
Electrical Engineering

ACDA5001

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Assignment Report – AC Response of an RLC Network

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Abstract

Within this report will be the contents of tasks set out in assignment one.

Assignment one consists of 3 tasks. Tasks one and two outlining the information described in the introduction of this report with RLC circuits in relations to resonance and phase angle.

The results in section 3 indicate premeditated results in the introduction supported by the findings in section 4 discussion.

1- Introduction

An RLC Circuit consists of a resistor, inductor and capacitor. They can be found in various forms such as in AC mains filters, noise filters and also in radio and television tuning circuits producing a very selective tuning circuit for the receiving of the different frequency channels [2]

The RLC circuit principles are used during power factor correction on electrical systems such as large industrial systems with a large load such as a motor. As this is an inductive reactance this can be balanced by a capacitive reactance of equal magnitude in opposite direction (phase angle). Whilst inductive and capacitive reactance equal zero we achieve maximum power transfer due to no reactive power being used.

A power factor correction unit is made up of a series of capacitors that switch in and out depending on inductive load.

I am going to identify the characteristics of the following in respect to a changing frequency with the same supply voltage:

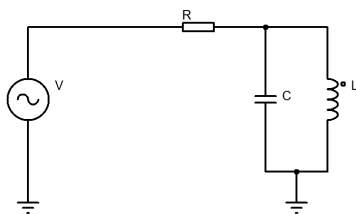
Supply current (I)

Voltage drop of components (VD)

Active, Reactive & Apparent Power (P, Q, S)

Power factor

Below is the RLC circuit I will use to demonstrate the above along with the values I will use for each component.



Inductor value = 201mH

Resistor value = 78Ω

Capacitor value = 02μF

Supply Voltage = 10V AC

2- Method

2.1 Task 1a

To begin I am required to calculate the Impedance of the LC branch of the circuit.

To do this I need to calculate the reactance of each reactive component individually. I used the following formulas:

For Inductor: $X_L = 2\pi fL$

For Capacitor: $X_C = \frac{1}{2\pi fC}$

I then calculated the total impedance of these components by using the product over sum formula: $Z_{LC} = \frac{(X_L * X_C)}{(X_L + X_C)}$

I then calculated total impedance of the circuit using: $Z = R + j(X_L - X_C)$

From calculating this total impedance, I was able to calculate total current using: $I = \frac{V}{R}$

Using the total current I was able to plot a graph of Current change depending on frequency.

2.2 Task 1b

To carry out task 1b of plotting voltage drop (VD) over frequency I was required to calculate voltage drop of the resistor and voltage drop of the LC branch of the circuit separately.

To do this I simply used the formula $V = IR$ to calculate the VD across the resistor.

I also used the formula $V = IR$ to calculate the VD of the LC branch where R is the total impedance of the LC branch thus turning my formula into $V = I(Z_{LC})$

With the values from the calculations above I was able to plot a graph detailing the characteristics of VD across the components with respect to frequency.

2.3 Task 1c

Following from the previous tasks, I used the results from them to calculate the following using the below formula:

Active Power - $P = |I|^2 R$

Reactive Power - $Q = |I|^2 X$

Apparent Power - $|S| = \sqrt{P^2 + Q^2}$

From these results I can then plot the change in Active, reactive & apparent power over frequency.

2.4 Task 1d

Having all the above calculation's for power I can calculate the phase angle (φ) for the circuit using $\varphi = \cos^{-1} \frac{P}{S}$

With the phase angle calculation, I can place into the power factor (pf) formula $pf = \cos \varphi$ to provide me with the power factor. I can then plot the trend in this over frequency.

2.5 Task 2

To create Phasor diagrams to represent phase angle at three different frequencies, I was required to calculate the phase angle for component voltage and current for the circuit. I was able to do this using the "imargument" function in Microsoft excel which will return the argument φ which is the angle required but expressed in radians. To calculate this in degrees I use "=degrees()" excel function.

