

Electrical Engineering

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L5 - Electrical Engineering

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**Electrical and Electronic Engineering Degree
Apprenticeship**

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Figure 1

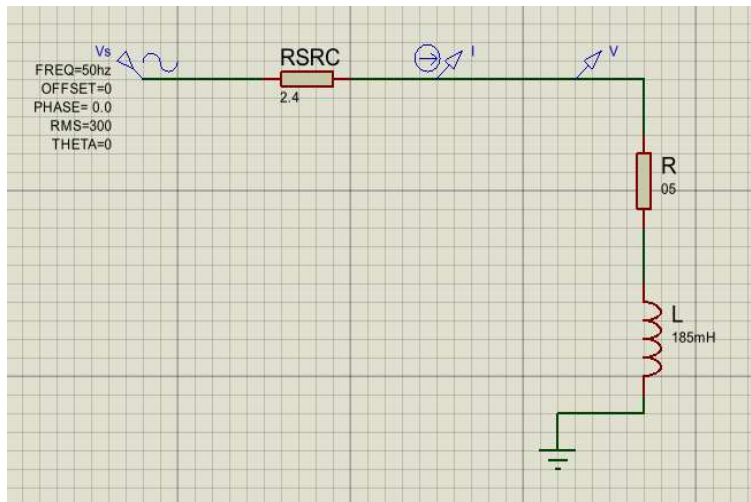
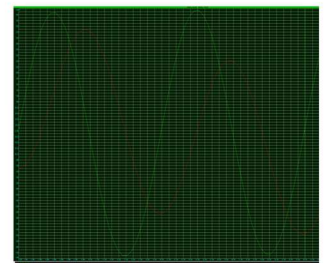
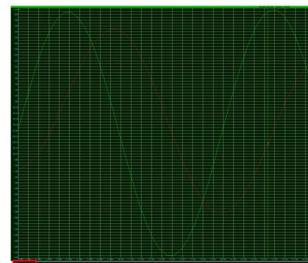
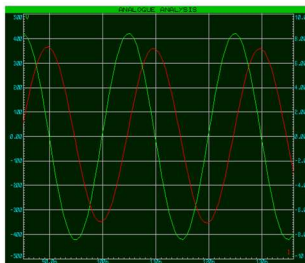


Figure 2

RL circuit



TIME: 19.9m V: 320m

TIME: 24.3m I: 2.12

TIME: 39.9m V: -264m

$$t = 24.3 - 19.9 = 4.4$$

$$\text{Time Difference} = \frac{t}{T} \times 360$$

$$= \frac{4.4}{20} \times 360$$

$$= 79.2$$

$$\text{Power Factor} = \cos(79.2) = 0.19$$

$$T = 39.9 - 19.9 = 20$$

Figure 3

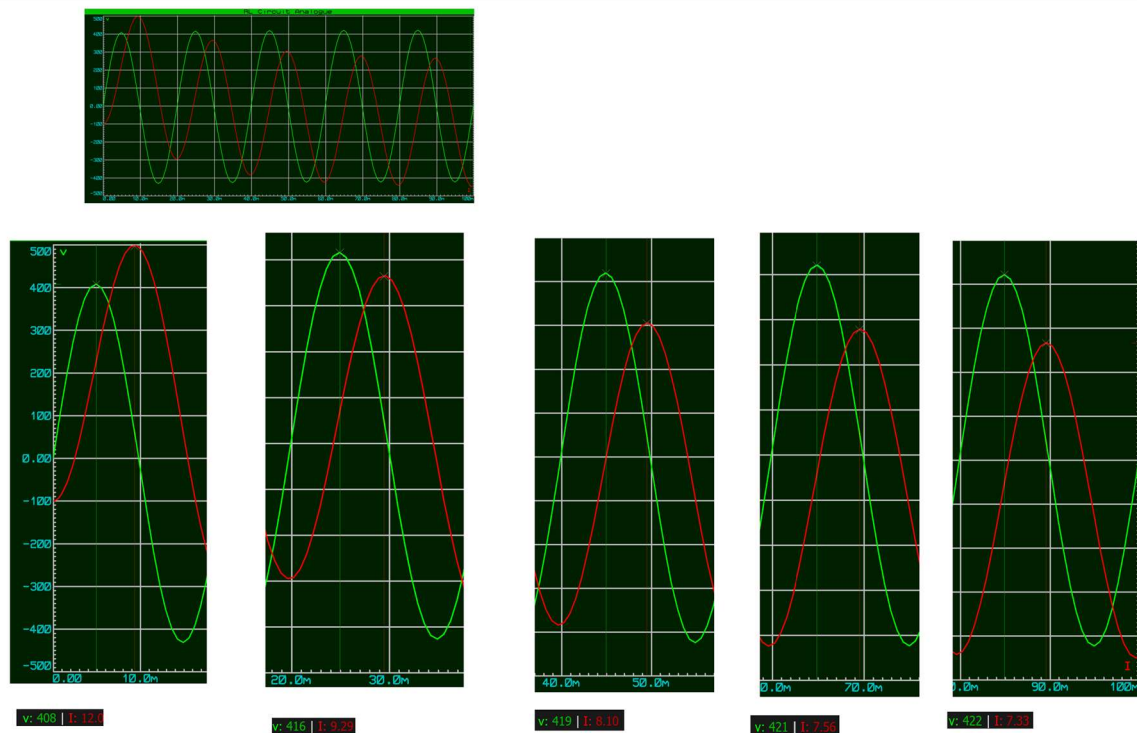


Figure 4

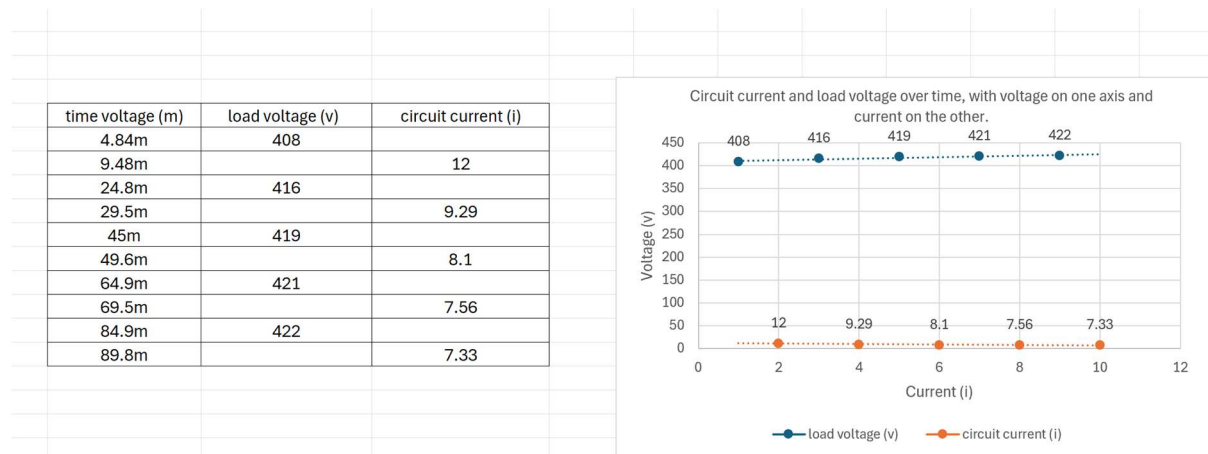


Figure 5

Cycle 1: $t_V = 4.84$ ms, $t_I = 9.48$ ms $\rightarrow \Delta t = 9.48 - 4.84 = 4.64$ ms

