Basic Electrical Science Lab
Course Code: EE152

Laboratory Manual

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Roll No: 20CSE1030

Section: B

Academic Session: April – August 2021

National Institute of Technology Goa

CERTIFICATE

This is to certify that Mr./ Ms. ______________________ of Class B.Tech 1st year (2nd Sem), Division Sec A/B, bearing Roll. No.______________, has satisfactorily completed the course experiments in the Laboratory Course Basic Electrical Science Lab (EE152) in the academic year 2020-2021 in the Institution of National Institute of Technology Goa.

Course Instructor

Table of Contents

1.A. Introduction:

This session makes students to understand the analysis of AC circuits through a Simulation platform, MATLAB/Simulink.

1.B. Objectives:

a. Acquire a good knowledge on the AC electrical circuits.

b. Verification of the theoretical knowledge on steady state characteristics of AC electrical circuits in MATLAB/Simulink Platform.

1.C. Theory: Refer to the notes or necessary materials mentioned in EE151 course.

1.D. Statement of Experiments:

Fig. 5.1 represents an AC network, where an AC sinusoidal voltage source ($V(t) = 230\sqrt{2}\sin(100\pi t)$) feds power to a load ($R = 10\ \Omega$, $L = 1$ mH, $C = 1$ mF). The following task has to be done theoretically and those have to be verified by simulation in MATLAB. 1. Find load impedance. 2. Derive the expression of various responses. 3. Draw the phasor diagram of these responses. 4. Calculate various power components. 5. Calculate Power Factor. 6. Find the value of source frequency at which the power factor will be unity.

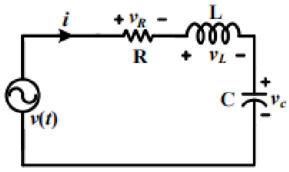


Fig. 5.1

1.E. Procedure:

Determine all the parameters asked in section-1.D theoretically and draw corresponding experimental circuit (necessary measuring instruments are to be incorporated in the circuit) of the circuit shown in Fig. 5.1. Construct the experimental circuits in Simulink domain, simulate it fill up the Table - 5.1. A brief procedure is mentioned below

- Draw only load in simulink and with the help of "***Impedance Measurement***" block, find impedance of the circuit.
- Draw the full experimental circuit in Simulink and plot all the responses in workspace. With the help of scope waveform and the plots in workspace, verify various expression derived theoretically.
- With the help of "***Power***" block, find various power components

1.F. Assignments:

Consider same parameters (as mentioned in Section – 1.D) for Fig. 5.2 and do the same as mentioned in Section – 1.D

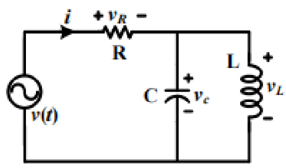


Fig. 5.2

Table - 5.1

Sl. No	Load Impedance, Ω		Active Power, kW		Reactive Power, kVAR		Apparent Power, kVA		Power Factor		Frequency (Hz) at UPF	
	Theoretical	Simulation	Theoretical	Simulation	Theoretical	Simulation	Theoretical	Simulation	Theoretical	Simulation	Theoretical	Simulation
1												
2												
3												

Experiment 5

Power calculations in AC circuits

1. **Aim:** To verify the theoretical power analysis of AC circuits through a simulation platform.

2. **Simulink Blockset used:** Resistors, Capacitor, Inductor, voltage source, AC source, current measurement, voltage measurement, add, divide, display, scope, constant, powergui, mux, Power, Fourier, Impedence measurement, goto, from

3. **Theory:**

Active, Reactive and Apparent Power

Active Power

Definition: The power which is actually consumed or utilised in an AC Circuit is called True power or Active power or Real power. It is measured in kilowatt (kW) or MW. It is the actual outcomes of the electrical system which runs the electric circuits or load.

Reactive Power

Definition: The power which flows back and forth that means it moves in both the directions in the circuit or reacts upon itself, is called Reactive Power. The reactive power is measured in kilo volt-ampere reactive (kVAR) or MVAR.

Apparent Power

Definition: The product of root mean square (RMS) value of voltage and current is known as Apparent Power. This power is measured in kVA or MVA.

It has been seen that power is consumed only in resistance. A pure inductor and a pure capacitor do not consume any power since in a half cycle whatever power is received from the source by these components, the same power is returned to the source. This power which returns and flows in both the direction in the circuit, is called Reactive power. This reactive power does not perform any useful work in the circuit.

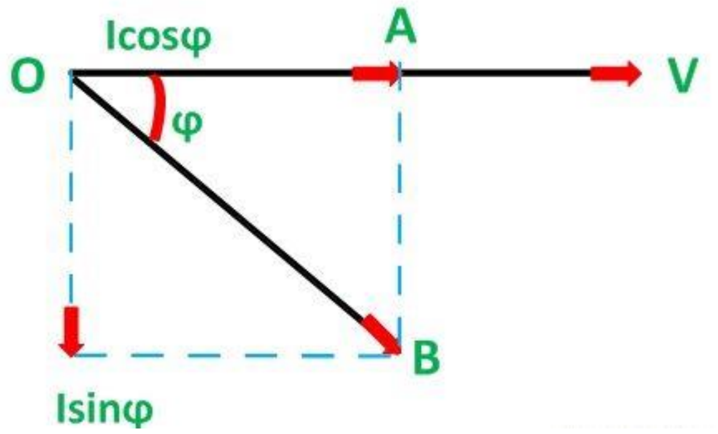
In a purely resistive circuit, the current is in phase with the applied voltage, whereas in a purely inductive and capacitive circuit the current is 90 degrees out of phase, i.e., if the inductive load is connected in the circuit the current lags voltage by 90 degrees and if the capacitive load is connected the current leads the voltage by 90 degrees.

Hence, from all the above discussion, it is concluded that the *current in phase with the voltage produces true or active power*, whereas, the *current 90 degrees out of phase with the voltage contributes to reactive power* in the circuit.

Therefore,

- True power = voltage x current in phase with the voltage
- Reactive power = voltage x current out of phase with the voltage

The phasor diagram for an inductive circuit is shown below:



Taking voltage V as reference, the current I lags behind the voltage V by an angle ϕ. The current I is divided into two components:

- I Cos ϕ in phase with the voltage V
- I Sin ϕ which is 90 degrees out of phase with the voltage V

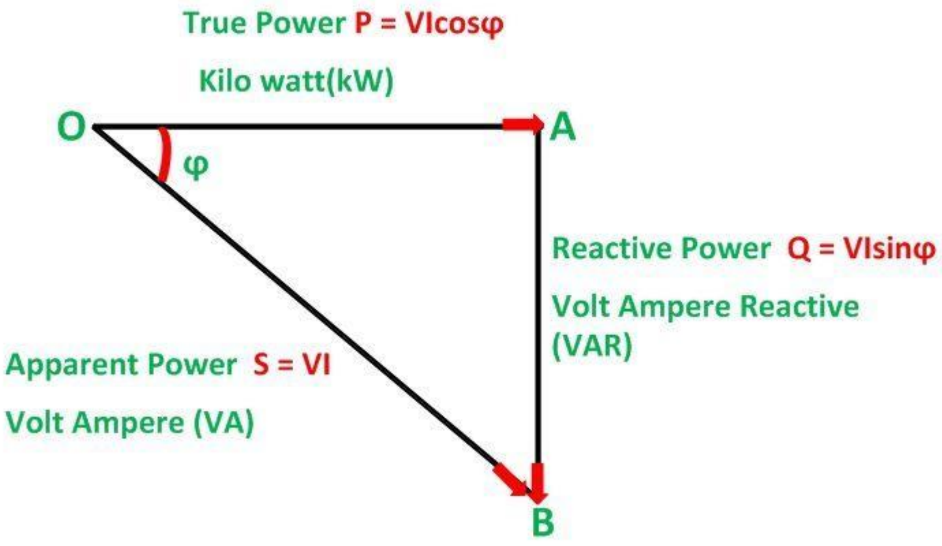
Therefore, the following expression shown below gives the active, reactive and apparent power respectively.

- Active power P = V x I cosϕ = V I cosϕ
- Reactive power P_r or Q = V x I sinϕ = V I sinϕ
- Apparent power P_a or S = V x I = VI

Power Triangle

Power Triangle is the representation of a right angle triangle showing the relation between active power, reactive power and apparent power.

When each component of the current that is the active component (Icosϕ) or the reactive component (Isinϕ) is multiplied by the voltage V, a power triangle is obtained shown in the figure below:



The power which is actually consumed or utilized in an AC Circuit is called True power or **Active Power** or real power. It is measured in kilowatt (kW) or MW.

The power which flows back and forth that means it moves in both the direction in the circuit or reacts upon it, is called **Reactive Power**. The reactive power is measured in kilovolt-ampere reactive (kVAR) or MVAR.

The product of root mean square (RMS) value of voltage and current is known as **Apparent Power**. This power is measured in KVA or MVA.

The following point shows the relationship between the following quantities and is explained by graphical representation called Power Triangle shown above.

- When an active component of current is multiplied by the circuit voltage V, it results in active power.it is this power which produces torque in the motor, heat in the heater, etc. This power is measured by the wattmeter.
- When the reactive component of the current is multiplied by the circuit voltage, it gives reactive power. This power determines the power factor, and it flows back and forth in the circuit.
- When the circuit current is multiplied by the circuit voltage, it results in apparent power.
- From the power triangle shown above the power, the factor may be determined by taking the ratio of true power to the apparent power.

$$\text{Power factor } \text{Cos}\varphi = \frac{\text{Active power}}{\text{Apparent power}} = \frac{\text{KW}}{\text{KVA}}$$

As we know simply power means the product of voltage and current but in AC circuit except for pure resistive circuit there is usually a phase difference between voltage and current and thus VI does not give real or true power in the circuit.

4. Statement of Experiments:

Fig. 5.1 represents an AC network, where an AC sinusoidal voltage source (V(t) =230√2sin(100πt)) feds power to a load (R = 10 Ω, L = 1 mH, C = 1 mF). The following task has to be done theoretically and those have to be verified by simulation in MATLAB.

1. Find load impedance.
2. Derive the expression of various responses.
3. Draw the phasor diagram of these responses.
4. Calculate various power components.
5. Calculate Power Factor.
6. Find the value of source frequency at which the power factor will be unity.

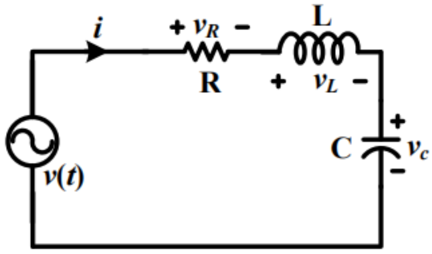


Fig. 5.1

5. Procedure:

Determine all the parameters asked in section-1.D theoretically and draw corresponding experimental circuit (necessary measuring instruments are to be incorporated in the circuit) of the circuit shown in Fig. 5.1.

