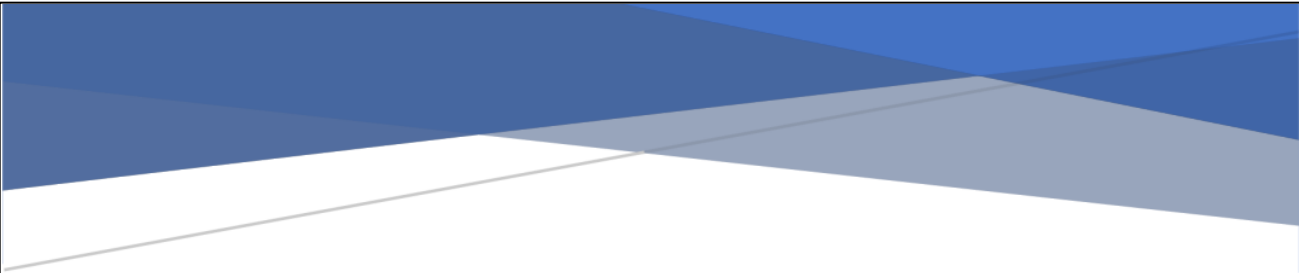


Daniel Davies Electrical Engineering Assignment

by Daniel Louis Davies

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ELECTRICAL ENGINEERING ACDA 5001

AC Response of an RLC network

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2073713
[09/12/2020](#)

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Abstract

Use of 1st Person Voice

In this report I will detail how I have carried out experiments to determine AC response within an RLC circuit. I have done this by using a mathematical approach in Microsoft Excel to simulate the RLC network. Using various formulae and equations, I have created excel tables to accurately calculate the various factors within the circuit as well produce graphs and phasor diagrams to graphically show my results. By carrying out these experiments I have produced results that will show how components in an RLC circuit behave at resonant frequency, as well as at frequencies above and below resonance. I produced graphs that compared the various frequencies against current, voltage through the resistor and the parallel LC circuit, active, reactive, and apparent powers, as well as power factor. From the graphs shown, it can be seen that at resonant frequency, the circuit is neither inductive nor capacitive, and that at resonance, the power factor becomes as close to 1 as possible and the phase angle becomes minute. I also created phasor diagrams to illustrate the component voltages and currents at resonance, as well as 25Hz above and below. I used excel to produce a table and graph that would allow me to find the component values to allow maximum power transfer, the graph shows the exact point of maximum power transfer and the values of load reactance and resistance in order to achieve this.

Introduction

RLC circuits have many applications in industrial settings, such as low and high pass filters, voltage multipliers and oscillator circuits, they are also used for tuning analogue radios. RLC circuits are also used in power factor correction. Power factor correction is the process of improving the phase angle between the supply voltage and current, but all while the power consumption stays the same. Using a capacitor in parallel with an inductive coil adds an impedance to the circuit which decreases the phase angle, this increases the power factor and therefore reduces the circuits rms drawn from the supply. Adding a capacitor and inductive coil in parallel reduces reactive power as well as also reducing the current taken from the supply. Power factor correction in industry is done by automated PFC panels, this works by adding and removing capacitors from the circuit in order to keep the power factor as close to unity as possible. A magnetic field is required for an inductive load to operate, but this causes the current to be out of phase and lagging behind the voltage, power factor correction works by creating a leading current to compensate for the lagging current by adding capacitors. ^[3]

