1}{2\pi \times 50 \times 10 \times 10^{-6}} = 318.5\Omega$

b) 20 kHz

$X_{C(20kHz)} = \frac{1}{2\pi \times 20 \times 10^{3} \times 10 \times 10^{-6}} = 7.96\Omega$

A capacitor has a reactance of 40 Ω when operated on a 50 Hz supply. Determine the value of its capacitance.

$X_C = 40\Omega$

$f_s = 50Hz$

$C = ?$

Solution

$X_C = \frac{1}{2\pi f C}$

$C = \frac{1}{2\pi f X_C} = \frac{1}{2\pi \times 50 \times 40} = 8\mu F$

Alternating Current

Calculate the current taken by a 23 μF capacitor when connected to a 240 V, 50 Hz supply.

$$\text{Current } I = \frac{V}{X_C} = \frac{V}{\left(\dfrac{1}{2\pi f C}\right)} = 2\pi f C V = 2\pi(50)(23 \times 10^{-6})(240)$$

$$= \mathbf{1.73\ A}$$

Alternating Current

Determine the capacitive reactance of a capacitor of 10 μF when connected to a circuit of frequency (a) 50 Hz (b) 20 kHz

(a) Capacitive reactance $X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi(50)(10 \times 10^{-6})}$

$$= \frac{10^6}{2\pi(50)(10)}$$

$$= \mathbf{318.3\ \Omega}$$

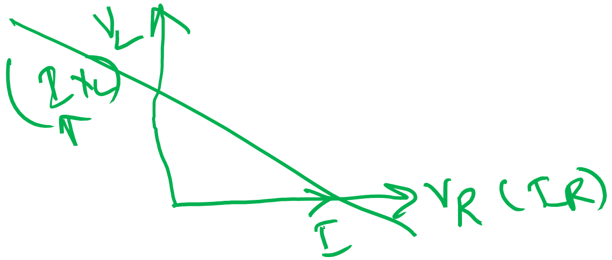
(b) $X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi(20 \times 10^3)(10 \times 10^{-6})} = \frac{10^6}{2\pi(20 \times 10^3)(10)}$

$$= \mathbf{0.796\ \Omega}$$

A capacitor has a reactance of 40 Ω when operated on a 50 Hz supply. Determine the value of its capacitance.

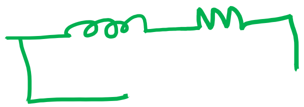
Since $X_C = \frac{1}{2\pi f C}$, capacitance $C = \frac{1}{2\pi f X_C} = \frac{1}{2\pi(50)(40)}$ F

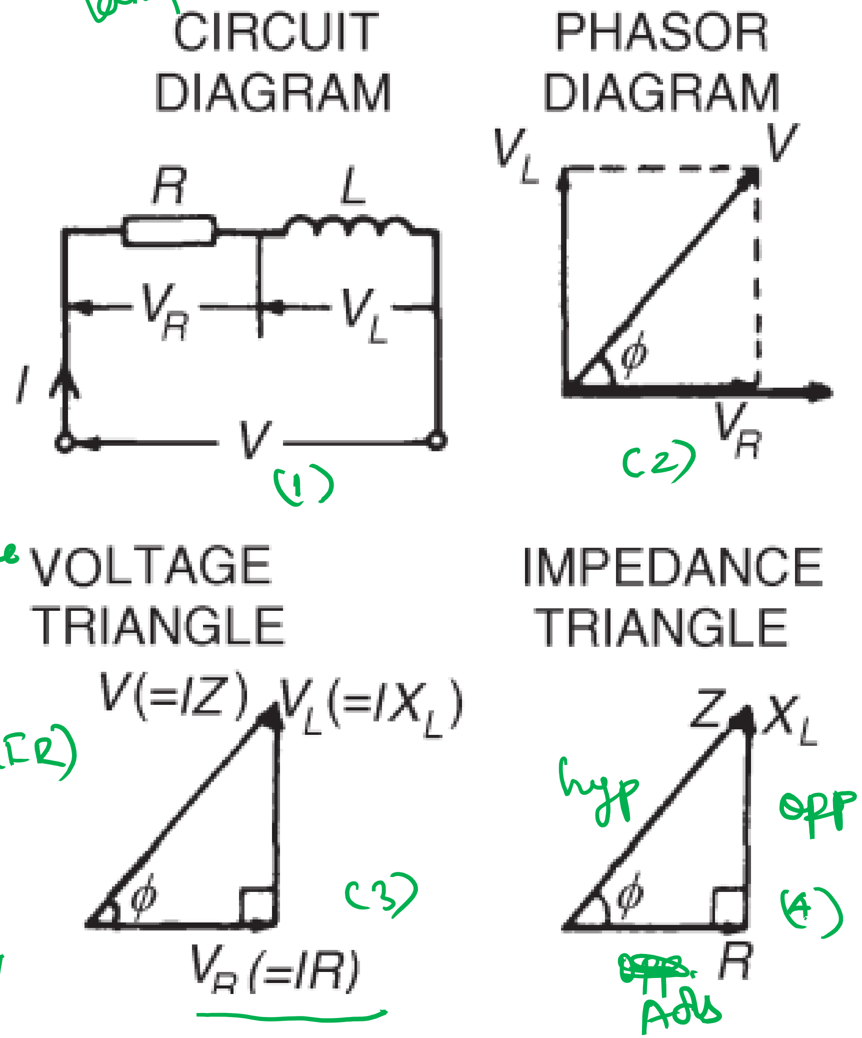
$$= \frac{10^6}{2\pi(50)(40)}\ \mu\text{F} = \mathbf{79.58\ \mu F}$$



RL Series AC Circuit

heater
Tubelight
lamp





For the R–L circuit: $V = \sqrt{(V_R^2 + V_L^2)}$ (by Pythagoras' theorem)

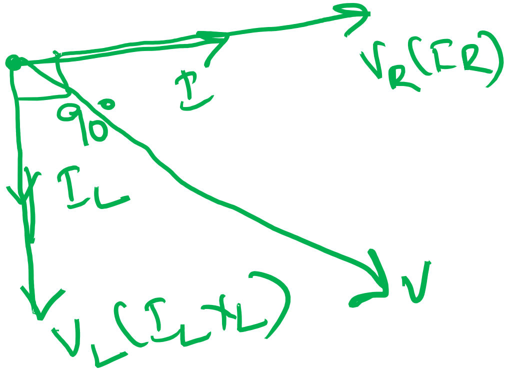
and $\tan\phi = \dfrac{V_L}{V_R}$ (by trigonometric ratios)

In an a.c. circuit, the ratio $\dfrac{\text{applied voltage } V}{\text{current } I}$ is called the **impedance** $\boldsymbol{Z}$, i.e.

$$\boxed{Z = \frac{V}{I}\,\Omega}$$

$$Z = \sqrt{(R^2 + X_L^2)}$$

Reactance + Resistance



$\tan\phi = \dfrac{X_L}{R}$, $\sin\phi = \dfrac{X_L}{Z}$ and $\cos\phi = \dfrac{R}{Z}$

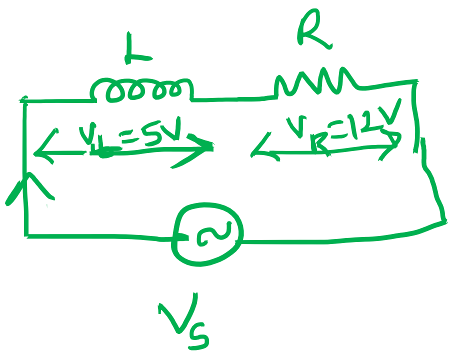
RL Series AC Circuit

In a series R–L circuit the p.d. across the resistance R is 12 V and the p.d. across the inductance L is 5 V. Find the supply voltage and the phase angle between current and voltage.

