1 Experiment No. 9

2 Experiment Title

Determination of Voltage Regulation of Single-Phase Transformer for different kinds of load.

3 Objective

The objectives of this lab are as follows:

- To determine the voltage regulation of a single-phase transformer under different types of loads.
- To analyze the effects of resistive, inductive, and capacitive loads on the voltage regulation of the transformer.
- To understand the theoretical and practical behavior of voltage regulation for various load conditions.

4 Theory

4.1 Voltage Regulation (V.R)

Voltage Regulation (V.R) is a measure of the change in the secondary voltage of a transformer as the load varies, from no-load (NL) to full-load (FL). It is expressed as a percentage of the full-load voltage.
The Voltage Regulation (V.R) is given by the formula:

$$\text{V.R} = \frac{V_{\text{NL}} - V_{\text{FL}}}{V_{\text{FL}}} \times 100\%$$

Where:

1. V_{NL} is the no-load voltage (the voltage across the secondary when the transformer is not supplying any load),
2. V_{FL} is the full-load voltage (the voltage across the secondary when the transformer is supplying full-load current),
3. V_S is the secondary side voltage, which depends on the load and its nature.

An alternate expression for voltage regulation can be written as:

$$\text{V.R} = \frac{V_{\text{NL}} - V_S}{V_S}$$

Where V_S is the voltage at the secondary side under load conditions.

4.2 Transformer Behavior Under Load Conditions

The behavior of the transformer under different load conditions can be analyzed using the phasor equation:

$$E_2 = V_S + I_S R_S + jI_S X_S$$

Where:

1. E_2: Secondary induced EMF (ideal voltage without losses),
2. V_S: Secondary terminal voltage under load,
3. R_S: Equivalent series resistance of the transformer,
4. X_S: Equivalent series reactance of the transformer,
5. I_S: Load current.

Phasor Diagrams

1. **Capacitive Load:** The current I_S leads the voltage V_S. The phasor diagram shows that this interaction reduces the voltage drop, potentially causing a voltage rise, resulting in a *negative* Voltage Regulation (V.R).
2. **Inductive Load:** The current I_S lags the voltage V_S. The phasor diagram demonstrates significant voltage drops across R_S and X_S, leading to a *positive* Voltage Regulation (V.R).
3. **Resistive Load:** The current I_S is in phase with the voltage V_S. The phasor diagram shows a moderate voltage drop, primarily due to $I_S R_S$.

4.3 Effect of Load Type on Voltage Regulation

Different kinds of loads affect the voltage regulation of the transformer in distinct ways. These loads can be broadly classified as inductive, resistive, and capacitive loads.

1. **Inductive Load:** For an inductive load, the load current (I_S) lags the voltage, creating a lagging power factor. The voltage drop across the load is given by:

$$\text{Voltage Drop} = I_S R_S + I_S X_S$$

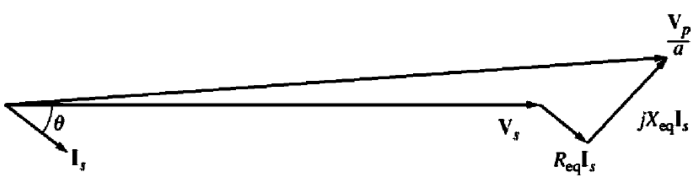

Figure 1: Phasor Diagram for Inductive Load

As I_S increases, the voltage drop increases, causing V_S to decrease, resulting in positive Voltage Regulation.

2. **Resistive Load:** For a resistive load, the load current is in phase with the voltage, and the voltage drop is given by:

$$\text{Voltage Drop} = I_S R_S$$

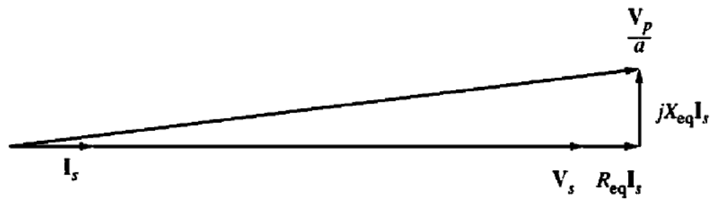

Figure 2: Phasor Diagram for Resistive Load

As I_S increases, the voltage drop increases, causing V_S to decrease. This results in positive Voltage Regulation, but the effect is smaller compared to an inductive load.

