

EE 256: POWER AND ENERGY
Experiment: Three Phase Measurements
(3 hours)

DATE: 2025/07/08

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 measurement of three phase system. In this section, the students will get hand on experience on measuring voltage and current in a real three phase system. Also, they will get an exposure on power measurements on three phase Delta connected/ Wye connected balanced and unbalanced loads using one wattmeter and two wattmeters.

LEARNING OUTCOMES:

- LO 1: Calculate the voltages, currents and power of delta and star connected three phase systems (covering attributes of WA1 and WA2)
- LO 2: Discuss and demonstrate different methods of power and energy measurements (covering attributes of WA1 and WA2)

OBJECTIVES:

1. Verify the relationship between the phase and line quantities of a balanced and unbalanced three phase system. (LO1)
2. Discuss and demonstrate different methods of three phase power measurement using Wattmeter. (LO2)

a) Measurements on a real three phase system

APPARATUS:

- Clip-on meter

PROCEDURE:

Step 1 – Use the clip-on ammeter to measure currents in each phase and the neutral of the incoming feeder to the lab. Note down the readings.

Step 2 – Use the multi-meter to measure the voltage of each phase with respect to the neutral and voltage between phases. Note down the readings.

OBSERVATIONS:

I_A / A	3.50
I_B / A	3.49
I_C / A	3.44
I_N / A	0.06

V_{AN}/V	242.9
V_{BN}/V	237.7
V_{CN}/V	244.6
V_{AB}/V	415.0
V_{BC}/V	412.0
V_{AC}/V	413.0

CALCULATIONS:

Calculate the apparent power of the three-phase system.

$$\begin{aligned}\text{Apparent Power} &= V_{AN}I_A + V_{BN}I_B + V_{CN}I_C \\ &= (242.9 \times 3.50) + (237.7 \times 3.49) + (244.6 \times 3.44) \\ &= \underline{2521.147 \text{ VA}}\end{aligned}$$

b) Power measurements of a three-phase delta connected balanced system using single wattmeter

APPARATUS:

- Single Phase Wattmeter: 5A, 480V (YOKOGAWA)
- AC Ammeter: 0-5A (YOKOGAWA) x 2Nos
- AC Voltmeter: 0-750V (YOKOGAWA)
- Three Phase Inductive Load: (Terco MV1101) – position 4 value = 185mH
- Water Load: Low Position value = 120Ω

PROCEDURE:

Step 1 – Connect the circuit as shown in Figure 1. Here the load is formed by parallel connection of the resistive and inductive loads.

Step 2 – Keep the water load at low position (120Ω). Set the inductor bank to position 4 (185mH).

Step 3 – Switch on the three-phase voltage supply.

Step 4 – Obtain meter readings

Step 5 – Switch off the supply.

Step 6 – Then, connect voltage coil of the wattmeter between;

- i. A and C
- ii. B and C

Step 7 – Then, follow the steps 2 – 5 for above two cases.

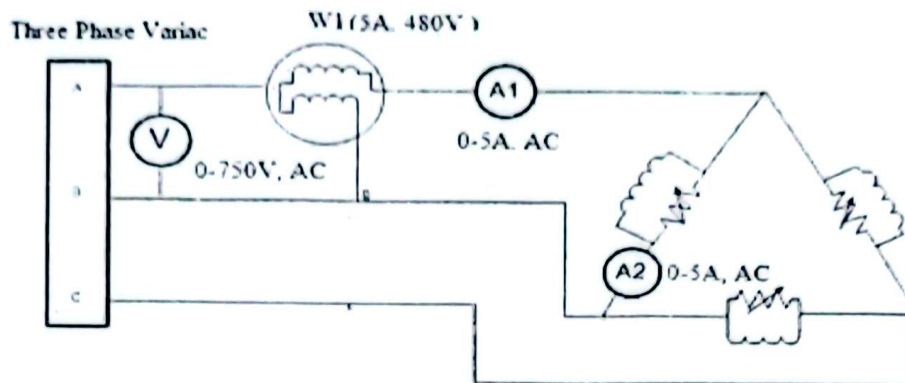


Figure 1: Circuit diagram for power measurement using single wattmeter

OBSERVATIONS:

Meter	V coil at A & B	V coil at A & C	V coil at B & C
V ₁	225 V	225V	220V
A ₁	3.4 A	3.5 A	3.4A
A ₂	2.0 A	2.0 A	2.0 A
W ₁	700 W	680W	660W

CALCULATIONS:

Calculate the Active power using watt meter reading:

$$\begin{aligned} \text{Active power} &= W_1(AB) + W_2(AC) \\ &= 700W + 680W \\ &= \underline{1380W} \end{aligned}$$

Calculate the Reactive power using wattmeter reading:

$$\begin{aligned} \text{Reactive power} &= \sqrt{3} \cdot W_1(BC) \\ &= \sqrt{3} \times 660W \\ &= \underline{1143.15 \text{ Var}} \end{aligned}$$

RESULTS:

Active Power	1380W
Reactive Power	1143.15Var

c) Power measurements of a balanced three phase system using two wattmeter method

A. Delta connected balanced system

APPARATUS:

- Single Phase Wattmeter: 5A, 480V (YOKOGAWA) x 2Nos
- AC Ammeter: 0-5A (YOKOGAWA) x 2Nos
- AC Voltmeter: 0-750V (YOKOGAWA)
- Three Phase Inductive Load: (Terco MV1101) – position 4 value = 185mH
- Water Load: Low Position value = 120Ω

PROCEDURE:

Step 1 – Connect the circuit as shown in Figure 2. Here the load is formed by parallel connection of the resistive and inductive loads.

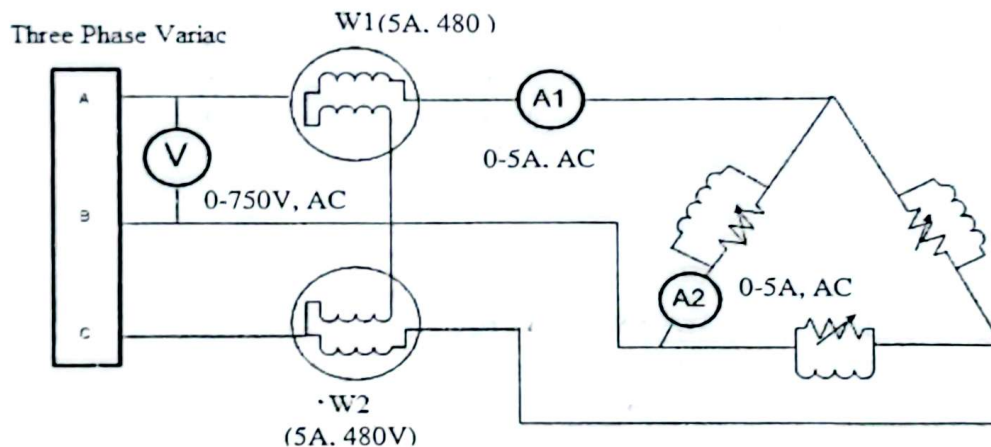


Figure 2: Circuit diagram for power measurement of a delta connected balanced system by two wattmeter method.

Step 2 – Keep the water load at low position (120Ω). Set the inductor bank to position 4 (185mH).

Step 3 – Switch on the three-phase voltage supply.

Step 4 – Obtain meter readings.

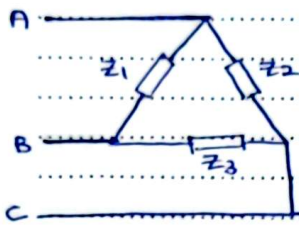
Step 5 – Switch off the supply.

OBSERVATIONS:

V ₁	225V
A ₁	3.8A
A ₂	2.0A
W ₁	680W
W ₂	660W

CALCULATIONS:

i. Obtain the relationship between line and phase quantities:



phase voltage = Line voltage

$$V_P = V_L \text{ --- (1)}$$

$\sqrt{3} \times$ phase current = Line current

$$\sqrt{3} \times I_P = I_L$$

$$\sqrt{3} I_P = I_L \text{ --- (2)}$$

ii. Calculate the active power factor, reactive power and apparent power of the system using wattmeter readings:

$$\text{Active power} = W_1 + W_2$$

$$P = 680 + 660 \text{ W}$$

$$= \underline{1340 \text{ W}}$$

$$\text{Reactive power} = \sqrt{3} (W_2 - W_1)$$

$$Q = \sqrt{3} (660 - 680)$$

$$= \underline{-34.64 \text{ Var}}$$

$$\text{Apparent power} = \sqrt{P^2 + Q^2}$$

$$S = \sqrt{(1340)^2 + (-34.64)^2}$$

$$S = \underline{1340.45 \text{ VA}}$$

iii. Calculate the power factor of the system using given impedance values:

$$R = 120 \Omega$$

$$L = 185 \text{ mH} \rightarrow Z_L = j\omega L$$

$$|Z| = 2\pi \times 50 \times 185 \text{ mH}$$

$$= \underline{58.1195 \Omega}$$

$$Z_R = 120 \Omega \quad Z_L = 58.1195 \Omega$$

$$Z_R \parallel Z_L = 52.31 \angle 64.16^\circ$$

$$\theta = 64.16^\circ$$

$$\text{power factor} = \cos(\theta) = \cos(64.16^\circ) = \underline{0.436}$$

iv. Calculate the power factor of the system using voltmeter and ammeter readings:

$$\text{Power Factor} = \frac{P}{\sqrt{3} V_L I_L} = \frac{1340}{\sqrt{3} \times 225 \times 3.9} = \underline{0.905}$$

$$$$

iv. Calculate the power factor of the system using Wattmeter readings:

$$\text{Power factor} = \cos \left[\tan^{-1} \left(\frac{\sqrt{3} (W_2 - W_1)}{W_1 + W_2} \right) \right]$$

$$= \cos \left[\tan^{-1} \left(\frac{-34.64}{1340} \right) \right]$$

$$= \underline{0.9997 \approx 1}$$

B. Wye connected balanced system

APPARATUS:

- Single Phase Wattmeter: 5A, 480V (YOKOGAWA) x 2Nos
- AC Ammeter: 0-5A (YOKOGAWA) x 3Nos
- AC Voltmeter: 0-750V (YOKOGAWA) x 2Nos
- Three Phase Inductive Load: (Terco MV1101) – position 4 value = 185mH
- Water Load: Low Position value = 120Ω

Procedure:

Step 1 – Connect the circuit as shown in Figure 3.

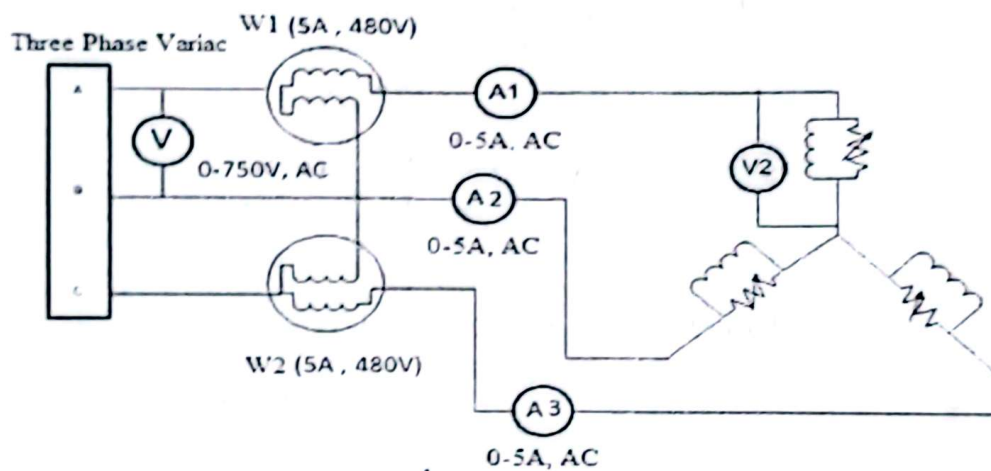


Figure 3: Circuit diagram for power measurement of a delta connected balanced system by two wattmeter method.

Step 2 – Keep the water load at low position. Set the inductor bank to position 4.

Step 3 – Switch on the three-phase voltage supply.

Step 4 – Obtain meter readings.

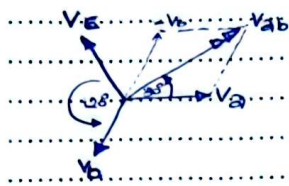
Step 5 – Switch off the supply.

