EE256 – POWER AND ENERGY MEASUREMENTS

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E/21/345

SEMESTER 4

GROUP EE.21.B.23

08/07/2025

EE 256: POWER AND ENERGY

Experiment: Power & Energy Measurements

Pre-Lab Questionnaire

1. What are the safety procedures you should follow when connecting a rheostat to the circuit?

2. Comment on the accuracy when taking the number of rotations in the energy meter.

3. How to find active power, reactive power, apparent power & power factor using voltmeter, ammeter and single wattmeter readings V, I & W?

4. How to find the energy acquired by the circuit using the energy meter readings; number of rotations, N & meter constant, K?

EE256: POWER AND ENERGY

POWER & ENERGY, MEASUREMENT.

E/21/345 - S.M.O.T. SAMARAKOON

① What are the safety procedures you should follow when connecting a rheostat to the circuit?

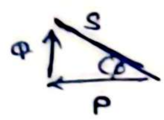
- First ensure the power supply is turned off and disconnected before making any connection.
- Adjust the rheostat to maximum resistance before turning on the power.
- Avoid touching live wires.
- Check all the connections before powering up the circuit.

② Comment on the accuracy when taking the number of rotations in the energy meter.

The accuracy of measuring the number of rotations of an energy meter disc is primarily affected by human error. Specially, reaction time, paralax error, counting error may affect to the accuracy of reading. To improve accuracy we should view the disk from a fixed position directly perpendicular to the meter's face and count the rotations over a longer time interval to minimize the relative effect of starting and stopping errors.

③ How to find active power, reactive power, apparent power & power factor using voltmeter, ammeter and single wattmeter reading V, I & W?

Active power (P) = wattmeter reading = $\underline{\underline{W}}$ (in watts)



$\cos\phi = \frac{P}{S}$

Apparent power (S) = $\underline{\underline{VI}}$ (in VA)

Reactive power (Q) = $\underline{\underline{\sqrt{(VI)^2 - W^2}}}$ (in VAR)

Power factor ($\cos\phi$) = $\frac{P}{S} = \underline{\underline{\frac{W}{VI}}}$

④ How to find the energy acquired by the circuit using the energy meter readings, number of rotations (N) & meter constant (K)?

$K \rightarrow rev/kWh.$

$$E = \frac{N}{K}.$$

$E \rightarrow$ energy consumed (kWh)

$N \rightarrow$ Number of rotations

$K \rightarrow$ meter constant (rev/kWh).

08/07

EE 256: POWER AND ENERGY

Experiment: Power & Energy Measurements

(3 hours)

DATE: 08/07/2025

CAUTION: High voltages are present in this Laboratory Experiment! Do not make any connections when the power is on. The power should be turned off after completing each set of measurements.

INTRODUCTION

This experiment covers power and energy measurement of a single-phase system. The power measurements are condcuted using a Wattmeter. Students are given the practical exposure to measure single phase power based on following loads; a resistive load, a capacitive load, an inductive load, a resistive load in parallel with an inductive load & a resistive load in parallel with an inductive load and Capacitive load.

LEARNING OUTCOMES:

- LO 2: Discuss and demonstrate different methods of power measurements (covering attributes of WA1 and WA2)

OBJECTIVES:

- Discuss and demonstrate single phase power measurements using one wattmeter (LO 2).

a) Measurement of Power and Power Factor of a Resistive Load

APPARATUS

- Single Phase Wattmeter: 1A, 240V (YOKOGAWA)
- Single Phase Energy meter: meter constant - 900 rev/kWh
- AC Ammeter: 0~2A (YOKOGAWA)
- AC Voltmeter: 0~300V (YOKOGAWA)
- Variable resistor: 330Ω/2A or 500Ω/2A
- Variable AC Supply

PROCEDURE

Step 1 – Examine the construction of the single-phase wattmeter module shown in Figure 1, paying particular attention to its terminals and wiring.

