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 1 ronics Assignment

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4 uction

This report will showcase an AC response of an RLC network, more specifically it will be a true LR-C parallel circuit with an alternating current supply. The capacitor within this circuit acts as a power correcting capacitor and in this report the before and after power factor corrections will be shown. Proteus will be used for the construction of the circuit, while giving current and voltage readings, as well as showcasing the power factor graphs. Additionally, how the power factor affects both the voltage current and maximum power transfer will be in the contents of this report.

The main objective of this report is to showcase power factor and the use of a capacitor to 'power correct'. A high power factor indicates that the electrical system is using energy efficiently, which can result in lower electricity bills and a reduced environmental impact. A poor power factor leads to an increase in the current flow, which in turn causes the voltage drop in the conductor to be increased. For example low voltage can cause serious damage to electrical components and electric motors, so in machinery its vital that the voltage doesn't drop due to a poor power factor. Power factor correction will reduce the voltage drop at the conductor, thereby increasing the voltage at the equipment. As a result, equipment runs more efficiently, it's safer, and you experience fewer maintenance problems.

Before power factor correction

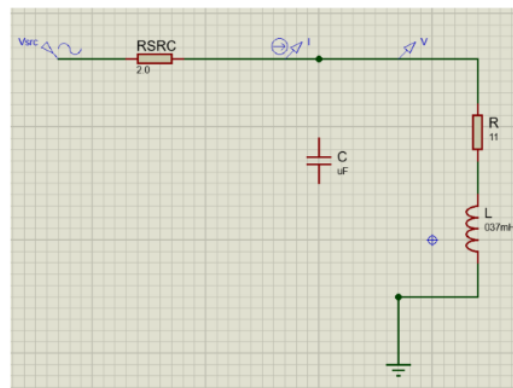


Figure 1

Figure 1 is the circuit that was constructed in proteus. As you can see it's an LR-C parallel circuit however, the capacitor is not yet connected as the power factor is not yet known. Before calculating the power factor correction capacitor value and incorporating it into the circuit, a graph will be made showing the waveform of both the voltage and the current in circuit, from where the voltage and current probes are placed which will showcase the phase difference before power factor correction.



Figure 2

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Figure 2 shows the phase difference before the power factor correction has been applied. The red line on the graph identifies the voltage and the green line identifies the current. It shows that the voltage is not in phase with the current, meaning the power factor is not equal to or above 0.95, which is what was expected as the power factor correcting capacitor has not yet been calculated or applied to the circuit as previously shown.



Figure 3

Another interesting point is that, as figure 3 shows, the voltage is peaking at around 44v and the current is peaking at 22A. With the purpose of power factor correction being to reduce current and in return reduce voltage therefore, making it more efficient. Also the measurements of both voltage and current will be taken after the applied power factor correction.

After power factor correction

Next is to calculate the active power, which is the result of resistive components, along with reactive power, which is the result of capacitive/inductive components and finally the apparent power which is both these powers combined. Once I have done those calculations I will calculate the power factor and choose an appropriate capacitor value to correct the power factor of the load to more than or equal to 0.95.

