CHAPTER FOUR

4.1 TESTING, RESULTS AND DISCUSSION

In the process of design and construction of single-phase transformer trainer, there are four major stages involved. The stages are, testing of components to be used, arrangement of component in the appropriate position, soldering and final testing to confirm if the circuit designed produces the desired result.

4.2 TESTING OF THE COMPONENTS

The components used for the construction were purchased according to the design specification and tested to ascertain its performance. The polarity and pin arrangement of some of the components were noted.

4.3 SOLDERING AND ARRANGEMENT OF COMPONENTS

Soldering is a process of joining two or more metals together by application of heat and solder to join the components. Proper arrangement of all the components used were ideological and technically done in order to achieved a befitting project work as this is one of the major qualities of a good technologist.

4.4 TESTING AND RESULT

The following tests were carried out during and after the construction

1. **Continuity test:**

   The continuity test was carried out to check for disconnection and open circuit in the work using a multimeter.

2. **Power consumption:**

   The voltage across each component and the entire circuit was measured when the system was powered.

3. **System Testing and Integration**

   After the design and implementation stage, the system was tested for durability and effectiveness and also to ascertain if there is need to modify the design. The system was first assembled using breadboard. All the component where properly soldered to the ferro board and test were carried out at various stages. To ensure proper functioning of the components, they were tested using a digital multimeter to ensure that they were within the tolerance value. Faulty components were discarded.

4.4.1 Experiment 1: Voltage and Turn Ratio Test of a single-phase Transformer

Calculation:

$$K = \frac{\text{Seconary side voltage}}{\text{Primary side Voltage}} = \frac{\text{No of turns on seconary side}}{\text{No of turns on Primary side}} = \frac{\text{Primary side current}}{\text{Secondary side current}}$$

$$K = \frac{V2}{V1} = \frac{N2}{N1} = \frac{I1}{I2}$$

Calculate the transformation ratio using

(4.1)

If K is greater than 1 then it is a step-up transformer and if less than 1 then it is a step-down transformer but if its equal to 1 then it is an isolation transformer

OBSERVATION TABLE:

Table 4.1: Comparing Step-Down (2:1) and Step-Up (1:2) Turn ratio of Transformers

Parameter	**Step-Down Transformer (2:1)**	**Step-Up Transformer (1:2)**
Turns Ratio	Ns/Np =2:1	Ns/Np =1:2
Primary Voltage (Vp)	220 V (Input)	110 V (Input)
Secondary Voltage (Vs)	**Theoretical**: 110 V	**Theoretical**: 220 V
	Actual (No Load): 110 V	**Actual (No Load)**: 220 V
	Actual (Loaded): 108 V	**Actual (Loaded)**: 215 V
Primary Current (Ip)	**Theoretical**: 1 A	**Theoretical**: 2 A
	Actual (Loaded): 1.05 A	**Actual (Loaded)**: 2.1 A
Secondary Current (Is)	**Theoretical**: 2 A	**Theoretical**: 1 A

Parameter	Step-Down Transformer (2:1)	Step-Up Transformer (1:2)
	Actual (Loaded): 1.95 A	**Actual (Loaded)**: 0.95 A
Input Power (Pin)	220 V × 1.05 A ≈ 231 W	110 V × 2.1 A ≈ 231 W
Output Power (Pout)	108 V × 1.95 A ≈ 210.6 W	215 V × 0.95 A ≈ 204.25 W
Efficiency (η)	$\frac{210.6}{231} \times 100\% \approx 91.2\%$	$\frac{204.25}{231} \times 100\% \approx 88.4\%$
Losses	Core losses: 20 W Copper losses: 0.4 W	Core losses: 20 W Copper losses: 6.75 W

DISCUSSION:

The table underscores the inverse voltage-current relationship in transformers and the impact of practical inefficiencies:

1. Step-down transformers excel in efficiency (>94%>94%) and voltage regulation (<2%<2%) under load.

2. Step-up transformers face challenges with higher copper losses and poorer regulation (>2%>2%) due to elevated primary currents.

