EEL101: Basic Electrical Lab

Experiment No: 8 **Date:**

Batch No.		**Team Number**	
	Team Member 1	**Team Member 2**	**Team Member 3**
Name			
ID No			
	Team Member 4	**Team Member 5**	**Team Member 6**
Name			
ID No			

Aim: Investigation of Star-Star, Delta-Delta, Star-Delta and Delta-Star Connections using Three Single-Phase Transformers.

Objective: To study the characteristics of a three-phase transformer when connected in star and delta configurations for all four possible configurations and investigating the relationship between line to line and line phase voltages on either side of the transformers.

Apparatus Required:

Single Phase Transformer (Name plate details):

Electrical Parameter	**Value**	**Unit**
KVA Rating		
Primary Voltage		
Primary Current		
Secondary Voltage		
Secondary Current		

S. No.	**Equipment**	**Specification**	**Quantity**
1.	Digital Voltmeter		
2.	Analog Voltmeter		
3.	Connecting leads		

Theory:

In a three-phase transformer, the primary and secondary windings can be connected in either star (Y) or delta (Δ) configuration. Understanding the relationship between line voltage (V_L) and phase voltage (V_P) is crucial in analyzing the performance of the transformer in different configurations.

Star (Y) Connection:

In a star connection, one end of each winding is connected together at a common point known as the neutral point, and the other ends are connected to the respective phases of the three-phase supply.

The line voltage (V_L) in a star-connected system is equal to the phase voltage (V_P).

Mathematically, $V_L = V_P$.

Delta (Δ) Connection:

In a delta connection, the windings are connected end-to-end to form a closed loop without a neutral point.

The line voltage (V_L) in a delta-connected system is √3 times the phase voltage (V_P).

Mathematically, $V_L = \sqrt{3} \times V_P$.

This relationship arises from the phasor sum of the voltages across the windings in a delta configuration.

Relationship between Line Voltage and Phase Voltage:

For a balanced three-phase system, where the loads are identical and equally distributed across the phases, the relationship between line voltage (V_L) and phase voltage (V_P) depends on the configuration.

In a star-connected system, VL is equal to VP, making the phase and line voltages the same whereas in a delta-connected system, V_L is √3 times V_P, meaning the line voltage is higher than the phase voltage.

This relationship is essential in designing electrical systems and understanding the distribution of power in three-phase circuits. For understanding the all four possible configurations, each one is explained briefly here. Fig. 1, 2, 3 and 4 shows the star-star, delta-delta, star-delta and delta-delta configurations of the transformers,

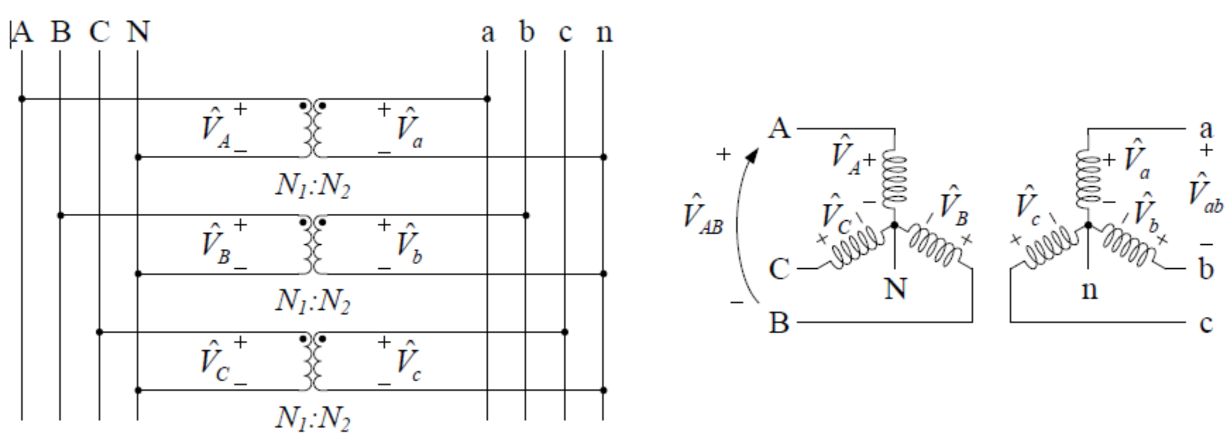

Fig 1: Star-Star configuration using three single phase transformers.