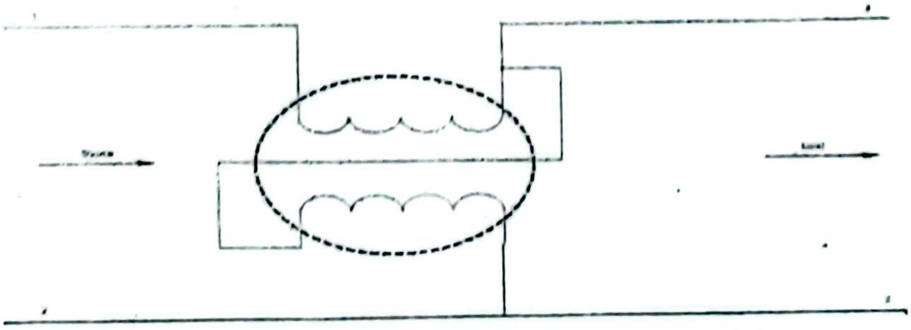


Figure 1: The wiring schematic of the single-phase wattmeter

Step 2 – Connect the circuit as shown in Figure 2.

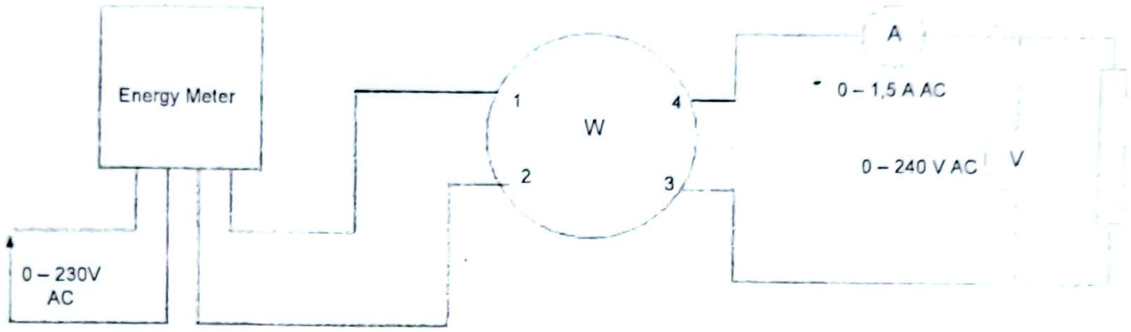


Figure 2: Power measurements with a resistive load

Step 3 – Turn on the power supply and increase the voltage from 0 to 200V in steps as mentioned below. Take the ammeter and the wattmeter readings and record in Table 1.

Step 4 – Find the number of rotations of the energy meter for 2mins, when the voltmeter reading is 160V (Suggest your own method).

Step 5 – After taking the readings, set the voltage to zero and turn off the power supply

OBSERVATIONS

Table 1: Meter readings for the test shown in Figure 2

Voltmeter reading, V/(V)	0	80	160	200
Ammeter reading, I/(A)	0	0.2	0.32	0.42
Wattmeter reading, P/(W)	0	18	78	122

Energy meter reading (Number of rotations): ....2.58....

RESULTS AND DISCUSSION

Step 6 – Calculate active power, reactive power, apparent power and power factor for the above voltage levels.

Step 7 – Calculate the energy acquired by the circuit using the energy meter.

Is there a good agreement between your measured values of power P and the product of E I? (Yes or No)

Step 8 – Interchange the terminals of either the current coil or the voltage coil. Turn on the power. Adjust the voltage to 200V. Is there a reading on the wattmeter? (Yes or No)

If "Yes" what is the reading? If "No" Why?

Table 2: Results of the experiment

Voltmeter reading, E/(V)	0	80	160	200
Active Power, P(W)	0	18	78	122
Reactive Power, Q(Var)	0	8.25j	58.84j	88.48j
Apparent Power, S(VA)	0	16	51.2	84
Power Factor, Cos (ϕ)	0	1.125	1.56	1.45

Energy acquired by the circuit using the energy meter = ...10.32....

b) Measurement of Power and Power Factor of a Capacitive Load

APPARATUS

- Single Phase Wattmeter: 1A, 240V (YOKOGAWA)
- Single Phase Energy meter: meter constant - ......900 rev/kWh..
- AC Ammeter: 0~5A (YOKOGAWA)
- AC Voltmeter: 0~300V (YOKOGAWA)
- Variable capacitor (Terco MV1102) – maximum position value = ..59.8μF
- Variable AC Supply

PROCEDURE

Step 1 – Connect the circuit shown in Figure 3. Select the **maximum** capacitance available from the capacitor module as the capacitor. Note that this circuit is identical to the circuit of Figure 2 except that the resistive load has been replaced by a capacitive load.