Given data

Inductive drop (V_L) = 5V

Resistive drop (V_R) = 12V



Required data

Phase angle (ϕ)

Supply voltage (V_s) ✓

Solution

WKT,

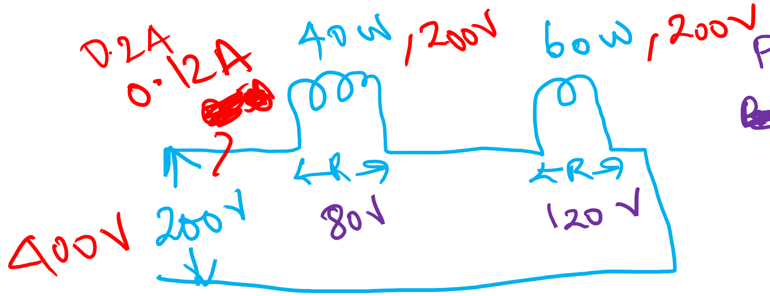
$$V_s = \sqrt{V_R^2 + V_L^2}$$

$$= \sqrt{12^2 + 5^2}$$

$$= \sqrt{144 + 25} = 13V$$

$$\tan\phi = \frac{V_L}{V_R} = \frac{5}{12}$$

$$\phi = \tan^{-1}\left(5/12\right) = 22.5^\circ$$



i) Total power of 80W

$P = V \cdot I$

$= V \cdot \frac{V}{R}$

$P = \frac{V^2}{R}$

$R = \frac{V^2}{P}$

$R_{40} = \frac{80^2}{40} = \frac{80 \times 80}{40} = 160\,\Omega$

$R_{60} = \frac{120 \times 120}{60} = 240\,\Omega$

$I = \frac{200}{240+160} = \frac{200}{400} = 0.5\,A$

R↓ P↑ BR↑

$\frac{0.12}{0.2}$ | $\frac{0.12}{0.3}$

60% | 40%

Full Brightness

$I_{40W} = \frac{P}{V} = \frac{40}{200} = 0.2\,A$

$I_{60W} = \frac{P}{V} = \frac{60}{200} = 0.3\,A$

$R_{40W} =$

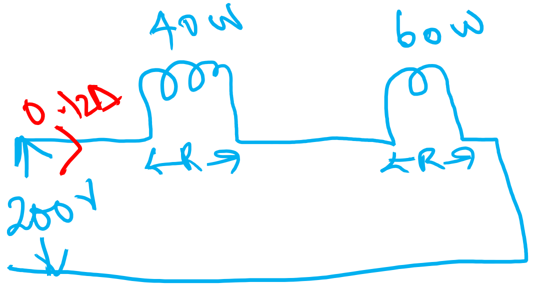
$P = I^2 R$

$R = \frac{40}{0.2 \times 0.2} = 1000\,\Omega$

$R = \frac{60}{0.3 \times 0.3} = 666\,\Omega$

$I_{rated} = \frac{200}{1666} = 0.12$

Dr. M.A Inayathullaah, AP/SELECT, VIT-Chennai

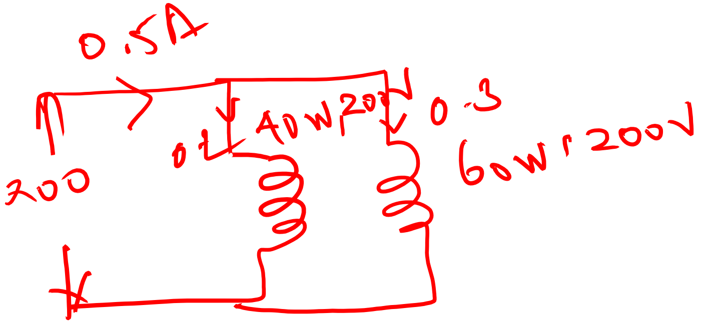


i) Total power of 50W ×

100W ×

60W ×

40W ✓



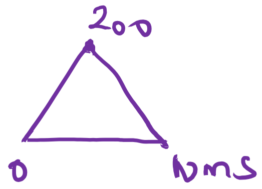
$$I_{40W} = \frac{P}{V} = \frac{40}{200} = 0.2A$$

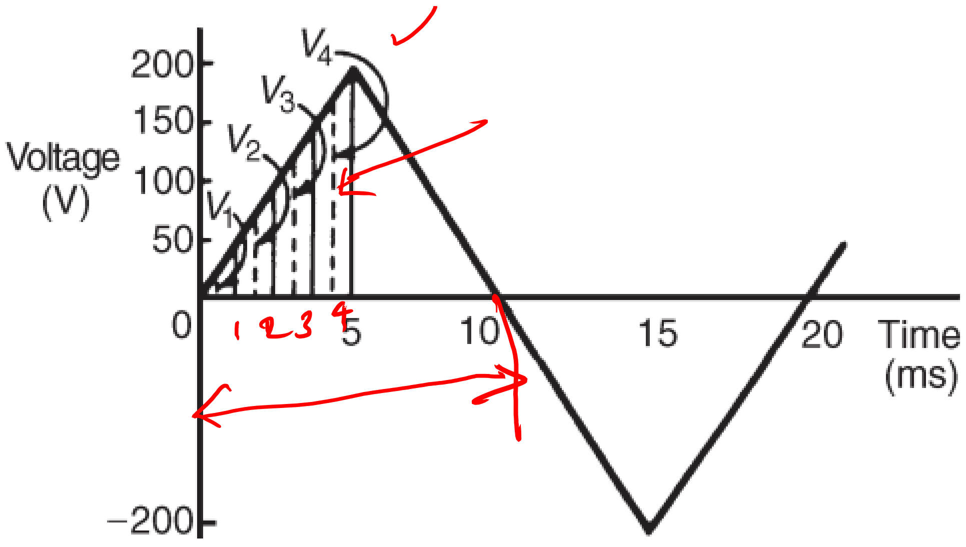
$$I_{60W} = \frac{P}{V} = \frac{60}{200} = 0.3A$$