Cycle 2: $t_V = 24.8$ ms, $t_I = 29.5$ ms $\rightarrow \Delta t = 4.7$ ms

Cycle 3: $t_V = 45.0$ ms, $t_I = 49.6$ ms $\rightarrow \Delta t = 4.6$ ms

Cycle 4: $t_V = 64.9$ ms, $t_I = 69.5$ ms $\rightarrow \Delta t = 4.6$ ms

Cycle 5: $t_V = 84.9$ ms, $t_I = 89.8$ ms $\rightarrow \Delta t = 4.9$ ms

$$\Delta t_{avg} = \frac{4.64 + 4.70 + 4.60 + 4.60 + 4.90}{5} = 4.688 \text{ ms}$$

$$\phi = \frac{4.688}{20} \times 360^\circ = 84.4^\circ$$

Figure 6

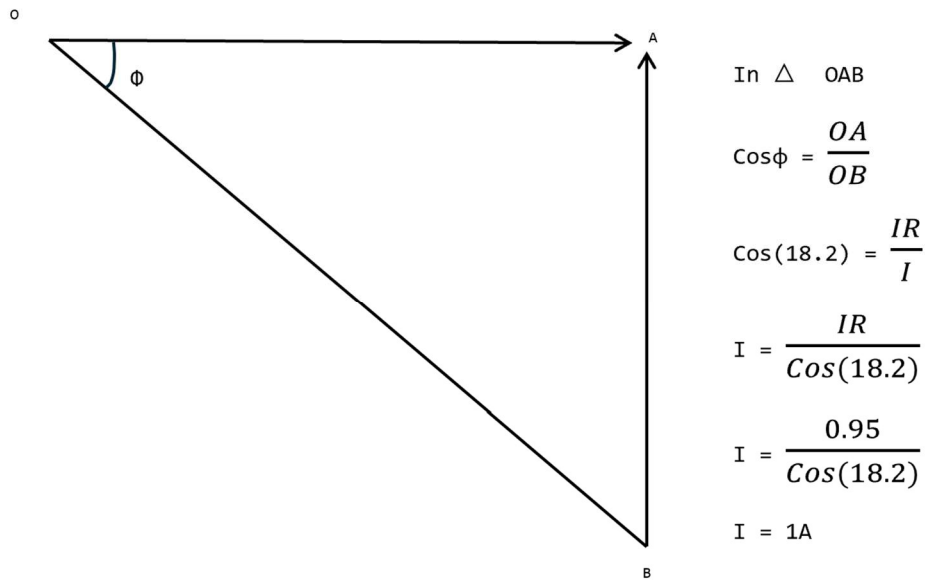


Figure 7

Power Calculations

Active/Real Power

$$P = VI \cos \phi_1 = 300 \times 1 \times \cos(79.2) = 56.2 \text{ W}$$

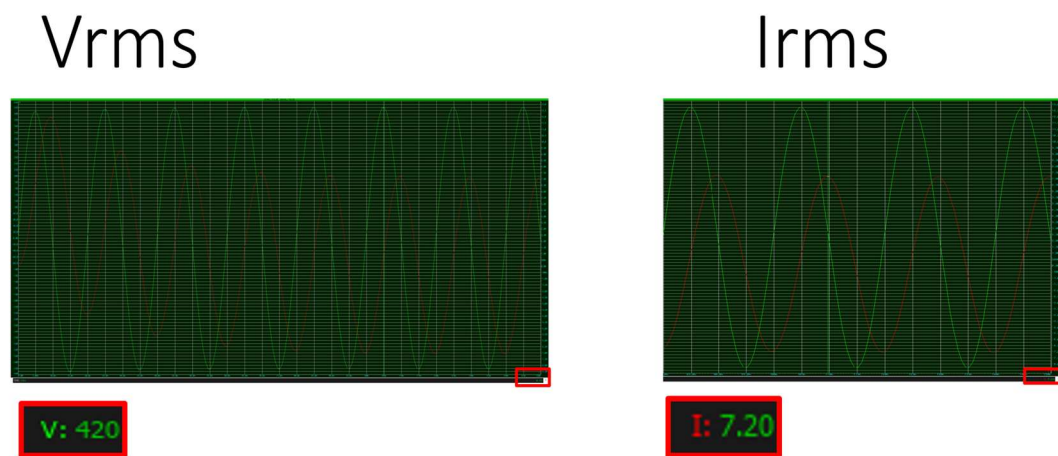
Reactive Power

$$Q = VI \sin \phi_1 = 300 \times 1 \times \sin(79.2) = 294.7 \text{ VAR}$$

Apparent Power

$$S = VI = 300 \times 1 = 300 \text{ VA}$$

Figure 8



$$\frac{420}{\sqrt{2}} = 297V$$

$$\frac{7.2}{\sqrt{2}} = 5.09A$$

Figure 9

Images of finding capacitor Value

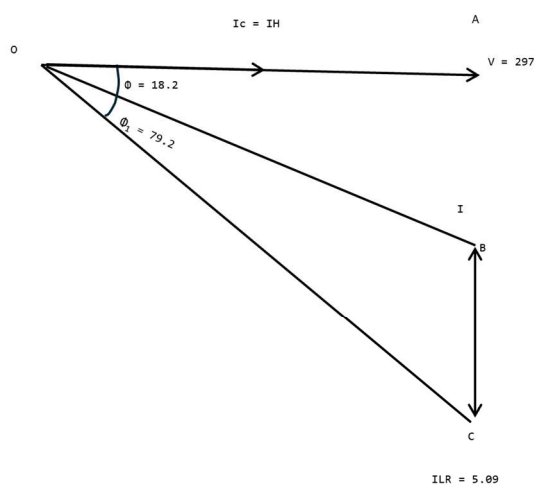


Figure 10

Images of finding capacitor Value

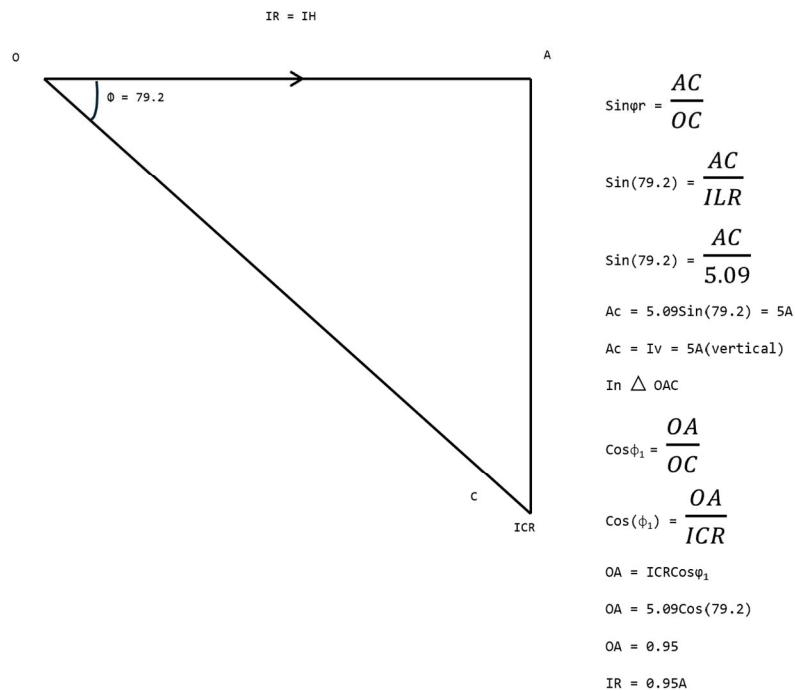


Figure 11

Images of finding capacitor Value

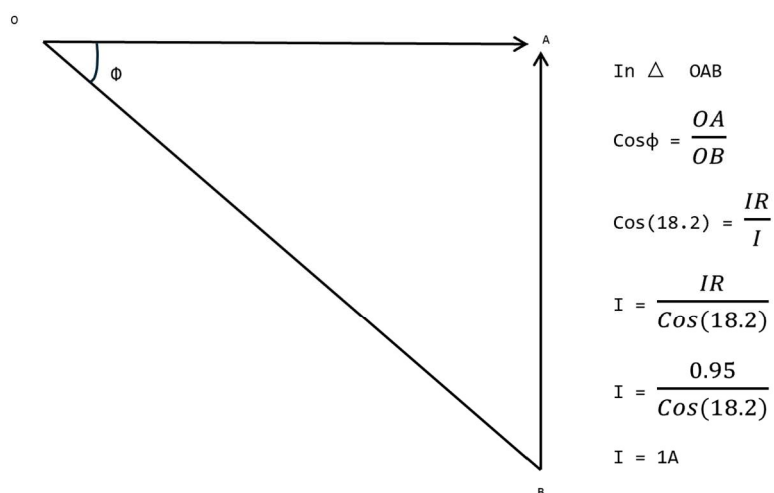


Figure 12

Images of finding capacitor Value

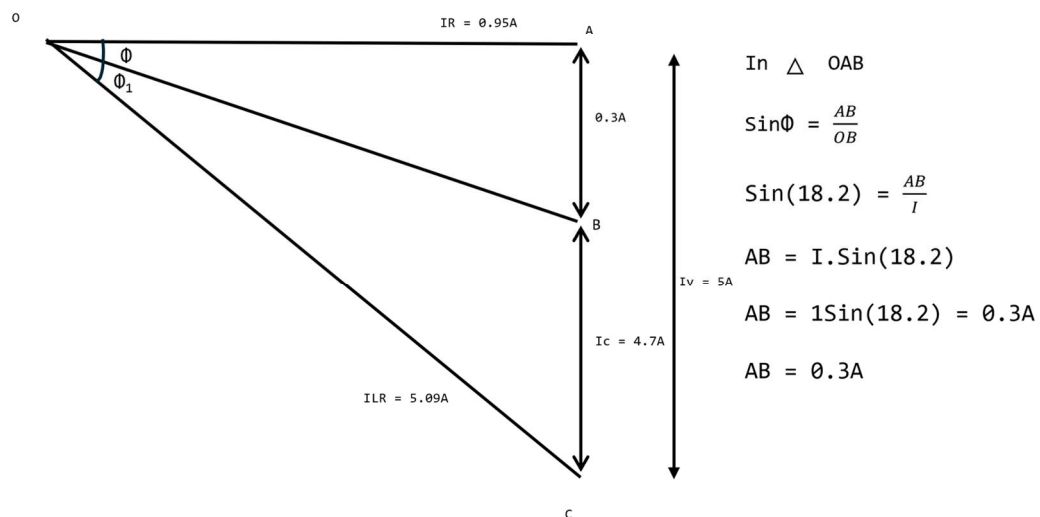
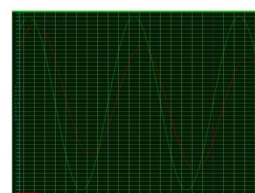
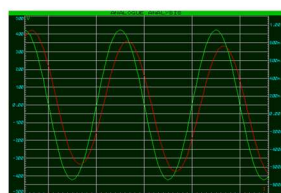
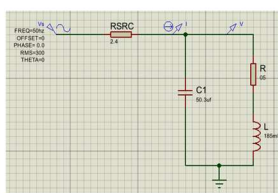
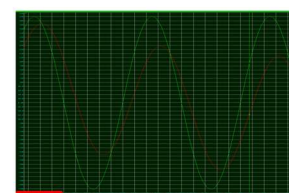


