

Charlie Rainey - Electrical engineering

by Charlie Rainey

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ACDA 5001 Electrical Engineering Assignment

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Abstract

In task 1 an AC RL-C circuit was designed using proteus using the given figures for the circuit components. From this a graph was plotted of the circuit current and load voltage over time. Once the circuit was designed, calculations could be made such as active, reactive and apparent power. Not only this but the power factor was calculated as well as power factor correction capacitor value. Two graphs were then plotted of power factor against capacitor value and phase angle against capacitor value. This then led nicely onto task 2 where four different phasor diagrams had to be displayed to show component voltages and current at resonant frequency, 25 Hz above and 25Hz below resonant frequency and at 50Hz frequency. Task 3 was a research task to explain how the power factor correcting capacitor affects resonance in the circuit, achieving maximum power transfer and energy efficiency in the circuit. Finally, for task 4 an engineering report was to be written explaining how all the previous tasks mentioned were achieved.

After completing all the above tasks, it is clear to see the benefits of adding the power factor correcting capacitor to the circuit and how the two circuits differ from each other and the graphs that were produced. By having a power factor rating as close to 1 it improves many things but the most important being circuit resonance, maximum power transfer and energy efficiency. All of this is explained in the report below with all relevant circuit drawings, graphs, tables and calculations.

Introduction

The assignment is based on an AC RL-C circuit and also the resonance, maximum power transfer and the power factor of the RL-C circuit. An RLC circuit is created when an alternating source of voltage is connected in series with the inductance L , resistance R , and capacitor C . They will all have the same amount of current flowing through them but because they are connected in series, however the voltage will differ. AC circuits are powered by alternating sources, such as sinusoidal alternating currents or voltages that fluctuate in amplitude and direction on a regular basis. Put otherwise, the oscillation of voltage or current is a sine wave pattern that changes over time. [1]¹

True power dissipation divided by apparent power dissipation is the power factor of an alternating current circuit. An RLC circuit's power factor shows how close it is to using up all of its energy. Power factor can be rated between 0-1 with a power factor of 1 being the best. [2]²

When the reactive effects of the capacitor and inductor cancel each other out, a series RLC circuit reaches resonance and becomes entirely resistive. The circuit displays some intriguing characteristics during resonance, including a maximum current and a minimum impedance. Resonant frequency can be calculated by equating X_L and X_C .

This will give the final equation of $f_r = \frac{1}{2\pi\sqrt{LC}}$ [3]

When the internal impedance of the circuitry driving the load is equal to the complex conjugate of the load impedance, the maximum load power is reached. Typically, this calls for the use of a Norton or Thévenin analog. Last but not least, while maximum power transfer is a desirable result in some circumstances, it is not in others. The efficiency factor is the cause. Efficiency is just 50% when the load power is at its highest. On the other hand, the efficiency will rise but the load power will drop when the load impedance exceeds the source impedance. A higher level of efficiency is especially crucial when trying to reduce heat and prolong battery life. [4]

Method

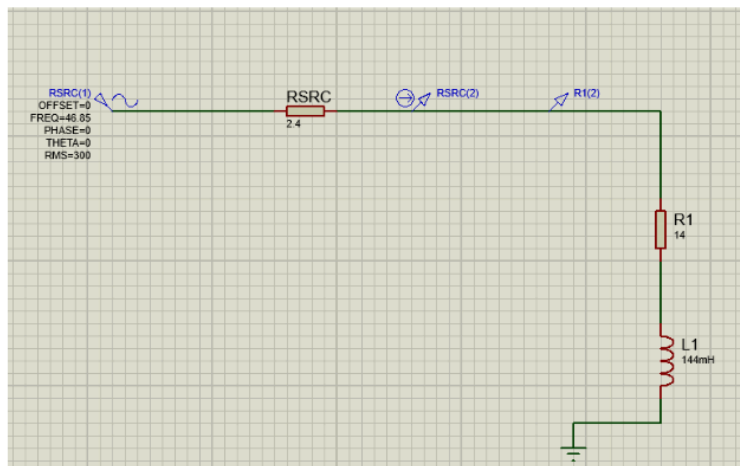
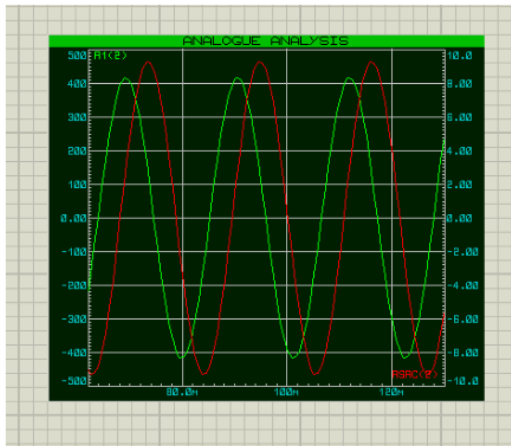