For the periodic waveforms shown in Figure determine for each: (i) frequency (ii) average value over half a cycle (iii) rms value (iv) form factor and (v) peak factor

a) $f = \frac{1}{\text{Time period}} = \frac{1}{20\times10^{-3}} = 50\,Hz$

b) $V_{avg} = \frac{\frac{1}{2}\times\cancel{10\times10^{-3}}\times 200}{\cancel{10\times10^{-3}}} = 100\,V$





c) $Rms = \sqrt{\frac{V_1^2+V_2^2+V_3^2+V_4^2}{T}}$

$Rms = \sqrt{\frac{75^2+125^2+175^2}{4\times10^{-3}}}$

$= \sqrt{\frac{50^2+100^2+150^2+200^2}{4\times10^{-3}}}$

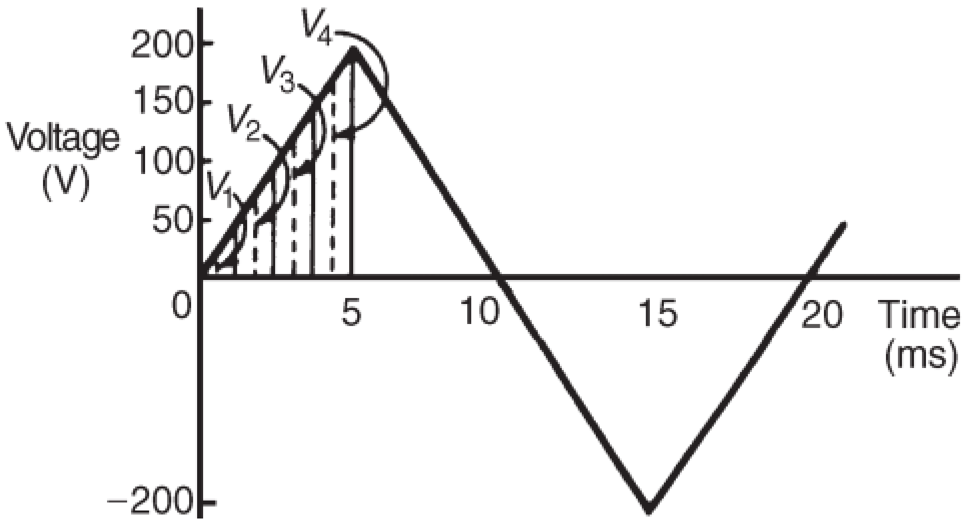
$= \cancel{3872.98}\,V$ 3872.98

4330.94

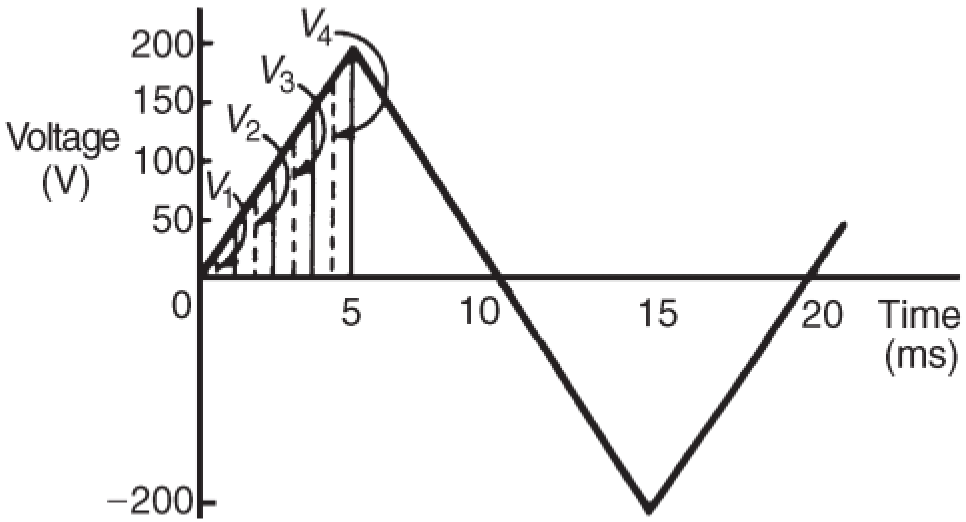
$FF = \frac{Rms}{Avg} =$

$PF = \frac{Max}{Rms} =$

For the periodic waveforms shown in Figure determine for each: (i) frequency (ii) average value over half a cycle (iii) rms value (iv) form factor and (v) peak factor



For the periodic waveforms shown in Figure determine for each: (i) frequency (ii) average value over half a cycle (iii) rms value (iv) form factor and (v) peak factor



RL Series AC Circuit

A coil has a resistance of 4Ω and an inductance of 9.55 mH. Calculate (a) the reactance, (b) the impedance, and (c) the current taken from a 240 V, 50 Hz supply. Determine also the phase angle between the supply voltage and current.

RL Series AC Circuit

A coil has a resistance of 4Ω and an inductance of 9.55 mH. Calculate (a) the reactance, (b) the impedance, and (c) the current taken from a 240 V, 50 Hz supply. Determine also the phase angle between the supply voltage and current.

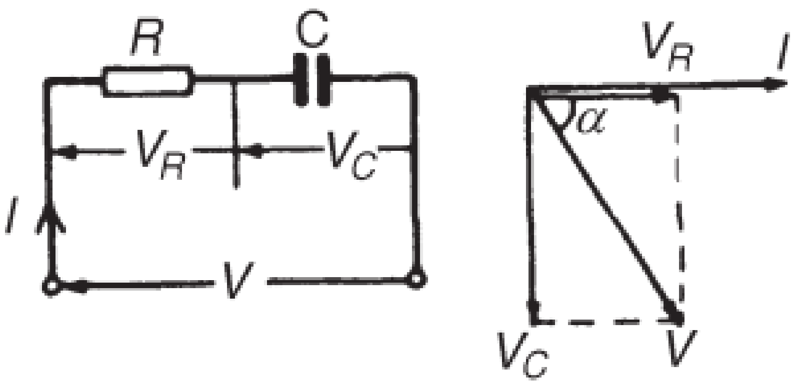
RC Series AC Circuit

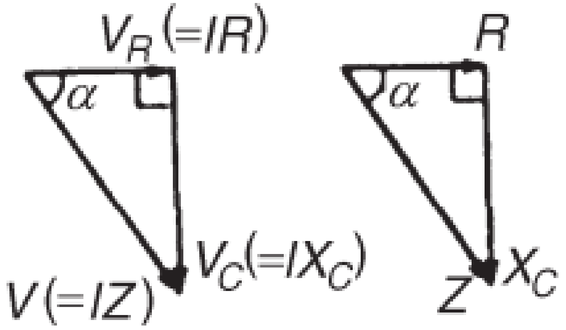
$$V = \sqrt{(V_R^2 + V_C^2)}$$

$$\tan\alpha = \frac{V_C}{V_R}$$

impedance *Z*, i.e. $Z = \dfrac{V}{I}\ \Omega$ $\qquad Z = \sqrt{(R^2 + X_C^2)}$

$$\tan\alpha = \frac{X_C}{R},\ \sin\alpha = \frac{X_C}{Z} \text{ and } \cos\alpha = \frac{R}{Z}$$





RC Series AC Circuit

A capacitor C is connected in series with a 40 Ω resistor across a supply of frequency 60 Hz. A current of 3 A flows and the circuit impedance is 50 Ω. Calculate: (a) the value of capacitance, C, (b) the supply voltage, (c) the phase angle between the supply voltage and current, (d) the p.d. across the resistor, and (e) the p.d. across the capacitor. Draw the phasor diagram.