Figure 13

RLC Circuit

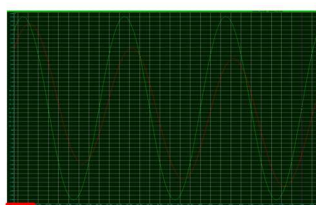


TIME: 100m V: 256m



TIME: 101m I: 108m

$$t = 101 - 100 = 1$$



TIME: 120m V: -1.67

$$T = 120 - 100 = 20$$

$$\text{Time Difference} = \frac{t}{T} \times 360$$

$$= \frac{1}{20} \times 360$$

$$= 18$$

$$\text{Power Factor} = \cos(18) = 0.95$$

Figure 14

Task 1 vi + vii PF and phase angle cap value graph 30 uF

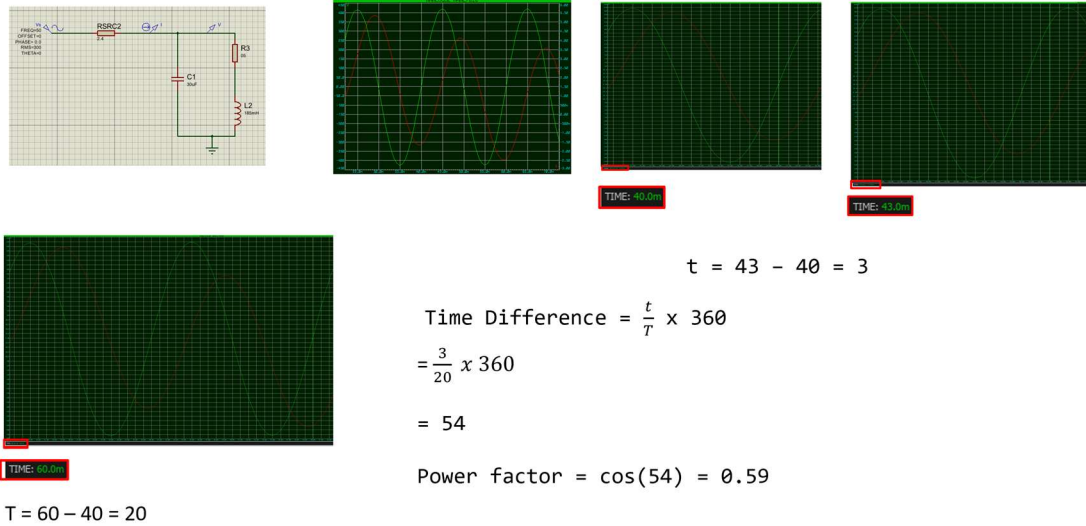


Figure 15

Task 1 vi + vii PF and phase angle cap value graph 40 uF

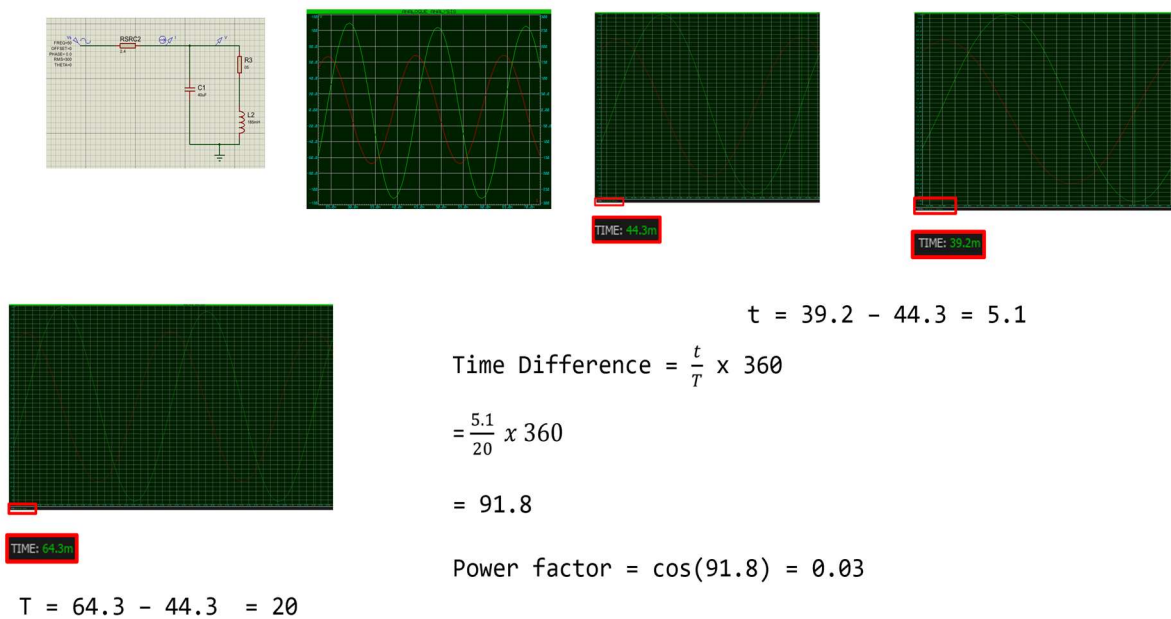
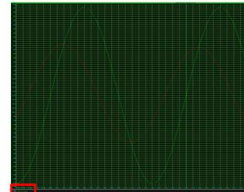
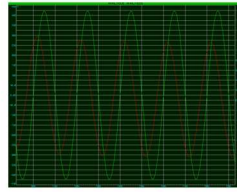
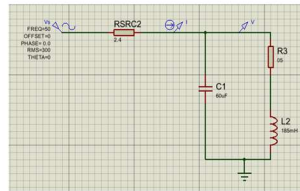


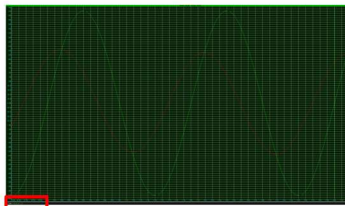
Figure 16

Task 1 vi + vii PF and phase angle cap value graph 60 uF



TIME: 120.0ms

TIME: 116.7ms



TIME: 140.0ms

$$t = 116.7 - 120 = -3.3$$

$$\text{Time Difference} = \frac{t}{T} \times 360$$

$$= \frac{-3.3}{20} \times 360$$

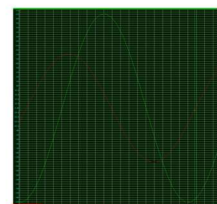
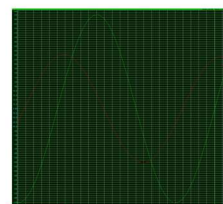
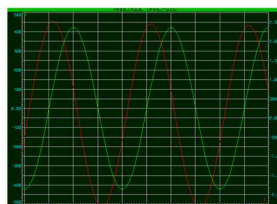
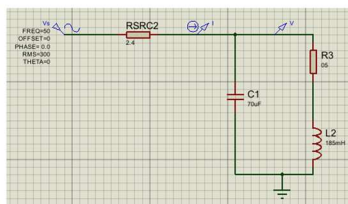
$$= -59.4$$

$$\text{Power factor} = \cos(59.4) = 0.51$$

$$T = 140 - 120 = 20$$

Figure 17

Task 1 vi + vii PF and phase angle cap value graph 70 uF



TIME: 120.0ms

TIME: 115.8ms



TIME: 140.0ms

$$t = 115.8 - 120 = -4.2$$

$$\text{Time Difference} = \frac{t}{T} \times 360$$

$$= \frac{-4.2}{20} \times 360$$

$$= -75.6$$

$$\text{Power factor} = \cos(75.6) = 0.25$$

$$T = 140 - 120 = 20$$

Figure 18

Graph and table for power factor against cap value



Figure 19

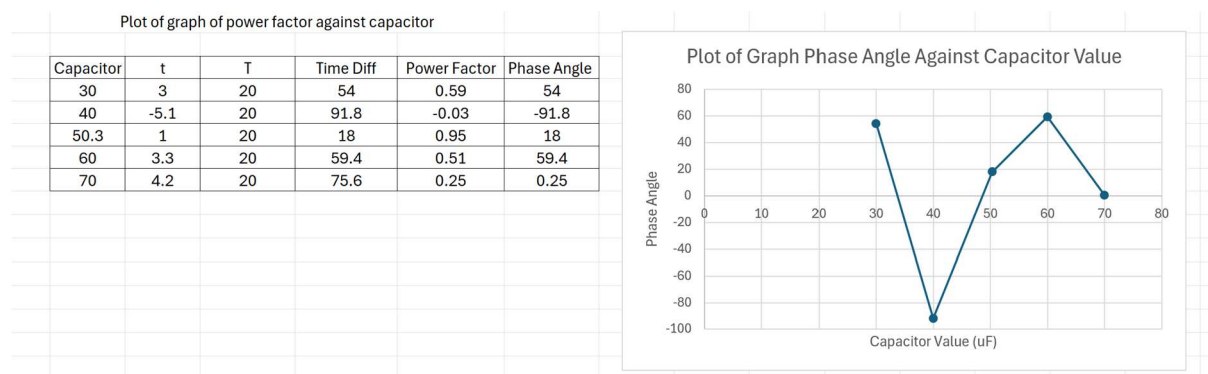
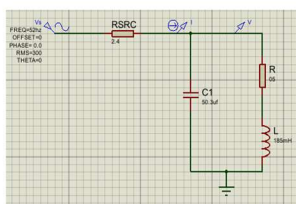


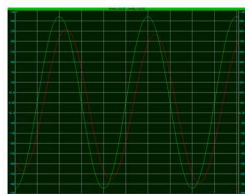
Figure 20

Resonance



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

$$f_r = \frac{1}{2\pi} \sqrt{\frac{1}{185 \times 10^{-3} \times 50.3 \times 10^{-6}} - \frac{5^2}{(185 \times 10^{-3})^2}} = 52.0 \text{ Hz}$$



$$t = 114.4 - 115.4 = -1$$

$$T = 134.6 - 115.4 = 19.2$$

$$\text{Time Difference} = \frac{t}{T} \times 360$$

$$\frac{-1}{19.2} \times 360 = -18.75$$

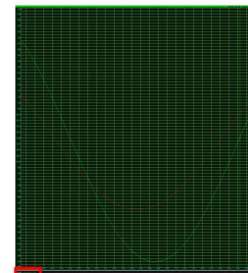
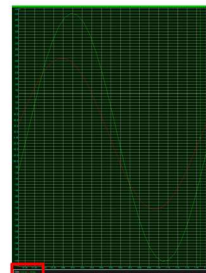
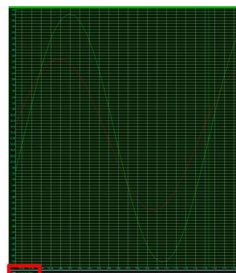
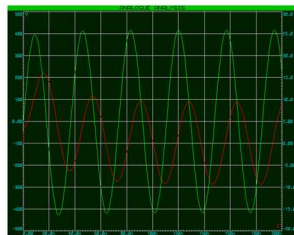
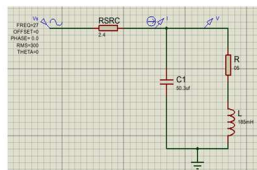