My overall formula used to calculate the angle of VR is
=DEGREES(IMARGUMENT(VR))

The formula used to calculate the angle of VLC is
=DEGREES(IMARGUMENT(VLC))

VR & VLC being imaginary numbers (j)

Next I was required to calculate the angle the current was in relation to voltage. To do this I used the same formula above but for current. This formula then was
=DEGREES(IMARGUMENT(I))

Again "I" being a complex number and not absolute.

As I had my values for VR and VLC I was able to make these into absolute values to give my magnitude.

With the above angles and magnitudes calculated I was able to plot these as X and Y coordinates to display on my phasor.

To calculate the X axis position I used the cos function following SOH CAH TOA.

The formula I used was =|VLC|*COS(radians(ThetaVLC+ABS(ITheta)))

|VLC| being my magnitude

*COS function as identified by SOH CAH TOA as my Hypotenuse is known and I'm looking for the adjacent

(radians function is used to convert my angle into radians

(ThetaVLC) is the angle in relation to the "x" axis.

+ABS(ITheta) is to take into account the angle of current but convert into an absolute value before adding to thetaVLC)

With my X value being calculated I now needed the Y values. This was calculated again using SOH CAH TOA. From this I derived I needed the Sin function as my Hypotenuse is known and opposite required. My formula was as follows:

$$=|VLC|*\sin(\text{radians}(\text{ThetaVLC}+\text{ABS}(I\text{Theta})))$$

This was repeated for VR with formulas shown:

X Axis

$$=|VR|*\cos(\text{radians}(\text{ThetaVR}+\text{ABS}(I\text{Theta})))$$

Y Axis

$$=|VR|*\sin(\text{radians}(\text{ThetaVR}+\text{ABS}(I\text{Theta})))$$

This method was used to plot phasor diagrams for the frequencies:

25hz Below Res = 226.019295hz

At Res = 251.019295

25hz Above Res = 276.019295

2.6 Task 3

If we look at this circuit at resonance, we know that $X_L = X_C$.

X_L is given by $X_L = 2 * \pi * f * L$

This will give me a value of my inductive reactance.

I can then use this value to place into the formula: $X_C = \frac{1}{2\pi f C}$ To give me a value of C

This formula can be converted to $C = \frac{1}{2\pi f X_C}$

If we assume a resonant frequency of 50hz and substitute this into $X_L = 2\pi f L$ we get:

$$X_L = 2 * \pi * 50 * 0.00015$$

$$X_L = 0.04712389$$

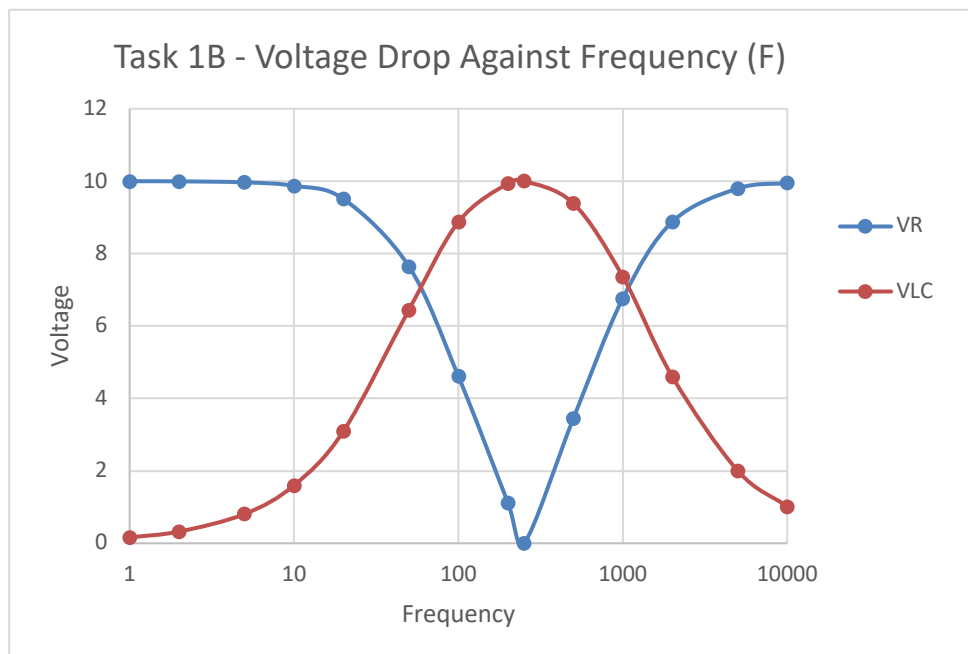
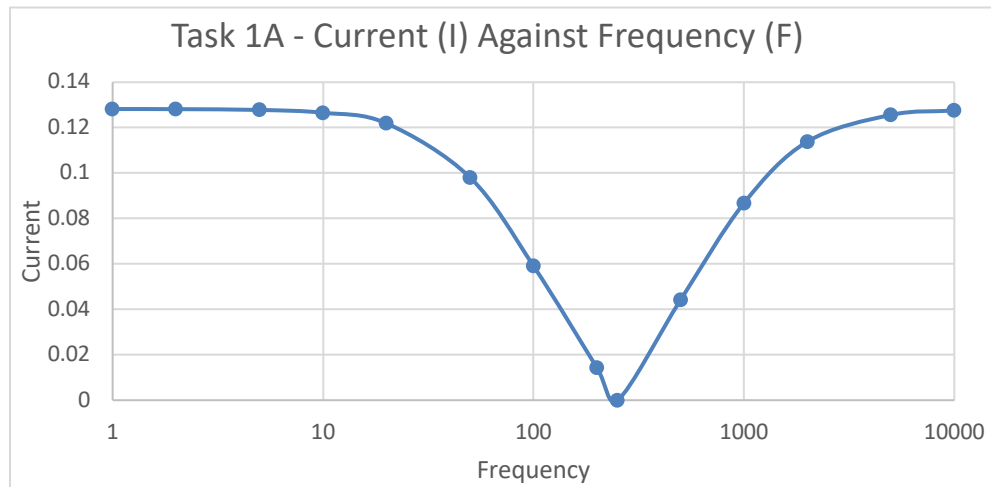
We know at resonance $X_L = X_C$ therefore $X_C = 0.04712389$