Construct the experimental circuits in Simulink domain, simulate it fill up the Table - 5.1. A brief procedure is mentioned below: -

- Draw only load in Simulink and with the help of ***Impedance Measurement***” block, find impedance of the circuit.
- Draw the full experimental circuit in Simulink and plot all the responses in workspace. With the help of scope waveform and the plots in workspace, verify various expression derived theoretically.
- With the help of “***Power***” block, find various power components.

6. Observations: -

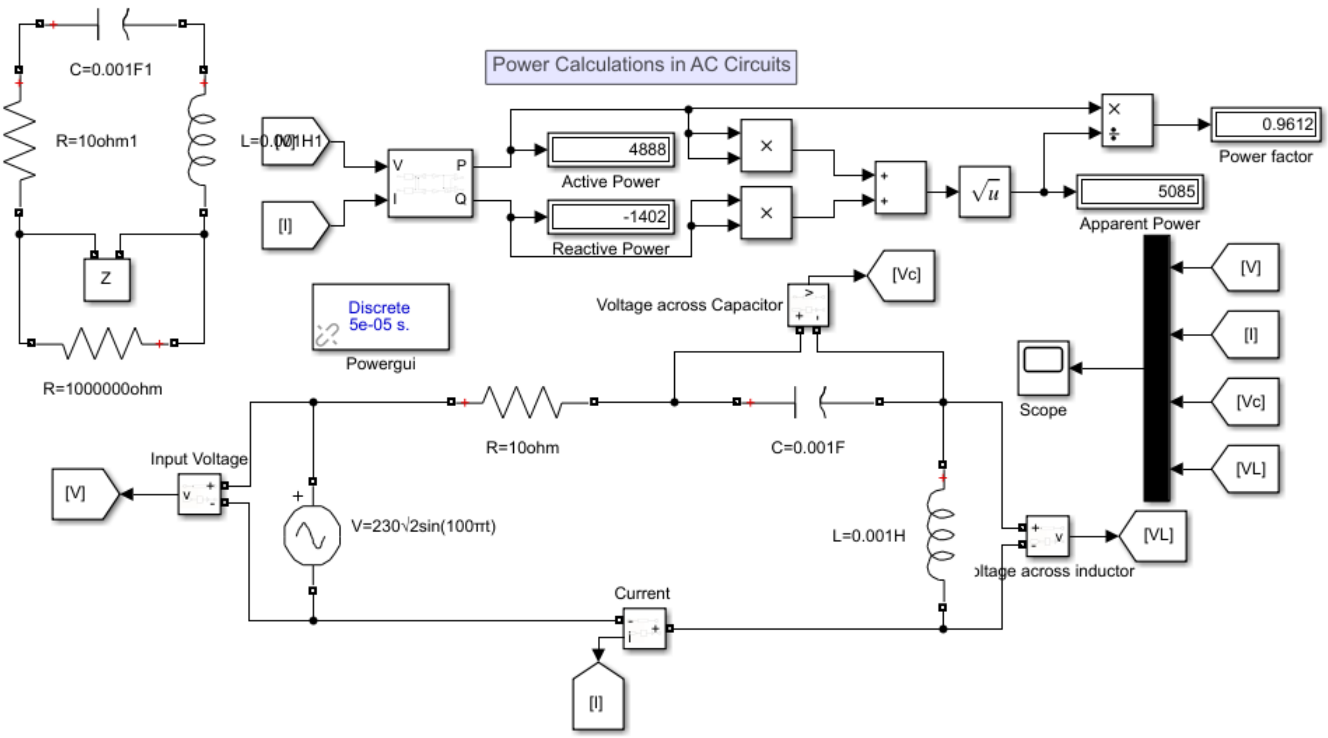


Fig5a: Circuit connections in Simulink

Sl. No	Parameters	Load Impedance, Ω		Active Power, kW		Reactive Power, kVAR		Apparent Power, kVA		Power Factor		Frequency (Hz) at UPF	
		Theoretical	Simulation	Theoretical	Simulation	Theoretical	Simulation	Theoretical	Simulation	Theoretical	Simulation	Theoretical	Simulation
1	R=10ohm L=1mH, C=1mF, f=50Hz	10.4	10.4	4.891	4.888	-1402	-1.402	5.087	5.085	0.9613	0.9612	159.2	159.2
2	R=10ohm L=20mH, C=10mF, f=50Hz	11.64	11.64	3.903	3.902	2.328	2.327	4.545	4.543	0.8588	0.8588	11.25	11.25
3	R=10ohm L=5mH, C=10mF, w=50Hz	10.07	10.07	5.216	5 .216	0.622	0.6222	5.253	5.5252	0.993	0.993	11.25	11.25

Table 5a: Comparison between Theoretical and Simulation power analysis

Calculations & Graphical Results:

For Obsv No:1 R=10 L=1mH C=1mF f=50Hz

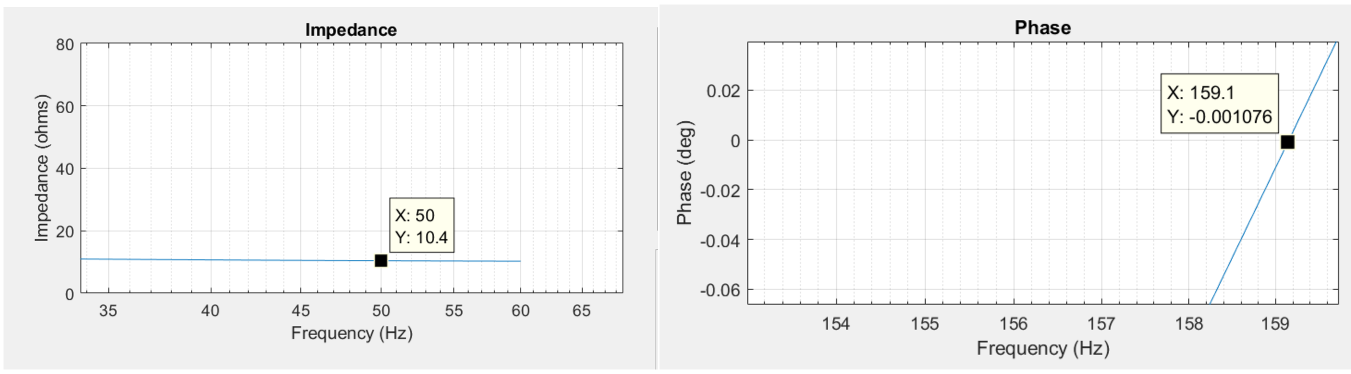
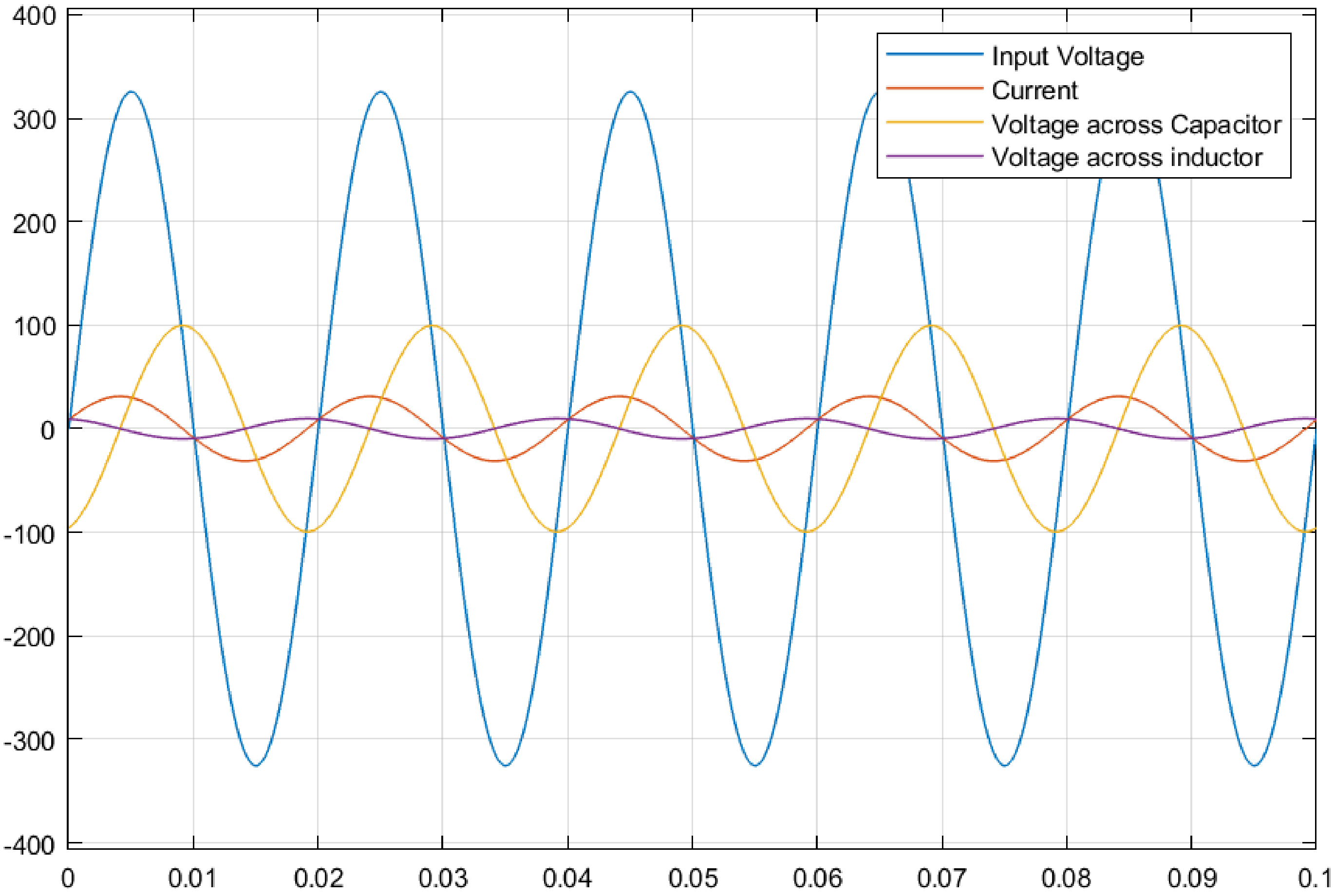
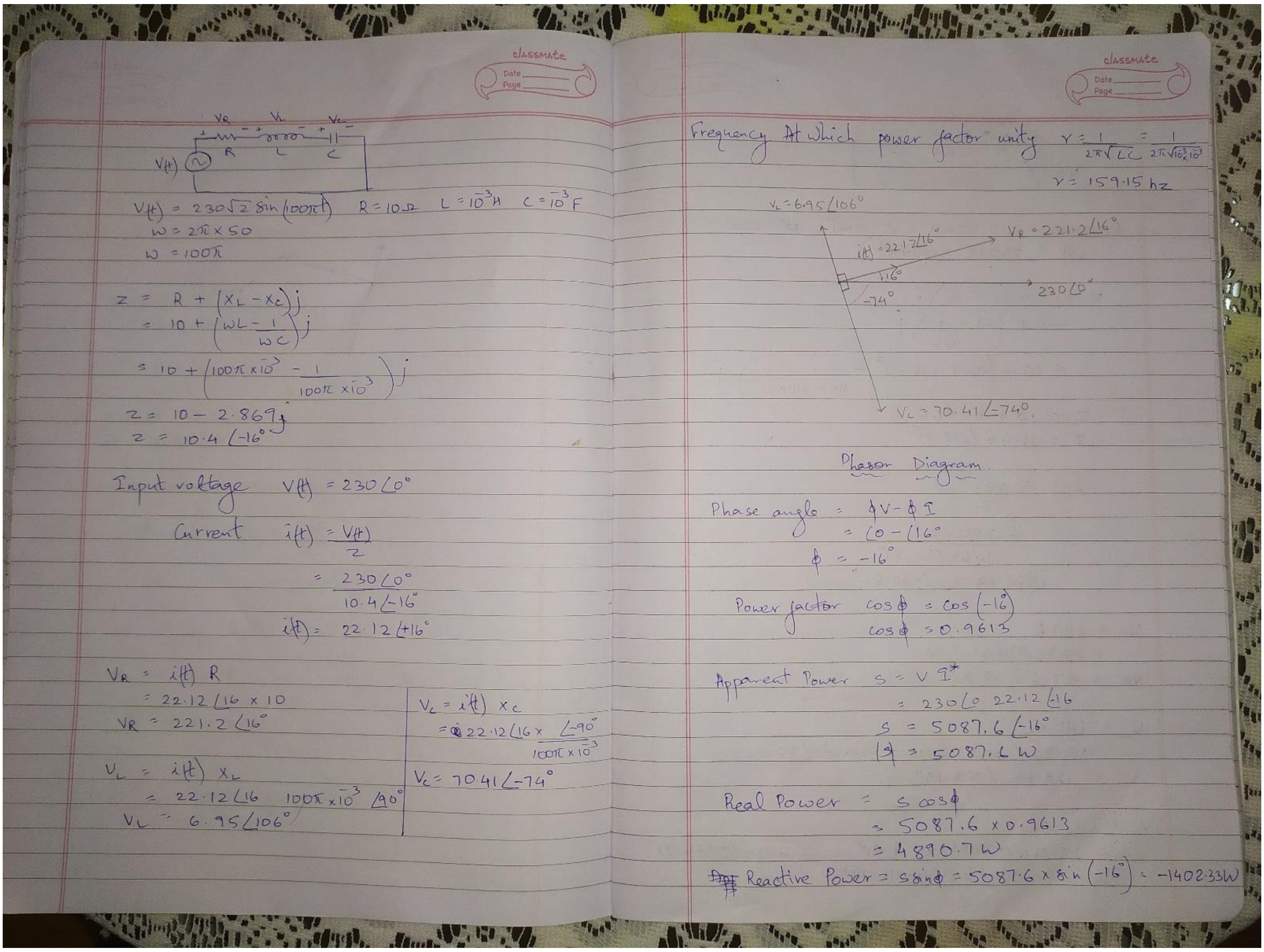