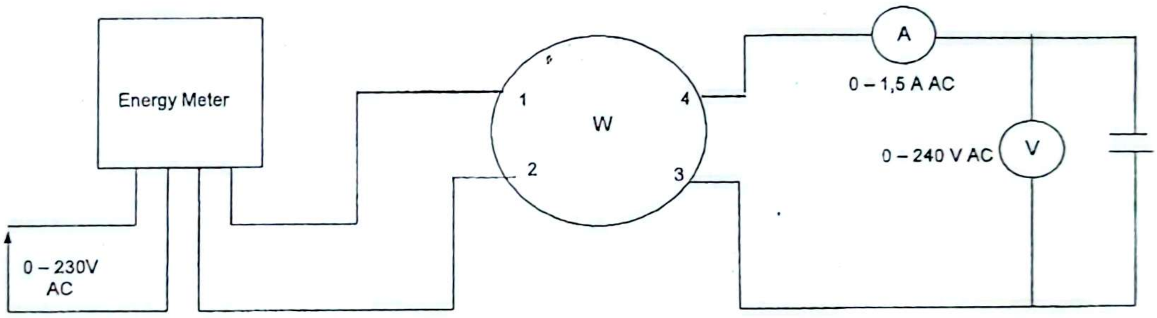


Figure 3: Power measurement on a capacitive load

Step 2 – Turn on the power supply and adjust the voltage for 200V as indicated by the voltmeter. Measure and record the load current I_L.

Step 3 – Measure and record the active input power as indicated by the wattmeter.

Step 4 – Find the number of rotations of the energy meter for 2mins, for the given load condition.

Step 5 – Set the voltage to zero and turn off the power supply.

OBSERVATIONS

- I_L = ...3.2........ A
- P = ...10........ W
- Number of rotations: ....0.83........

CALCULATION

Step 6 – Calculate and record reactive power, apparent power and power factor.

Step 7 – Calculate the energy acquired by the circuit using the energy meter.

Note that the apparent power (in VA) is appreciably larger than the active power (in W)

RESULTS

- Reactive power, Q(Var) = ...639.92 VAr....
- Apparent power, S(VA) = ...640 VA....
- Power Factor, Cos (φ) = ...0.0156....
- Energy acquired by the circuit using the energy meter = ...3.32 kJ....

c) Measurement of Power and Power Factor of an Inductive Load

APPARATUS

- Single Phase Wattmeter: 1A, 240V (YOKOGAWA)
- Single Phase Energy meter: meter constant - ....900 rev/kWh..
- AC Ammeter: 0~5A (YOKOGAWA)
- AC Voltmeter: 0~300V (YOKOGAWA)
- Variable inductor (Cosford) – 2A position value = .278 mH.
- Variable AC Supply

PROCEDURE

Step 1 – Connect the circuit as shown in Figure 4. Switch on appropriate inductance so that 2 A of current flows through it which is measured by the ammeter. Note that this circuit is identical to the circuit of Figure 2, except that the resistive load has been replaced by an inductive load.

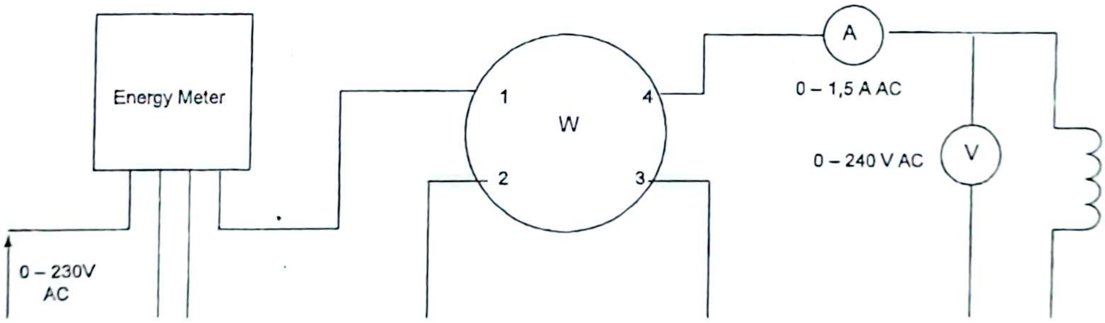


Figure 4: Power measurement on an inductive load

Step 2 – Turn on the power supply and adjust the voltage for 240V as indicated by the voltmeter. Measure and record the load current I_L.