2

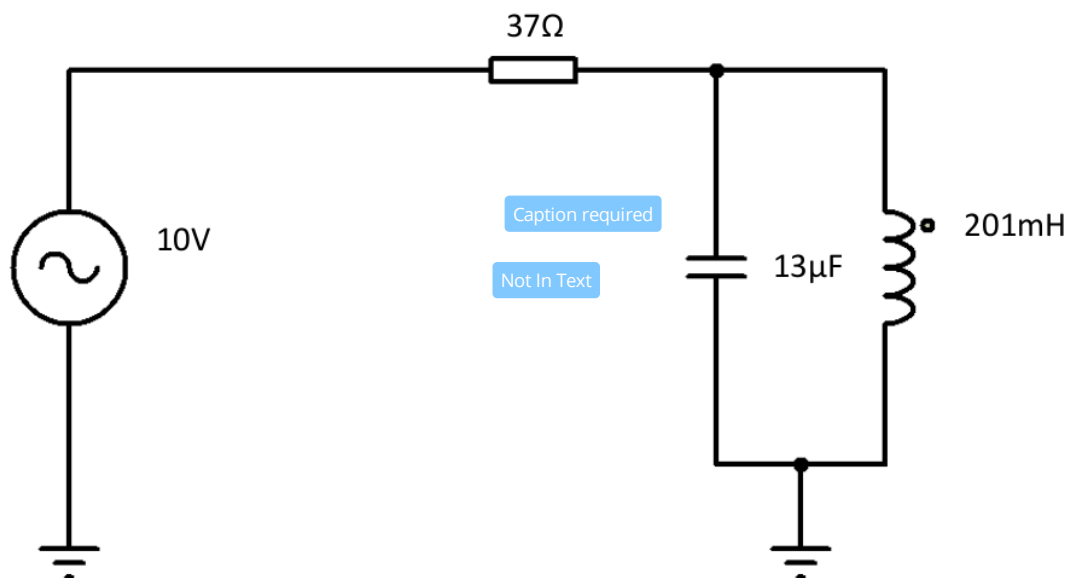
Resonance is where the reactance of a capacitor is equal to the resonance of the inductor while the imaginary part of the function is equal to zero. When at resonance, the impedance of the circuit is equal to the resistance value ($Z=R$). Resonant RLC circuits have many uses, such as in oscillator circuits and in radio receivers (where they are used to fine tune radio signals), they are also used in signal processing and communication systems, and can also be used in induction heating.

Maximum power transfer is where the most power is obtained from a power source. In an AC circuit occurs when the impedance of the load is equal to the conjugate of the impedance of the power source. Maximum Power Transfer is used in order to calculate the optimal ratio of load impedance to source impedance, this does not mean that it will be the most efficient use of power, just that the

maximum magnitude of power will be transferred. Where power is limited, it is essential that impedance matching is essential as it is critical to transfer as much power as possible. ^[4]

Use of 1st Person Voice

I am going to be essentially simulating an RLC circuit using determined values for my components, I have worked these out using my student ID number (2013713), this gives me the values of 201mH, 13 μ F and 37 Ω . These will be used alongside a 10V AC power supply and using various frequencies ranging from 1 to 1000000Hz. I will use formulae to calculate the resonant frequency, reactance of the inductor and capacitor, impedance of the parallel LC circuit and the total impedance of the circuit. I will then use these values to calculate the current, voltage drops, and then reactive, active and apparent powers in the circuit at various frequencies. I will create graphs to show my findings and this will allow me to compare what happens at the different frequencies, including resonant frequency. I will also be creating phasor diagrams to show current and voltage at resonant frequency, as well as 25Hz above and below resonance. I will also be calculating maximum power transfer in order to find the conditions at which it will occur within the circuit and creating a graph to show this.



Method

In the spreadsheet I used various formulae to calculate everything I needed, these are as follows:

$$\text{Resonant Frequency: } F_{\text{RES}} = \frac{1}{2\pi\sqrt{LC}}$$

$$\text{Inductive Reactance: } X_L = 2\pi fL$$

$$\text{Capacitive Reactance: } X_C = \frac{1}{2\pi fC}$$

$$\text{Parallel Impedance: } Z_{LC} = \frac{X_L \times X_C}{X_L + X_C}$$

$$\text{Total Impedance: } Z_{\text{Total}} = R + Z_{LC}$$

$$\text{Current: } I = \frac{V}{Z_{\text{Total}}}$$

$$\text{Voltage drop across resistor: } V_R = I \times R$$

$$\text{Voltage drop across LC parallel: } V_P = I \times Z_{LC}$$

$$\text{Active Power: } P = I^2 Z_{\text{Total}}$$

$$\text{Reactive Power: } Q = \text{Imaginary}(I^2 Z_{\text{Total}})$$

$$\text{Apparent Power: } S = \sqrt{P^2 + Q^2}$$

$$\text{Phase Angle: } \phi = \cos^{-1}(P/S) \text{ in Degrees}$$

$$\text{Power Factor: } PF = \cos \phi \text{ in Radians}$$

$$\text{Source Reactance: } X_{\text{SRC}} = 2\pi f \times 0.00015$$

$$\text{Source Impedance: } Z_{\text{SRC}} = R_{\text{SRC}} + jX_{\text{SRC}}$$

$$\text{Load Power: } P = \Re \left[\left(\frac{V}{Z_{\text{Load}} + Z_{\text{SRC}}} \right)^2 Z_{\text{Load}} \right]$$

The spreadsheet works by firstly entering the known values for the resistor, inductor, capacitor and the voltage source. I firstly calculated the resonant frequency, using the resonant frequency calculation and then created my frequency column which goes from 1 to 1000000 Hz with my resonant frequency placed in the right place. I then created a column where my resistance is copied all the way down. I then used the equations for inductive reactance and capacitive reactance to create columns for them, parallel impedance is then calculated using the formula and the values are produced in accordance with the reactance and frequency variations in the same row. Total impedance is calculated using the value of the parallel impedance and the resistor value. Current can

then be found using $I = V/Z_{\text{Total}}$. When using the spreadsheet, for various calculations, different forms of the values need to be used, in some cases, the complex form of the number needs to be used and in other cases the absolute form needs to be used. I then calculate the voltage drops across the resistor and the parallel LC circuit.

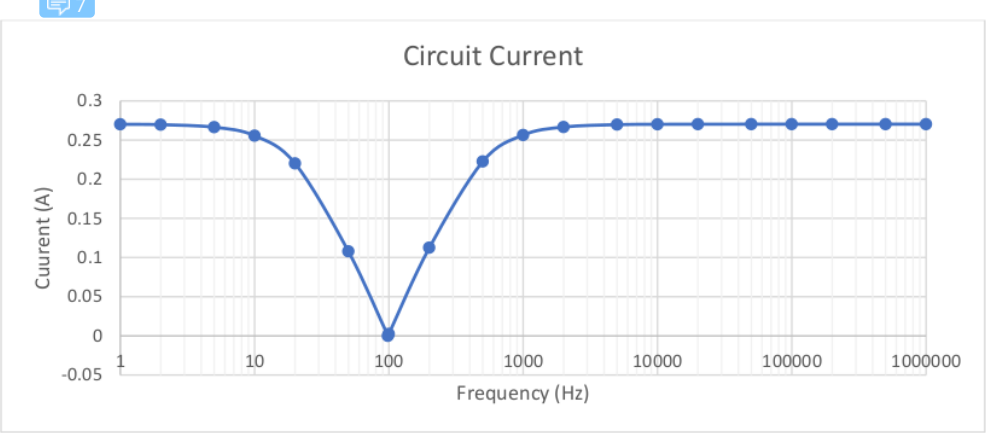
Using these values calculated so far, the active power, reactive power, apparent power, phase angle and power factor can all be determined using the calculations above in order of how I have listed them in this paragraph. Using these results, I created graphs by highlighting the various aspects of my spreadsheet and compared them to the frequency column to show how Current, V_R , V_{LC} , Power and Power Factor are related to frequency as it increases.

The resonant frequency is used as well the frequencies that are 25Hz above and below resonance, to calculate, in a separate part of the spreadsheet, the same values as above, such as reactance, power, impedance etc. As well as calculating the angle of V_{LC} and the angle of V_R . These values are used to produce phasor diagrams to show the voltage and current at the frequency values stated above.