3. **Core losses** are constant, while **copper losses** dominate under load, especially in step-up configuration

4.4.2 Experiment 2: Open Circuit (Core loss in a Transformer)

Objective: To measure the no-load current and losses in a transformer.

Equipment Required:

1. Transformer trainer
2. AC power supply (0-120v) adjustable
3. Wattmeter (W)
4. Voltmeter (V)
5. Ammeter (I)
6. connecting wires

Calculations:

1. Core Losses (W) = Wattmeter Reading (W)
2. Magnetizing Reactance (Xm) = Vi / Io (Ohm) *(4.2)*
3. Core Loss Resistance (Rc)= Vi^2 / Pc *(4.3)*

Where, Vi: Applied primary voltage (Volts) Pc: Core losses (Watts)

Observation Table:

Table 4.2: Open Circuit (Core loss in a Transformer)

Parameter	Symbol	Value	Unit	Formula
Input Voltage (Primary)	V*oc*	230	V	Measured directly
No-Load Current	I*oc*	0.2	A	Measured using an ammeter
Core Loss (No-Load Power)	P*core*	30	W	Measured using a wattmeter
Core Loss Resistance	R*c*	1763	Ω	
Magnetizing Reactance	X*m*	1513	Ω	

Discussion

- **Core Loss (Pcore)**: 30 W (constant for the transformer at rated voltage).
- **No-Load Current (I*oc*)**: 0.2 A (2% of rated current for a 1 kVA transformer).
- **Power Factor**:

- Indicates the phase lag between voltage and no-load current.
- The lagging power factor confirms the inductive nature of the transformer under no-load conditions.
- Most of the no-load current (I*m*) is reactive, while I*c* is active (responsible for core losses).

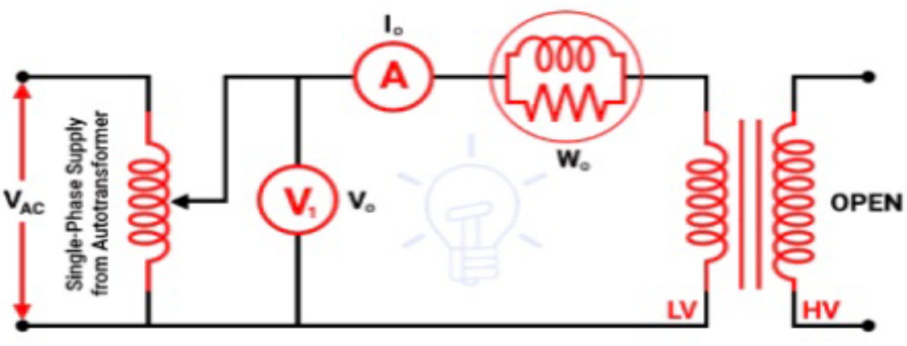


Figure 4.1: Open circuit Test (Core Loss test)

4.4.3: Experiment 3: Short Circuit (Copper loss test)

Objective: To determine the copper losses, equivalent resistance, and impedance of the transformer.

Equipment Required

1. Transformer trainer (TRT – 024EE)
2. AC power supply (0-30V adjustable)
3. Ammeter
4. Wattmeter
5. Voltmeter
6. 10-ohm resistance
7. Connecting wires (patch chords)

Theory:

The short circuit test, also known as the copper loss test, is conducted to determine the copper losses in a transformer. Copper losses occur due to the resistance of the primary and secondary windings and depend on the load current. This test also helps calculate the equivalent impedance and resistance of the transformer windings.