Figure 21

-25Hz Resonance

$$f_r = 52 - 25 = 27 \text{ Hz}$$

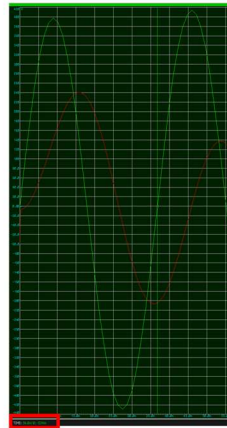


$$t = 46 - 36.8 = 9.2$$

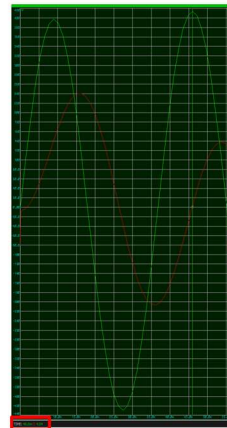
$$T = 73.8 - 46 = 27.8$$

$$\text{Time Difference} = \frac{t}{T} \times 360$$

$$\frac{9.2}{27.8} \times 360 = 119.14$$



TIME: 36.8m



TIME: 46.0m

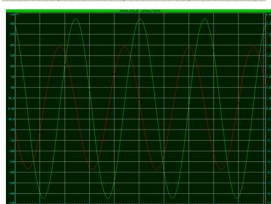
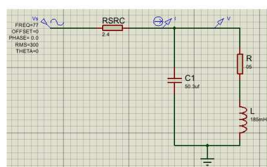