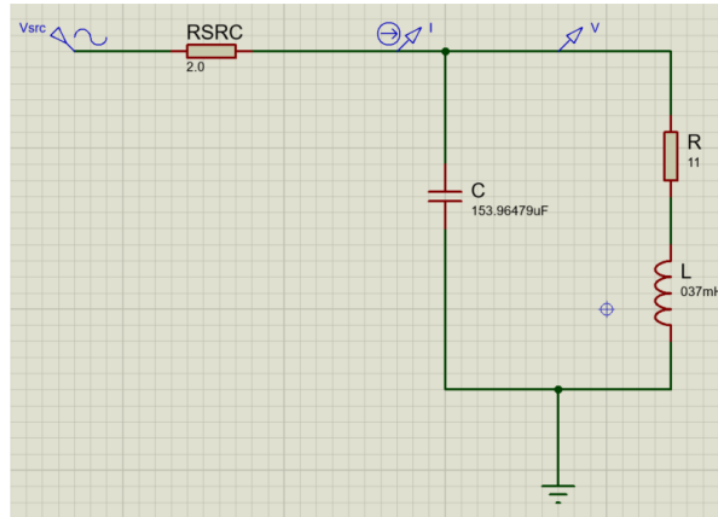


Figure 4

Figure 4 shows the circuit that was constructed on proteus now with the power factor correction connected in parallel with a value of 154uF. Later in the report will be the working out and calculations used to calculate this value.

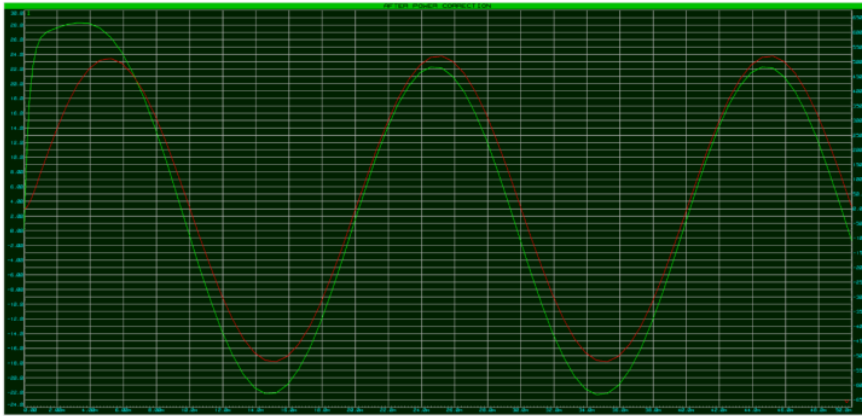


Figure 7



Figure 7 shows the phase difference after power factor correction is applied. Similarly to figure 2, red line shows the voltage waveform and the green line shows the current waveform. Its now clear that the voltage and current are now in phase with each other. The value of the power correcting capacitor I used corrected the power factor to 0.95 which is why on the graph if inspected it shows that's its slightly out of phase.



Figure 8

Figure 8 now shows the current and voltage within the circuit after the power factor correcting capacitor is connected in parallel. In comparison to figure 3, showing the voltage and current before the power factor correction, its clear that after the values of both the current and voltage is a lot lower. This is what would be expected as the purpose is to make the circuit more efficient.

