Electrical Circuits (2)

Lecture 3
Resonance

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References

A. Fundamentals of Electric Circuits (Alexander and Sadiku)
B. Principles of Electric Circuits (Floyd)
C. Circuit Analysis – Theories and Practice (Robinson & Miller)
D. Introductory Circuit Analysis (Boylestad)

Series Resonance Circuit (Cont.)

Quality Factor (Different Formulas)

$$Q_s = \frac{\omega_s L}{R}$$

$$Q_s = \frac{\omega_s L}{R} = \frac{2\pi f_s L}{R} = \frac{2\pi}{R}\left(\frac{1}{2\pi\sqrt{LC}}\right)L$$

$$= \frac{L}{R}\left(\frac{1}{\sqrt{LC}}\right) = \left(\frac{\sqrt{L}}{\sqrt{L}}\right)\frac{L}{R\sqrt{LC}}$$

$$Q_s = \frac{1}{R}\sqrt{\frac{L}{C}}$$

Series Resonance Circuit (Cont.)

EXAMPLE 20.5 A series *R-L-C* circuit is designed to resonant at $\omega_s = 10^5$ rad/s, have a bandwidth of $0.15\omega_s$, and draw 16 W from a 120-V source at resonance.

a. Determine the value of *R*.
b. Find the bandwidth in hertz.
c. Find the nameplate values of *L* and *C*.
d. Determine the Q_s of the circuit.

$$BW = f_2 - f_1 = \frac{R}{2\pi L}$$

a. $P = \frac{E^2}{R}$ and $R = \frac{E^2}{P} = \frac{(120\text{ V})^2}{16\text{ W}} = \mathbf{900\ \Omega}$

b. $BW = 0.15 f_s$ $\quad f_s = \frac{\omega_s}{2\pi} = \frac{10^5\text{ rad/s}}{2\pi} = 15{,}915.49\text{ Hz}$

$$BW = 0.15 f_s = 0.15(15{,}915.49\text{ Hz}) = \mathbf{2387.32\ Hz}$$

c. $BW = \frac{R}{2\pi L}$ and $L = \frac{R}{2\pi BW} = \frac{900\ \Omega}{2\pi(2387.32\text{ Hz})} = \mathbf{60\ mH}$

$f_s = \frac{1}{2\pi\sqrt{LC}}$ and $C = \frac{1}{4\pi^2 f_s^2 L} = \frac{1}{4\pi^2(15{,}915.49\text{ Hz})^2(60 \times 10^{-3}\text{ H})}$
$= \mathbf{1.67\ nF}$

d. $Q_s = \frac{X_L}{R} = \frac{2\pi f_s L}{R} = \frac{2\pi(15{,}915.49\text{ Hz})(60\text{ mH})}{900\ \Omega} = \mathbf{6.67}$

Series Resonance Circuit (Cont.)

Note that at resonance:

1. The impedance is purely resistive, thus, $\mathbf{Z} = R$. In other words, the LC series combination acts like a short circuit, and the entire voltage is across R.
2. The voltage $\mathbf{V}_s$ and the current $\mathbf{I}$ are in phase, so that the power factor is unity.
3. The inductor voltage and capacitor voltage can be much more than the source voltage.

- Point (3) can be verified by applying the voltage divider rule to the circuit of Fig. 20.2, we obtain

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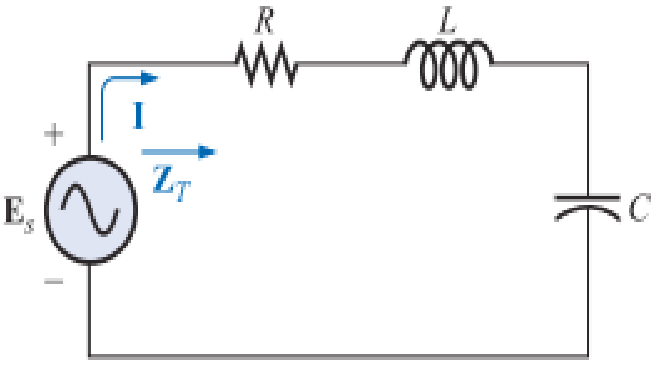
$$V_L = \frac{X_L E}{Z_T} = \frac{X_L E}{R} \quad \text{(at resonance)}$$

$$V_{L_s} = Q_s E$$

$$V_C = \frac{X_C E}{Z_T} = \frac{X_C E}{R}$$

$$V_{C_s} = Q_s E$$

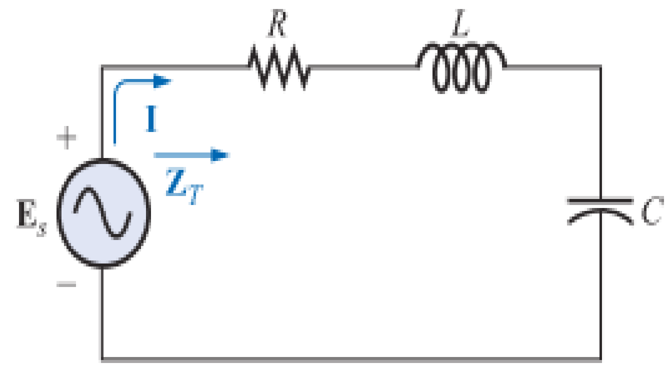


Series Resonance Circuit (Cont.)

$V_{L_s} = Q_s E$ $V_{C_s} = Q_s E$

- Since Q s is usually greater than 1, the voltage across the capacitor or inductor of a series resonant circuit can be significantly greater than the input voltage.

- Analyze the circuit, and verify your results by simulation?



- L = 10 mH
- C = 4.05 nF
- R = 25 Ohms
- Es = 625 mV

- F = 1/(2 Pi Sqrt(L*C) = 25008.75xxxxx Hz
- Q = XL/R = W L/R = 62.854
- VL = Q Es = 62.854 * 635 mV = 39.9 Volts

Check Proteus Simulation Tutorials at the following link

http://www.bu.edu.eg/staff/basem.mamdoh-courses/12142/URLs

Next Lecture

Parallel Resonance