TIME: 73.8m

Figure 22

+25Hz Resonance

$$f_r = 52 + 25 = 77 \text{ Hz}$$



$$t = 100.8 - 104 = -3.2$$

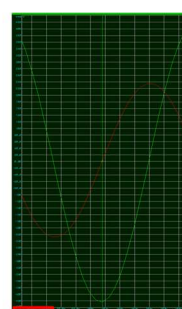
$$T = 117 - 104 = 13$$

$$\text{Time Difference} = \frac{t}{T} \times 360$$

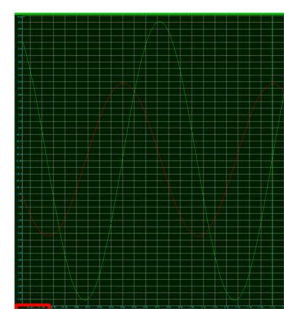
$$\frac{-3.2}{13} \times 360 = -88.62$$



TIME: 104.0m



TIME: 100.8m



TIME: 117.0m

Figure 23

PHASOR Diagram 52hz resonance

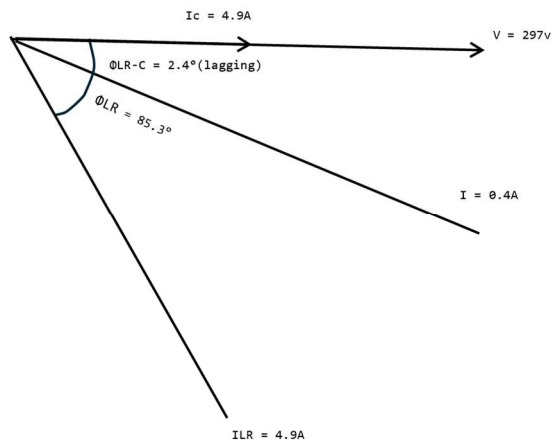


Figure 24

PHASOR Diagram 27hz resonance

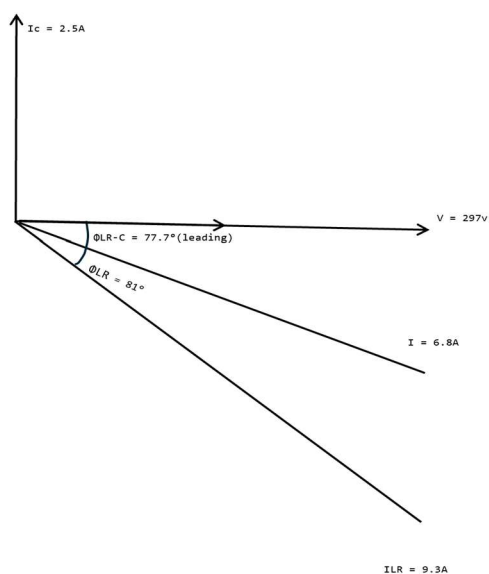


Figure 25

PHASOR Diagram 77hz resonance

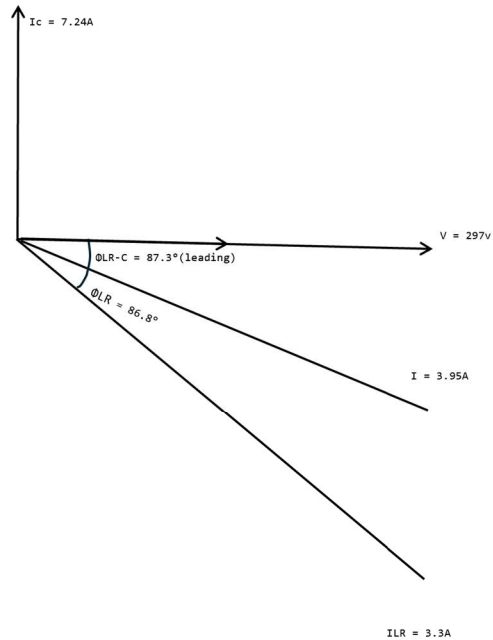


Figure 26

PHASOR Diagram 50hz resonance

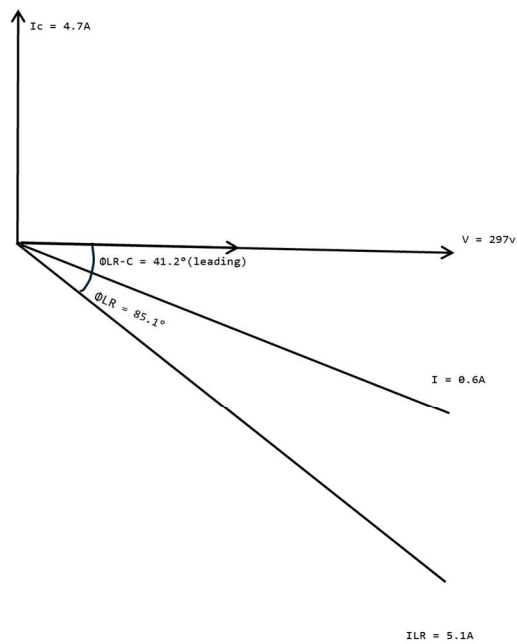


Figure 27

FORMULAS PHASOR Diagram 52hz resonance

$$X_C = \frac{1}{2\pi fC}$$

$$X_C = \frac{1}{2\pi \times 52 \times 50.3 \times 10^{-6}} = 60.8\Omega$$

$$X_L = 2\pi fL$$

$$X_L = 2\pi \times 52 \times 185 \times 10^{-3} = 60.4\Omega$$

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

$$Z_{LR} = \sqrt{5^2 + 60.4^2} = 60.6\Omega$$

$$I_{LR} = \frac{V}{Z}$$

$$I_{LR} = \frac{297}{60.6}$$

$$I_{LR} = 4.9A$$

Figure 28

FORMULAS 2 PHASOR Diagram 52hz resonance

From graph

$$V_{LR}(\max) = 420V$$

$$V_{LR}(RMS) = \frac{420}{\sqrt{2}} = 297V$$

$$I_C = \frac{V_C}{X_C} = \frac{297}{60.8} = 4.9A$$

$$\phi_{LR} = \tan^{-1}\left(\frac{60.4}{5}\right) = 85.3$$

$$I_{LR}\sin\phi_{LR} = 4.9\sin(85.3) = 4.9A$$

$$\phi = \tan^{-1}\left(\frac{4.9\sin(85.3) - 4.9}{4.9\cos(85.3)}\right) = 2.4 \text{ (lagging)}$$

$$I = \sqrt{(4.9\cos(85.3))^2 + (4.9\sin(85.3) - 4.9)^2} = 0.4A$$

Figure 29

FORMULAS PHASOR Diagram 77hz resonance

$$X_C = \frac{1}{2\pi fC}$$

$$X_C = \frac{1}{2\pi \times 77 \times 50.3 \times 10^{-6}} = 41\Omega$$

$$X_L = 2\pi fL$$

$$X_L = 2\pi \times 77 \times 185 \times 10^{-3} = 89.5\Omega$$

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

$$Z_{LR} = \sqrt{5^2 + 89.5^2} = 89.64\Omega$$

$$ILR = \frac{V}{Z}$$

$$ILR = \frac{297}{89.64}$$

$$ILR = 3.3A$$

Figure 30

Formulas 2 PHASOR Diagram 77hz resonance

From graph

$$V_{LR}(\max) = 420V$$

$$V_{LR}(RMS) = \frac{420}{\sqrt{2}} = 297V$$

$$I_C = \frac{V_C}{X_C} = \frac{297}{41} = 7.24A$$

$$\phi_{LR} = \tan^{-1}\left(\frac{89.5}{5}\right) = 86.8$$

$$\phi = \tan^{-1}\left(\frac{3.3 \sin(86.8) - 7.24}{3.3 \cos(86.8)}\right)$$

$$ILR \sin \phi_{LR} = 3.3 \sin(86.8) = 3.29A$$

$$\phi = \tan^{-1}\left(\frac{7.24 - 3.29}{3.3 \cos(86.8)}\right)$$

$$\phi = 87.3^\circ \text{ (Leading)}$$

$$I = \sqrt{(3.3 \cos(86.8))^2 + (3.3 \sin(86.8) - 7.24)^2} = 3.95A$$

Figure 31

FORMULAS PHASOR Diagram 27hz resonance

$$X_C = \frac{1}{2\pi fC}$$

$$X_C = \frac{1}{2\pi \times 27 \times 50.3 \times 10^{-6}} = 117.2\Omega$$

$$X_L = 2\pi fL$$

$$X_L = 2\pi \times 27 \times 185 \times 10^{-3} = 31.4\Omega$$

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

$$Z_{LR} = \sqrt{5^2 + 31.4^2} = 31.8\Omega$$

$$ILR = \frac{V}{Z}$$

$$ILR = \frac{297}{31.8}$$

$$ILR = 9.3A$$

Figure 32

FORMULAS 2 PHASOR Diagram 27hz resonance

From graph

$$V_{LR}(\max) = 420V$$

$$V_{LR}(RMS) = \frac{420}{\sqrt{2}} = 297V$$

$$I_C = \frac{V_C}{X_C} = \frac{297}{117.2} = 2.5A$$

$$\phi_{LR} = \tan^{-1}\left(\frac{31.4}{5}\right) = 81$$

