GANDHI SCHOOL OF ENGINEERING

Chidananda Hills, Bhabandha, Berhampur, Ganjam

EEM LABORATORY EXPERIMENTS

EXPERIMENT NO. 01

Aim of the Experiment

Identification of measuring instruments.

Apparatus Required

Sl. No.	Name of the Instrument	Range	Quantity
01	Ammeter (PMMC)	0–10 A	01
02	Ammeter (MI Type)	0–10 A	01
03	Voltmeter (PMMC)	0–300 V	01
04	Voltmeter (MI Type)	0–300 V	01
05	Wattmeter	0–500 V	01
06	Energy Meter	230 V, 5–10 A	01

Theory

1. Symbol on Dial

- ∼ → AC
- ⎓ → DC
- ∼⎓ → AC and DC
- W → Wattmeter
- kWh → Energy Meter

2. Type of Instrument

- PMMC → For DC
- MI → For AC
- Dynamometer → Power Measurement
- Induction → Energy Meter

3. Accuracy

Accuracy is indicated on the dial of the instrument.

4. Position

- ⊥ → Vertical
- — → Horizontal / Universal Position

5. Scale

- Uniform Scale → PMMC
- Non-uniform Scale → MI, Multirange

Procedure

1. Collect the different instruments from the lab.
2. Observe the dial carefully.
3. Note the symbol of operation.
4. Record the type of instrument.
5. Identify and record the accuracy on the dial.
6. Check the position of use.
7. Note the type of scale used.
8. Tabulate the observation.

Observation Table

Sl. No.	Name of the Instrument	Symbol	Type	Position	Scale	Range
01	PMMC Ammeter	⎓	DC (PMMC)	⊥ (Vertical)	Uniform	0–5 A
02	MI Ammeter	∼	AC (MI)	⊥ (Vertical)	Non-uniform	0–10 A
03	Voltmeter	∼ ⎓	AC	Universal	Non-uniform	0–300 V
04	Wattmeter	W	Dynamometer	⊥ (Vertical)	Uniform	0–500 V
05	Energy Meter	kWh	Induction	⊥ (Vertical)	Dial Type	230 V, 5–10 A

Result

We have studied the symbol, type, position, scale and range of the given instruments.

EXPERIMENT NO. 02

Aim of the Experiment

To study and identify the main components of Permanent Magnet Moving Coil (PMMC) and Moving Iron (MI) instruments.

Apparatus Required

Sl. No.	Name of the Apparatus	Range	Quantity
01	PMMC Voltmeter	0–10 V DC	01
02	PMMC Ammeter	0–50 mA DC	01
03	MI Voltmeter	0–15 V AC/DC	01
04	MI Ammeter	0–5 A AC/DC	01
05	Screwdriver Set	—	01
06	Magnifying Glass	—	01

Theory

1. PMMC Instrument (Permanent Magnet Moving Coil)

A PMMC instrument works on the principle that a current-carrying coil placed in a magnetic field experiences a deflecting torque proportional to the current. It is mainly used for DC measurements.

Components

(1) Permanent Magnet: Provides a steady magnetic field.

(2) Moving Coil: Wound with fine copper wire; carries current.

(3) Soft Iron Core: Ensures uniform magnetic field.

(4) Pointer: Indicates deflection over the calibrated scale.

(5) Control Springs: Provide controlling torque and act as current leads.

(6) Damping Mechanism: Eddy current damping using aluminium former.

(7) Scale: Linear, calibrated in current or voltage.

(8) Spindle and Bearings: Support and allow smooth motion of the coil system.