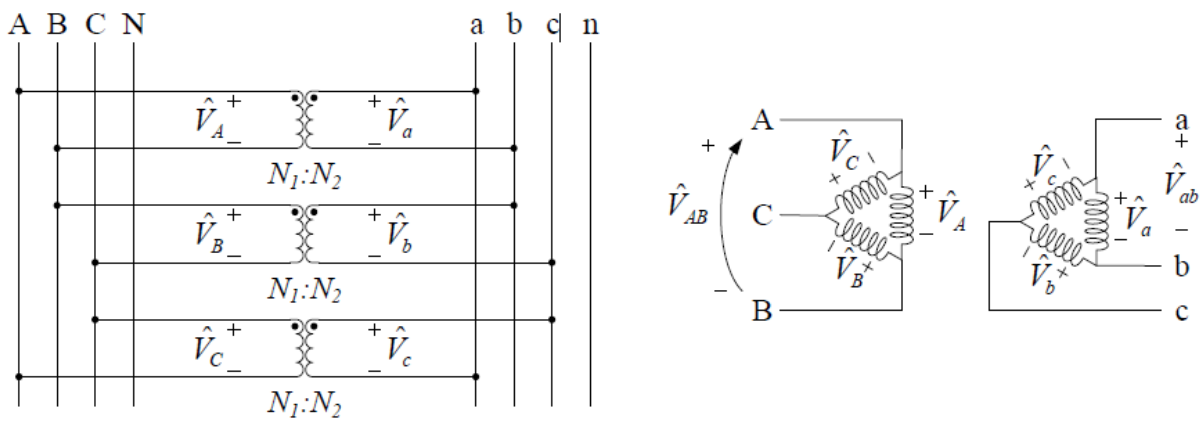

Fig 2: Delta-Delta configuration using three single phase transformers.

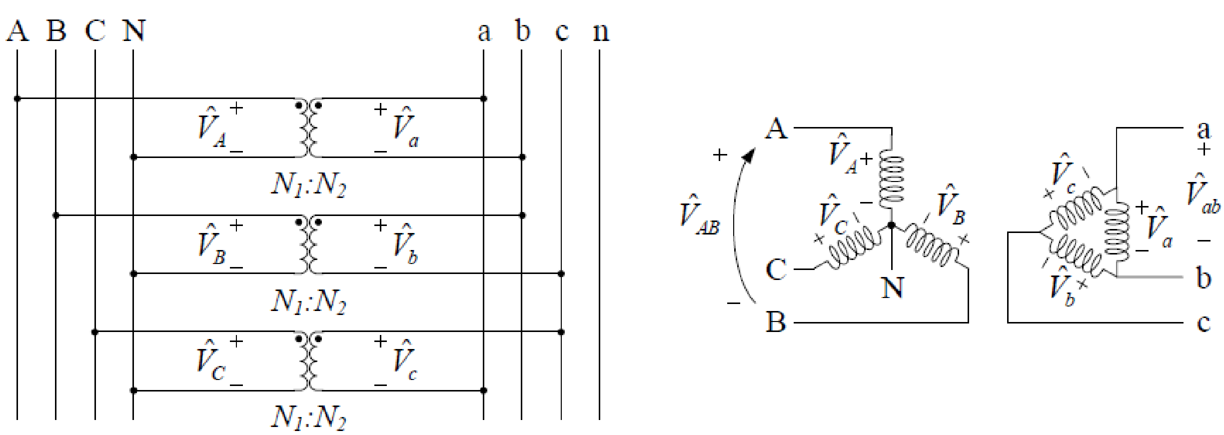

Fig 3: Star-Delta configuration using three single phase transformers.