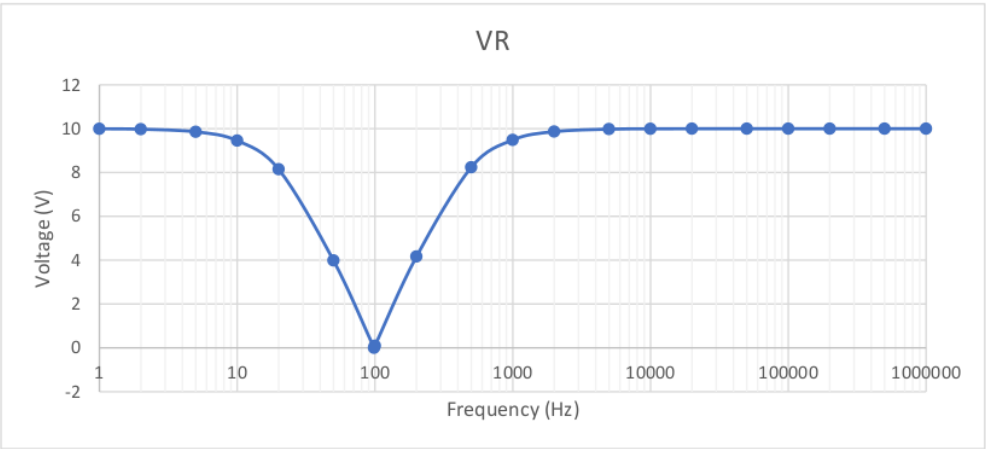
A maximum power transfer graph was also created on a separate spreadsheet, using a random frequency, a voltage supply of 10V with an internal resistance value of 5Ω , and an inductance of $0.00015\mu\text{H}$. I calculated the reactance of the inductor and the total internal impedance of the voltage source. I then set up two axis, my Y axis being load resonance and my X axis being load resistance. Using these two axis and the calculation for Load Power shown above, I created a table that shows load power against load reactance and load resistance when using the specified voltage source. This gave me a graph to show the precise point where maximum power transfer occurs.