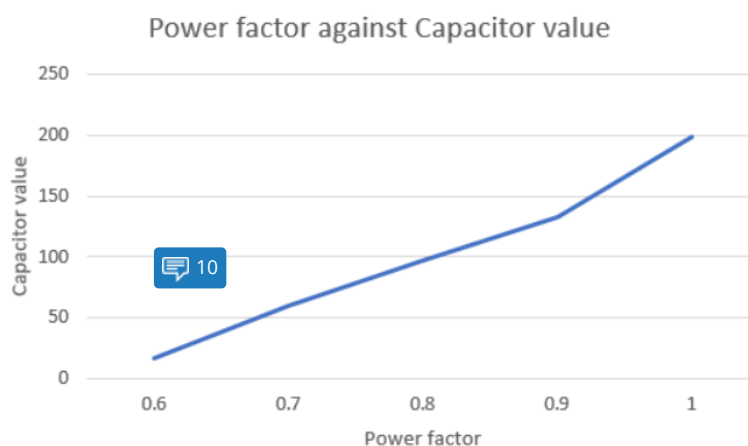


Figure 5



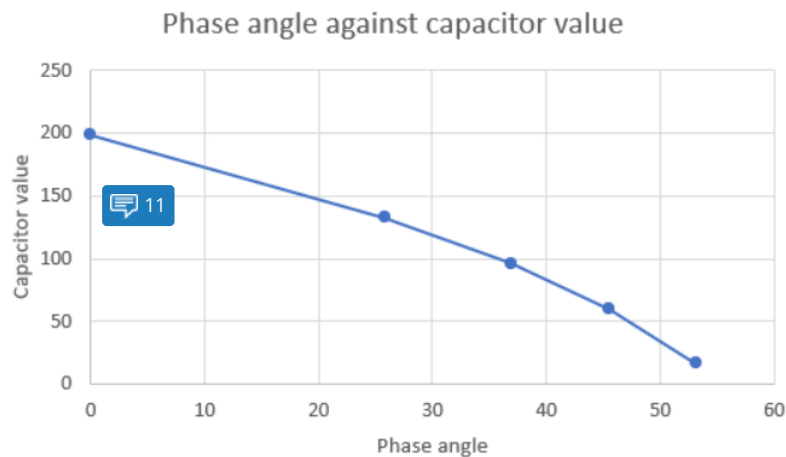


Figure 6

Figure 5 and 6 are the graphs which show power factor against capacitor value and the phase angle against capacitor value. Although the results calculated in figure 4 went below a power factor of 0.5, I did not showcase this the graphs. By having a power factor below 0.5 it means the load is inductive and therefore shouldn't be plotted on a graph showing capacitor value. The phase angle between voltage and current in an AC circuit is inversely proportional to the capacitance. Basically, as the capacitance increases of the capacitor, then the phase angle between voltage and current decreases.

Energy stored in the capacitor and inductor at power factors close to 1

At power factors close to 1, the energy stored in the capacitor and in the inductor is continuously exchanged between the two components. This means that the energy stored in the capacitor and inductor is being transferred back and forth between them, resulting in a continuous oscillation of energy. This oscillation of energy results in a reactive power flow that does not contribute to useful work. Therefore, a low power factor means that a significant amount of the supplied energy is not being used efficiently.

Finding current in my circuit

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$$I = V/Z$$

$$Z = \sqrt{R^2 + XL^2}$$

Find XL

$$XL = 2\pi FL = 2 \times \pi \times 50 \times 0.037 = 11.6238\Omega$$

$$\text{So 'Z' then equals } Z = \sqrt{(11)^2 + (11.6238)^2} = 16.0035\Omega$$

Sub 'Z' in I

$$I = \frac{565.7}{16.0035} = 35.3485 \text{ A}$$

Power consumed

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

$$P = 565.7 \times 35.3 \cos \theta$$

$$\theta = \tan^{-1}\left(\frac{XL}{R}\right)$$

$$\tan^{-1}\left(\frac{11.623}{11}\right) = 46.577 \text{ degrees}$$

Active power

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

$$V_{rms} = \frac{1}{\sqrt{2}} \times V_{pk}$$

$$= 400 \times 22.91 \cos(46.57)$$

$$= \frac{1}{\sqrt{2}} \times 565.7 = 400 \text{ V}$$

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$$P = 6299.96 \text{ watts}$$

$$I_{rms} = \frac{Im}{\sqrt{2}}$$

$$= 6.3 \text{ KW}$$

$$= \frac{2.4}{\sqrt{2}} = 22.91 \text{ A}$$

Reactive power

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

$$= 400 \times 22.91 \sin(46.57)$$

$$= 6655.03 \text{ watts}$$

$$= 6.7 \text{ VAR}$$

Apparent power

$$S = V I$$

$$\text{Apparent power } S = \sqrt{(\text{Active power})^2 + (\text{Reactive power})^2}$$

