Simulation # 1

Resonance in Series and Parallel Single Phase AC Circuits

Electrical Network Simulation Laboratory (EE2701)
Department of Electrical Engineering,
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Aim of the Expt.:

1. To study various configurations of R, L, and C components to study resonating behavior of an AC circuit

Theory:

Series resonance:

For a circuit excited with ac source which has R, L and C connected in series, as shown in Figure 1, various reactance values are given by

$$|X_L| = \omega L = 2\pi f L$$

$$|X_c| = \frac{1}{\omega C} = \frac{1}{2\pi f \mathrm{C}}$$

$$|Z| = \sqrt{\{R^2 + (X_L - X_C)^2\}}$$

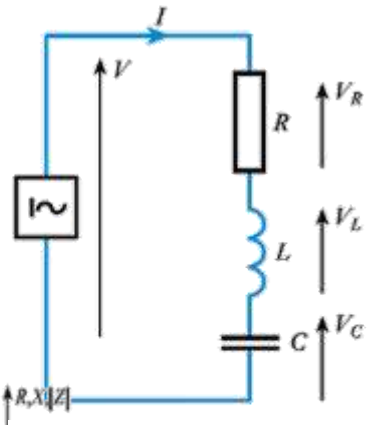


Figure 1 Series RLC circuit 'A'

Above equation shows the dependence of X_L and X_C on the frequency. An interesting phenomenon, known as series resonance, occurs when the frequency of excitation is such that X_L=X_C. Value of resonating frequency for RLC series circuit is given by

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

The plot of frequency versus resistance, reactance, and current is as shown in Figure 2. At resonating condition, the impedance Z is purely resistive. The circuit behaves AS Inductive above f_r $(since\ |XL| > |XC\ |)$, and circuit bthe ecomes capacitive below f_r $when|XL| < |XC\ |$. The impedance diagram for all three conditions is drawn in Figure 3.