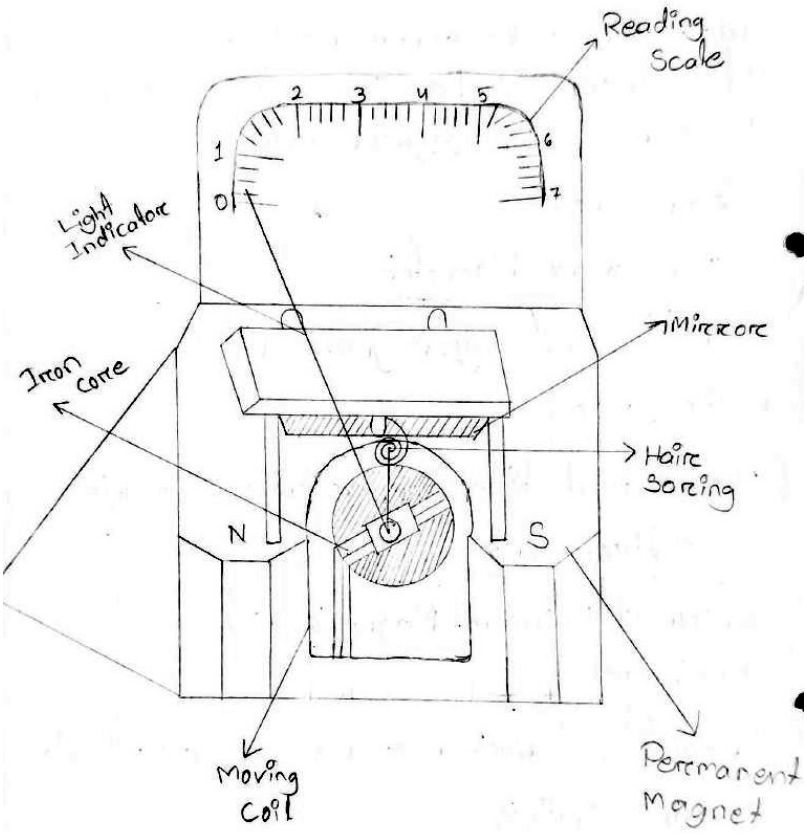


Fig.: PMMC Instrument

2. MI Instrument

An MI instrument works on the principle that a soft iron piece placed in a magnetic field is attracted towards stronger flux regions. The deflecting torque is proportional to I^2, so the instrument works for both AC and DC.

Components

(1) Fixed Coil: Stationary coil producing magnetic field.

(2) Moving Iron Piece: Soft iron rod attached to spindle.

(3) Pointer: Shows deflection on scale.

(4) Control Springs: Provide restoring torque.

(5) Damping Mechanism: Air friction damping with a vane in an air chamber.

(6) Scale: Non-linear (compressed at lower values, spread at higher).

(7) Spindle and Bearings: Support the moving iron system.

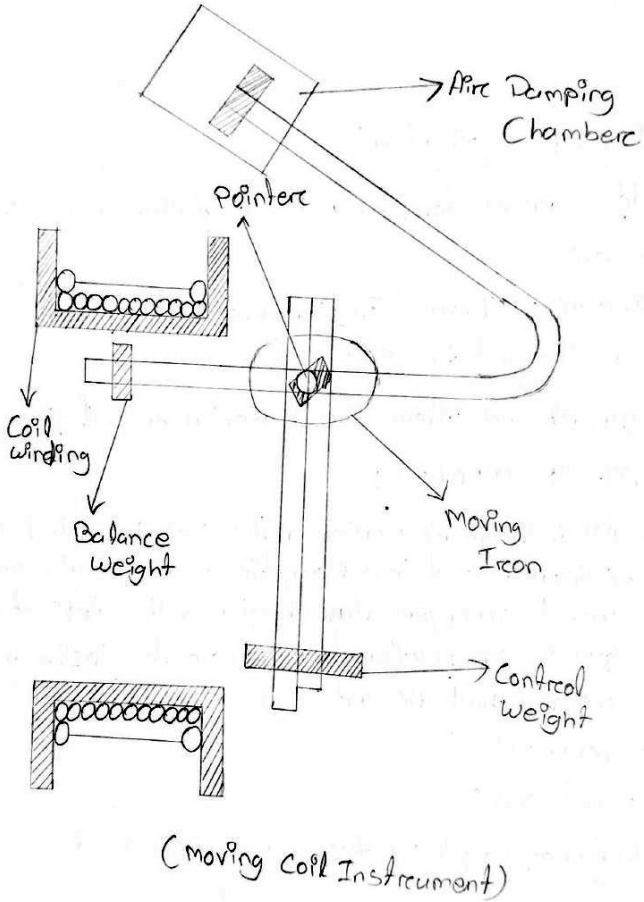


Fig.: Moving Iron Instrument

Result

The components of PMMC and MI instruments were identified and their functions studied.

EXPERIMENT NO. 03

Aim of the Experiment

To extend the range of an ammeter and a voltmeter using a shunt resistor and a multiplier resistor respectively.

Apparatus Required

Sl. No.	Name of the Apparatus	Range / Specification	Quantity
01	DC Ammeter (PMMC Type)	0–1 A	01
02	DC Voltmeter (PMMC Type)	0–5 V	01
03	Shunt Resistor (Low Resistance)	As required (calculated value)	01
04	Multiplier Resistor (High Resistance)	As required (calculated value)	01
05	Regulated DC Power Supply	0–30 V, 2 A	01
06	Rheostat	0–200 Ω, 2 A	01
07	Connecting Wires	—	As required
08	Switch / Key	—	01
09	Digital Multimeter	0–10 A / 0–50 V	01

Theory

(A) Extension of Ammeter Range (using Shunt)

A shunt resistor (low resistance) is connected in parallel with the ammeter to allow a large portion of current to bypass the meter.

If,

- I = Total current
- Im = Full-scale deflection current of ammeter
- Rm = Resistance of the meter

Then, the shunt resistance Rs is given by:

$$Rs = (Im \times Rm) / (I - Im)$$

(B) Extension of Voltmeter Range (using Multiplier)

A multiplier resistor (high resistance) is connected in series with the voltmeter to limit the current through the meter.

