ELECTRICAL MACHINES PROJECT REPORT

LAIBA JABBAR 373318
AZLAAN RANJHA 392438
BILAL YOUNAS CHAUDHARY 389110
RANA ABDULLAH AZHAR 398569

Prepared For :

Naeem-uz-Zaman

Title

Design of a Single-Phase Transformer with Multiple Taps for Variable Output Voltages

Abstract

This project outlines the design of a single-phase transformer meeting standard specifications: primary voltage of 12V, secondary voltage of 24V, secondary current of 2A, and an apparent power of 48 VA. As a unique feature, the transformer includes multiple taps for variable output voltages at 8V, 16V, and 24V. The design process involves turn ratio calculations, optimization of core material, and practical considerations. This innovation enhances the transformer's adaptability, catering to diverse applications without external regulation circuits. The research contributes a versatile solution to transformer design, showcasing potential benefits in power distribution networks and electronic devices.

Introduction

This project focuses on designing a single-phase transformer to meet specific electrical requirements. With a primary voltage of 12V, secondary voltage of 24V, secondary current of 2A, and an apparent power of 48 VA, the transformer aims for efficient energy transfer. The innovative addition of multiple taps at 8V, 16V, and 24V introduces adaptability, catering to diverse voltage needs without external regulation circuits.

Objectives

1. Design a transformer with 12V primary and 24V secondary for standard power distribution.
2. Optimize core material for efficiency and minimal losses.
3. Enhance energy transfer efficiency through optimal turns ratio and winding materials.
4. Manage apparent power to meet the 48 VA requirement for diverse applications.
5. Introduce taps for variable output voltages (8V, 16V, 24V) to enhance adaptability.

Equipment Used

Transformer Bobbin:
A transformer bobbin is a crucial component in electronic transformers, designed to efficiently transfer electrical energy between two or more circuits. Typically made of insulating materials like plastic or ferrite, the bobbin provides structural support for the transformer windings. Its design ensures proper winding alignment, insulation, and protection, contributing to the overall performance and reliability of the transformer in power supply applications.

Figure 1:Transformer Bobbin is used so that the winding of the wires is done properly with correct alignment

Iron Laminations Plates:

Transformer iron lamination plates are thin sheets of magnetic material, commonly made of silicon steel or other alloys. These plates serve a critical role in transformers by minimizing energy losses through eddy currents. The lamination design reduces electrical conductivity within the core, improving the overall efficiency of the transformer by concentrating the magnetic flux and mitigating heat generation. These plates are stacked and insulated to form the transformer core, optimizing the magnetic circuit for efficient energy transfer.

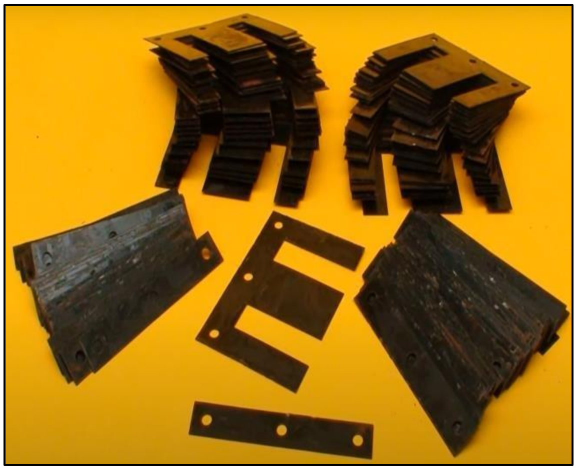

Figure 2: Lamination Core is used to reduce the eddy currents and improve efficiency. Iron Core is being used

Copper Wire:

Transformer copper wires play a vital role in conducting electrical currents within the transformer windings. Known for their excellent conductivity, copper wires efficiently transmit electrical energy while minimizing resistive losses. These wires are carefully wound around the transformer core to create coils, forming the primary and secondary windings. The quality of the copper and precision in winding impact the transformer's overall performance and energy efficiency.

Figure 3: Copper wires are being used for the windings. AWG 17 is being used for the primary coil and AWG 18 for the secondary coil.

Insulation Paper:

Transformer insulation paper is a dielectric material crucial for preventing electrical breakdown between the windings in transformers. Typically made of cellulose or synthetic materials, it provides a barrier that isolates the conductive elements, ensuring a safe and reliable operation. The insulation paper is carefully inserted between the transformer layers, providing thermal stability, mechanical strength, and resistance to moisture, contributing to the insulation and longevity of the transformer.