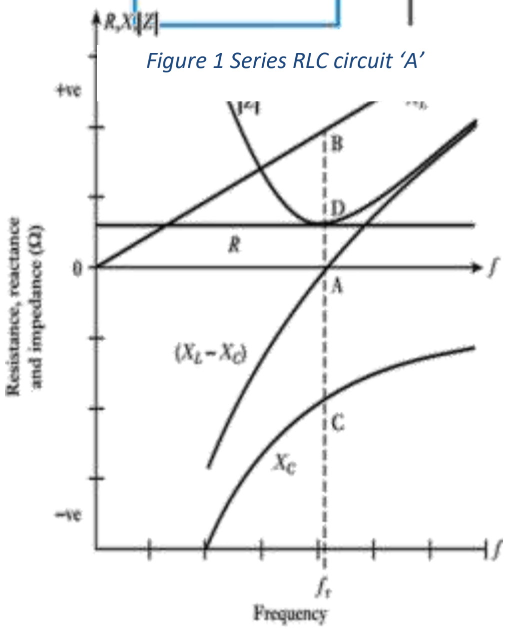


Figure 2 Variation of reactance and impedance with frequency

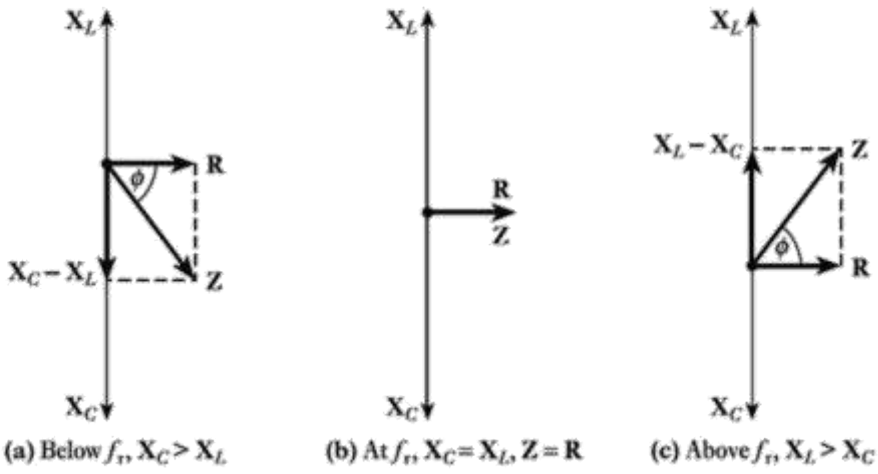


Figure 3 Phasor diagram for the various values of fr for series RLC circuit

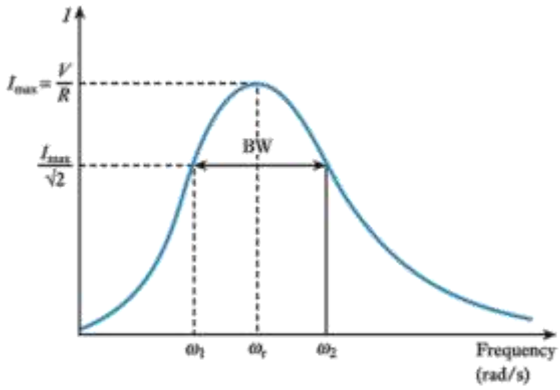


Figure 4 Variation of current due to change in frequency. The graph exhibits resonating and two half-power points

The bandwidth (BW) of a circuit: the frequency range between the **half-power points,** when $I = I_{max}/\sqrt{2}$ as shown in Figure 4.

BW = ω_2-ω_1, where ω_1 and ω_2 being lower and upper cut off frequencies

Resonance in the parallel circuit:

The resonating frequency for the parallel circuit shown in Figure 5 is given by

$$f_r = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$$

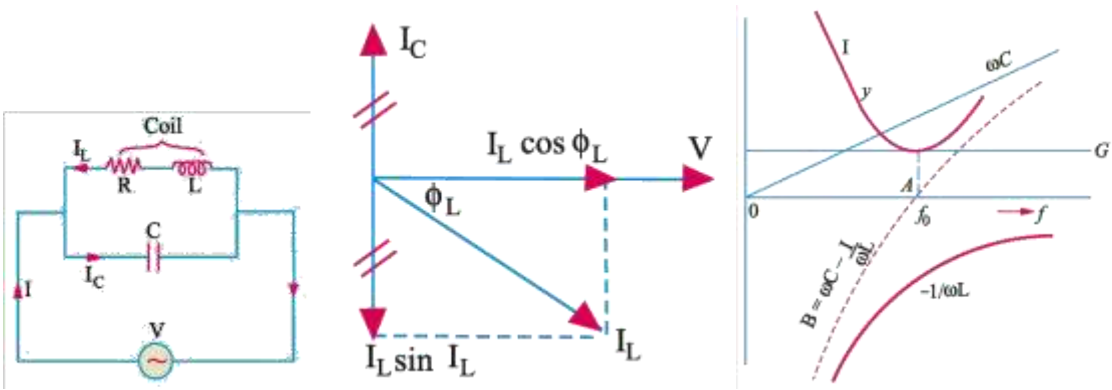


Figure 5 (a) Parallel RL-C circuit under consideration (b) Phasor diagram at resonance (c) Graph for variation in reactance, admittance, current due to change in frequency

Comparison of series and parallel resonance circuit:

item	*series circuit (R–L–C)*	*parallel circuit (R–L and C)*
Impedance at resonance	Minimum	Maximum
Current at resonance	Maximum = V/R	Minimum = $V/(L/CR)$
Effective impedance	R	L/CR
Power factor at resonance	Unity	Unity
Resonant frequency	$1/2\pi\sqrt{(LC)}$	$\frac{1}{2\pi}\sqrt{\left(\frac{1}{LC}-\frac{R^2}{L^2}\right)}$
It magnifies	Voltage	Current
Magnification is	$\omega L/R$	$\omega L/R$

Figure 6 Comparison of series and parallel resonance circuit

Circuit Analysis:

1. For circuit in Figure 1, calculate f_r, BW, Q-factor, current and voltage across all components at resonance. Values of components in the circuit are: C = 159.2 uF, L = 63.7 mH, R = 4Ω, V_{in}=20V, 50 Hz.