If,

- V = Total voltage to be measured
- Vm = Voltage drop across meter

- Im = Full-scale deflection current
- Rm = Resistance of the meter

Then, the multiplier resistance Rmulti is given by:

$$Rmulti = (V - Vm) / Im = Rm (V / Vm - 1)$$

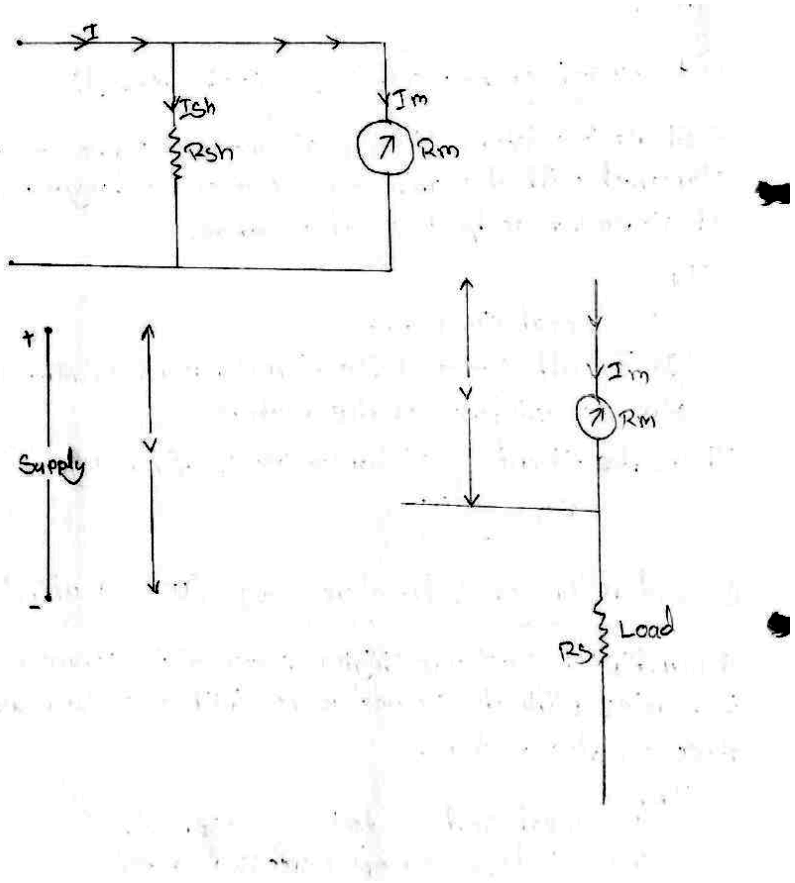


Fig.: Circuit diagrams for extension of ammeter and voltmeter range

Procedure

(A) To Extend Ammeter Range

1. Connect the shunt resistor in parallel with the ammeter.
2. Connect the circuit as per the ammeter extension diagram.
3. Apply a small voltage from the DC power supply and note the current reading.
4. Gradually increase the supply and note corresponding readings.
5. Compare measured current with calculated (expected) current.

(B) To Extend Voltmeter Range

1. Connect the multiplier resistor in series with the voltmeter.
2. Connect the circuit as per the voltmeter extension diagram.
3. Apply different voltages using the DC supply.
4. Record voltmeter readings and compare with actual supply voltage.

Observation Table

Applied Voltage (V)	Voltmeter Reading (V)	Ammeter Reading (A)	Calculated Value	Remark
5				—
10				—
15	15.3			—

Result

- The range of the ammeter and voltmeter was successfully extended using shunt and multiplier resistors.
- The experimental readings were found to be in good agreement with theoretical values.

EXPERIMENT NO. 04

Aim of the Experiment

To measure the active (real) power consumed by a single-phase load using an electrodynamometer wattmeter, to compare the measured power with the power calculated from measured voltage and current ($P = VI \cos \varphi$), and to determine the percent error.

Apparatus Required

Sl. No.	Name of the Apparatus	Quantity
01	Electrodynamometer wattmeter (single phase, 0–300 W typical)	
02	Single-phase AC supply (mains or variac)	
03	Voltmeter (AC, suitable range e.g. 0–300 V)	
04	Ammeter (AC, suitable range e.g. 0–5 A)	
05	Power factor meter or phase sequence indicator (optional)	
06	Load (resistive: filament lamp or resistive bank)	
07	Inductive load (coil) – for power factor variation (optional)	
08	Connecting leads with shrouded banana plug connectors	
09	Lamp rheostat or variable resistor for load control	
10	Fuse and fuse holder (appropriate rating)	
11	Switch / isolator	
12	Wooden base / mounting board (for safe wiring)	
13	Multimeter (digital, for verification) (optional)	
14	Earth / ground connection lead	
15	Instruction sheet / experiment record book	

Theory

An electrodynamometer wattmeter measures true (active) power in an AC circuit. It has two coils – a current coil (CC) and a potential (voltage) coil (PC). The current coil is connected in series with the load and carries the load current. The potential coil is connected across the load (through a multiplier if needed) and produces a magnetic field proportional to the voltage. The interaction between the magnetic fields produces a torque proportional to the product of instantaneous current and voltage; the steady deflection (with proper damping) is proportional to the average (real) power:

$$P(wattmeter) \propto V \times I \times \cos \varphi$$

where φ is the phase angle between voltage and current. For a single-phase circuit, a single electrodynamometer wattmeter with appropriate connections measures the real power directly.