$$= 9164\text{VA}$$

Power Factor

$$\text{Power factor} = \frac{\text{Active power}}{\text{Apparent power}}$$

$$= 0.687468 \text{ BEFORE POWER FACTOR CORRECTION}$$

Calculate new phase angle

$$\theta = \cos^{-1} \text{ Power factor}$$

$$\text{New Power factor} = \cos \theta = 0.95$$

$$\cos^{-1}(0.95) \approx 18.19487 \text{ degrees}$$

Calculate new reactive power

$$\text{New reactive power} = \text{Real power} \times \tan \theta$$

$$\text{Real power} = P = I^2 R$$

$$= 35.3485^2 \times 11$$

$$= 13744.68 \text{ watts}$$

$$\text{New reactive power} = 13744.68 \times \tan(18.19487)$$

$$= 4517.65\text{VAR}$$

$$\text{Calculate change in reactive power} =$$

$$S = V I$$

$$565.7 \times 35.3485 = 19996.64$$

$$= 19996 - 4517.65 = 15478.996\text{VAR}$$

Calculate capacitive reactance needed for this change in reactive power

$$Q = \frac{|V|^2}{X}$$

$$X = \frac{|V|^2}{Q} = \frac{565.7^2}{15478.996} = 20.6742... = 20.67\Omega \text{ (cap)}$$

Calculate required capacitor value

$$XC = \frac{1}{2\pi FC}$$

$$C = \frac{1}{2\pi FX}$$

$$C = \frac{1}{2\pi \times 50\text{Hz} \times 20.6742}$$

$$= 1.5396479 \times 10^{-4} \text{ F}$$

$$= 0.00015396479 \text{ F}$$

$$= 153.96479 \mu\text{F}$$

Resonant Frequency

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

$$f_r = \frac{1}{2\pi} \times \sqrt{\frac{1}{0.037 \times 10 \times 154 \times 10^{-6}} - \frac{11^2}{0.037^2}}$$

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$$\text{Resonant Frequency} = 46.974\text{Hz}$$

Reactance of the inductor

$$X_L = 2\pi f L = 2\pi \times 46.974 \times 0.037 = 10.92\Omega$$

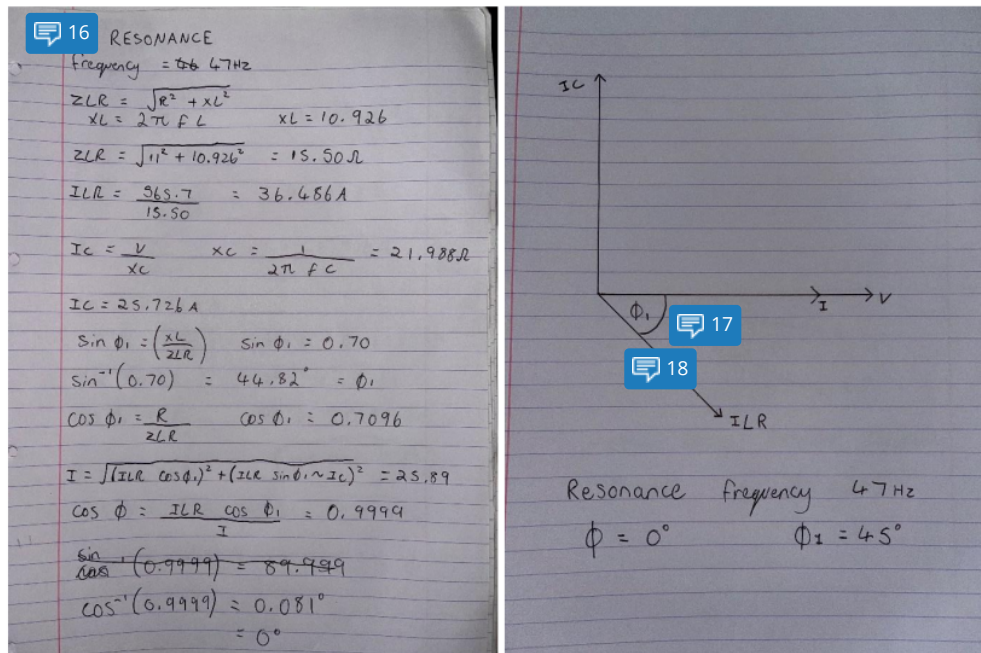
Reactance of capacitor

$$X_C = \frac{1}{2\pi f C} = \frac{1}{2\pi \times 46.974\text{Hz} \times 154 \times 10^{-6}} = 22.00\Omega$$