Step 3 – Measure and record active power as indicated by the wattmeter.

Step 4 – Find the number of rotations of the energy meter for 2mins for the given load condition.

Step 5 – Set the voltage to zero and turn off the power supply.

OBSERVATIONS

- I_L = ...1.55.... A
- P = ...20.... W
- Number of rotations: ....1.03....

CALCULATIONS

Step 6 – Calculate and record reactive power, apparent power and power factor.

Step 7 – Calculate the energy acquired by the circuit using the energy meter. -

Note that the apparent power (in VA) is appreciably larger than the active power (in W).

RESULTS

- Reactive Power, Q(Var) = ...371.46 Var.......
- Apparent Power, S(VA) = ...372 VA............
- Power Factor, Cos (φ) = ...0.0538................
- Energy acquired by the circuit using the energy meter = ...4.12 kJ..

d) Measurement of power and power factor of a resistive load connected in parallel with an inductor

APPARATUS

- ➢ Single Phase Wattmeter: 1A, 240V (YOKOGAWA)
- ➢ Single Phase Energy meter: meter constant - ....900 rev/kWh.
- ➢ AC Ammeter: 0~5A (YOKOGAWA)
- ➢ AC Voltmeter: 0~300V (YOKOGAWA)
- ➢ Variable resistor: 330Ω/2A or 500Ω/2A
- ➢ Variable inductor (Cosford) – 2A position value = .238 mH.
- ➢ Variable AC Supply

PROCEDURE

Step 1 – Connect the circuit as shown in Figure 5. Increase the variable resistor position to its maximum value. Turn on the power and set the input voltage to 200V.

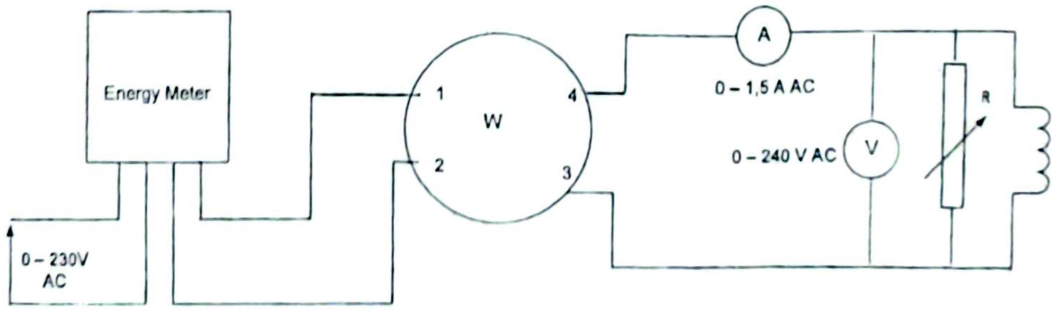


Figure 5: Power measurement on a parallel RL circuit

Step 2 – Measure and record the load current I_L.

Step 3 – Measure and record active power as indicated by the wattmeter.

Step 4 – Find the number of rotations of the energy meter for 2mins for the given load condition.

Step 5 – Set the input voltage to zero & turn off the power supply.

CamScanner

OBSERVATIONS

- Current (I_L) = ...1.45.... A
- Active Power (P) = ...138.... W
- Number of rotations: ....4.42....

CALCULATIONS

Step 6 – Calculate and record reactive power, apparent power and power factor.

Step 7 - Calculate the energy acquired by the circuit using the energy meter.

RESULTS

- Reactive Power, Q (Var) = ...255.06 Var....
- Apparent Power, S (VA) = ...290 VA....
- Power Factor, Cos (φ) = ...0.476....
- Energy acquired by the circuit using the energy meter = ...17.68 kJ....

e) Measurement of Power and Power Factor of a Resistive Load connected in parallel with Inductor and Capacitor

APPARATUS

- Single Phase Wattmeter: 1A, 240V (YOKOGAWA)
- Single Phase Energy meter: meter constant - ....900 rev/kWh....
- AC Ammeter: 0~5A (YOKOGAWA)
- AC Voltmeter: 0~300V (YOKOGAWA)
- Variable resistor: 330Ω/2A or 500Ω/2A
- Variable capacitor (Terco MV1102)
- Variable inductor (Cosford) – 2A position value = ...
- Variable AC Supply

PROCEDURE

Step 1 – Connect the capacitor module in parallel to R & L (Keep the values of the R & L unchanged) as shown in Figure 6. Turn on the power and set the voltage to 200V.