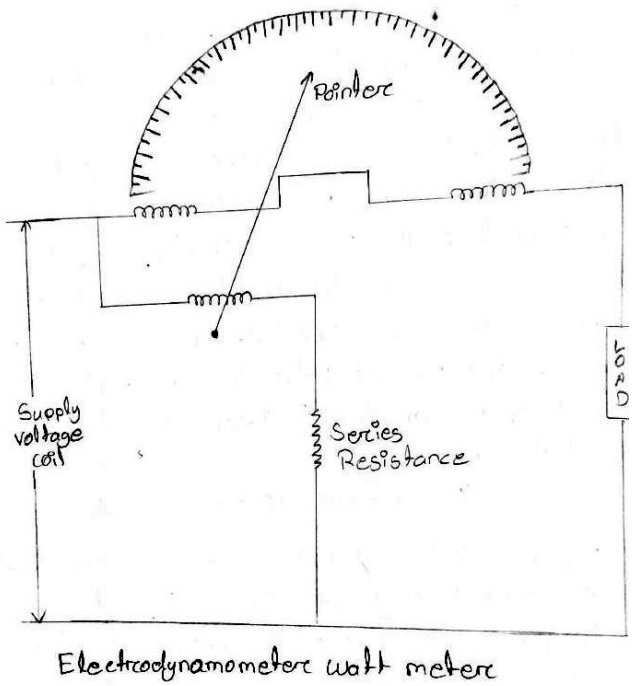


Fig.: Electrodynamometer Wattmeter

Advantages

Measures true power for any waveform (if instrument bandwidth is adequate); high accuracy for low power factor.

Limitations

Requires correct connections to avoid sign errors; potential coil must carry voltage in correct polarity; sensitive to stray magnetic fields.

Circuit Connections and Polarity

(1) Identify wattmeter terminals: They are usually marked with two terminals for the potential coil (P+, P−) and two terminals for the current coil (C+, C−). Also note any direction arrows or polarity marks on the instrument.

(2) Typical single-phase connection (direct measurement):

- Connect one terminal of the supply (line) to one terminal of the wattmeter current coil (C+).
- Connect the other terminal of the current coil (C−) to the load terminal.
- Connect the other load terminal to the neutral (return) of the supply.
- Connect the potential coil across the load. Ensure the P+ terminal is connected to the same side of the load as the current coil (e.g., P+ is in parallel with the load). Ensure the

P polarity corresponds to the load terminal on the same side as C− (follow instrument markings).

(3) An ammeter is placed in series with the load (or use the current coil as an ammeter if provided). A voltmeter is placed across the load.

(4) Insert fuses and a switch in the supply line for safety.

(5) If the wattmeter has separate multiplier resistors for the potential coil, ensure they are kept in the circuit.

Procedure

1. Inspect all instruments and ensure they are properly calibrated and set to their correct ranges.
2. Mount all instruments securely on a wooden board; verify that the main supply switch is turned off.
3. Wire the circuit as described in the Circuit Connections and Polarity section. Place fuses and the switch in series with the supply.
4. Set the load (rheostat or lamp bank) to start with a minimum / low load condition.
5. Switch on the supply and allow the instruments to settle.
6. Record the following readings:

- Wattmeter reading W (in watts).
- Voltmeter reading V (RMS, in volts).
- Ammeter reading I (RMS, in amperes).
- If available, record the reading from a power factor meter or measure the phase angle using an oscilloscope (otherwise compute cos φ from W / (V × I)).

1. Repeat the readings for at least three different load settings (e.g., low, medium, high). If possible, change the load power factor by adding an inductive load and repeat the procedure.
2. For each set of readings, compute the following:

- Calculated Power: Pcalc = V × I × cos φ (if cos φ is not directly measured, compute cos φ = W / (V × I) for a cross-check).
- Percent Error: % Error = [(W − Pcalc) / Pcalc] × 100%

1. Once all readings are completed, switch off the AC supply, de-energize the circuit, and safely disconnect all wiring.

Observation Table

Sl. No.	**Supply Voltage V (V)**	**Load Current I (A)**	**Wattmeter Reading W (W)**	**Calculated Power Pcalc = V × I × cos φ (W)**	**Power Factor cos φ = W/(V × I)**	**% Error [(W − P)/P] × 100**
01	200	0.8	150	150.4	0.94	−0.27%
02	210	1.0	190	191.1	0.90	−0.58%
03	220	1.2	230	231.0	0.87	−0.43%

Sl. No.	Supply Voltage V (V)	Load Current I (A)	Wattmeter Reading W (W)	Calculated Power Pcalc = V × I × cos φ (W)	Power Factor cos φ = W/(V × I)	% Error [(W − P)/P] × 100
04	230	1.2	280	278.0	0.81	+0.72%
05	230	1.8	320	322.0	0.77	−0.62%

Sample Calculation

For Trial 1:

Given: V = 200 V, I = 0.8 A, W = 150 W

$$\cos \varphi = W / (V \times I) = 150 / (200 \times 0.8) = 150 / 160 = 0.9375 \approx 0.94$$

$$Pcalc = V \times I \times \cos \varphi = 200 \times 0.8 \times 0.94 = 150.4 \text{ W}$$

$$\% \text{ Error} = [(150 - 150.4) / 150.4] \times 100 = -0.266\% \approx -0.27\%$$

Conclusion

The electrodynamometer wattmeter accurately measures the true power in a single-phase AC circuit, with only minor errors observed. These small percentage discrepancies are primarily attributed to internal instrument losses and minor connection resistances during the experiment.