2. For Figure 11, calculate f_r, BW, Q-factor, current and voltage across all components at resonance. Values of components in the circuit are: C = 10 uF, L = 100 mH, R = 100 Ω, V_{in}=10 V, 50 Hz.

Simulation:

1. Build the circuits in Figure 7 and save the Multisim file for later use.
2. Simulate each for variable frequency AC analysis.
   Go to Simulate -> Analyses -> AC analysis
3. Choose the range of start and stop frequency appropriately to showcase the resonating phenomenon. Choose the output variables (I(R1) and P(R1) to display and run the simulation.

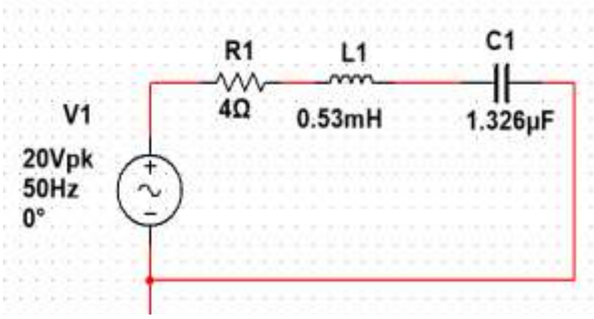


Figure 7 Circuit A for simulation

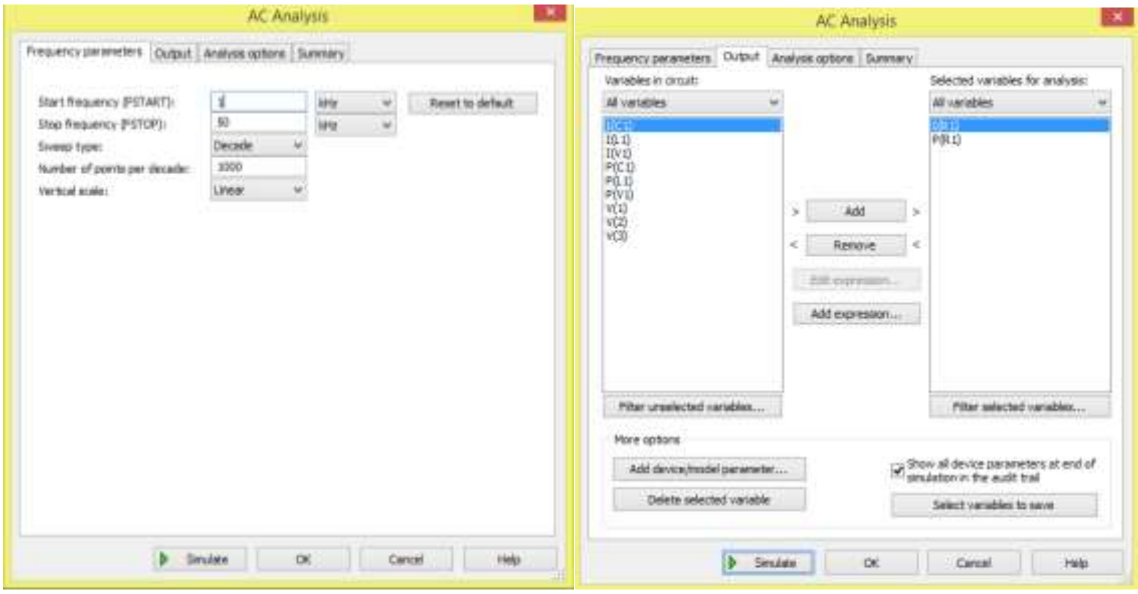
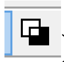
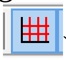
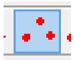
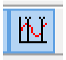


Figure 8 Parameters for AC analysis

4. Save the graph after
    a. Converting the background color to black (Click this )
    b. Add grid (Click this )
    c. Thicken the curve if required. Click this icon 
    d. Add cursor and move it to the desired point (In this case, it is at fr). To add cursor click this 
    e. Always use this procedure to save the graph for EE 273 lab.
    f. The graph should look similar to the one shown in Figure 9.