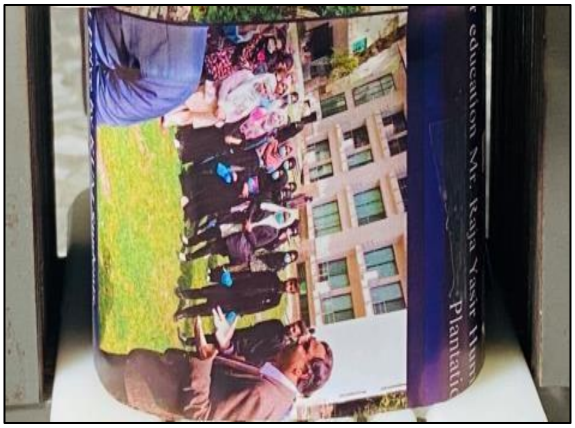

Figure 4: Insulation Paper is used so the coils do not interact or touch each other. This can result in numerous issues such as short circuiting or the circuit heating up which can result in undue and unwanted damages to the transformer windings. Performance would, thus, vary with temperature which we do not want.

Methodology

1. Calculate turns ratio using primary and secondary voltages.
2. Determine primary current using apparent power and primary voltage.
3. Confirm secondary current meets specified 2A requirement.
4. Calculate number of turns for primary and secondary based on turns ratio.
5. Introduce multiple taps (8V, 16V, 24V) by adjusting turns ratio.
6. Select core material for optimal magnetic properties.

Calculations and Formulas

Calculation

frequency : 50Hz

$B_{max} = 1.5\,T$

Area of core $= \dfrac{1}{4.44 \times f \times B_{max} \times T_e}$

1.5 inch in meter = 0.0381 m

$A_{core} = 0.0381 \times 0.0381 = (0.0381)^2$

$= 1.45 \times 10^{-3}\ m^2$

Turns per volt $= T_e = \dfrac{1}{4.44 \times f \times B_{max} \times A_{core}}$

$= 2.071$ Turn per volt

Turns:

Number of turns of primary side for 12V = $T_e V \times V_{primary}$

= 2.071×12

= 24.852

= 25 turns

Number of turns of secondary side for:

8 : $2.071 \times 8 = 16.568 = 17$

16 : $2.071 \times 16 = 33.136 = 33$

24 : $2.071 \times 24 = 49.704 = 50$

length = 1.5 inches = 0.0381m

width = 1.5 inches = 0.0381m

Turns ratio = P / S = 1 : 2

Hysterisis loss = 4.6×10^{-3}

Primary current = 4A

Secondary current = 2A

45 - RULE

$$TPV = \frac{N}{V} = \frac{1}{4.44 \times f \times B_{max} \times CA \times 10^{-4}}$$

$$= \frac{1}{4.44 \times 50 \times 1 \times 10^{-4}} \times \frac{1}{CA}$$

// for $f = 50Hz$ and $B_{max} = 1$

$$= 45 \times \frac{1}{CA}$$

$$TPV = \frac{N}{V} = \frac{45}{CA (m^2)}$$

7- Rule

$$TPV = \frac{N}{V} = \frac{45}{CA(m^2)}$$

m^2 into inches square :

$$45 / 6.452 = 6.97 \approx 7 \text{ inch}^2$$

$$TPV = \frac{N}{V} = \frac{7}{CA(\text{inch}^2)}$$

Hardware

Input Side:

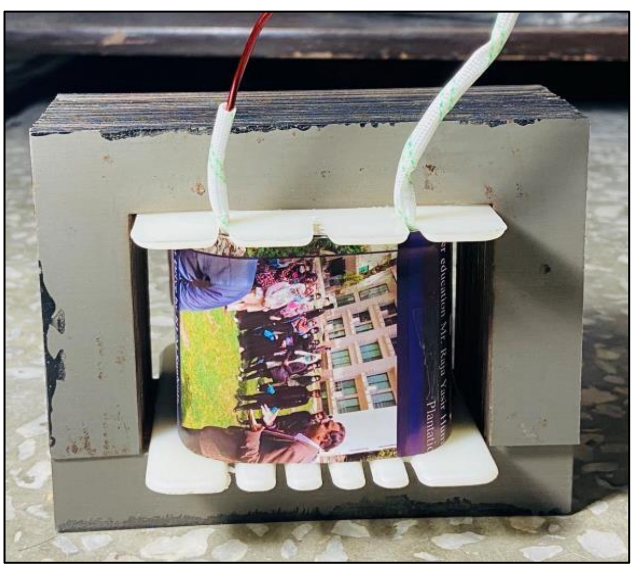

Figure 5: Primary Side of the transformer. Right side is the Neutral Terminal and the left side is the positive terminal.

