PURE INDUCTIVE CIRCUIT AND L R CIRCUIT

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AC INDUCTANCE AND INDUCTIVE REACTANCE

The opposition to current flow through an AC Inductor is called Inductive Reactance and which depends lineally on the supply frequency

Inductors and chokes are basically coils or loops of wire that are either wound around a hollow tube former (air cored) or wound around some ferromagnetic material (iron cored) to increase their inductive value called inductance.

- Inductors store their energy in the form of a magnetic field that is created when a voltage is applied across the terminals of an inductor.

- The growth of the current flowing through the inductor is not instant but is determined by the inductors own self-induced or back emf value.

- Then for an inductor coil, this back emf voltage VL is proportional to the rate of change of the current flowing through it.

- This current will continue to rise until it reaches its maximum steady state condition which is around five time constants when this self-induced back emf has decayed to zero.

- At this point a steady state current is flowing through the coil, no more back emf is induced to oppose the current flow and therefore, the coil acts more like a short circuit allowing maximum current to flow through it.

However, in an alternating current circuit which contains an AC Inductance, the flow of current through an inductor behaves very differently to that of a steady state DC voltage.

Now in an AC circuit, the opposition to the current flowing through the coils windings not only depends upon the inductance of the coil but also the frequency of the applied voltage waveform as it varies from its positive to negative values.

The actual opposition to the current flowing through a coil in an AC circuit is determined by the AC Resistance of the coil with this AC resistance being represented by a complex number. But to distinguish a DC resistance value from an AC resistance value, which is also known as Impedance, the term Reactance is used.

Like resistance, reactance is measured in Ohm's but is given the symbol "X" to distinguish it from a purely resistive "R" value and as the component in question is an inductor, the reactance of an inductor is called Inductive Reactance, (XL) and is measured in Ohms. Its value can be found from the formula.

INDUCTIVE REACTANCE

$$X_L = 2\pi f L$$

Where:

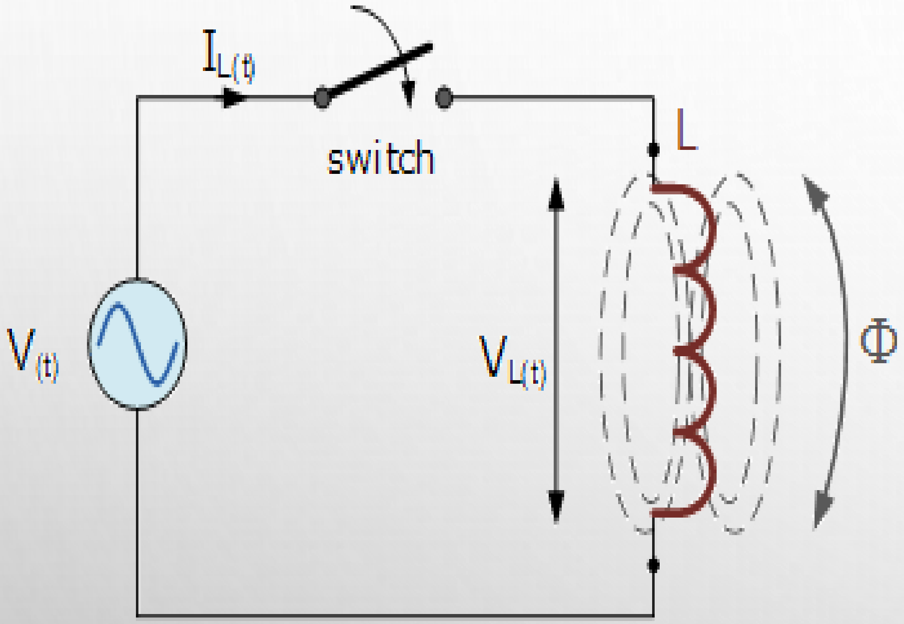
XL = Inductive Reactance in Ohms, (Ω)
π (pi) = a numeric constant of 3.142
f = Frequency in Hertz, (Hz)
L = Inductance in Henries, (H)

$$X_L = \omega L$$

We can also define inductive reactance in radians, where Omega, ω equals $2\pi f$.

