DESIGN AND CONSTRUCTION OF 2000VA, 230V TO 530V STEP UP TRANSFORMER

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A PROJECT SUBMITTED TO THE DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG)

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ABSTRACT

The project was carried out to design and construct a step up transformer capable of stepping a 230 volts input supply to 530 volts output at 2000 watt. This was effectively achieved by first designing the transformer; taking into consideration the underlying principle of operation of the device, the power rating of the device, the cross sectional area and number of lamination sheets that can provide the flux for the transformer rating. The minimum cross sectional area of the primary windings that can withstand a power of 2000 watts was also determined. This was followed by calculation of the number of windings to give 230 volts input primary voltage and then the transformer ratio formula was used to calculate the number of secondary winding. The design simplified the construction process. It was ensured that the coiling of the windings was uniform to ensure a uniformly distributed magnetic field during mutual induction so as to increase transformer efficiency. Analog meters were incorporated with the transformer during construction to display both primary and secondary voltage values.

DEDICATION

This project is dedicated to all staff of the department of Electrical and Computer Engineering at Federal University of Technology, Minna. For without their constant help and guidance I wouldn't have been able to get through this prestigious institution.

CHAPTER THREE: SYSTEM DESIGN PROCEDURE

CHAPTER FOUR: TEST AND RESULTS

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

CHAPTER ONE

INTRODUCTION

1.1 INTRODUCTION TO PROJECT STUDY

Over the years, electrical energy has taken a remarkable place as a major source of the world's energy. This is due to the fact that there are several transducers for converting it to other forms of energy e.g. the incandescent lamp converts electrical energy to light energy, the electric motor to mechanical energy, the electric]heater to heat energy and the electrolytic cell to chemical energy. Most developed countries provide this source of energy for their citizens by building a high powered plant from either hydro, thermal or nuclear energy. These plants are always designed to produce very high voltage so as to minimize power loss during transmission and distribution. All these have been made possible by a very important device, 'the transformer'.

According to Wikipedia encyclopedia, a transformer is a static device that transfers electrical energy from one circuit to another through inductively coupled conductors called the transformer coils. It works with the principle of electromagnetic induction. The first circuit is called, 'the primary winding' and the second which is the secondary winding.

A transformer could also be defined as a device in which two circuits are coupled by a magnetic field that is linked to both. There is no conductive connection between the circuits, which may be at arbitrary constant potentials. Only changes in one circuit affect the other. The circuits often carry at least approximately sinusoidal currents, and the effect of the transformer is to change the voltages, while transferring power with little loss. Sinusoidal excitation is not necessary, and transformers may handle arbitrary signals, in which the action can be considered as a transformation of impedances. The magnetic field coupling the circuits can be in air, but is usually in a ferromagnetic material, the core, in which the field can be thousands of times greater than it would be in air, making the transformer efficient and small. The transformer is an honorary electrical "machine" in which the flux changes occur by variation in currents with time, instead of by motion. [2]

Most transformers with iron cores can be considered as *ideal* when you use them. An ideal transformer has no losses, an aim that is closely attained in practice, so the energy transfer from the primary circuit to the secondary circuit is perfect. The mutual flux φ is the means of transfer of energy from primary to secondary, and links both windings. In an ideal transformer, this flux requires negligibly small ampere-turns to produce it, so the net ampere-turns, primary plus secondary are about zero. When a current is drawn from the secondary in the positive direction, ampere-turns decrease substantially. This must be matched by an equal increase in primary ampere-turns, which is caused by an increase in the current entering the primary in the positive direction. In this way, the back-emf of the primary (the voltage induced in it by the flux φ) equals the voltage applied to the primary, as it must. However, by designing to rated specifications, consideration is not explicitly given to what materials and sizes are actually available. Core and winding material suppliers offer catalogues of preferred sizes. This reflects the supplier's manufacturing capabilities in extrusion, rolling and forming tools and equipment. It is not economic to offer customers any size and shape they require. It is possible that an engineer, having designed a transformer, may then find the material sizes do not exist. The engineer may then be forced to use available materials. Consequently the performance of the actual transformer built is likely to be different from that of the design calculations. [4]