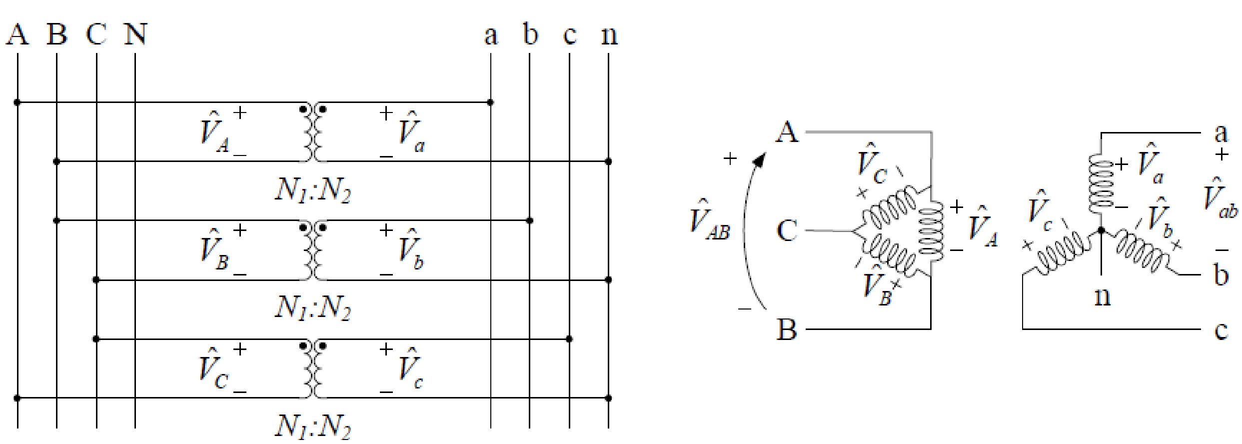

Fig 4: Delta-Star configuration using three single phase transformers.

For mathematical analysis, the transformers will be treated as if they were ideal. Figure 1 and 2 indicates the three transformers as well as the lines and neutrals on the two sides, which may be connected to the transformers in various ways. Being ideal, they satisfy the following voltage relationships:

$$\hat{V}_a = \frac{N_2}{N_1}\hat{V}_A$$
$$\hat{V}_b = \frac{N_2}{N_1}\hat{V}_B$$
$$\hat{V}_c = \frac{N_2}{N_1}\hat{V}_C$$

The three primary coils may be connected in delta or wye, and the three secondaries coils may be connected in delta or wye, for four possible configurations1. For wye-wye and delta-delta (Figures 3 and 4), the line voltages are related as

$$\hat{V}_{ab} = \frac{N_2}{N_1}\hat{V}_{AB}$$
$$\hat{V}_{bc} = \frac{N_2}{N_1}\hat{V}_{BC}$$
$$\hat{V}_{ca} = \frac{N_2}{N_1}\hat{V}_{CA}$$

A more common configuration is delta-wye, as shown in Figure 5. With abc sequence, That is, the secondary line voltage leads the primary voltage by 30°, and is scaled by both the turns ratio and 1.732.

$$\begin{aligned}\hat{V}_{ab} &= \hat{V}_a - \hat{V}_b \\ &= \frac{N_2}{N_1}(\hat{V}_A - \hat{V}_B) \\ &= \frac{N_2}{N_1}(\hat{V}_{AB} - \hat{V}_{BC}) \\ &= \hat{V}_{AB} \times \frac{N_2}{N_1}\sqrt{3}\underline{/30^\circ}\end{aligned}$$

Similarly, for the wye-delta configuration of Figure 6, the secondary voltage is

$$\hat{V}_{ab} = \hat{V}_{AB} \times \frac{N_2}{N_1}\frac{1}{\sqrt{3}}\underline{/-30^\circ}$$

That is, the secondary voltage lags the primary voltage by 30° and is scaled by both the turns ratio and 0.577.