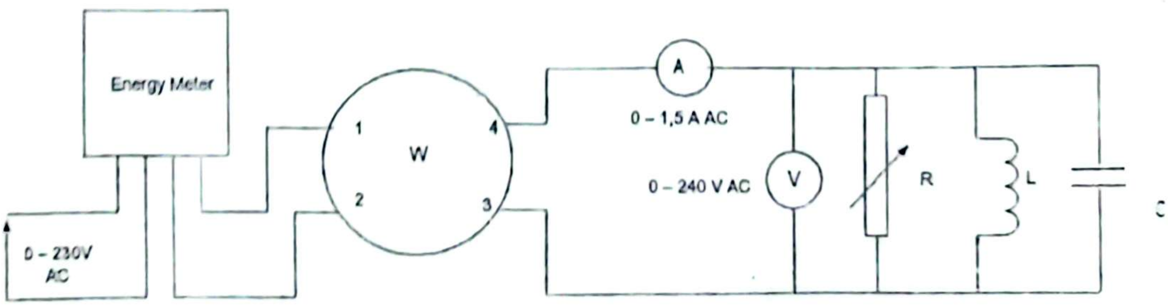


Figure 6: Power measurement on a parallel RLC circuit

Is there any change in the Wattmeter reading as the capacitance is increased? (Yes or No)
Explain your observations.

Step 2 – Adjust the capacitance for minimum line current. Measure the Ammeter reading, Wattmeter reading and the Capacitance for minimum current.

Step 3 – Find the number of rotations of the energy meter for 2mins for the given load condition.

Step 4 – Set the input voltage to zero & turn off the power supply.

OBSERVATIONS

- Current (I_L) = 0.65 A
- Active Power (P) = 138 W
- Capacitance for minimum current (C) = 19.87 μF
- Number of rotations: 4.50

CALCULATIONS

Step 5 – Calculate and record reactive power, apparent power & power factor.

Step 6 – Calculate the energy acquired by the circuit using the energy meter.

RESULTS

- Reactive Power, Q (Var) = 46.303j
- Apparent Power, S (VA) = 130
- Power Factor, Cos (φ) = 1.06
- Energy acquired by the circuit using the energy meter = 18 kJ

COMPARISON OF RESULTS

Step 1: Fill in the blanks in the Table 3

Table 3: Results

Part	Power (W)		Q (Var)	S (VA)	Power factor	
	Wattmeter	Energy meter			Impedance	Meter reading
a	78	86.00	58.84	51.2	1.00	–
b	10	27.67	639.92	640.0	0.00	0.0156
c	20	34.33	371.46	372.0	0.00	0.0538
d	138	147.33	255.06	290.0	0.23	0.4760
e	138	15	46.30	130.0	0.96	1.0600

Note: Specimen Calculations should be attached for each part separately. Power factor should be calculated using both impedance values and meter reading values.

REPORT

1. Is there a difference between the power values from Wattmeter and Energy meter? Comment
2. Is there a difference between the power factor values from impedance values and meter readings? Comment
3. Name two household appliances that have a high-power factor (nearly unity).
4. Can you suggest one domestic appliance, which might have a low power factor?

CALCULATIONS

PART- (a)