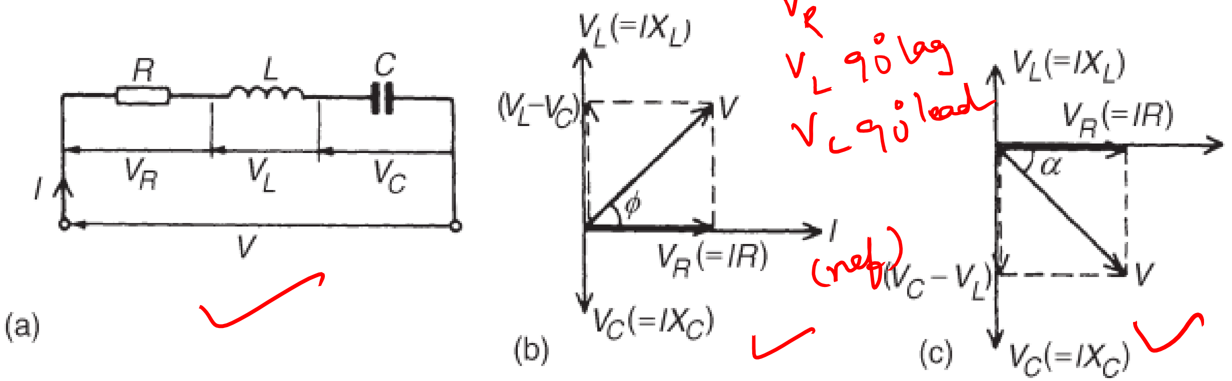
RC Series AC Circuit

A capacitor C is connected in series with a 40 Ω resistor across a supply of frequency 60 Hz. A current of 3 A flows and the circuit impedance is 50 Ω. Calculate: (a) the value of capacitance, C, (b) the supply voltage, (c) the phase angle between the supply voltage and current, (d) the p.d. across the resistor, and (e) the p.d. across the capacitor. Draw the phasor diagram.

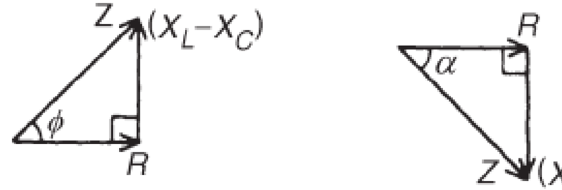
RLC Series AC Circuit

When $X_L > X_C$: $Z = \sqrt{[R^2 + (X_L - X_C)^2]}$

and $\tan\phi = \dfrac{(X_L - X_C)}{R}$



I
V_R
V_L 90° lag
V_C 90° lead
(neg)

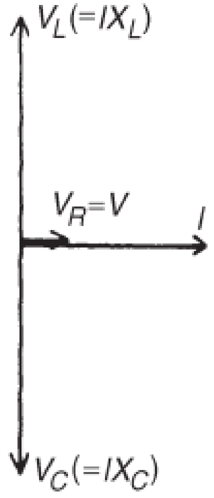


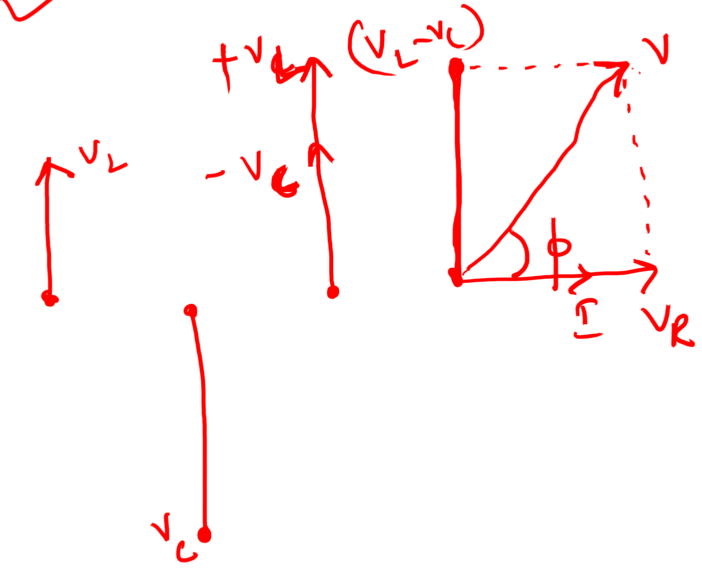
IMPEDANCE TRIANGLE IMPEDANCE TRIANGLE

When $X_C > X_L$: $Z = \sqrt{[R^2 + (X_C - X_L)^2]}$

and $\tan\alpha = \dfrac{(X_C - X_L)}{R}$

When $X_L = X_C$ the applied voltage V and the current I are in phase. This effect is called **series resonance**

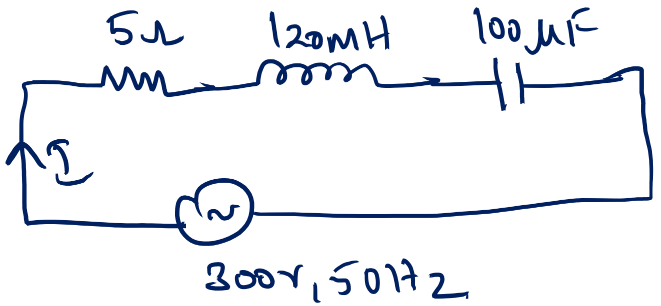




Dr. M.A Inayathullaah, AP/SELECT, VIT-Chennai

RLC Series AC Circuit

A coil of resistance 5 Ω and inductance 120 mH in series with a 100 μF capacitor, is connected to a 300 V, 50 Hz supply. Calculate (a) the current flowing, (b) the phase difference between the supply voltage and current, (c) the voltage across the coil and (d) the voltage across the capacitor.



300 sin ωt

Given data

Resistance (R) = 5Ω

Inductance (L) = 120×10^{-3} H

Capacitance (C) = 100×10^{-6} F

Voltage (V) = 300V

Frequency (f) = 50Hz

Required data

Supply current (I)

Phase angle (ϕ)

Inductive drop (V_L)

Capacitive drop (V_C)

Soln

* (X_L) Inductive reactance

$$X_L = 2\pi f L = 2\times\frac{22}{7}\times 50\times 120\times10^{-3}$$

$$= 37.68\,\Omega$$

* Capacitive reactance

$$X_C = \frac{1}{2\pi f C}$$

$$= \frac{1}{2\times\frac{22}{7}\times 50\times 100\times10^{-6}}$$

$$= 31.38\,\Omega$$

* We infer, $X_L > X_C$

RLC Series AC Circuit

A coil of resistance 5 Ω and inductance 120 mH in series with a 100 µF capacitor, is connected to a 300 V, 50 Hz supply. Calculate (a) the current flowing, (b) the phase difference between the supply voltage and current, (c) the voltage across the coil and (d) the voltage across the capacitor.