Output Side:

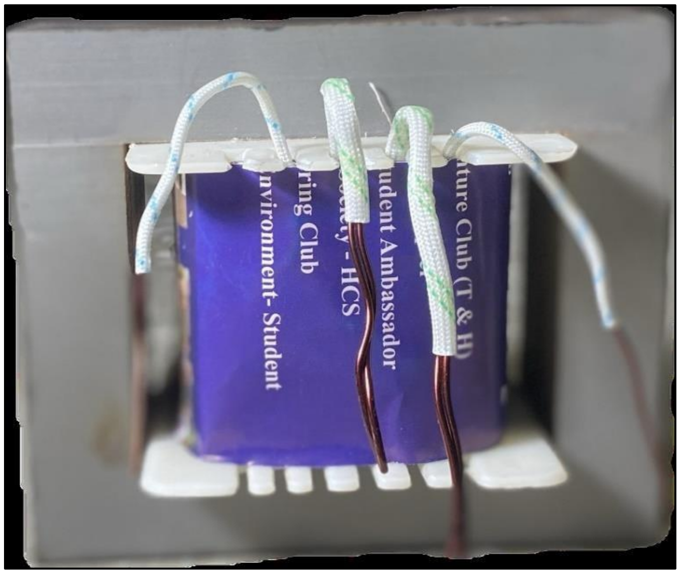

Figure 6: The right-most terminal is the neutral terminal. Then the first right one is 8V, the second left one is 16V and the leftmost one is for 24V output.

Testing of Transformer

OBSERVATIONS & CALCULATIONS	
Wattmeter Reading = W	4.1
Input Primary Voltage = V_1	11.18
No-Load Current = I_0	1.26
No Load Power Factor = $\cos\phi_0 = \frac{W}{V_1 I_0}$	0.290
Magnetizing Current Component = $I_M = I_\mu = I_0 \sin\phi_0$	1.206
Working Current Component $= I_W = I_0 \cos\phi_0$	0.3654
$X_0 = V_1/I_\mu$	9.270
$R_0 = V_1/I_W$	30.597
Exciting Admittance = $Y_0 = I_0/V_1$	0.113
Exciting Conductance = $G_0 = W/V_1^2$	0.0328
Exciting Susceptance = $B_0 = \sqrt{(Y_0^2 - G_0^2)}$	0.108

Table 1: This table has details for the Open Circuit Test of our transformer

OBSERVATIONS & CALCULATIONS	
Wattmeter Reading = W	
Input Primary Voltage = V_{SC}	
Primary Current = I_1	
Impedance of Transformer referred to Primary = $Z_{01} = V_{SC}/I_1$	
Resistance of Transformer referred to Primary = $R_{01} = W/I^2{}_1$	
Reactance of Transformer referred to Primary = $X_{01} = \sqrt{(Z_{01}^2 - R_{01}^2)}$	
Measured value of Resistance of Primary (127V) = R_1	
$R'_{2n} = R_{01} - R_1$	

Table 2: This table has details for the Short Circuit Test of our transformer

Conclusion

In summary, the designed single-phase transformer achieves the specified electrical parameters and introduces a valuable feature with multiple taps at 8V, 16V, and 24V. The calculated turns ratio, optimized core material, and consideration of practical constraints ensure efficiency and feasibility. This transformer not only meets standard specifications but also offers adaptability, making it a versatile solution for modern electrical applications. In summary, the designed single-phase transformer achieves the specified electrical parameters and introduces a valuable feature with multiple taps at 8V, 16V, and 24V. The calculated turns ratio, optimized core material, and consideration of practical constraints ensure efficiency and feasibility. This transformer not only meets standard specifications but also offers adaptability, making it a versatile solution for modern electrical applications.