EXPERIMENT NO. 05

Aim of the Experiment

To measure the active and reactive power of a three-phase balanced load using a single wattmeter.

Apparatus Required

Sl. No.	Name of the Apparatus	Range	Quantity
01	Electrodynamometer Wattmeter	10 A, 600 V	01
02	Ammeter (MI Type)	0–10 A	01
03	Voltmeter (MI Type)	0–600 V	01
04	3-Phase Balanced Load (lamp / inductive load)	415 V, 3 kW	01
05	3-Phase Variac	0–415 V	01
06	TPIC Switch	32 A, 415 V	01
07	Connecting Wires	1.5 mm^2	As required

Theory

In a three-phase balanced load, the power in each phase is equal. Therefore, one wattmeter can be used to measure the total power.

Active power: The current coil (CC) of the wattmeter is connected in one line (R) and the potential coil (PC) is connected between that line and the star point (neutral). The wattmeter then reads the power of one phase, and the total active power is:

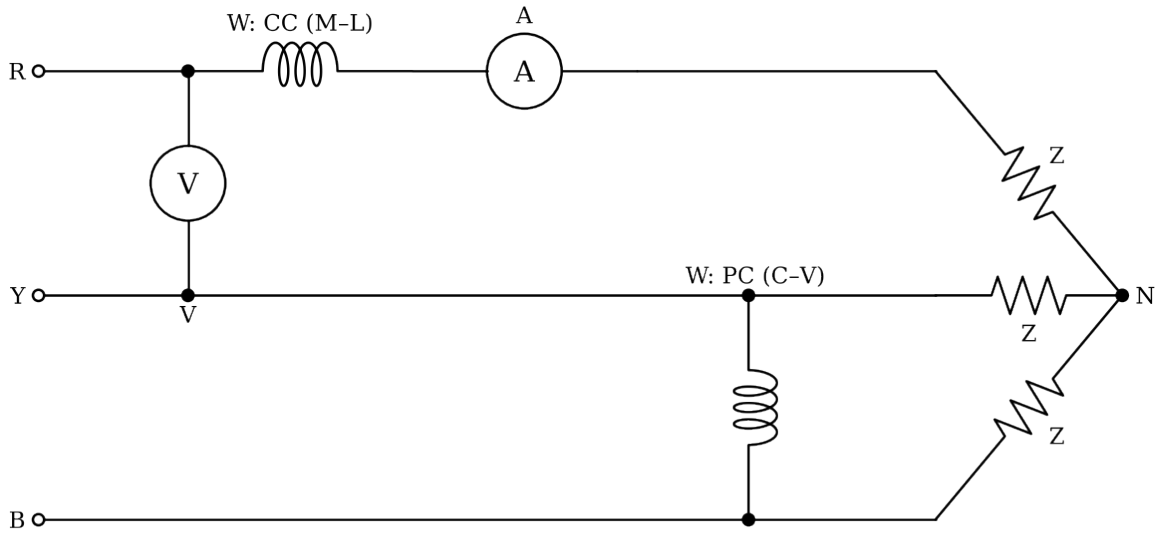
$$P = 3 \times W = 3 \times Vph \times Iph \times \cos \varphi$$

Reactive power: The current coil is connected in line R and the potential coil is connected across the other two lines (Y and B). The voltage VYB lags the phase voltage VR by 90°, so the wattmeter reads:

$$W = VL \times IL \times \cos (90° - \varphi) = VL \times IL \times \sin \varphi$$

The total reactive power of the three-phase balanced load is:

$$Q = \sqrt{3} \times W \ \ (VAr)$$



3-φ, 415 V, 50 Hz supply → balanced star-connected load

Fig.: Measurement of reactive power using a single wattmeter

Procedure

1. Connect the circuit as per the circuit diagram, with the current coil in line R and the potential coil across lines Y and B.
2. Keep the 3-phase variac at the zero position and switch on the TPIC switch.
3. Gradually increase the supply voltage up to the rated value.
4. Note down the readings of the voltmeter, ammeter and wattmeter.
5. Change the load and take readings for at least three different load conditions.
6. For active power, connect the potential coil between line R and the neutral point, and repeat the readings.
7. Reduce the voltage to zero and switch off the supply.