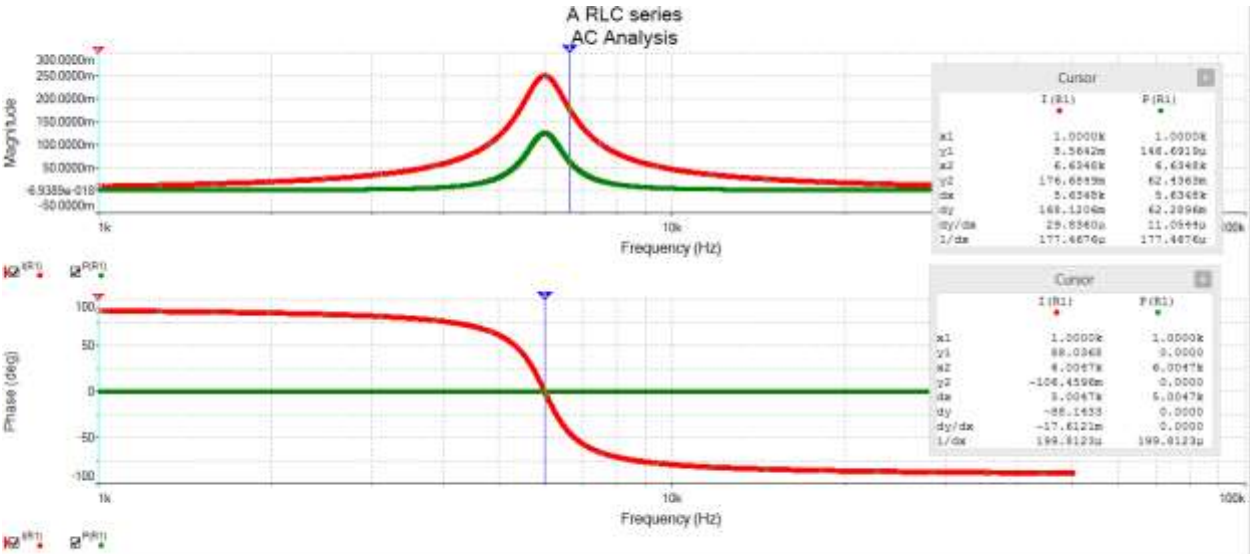


Figure 9 Graph for Series RLC and the analysis using cursors

5. Note various parameters approximately (f_r and Half power frequencies) from the graph and fill the following table for each circuit.

6. To find parameters at resonance, first, find fr and then simulate the circuit with source frequency changed to f_r.

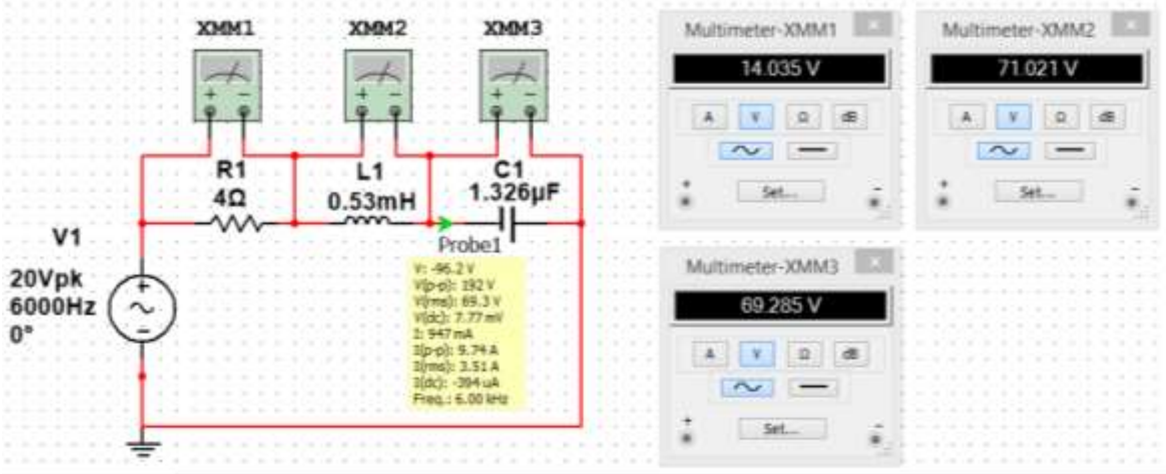


Figure 10 Determination of various circuit parameters at the resonating frequency