So whenever a sinusoidal voltage is applied to an inductive coil, the back emf opposes the rise and fall of the current flowing through the coil and in a purely inductive coil which has zero resistance or losses, this impedance (which can be a complex number) is equal to its inductive reactance. Also reactance is represented by a vector as it has both a magnitude and a direction (angle)

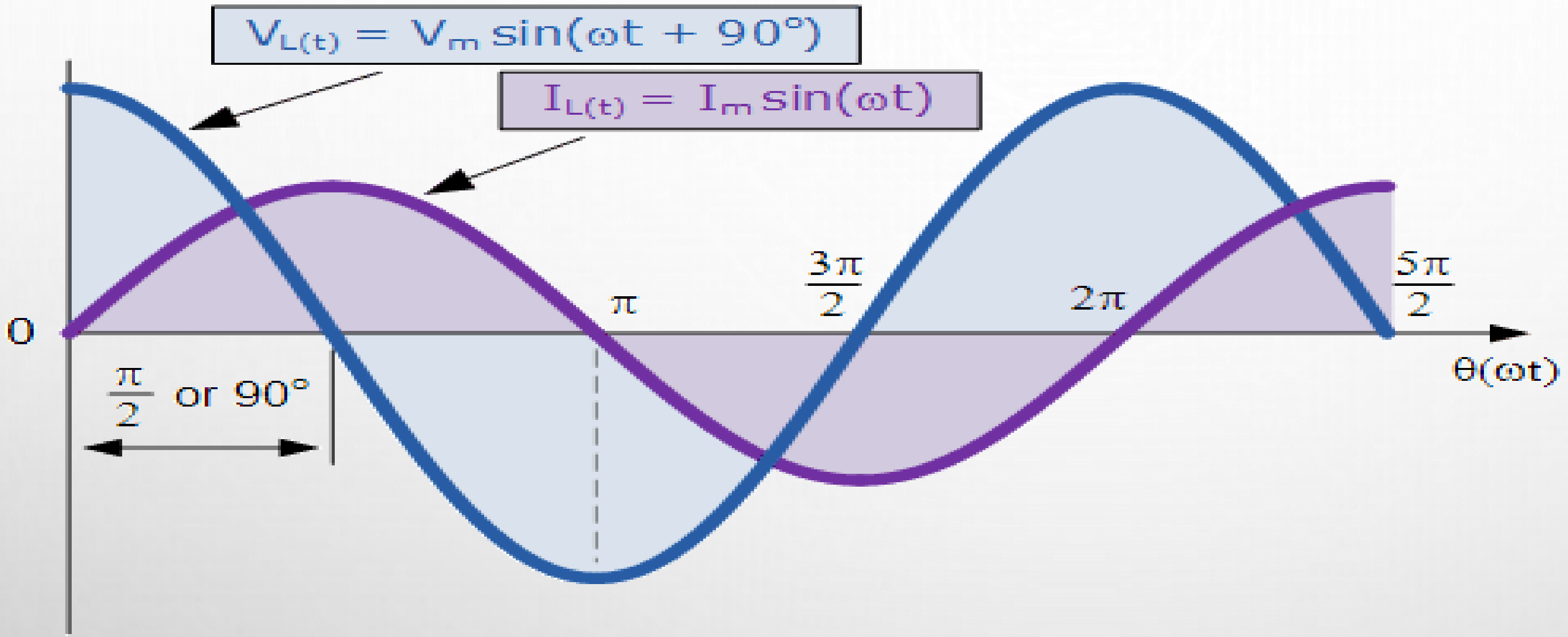
AC INDUCTANCE WITH A SINUSOIDAL SUPPLY



This simple circuit above consists of a pure inductance of L Henries (H), connected across a sinusoidal voltage given by the expression:
V(t) = Vmax sin ωt. When the switch is closed this sinusoidal voltage will cause a current to flow and rise from zero to its maximum value. This rise or change in the current will induce a magnetic field within the coil which in turn will oppose or restrict this change in the current.

But before the current has had time to reach its maximum value as it would in a DC circuit, the voltage changes polarity causing the current to change direction. This change in the other direction once again being delayed by the self-induced back emf in the coil, and in a circuit containing a pure inductance only, the current is delayed by 90o.