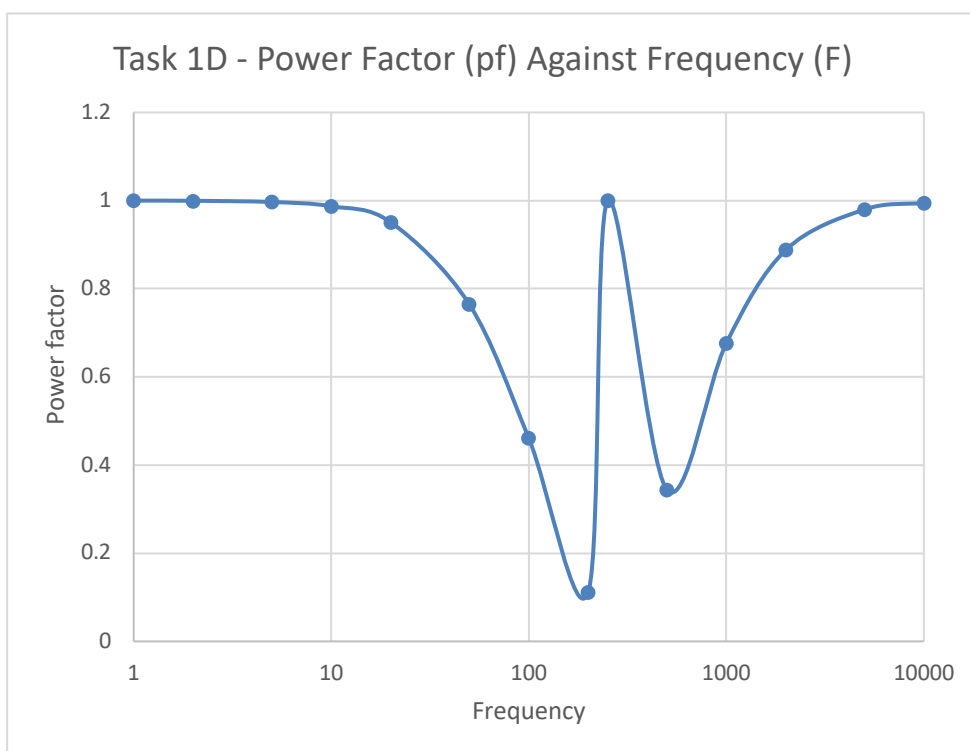
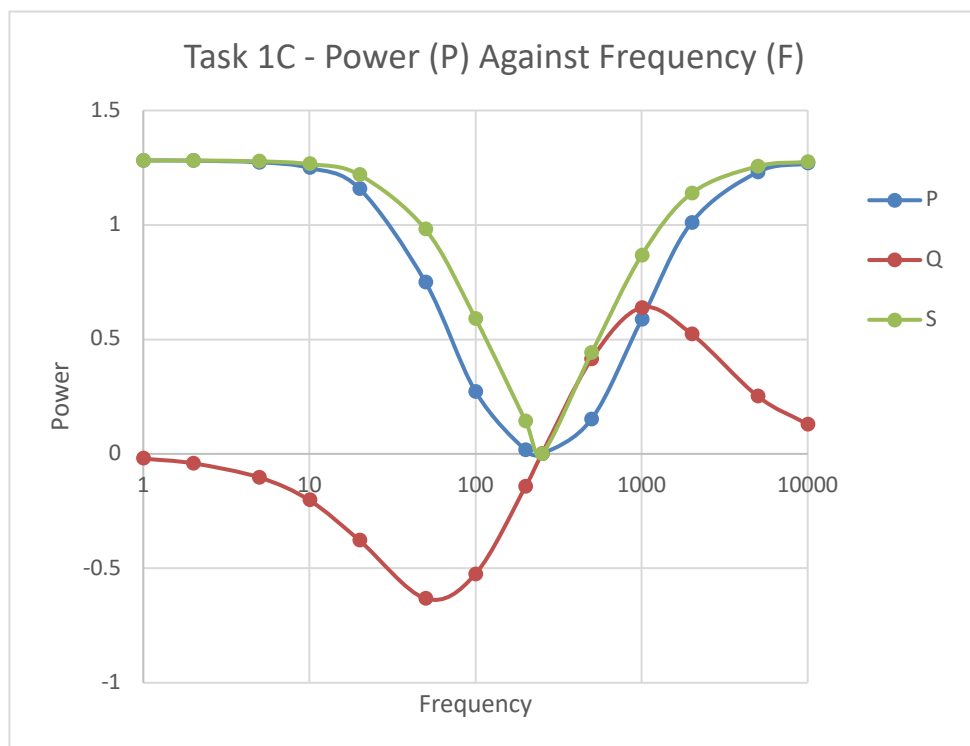
So if we substitute this into the above formula we get $C = \frac{1}{2 * \pi * 50 * 0.047}$