3. **Capacitive Load:** For a capacitive load, the current leads the voltage, resulting in a leading power factor. The voltage drop across the load is:

$$\text{Voltage Drop} = I_S R_S - I_S X_C$$

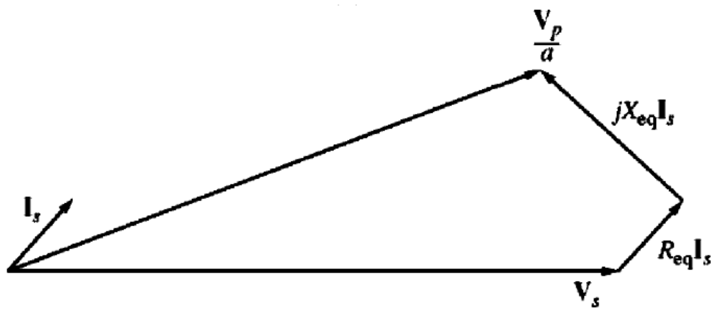

Figure 3: Phasor Diagram for Capacitive Load

As I_S increases, the voltage drop decreases, causing V_S to increase. This results in negative Voltage Regulation.

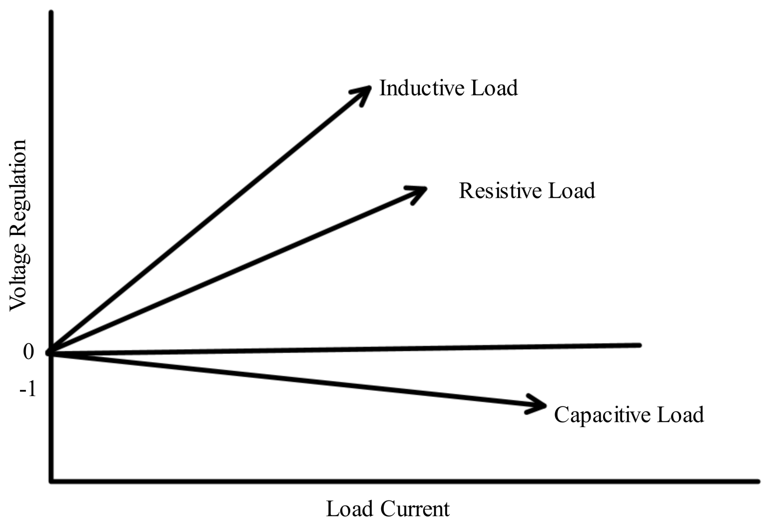

Figure 4: Voltage Regulation vs Load Current

5 Required Apparatus

1. **Transformer**
   (a) Power (P): 760 VA
   (b) Primary Voltage (U_1): 230 V
   (c) Secondary Voltage (U_2): 400 – 230 V
   (d) Frequency (f): 50 Hz
   (e) Primary Current (i_1): 3.7 A
   (f) Secondary Current (i_2): 1 – 1.7 A
2. **Resistive Loads (Mod. RL-1/EV: Ratings: 220-230V(DC)/380-400V(AC), 462W max):**
   (a) Load no. 1: Resistance: 2200 Ω, Current: 0.1 A
   (b) Load no. 2: Resistance: 1100 Ω, Current: 0.2 A
   (c) Load no. 3: Resistance: 550 Ω, Current: 0.4 A
3. **Capacitive Loads (Mod. CL-1/EV: Ratings: 220-230V/380-400V, 50Hz, 462VA max):**
   (a) Load no. 1: Capacitance: 1.4 μF, Current: 0.1 A, Reactance: 2200 Ω
   (b) Load no. 2: Capacitance: 2.9 μF, Current: 0.2 A, Reactance: 1100 Ω
   (c) Load no. 3: Capacitance: 5.8 μF, Current: 0.4 A, Reactance: 550 Ω
4. **Inductive Loads (Mod. IL-1/EV: Ratings: 220-230V/380-400V, 50Hz, 462VA max):**
   (a) Load no. 1: Current: 0.1 A, Reactance: 2200 Ω
   (b) Load no. 2: Current: 0.2 A, Reactance: 1100 Ω
   (c) Load no. 3: Current: 0.4 A, Reactance: 550 Ω
5. **Three Phase AC Meter:**
   (a) Ammeter: Current: 5 A max
   (b) Voltmeter: Voltage: 500 V AC rms max
6. **Three Phase AC Meter Display**
7. **Connecting Wires**