$$\phi = \tan^{-1}\left(\frac{9.3 \sin(81) - 2.5}{9.3 \cos(81)}\right) = 77.7(\text{leading})$$

$$I = \sqrt{(9.3 \cos(81))^2 + (9.3 \sin(81) - 2.5)^2} = 6.8A$$

Figure 33

FORMULAS PHASOR Diagram 50hz resonance

$$X_C = \frac{1}{2\pi fC}$$

$$X_C = \frac{1}{2\pi \times 50 \times 50.3 \times 10^{-6}} = 63.3\Omega$$

$$X_L = 2\pi fL$$

$$X_L = 2\pi \times 50 \times 185 \times 10^{-3} = 58.1\Omega$$

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

$$Z_{LR} = \sqrt{5^2 + 58.1^2} = 58.3\Omega$$

$$I_{LR} = \frac{V}{Z}$$

$$I_{LR} = \frac{297}{63.3}$$

$$I_{LR} = 4.7A$$

Figure 34

FORMULAS 2 PHASOR Diagram 50hz resonance

$$\phi_{LR} = \tan^{-1}\left(\frac{58.1}{5}\right) = 85.1$$

$$\phi = \tan^{-1}\left(\frac{5.1 \sin(85.1) - 4.7}{5.1 \cos(85.1)}\right) = 41.2(\text{leading})$$

$$I = \sqrt{(5.1 \cos(85.1))^2 + (5.1 \sin(85.1) - 4.7)^2} = 0.6A$$

Abstract

This report looks at the behaviour of a parallel RLC circuit supplied by a 300 V, 50 Hz AC source using proteus simulation. The voltage and current waveforms were analysed to find the phase difference and power factor of the circuit before correction. From this, the active, reactive and apparent power were calculated, showing that the load was mainly inductive. A capacitor was then added to improve the power factor to at least 0.95. Graphs and phasor diagrams were used to show how power correction and changes in frequency affect the circuit. Overall, the results show that power factor correction reduces reactive power and improves circuit efficiency.

Introduction

Alternating current also known as AC is the standard form of electrical power used in modern power systems due to its efficiency in generation, transmission, and distribution [1]. In an AC system, voltage and current vary sinusoidally with time, and their relationship depends on the electrical components present in the circuit [2]. Understanding how different components affect voltage, current, and power is essential for analysing real electrical systems [1].

An RLC circuit is composed of a resistor (R), an inductor (L), and a capacitor (C). Each component behaves differently under AC conditions [3]. A resistor dissipates energy as heat causes voltage and current to remain in phase [4]. An inductor stores energy in a magnetic field and causes the current to lag behind the voltage, while a capacitor stores energy in an electric field and causes the current to lead the voltage. When combined in an AC circuit, these components introduce both magnitude and phase changes, which affect the overall impedance of the circuit [5].

Power factor is a key parameter in AC circuit analysis and is defined as the cosine of the phase angle between voltage and current [6]. A power factor close to unity indicates that most of the supplied power is converted into useful work. However, inductive loads such as motors and transformers cause the current to lag the voltage, resulting in a low power factor. This leads to increased apparent power, higher current demand, and additional losses in the system [7]. Power factor correction is commonly used to address this issue by adding capacitors that supply leading reactive power, thereby reducing the phase difference and improving efficiency [8].