The value for our capacitor is: 0.067F

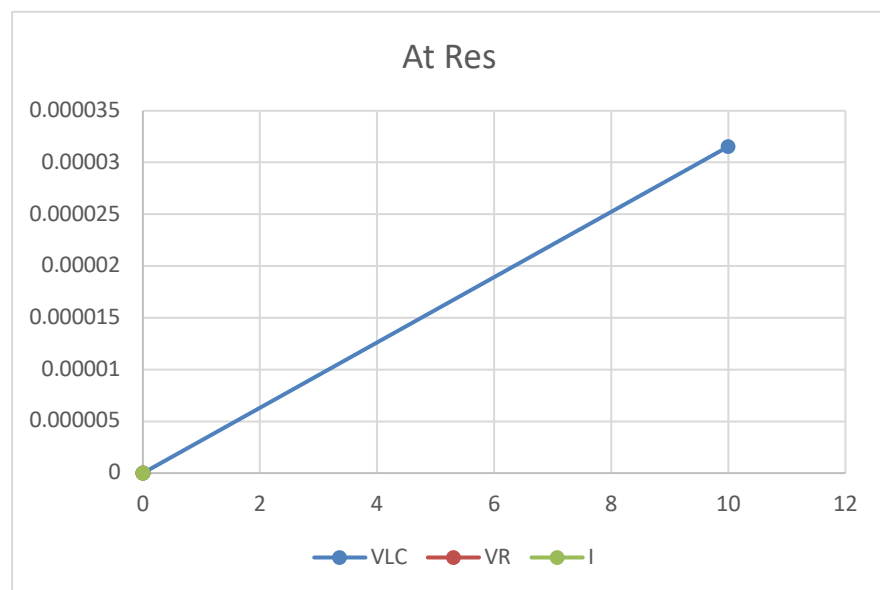
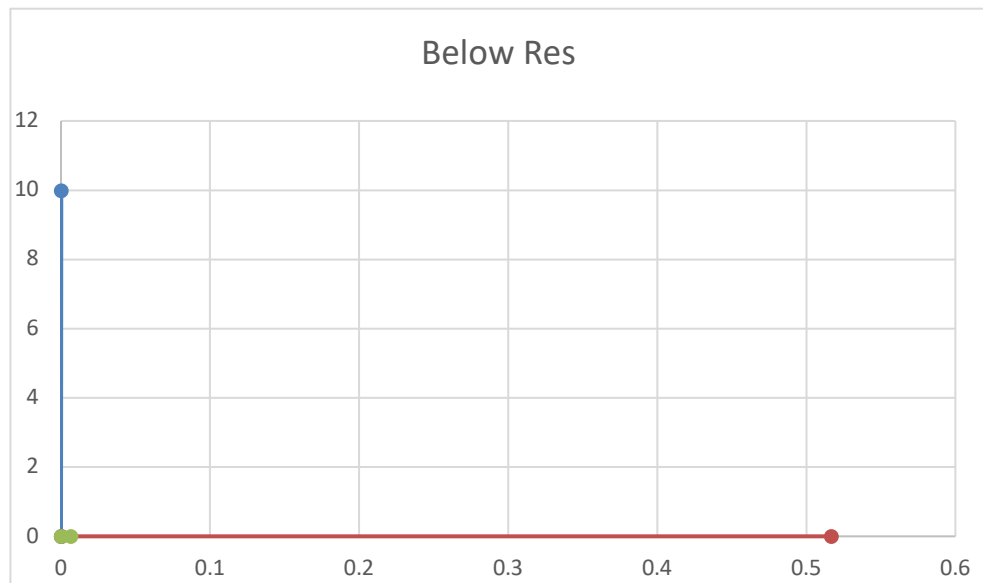
3- Results