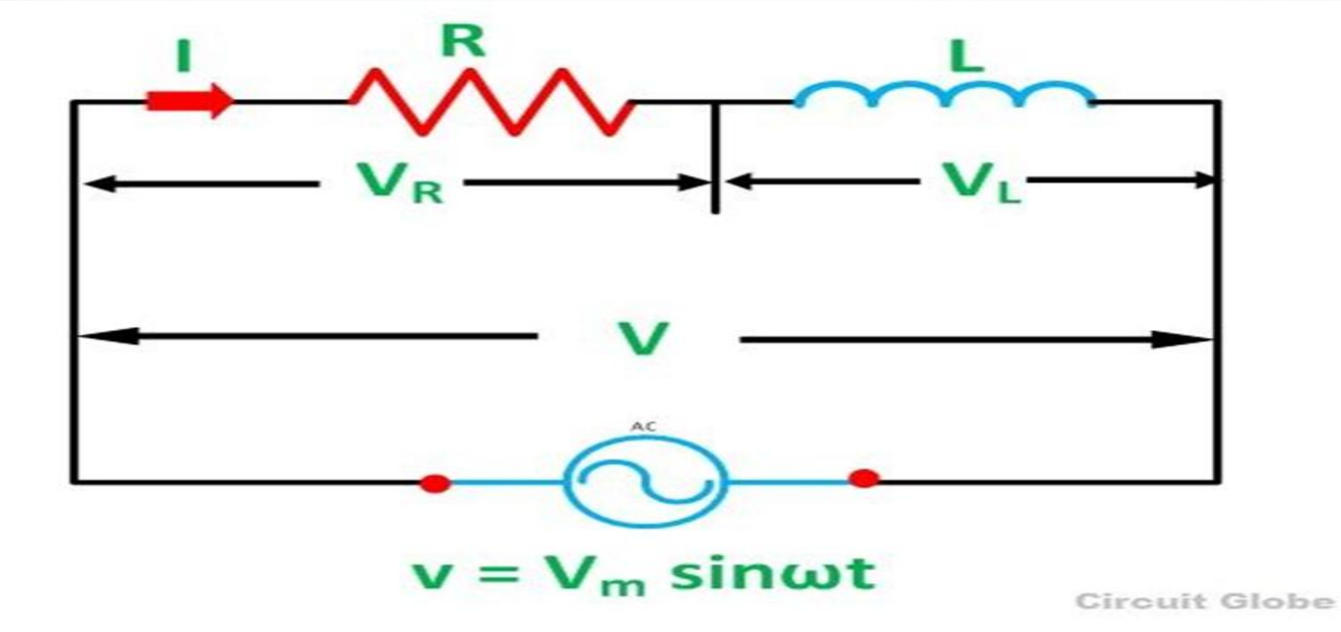
SINUSOIDAL WAVEFORMS FOR AC INDUCTANCE



This effect can also be represented by a phasor diagram were in a purely inductive circuit the voltage "LEADS" the current by 90o. But by using the voltage as our reference, we can also say that the current "LAGS" the voltage by one quarter of a cycle or 90o as shown in the vector diagram .