Resonance is an important phenomenon in RLC circuits and occurs when the inductive reactance and capacitive reactance are equal in magnitude. At the resonant frequency, the reactive effect cancels, and the circuit behaves as if it were purely resistive [9]. In series RLC circuits, resonance results in maximum

current, while in parallel RLC circuits, impedance is maximised. Resonance is widely used in tuning and filtering applications but can also cause excessive currents or voltages if not carefully controlled [9].

The maximum power transfer theorem states that maximum power is delivered to a load when the load impedance matches the complex conjugate of the source impedance. In AC systems, this requires both resistive and reactive components to be matched. Although this condition ensures maximum power delivery, it does not provide maximum efficiency, as significant power is dissipated in the source resistance. For this reason, maximum power transfer is mainly applied in low-power and communication systems rather than power distribution networks [10].

This report applies these principles to the analysis of a parallel RLC circuit, focusing on phase difference, power factor, resonance, and power transfer using simulation techniques.

Method

Task 1

Figure 1 illustrates RL proteus circuit

Figure 2 illustrates the waveform of the RL circuit with also the calculations of the time difference and power factor

i)

The circuit shown in Figure 1 was modelled using Proteus to represent a parallel RL circuit supplied by a single-phase AC source. The supply was configured as a sinusoidal voltage source with a magnitude of 300 V RMS and a frequency of 50 Hz, as specified in the assignment brief. A source resistance of $2.4\ \Omega$ was included in series with the supply to represent losses associated with cabling and transformer windings. This value was derived from the first two digits of the student identification number.

The load consisted of a resistor and an inductor connected in series to represent an inductive load such as a motor. The resistor value of $05\ \Omega$ and the inductor value of 185 mH were also derived from the student identification number, as specified in the assignment brief. The load was connected between the supply and ground. Voltage and current probes were placed at appropriate points in the circuit to measure the load voltage and total circuit current during simulation. The power factor correction branch was introduced at a later stage of the analysis.

The time difference was also calculated of the RL circuit by utilising the waveform of the circuit as shown in figure 2. Once the time difference had been calculated the power factor could also then be calculated.

ii)

Figure 3 illustrates waveform of voltage and current for graph

Figure 4 illustrates excel graph of voltage and current over time

Figure 5 illustrates calculation of phase difference

The load voltage and total circuit current were obtained from the proteus simulation prior to the application of power factor correction. Measurements were taken at corresponding points over several cycles of the 50 Hz supply waveform. The recorded values of load voltage and circuit current, together with their associated time stamps, are shown in figure 3.

The measured data were imported into Microsoft excel and plotted on a single graph against time. A dual y-axis format was used, with load voltage plotted on the primary axis and circuit current plotted on the secondary axis, to allow both quantities to be displayed clearly despite their different magnitudes. The resulting graph is shown in figure 4.

The phase difference was determined using the proteus oscilloscope by measuring the time delay between voltage and current peaks across five cycles. The individual time delays were averaged to give an average time difference of 4.688ms. Using a supply period of 20 ms, the phase difference was calculated at 84.4° as shown in figure 5.

iii)

Figure 6 illustrates how 'I' was calculated

Figure 7 illustrates equation of Active, Reactive, Apparent power

Active, reactive, and apparent power were calculated using standard AC power relationships.

The apparent power was calculated from the product of RMS voltage and RMS current:

$$S = VI$$

Active / Real power was calculated using:

$$P = V\cos\Phi_1$$

Reactive power was calculated using:

$$Q = V\sin\Phi_1$$

Using the values applied in the calculation $V = 300\text{ V}$ (from the assignment brief), $I = 1\text{ A}$ (shown in figure 6), $\Phi = 79.2^\circ$ (from power factor in figure 2). The calculated powers were recorded as:

$$S = VI = 300 \times 1 = 300\text{ VA}$$

$$P = V\cos\Phi_1 = 300 \times 1 \times \cos(79.2) = 56.2\text{ W}$$

$$Q = V\sin\Phi_1 = 300 \times 1 \times \sin(79.2) = 294.7\text{ VAR}$$

As shown in Figure 7.

iv)

The power factor of the RL circuit prior to power factor correction was calculated using the phase difference obtained from the voltage and current waveforms as shown in figure 2. The measured time delay between the waveforms gave a phase angle of $\Phi = 79.2^\circ$. The power factor was calculated using:

$$PF = \cos(\Phi)$$

$$PF = \cos(79.2)$$

Substituting the measured phase angle gave a power factor of 0.19. This value was recorded as the initial power factor of the RL circuit before correction.

v)

Figure 8 illustrates irms and vrms calculations

Figure 9 illustrates calculation to find capacitor value (1)

Figure 10 illustrates calculation to find capacitor value (2)

Figure 11 illustrates calculation to find capacitor value (3)

Figure 12 illustrates calculation to find capacitor value (4)

Figure 13 illustrates RLC circuit

A power factor correction (PFC) capacitor value was calculated to improve the RL circuit power factor to at least 0.95 at 50 Hz. The RMS load voltage and RMS circuit current were taken from the waveform readings shown in figure 8. The Voltage peak was 420 V and current peak was 7.2 A. The Vrms and Irms is calculated by the following formulas:

$$\frac{420}{\sqrt{2}} = 297V \qquad \frac{7.2}{\sqrt{2}} = 5.09A$$

Once the Vrms and Irms are calculated the process to finding the capacitor value can begin and shown in figure 9, 10, 11, 12.

A target power factor of 0.95 was used, corresponding to a target phase of $\Phi = 18^\circ$. Using the current phasor construction screenshots, the required capacitor current was obtained as $I_c = 4.7A$. The capacitor reactance was then calculated using: $X_c = \frac{V}{I_c}$

Giving $X_c = 63.2 \Omega$. The capacitor value was calculated using:

$$C = \frac{1}{2\pi f x}$$
$$C = \frac{1}{2\pi \times 50 \times 63.2}$$

This gave a final capacitor value of $C = 50.3 \mu F$ as shown in figure 13.

vi & vii)

Figure 14 illustrates capacitor value 30uF

Figure 15 illustrates capacitor value 40uF

Figure 16 illustrates capacitor value 60uF

Figure 17 illustrates capacitor value 70uF

Figure 18 illustrates power factor graph and table

Figure 19 illustrates phase angle graph and table

This section investigates how changing the capacitor value affects the phase angle and power factor of the RLC circuit. Simulations were carried out for capacitor values of 30 uF, 40 uF, 50.3 uF, 60uF and 70 uF. For each, value, voltage and current waveforms were observed, and the time difference between them was measured directly from the simulation graphs as shown in figure 13, 14, 15, 16 and 17.

The measured time difference was then used to calculate the phase angle using the waveform period of 20 ms, corresponding to a supply frequency of 50 Hz. From the phase angle, the power factor was determined for each capacitor value.

The results show a clear variation in power factor with capacitance. The higher power factor was obtained at 50.3 uF, where the phase was reduced to 18° and the power factor increased to 0.95, indicating operation close to unity power factor. Capacitor values either side of this resulted in larger phase angles and reduced power factor, demonstrating under and overcompensation effects.