Observation Table

Sl. No.	**Line Voltage VL (V)**	**Line Current IL (A)**	**Wattmeter Reading W (W)**	**Reactive Power Q = √3 W (VAr)**
01				
02				
03				

Calculation

$$\textit{Reactive power } Q = \sqrt{3} \times W$$

$$\textit{Power factor angle } \varphi = \tan^{-1}(Q / P)$$

Precautions

1. All connections should be tight.

2. The current coil must be connected in series and the potential coil in parallel.
3. The load should be balanced.
4. Do not touch any live terminal.

Result

The active and reactive power of the three-phase balanced load were measured using a single wattmeter.

EXPERIMENT NO. 06

Aim of the Experiment

To measure the active power of a three-phase balanced load using two wattmeters.

Apparatus Required

Sl. No.	Name of the Apparatus	Range	Quantity
01	Electrodynamometer Wattmeter	10 A, 600 V	02
02	Ammeter (MI Type)	0–10 A	01
03	Voltmeter (MI Type)	0–600 V	01
04	3-Phase Balanced Load (lamp / inductive load)	415 V, 3 kW	01
05	3-Phase Variac	0–415 V	01
06	TPIC Switch	32 A, 415 V	01
07	Connecting Wires	1.5 mm^2	As required

Theory

The two-wattmeter method is used to measure power in a three-phase, three-wire system for both balanced and unbalanced loads. The current coils of the two wattmeters are connected in any two lines (R and B), and their potential coils are connected between those lines and the third line (Y).

The total power is equal to the sum of the two wattmeter readings:

$$P = W1 + W2$$

For a balanced load with power factor angle φ:

$$W1 = VL \times IL \times \cos(30° - \varphi)$$

$$W2 = VL \times IL \times \cos(30° + \varphi)$$

The power factor of the load can be found from the two readings:

$$\tan\varphi = \sqrt{3} \times (W1 - W2) / (W1 + W2)$$

Effect of power factor on the wattmeter readings:

- At unity p.f. (φ = 0°): W1 = W2
- At 0.5 p.f. (φ = 60°): W2 = 0, and the total power is read by W1 only.
- Below 0.5 p.f. (φ > 60°): W2 reads negative. Its current coil or potential coil connections must be reversed, and the reading is taken as negative.

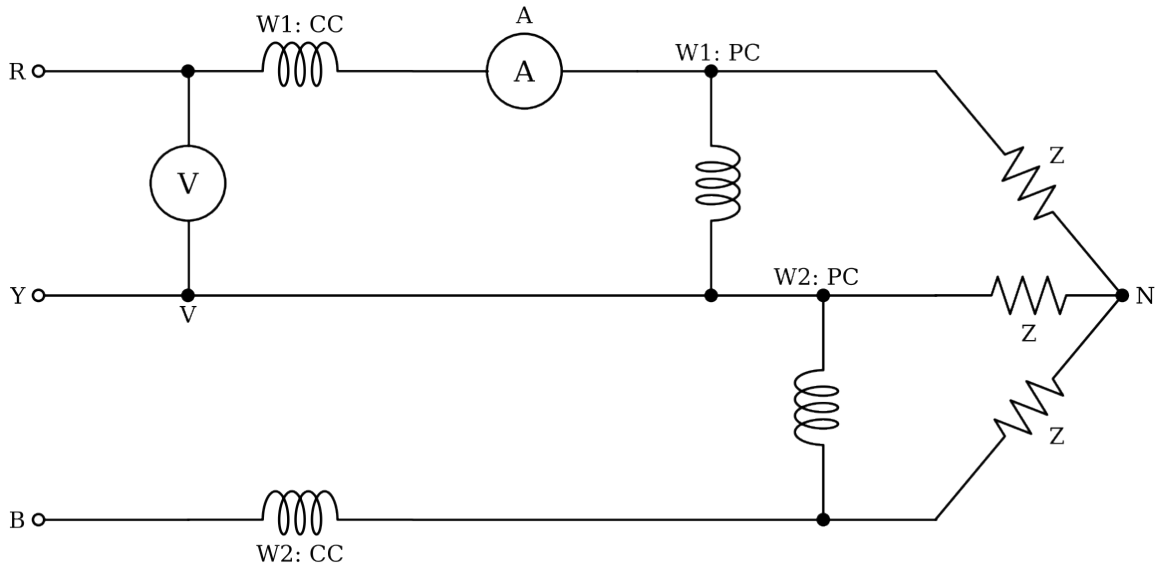


Fig.: Two-wattmeter method for measurement of three-phase power

Procedure

1. Connect the circuit as per the circuit diagram.
2. Keep the 3-phase variac at the zero position and switch on the TPIC switch.
3. Gradually increase the voltage up to the rated value.
4. Note down the readings of the voltmeter, ammeter, W1 and W2.
5. If any wattmeter deflects in the reverse direction, switch off the supply, interchange its current coil terminals and take the reading as negative.
6. Repeat the readings for different loads.
7. Reduce the voltage to zero and switch off the supply.