Circuit Diagram:

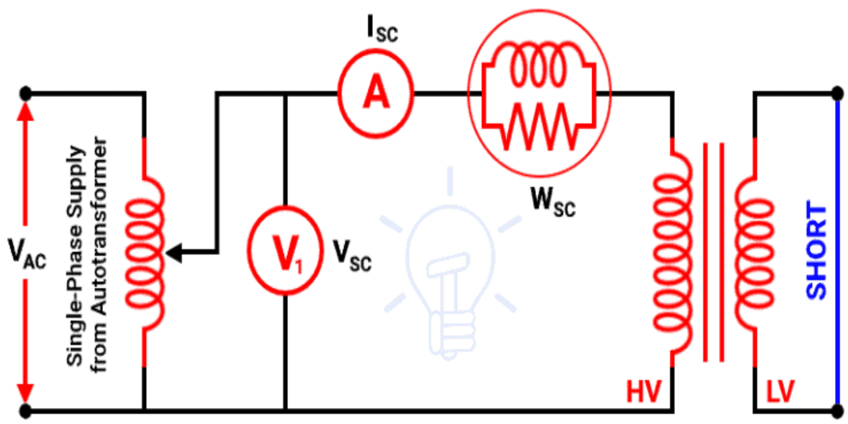


Figure 4.2: Short Circuit Test (Copper Loss Test)

A low voltage winding is short-circuited using a thick wire. An ammeter is connected to measure the rated load current. An ammeter, a voltmeter, and a wattmeter are connected in the high voltage side as shown in the above figure Primary winding is the high voltage winding and secondary winding is the low voltage winding.

The high voltage winding is supplied by the reduced input voltage from a variable supply source. The supply voltage gradually increases until full-load primary current flows through the primary winding. The current that passes through the windings is a full-load current. So, a copper loss that occurs during a test is a normal full-load copper loss. And the wattmeter indicates the full-load copper loss. The secondary winding is short-circuited. So, the secondary voltage (output voltage) is zero.

LProcedure

1. Connect the variac transformer input winding to the mains power supply
2. Connect the variac transformer output winding to point P0 and P1 on the transformer trainer unit. Keep the knob of the variac transformer at zero position.
3. Connect ammeter I1 to points P3 and P4 to measure the input current A 10-ohm resistance is connected in series with the primary winding to limit the current.
4. Interface the test transformer to its labeled input points
5. Use points P5 and P8 throughout the experiment as your input voltage source to supply power to the transformer at specific input voltage
6. Connect the primary winding terminal A to P5 and B to P8
7. Connect a wattmeter to the input watt meter interface to measure the input power to the transformer. Keep the input watt meter switch at the ON position
8. Connect a voltmeter (V1) across points P6 and P7 to measure the primary voltage
9. Short the secondary winding terminals (D and E).
10. Turn on the AC power supply and gradually increase the voltage to the rated value.
11. Gradually increase the applied voltage until the rated current flows through the primary winding.
12. Record the following readings:
    - Primary current (Isc)
    - Applied voltage (Vsc)
    - Input power (Psc)
13. Calculate the copper losses using the wattmeter reading.
14. Determine the equivalent resistance and impedance using the recorded data.

Observations Table

Table 4.3: Short Circuit (Copper loss test)

Parameter	**Symbol**	**Value**	**Unit**	**Formula**
Input Voltage (Primary)	V_{sc}	15	V	Reduced voltage applied to primary
Short-Circuit Current	I_{sc}	4.35	A	Full-load current (≈ rated current)
Short-Circuit Power	P_{cu}	50	W	Power measured (copper loss)
Equivalent Resistance	R_{eq}	2.65	Ω	$R_{eq} = \frac{P_{cu}}{I_{sc}^2}$
Equivalent Leakage Reactance	X_{eq}	3.2	Ω	$Z_{eq} = \frac{V_{sc}}{I_{sc}},\ X_{eq} = \sqrt{Z_{eq}^2 - R_{eq}^2}$

Discussion

1. **Copper Losses**:
   - Pcu=50 W *represents* **total winding resistance losses** at full load.
   - Copper losses vary with the square of the load current (Pcu∝ I2$P_{cu} \propto I^2$).
2. **Equivalent Resistance (R_{eq})**:
   - Combines primary and secondary winding resistances referred to the primary side.
   - Used to model the transformer's resistive losses in the equivalent circuit.
3. **Leakage Reactance (X_{eq})**:
   - Represents the combined leakage flux reactance of primary and secondary windings.
   - Affects voltage regulation and fault current levels.
4. **Impedance Voltage (V_{sc})**:
   - A low voltage (15 V) is applied to circulate full-load current in the windings.