Fig5b: Impedence at 50Hz and frequency at UPF



Graph5a: Waveforms of various responses



$v(t) = 230\sqrt{2}\sin(100\pi t)$ $R = 10\Omega$ $L = 10^{-3}H$ $C = 10^{-3}F$

$\omega = 2\pi \times 50$

$\omega = 100\pi$

$Z = R + (X_L - X_C)j$

$= 10 + \left(\omega L - \frac{1}{\omega C}\right)j$

$= 10 + \left(100\pi \times 10^{-3} - \frac{1}{100\pi \times 10^{-3}}\right)j$

$Z = 10 - 2.869j$

$Z = 10.4\angle -16^\circ$

Input voltage $V(t) = 230\angle 0^\circ$

Current $i(t) = \frac{V(t)}{Z}$

$= \frac{230\angle 0^\circ}{10.4\angle -16^\circ}$

$i(t) = 22.12\angle +16^\circ$

$V_R = i(t)\,R$

$= 22.12\angle 16 \times 10$

$V_R = 221.2\angle 16^\circ$

$V_L = i(t)\,X_L$

$= 22.12\angle 16 \quad 100\pi \times 10^{-3}\angle 90^\circ$

$V_L = 6.95\angle 106^\circ$

$V_C = i(t)\,X_C$

$= 22.12\angle 16 \times \frac{\angle -90^\circ}{100\pi \times 10^{-3}}$

$V_C = 70.41\angle -74^\circ$

Frequency At which power factor unity $\gamma = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{10^{-3}10^{-3}}}$

$\gamma = 159.15$ hz

$V_L = 6.95\angle 106^\circ$ $i(t) = 22.12\angle 16^\circ$ $V_R = 221.2\angle 16^\circ$ 16° $230\angle 0^\circ$ -74° $V_C = 70.41\angle -74^\circ$

Phasor Diagram

Phase angle $= \phi V - \phi I$

$= \angle 0 - \angle 16^\circ$

$\phi = -16^\circ$

Power factor $\cos\phi = \cos(-16^\circ)$

$\cos\phi = 0.9613$

Apparent Power $S = V I^*$

$= 230\angle 0 \quad 22.12\angle -16$

$S = 5087.6\angle -16^\circ$

$|S| = 5087.6$ W

Real Power $= S\cos\phi$

$= 5087.6 \times 0.9613$

$= 4890.7$ W

Reactive Power $= S\sin\phi = 5087.6 \times \sin(-16^\circ) = -1402.33$W

Theoretical Calculations for Observation No:1

For Obsv No:2 R=10 L=20mH C=10mF f=50Hz

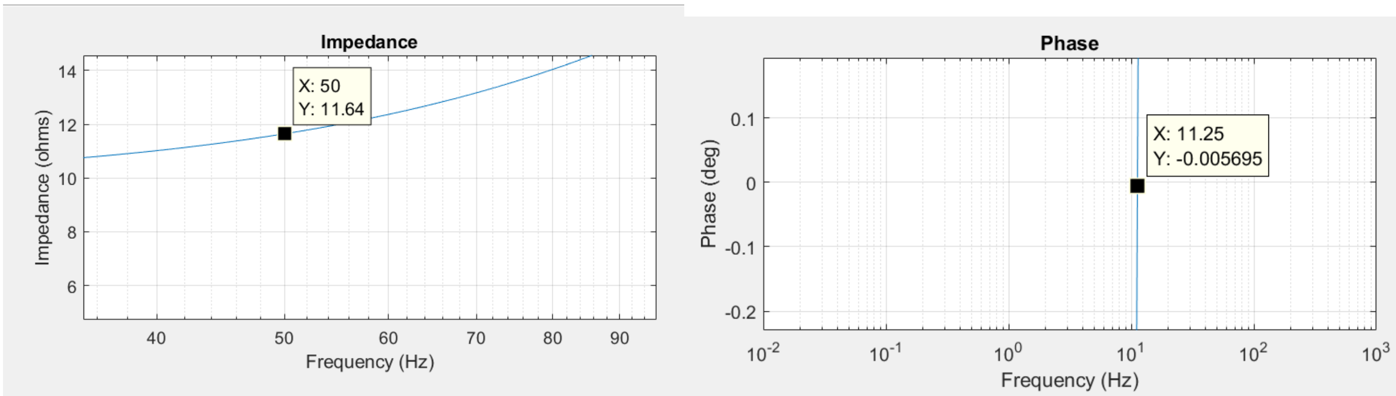
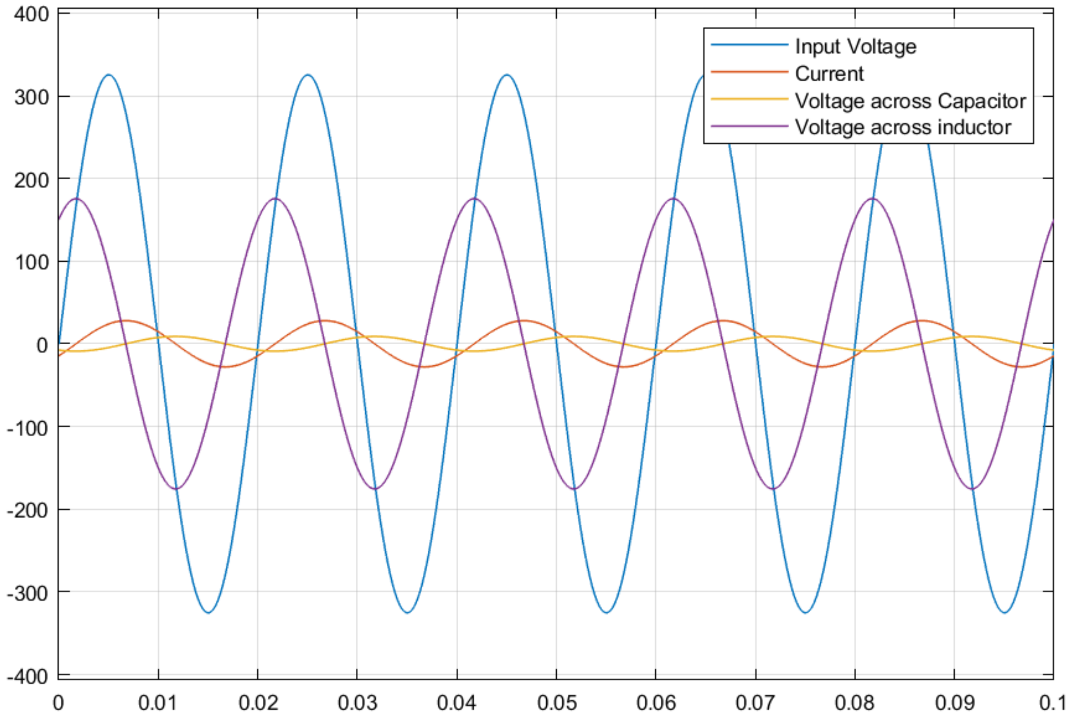
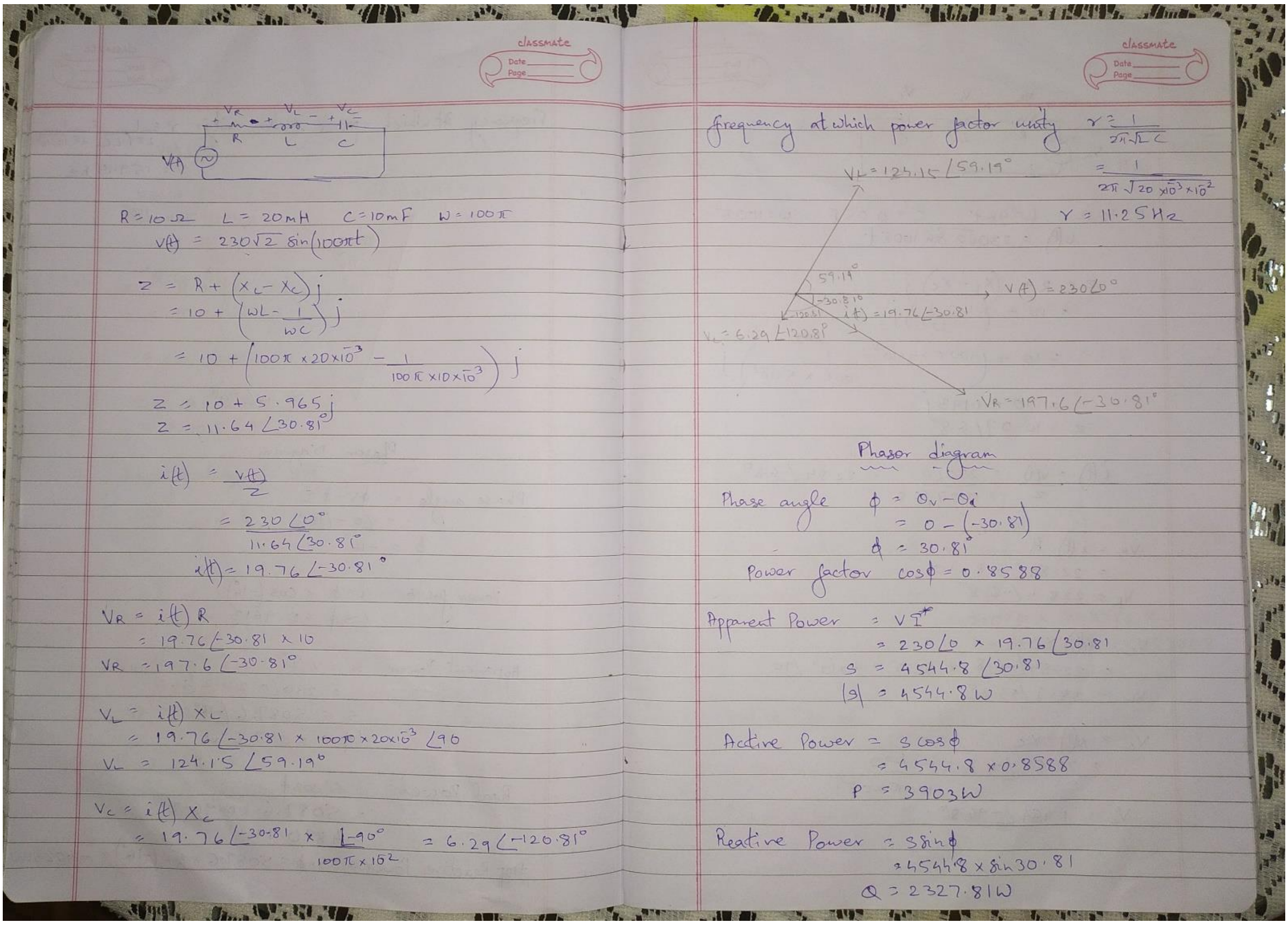


