

Marwari college Darbhanga

Subject---physics Hons

Class--- B. Sc. Part 2

Paper –04 ; Group—A

Topic--- Series LCR circuit Resonance(Electricity)

Lecture series --69

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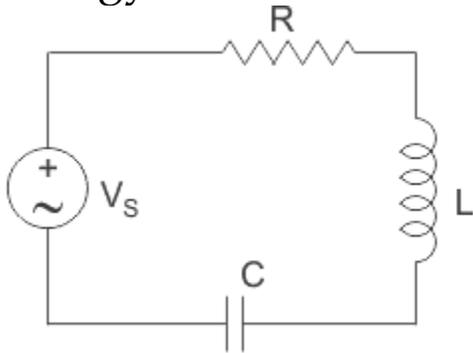
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Series LCR circuit Resonance

Consider a RLC circuit in which resistor, inductor and capacitor are connected in series across a voltage supply. This series RLC circuit has a distinguishing property of resonating at a specific frequency called resonant frequency.

In this circuit containing inductor and capacitor, the

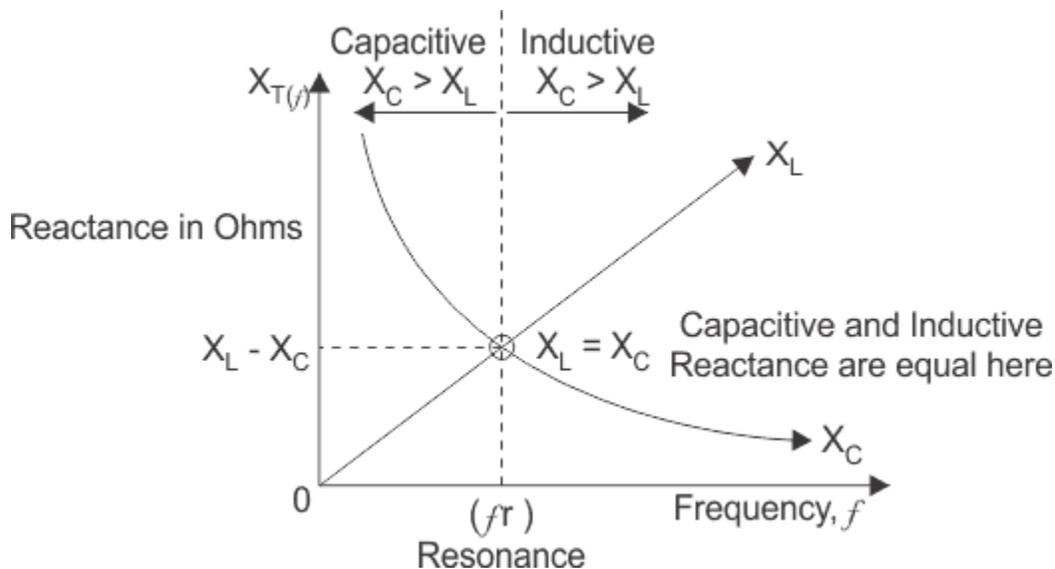
energy is stored in two different ways.



1. When a current flows in an inductor, energy gets stored in magnetic field.
2. When a capacitor is charged, energy gets stored in static electric field.

The magnetic field in the inductor is built by the current, which is provided by the discharging capacitor. Similarly, the capacitor is charged by the current produced by collapsing magnetic field of inductor and this process continues on and on, causing electrical energy to oscillate between the magnetic field and the electric field. In some cases, at certain frequency called resonant frequency, the inductive reactance of the circuit becomes equal to capacitive reactance which causes the electrical energy to oscillate between the electric field of the capacitor and magnetic field of the inductor. This forms a harmonic oscillator for current. In RLC circuit, the presence of resistor causes these oscillation to die out over period of time and is called damping effect of resistor.

Inductive Reactance and Capacitive Reactance Vs Frequency



The inductive reactance is directly proportional to frequency and capacitive reactance is inversely proportional to frequency, i.e. at low frequency X_L is low and X_C is high but there must be a frequency, where the value of inductive reactance becomes equal to capacitive reactance. Now if we plot a single graph of inductive reactance vs frequency and capacitive reactance vs frequency, then there must occur a point where these two graphs cut each other. At that point of intersection, the inductive and capacitive reactance becomes equal and the frequency at which these two reactances become equal, is called resonant frequency, f_r

At resonant frequency, $X_L = X_C$

$$X_L = 2\pi fL \text{ and } X_C = \frac{1}{2\pi fC}$$

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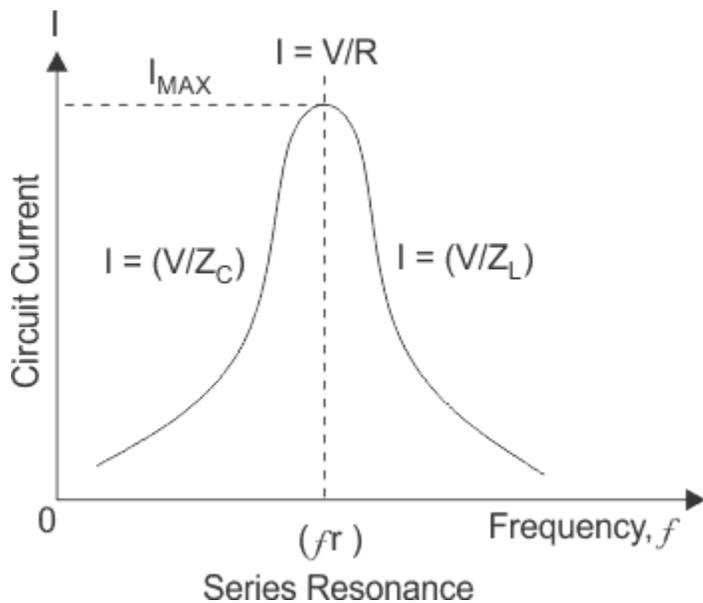
At resonance $f = f_r$ and on solving above equation we get,