Observation Table

Sl. No.	VL (V)	IL (A)	W1 (W)	W2 (W)	P = W1 + W2 (W)	cos φ
01						
02						
03						

Calculation

$$\text{Total power } P = W1 + W2$$

$$\varphi = \tan^{-1}\left[\sqrt{3} \times (W1 - W2) / (W1 + W2)\right], \quad \text{Power factor} = \cos\varphi$$

Precautions

1. All connections should be tight.
2. The current coils must be connected in series with the lines and the potential coils in parallel.

3. Take care of the negative reading of a wattmeter at low power factor.

Result

The active power of the three-phase balanced load was measured by the two-wattmeter method, and the power factor of the load was calculated.

EXPERIMENT NO. 07

Aim of the Experiment

To calibrate a single-phase electronic energy meter by direct loading.

Apparatus Required

Sl. No.	Name of the Apparatus	Range	Quantity
01	Single-Phase Electronic Energy Meter	230 V, 5–30 A	01
02	Wattmeter (Electrodynamometer)	10 A, 300 V	01
03	Ammeter (MI Type)	0–10 A	01
04	Voltmeter (MI Type)	0–300 V	01
05	Lamp Load	230 V, 2 kW	01
06	Stopwatch	—	01
07	DPIC Switch	16 A, 230 V	01
08	Connecting Wires	1.5 mm²	As required

Theory

An energy meter measures the electrical energy consumed by a load in kWh. In an electronic energy meter, the voltage and current are sampled and multiplied electronically, and the energy is indicated by an LED that blinks (pulses) and by a digital display.

The meter constant (K) is written on the nameplate, for example 3200 imp/kWh, which means the LED blinks 3200 times for 1 kWh of energy.

In calibration by direct loading, the energy recorded by the meter is compared with the true energy calculated from a standard wattmeter and a stopwatch.

$$\textit{Energy recorded by meter } Em = N / K \ \ (kWh)$$

where N is the number of pulses (blinks) counted in time t.

$$\textit{True energy } Et = (W \times t) / (1000 \times 3600) \ \ (kWh)$$

where W is the wattmeter reading in watts and t is the time in seconds.

$$\% \ Error = [(Em - Et) / Et] \times 100$$

A positive error means the meter runs fast and a negative error means the meter runs slow.

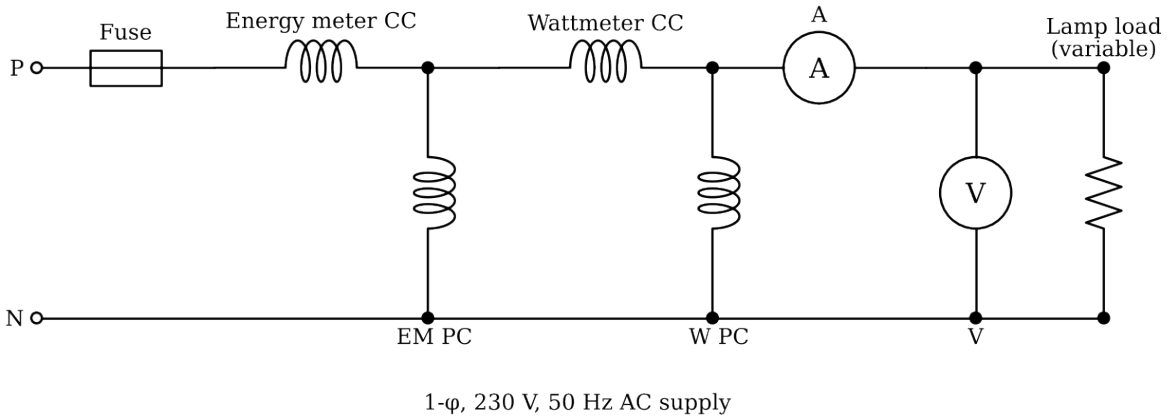


Fig.: Calibration of single-phase energy meter by direct loading

Procedure

1. Note the nameplate details and the meter constant of the energy meter.
2. Connect the circuit as per the circuit diagram.
3. Switch on the supply and apply a small load.
4. Count a fixed number of pulses (for example 10) of the LED and note the time taken using a stopwatch.
5. Note the readings of the voltmeter, ammeter and wattmeter.
6. Increase the load in steps and repeat the above steps.
7. Calculate the percentage error for each load.
8. Switch off the load and the supply.

Observation Table

Sl. No.	V (V)	I (A)	W (W)	No. of Pulses (N)	Time t (s)	Em (kWh)	Et (kWh)	% Error
01								
02								
03								

Precautions

1. All connections should be tight.
2. Pulses should be counted carefully and the stopwatch started and stopped at the right instant.
3. The supply voltage should remain constant during the test.

Result

The single-phase electronic energy meter was calibrated by direct loading, and its percentage error at different loads was calculated.

EXPERIMENT NO. 08

Aim of the Experiment

To measure low resistance using Kelvin's double bridge.