6 Circuit Diagrram

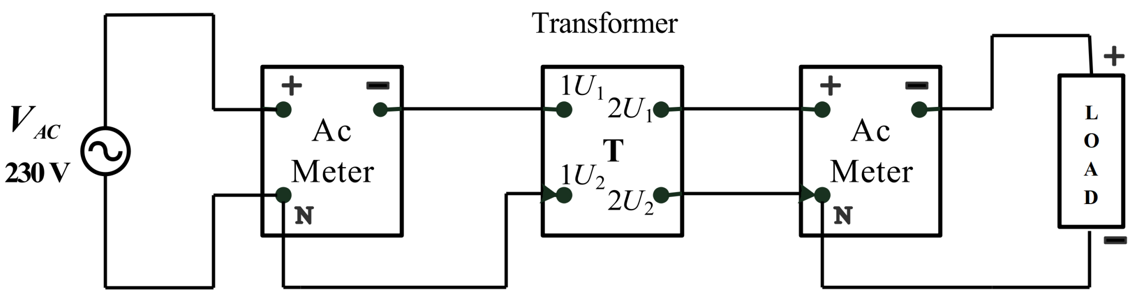

Figure 5: Connection of single phase transformer for different kinds of load.

7 Data Table

Table 1: Voltage Regulations for Inductive Loads

Sl. No.	No Load Voltage $E_2(V)$	Load Current, $I_S(A)$	Full Load Voltage, $V_S(V)$	Voltage Regulation $V_R(\%)$
01.	424.6	0.000	424.6	0
02.	424.6	0.174	419.0	0.28
03.	424.6	0.208	423.7	0.47
04.	424.6	0.69	422.6	0.88
05.	424.6	0.919	417.1	1.34
06.	424.6	1.104	420.9	1.58
07.	424.6	1.373	418.0	1.8
08.	424.6	1.581	416.8	1.87

Table 2: Voltage Regulations for Resistive Loads

Sl. No.	No Load Voltage $E_2(V)$	Load Current, $I_S(A)$	Full Load Voltage, $V_S(V)$	Voltage Regulation $V_R(\%)$
01.	424.6	0.000	424.6	0
02.	424.6	0.188	421.4	0.76
03.	424.6	0.374	417.5	1.94
04.	424.6	0.737	411.3	3.23
05.	424.6	0.857	415.0	3.81
06.	424.6	0.915	408.1	4.04
07.	424.6	1.09	404.5	4.97
08.	424.6	1.26	401.1	5.86

Table 3: Voltage Regulations for Capacitive Loads

Sl. No.	No Load Voltage $E_2(V)$	Load Current, $I_S(A)$	Full Load Voltage, $V_S(V)$	Voltage Regulation $V_R(\%)$
01.	424.6	0.00	423.0	0.00
02.	424.6	0.204	424.0	-0.24
03.	424.6	0.422	424.4	-0.33
04.	424.6	0.619	424.7	-0.40
05.	424.6	0.791	424.8	-0.42
06.	424.6	0.984	424.9	-0.45
07.	424.6	1.195	425.1	-0.49
08.	424.6	1.402	425.3	-0.54