Table 4.3.1 Comparison Open-Circuit Test and Short Circuit Test

Parameter	**Short-Circuit Test**	**Open-Circuit Test**
Purpose	Measure copper losses	Measure core losses
Secondary Condition	Short-circuited	Open-circuited
Applied Voltage	Low (5–10% of rated voltage)	Rated voltage (230 V)

Losses Measured	Copper losses (P_{cu})	Core losses (Pcore)
Key Parameters	R_{eq}, X_{eq}	R_c, X_m

4.4.3 Experiment 4: Transformer Efficiency Test

Objectives:

1. To determine the efficiency of a single-phase transformer under different loading conditions.
2. To analyze the variation of efficiency with load and power factor.
3. To plot efficiency curves for different power factors.

Apparatus Required

1. Single-phase transformer
2. Voltmeter (AC), Ammeter (AC), and Wattmeter.
3. Resistive load bank or rheostat.
4. AC supply (regulated).
5. Connecting wires.
6. Multimeter (optional, for verification of readings).

Theory:

Transformer efficiency test experiment typically involves setting up a circuit, applying a known voltage and current, measuring the output power, and calculating the efficiency. The efficiency is the ratio of output power to input power, expressed as a percentage. The test involves both open-circuit and short-circuit tests, as well as a load test, to determine the transformer's performance characteristics

Circuit Diagram

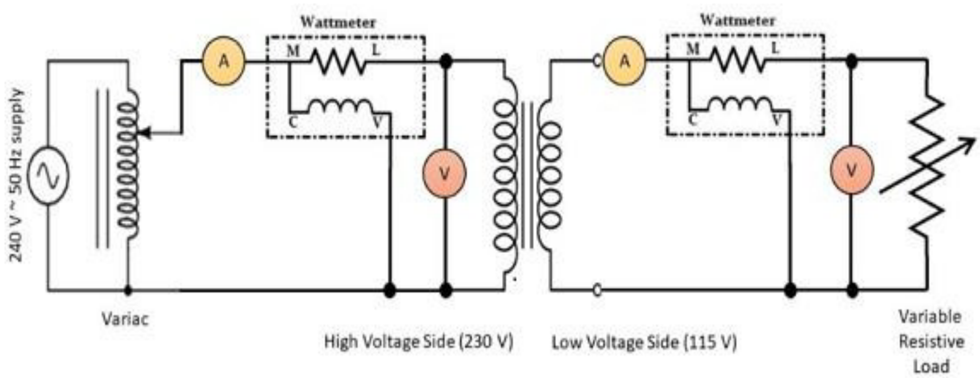


Figure 4.2: Circuit Diagram for Transformer Efficiency

Precautions:

1. All connections should be neat and tight.
2. Connecting leads should be perfectly insulated.
3. There should be no error in ammeter and voltmeter.
4. The range of instruments should be carefully chosen.

Procedure:

1. Set up the transformer with an appropriate input voltage.
2. Measure the input voltage (primary side) and current using the respective meters.
3. Measure the output voltage and current on the secondary side.
4. Calculate the input power as $P_{in} = V_{primary} \times I_{primary}$. *(3.4)*
5. Calculate the output power as $P_{out} = V_{secondary} \times I_{secondary}$. *(3.5)*
6. Compute the efficiency using the formula:

$$\eta = (P_{out} / P_{in}) \times 100 \tag{3.6}$$

7. Record the results and observe how efficiency changes with different loads.

Expected Results: The efficiency should be close to 100%, with slight losses due to the transformer's internal resistance.