Fig5b: Impedence at 50Hz and frequency at UPF



Graph5b: Waveforms of various responses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V_R V_L V_C
R L C
$v(t)$

$R = 10\,\Omega \quad L = 20\,mH \quad C = 10\,mF \quad \omega = 100\pi$

$v(t) = 230\sqrt{2}\sin(100\pi t)$

$Z = R + (X_L - X_C)j$

$= 10 + \left(\omega L - \frac{1}{\omega C}\right)j$

$= 10 + \left(100\pi \times 20\times 10^{-3} - \frac{1}{100\pi \times 10 \times 10^{-3}}\right)j$

$Z = 10 + 5.965j$

$Z = 11.64\angle 30.81^\circ$

$i(t) = \frac{v(t)}{Z}$

$= \frac{230\angle 0^\circ}{11.64\angle 30.81^\circ}$

$i(t) = 19.76\angle -30.81^\circ$

$V_R = i(t)\,R$

$= 19.76\angle -30.81 \times 10$

$V_R = 197.6\angle -30.81^\circ$

$V_L = i(t)\,X_L$

$= 19.76\angle -30.81 \times 100\pi \times 20\times 10^{-3}\angle 90$

$V_L = 124.15\angle 59.19^\circ$

$V_C = i(t)\,X_C$

$= 19.76\angle -30.81 \times \frac{\angle -90^\circ}{100\pi \times 10^{-2}} = 6.29\angle -120.81^\circ$

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frequency at which power factor unity $\quad r = \frac{1}{2\pi\sqrt{LC}}$