Circuit Diagram:

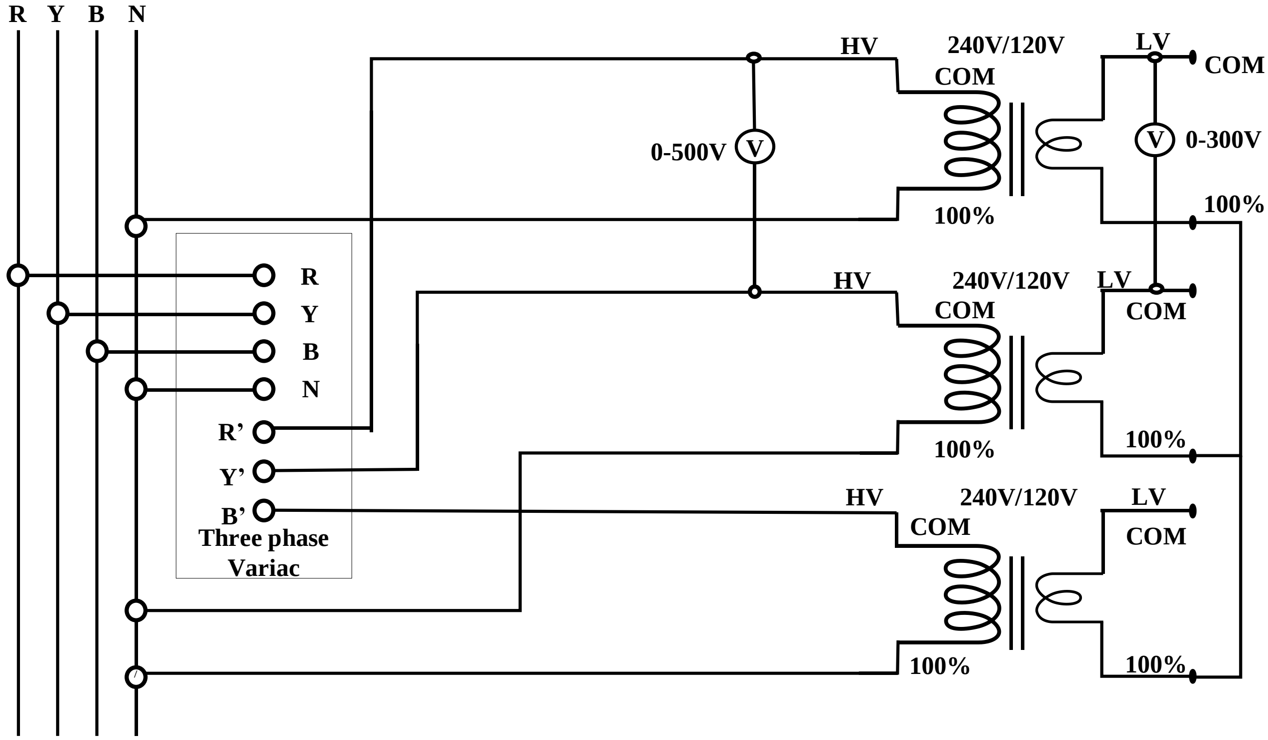

Fig 5: Star-Star configuration using three single phase transformers Lab set-up.

