Marwari college Darbhanga

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Lecture series –54

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LCR circuit

An RLC circuit is an electrical circuit consisting of a resistor (R), an inductor (L), and a capacitor (C), connected in series or in parallel. The name of the circuit is derived from the letters that are used to denote the constituent components of this circuit, where the sequence of the components may vary from RLC.The circuit forms a harmonic oscillator for current, and resonates in a similar way as an LC circuit. Introducing the resistor increases the decay of these oscillations, which is also known as damping. The resistor also reduces the peak resonant frequency. In ordinary conditions, some resistance is unavoidable even if a resistor is not specifically included as a component; an ideal, pure LC circuit exists only in the domain of superconductivity, a physical effect demonstrated to this point only at temperatures far below ambient temperatures found anywhere on the Earth's surface.

RLC circuits have many applications as oscillator circuits. Radio receivers and television sets use them for tuning to select a narrow frequency range from ambient radio waves. In this role, the circuit is often referred to as a tuned circuit. An RLC circuit can be used as a band-pass filter, band-stop filter, low-pass filter or high-pass filter. The tuning application, for instance, is an example of band-pass filtering. The RLC filter is described as a second-order circuit, meaning that any voltage or current in the circuit can be described by a second-order differential equation in circuit analysis.

The three circuit elements, R, L and C, can be combined in a number of different topologies. All three elements in series or all three elements in parallel are the simplest in concept and the most straightforward to analyse. There are, however, other arrangements, some with practical importance in real circuits.

Series circuit

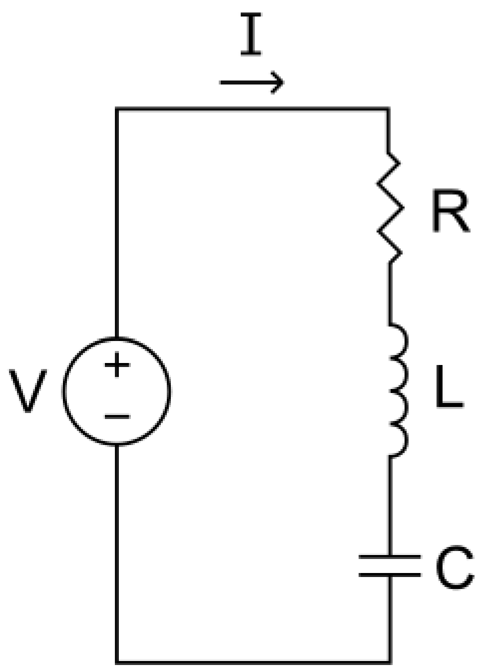

Figure 1: RLC series circuit

- V, the voltage source powering the circuit
- I, the current admitted through the circuit
- R, the effective resistance of the combined load, source, and components
- L, the inductance of the inductor component
- C, the capacitance of the capacitor component

In this circuit, the three components are all in series with the voltage source. The governing differential equation can be found by substituting into Kirchhoff's voltage law (KVL) the constitutive equation for each of the three elements. From the KVL,

$$V_R + V_L + V_C = V(t)\,,$$

where V_R, V_L and V_C are the voltages across R, L and C respectively and $V(t)$ is the time-varying voltage from the source.

Substituting $V_R = RI(t)$, $V_L = L\frac{dI(t)}{dt}$ and $V_C = V(0) + \frac{1}{C}\int_0^t I(\tau)\,d\tau$ into the equation above yields:

$$RI(t) + L\frac{dI(t)}{dt} + V(0) + \frac{1}{C}\int_0^t I(\tau)$$

For the case where the source is an unchanging voltage, taking the time derivative and dividing by L leads to the following second order differential equation:

$$\frac{d^2}{dt^2}I(t) + \frac{R}{L}\frac{d}{dt}I(t) + \frac{1}{LC}I(t) = 0\,.$$

This can usefully be expressed in a more generally applicable form:

$$\frac{d^2}{dt^2}I(t) + 2\alpha\frac{d}{dt}I(t) + \omega_0^2 I(t) = 0\,.$$

α and ω_0 are both in units of angular frequency. α is called the neper frequency, or attenuation, and is a measure of how fast the transient response of the circuit will die away after the stimulus has been removed. Neper occurs in the name because the units can also be considered to be nepers per second, neper being a unit of attenuation. ω_0 is the angular resonance frequency.

For the case of the series RLC circuit these two parameters are

given by

$$\alpha = \frac{R}{2L}$$

$$\omega_0 = \frac{1}{\sqrt{LC}}\,.$$

A useful parameter is the damping factor, ζ, which is defined as the ratio of these two; although, sometimes α is referred to as the damping factor and ζ is not used.

$$\zeta = \frac{\alpha}{\omega_0}\,.$$

In the case of the series RLC circuit, the damping factor is given by

$$\zeta = \frac{R}{2}\sqrt{\frac{C}{L}}\,.$$

The value of the damping factor determines the type of transient that the circuit will exhibit..