$= \frac{1}{2\pi\sqrt{20\times 10^{-3} \times 10^{-2}}}$

$r = 11.25\,Hz$

$V_L = 124.15\angle 59.19^\circ$

59.19°

$v(t) = 230\angle 0^\circ$

-30.81°

-120.81

$i(t) = 19.76\angle -30.81$

$V_C = 6.29\angle -120.81^\circ$

$V_R = 197.6\angle -30.81^\circ$

Phasor diagram

Phase angle $\quad \phi = \theta_v - \theta_i$

$= 0 - (-30.81^\circ)$

$\phi = 30.81^\circ$

Power factor $\quad \cos\phi = 0.8588$

Apparent Power $= VI^*$

$= 230\angle 0 \times 19.76\angle 30.81$

$S = 4544.8\angle 30.81$

$|S| = 4544.8\,W$

Active Power $= S\cos\phi$

$= 4544.8 \times 0.8588$

$P = 3903\,W$

Reative Power $= S\sin\phi$

$= 4544.8 \times \sin 30.81$

$Q = 2327.81\,W$

Theoretical Calculations for Observation No:2

For Obsv No:3 R=10 L=5mH C=10mF f=50Hz

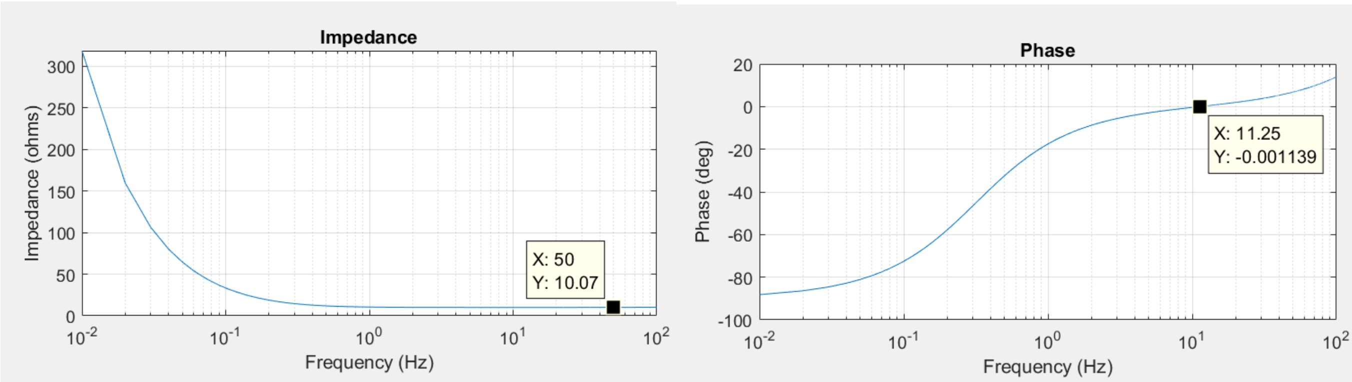
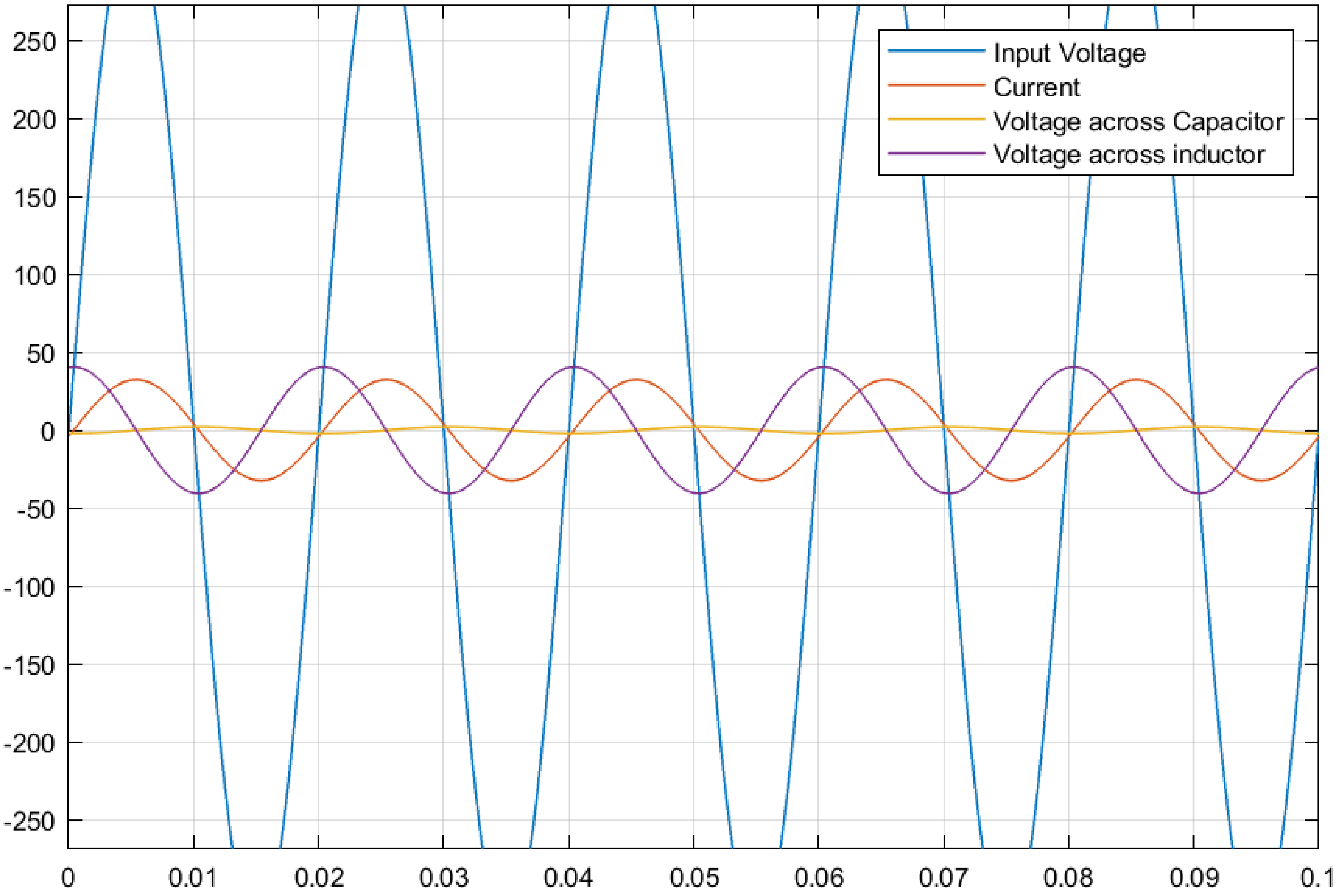
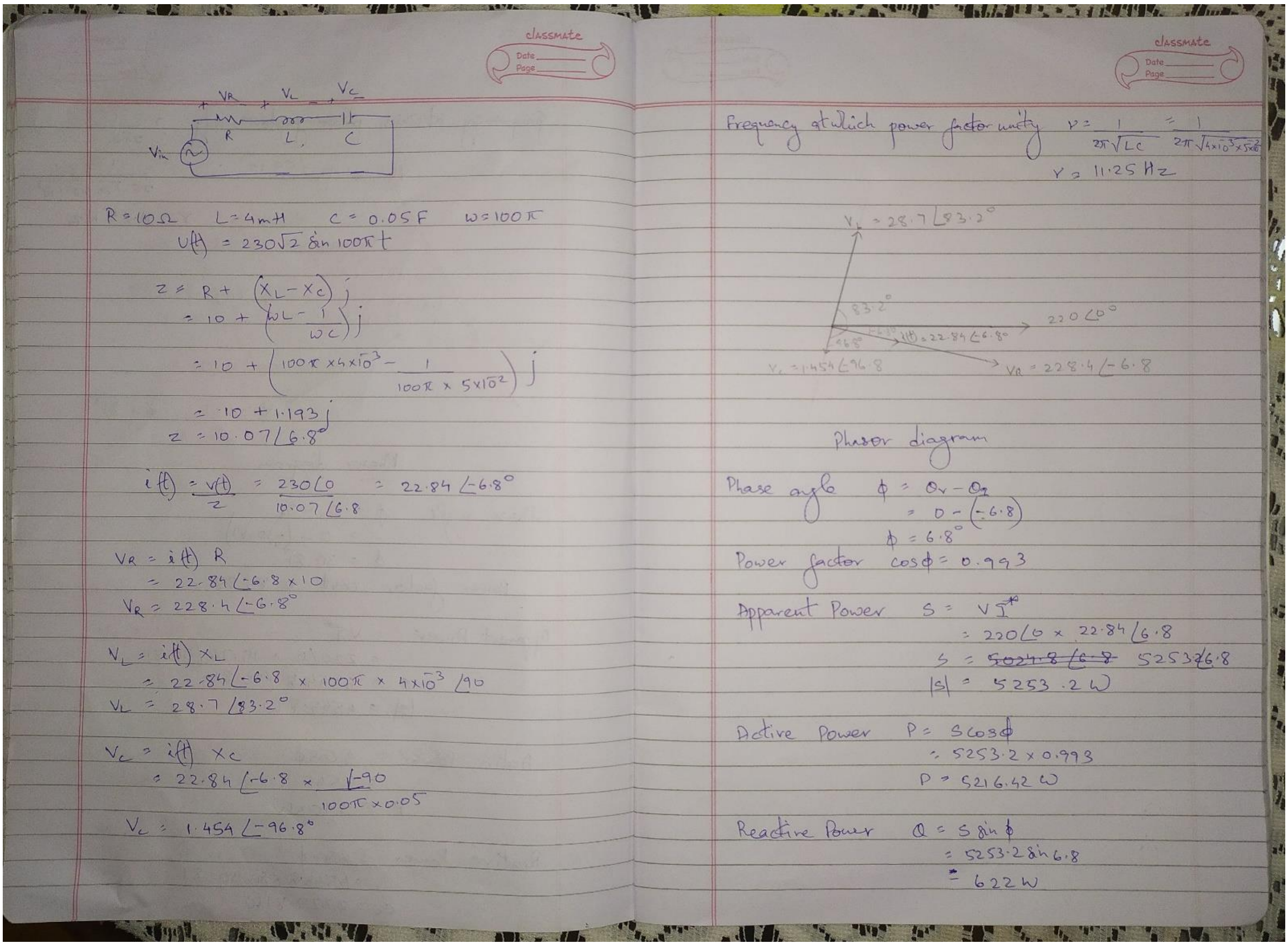


Fig5b: Impedence at 50Hz and frequency at UPF



Graph5c: Waveforms of various responses



$R = 10\Omega \quad L = 4mH \quad C = 0.05F \quad \omega = 100\pi$

$v(t) = 230\sqrt{2}\sin 100\pi t$

$z = R + (X_L - X_c)j$

$= 10 + \left(\omega L - \frac{1}{\omega C}\right)j$

$= 10 + \left(100\pi \times 4\times10^{-3} - \frac{1}{100\pi \times 5\times10^{-2}}\right)j$

$= 10 + 1.193j$

$z = 10.07\angle 6.8^\circ$

$i(t) = \frac{v(t)}{z} = \frac{230\angle 0}{10.07\angle 6.8} = 22.84\angle -6.8^\circ$

$V_R = i(t)\,R$

$= 22.84\angle -6.8 \times 10$

$V_R = 228.4\angle -6.8^\circ$

$V_L = i(t)\,X_L$

$= 22.84\angle -6.8 \times 100\pi \times 4\times10^{-3}\angle 90$

$V_L = 28.7\angle 83.2^\circ$

$V_c = i(t)\,X_c$

$= 22.84\angle -6.8 \times \frac{1\angle -90}{100\pi \times 0.05}$

$V_c = 1.454\angle -96.8^\circ$

Frequency at which power factor unity $f = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{4\times10^{-3}\times5\times10^{-2}}}$

$f = 11.25\ Hz$

$V_L = 28.7\angle 83.2^\circ$

$220\angle 0^\circ$

$i(t) = 22.84\angle -6.8^\circ$

$V_c = 1.454\angle -96.8$

$V_R = 228.4\angle -6.8$

Phasor diagram

Phase angle $\phi = \theta_v - \theta_i$

$= 0 - (-6.8)$

$\phi = 6.8^\circ$

Power factor $\cos\phi = 0.993$

Apparent Power $S = VI^*$

$= 220\angle 0 \times 22.84\angle 6.8$

$S = \cancel{5024.8\angle 6.8}\ 5253\angle 6.8$

$|S| = 5253.2\ W$

Active Power $P = S\cos\phi$

$= 5253.2 \times 0.993$

$P = 5216.42\ W$

Reactive Power $Q = S\sin\phi$

$= 5253.2\sin 6.8$

$= 622\ W$

Theoretical Calculations for Observation No:3

8. **Precautions:**

a) Ensure that 'powergui' block set is included in the Simulink file.
b) Ensure that connections are properly made.
c) Ensure that the scale of the graphs should be adjusted to the range in which the readings vary.
d) Ensure that a very high resistor to an order of 10^6 is attached in parallel to impedence measurement block.

9. **Inferences**: Theoretical Power analysis are verified through simulation.

10. **Conclusion:** Theoretical knowledge on steady state characteristics of AC electrical circuits stands true.

Assignment:

Consider same parameters (as mentioned in Section – 1.D) for Fig. 5.2 and do the same as mentioned in Section – 1.D