Results

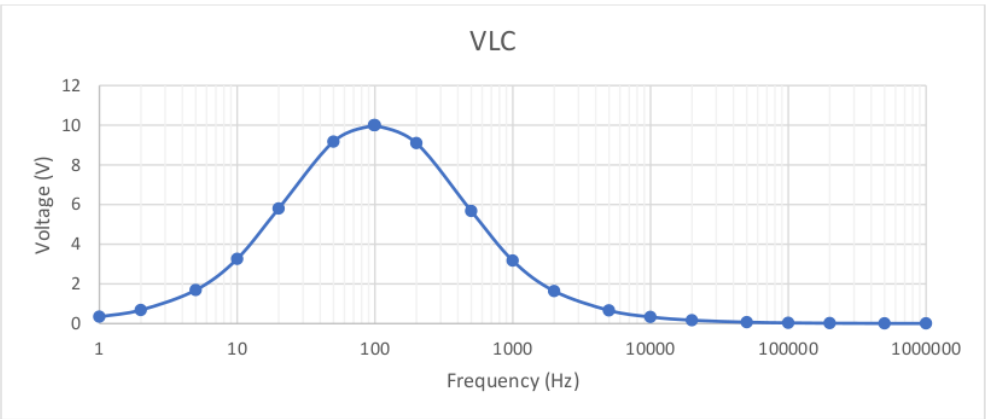
Graph 1



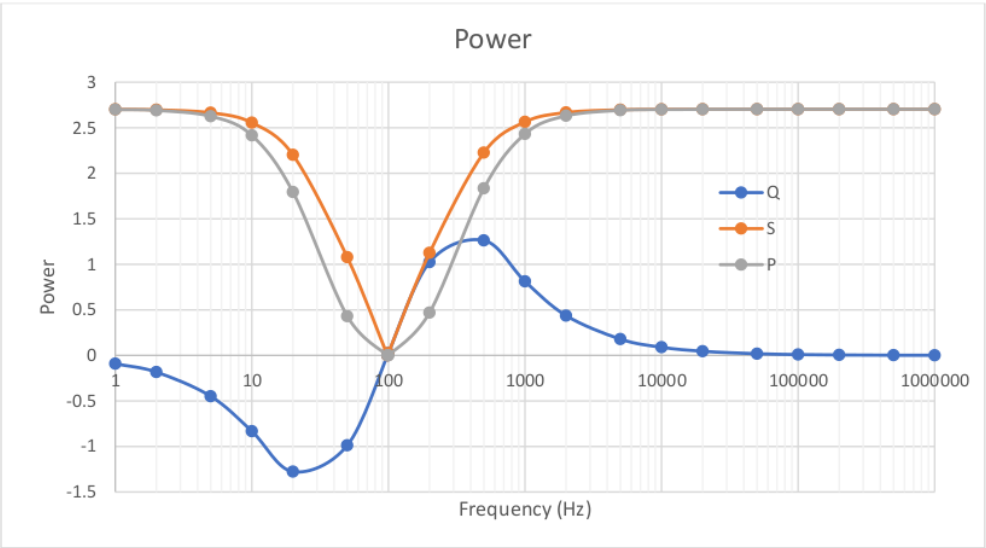
Graph 2



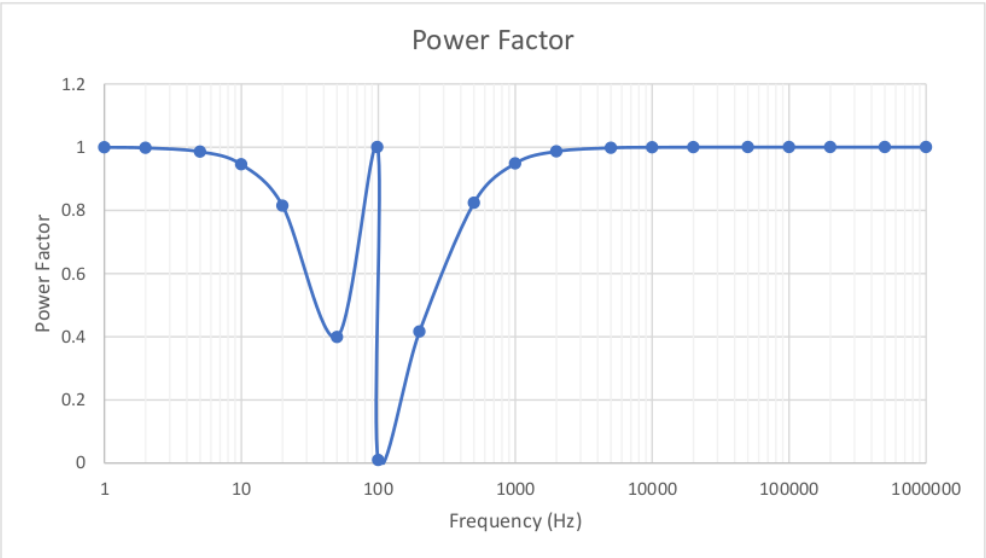
Graph 3



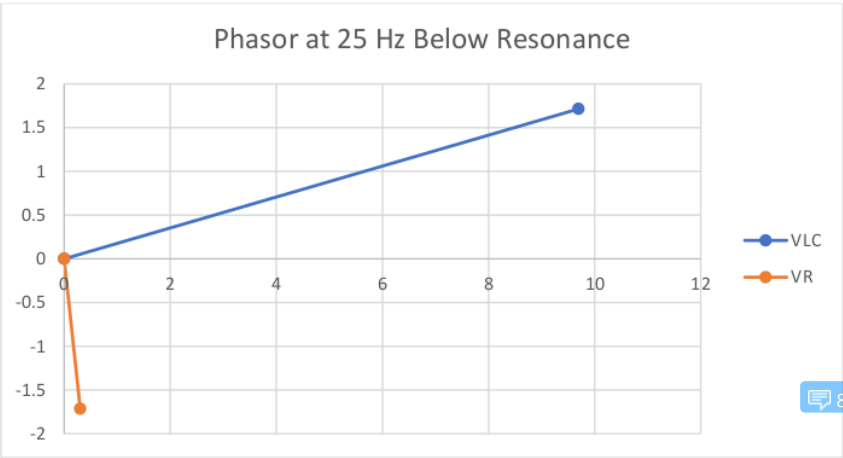
Graph 4



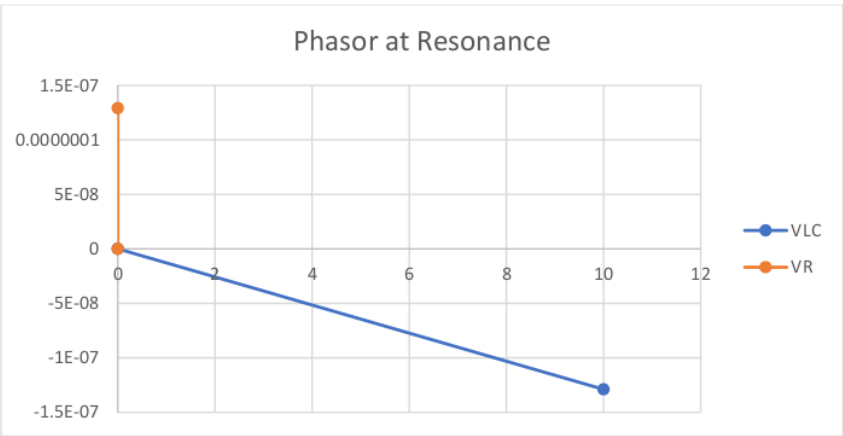
Graph 5



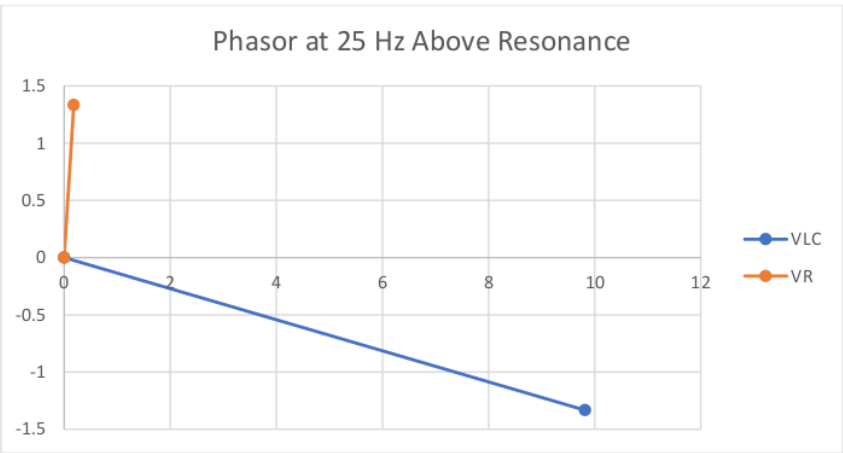
Phasor 1

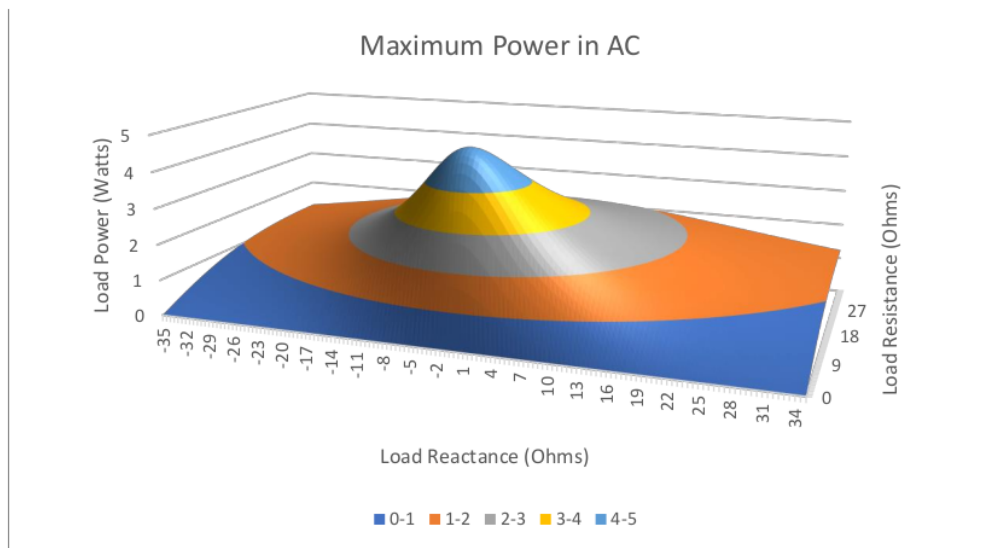


Phasor 2



Phasor 3





Discussion

The graphs 1-3 show that before resonance (98.45787Hz), the circuit is capacitive and after resonance it is inductive. This is due to the reactance's are not equal and one is larger than the other. As can be seen from the graphs, at resonance, current, and voltage across the resistor (VR) are zero while voltage across the parallel LC circuit becomes a maximum of 10V. Graphs 4 and 5 show that the active power, reactive power and apparent power all become very close to zero too which although minimal proves that maximum power factor occurs at this point, as also seen in graph 5.

The phasor diagrams show the difference at resonance as well as 25Hz above and below this frequency. They show that at resonance, the voltage drop across the resistor and the parallel circuit are minimal and that the phase angle of the voltage across the resistor is almost 0. At 25Hz below resonance you can see how the voltage across the resistor and parallel LC circuit are opposite of the phasor showing VR and VLC at 25Hz above resonance, this shows how the circuit is capacitive before the resonant frequency and inductive after the resonant frequency.