OBSERVATIONS:

V ₁	225V
V ₂	130V
A ₁	1.15A
A ₂	1.10A
A ₃	1.10A
W ₁	220W
W ₂	220W

CALCULATIONS:

i. Obtain the relationship between line and phase quantities:



Line current = phase current.

$$I_L = I_P$$

$$V_{ab} = V_a \cos 30^\circ + V_b \cos 30^\circ$$

$$V_{ab} = 2V_P \cos 30^\circ$$

$$V_L = \sqrt{3} V_P \angle +30^\circ$$

ii. Calculate the total power dissipated in the loads using Wattmeter readings:

$$\text{Active power (P)} = W_1 + W_2 = 220 + 220 = 440 \text{ W}$$

$$\text{Reactive power (Q)} = \sqrt{3} (W_2 - W_1) = \sqrt{3} (0) = 0 \text{ W}$$

$$\begin{aligned} \text{Apparent power (S)} &= \sqrt{P^2 + Q^2} \\ &= \sqrt{440^2 + 0} \\ &= 440 \text{ VA} \end{aligned}$$

iii. Calculate the power factor of the system using Voltmeter and Ammeter readings:

$$\begin{aligned} \text{Power factor} &= \frac{P}{\sqrt{3} V_L I_L} = \frac{440}{\sqrt{3} \times 225 \times 1.15} \\ &= 0.9818 \end{aligned}$$

iv. Calculate the power factor of the system using Wattmeter readings:

$$\begin{aligned} \text{Power factor} &= \cos \left[\tan^{-1} \left[\frac{\sqrt{3} (W_2 - W_1)}{W_2 + W_1} \right] \right] \\ &= 1.00 \end{aligned}$$

RESULTS:

	Delta connected System	Wye connected system
Active power	1340 W	440 W
Reactive power	34.64 Var	0 Var
Apparent power	1340.45 VA	440 VA
Power factor	1.0	1.0

d) Power measurement of unbalanced wye connected system

PROCEDURE:

Step 1 – Use the circuit in Figure 3

Step 2 – Keep the inductor bank at position 4.

Step 3 – Change the water load connected to phase A, to medium position while keeping other water loads at low position.

Step 4 – Switch on the three-phase voltage supply.

Step 5 – Obtain meter readings.

Step 6 – Use the multi-meter to measure the voltage of the load neutral point (N') with respect to supply neutral (N) and phase voltage of each load.

Step 7 – Switch off the supply.

OBSERVATIONS:

Meter readings	V_1	230V
	A_1	1.75A
	A_2	1.30A
	A_3	1.30A
	W_1	340W
	W_2	340W

Voltage of the load neutral point (N') with respect to supply neutral (N)

$V_{NN'}$	35V
$V_{AN'}$	99.5V
$V_{BN'}$	152.5V
$V_{CN'}$	151.0V

CALCULATIONS:

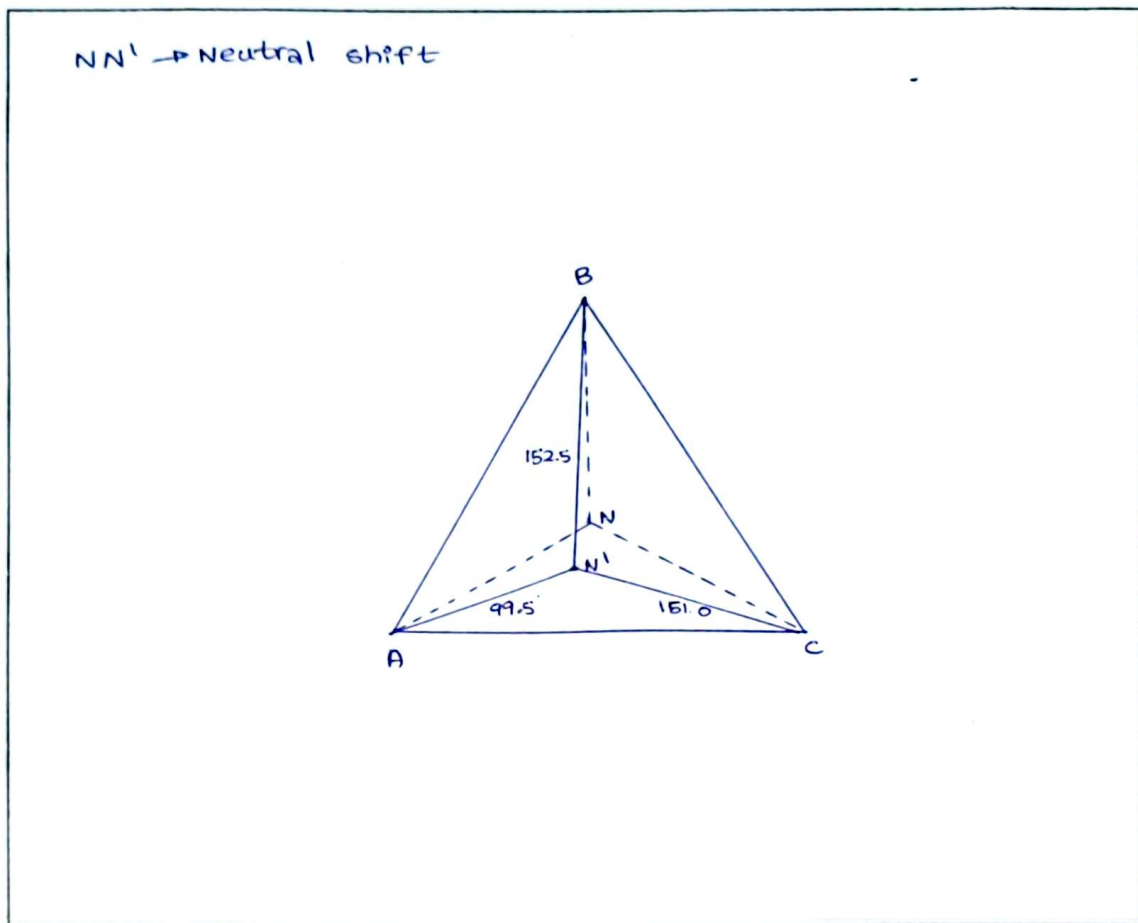
i. Calculate the total power dissipated in the loads using Wattmeter readings:

$$\begin{aligned}\text{Power dissipated} &= W_1 + W_2 \\ &= 340 + 340 \\ &= \underline{\underline{680W}}\end{aligned}$$

ii. Calculate the power factor of the system using Wattmeter readings:

$$\begin{aligned}\text{Power factor} &= \cos \left[\tan^{-1} \left(\frac{\sqrt{3}(W_2 - W_1)}{W_2 + W_1} \right) \right] \\ &= \cos \left[\tan^{-1} \left(\frac{0}{680} \right) \right] \\ &= \underline{\underline{1.00}}\end{aligned}$$

iii. Draw the phasor diagram to illustrate the neutral shift.



TABULATION:

	1 wattmeter method, Δ , balanced	2 Wattmeter method		
		Balanced		Unbalanced
		Δ	Y	Y
Active Power	1380 W	1340 W	440 W	680 W
Reactive power	1143.15 Var	34.64 Var	0 Var	0 Var
Apparent power	1791.98 VA	1340.45 VA	440 VA	680 VA
Power factor	0.77	1.00	1.00	1.00

DISCUSSION:

1. Compare the values obtained for the power factor in steps 1, 2 and 3 in your calculations.
2. What happens if the neutral connection in the lab supply is disconnected?

DISCUSSION

- ① Compare the values obtained for the power factor in step 1, 2 and 3 in calculations.

From one wattmeter method we obtained power factor as 0.77, while in step 2, 3. methods resulted in a unity power factor of 1.

A perfect unity power factor is ideal but highly unlikely in a practical lab experiment, suggesting a potential error in two wattmeter measurements. This discrepancy likely arises from incorrect wiring of the wattmeters or an instrument fault. Therefore, the lagging power factor of 0.77 is a more plausible and realistic for a typical inductive load, making the one-wattmeter method's result more credible in this case.

- ② What happens if the neutral connection in the lab supply is disconnected?

If the neutral connection from the lab supply is disconnected, the three-phase system becomes dangerously unbalanced. Particularly, for loads connected in star configuration. Without the neutral wire providing a return path, the star point is no longer held at a stable potential. This causes the phase voltages across the load to become unequal. Some will experience over voltage, which may destroy or damage equipments, while some experience under voltage, causing them malfunction.

REFERENCES

- [1] E.-E. E. Portal, "Floating Neutral Impacts in Power Distribution", EEP-
Electrical Engineering Portal, Aug. 27, 2012. <https://electrical-engineering-portal.com/floating-neutral-impacts-in-power-distribution>.