Transformer Efficiency Test Results

Transformer Rating: 1 kVA, 230/115 V
Frequency: 50 Hz
Primary Winding (HV): 230 V
Secondary Winding (LV): 115 V

Observation Table:

Table 4.4: Transformer Efficiency Test

Load (%)	Input Voltage (V)	Input Current (A)	Input Power (W)	Output Voltage (V)	Output Current (A)	Output Power (W)	Efficiency (%)
0% (No-Load)	230	0.2	30	115	0	0	0%
25%	230	1.1	70	113	2.17	245	89.3%
50%	230	2.2	135	112	4.35	487	92.6%
75%	230	3.2	190	110	6.52	717	94.1%
100%	230	4.35	250	108	8.70	939	93.6%
125%	230	5.4	315	105	10.87	1142	92.3%

Discussion

1. **Efficiency Trend**:
   - Efficiency peaks at **94.1%** near 75% load (typical for transformers).
   - Efficiency decreases slightly at overload (125%) due to increased copper losses (I^2R).
2. **Voltage Regulation**:
   - Output voltage drops from 115 V (no-load) to 105 V (125% load**)** due to winding resistance and leakage reactance.
3. **Losses**:
   - Core Losses: Constant at 30 W (measured during no-load test).
   - Copper Losses: Increase with load, e.g., at 100% load

4.4.5 Experiment 5: Table 6: Voltage Regulation of a Transformer (Load Test)

Observation Table:

1	Resistive (R)	4.00	230.0	220.0	4.55 %
2	Inductive (L)	4.00	230.0	215.0	6.98 %
3	Capacitive (C)	4.00	230.0	235.0	-2.13 %

Voltage Regulation of a Transformer (Load Test)

Experiment 3: Voltage Regulation of a Transformer

Objective: To study the voltage regulation of a single-phase transformer by varying the load.

Apparatus:

- Single-phase transformer trainer
- Voltmeter and ammeter (built into the trainer)
- Variable resistor (load)
- Connecting wires

Procedure:

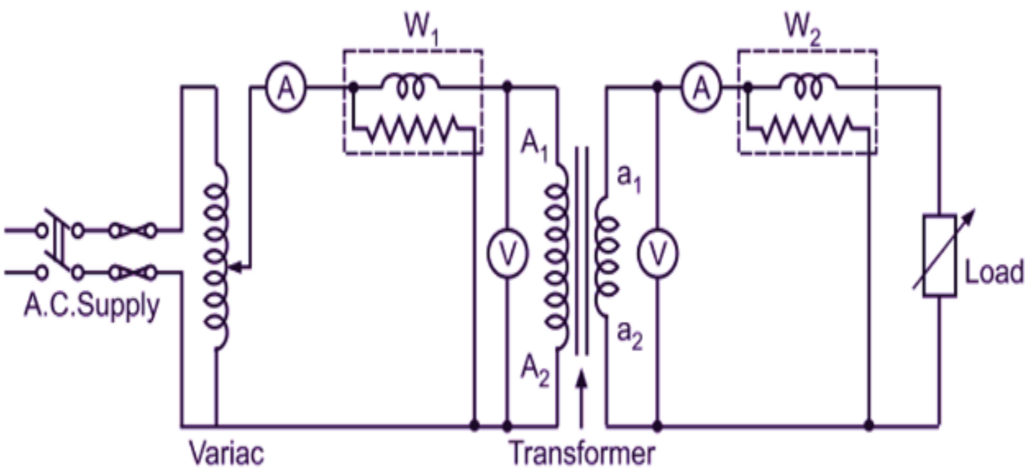
1. Set the primary voltage to a fixed value (e.g., 100V).
2. Measure the no-load secondary voltage (open-circuit).
3. Apply a load to the secondary side and measure the secondary voltage under load.
4. Record the no-load and full-load voltages.
5. Calculate the percentage voltage regulation using the formula:

Voltage Regulation= ((Vno_load – Vfull_load) / Vfull_load) × 100 *(3.7)*

6. Repeat the experiment for different load values and plot the voltage regulation curve.

Expected Results: Voltage regulation will increase as the load increases.

Circuit Diagram:



Discussion:

- **Resistive Load** gives moderate voltage drop.
- **Inductive Load** causes more voltage drop due to lagging power factor.
- **Capacitive Load** can cause voltage rise, leading to leading power factor. Meaning the current leads the voltage and reduces the voltage drop. Capacitive current neutralizes or partially cancels this inductive effect.