* Supply current (I)

Impedance $(Z) = \sqrt{R^2 + (X_L - X_C)^2}$

$= \sqrt{5^2 + (37.68 - 31.38)^2}$

$= 7.681\,\Omega$

By ohms law, $I = \frac{V}{Z} = \frac{300}{7.681} = 39.05\,A$

* Phase angle (ϕ)

$\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$

$= \tan^{-1}\left(\frac{37.68 - 31.38}{5}\right) = 49.43^\circ$

* Inductive drop (V_L)

$V_L = I X_L$

$= 39.05 \times 37.68 = 1471.4\,V$

* Capacitive drop (V_C)

$V_C = I X_C$

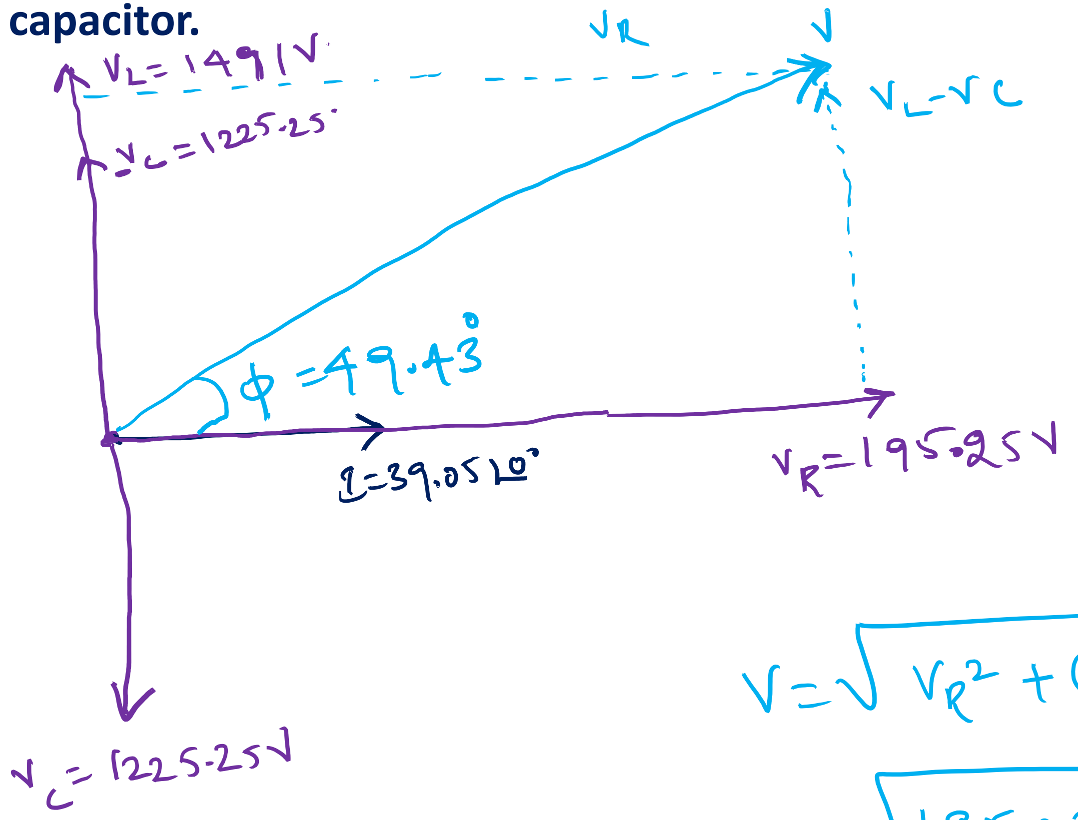
$= 39.05 \times 31.38 = 1225.38\,V$

* Resistive drop (V_R)

$V_R = 39.05 \times 5 = 195.25\,V$

RLC Series AC Circuit

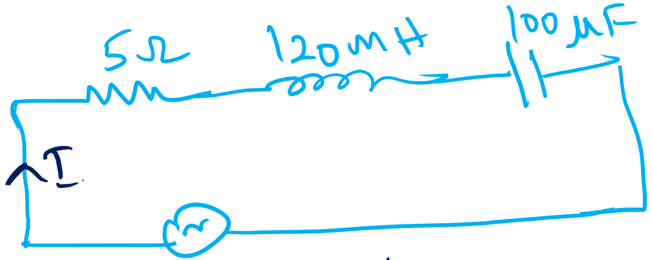
A coil of resistance 5 Ω and inductance 120 mH in series with a 100 μF capacitor, is connected to a 300 V, 50 Hz supply. Calculate (a) the current flowing, (b) the phase difference between the supply voltage and current, (c) the voltage across the coil and (d) the voltage across the capacitor.



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

$$= \sqrt{195.25 + (1471 - 1225)^2}$$

$$\simeq 300V$$



* 300 sin 10t

$V_m \sin(\omega t + \phi)$

$\phi = 0^\circ$

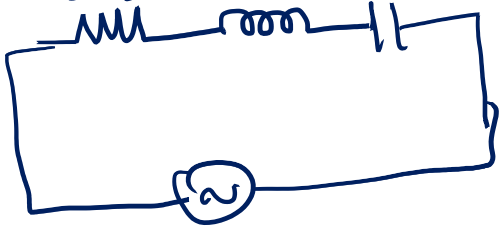
$\omega = 10 = 2\pi f$

$f = \frac{10 \times 7}{2 \times 22} = \frac{70}{44} = 1.59\,Hz$

* $X_L = 120 \times 10^{-3} \times 2 \times \frac{22}{7} \times 1.59 = 1.2\,\Omega$

$X_C = \frac{1}{10 \times 100 \times 10^{-6}} = 1000\,\Omega$

* Circuit diagram in freq domain



$Z = 5 + j1.2 - j1000\,\Omega$

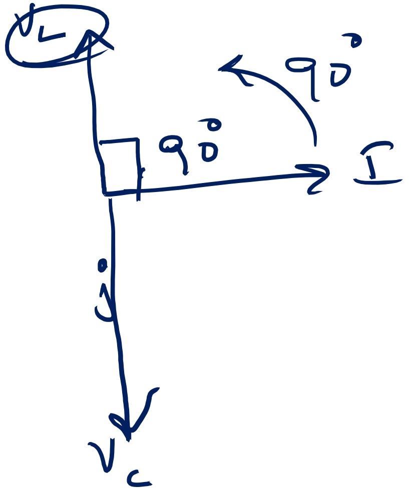
$= 5 - j998.8$

$= 998.8 \angle 270^\circ\,\Omega$

$a + ib = r\angle\theta$

$r = \sqrt{a^2+b^2} = 998$

$\theta = \tan^{-1}(b/a) = 270$



$I = \frac{V}{Z}$

$= \frac{300\angle 0^\circ}{998.8\angle 270^\circ}$

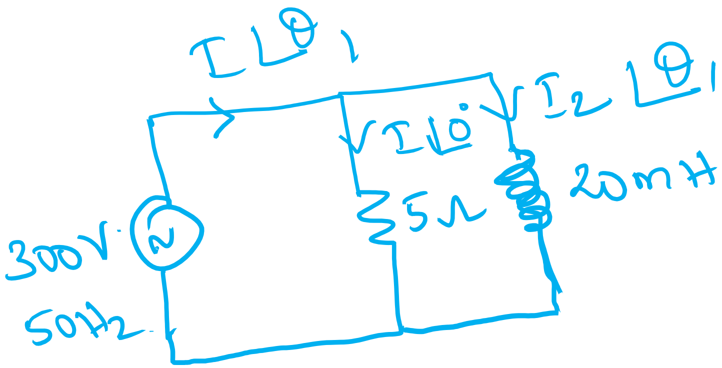
$\boxed{I = 0.3\angle -270^\circ\,A}$

* Resistive drop (V_R)