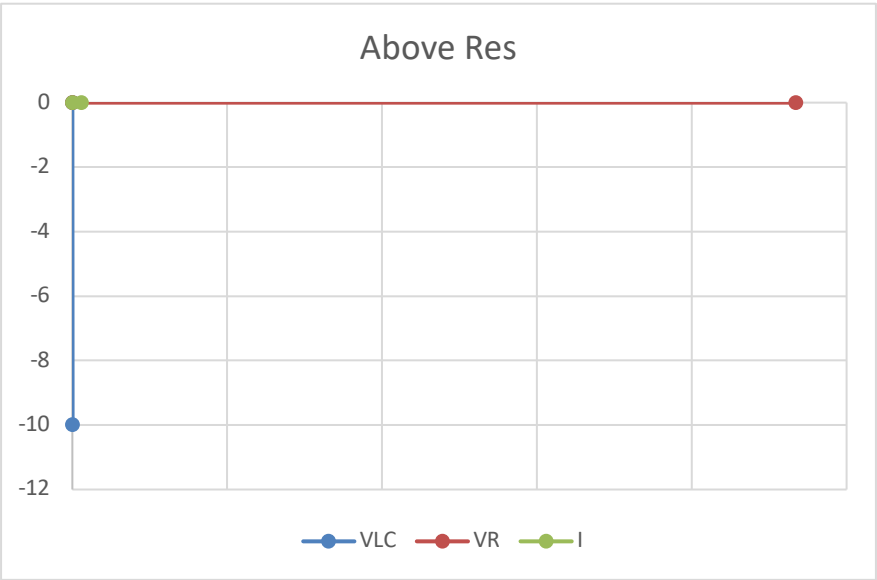
3.1 Task 1





3.2 Task 2





4- Discussion

4.1 Task 1

Shown in the first graph we can see as described in our introduction the relationship current has over frequency. At resonance we can see the current drops to zero in our circuit. This occurs when the inductive reactance (X_L) is equal to the Capacitive Reactance (X_C).

In our second chart we can see the voltage drop of the resistor (V_R) decreases as the voltage drop of the LC branch (V_{LC}) increases. This is due to the

Our third chart indicates Power (P) against Frequency (F). It illustrates clearly the drop in reactive power whilst at resonance. In turn this brings the apparent power down.

Our final chart for task 1 indicates our power factor for the circuit. At resonance we achieve perfect power factor correction of 1. This indicating all the energy supplied from the source is being utilised by the load [3] This meaning the voltage and current are in phase.

At resonance the capacitive energy stored as a static energy in the capacitor discharges at the same rate of inductance from the inductor. As these amounts are equal value and opposite angle to each other they are in balance. Meaning as the capacitor discharges the inductor induces the same current. This creates a purely resistive circuit balancing out reactive losses of inductance and impedance.

4.2 Task 2

The three charts in this task clearly indicate the voltage drop of the components in relation to phase angle.

In our first task before resonance, we can see that the voltage in the LC branch (V_{LC}) is leading the voltage of the resistor (V_R). This is a difference in phase angle of 90 degrees.

In our second chart both V_{LC} & V_R are in phase which each other indicating they are now at resonance.

In our final chart (after resonance) we see the voltage of the LC branch (V_{LC}) is now lagging the voltage of our resistive branch (V_R)

4.3 Task 3

Maximum power transfer occurs at resonance. This is when the capacitive reactance and inductive reactance are equal and opposite to each other. This bring the total impedance of the circuit to be purely the load resistor providing maximum power transfer.

The task we completed was introducing a capacitor to an inductive load to create power factor correction and in turn reduce reactive power.

With the addition of the capacitor of the value we calculated we made the circuit more towards resonance and balanced out the reactive loads.

5- Conclusion

From carrying out this assignment, we can conclude that:

- Current draw drops at resonance due to zero reactive power.
- At resonance the capacitive reactance is equal to inductive reactance. This causes the circuit to be a purely resistive circuit. This occurs due to equal
- Maximum power transfer occurs at resonance due to no reactive power being present.
- We can achieve maximum power transfer of an inductive circuit by adding capacitors to a value of reactance equal to the inductive reactance. This is called Power Factor Correction.
- At resonance we achieve Power Factor Correction of 1.
- Voltage and Current are in phase at resonance.

6- References

- [1] <https://www.electrical4u.com/resonance-in-series-rlc-circuit/>
- [2] <https://www.electronics-tutorials.ws/accircuits/series-resonance.html>
- [3] https://en.wikipedia.org/wiki/Power_factor