Step-6

Considering the 4th set of the readings from table 1,

Active power (P) $= 122W$

Apparent Power (S) $= VI$

$= 200\ V \times 0.42A$

$= \underline{\underline{84.0\ \ VA}}$

Reactive Power (Q) $= \sqrt{S^2 - P^2}$

$= \sqrt{84^2 - 122^2}$

$= \underline{\underline{88.48j\ VAR}}$

Power Factor (cos φ) $= \frac{P}{S}$

$= \frac{78}{51.2}$

$= \underline{\underline{1.56}}$

Impedance of the resistor $= \underline{\underline{330\ \Omega}}$

Impedance of the circuit $= \underline{\underline{330\ \Omega}}$

Power factor using the impedance $= \frac{Resistance}{Impedance}$

$= \frac{330}{330}$

$= \underline{\underline{1}}$

Step -7

Energy acquired by the circuit

Using the energy meter $= \frac{Number\ of\ rotations}{Meter\ constant}$

$= \frac{2.58}{900}\ kW\ h$

$= \frac{2.58}{900} \times 3600\ kJ$

$= \underline{\underline{10.32\ \ kJ}}$

Step -8

Q. Interchange the terminals of either the current or voltage coil. Turn on the power. Adjust the voltage to 200V. Is there a reading on the Wattmeter?(Yes or No). If "Yes" what is the reading? If "No" why?

No. The wattmeter doesn't show a reading because it relies on the correct polarity of both voltage and current inputs to measure power accurately. When you reverse the terminals of either coil, it messes up the phase alignment between voltage and current. Since power is calculated as P=VIcosϕ, any disruption in that phase relationship causes the meter to cancel out the measurement. Essentially, it sees equal and opposite power contributions and ends up showing nothing.

PART - (b)

Step-6

Considering the observations,

Active power (P) = 10 W

Apparent Power (S) = VI

= 200 V × 3.2 A

= 640 VA

Reactive Power (Q) = $\sqrt{S^2 - P^2}$

= $\sqrt{640^2 - 10^2}$

= 639.92 VAR

Power Factor (cos φ) = $\frac{p}{S}$

= $\frac{10}{640}$

= 0.0156

Impedance of the capacitor = $\frac{-j}{\omega C}\,\Omega$

= $\frac{-j}{2\pi \times 50 \times 59.8 \times 10^{-6}}\,\Omega$

= -55.03j Ω

Impedance of the circuit = -55.03j Ω

Power factor using the impedance = $\frac{Resistance}{Impedance}$

= $\frac{0}{-55.03j}$

= 0

Step-7

Energy acquired by the circuit

Using the energy meter = $\frac{Number\ of\ rotations}{Meter\ constant}$

= $\frac{0.83}{900}$

= $\frac{0.83}{900} \times 3600$

= 3.32 kJ

PART-(C)

Step-6

Considering the observations,

Active power (P) = 20 W

Apparent Power (S) = VI

= 240V × 1.55 A

= 372 VA

Reactive Power (Q) $= \sqrt{S^2 - P^2}$

$= \sqrt{372^2 - 20^2}$

= 371.46 VAR

Power Factor (cos φ) $= \frac{P}{S}$

$= \frac{20}{371.46}$

= 0.0538

Impedance of the inductor $= j\omega L\ \Omega$

$= j \times 2\pi \times 50 \times 0.278\ \Omega$

= 87.34j Ω

Impedance of the circuit = 87.34j Ω

Power factor using the impedance $= \frac{Resistance}{Impedance}$

$= \frac{0}{87.34j}$

= 0

Step-7

Energy acquired by the circuit

Using the energy meter $= \frac{Number\ of\ rotations}{Meter\ constant}$

$= \frac{1.03}{900}$

$= \frac{1.03}{900} \times 3600\ kJ$

= 4.12 kJ

PART– (d)

Step-6

Considering the observations,

Active power (P) = 138 W

Apparent Power (S) = VI

= 200V × 1.45 A

= 290 VA

Reactive Power (Q) $= \sqrt{S^2 - P^2}$

$= \sqrt{290^2 - 138^2}$

= 255.06 VAR

Power Factor (cos φ) $= \frac{P}{S}$

$= \frac{138}{290}$

= 0.476

Resistance of the circuit = 330 Ω

Impedance of the inductor $= j\omega L\ \Omega$

$= j\times 2\pi \times 50 \times 0.238\ \Omega$

= 74.77j Ω

Impedance of the circuit $= \frac{1}{\frac{1}{330}+\frac{1}{74.77j}}$

= 16.11 + 71.12j

Power factor using the impedance $= \frac{Resistance}{Impedance}$

$= \frac{16.11}{71.12}$

= 0.23

Step-7

Energy acquired by the circuit

Using the energy meter $= \frac{Number\ of\ rotations}{Meter\ constant}$

$= \frac{4.42}{900}$ kW h

$= \frac{4.42}{900} \times 3600\ kJ$

= 17.68 kJ

PART- (e)

Step – 1 Q. Is there any change in the Wattmeter reading as the capacitance is increased? (Yes or No) Explain your observations

Capacitance (μF)	Current (A)	Power (W
10.05	136	1.0
19.87	138	0.65
29.6	140	0.65
39.4	142	1.05
49.8	144	1.50
59.8	146	1.95

Yes.