$V_R = I\,R$

$= 0.3 \angle -270^\circ \times 5$

$= 1.5 \angle -270^\circ$ V //



$$\cancel{Z=\sqrt{\left(\frac{1}{X_L}-\frac{1}{X_L}\right)^2+R^2}}$$

$$\frac{1}{Z}=\sqrt{\left(\frac{1}{X_L}-\frac{1}{X_L}\right)^2+\frac{1}{R^2}}$$

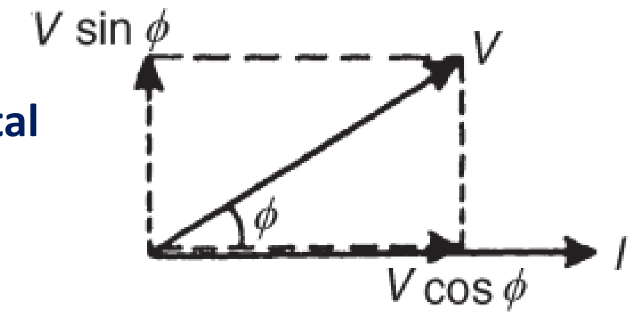
$$\underline{\underline{X_L > X_C}}$$

By Ohms law $(I_1) = \frac{V}{R} = \frac{300}{5} = 60\,A$

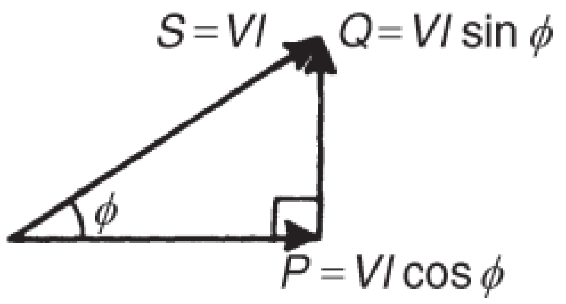
$$I_2 = \frac{V}{X_L} = \frac{300}{2\pi\times 50\times 20\times 10^{-3}} =$$

Power Factor

The phasor diagram in which the current I lags the applied voltage V by angle Φ. The horizontal component of V is V cos Φ and the vertical component of V is V sin Φ . If each of the voltage phasors is multiplied by I, known as the 'power triangle'.



(a) PHASOR DIAGRAM



(b) POWER TRIANGLE

Apparent power, $S = VI$ volt amperes (VA)

True or active power, $P = VI \cos \Phi$ watts (W)

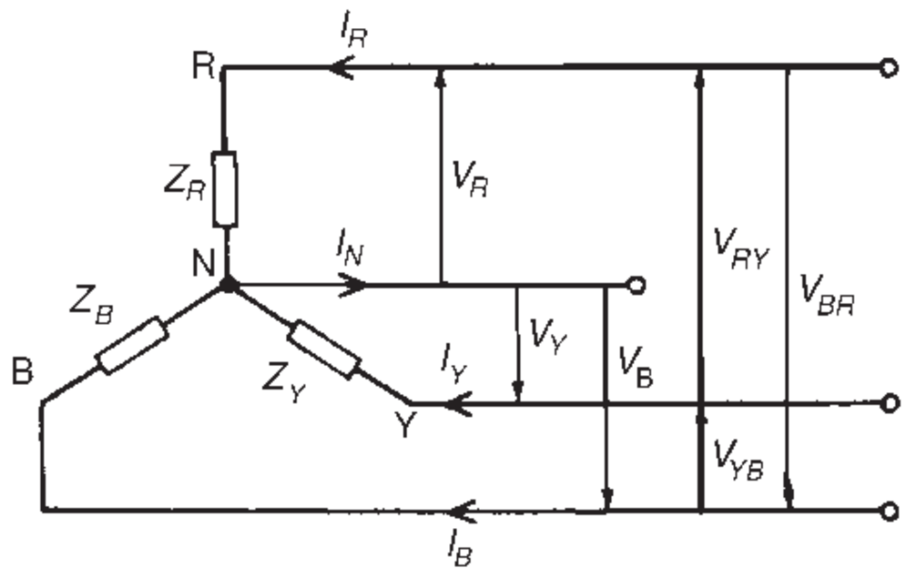
Reactive power, $Q = VI \sin\Phi$ reactive volt amperes (var)

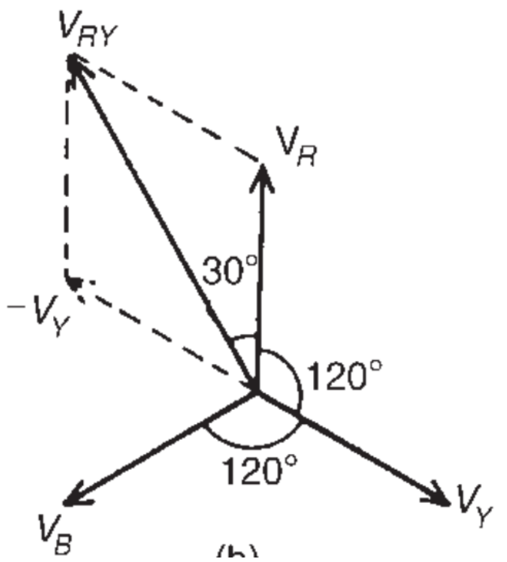
$$\text{Power factor} = \frac{\text{True power } P}{\text{Apparent power } S}$$

For sinusoidal voltages and currents, power factor $= \dfrac{P}{S} = \dfrac{VI \cos \phi}{VI}$, i.e.

$$\boxed{\text{p.f.} = \cos \phi = \frac{R}{Z}}$$

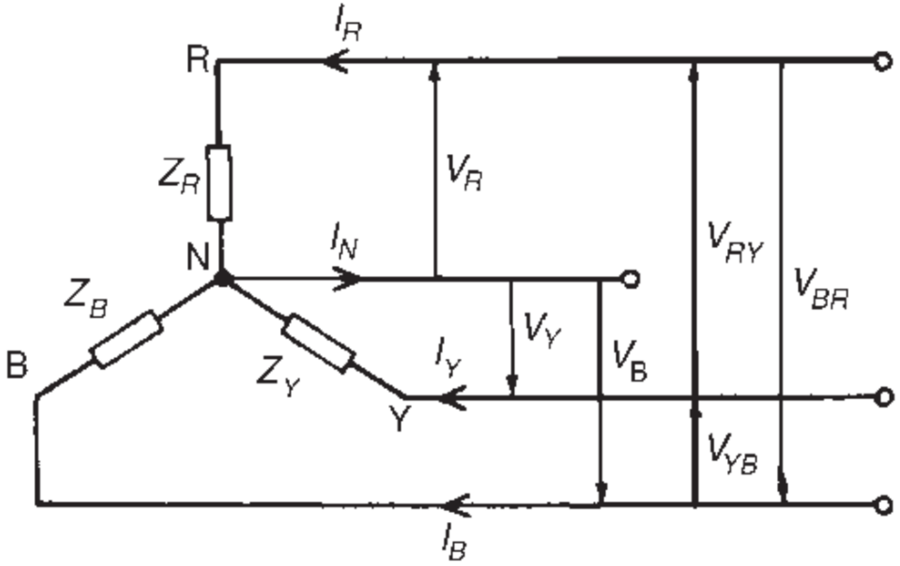
Three Phase Systems – Star and Delta Connection