Figure 1.0 - RL Circuit

To start off task 1, a circuit was built using proteus without the power factor correction capacitor as shown above in figure 1.0, from building this circuit it allowed the ability to build an important graph of circuit current and load voltage over time as show below in graph 1.0. From this graph figures were taken to allow the following calculations to be carried out.



6 1.0 - RL Circuit, circuit current and load voltage

After this, calculations were carried out to find the power factor of the circuit, what the power factor correction capacitor value needs to be to achieve a power factor of ≥ 0.95 and the active, reactive and apparent power of the circuit. To calculate the power factor the equation $P.F \text{ (power factor)} = \cos \phi$ however to use this equation ϕ had to be calculated by using the equation

$$\phi = \frac{t}{T} \times 360$$

From using the graph figures could be used for this sum so it looks like

$$\phi = \frac{2.54}{20} \times 360 = 45.72$$

Finally, $P.F = \cos(45.72)$ this gave a power factor of 0.698.

To calculate the power factor correction capacitor value there are a series of multiple different calculations to allow the equation

$$C = \frac{1}{2\pi \times f \times X_c}$$

As a power factor of 0.95 is wanted then $\cos \phi = 0.95$ which means

$$\phi = \cos^{-1}(0.95)$$

So finally, $\phi = 18.2$ degrees. From here on I_r , I , A_c , I_c , and X_c were able to be calculated. They all needed to be calculated to allow the ability to calculate the next so

that means without I_r then a figure for I would not have been calculated and so on. The most important being X_c so it can be used in the equation calculate C . After all this the equation finally looked like

$$C = \frac{1}{2\pi \times 50 \times 94.038}$$

This gave the answer of $C = 33.85\mu$

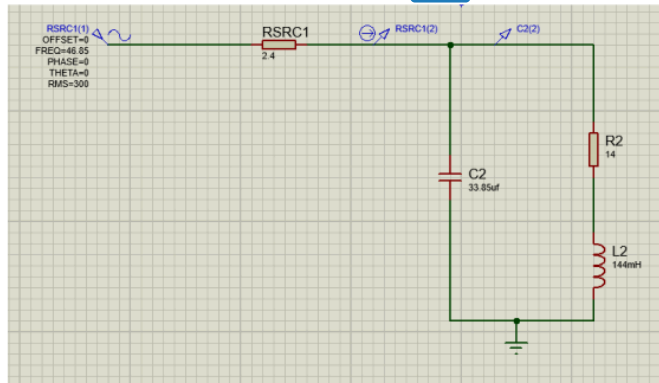
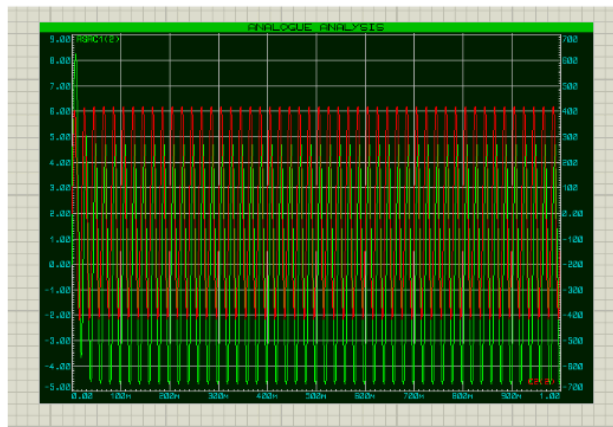


Figure 2.0 - RL-C Circuit

Now that the power factor correction capacitor value has been calculated this could be added into the RL circuit to create a RL-C circuit as shown in figure 2.0 this circuit has a power factor of 0.95 which was the desired goal in task 1. Another graph of circuit current and load voltage against time was created as shown below in Graph 2.0.