The wattmeter reading clearly changes with increasing capacitance. At lower capacitance values, the circuit behaves more inductively, so the real power is low. As capacitance increases, it begins to cancel out some of that inductive reactance. Around the point of resonance, where inductive and capacitive effects balance out. The power drops to a minimum (0.65W). After that, as capacitance continues to increase, the circuit becomes more capacitive, and the power starts rising again. This is because the phase angle between voltage and current shifts with capacitance, which directly impacts the real power measured by the wattmeter.

<u>Step-6</u>

Considering the minimum Load current ,

Active power (P)	= 138 W
Apparent Power (S)	= VI
	= 200 V × 0.65 A
	=<u>130 VA</u>
Reactive Power (Q)	= $\sqrt{S^2 - P^2}$
	= $\sqrt{130^2 - 138^2}$
	= <u>46.303j VAR</u>
Power Factor (cos φ)	= $\frac{P}{S}$
	= $\frac{138}{130}$
	= <u>1.06</u>
Impedance of the inductor	= $j\omega L$ Ω
	= j× $2\pi \times 50 \times 0.238$ Ω
	= <u>74.77j Ω</u>

Impedance of the capacitor $= \frac{-j}{\omega C}\,\Omega$

$= \frac{-j}{2\pi\times 50\times 59.8\times 10^{-6}}\,\Omega$

$= \underline{\underline{-55.03j\ \Omega}}$

Resistance of the circuit $= 330\ \Omega$

Impedance of the circuit $= \frac{1}{(\frac{1}{330}+\frac{1}{74.77j}-\frac{j}{55.03}\}}\,\Omega$

$= \underline{\underline{3.02 + 31.41j\ \Omega}}$

Power factor using the impedance $= \frac{Resistance}{Impedance}$

$= \frac{3.02}{31.41}$

$= \underline{\underline{0.96\Omega}}$

<u>Step-7</u>

Energy acquired by the circuit

Using the energy meter $= \frac{Number\ of\ rotations}{Meter\ constant}$

$= \frac{4.5}{900}\,kWh$

$= \frac{4.5}{900}\times 3600\ kJ$

$= \underline{\underline{18\ kJ}}$

DISCUSSION

1. Difference between Wattmeter and Energy Meter Power Values

   Wattmeter and Energy Meter show different power values because they work in different ways. Wattmeter shows real power at that moment using $P=VI\cos\phi$. It's like a live snapshot. But Energy Meter measures how much energy is used over time, so it adds up everything during the test. For example, in Part (a), Wattmeter shows 78W but Energy Meter shows 96W. This is because the Energy Meter includes small ups and downs in power during the whole test, which Wattmeter might not catch. Also, things like voltage/current changes, meter accuracy, and when we take the reading can make a difference. So basically, Wattmeter gives instant power, but Energy Meter shows total usage, that's why its value is usually higher.

2. Difference between Power Factor from Impedance vs. Meter Readings

   Power factor from impedance is more like theory, it uses resistance and reactance only. For example, in Part (d), we calculated 0.23. But the value from the meter was 0.476. That one is based on actual current, voltage, and power. The real circuit has extra stuff like wire resistance, coil losses, and small phase delays that the formula doesn't include. Also, instruments may have small errors too. So, the meter power factor is more correct in real life, while impedance method just gives an idea. That's why both values don't match.

3. Two household appliances with high power factor (near 1)?

   - Ovens using resistance elements
   - Incandescent bulb

4. One domestic appliance with low power factor?

   - Ceiling fan

REFERENCES

[1]“Difference between Wattmeter and Energy Meter,” *www.tutorialspoint.com*. https://www.tutorialspoint.com/difference-between-wattmeter-and-energy-meter

[2]“Practical values of power factor - Electrical Installation Guide,” *www.electrical-installation.org*. https://www.electricalinstallation.org/enwiki/Practical_values_of_power_factor