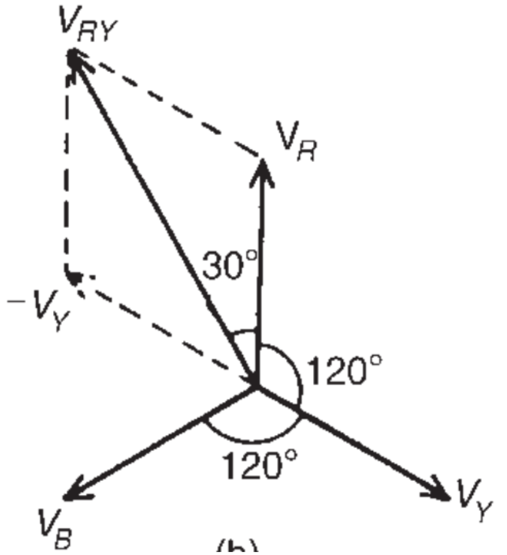




- A star-connected load is shown in Figure , where the three line conductors are each connected to a load and the outlets from the loads are joined together at N to form what is termed the neutral point or the star point.
- The voltages, V_R, V_Y and V_B are called phase voltages or line to neutral voltages. Phase voltages are generally denoted by V_p
- The voltages, V_{RY}, V_{YB} and V_{BR} are called line voltages
- The phase currents (generally denoted by I_p) are equal to their respective line currents I_R, I_Y and I_B, i.e. for a star connection I_L=I_P

Relation between Line and Phase Voltage in Star Connection





From the diagram, it is found that

$$V_{RY} = V_R + (-V_Y)$$

Similarly, $V_{YB} = V_Y + (-V_B)$

$$V_{BR} = V_B + (-V_R)$$

$$V_L = |V_{RY}| = \sqrt{V_R^2 + V_Y^2 + 2V_R V_Y \cos 60^o}$$

$$= \sqrt{V_{ph}^2 + V_{ph}^2 + 2V_{ph}V_{ph} \times \frac{1}{2}}$$

$$= \sqrt{3}V_{ph}$$

$$\therefore V_L = \sqrt{3}V_{ph}$$

Thus, for the star-connected system line voltage = √3 × phase voltage.

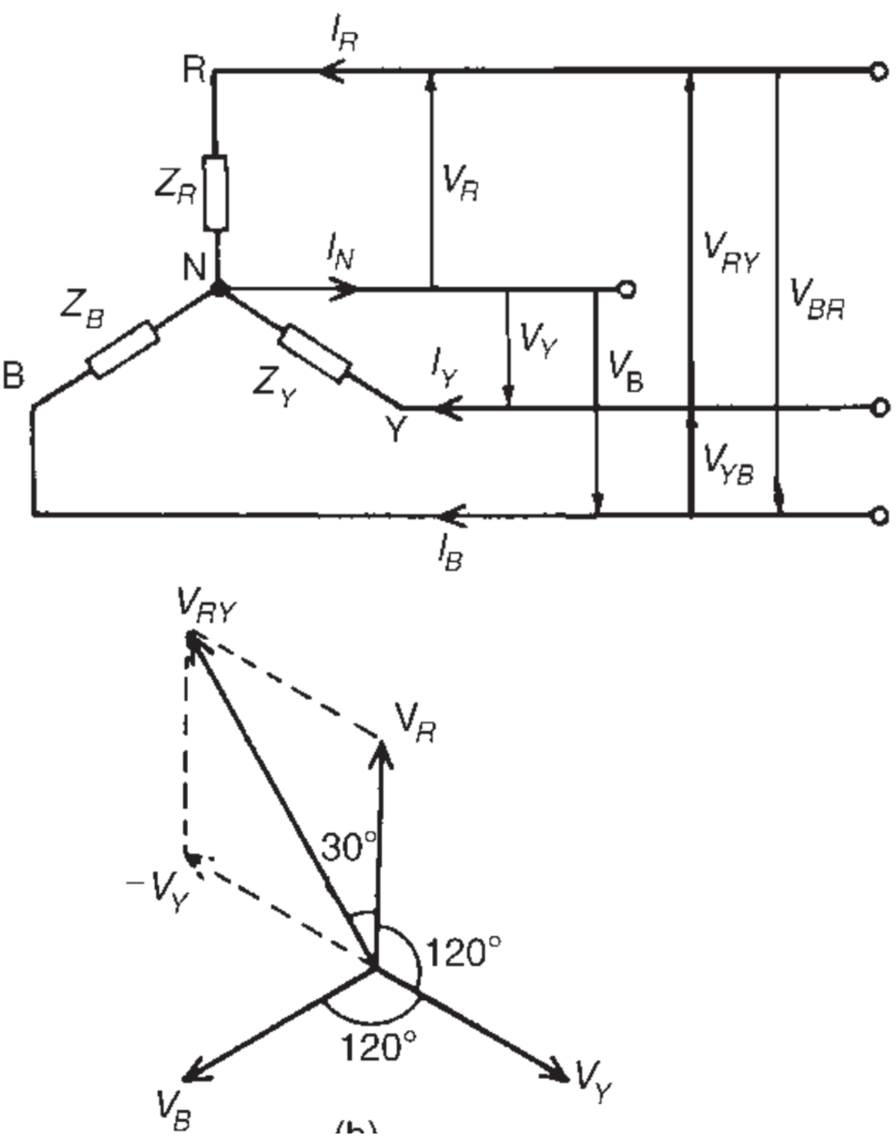
Line current = Phase current

$$V_{ph}I_{ph}cos\phi = \frac{V_L}{\sqrt{3}}I_L \cos\phi$$

So the total power of three phase system is

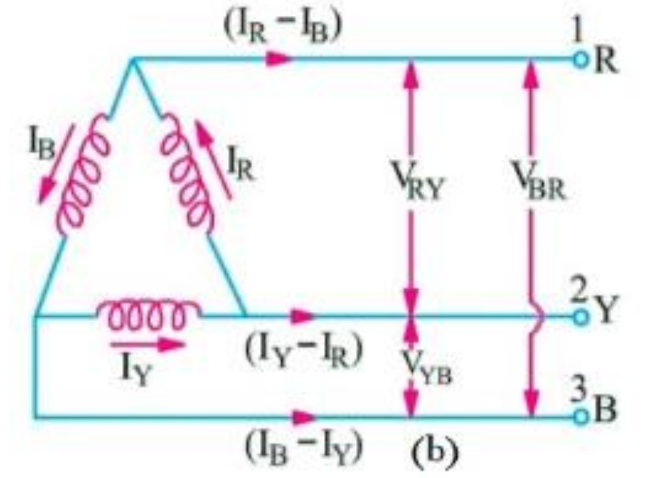
$$3 \times \frac{V_L}{\sqrt{3}}I_L \cos\phi = \sqrt{3}V_L I_L \cos\phi$$

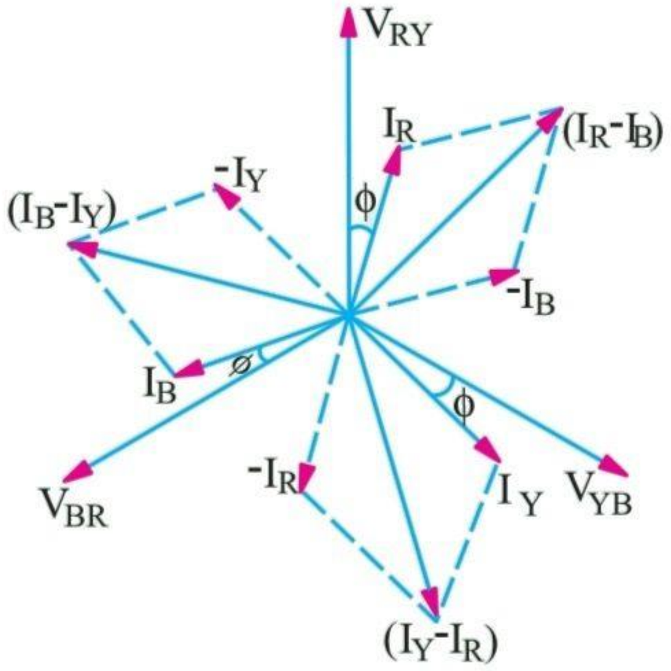
Three Phase Systems – Star and Delta Connection