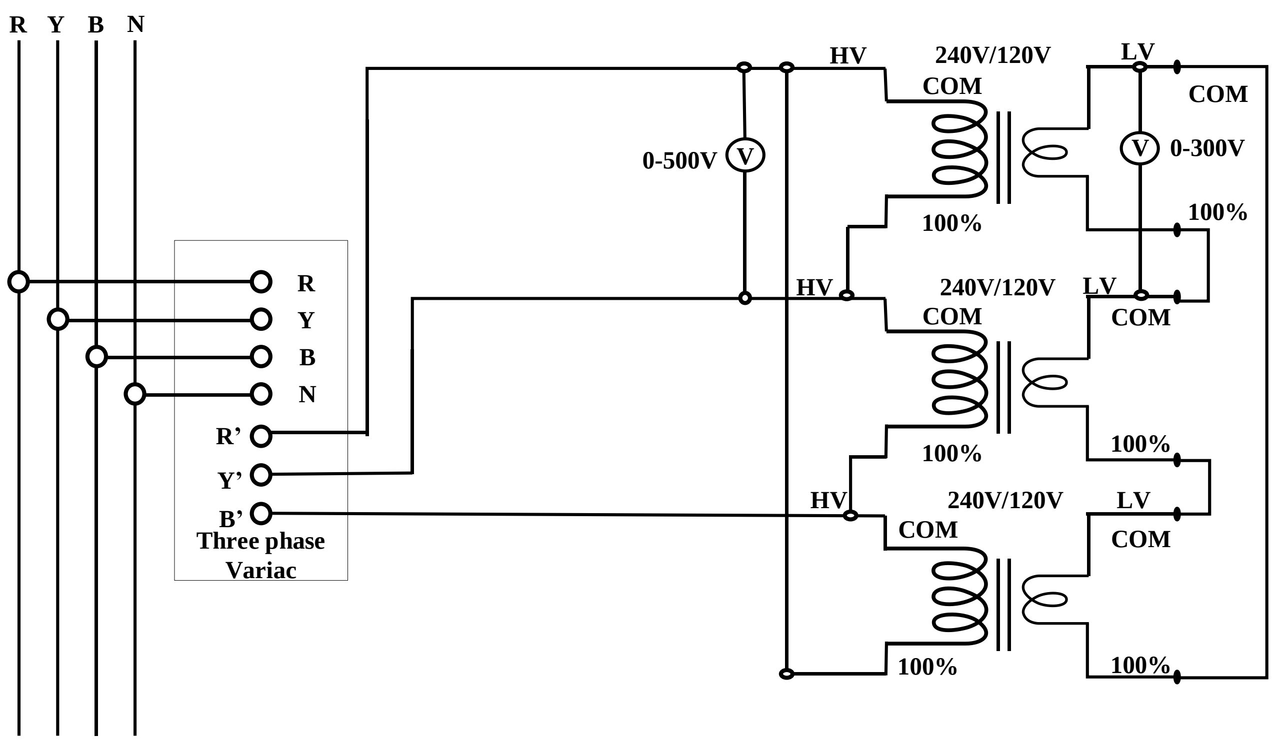

Fig 6: Delta-Delta configuration using three single phase transformer Lab set-up.