7. Carry out simulation in a similar way to simulate circuit B, C, and D.

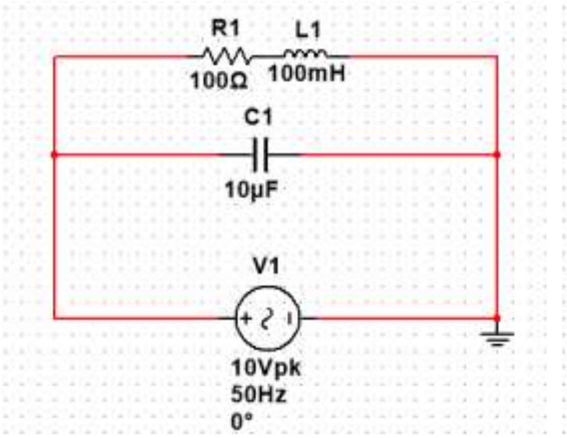


Figure 11Circuit B

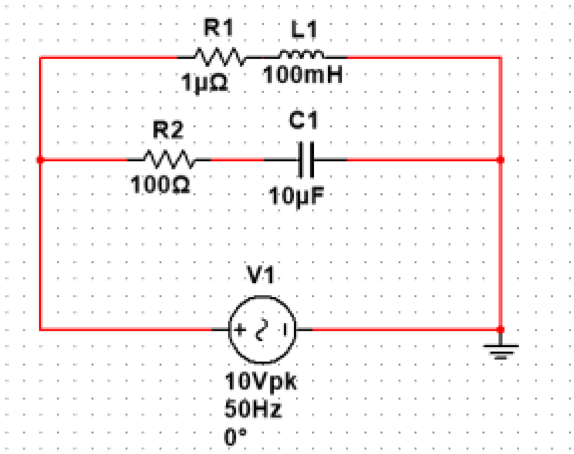


Figure 12Circuit C

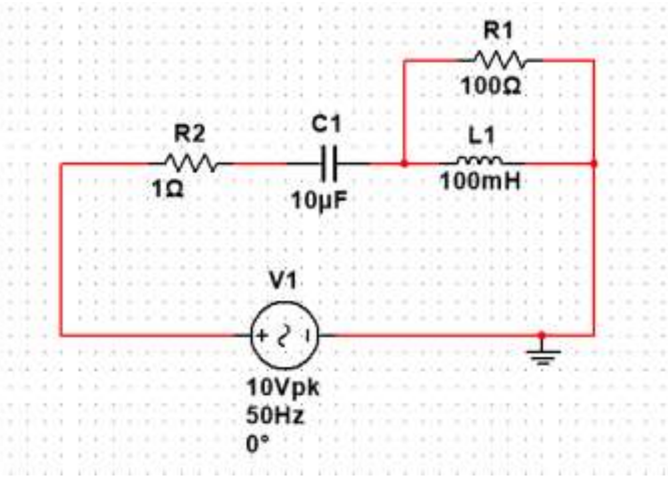


Figure 13 Circuit D

Questions:

1. Fill the table using quantities found in the simulation.
   Note: Leave parameters blank if cannot be calculated using graph.

Circuit	Resonating frequency	Half Power frequencies		Bandwidth	Q-factor	Parameters at resonance			
		f_1	f_2			Current	V_R	V_L	V_C
A									
B									
C									
D									

2. What happens if circuit C is simulated with R (which is in series with L) removed?

3. Discuss how the phase diagram can be used to determine the power of the circuit or nature (Reactive/resistive/ capacitive) of the circuit?