Graph 2.0 - RL-C Circuit, circuit current and load voltage

Finally, the reactive, active and apparent power of the circuit were calculated using the following formulas. For active power,

$$P = V \times I \times \cos\theta$$

$$= P = 300 \times 4.703 \times \cos(18.2)$$

This gives the active power to be P=1340.32W. For reactive power,

$$Q = V \times I \times \sin\theta$$

$$= Q = 300 \times 4.703 \times \sin(18.2)$$

This gives the reactive power to be Q=440.67VAR. Finally for apparent power,

$$S = V \times I$$

$$= S = 300 \times 4.703$$

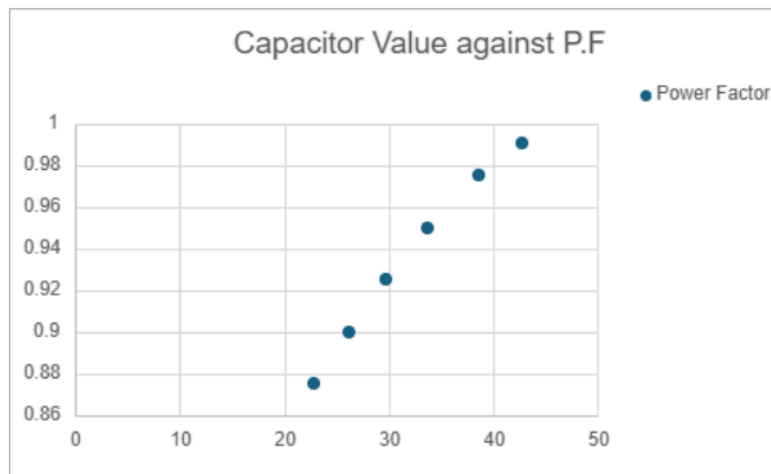
This gives the apparent power to be S=1410.9VA.

For the final part of task 1, two graphs were to be plotted, one graph being capacitor value against power factor and the other graph being capacitor value against phase angle. All the figures for the graphs are displayed in table 1.0 below.

2				
3		Capacitor Value (uf)	Power Factor	θ
4		22.96	0.875	28.96
5		26.33	0.9	25.85
6		29.82	0.925	22.33
7		33.85	0.95	18.2
8		38.73	0.975	12.84
9		42.86	0.99	8.11
10				
11				

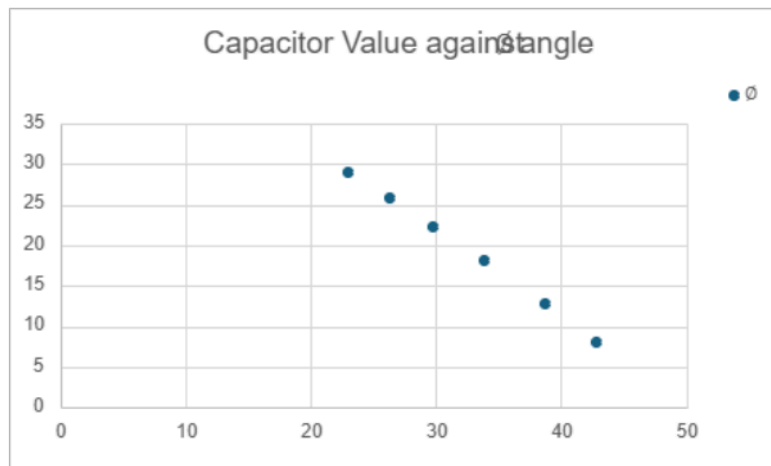
Table 1.0 - Figure 8 for capacitor value against power factor and phase angle

These figures were calculated and are the figures that have been used in graph 3.0 and graph 4.0 below. The two graphs were both created using excel and show the correlation between capacitor value and power factor as well as the correlation between capacitor value and phase angle.