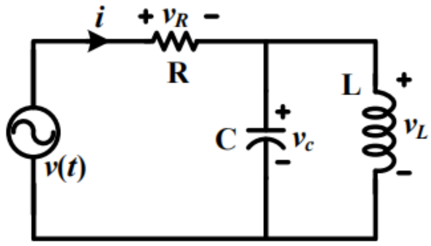


Fig. 5.2

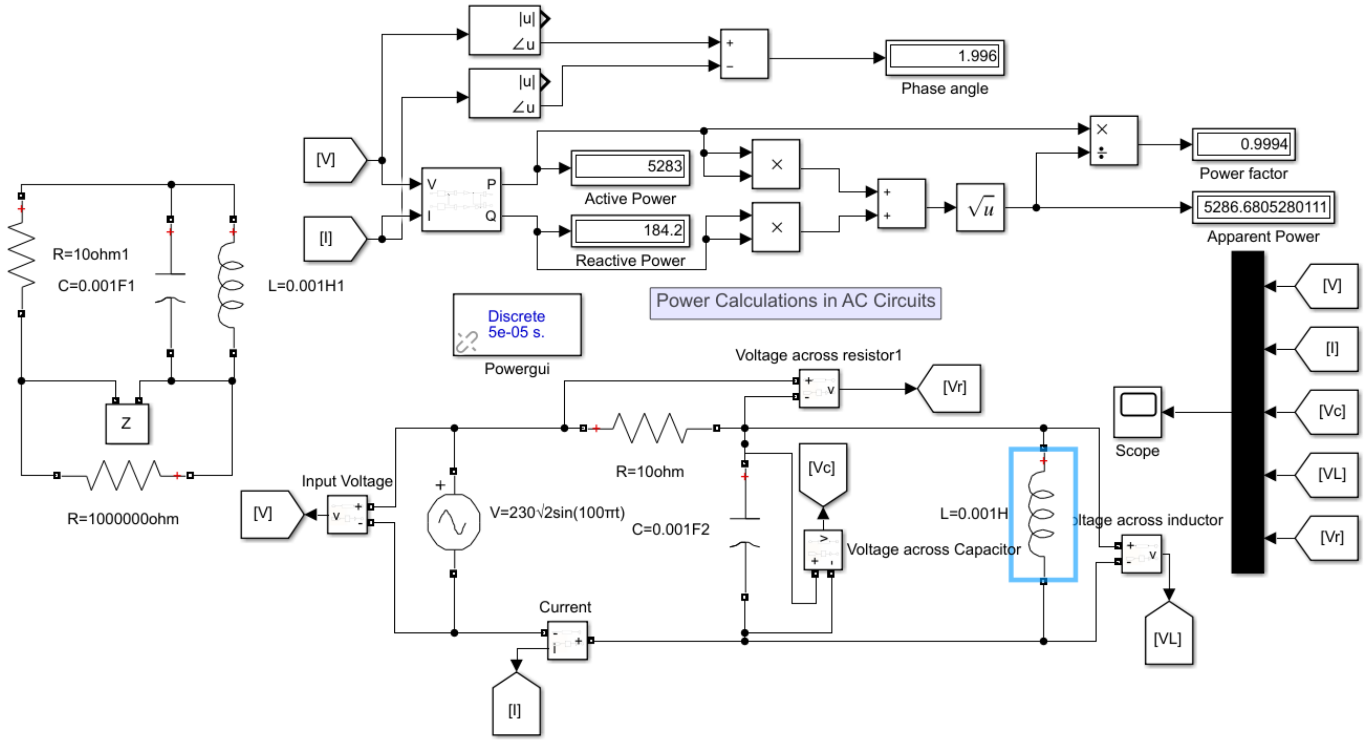
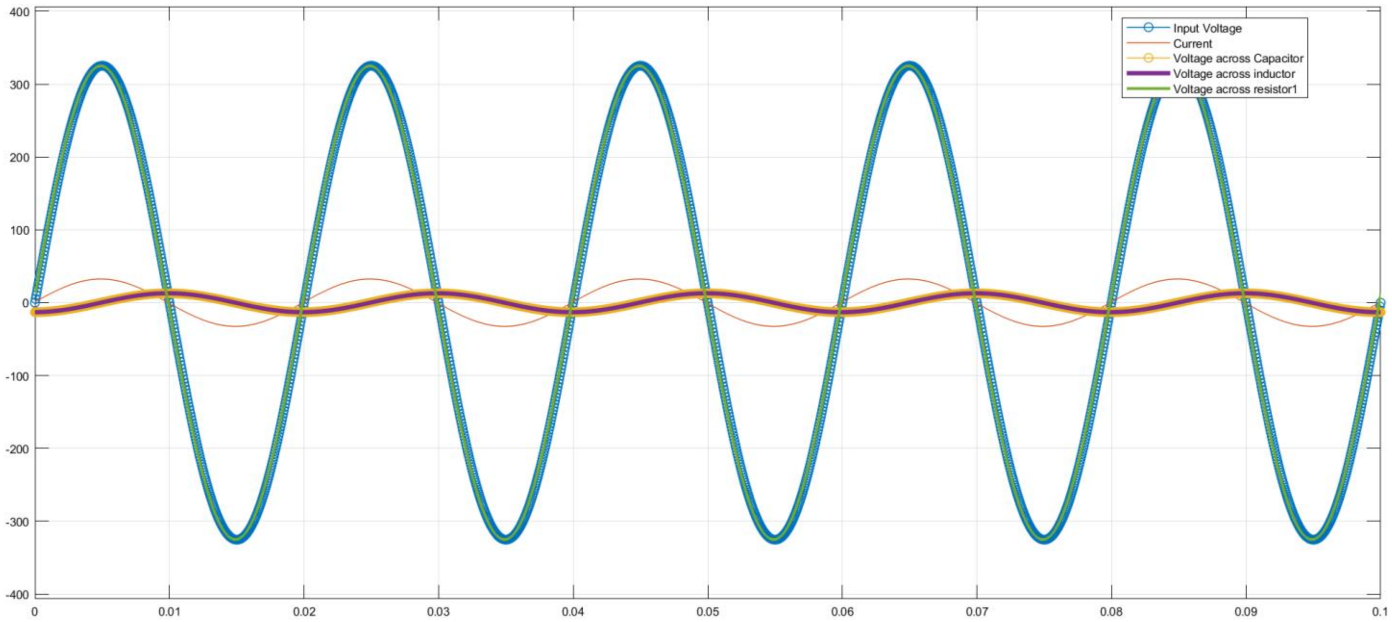


Fig5e: Circuit connections in Simulink

Sl. No	Parameters	Load Impedance, Ω		Active Power, kW		Reactive Power, kVAR		Apparent Power, kVA		Power Factor		Frequency (Hz) at UPF	
		Theoretical	Simulation	Theoretical	Simulation	Theoretical	Simulation	Theoretical	Simulation	Theoretical	Simulation	Theoretical	Simulation
1	R=10ohm L=1mH, C=1mF, f=50Hz	10	10	5.286	5.283	0.1837	0.1842	5.290	5.287	0.9994	09994	0	0
2	R=10ohm L=5mH, C=10mF, f=50Hz	10	10	5.286	5.281	-0.2109	-0.2108	5.290	5.286	0.9992	0.9992	0	0
3	R=10ohm L=50mH, C=4mF, w=50Hz	10.03	10.07	5.255	5.253	-0.4405	-0.4403	5.274	5.272	0.9965	0.9965	0	0

Table5b: Comparison between theoretical and simulated power analysis

For Obsv No:1 R=10 L=1mH C=1mF f=50Hz



Graph5d: Waveforms of various responses

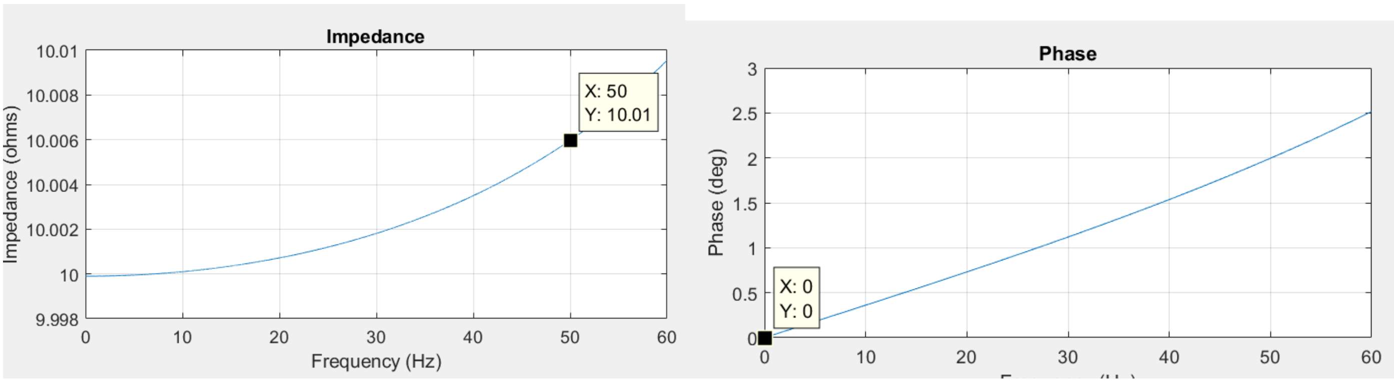
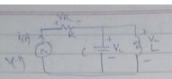


Fig5b: Impedence at 50Hz and frequency at UPF



$R = 10\,\Omega \quad L = 1\,mH \quad C = 1\,mF \quad \omega = 100\pi \quad v(t) = 230\sqrt{2}\sin(100\pi t)$

$$Z = R + \frac{X_L X_C}{X_L + X_C}$$

$$= R + \left(\frac{\omega L j \left(\frac{-j}{\omega C}\right)}{\omega L j - \frac{1}{\omega C}}\right)$$

$$= R + \frac{\left(\frac{L}{C}\right)(-j)}{\omega L - \frac{1}{\omega C}}$$

$$= 10 + \frac{\frac{10^{-3}}{10^{-3}} \times (-j)}{\left(100\pi \times 10^{-3} - \frac{1}{100\pi \times 10^{-3}}\right)}$$

$Z = 10 + 0.348j$

$Z = 10\angle 1.99^\circ$

Frequency when power factor unity $\gamma = 0$

for power factor to be unity:
Z should be real (completely)

$\text{img } Z = 0$

$$\frac{-L \times j}{C\left(\omega L - \frac{1}{\omega C}\right)} = 0$$

$$\frac{-\omega L}{(\omega^2 LC - 1)} = 0$$

$\omega = 0$

$\therefore \gamma = 0$

$$i(t) = \frac{v(t)}{Z} = \frac{230\angle 0}{10\angle 1.99}$$

$i(t) = 23\angle -1.99^\circ$

$VR = i(t)\,R$

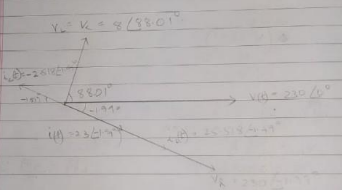
$= 230\angle -1.99^\circ$

$$V_C = \left(\frac{X_L X_C}{X_L + X_C}\right) i(t)$$

$$= \frac{-\omega L j}{(\omega^2 LC - 1)} \quad 23\angle -1.99^\circ$$

$V_L = 8\angle 88.01^\circ \quad V_C = V_L = 8\angle 88.01^\circ$

$\cancel{= 8\angle -1.99}$



Phasor diagram

$$i_C(t) = \frac{X_L}{X_L + X_C}\, i(t)$$

$$= \left(\frac{j\omega L}{\omega L j - \frac{j}{\omega C}}\right) i(t)$$

$$= \frac{100\pi \times 10^{-3}}{\frac{\pi}{10} - \frac{10}{\pi}} \quad 23\angle -1.99^\circ$$