The table and graph summarise the relationship between capacitor value and power factor, clearly showing an optimum capacitance for this circuit configuration as shown in figure 18 and 19.

viii)

As the power factor of the parallel RLC circuit approaches unity, the phase angle between voltage and current reduces and reactive power is minimised. In the inductive load, energy is stored in the magnetic field of the inductor and returned to the supply each cycle. Adding a capacitor introduces electric-field energy storage that opposes the inductive reactive current. At the optimum capacitance, reactive energy is exchanged mainly between the inductor and capacitor rather than the supply, reducing reactive current demand and improving power towards 1 [11].

Results

This section presents the simulation outputs, calculated values, and plotted results obtained from the analysis of the RL and RLC circuits using proteus.

Figure 1 shows the initial RL circuit constructed using component values derived from the student number. The corresponding voltage and current waveforms are shown in figure 2, where it can be observed that the circuit current lags the supply voltage. Using the measured time difference between voltage and current peaks, an average time delay of 4.688 ms was calculated (figure 5), resulting in a phase angle of 84.4° . This confirms a highly inductive load. Using this phase angle, the power was calculated as 0.19. Active, reactive, and apparent power values were calculated and are presented in figure 7.

The RMS voltage and current were obtained directly from proteus measurements (figure 8). The peak voltage of 420 V and peak current of 7.2 A were converted to RMS values of 297 V and 5.09 A respectively. These values were used in subsequent power and capacitor calculations.

Figures 9 to 12 show the phasor diagrams used to determine the required capacitor current and resistance current needed to improve the power factor. From this analysis, a capacitor of 50.3 μF was calculated. The completed RLC circuit using this capacitor is shown in figure 13. The updated voltage and current waveforms indicate a significantly reduced phase difference. Using the measured time delay of 1 ms (Figure 13), a phase angle of 18° was calculated, giving a corrected power factor of 0.95.

To investigate the effect of capacitance on power factor, simulations were repeated for capacitor values of 30 μF , 40 μF , 50.3 μF , 60 μF , and 70 μF . The resulting waveforms and time measurements are shown in figures 14 to 17. The calculated phase angles and power factors are summarised in Figure 18. Figure 19 presents the plots of power factor and phase angle against

capacitor value, showing a clear peak in power factor at approximately 50 μF , confirming this as the optimal correction point.

Task 2

Figure 20 illustrates resonance (52 Hz)

Figure 21 illustrates -25 Hz resonance (27 Hz)

Figure 22 illustrates +25 Hz resonance (77 Hz)

Figure 23 Illustrates Phasor Diagram at resonance (52Hz)

Figure 24 Illustrates Phasor Diagram at -25 Hz resonance (27 Hz)

Figure 25 Illustrates Phasor Diagram at +25 resonance (77 Hz)

Figure 26 Illustrates Phasor Diagram at 50 Hz

Figure 27 and 28 illustrates calculations for phasor diagram (52 Hz)

Figure 29 and 30 illustrates calculations for phasor diagram (77 Hz)

Figure 31 and 32 illustrates calculations for phasor diagram (27 Hz)

Figure 33 and 34 illustrates calculations for phasor diagram (50 Hz)

The circuit behaviour at the calculated resonant frequency of 52Hz is shown in figure 20, where the voltage and current waveforms are almost in phase, indicating resonance. This behaviour is represented in the corresponding phasor diagram in figure 23, where the inductive and capacitive currents are approximately equal in magnitude and opposite in direction, resulting in a small supply current. The calculations used to construct this phasor diagram are shown in figures 27 and 28, where reactance's, branch currents, phase angles, and the resultant current are determined using RMS values and circuit parameters.

The circuit behaviour above resonance at 77Hz is shown in figure 22, where the current leads the voltage, indicating capacitive dominance. This is reflected in the

phasor diagram in figure 25, where the capacitive current is larger than the inductive current, producing a large leading angle. The supporting calculations for this condition are presented in figures 29 and 30, showing the change in reactance.

The circuit behaviour below resonance at 27Hz is shown in figure 21, where the current lags the voltage, demonstrating inductive dominance. This is reflected in the phasor diagram in figure 25, where the capacitive current is larger than the inductive current, producing a large leading phase angle. The supporting calculation for this condition are presented in figures 29 and 30, showing the change in reactance and the resulting phase angle.

The circuit behaviour below resonance at 27Hz is shown in figure 21, where the current lags the voltage, demonstrating inductive dominance. The corresponding phasor diagram is shown in figure 24, where the inductive current significantly exceeds the capacitive current. The calculations used to produce this diagram are shown in figures 31 and 32.

The circuit behaviour at 50Hz is shown in the phasor diagram in Figure 26, where the circuit is close to resonance but still possesses a leading phase angle. The calculations supporting this phasor diagram are shown in figures 33 and 34.

Discussion

Task 3

i)

Power factor correction in the circuit is closely linked to resonance. The original RL load is inductive, meaning the current lags the voltage due to the inductive reactance X_L . By adding a capacitor, a capacitive reactance X_C is introduced which opposes the effect of the inductor [11]. As X_C approaches X_L , the phase angle between voltage and current reduces. This moves the circuit closer to resonance, where the reactive effects cancel and the circuit behaves more like a purely resistive load. This explains why the power factor improves towards 0.95 or higher.

ii)

This also relates to maximum power transfer. When the phase angle is reduced, more of the supplied power becomes real power rather than reactive power [10]. The current drawn from the supply is better aligned with the voltage, allowing more power to be delivered to the load without increasing supply voltage or current. As a result, the system operates more effectively.

iii)

Improving the power factor also improves energy efficiency. A lower phase angle reduces the overall the overall current drawn from the supply, which reduces I^2R losses in conductors and components. This means less energy is wasted as heat and thew electrical system becomes more efficient overall [12].

Task 4

Electricity in the UK and most developed countries is transmitted using three-phase systems because they are more efficient and reliable than single-phase systems. Three-phase systems deliver constant power, reduce conductor material requirements [13] [3], and are well suited for large motors and industrial loads [14]. Using more than three phases offers little additional benefit while significantly increasing system complexity, cost and control requirements, which is why systems with more than three phases are not used [15].

Task 5

Power factor is the real ratio of real power to apparent power and indicates how effectively electrical power is being used [16]. Poor power leads to higher currents, increased losses, and reduced system capacity. Power factor correction, typically using capacitors, is essential in electrical engineering systems to reduce losses, improve voltage regulation, and increase overall efficiency. This is particularly important in industrial and power distribution systems where inductive loads are common [17].

Conclusion

This assignment investigated the behaviour of an RLC circuit at resonance and at frequencies above and below resonance. The results showed how frequency affect reactance, phase angle, current, and how these factors influence power transfer and efficiency.

At resonance, the inductive reactance and capacitive reactance were equal and cancelled each other. This meant the circuit behaved almost like a purely resistive load. As a result, the phase angle between voltage and current was very small. Under these conditions, almost all of the supplied power was active power, which is the useful power delivered to the load. Reactive power was minimal, showing that resonance allows efficient power transfer.

When the circuit operated above or below resonance, either inductive or capacitive reactance dominated. This increased the phase angle, reduced the power factor, and caused higher reactive currents to flow.

Overall, the results clearly demonstrate that resonance and power factor correction are essential in AC systems to maximise useful power transfer, reduce unnecessary current, and improve overall energy efficiency.

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