- For a balanced system: $I_R = I_Y = I_B$, $V_R = V_Y = V_B$, $V_{RY} = V_{YB} = V_{BR}$, $Z_R = Z_Y = Z_B$
- The current in the neutral conductor, $I_N = 0$, When a star connected system is balanced, then the neutral conductor is unnecessary and is often omitted.
- The line voltage, V_{RY}, shown in Figure is given by $V_{RY} = V_R - V_Y$ (V_Y is negative since it is in the opposite direction to V_{RY}).
- The phasor V_Y is reversed (shown by the broken line) and then added phasorially to V_R (i.e. $V_{RY} = V_R + (-V_Y)$).
- By trigonometry, or by measurement, $V_{RY} = \sqrt{3} V_R$, i.e. for a balanced star connection.
- $V_L = \sqrt{3} V_P$

Relation between Line and Phase Voltage in Delta Connection

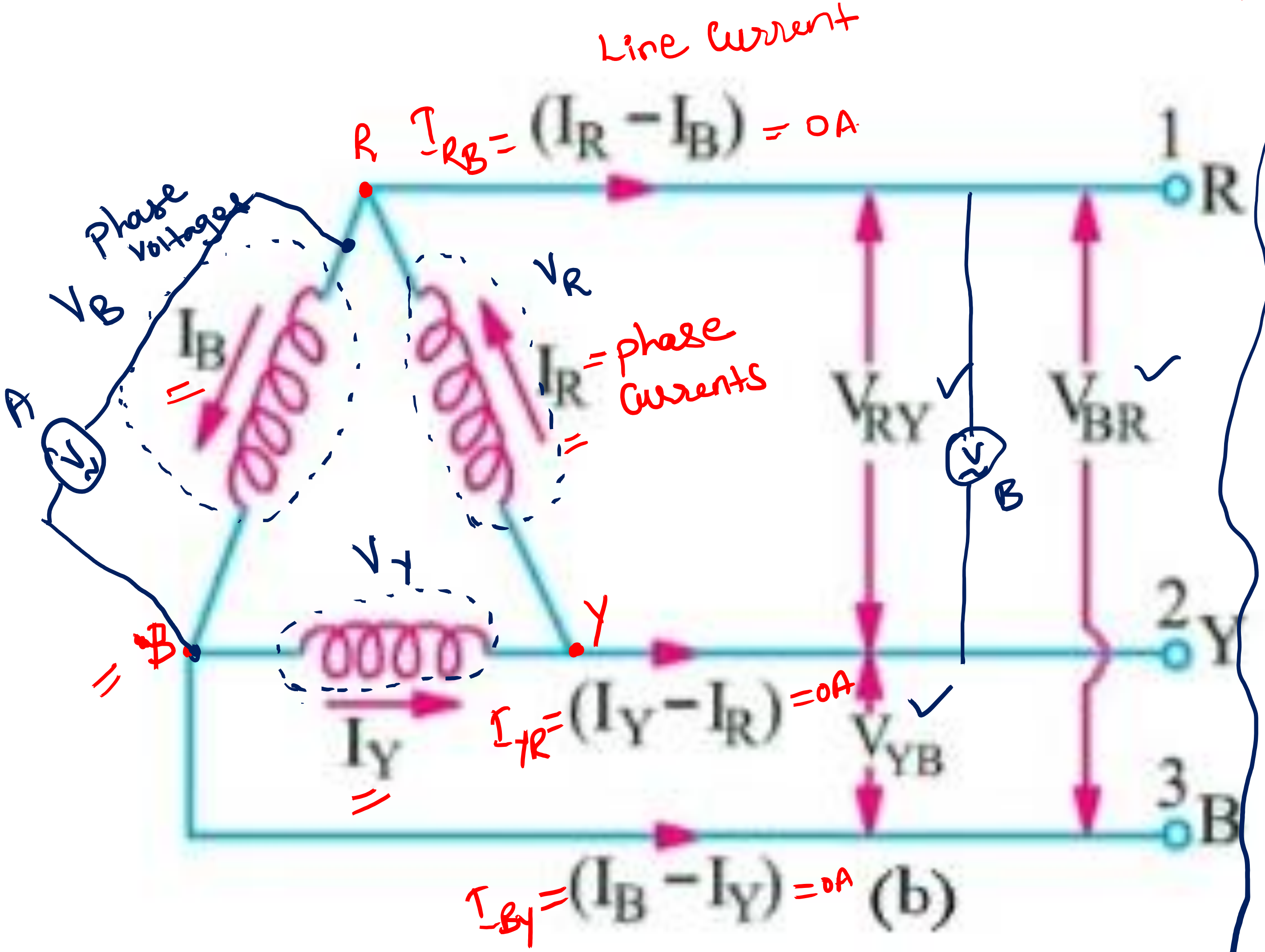




	STAR	DELTA
Voltage Relation	$V_L = \sqrt{3}\, V_{ph}$	$V_L = V_{ph}$
Current Relation	$I_L = I_{ph}$	$I_L = \sqrt{3}\, I_{ph}$

Balanced system

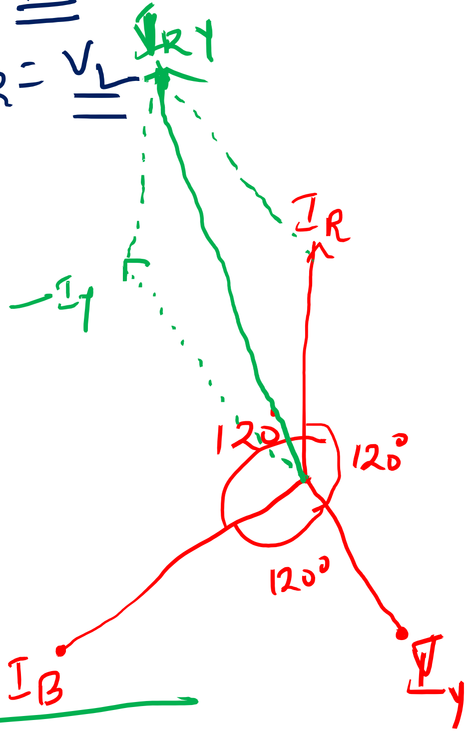
$I_R = I_B = I_y = 10A$



$V_R = V_y = V_B = V_{ph}$

$V_{Ry} = V_{yB} = V_{BR} = V_L$

$$\boxed{V_L = V_{ph}}$$



$$I_{Ry} = \sqrt{I_R^2 + I_y^2 + 2 I_y I_R \cos 60^\circ}$$

$$= \sqrt{I_{ph}^2 + I_{ph}^2 + 2 I_{ph}^2 (1/2)}$$

$$\boxed{I_L = \sqrt{3}\, I_{ph}}$$