Graph 3.0 - Capacitor value against power factor

The x axis for this graph is the capacitor value in microfarads and the y axis is the power factor.



Graph 4.0 - Capacitor value against the phase angle

The x axis for this graph is capacitor value in microfarads and the y axis is phase angle in degrees.

The final part of task one was to describe what happens to the capacitor and inductor when the power factor increases, in order to eliminate the additional power needed from the supply, it is possible to balance the inductive and capacitive loads. The leading current from a PFC capacitor

will assist the measurement approach unity (power factor of 1). This represents the point of equilibrium between the voltage and current waveforms. Power drawn from the supply decreases as the metric gets closer to unity. As a result, less electricity must be generated to meet demand. A circular route that permits the flow of electricity is called an electrical circuit. Since this network is closed, the current has a way to return. Power factor correction (PFC) is the process of increasing an electrical circuit's power factor. Adding a capacitor to a circuit in addition to your switchgear is one method of achieving PFC. By storing energy in an electric field, the capacitor can help your electrical systems operate more efficiently, which will lower your electricity bills.  10

The inductive load causes a distorted current waveform which causes a phase difference between the voltage and current. This is then cancelled out by the addition of the power factor correcting capacitor.  11

Results

For task two, four different phasor diagrams had to be drawn and each phasor diagram representing a different frequency showing how the circuit reacts to the change in frequency. To create these phasor diagrams a numerous number of calculations were carried out prior to giving us the values for:

I , I_L , V , ϕ_L , ϕ , I

All these component values are key to drawing all the phasor diagrams.

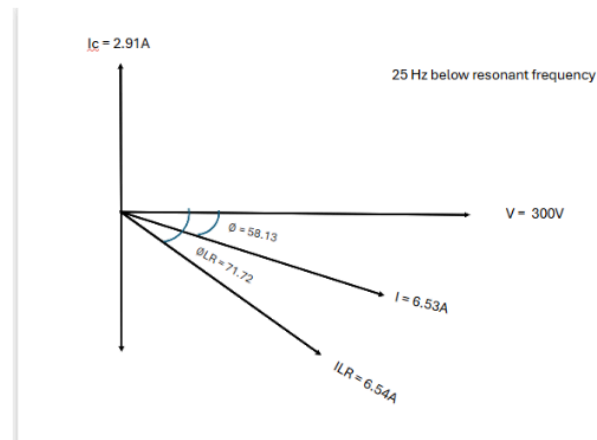


Diagram 1.0 - Phasor diagram at 25Hz below resonant frequency

To create this phasor diagram the following calculations were used:

$$Xl = 2\pi \times F \times L$$

With the values added into the equation:

$$Xl = 2\pi \times 46.85 \times 144 \times 10^{-3}$$

$$Xl = 42.39\Omega$$

$$Xc = \frac{1}{2\pi \times f \times c}$$

With the values added into the equation:

$$Xc = \frac{1}{2\pi \times 46.85 \times 33.85 \times 10^{-6}}$$

$$Xc = 100.36\Omega$$

$$I_{lr} = \frac{V_{lr}}{Z_{lr}}$$

With the values added into the equation:

$$I_{lr} = \frac{292.04}{44.64}$$

$$I_{lr} = 6.54A$$

$$I_c = \frac{V_c}{X_c}$$

With the values added into the equation:

$$I_c = \frac{292.04}{100.36}$$

$$I_c = 2.91A$$

$$\phi_{lr} = \tan^{-1} \left(\frac{42.39}{14} \right)$$

$$\phi_{lr} = 71.72^\circ$$

$$I_{lr} \sin \phi_{lr} = 6.21$$

$$I = \frac{9.24}{\sqrt{2}} = 6.53A$$

$$\phi = \tan^{-1} \left(\frac{3.3}{6.54 \cos(71.72)} \right)$$

$$\phi = 58.13^\circ$$

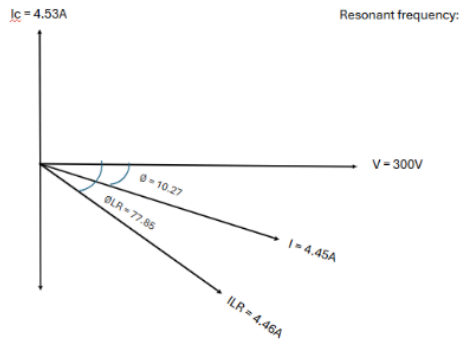


Diagram 2.0 - Phasor diagram at resonant frequency

To create this phasor diagram the following calculations were used:

$$Xl = 2\pi \times f \times l$$

With the values added into the equation:

$$Xl = 2\pi \times 71.85 \times 144 \times 10^{-3}$$

$$Xl = 65.01\Omega$$

$$Xc = \frac{1}{2\pi \times f \times c}$$

With the values added into the equation:

$$Xc = \frac{1}{2\pi \times 71.85 \times 33.85 \times 10^{-6}}$$

$$Xc = 65.44\Omega$$

$$I_{lr} = \frac{V_{lr}}{Z_{lr}}$$

With the values added into the equation:

$$I_{lr} = \frac{296.28}{66.5}$$

$$I_{lr} = 4.46A$$

$$I_c = \frac{V_c}{X_c}$$

With the values added into the equation:

$$I_c = \frac{296.28}{65.44}$$

$$I_c = 4.53A$$

$$\phi_{lr} = \tan^{-1} \left(\frac{65.01}{14} \right)$$

$$\phi_{lr} = 77.85^\circ$$

$$I_{lr} \sin \phi_{lr} = 4.36$$

$$I = \frac{6.30}{\sqrt{2}} = 4.45A$$

$$\phi = \tan^{-1} \left(\frac{0.17}{4.46 \cos(77.85)} \right)$$

$$\phi = 10.27^\circ$$

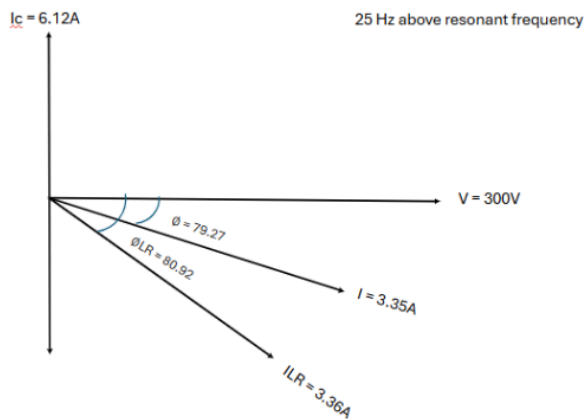


Diagram 3.0 Phasor diagram at 25Hz above resonant frequency

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The create this phasor diagram the following calculations were used:

$$X_l = 2\pi \times f \times l$$

With the values added into the equation:

$$X_l = 2\pi \times 96.85 \times 144 \times 10^{-3}$$

$$X_l = 87.63\Omega$$

$$X_c = \frac{1}{2\pi \times f \times c}$$

With the values added into the equation:

$$X_c = \frac{1}{2\pi \times 96.85 \times 33.85 \times 10^{-6}}$$

$$X_c = 48.55 \Omega$$

$$I_{lr} = \frac{V_{lr}}{Z_{lr}}$$

With the values added into the equation:

$$I_{lr} = \frac{296.98}{88.42}$$

$$I_{lr} = 3.36 \text{ A}$$

$$I_c = \frac{V_c}{X_c}$$

With the values added into the equation:

$$I_c = \frac{296.98}{48.55}$$

$$I_c = 6.12 \text{ A}$$

$$\phi_{lr} = \tan^{-1} \left(\frac{87.63}{14} \right)$$

$$\phi_{lr} = 80.92^\circ$$

$$I_{lr} \sin \phi_{lr} = 3.32$$

$$I = \frac{4.74}{\sqrt{2}}$$

$$I = 3.35 \text{ A}$$

$$\phi = \tan^{-1} \left(\frac{2.8}{3.36 \cos(80.92)} \right)$$

$$\phi = 79.27^\circ$$

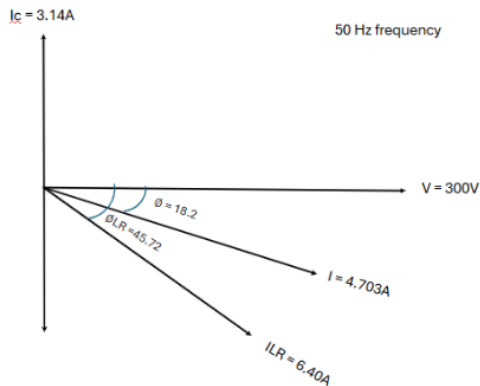


Diagram 4.0 - Phasor diagram at 50Hz frequency

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To create this phasor diagram the following calculations were used:

$$Xl = 2\pi \times f \times l$$

With the values added into the equation:

$$Xl = 2\pi \times 50 \times 144 \times 10^{-3}$$

$$Xl = 45.24\Omega$$

$$Xc = \frac{1}{2\pi \times f \times c}$$

With the values added into the equation:

$$Xc = \frac{1}{2\pi \times 50 \times 33.85 \times 10^{-6}}$$

$$Xc = 94.04\Omega$$

$$I_{lr} = \frac{V_{lr}}{Z_{lr}}$$

With the values added into the equation:

$$I_{lr} = \frac{294.86}{47.36}$$

$$I_{lr} = 6.23A$$

$$I_c = \frac{V_c}{X_c}$$

With the values added into the equation:

$$I_C = \frac{294.86}{94.04}$$

$$I_C = 3.14 \text{ A}$$

$$\phi_{lr} = \tan^{-1} \left(\frac{45.24}{14} \right)$$

$$\phi_{lr} = 72.80^\circ$$

$$I_{lr} \sin \phi_{lr} = 5.95$$

$$I = \frac{8.74}{\sqrt{2}}$$

$$I = 6.18 \text{ A}$$

$$\phi = \tan^{-1} \left(\frac{2.81}{6.23 \cos(72.8)} \right)$$

$$\phi = 56.75^\circ$$

Discussion

After calculating a suitable capacitor value for the circuit to achieve a power factor of 0.95, this relates to three key things in the circuit. These three things being circuit resonance, achieving maximum power transfer and energy efficiency. With regards to energy efficiency, achieving a power factor of 0.95 or higher is important for the circuit because the reactive power is essentially just wasted energy and this needs to be reduced. The reason it needs to be reduced is because energy companies will fine large industrial customers if their power factor is under a certain amount, usually in the region of below 0.9-0.8. Having a high, power factor will reduce the current flow in a supply system which consequently reduces the losses and results in cheaper running costs.

When the resistive value of the load equals the internal resistance of the voltage source, maximum power transfer takes place, enabling the supply of maximum power. When inductors or capacitors are used, the source resistance, or even the impedance, is often fixed at a value in Ohm's. The load's impedance will change from an open-circuit to a

short-circuit condition when a load resistance, R_L , is connected across the power source's output terminals. As a result, the power that the load absorbs will become reliant on the impedance of the real power source. Maximum Power Transfer is based on the requirement that the load resistance be "matched" to the power source's impedance in order for it to absorb the maximum amount of power. Another helpful circuit analysis technique is the Maximum Power Transfer Theorem, which guarantees that when the load resistance is precisely equal to the resistance of the power source, the maximum amount of power will be wasted in the load resistance. The power in the load is determined by the relationship between the load impedance and the energy source's internal impedance. Having a higher power factor means that when this power transfer takes place it is more likely to achieve a higher power transfer and closer to the maximum amount possible. [7]

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The frequency of the alternating potential difference has an impact on the circuit's impedance. The inductive reactance rises and the capacitive reactance falls (but not equally) as the frequency of the alternating potential difference increases. The absolute difference between a circuit's capacitive and inductive reactance determines its impedance. The applied alternating potential difference frequency that produces the most current in a circuit is known as its resonant frequency. While frequencies farther from the resonant frequency produce currents of reduced amplitude, alternating potential difference frequencies close to the resonant frequency produce currents of currents that are almost equal to the resonance frequency current. The effects of the capacitor and inductor cancel each other out at resonance, and the RL-C circuit operates as a simply resistive circuit. The circuit that operates the most efficiently is this one. Because of this, a lot of electric companies even offer incentives to businesses that have a power factor that is extremely near to 1. [8]