As can be seen, the graphs 1-5 have certain features at roughly 100Hz, this is because the resonant frequency of the circuit is 98.45787Hz. At this frequency, the reactance's of the capacitor and the inductor are equal and opposite, this happens because the inductor has a collapsing magnetic field that generates a current in its windings and charges the capacitor that is in parallel with it, but the capacitor is discharging which provides an electrical current that supplies the inductors magnetic field. Since the current in both the capacitor and the inductor are equal and opposite, the discharging of the capacitor and the inductors magnetic field breaking down happens continually and repeatedly at this frequency. This means that there is the minimum amount of current in this loop of the circuit. ^[1]

As seen in the graph for maximum power transfer, the point of maximum power transfer occurs when the load resistance is 5Ω and the load reactance is 0Ω . If the reactance is 0 then this means that $X_L = X_C$, at resonance this is also the case as seen in the above graphs and for power factor correction, power factor correction is done so that the maximum power transfer is maintained at a value as close to 1 as possible. For maximum power transfer the total impedance of the load should be equal to the conjugate of the internal impedance of the power source.

Conclusion

Throughout this work I have found that maximum power transfer occurs when the impedance of the load is equal to the conjugate of the internal impedance of the power source. That when reactance's are equal and opposite you get a power factor of 1 and that this is where resonance occurs. I have also found that maximum power transfer and resonance occur when $X_L = X_C$ and this allows for the greatest power factor possible in a circuit, I have also found that max power transfer does not necessarily mean most efficient. I have found that before resonance a parallel RLC circuit is capacitive and after resonance it is inductive.

References

1. Academic Dictionaries and Encyclopedias. 2010. *Electrical Resonance*. [online] Available at: <<https://enacademic.com/dic.nsf/enwiki/1700977>> [Accessed 13 November 2020].
2. Electronics Tutorials. 2020. *Power Factor Correction*. [online] Available at: <<https://www.electronics-tutorials.ws/accircuits/power-factor-correction.html>> [Accessed 26 November 2020].
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4. Triad Magnetics. 2020. *Understanding The Maximum Power Theorem*. [online] Info.triadmagnetics.com. Available at: <<https://info.triadmagnetics.com/blog/maximum-power-theorem#:~:text=The%20maximum%20power%20theorem%2C%20better,exactly%20matched%20to%20load%20impedance.>> [Accessed 26 November 2020].

