

15.8: Alternating-Current Circuits (Summary)

Key Terms

ac current	current that fluctuates sinusoidally with time at a fixed frequency
ac voltage	voltage that fluctuates sinusoidally with time at a fixed frequency
alternating current (ac)	flow of electric charge that periodically reverses direction
average power	time average of the instantaneous power over one cycle
bandwidth	range of angular frequencies over which the average power is greater than one-half the maximum value of the average power
capacitive reactance	opposition of a capacitor to a change in current
direct current (dc)	flow of electric charge in only one direction
impedance	ac analog to resistance in a dc circuit, which measures the combined effect of resistance, capacitive reactance, and inductive reactance
inductive reactance	opposition of an inductor to a change in current
phase angle	amount by which the voltage and current are out of phase with each other in a circuit
power factor	amount by which the power delivered in the circuit is less than the theoretical maximum of the circuit due to voltage and current being out of phase
quality factor	dimensionless quantity that describes the sharpness of the peak of the bandwidth; a high quality factor is a sharp or narrow resonance peak
resonant frequency	frequency at which the amplitude of the current is a maximum and the circuit would oscillate if not driven by a voltage source
rms current	root mean square of the current
rms voltage	root mean square of the voltage
step-down transformer	transformer that decreases voltage and increases current
step-up transformer	transformer that increases voltage and decreases current
transformer	device that transforms voltages from one value to another using induction
transformer equation	equation showing that the ratio of the secondary to primary voltages in a transformer equals the ratio of the number of turns in their windings

Key Equations

AC voltage	$v = V_0 \sin \omega t$
AC current	$i = I_0 \sin \omega t$
capacitive reactance	$\frac{V_0}{I_0} = \frac{1}{\omega C} = X_C$
rms voltage	$V_{rms} = \frac{V_0}{\sqrt{2}}$

rms current	$I_{rms} = \frac{I_0}{\sqrt{2}}$
inductive reactance	$\frac{V_0}{I_0} = \omega L = X_L$
Phase angle of an RLC series circuit	$\phi = \tan^{-1} \frac{X_L - X_C}{R}$
AC version of Ohm's law	$I_0 = \frac{V_0}{Z}$
Impedance of an RLC series circuit	$Z = \sqrt{R^2 + (X_L - X_C)^2}$
Average power associated with a circuit element	$P_{ave} = \frac{1}{2} I_0 V_0 \cos \phi$
Average power dissipated by a resistor	$P_{ave} = \frac{1}{2} I_0 V_0 = I_{rms} V_{rms} = I_{rms}^2 R$
Resonant angular frequency of a circuit	$\omega_0 = \sqrt{\frac{1}{LC}}$
Quality factor of a circuit	$Q = \frac{\omega_0}{\Delta \omega}$
Quality factor of a circuit in terms of the circuit parameters	$Q = \frac{\omega_0 L}{R}$
Transformer equation with voltage	$\frac{V_S}{V_P} = \frac{N_S}{N_P}$
Transformer equation with current	$I_S = \frac{N_P}{N_S} I_P$

Summary

15.2 AC Sources

- Direct current (dc) refers to systems in which the source voltage is constant.
- Alternating current (ac) refers to systems in which the source voltage varies periodically, particularly sinusoidally.
- The voltage source of an ac system puts out a voltage that is calculated from the time, the peak voltage, and the angular frequency.
- In a simple circuit, the current is found by dividing the voltage by the resistance. An ac current is calculated using the peak current (determined by dividing the peak voltage by the resistance), the angular frequency, and the time.

15.3 Simple AC Circuits

- For resistors, the current through and the voltage across are in phase.
- For capacitors, we find that when a sinusoidal voltage is applied to a capacitor, the voltage follows the current by one-fourth of a cycle. Since a capacitor can stop current when fully charged, it limits current and offers another form of ac resistance, called capacitive reactance, which has units of ohms.
- For inductors in ac circuits, we find that when a sinusoidal voltage is applied to an inductor, the voltage leads the current by one-fourth of a cycle.
- The opposition of an inductor to a change in current is expressed as a type of ac reactance. This inductive reactance, which has units of ohms, varies with the frequency of the ac source.

15.4 RLC Series Circuits with AC

- An **RLC** series circuit is a resistor, capacitor, and inductor series combination across an ac source.
- The same current flows through each element of an **RLC** series circuit at all points in time.
- The counterpart of resistance in a dc circuit is impedance, which measures the combined effect of resistors, capacitors, and inductors. The maximum current is defined by the ac version of Ohm's law.
- Impedance has units of ohms and is found using the resistance, the capacitive reactance, and the inductive reactance.

15.5 Power in an AC Circuit

- The average ac power is found by multiplying the rms values of current and voltage.
- Ohm's law for the rms ac is found by dividing the rms voltage by the impedance.
- In an ac circuit, there is a phase angle between the source voltage and the current, which can be found by dividing the resistance by the impedance.
- The average power delivered to an **RLC** circuit is affected by the phase angle.
- The power factor ranges from -1 to 1 .

15.6 Resonance in an AC Circuit

- At the resonant frequency, inductive reactance equals capacitive reactance.
- The average power versus angular frequency plot for a **RLC** circuit has a peak located at the resonant frequency; the sharpness or width of the peak is known as the bandwidth.
- The bandwidth is related to a dimensionless quantity called the quality factor. A high quality factor value is a sharp or narrow peak.

15.7 Transformers

- Power plants transmit high voltages at low currents to achieve lower ohmic losses in their many kilometers of transmission lines.
- Transformers use induction to transform voltages from one value to another.
- For a transformer, the voltages across the primary and secondary coils, or windings, are related by the transformer equation.
- The currents in the primary and secondary windings are related by the number of primary and secondary loops, or turns, in the windings of the transformer.
- A step-up transformer increases voltage and decreases current, whereas a step-down transformer decreases voltage and increases current.

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