Resonant frequency occurs when the inductance and capacitance in the circuit are balanced, resulting in minimum impedance and maximum current flow. We determine the resonant frequency from the values of the inductance and capacitance within the circuit.

phasor diagrams showing the component voltages and current for the circuit in task 1

This report now shows the phasor diagrams showing the component voltages and currents for the circuit in task 1 at different frequencies. Phasor diagrams are graphical representations of the phase relationship between voltage and current in an AC circuit. In a resonance circuit you would expect to see the voltage and current in phase. As you can see from the resonance phasor diagram, the current and voltage are both in phase. The calculations along with the phasor diagrams are shown below for the resonance frequency, 25Hz above resonant frequency, 25Hz below resonant frequency and finally at 50Hz.



+ 2.5 Hz
frequency = 72 Hz

$$Z_{LR} = \sqrt{R^2 + X_L^2}$$

$$X_L = 2\pi fL \quad X_L = 16.738 \Omega$$

$$Z_{LR} = 20.029$$

$$I_{LR} = \frac{565.7}{20.029} = 28.243 \text{ A}$$

$$I_C = \frac{V}{X_C} \quad X_C = 14.353 \Omega$$

$$I_C = 39.411 \text{ A}$$

$$\sin \phi_1 = \left(\frac{X_L}{Z_{LR}} \right) \quad \sin \phi_1 = 0.835$$

$$\sin^{-1}(0.835) = 56.68^\circ = \phi_1$$

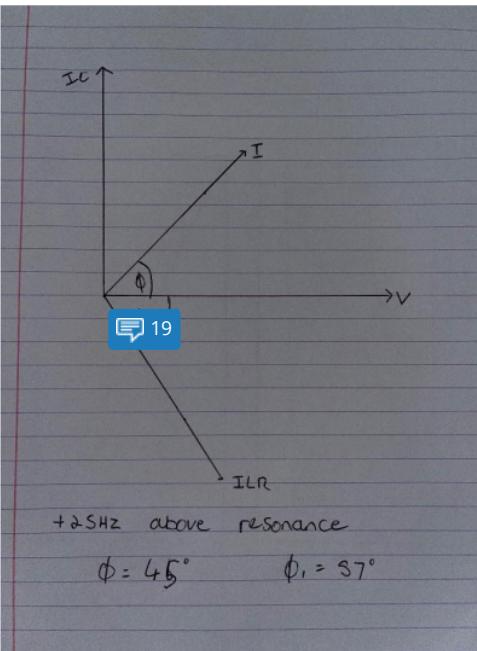
$$\cos \phi_1 = \frac{R}{Z_{LR}} \quad \cos \phi_1 = 0.5492$$