$i_C(t) = -2.518\angle -1.99^\circ$

$i_L(t) = i(t) - i_C(t) = 25.518\angle -1.99^\circ$

Phase angle $\phi = \theta_v - \theta_i$

$= 0 - (-1.99)$

$\phi = 1.99^\circ$

Power factor $\cos\phi = 0.9994$

Apparent power $S = V I^*$

$= 230\angle 0 \times (23\angle 1.99^\circ)$

$S = 5290\angle 1.99^\circ$

$|S| = 5290\,W$

Active Power $P = S\cos\phi$

$= 5290 \times 0.9994$

$P = 5286.8\,W$

Reactive Power $Q = S\sin\phi$

$= 5290\sin(1.99)$

$Q = 183.69\,W$

For Obsv No:2 R=10 L=5mH C=10mF f=50Hz

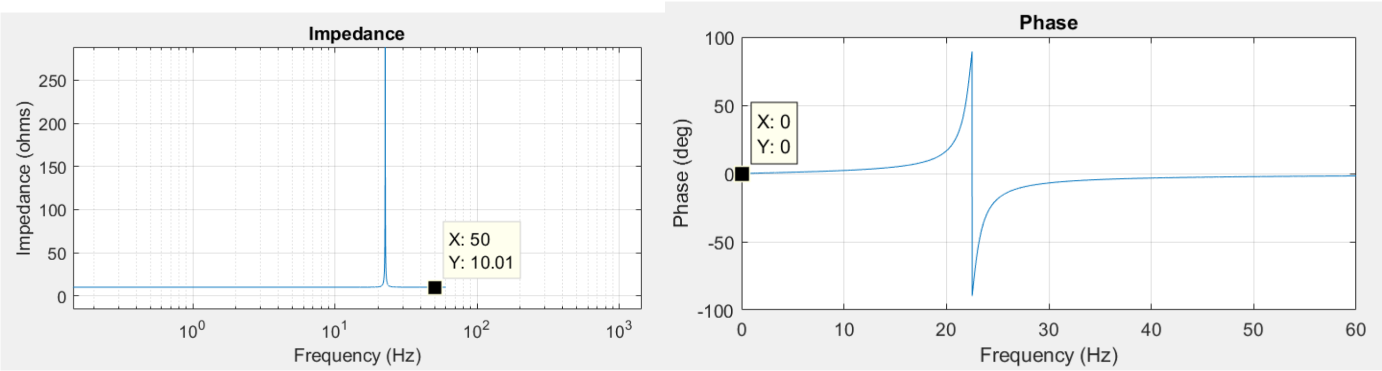
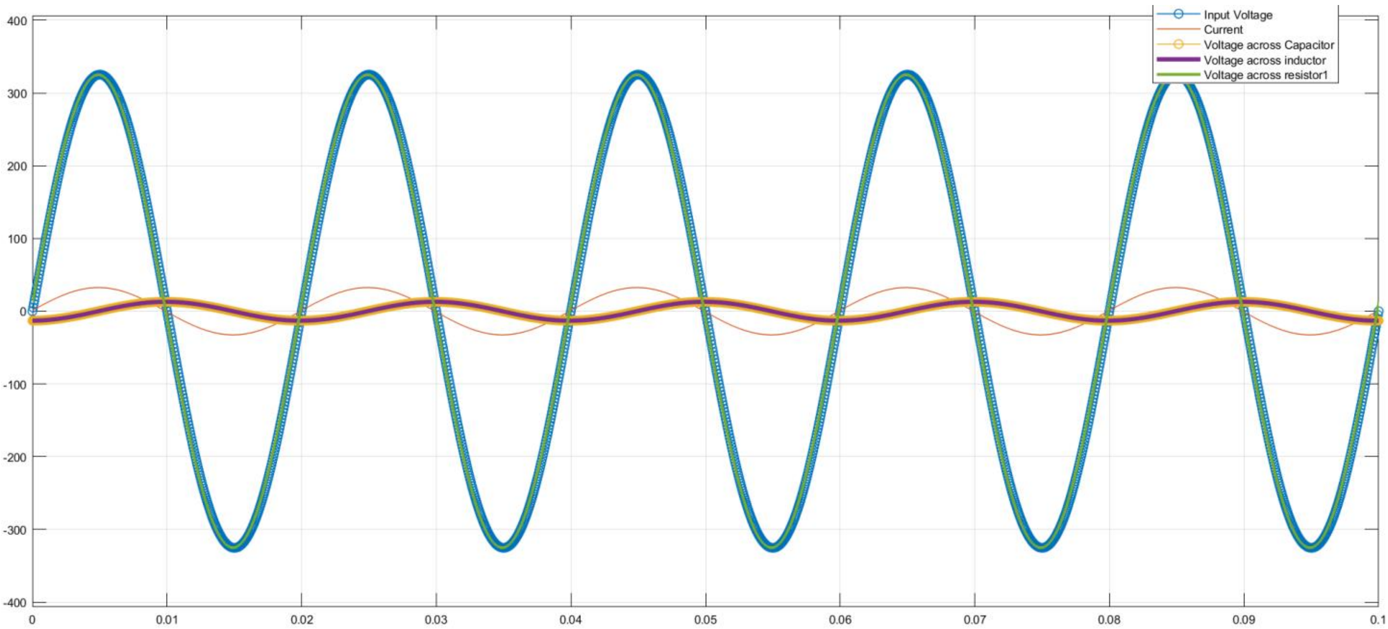
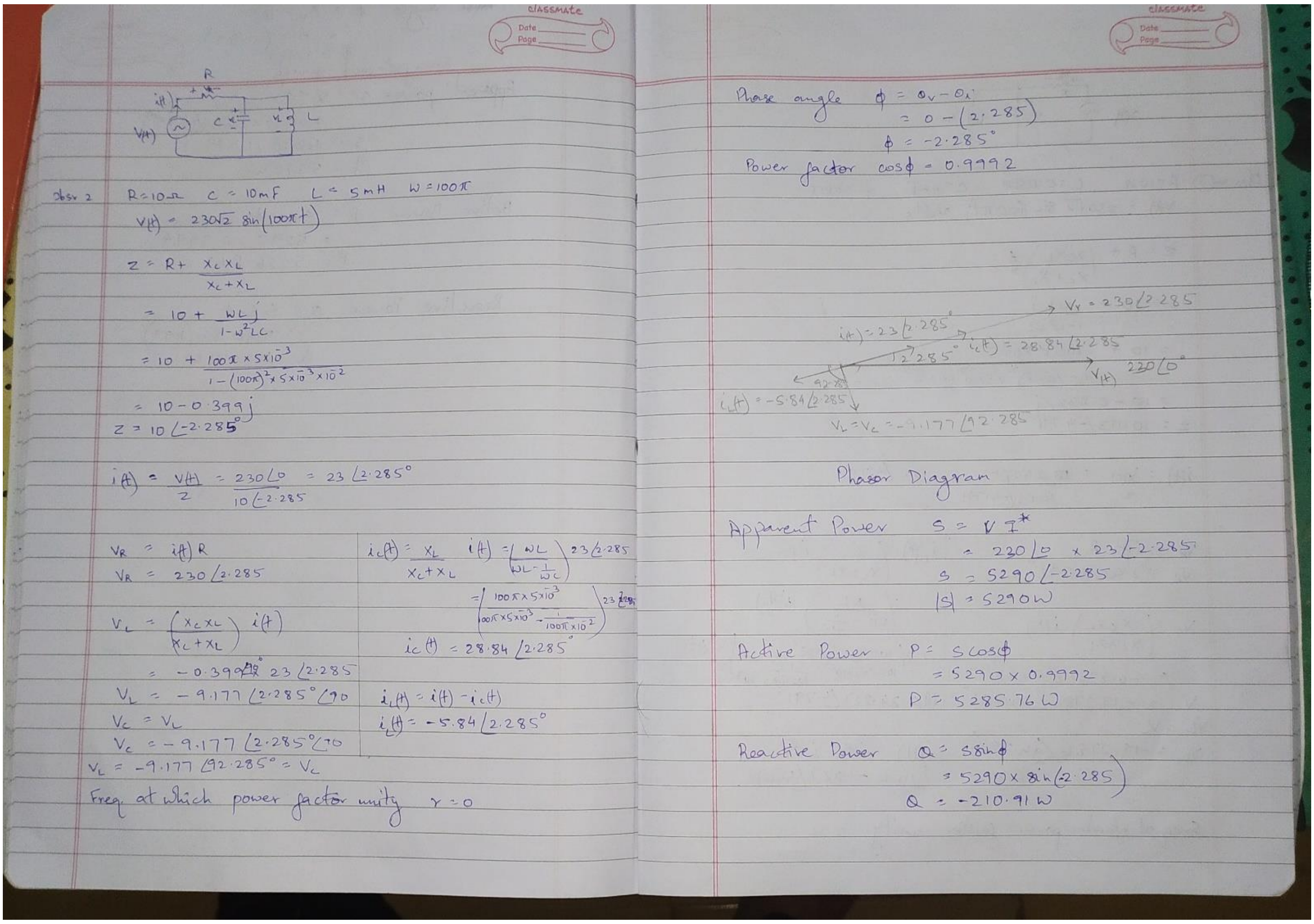


Fig5b: Impedence at 50Hz and frequency at UPF



Graph5e: Waveforms of various responses


Obsv 2 $R=10\Omega$ $C=10mF$ $L=5mH$ $\omega=100\pi$

$v(t) = 230\sqrt{2}\sin(100\pi t)$

$Z = R + \frac{X_C X_L}{X_C + X_L}$

$= 10 + \frac{\omega L j}{1-\omega^2 LC}$

$= 10 + \frac{100\pi \times 5\times10^{-3}}{1-(100\pi)^2\times5\times10^{-3}\times10^{-2}}$

$= 10 - 0.399j$

$Z = 10\angle -2.285°$

$i(t) = \frac{v(t)}{Z} = \frac{230\angle 0}{10\angle -2.285} = 23\angle 2.285°$

$V_R = i(t)R$

$V_R = 230\angle 2.285$

$V_L = \left(\frac{X_C X_L}{X_C+X_L}\right) i(t)$

$= -0.399\angle 90° \; 23\angle 2.285$

$V_L = -9.177\angle 2.285° \angle 90$

$V_C = V_L$

$V_C = -9.177\angle 2.285° \angle 90$

$V_L = -9.177\angle 92.285° = V_C$

$i_C(t) = \frac{X_L}{X_C+X_L} i(t) = \left(\frac{\omega L}{\omega L - \frac{1}{\omega C}}\right) 23\angle 2.285$

$= \left(\frac{100\pi\times5\times10^{-3}}{100\pi\times5\times10^{-3} - \frac{1}{100\pi\times10^{-2}}}\right) 23\angle 2.285$