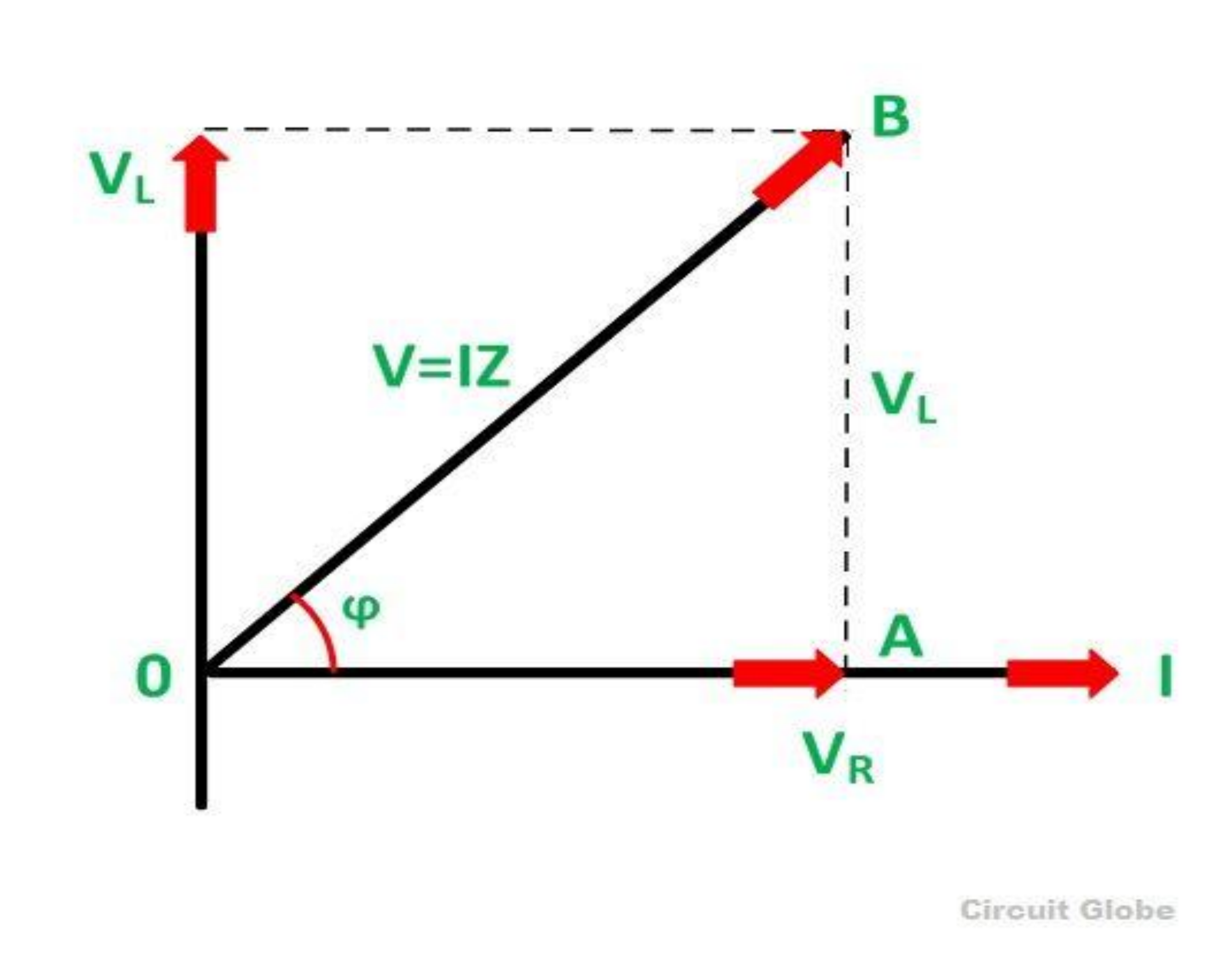
RL SERIES CIRCUIT

A circuit that contains a pure resistance R ohms connected in series with a coil having a pure inductance of L (Henry) is known as RL Series Circuit. When an AC supply voltage V is applied, the current, I flows in the circuit.



Phasor Diagram of the RL Series Circuit

The phasor diagram of the RL Series circuit is shown below:



STEPS TO DRAW THE PHASOR DIAGRAM OF RL SERIES CIRCUIT

The following steps are given below which are followed to draw the phasor diagram step by step:

Current I is taken as a reference.

The Voltage drop across the resistance VR = IR is drawn in phase with the current I.

The voltage drop across the inductive reactance VL =IXL is drawn ahead of the current I.

As the current lags voltage by an angle of 90 degrees in the pure Inductive circuit.

The vector sum of the two voltages drops VR and VL is equal to the applied voltage V.

In right-angle triangle OAB

VR = IR and VL = IXL where XL = 2πfL

$$V = \sqrt{(V_R)^2 + (V_L)^2} = \sqrt{(IR)^2 + (IX_L)^2}$$

$$V = I\sqrt{R^2 + X_L^2} \quad \text{or}$$

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

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

Z is the total opposition offered to the flow of alternating current by an RL Series circuit and is called impedance of the circuit. It is measured in ohms (Ω)

Phase Angle

In RL Series circuit the current lags the voltage by 90 degrees angle known as phase angle. It is given by the equation:

$$\tan\varphi = \frac{V_L}{V_R} = \frac{IX_L}{IR} = \frac{X_L}{R} \quad \text{or}$$

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

POWER IN R L SERIES CIRCUIT

If the alternating voltage applied across the circuit is given by the equation:

$$v = V_m \text{Sin}\omega t \ldots\ldots\ldots\ldots\ldots(1)$$

The equation of current I is given as:

$$i = I_m \sin(\omega t - \varphi) \ldots\ldots\ldots\ldots(2)$$

$$p = v\,i \ldots\ldots\ldots\ldots(3)$$

Then the instantaneous power is given by the equation:

$$P = (V_m \text{Sin}\omega t) \text{x}\ I_m \sin(\omega t - \varphi)$$

$$p = \frac{V_m I_m}{2} 2\sin(\omega t - \varphi) \sin\omega t$$

$$P = \frac{V_m}{\sqrt{2}} \frac{I_m}{\sqrt{2}} [\cos\varphi - \cos(2\omega t - \varphi)]$$

$$P = \frac{V_m}{\sqrt{2}} \frac{I_m}{\sqrt{2}} \cos\varphi - \frac{V_m}{\sqrt{2}} \frac{I_m}{\sqrt{2}} \cos(2\omega t - \varphi)$$

The average power consumed in the circuit over one complete cycle is given by the equation shown below:

$$P = \text{average of } \frac{V_m}{\sqrt{2}} \frac{V_m}{\sqrt{2}} \cos\varphi - \text{average of } \frac{V_m}{\sqrt{2}} \frac{V_m}{\sqrt{2}} \cos(2\omega t - \varphi) \quad \text{or}$$

$$P = \frac{V_m}{\sqrt{2}} \frac{I_m}{\sqrt{2}} \cos\varphi - \text{Zero} \quad \text{or}$$

$$P = V_{r.m.s} I_{r.m.s} \cos\varphi = V\, I \cos\varphi$$

Where $\cos\varphi$ is called the power factor of the circuit.

$$\cos\varphi = \frac{V_R}{V} = \frac{IR}{IZ} = \frac{R}{Z} \ldots\ldots\ldots\ldots (4)$$

The power factor is defined as the ratio of resistance to the impedance of an AC Circuit.