$$I = \sqrt{(28.24 \cos \phi_1)^2 + (28.24 \sin \phi_1 - I_C)^2}$$

$$I = 22.16 \text{ A} \quad (I_C - I_{LR} \sin \phi_1)$$

$$\cos \phi = \frac{I_{LR} \cos \phi_1}{I} = 0.699$$

$$\cos^{-1}(0.699) = 45.57^\circ = \phi$$



- 2.5 Hz
frequency = 22 Hz

$$Z_{LR} = \sqrt{R^2 + X_L^2}$$

$$X_L = 2\pi fL \quad X_L = 5.114 \Omega$$

$$Z_{LR} = 12.130$$

$$I_{LR} = \frac{565.7}{12.130} = 46.633 \text{ A}$$

$$I_C = \frac{V}{X_C} \quad X_C = 46.976 \Omega$$

$$I_C = 12.042 \text{ A}$$

$$\sin \phi_1 = \left(\frac{X_L}{Z_{LR}} \right) \quad \sin \phi_1 = 0.421599$$

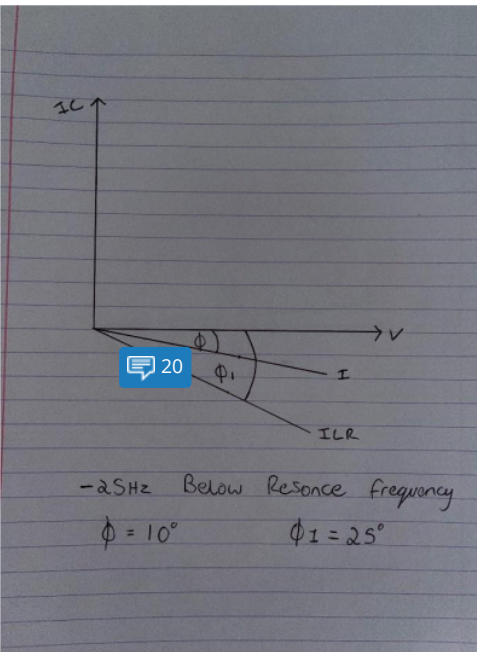
$$\sin^{-1}(0.421599) = 24.94^\circ = \phi_1$$

$$\cos \phi_1 = \frac{R}{Z_{LR}} \quad \cos \phi_1 = 0.90684$$

$$I = 42.969 \quad (I_{LR} \sin \phi_1 > I_C)$$

$$\cos \phi = \frac{I_{LR} \cos \phi_1}{I} = 0.984$$

$$\cos^{-1}(0.984) = 10.21^\circ = \phi$$



50 Hz
 frequency = 50 Hz

$$Z_{LR} = \sqrt{R^2 + X_L^2}$$

$$X_L = 2\pi fL \quad X_L = 11.623 \Omega$$

$$Z_{LR} = \sqrt{11^2 + 11.623^2} = 16.00 \Omega$$

$$I_{LR} = \frac{565.7}{16.00} = 35.348 A$$

$$I_C = \frac{V}{X_C} \quad X_C = 20.669 \Omega$$

$$I_C = 27.368 A$$

$$\sin \phi_1 = \left(\frac{X_L}{Z_{LR}} \right) \quad \sin \phi_1 = 0.726$$

$$\sin^{-1}(0.726) = 46.58^\circ = \phi_1$$

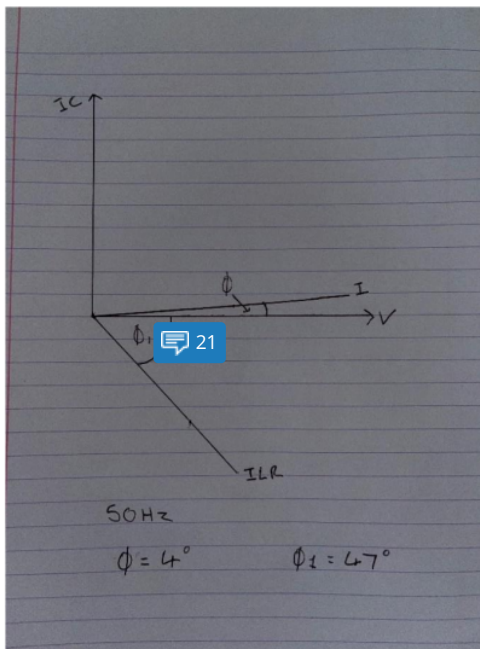
$$\cos \phi_1 = \frac{R}{Z_{LR}} \quad \cos \phi_1 = 0.6875$$

$$I = 24.361 A$$

$$\cos \phi = \frac{Z_{LR} \cos \phi_1}{I} = 0.99756$$

$$\cos^{-1}(0.99756) = 3.996^\circ$$

$$= 4^\circ$$



How power factor relates to resonance and maximum power transfer

In task 1, a suitable capacitor value was calculated and used to correct the original power factor to a new power factor of 0.95. Active power generation directly affects the frequency and the reactive power generation directly affects the voltage. Active power is a result of resistive components, reactive power being the result of capacitive/inductive components and apparent power the combination of both the real power as well as the reactive power. If active power generation increases so does the frequency, according to the ratio, therefore the power factor increases. That is the ratio between power factor and frequency.