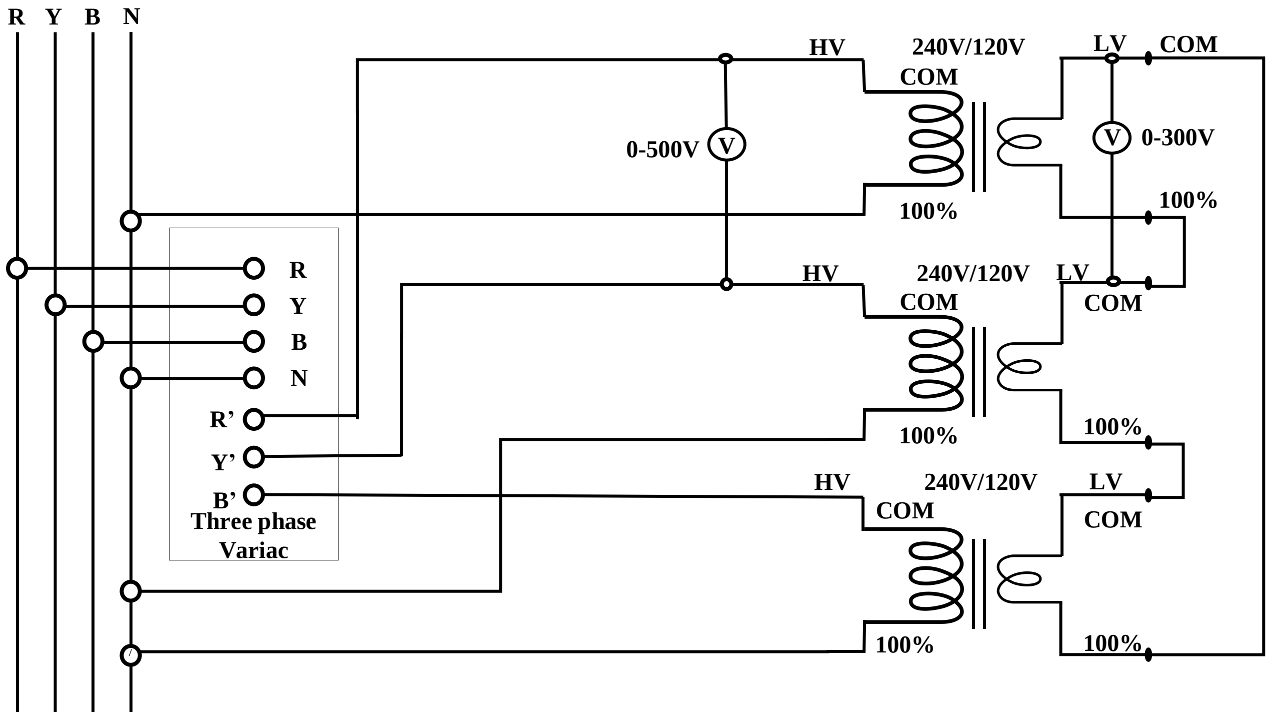

Fig 7: Star-delta configuration using three single phase transformers Lab set-up.

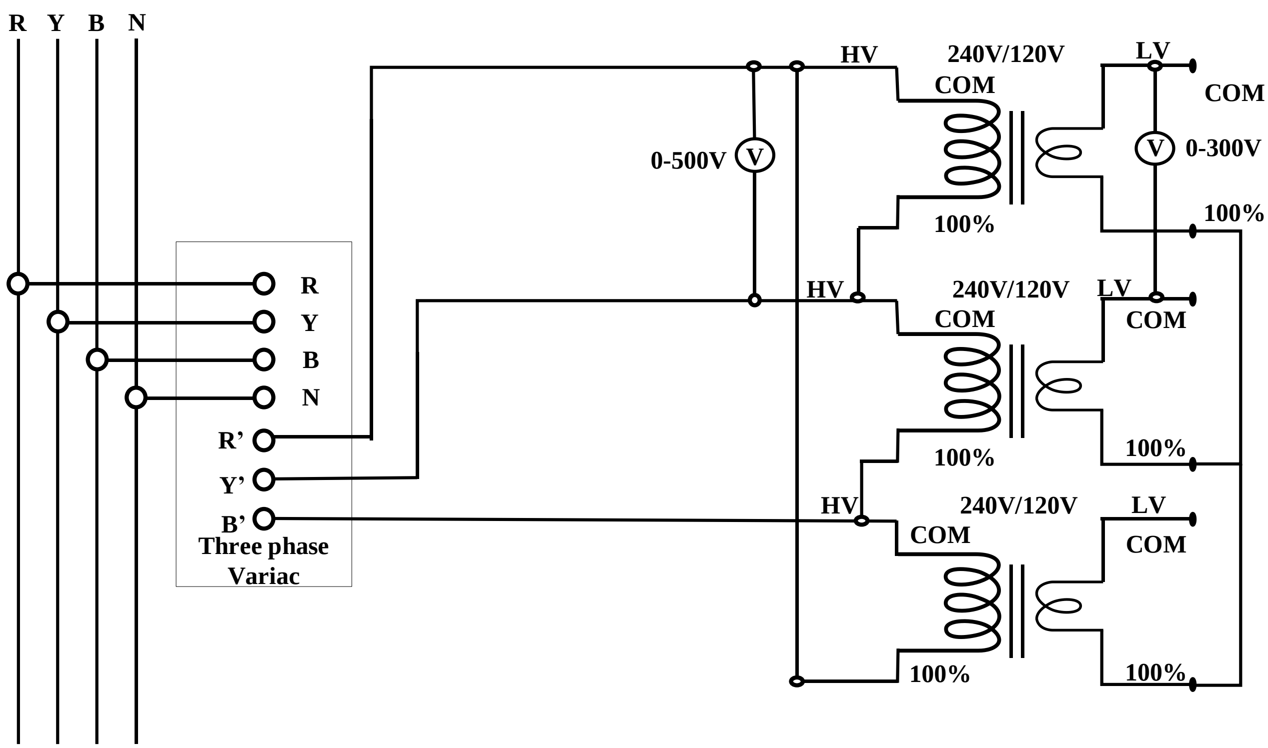

Fig 8: Delta-Star configuration using three single phase transformers Lab set-up.