$$\frac{1}{2\pi\sqrt{LC}} = f_r \text{ Hz}$$

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At resonance in series RLC circuit, two reactances become equal and cancel each other. So in resonant series RLC circuit, the opposition to the flow of current is due to resistance only. At resonance, the total impedance of series RLC circuit is equal to resistance i.e $Z = R$, impedance has only real part but no imaginary part and this impedance at resonant frequency is called dynamic impedance and this dynamic impedance is always less than impedance of series RLC circuit. Before series resonance i.e before frequency, f_r capacitive reactance dominates and after resonance, inductive reactance dominates and at resonance the circuit acts purely as resistive circuit causing a large amount of current to circulate through the circuit.

Resonant Current



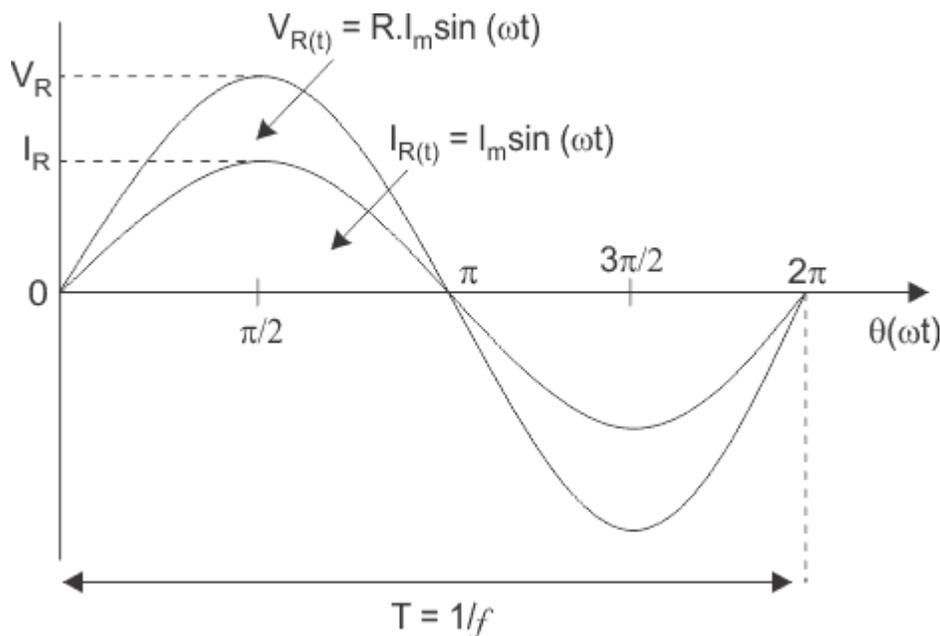
In series RLC circuit, the total voltage is the phasor sum of voltage across resistor, inductor and capacitor. At resonance in series RLC circuit, both inductive and capacitive reactance cancel each other and we know that in series circuit, the current flowing through all the elements is same, So the voltage across inductor and capacitor is equal in magnitude and opposite in direction and thereby they cancel each other. So, in a series resonant circuit, voltage across resistor is equal to supply voltage i.e. $V = V_r$.

In series RLC circuit current, $I = V / Z$ but at resonance current $I = V / R$, therefore the current at resonant frequency is maximum as at resonance in impedance of circuit is resistance only and is minimum.

The above graph shows the plot between circuit current and frequency. At starting, when the frequency increases,

the impedance Z_c decreases and hence the circuit current increases. After some time frequency becomes equal to resonant frequency, at that point inductive reactance becomes equal to capacitive reactance and the impedance of circuit reduces and is equal to circuit resistance only. So at this point, the circuit current becomes maximum $I = V / R$. Now when the frequency is further increased, Z_L increases and with increase in Z_L , the circuit current reduces and then the current drops finally to zero as frequency becomes infinite.

Power Factor at Resonance



At resonance, the inductive reactance is equal to capacitive reactance and hence the voltage across inductor and capacitor cancel each other. The total impedance of circuit is resistance only. So, the circuit behaves like a pure

resistive circuit and we know that in pure resistive circuit, voltage and the circuit current are in same phase i.e. V_r , V and I are in same phase direction. Therefore, the phase angle between voltage and current is zero and the power factor is unity.

Application of Series RLC Resonant Circuit

Since resonance in series RLC circuit occurs at particular frequency, so it is used for filtering and tuning purpose as it does not allow unwanted oscillations that would otherwise cause signal distortion, noise and damage to circuit to pass through it.