When resonance occurs in the circuit, the result is extremely high voltage and current flowing at the resonant frequency. The use of power factor correction capacitors is to act as a low impedance device to the resonant currents. By having the power factor 0.95 or greater it means the capacitor is larger and therefore 'absorbing' more of the resonant currents. While reducing current it does not reduce voltage meaning the voltage can stay at the same value which only brings down the current.

Maximum power theorem states that the maximum power that can be transferred from source to load is 50%, this occurs when the source impedance is matched with the load impedance. By having a high power factor it directly affects the maximum power transfer by allowing greater power to be transferred. Basically having a low power factor will decrease the maximum power transfer and having a high power factor will increase the maximum power transfer. Maximum power is achieved when the power factor is 1. In other words, maximum power transfer occurs at the unity power factor, that being when the reactive (useless) power is zero.

Conclusion

In conclusion this report shows the importance of power factor correction and why it is used in electronic circuits. Making the circuit more efficient and use less power is beneficial in many ways such as, reducing electricity costs, saving the planet and ensuring parts don't overheat and cause damage to machinery etc. Additionally, phasor diagrams are very important as they allow you to work out many different things such as the relative phase angle between the different components as well as the magnitude and phase of the voltage and current for each component.

FINAL GRADE

48/100

GENERAL COMMENTS

Instructor

Engagement with Literature Skills: Marks: 0/10

Little or no evidence of reading and/or reliance on inappropriate sources. Views and findings mostly unsupported and non-authoritative

Knowledge and Understanding Skills: Marks: 17/30

Knowledge is reasonably detailed and accurate. A good understanding of the well-established concepts and principles of RLC circuit.

Cognitive and Intellectual Skills: Marks: 12/30

Limited attempt at critical evaluation and analysis of concepts and principles, tending towards description. Some valid conclusions. The interpretation of key data's are missing in certain areas of the report.

Practical Application Skills: Marks : 14/20

A good and appropriate application of established methods, materials, tools and/or techniques. Clear appreciation of the context of the application. Mainly consistent, accurate and logical application of theory to practice, making appropriate links between the two.

Transferable Skills for Life and Professional Practice: Marks : 5/10

Can communicate effectively in a suitable medium for the audience, mostly coherent organised work, in a suitable structure and is for the most part clearly expressed.

Total: 48/100



Comment 1

Good Attempt, the first page or the title page of the report should have the name, student ID, Module Name, Module code, Title of the Coursework, programme of study. Most of these are in the title page, but however few are missing.



Comment 2

Page number is missing



Comment 3

It is better to have a table of content.



Comment 4

Abstract is missing, it is better to have an abstract. So the reader can get an overall idea of what is discussed in the report.



Comment 5

Do not use contractions like "it's", instead use the entire phrase "it is"



Comment 6

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



Comment 7

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Comment 8

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



Comment 9

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Comment 10

The range of values of capacitor chosen for plotting graph is not enough. The graph should clearly show the capacitor value at which the power factor is maximum.



Comment 11

The range of values chosen should be more, so that the point at which it reaches maximum can be obtained.



Comment 12

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



Comment 13

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 14

You should always include a caption equations to allow you to refer to them in your text.



Comment 15

It is better to number the equations.



Comment 16

The calculations should have been done in the word document and not in a paper



Comment 17

The phase angle should be indicated here



Comment 18

The figure should be named and numbered

PAGE 10



Comment 19

The figure should be named and numbered



Comment 20

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PAGE 11



Comment 21

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

PAGE 12



Comment 22

Good



Comment 23

Referencing is missing, You should try to use referencing from high quality reference sources, such as textbooks from reputable academic publishers and articles from peer reviewed journals