Daniel Davies Electrical Engineering Assignment

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

61 / 100

PAGE 1

PAGE 2

PAGE 3

QM

Use of 1st Person Voice

When writing technical reports, do not use first person voice. Instead, use the third person passive voice.

You should not use words like "I", "you", "we" etc..



Comment 1

Nice abstract, but you should also include a statement of your results.



Comment 2

reactance not resonance

PAGE 4



Comment 3

repetition

QM

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Comment 4

There are far too many zeros to count here.

You should always use standard prefixes for units. This should be written as 1 MHz and not 1000000 Hz



Caption required

You should always include a caption on figures, equations and tables to allow you to refer to them in your text.

e.g. An illustration of this can be seen in figure 2. The relationship of the variables is shown in equation 2. Table 1 shows the results of the first experiment where the control variable, temperature in degrees celsius is shown in the first column....



Not In Text

You have included a figure without mentioning it in the text. You should refer to the figure in the text, otherwise it is not worth including as the reader will not know what it relates to.

PAGE 5



Comment 5

Use standard prefixes

PAGE 6



Use of 1st Person Voice

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Comment 6

reactance not resonance

PAGE 7



Comment 7

Captions should be placed beneath the item it belongs to.

PAGE 8

PAGE 9



Comment 8

Why have you not included the circuit current on these?

QM

Misplaced apos.

Misplaced apostrophe:

An apostrophe can function to indicate a possessive when accompanied by an -s ("the book that belongs to Roy" = "Roy's book"). For words that already have an -s at the end, just adding the apostrophe will do ("the team belonging to the boys" = "the boys' team"). Certain exceptions to this rule apply, and possessive personal pronouns ("like ours," "yours," "hers," "his," "its") are possessive already and therefore do not take an apostrophe. It is always wrong to use a possessive apostrophe to simply make a word plural.



Comment 9

total reactance is zero



Comment 10

Not the load reactance, the total combined reactance of the source and load.

At the point of maximum power transfer, the load reactance can be any value (capacitive or inductive) so long as the source reactance is equal and opposite.

QM

Use of 1st Person Voice

When writing technical reports, do not use first person voice. Instead, use the third person passive voice.

You should not use words like "I", "you", "we" etc..

QM

Ref Qual

You should try to use more high quality reference sources, such as textbooks from reputable academic publishers and articles from peer reviewed journals.



Comment 11

I would have like to see a few more references.

ENGAGEMENT WITH LITERATURE

including reading, referencing, academic conventions and academic honesty



References to a limited range of mostly relevant sources. Some omissions. Referencing conventions evident though not always applied consistently.

4.9

KNOWLEDGE & UNDERSTANDING

Knowledge of the basic underlying concepts and principles of a subject.



Knowledge is extensive. Exhibits understanding of the breadth and depth of established views.

20.4

COGNITIVE & INTELLECTUAL

Evaluate underlying concepts and principles of a subject and interpret qualitative and quantitative data in order to develop lines of argument and make sound judgements.



Sound, logical, analytical thinking; synthesis and evaluation. Ability to devise and sustain persuasive arguments. Ability to communicate ideas and evidence accurately and convincingly. Sound, convincing conclusions

18.3

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.

 A very good application of a range of methods, materials, tools and techniques. Very good consideration of the context of the application, with perceptive use of examples, where relevant.

12.4

TRANSFERABLE SKILLS

Communicate the results of their study/work accurately and reliably, and with structured and coherent arguments; the qualities needed for employment requiring the exercise of some personal responsibility within a structured and managed environment.

 Can communicate effectively in a suitable format, but may have minor errors. Mostly coherent work and is in a suitable structure.

5.2