Apparatus Required

Sl. No.	Name of the Apparatus	Range	Quantity
01	Kelvin's Double Bridge Kit	0.001 Ω – 10 Ω	01
02	Low Resistance (unknown)	Below 1 Ω	01
03	Standard Low Resistance	0.01 Ω	01
04	DC Power Supply / Battery	0–5 V, 2 A	01
05	Galvanometer	Centre zero	01
06	Rheostat	0–10 Ω, 5 A	01
07	DC Ammeter	0–5 A	01
08	Connecting Wires	—	As required

Theory

Resistances below 1 Ω are called low resistances. They cannot be measured accurately by the Wheatstone bridge because the resistance of the leads and contacts causes a large error.

Kelvin's double bridge is a modified Wheatstone bridge. It has a second set of ratio arms (p and q), and the galvanometer is connected to the link (r) between the unknown resistance R and the standard resistance S through these arms. This eliminates the effect of lead and contact resistance.

At balance, when the ratio of the outer arms equals the ratio of the inner arms (P/Q = p/q), the unknown resistance is:

$$R = (P / Q) \times S$$

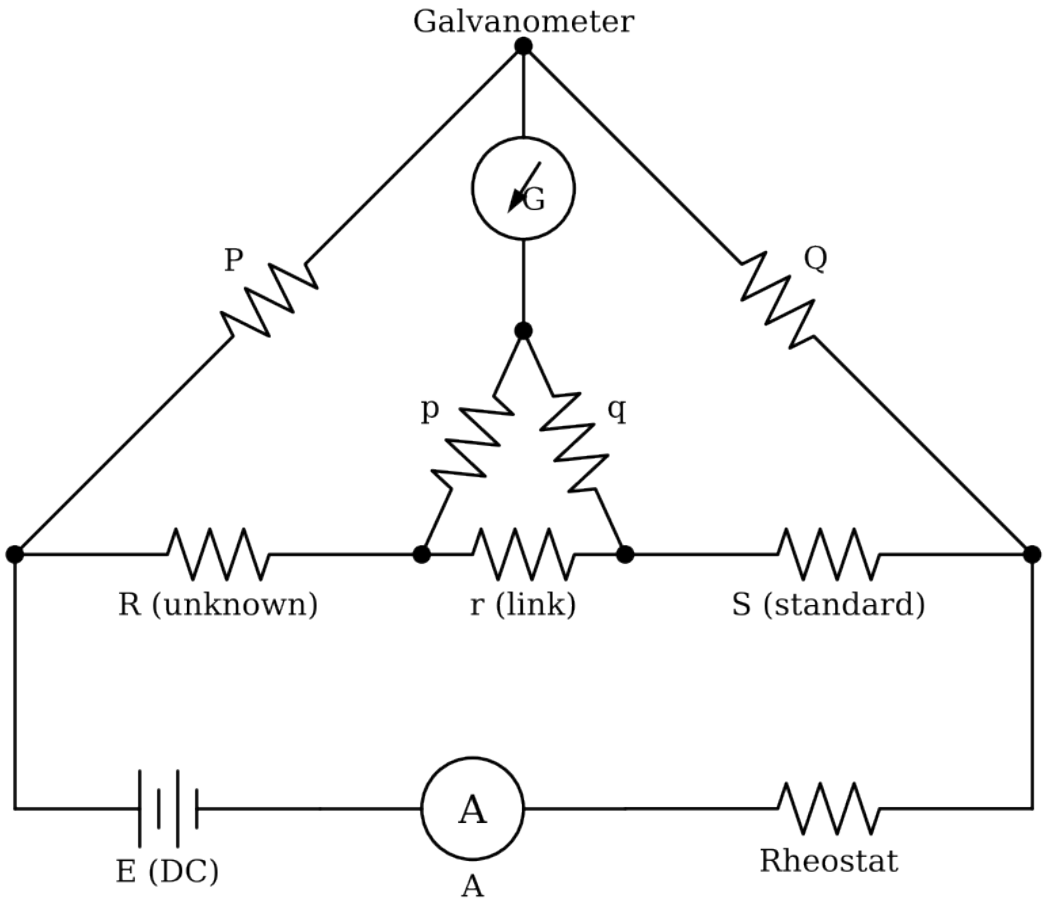


Fig.: Kelvin's double bridge

Procedure

1. Connect the circuit as per the circuit diagram.
2. Connect the unknown low resistance R and the standard resistance S with thick, short leads.
3. Set the ratio arms so that P/Q = p/q.
4. Switch on the DC supply and adjust the current with the rheostat.
5. Vary the standard resistance S until the galvanometer shows zero deflection (balance).
6. Note the values of P, Q and S.
7. Repeat for different ratio settings and find the average value of R.
8. Switch off the supply.

Observation Table

Sl. No.	P (Ω)	Q (Ω)	S (Ω)	R = (P/Q) × S (Ω)
01				
02				
03				

Average R = (R1 + R2 + R3) / 3

Precautions

1. Connections should be tight and leads should be short and thick.
2. The current should not exceed the rating of the resistance.
3. The galvanometer should be protected with a shunt at the start.

Result

The value of the given low resistance was measured using Kelvin's double bridge.