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Conclusion

From carrying out this assignment it is clear to see the many differences between the circuits in figure 1.0 and figure 2.0, as well as graph 1.0 and graph 2.0 after applying a power factor correction capacitor to the circuit to achieve a power factor of 0.95. In graph 2.0 the current and voltage waveforms are much closer together than in graph 1.0 which shows that the circuit is more in phase after adding the capacitor. By adding this into the circuit it makes the circuit more energy efficient, allows maximum power transfer and circuit resonance. This just shows how important the power factor of a circuit is and why companies aim to have a power factor rating of over 0.9. If the circuit shown in figure 1.0 was to be used in industry, then energy companies would fine the company using that circuit due to the power factor being so low. The circuit in figure 1.0 is

consuming a high amount of energy and most of it is being wasted. However, the circuit in figure 2.0 wastes less energy due to the power factor correction capacitor. This circuit still may consume a large amount of energy however the energy it consumes is being used. By correcting the power factor, it can save companies money and allow them to get the most out of what they are paying for at the same time. Not only this but having a power factor rating closer to one also allows resonance. The effects of the capacitor and inductor cancel each other out at resonance, and the RL-C circuit operates as a simply resistive circuit. This is the most efficient circuit and again by achieving this you can save more money as energy companies will offer incentives if you are able to prevent energy waste.

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GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

75/100

PAGE 1

PAGE 2



Comment 1

It would have been better with table of content.



Comment 2

The
citation should be mentioned before the full stop



Comment 3

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citation should be mentioned before the full stop

PAGE 3



Comment 4

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Comment 5

Good work



Comment 6

It is better to name it as figure



Comment 7

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Caption for the table should be positioned at the top of the table



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Line
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PAGE 17

GRADING FORM: GRADING

CHARLIE RAINEY

74.90

ENGAGEMENT WITH LITERATURE

Marks will be awarded based on the extent of research and/or own reading, selection of credible sources, application of appropriate referencing conventions. You must include evidence of sources that you have discovered yourself during the course of your own student centred work.



Engagement with an extensive range of relevant and credible literature. Consistently accurate application of referencing. Need improvement in referencing and Citation

7

KNOWLEDGE AND UNDERSTANDING

Marks will be awarded for the depth and accuracy of understanding shown in explaining concepts, theories, and principles related to the topic. Work should reflect an understanding of the foundational principles as well as recent developments in the field. Explanations should show depth and clarity in conveying complex information.



Excellent, detailed knowledge and highly critical understanding of the well-established concepts

and principles of Electrical Engineering in Power factor correction. It would have been better if more information's were provided about theory behind PFC with appropriate referencing.

23.4

COGNITIVE AND INTELLECTUAL

Marks will be awarded for evidence of critical thinking, logical reasoning, and analytical depth. Explaining why specific methods or approaches were chosen and how they address the problem. Evidence of synthesis and evaluation should be present, breaking down information and offering well-supported conclusions.



Excellent critical evaluation and analysis of concepts and principles of Electrical Engineering leading to logical, evidence-based, reasoned arguments and judgements. It would have been better with more detailed interpretation of obtained data.

22.5

PRACTICAL SKILLS

Apply relevant techniques and tools effectively, demonstrating how theoretical knowledge is translated into practice. Use simulation to address practical scenarios, with attention to how they apply in real-world contexts. Work should be well-organised, with awareness of limitations and considerations relevant to practical applications.



An advanced application of a range of established methods, materials, tools and/or techniques. The context of the application is well considered, and insightful. Consistent, accurate and logical application of theory to practice, making well-developed links between the two.

15.5

TRANSFERABLE SKILLS FOR LIFE

Marks will be awarded for the overall quality and professionalism of the work, including organisation, coherence, and presentation. Effective communication of technical information, use of visuals, and a well-structured report, Fluency and clarity in language are essential for higher scores.



Can communicate professionally confidently and consistently in a suitable medium for the audience. Work is coherent, very fluent and is presented proficiently. It would have been better with a table of content, proper caption for each figure and proper alignment. The ability to simulate the Electrical and Electronic circuit and the critical analysis of the collected data are evident from the report.

6.5