Procedure:

Star-Star Configuration:

1. Make the connections as per the circuit diagram given in Fig. 5.
2. Now Switch on the supply and increase the voltage from three-phase auto transformer.
3. Measure and record the voltage on the digital multimeter on the HV side and on the analog meter in LV side.
4. Repeat steps 2 and 3 for five sets of voltages between 0 and 415 volts on the HV side.

Delta-Delta Configuration:

1. Make the connections as per the circuit diagram given in Fig. 6.
2. Now Switch on the supply and increase the voltage from three-phase auto transformer.
3. Measure and record the voltage on the digital multimeter on the HV side and on the analog meter in LV side.
4. Repeat steps 2 and 3 for five sets of voltages between 0 and 240 volts on the HV side.

Star-Delta Configuration:

1. Make the connections as per the circuit diagram given in Fig. 7.
2. Now Switch on the supply and increase the voltage from three-phase auto transformer.
3. Measure and record the voltage on the digital multimeter on the HV side and on the analog meter in LV side.
4. Repeat steps 2 and 3 for five sets of voltages between 0 and 415 volts on the HV side.

Delta-Star Configuration:

1. Make the connections as per the circuit diagram given in Fig. 8.
2. Now Switch on the supply and increase the voltage from three-phase auto transformer.
3. Measure and record the voltage on the digital multimeter on the HV side and on the analog meter in LV side.
4. Repeat steps 2 and 3 for five sets of voltages between 0 and 240 volts on the HV side.

Observation Table:

Star-Star Configuration:

S.No.	Voltmeter Reading (HV) Volts (V_L)	Voltmeter Reading (LV) Volts (V_l)	Phase voltage (HV) Volts (V_P)=(V_L/1.732)	Phase voltage (LV) Volts (V_p)=(V_l/1.732)

Delta-Delta Configuration:

S.No.	Voltmeter Reading (HV) Volts (V_L)	Voltmeter Reading (LV) Volts (V_l)	Phase voltage (HV) Volts (V_P)=(V_L)	Phase voltage (LV) Volts (V_p)=(V_l)

Star-Delta Configuration:

S.No.	Voltmeter Reading (HV) Volts (V_L)	Voltmeter Reading (LV) Volts (V_l)	Phase voltage (HV) Volts (V_P)=(V_L/1.732)	Phase voltage (LV) Volts (V_p)=(V_l)

Delta-Star Configuration:

S.No.	Voltmeter Reading (HV) Volts (V_L)	Voltmeter Reading (LV) Volts (V_l)	Phase voltage (HV) Volts (V_P)=(V_L)	Phase voltage (LV) Volts (V_p)=(V_l/1.732)

Conclusions: Through this experiment, the principles and characteristics of star-delta connections in three-phase transformer systems are demonstrated. Students gain practical insights into the advantages and applications of each configuration, enhancing their understanding of three-phase power distribution systems. Do the calculations as per the relations given earlier and give the analysis in your own language.

Precautions:

1. Switch on the power supply only in the presence of TAs.
2. Always wear shoes while performing the experiment and entering into the lab.
3. Instruments used should be of proper range.
4. All the connections should be tight.
5. Give the supply through auto transformer only by gradually rotating the knob. Do not operate the autotransformer abruptly and before switching on the supply keep the knob of the autotransformer to zero position.
6. Never touch live conductors or Terminals.

Post Lab Questions:

1. Discuss the differences between star and delta connections in three-phase transformer systems. What are the advantages and disadvantages of each configuration?
2. During the experiment, did you observe any differences in voltage distribution between the star and delta connections? Explain your observations.
3. In practical applications, when would you prefer to use a star connection over a delta connection, and vice versa? Provide examples to support your answer.
4. What safety precautions should be taken when working with three-phase transformer connections? Explain why these precautions are necessary.
5. How does the phase relationship between line and phase voltages differ in star and delta connections? How does this affect the overall performance of the transformer system?