$i_C(t) = 28.84\angle 2.285°$

$i_L(t) = i(t) - i_C(t)$

$i_L(t) = -5.84\angle 2.285°$

Freq at which power factor unity $r = 0$

Phase angle $\phi = \theta_v - \theta_i$

$= 0 - (2.285)$

$\phi = -2.285°$

Power factor $\cos\phi = 0.9992$

Phasor Diagram

Apparent Power $S = V I^*$

$= 230\angle 0 \times 23\angle -2.285$

$S = 5290\angle -2.285$

$|S| = 5290W$

Active Power $P = S\cos\phi$

$= 5290 \times 0.9992$

$P = 5285.76\ W$

Reactive Power $Q = S\sin\phi$

$= 5290 \times \sin(-2.285)$

$Q = -210.91\ W$

Theoretical Calculations for Observation No:2

For Obsv No:3 R=10 L=50mH C=4mF f=50Hz

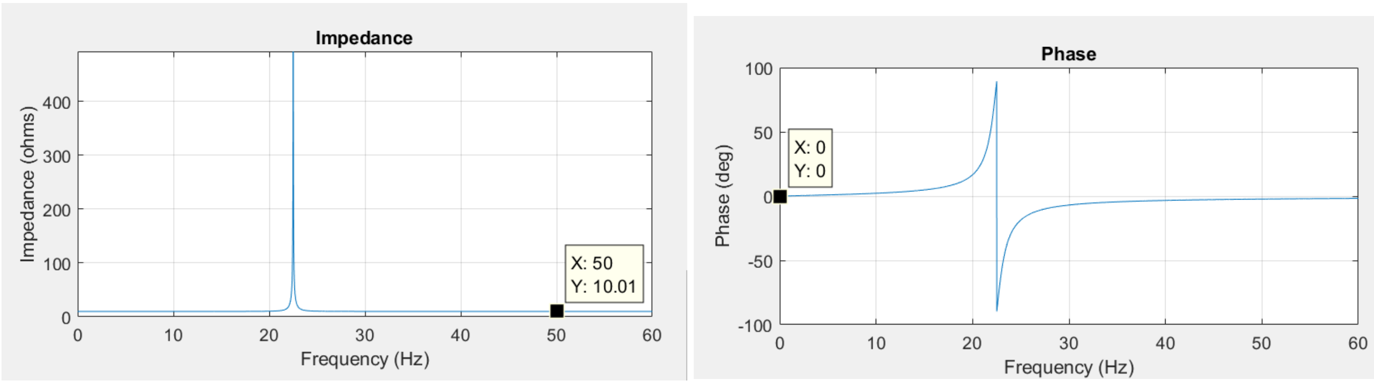
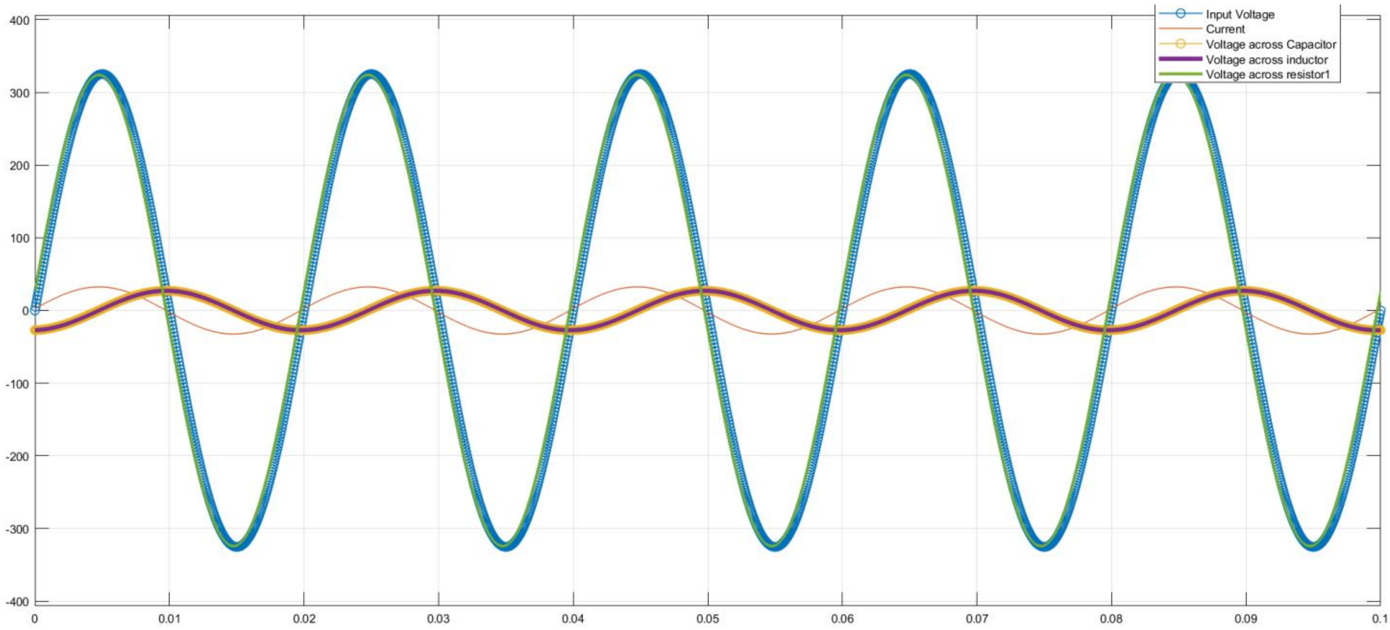
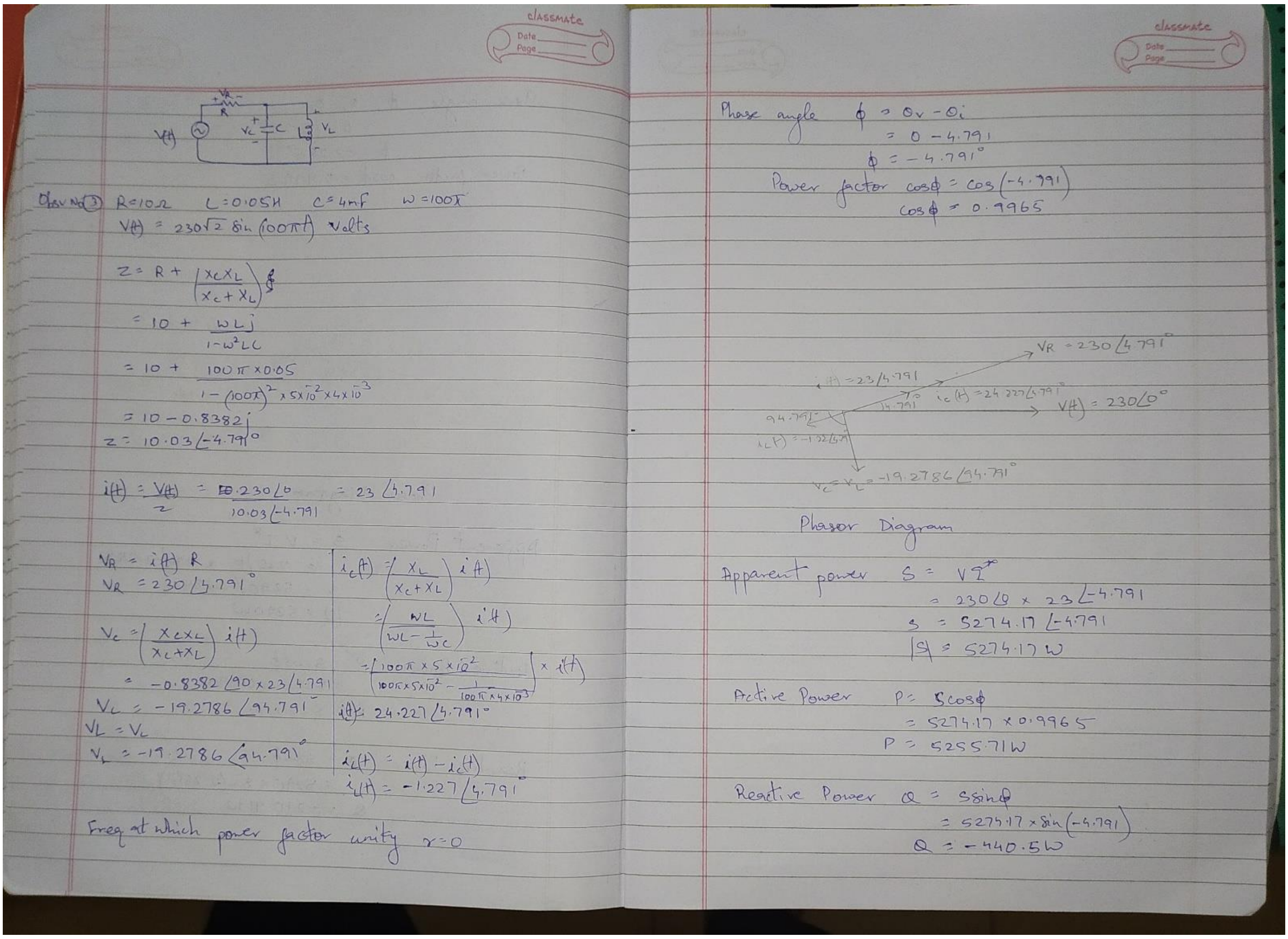


Fig5b: Impedence at 50Hz and frequency at UPF



Graph5f: Waveforms of various responses



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Obsv No (3) $R = 10\Omega$ $L = 0.05H$ $C = 4mF$ $\omega = 100\pi$

$V(t) = 230\sqrt{2}\sin(100\pi t)$ Volts

$Z = R + \left(\frac{X_C X_L}{X_C + X_L}\right)$

$= 10 + \frac{\omega L j}{1 - \omega^2 LC}$

$= 10 + \frac{100\pi \times 0.05}{1 - (100\pi)^2 \times 5\times10^{-2} \times 4\times10^{-3}}$

$= 10 - 0.8382j$

$Z = 10.03\angle{-4.791}^\circ$

$i(t) = \frac{V(t)}{Z} = \frac{230\angle 0}{10.03\angle{-4.791}} = 23\angle 4.791$

$V_R = i(t) R$

$V_R = 230\angle 4.791^\circ$

$V_C = \left(\frac{X_C X_L}{X_C + X_L}\right) i(t)$

$= -0.8382\angle 90 \times 23\angle 4.791$

$V_C = -19.2786\angle 94.791^\circ$

$V_L = V_C$

$V_L = -19.2786\angle 94.791^\circ$

$i_C(t) = \left(\frac{X_L}{X_C + X_L}\right) i(t)$

$= \left(\frac{\omega L}{\omega L - \frac{1}{\omega C}}\right) i(t)$

$= \left(\frac{100\pi \times 5\times10^{-2}}{100\pi\times5\times10^{-2} - \frac{1}{100\pi\times4\times10^{-3}}}\right) \times i(t)$

$i(t) = 24.227\angle 4.791^\circ$

$i_L(t) = i(t) - i_C(t)$

$i_L(t) = -1.227\angle 4.791^\circ$

Freq at which power factor unity $x = 0$

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Phase angle $\phi = \theta_v - \theta_i$

$= 0 - 4.791$

$\phi = -4.791^\circ$

Power factor $\cos\phi = \cos(-4.791)$

$\cos\phi = 0.9965$

$V_R = 230\angle 4.791^\circ$

$i(t) = 23\angle 4.791$

$i_C(t) = 24.227\angle 4.791^\circ$

$V(t) = 230\angle 0^\circ$

94.791°

4.791

$i_L(t) = -1.227\angle 4.791$

$V_C = V_L = -19.2786\angle 94.791^\circ$

Phasor Diagram

Apparent power $S = VI^*$

$= 230\angle 0 \times 23\angle{-4.791}$

$S = 5274.17\angle{-4.791}$

$|S| = 5274.17\ W$

Active Power $P = S\cos\phi$

$= 5274.17 \times 0.9965$

$P = 5255.71W$

Reactive Power $Q = S\sin\phi$

$= 5274.17 \times \sin(-4.791)$

$Q = -440.5W$

Theoretical Calculations for Observation No:3

Conclusion: All theoretical readings match with the simulated readings, thus theoretical power analysis is verified for the given circuit.