8 Graph

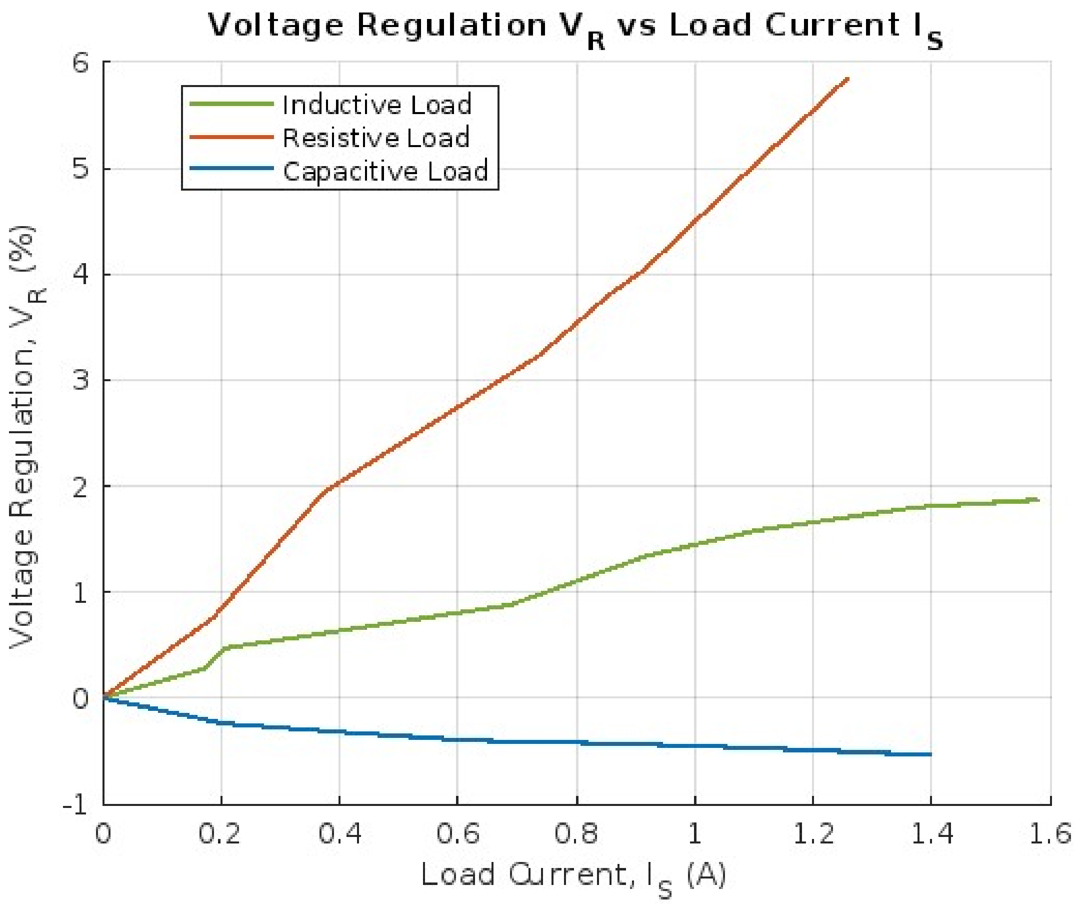

Figure 6: Voltage Regulation V_R vs Load Current I_S

9 Discussion

The experiment was conducted to determine the voltage regulation of a single-phase transformer for different types of loads.

It was demonstrated through the experiment that the voltage regulation of a single-phase transformer was significantly affected by the type of load connected. Theoretically, the voltage regulation for inductive loads should have been greater than for resistive loads. However, positive voltage regulation was observed to be the highest with resistive loads, while moderate voltage regulation was exhibited under inductive loads due to the combined effects of magnitude and phase changes. Negative voltage regulation, indicating a voltage rise, was recorded for capacitive loads. These variations were found to be essential for understanding transformer behavior and ensuring their performance under different load conditions.