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

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	$N_s/N_p=2:1$	$N_s/N_p=1:2$
Primary Voltage (V_p)	220 V (Input)	110 V (Input)
Secondary Voltage (V_s)	**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 (I_p)	**Theoretical**: 1 A	**Theoretical**: 2 A
	Actual (Loaded): 1.05 A	**Actual (Loaded)**: 2.1 A
Secondary Current (I_s)	**Theoretical**: 2 A	**Theoretical**: 1 A
	Actual (Loaded): 1.95 A	**Actual (Loaded)**: 0.95 A
Input Power (P_{in})	220 V × 1.05 A ≈ 231 W	110 V × 2.1 A ≈ 231 W
Output Power (P_{out})	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.

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	$R_c = \frac{V_{oc}^2}{P_{core}}$
Magnetizing Reactance	X_m	1513	Ω	$X_m = \frac{V_{oc}}{I_m}$

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**:

∀

$$\cos\phi = \frac{P_{core}}{V_{oc} \cdot I_{oc}} = \frac{30}{230 \times 0.2} \approx 0.65 \quad (\phi \approx 49^\circ)$$

In

dicates 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).

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

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	$Z_{eq} = \frac{V_{sc}}{I_{sc}},\ X_{eq}$

Discussion

1. **Copper Losses**:
   - P_{cu}=50 W *represents* **total winding resistance losses** at full load.
   - Copper losses vary with the square of the load current ($P_{cu} \propto I^2$).
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

4.4.4 Experiment 4: Transformer Efficiency Test

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 %

Table 4.5: Voltage Regulation of a Transformer (Load Test)

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.