A transformer can either be a step-up or a step-down depending on whether it is reducing its input voltage or increasing it. In any power network, a number of these transformers are arranged to reduce power loss and cost of equipments. The final transformer used depends on the input requirements of the electronic gadgets used. In a country like Nigeria, 230 volts has been selected as a standard and most gadgets used comply with this standard but a country like United States of America, 110 volts is the output voltage of the power system. There are instances when a device is designed in America with an input specification of 110 volts and then exported to Nigeria likewise a made in Nigeria electronic device can be exported to America. In both cases a step up or step down transformer is required to convert the supply voltage to the input voltage of the devices. This project will focus on the design of a 2KVA 230V/530V step up transformer for correcting a supply voltage of 230V to 530V. [3]

1.2 AIMS AND OBJECTIVES

The primary aim of this project is to design a 2KVA, 230V/530V step up transformer to enable devices with input specifications of 530V to be used in a place with a supply voltage of 230V and to be able to power a complete set of home appliances.

It is also aimed at reducing the cost of designs of such transformers bye carefully designing it taking into considerations all the possible ways to economize the available resources and minimizing waste to the best possible.

1.3 METHODOLOGY

Both windings of the transformer will be copper wound and will be properly insulated. The number of turns of each winding will be calculated taking into consideration the power requirement of the transformer as well as the input and output voltage. The diameters of copper wire for both primary and secondary winding will be calculated to withstand a power rating of 2000 Watt. The area and shape of lamination will also be determined on this basis. After winding the transformer, the input and output voltage outlets will then be connected to an analog meter to indicate the instantaneous values of both input and output voltages.

CHAPTER TWO

LITERATURE REVIEW AND THEORITICAL BACKGROUND

This chapter will present a proper review of relevant literature to this project. The devise in study, 'the transformer' will be clearly discussed. Its principle of operation will be properly explained. The different components that make up the devise will be studied as well as how the different components work in harmony to produce the transformer action.

2.1 HISTORY OF TRANSFORMER

The transformer is a device that resulted from the discovery of electromagnetic induction. The phenomenon of electromagnetic induction was discovered independently by Michael Faraday and Joseph Henry in 1831. However, Faraday was the first to publish the results of his experiments and thus receive credit for the discovery. The relationship between electromotive force (EMF) or "voltage" and magnetic flux was formalized in an equation now referred to as "Faraday's law of induction". The magnitude of the EMF in volts and is the absolute value of the rate of change of magnetic flux ($\Phi_{B)}$ in Weber with time. Faraday's experiments included winding a pair of coils around an iron ring, thus creating the first toroidal closed-core transformer. [5]

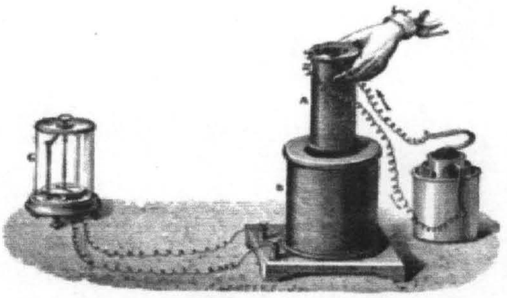


Fig 2.1 Faraday's experiment with induction between coils of wire

The first type of transformer to see wide use was the induction coil, invented by Rev. Nicholas Callan of Maynooth College, Ireland in 1836. He was one of the first researchers to realize that the more turns the secondary winding has in relation to the primary winding, the larger is the increase in EMF. Induction coils evolved from scientists' and inventors' efforts to get higher voltages from batteries. Since batteries produce direct current (DC) rather than alternating current (AC), induction coils relied upon vibrating electrical contacts that regularly interrupted the current in the primary to create the flux changes necessary for induction. Between the 1830s and the 1870s, efforts to build better induction coils, mostly by trial and error, slowly revealed the basic principles of transformers. [7]

In 1876, Russian engineer Pavel Yablochkov invented a lighting system based on a set of induction coils where the primary windings were connected to a source of alternating current and the secondary windings could be connected to several electric candles (arc lamps) of his own design. The coils Yablochkov employed functioned essentially as transformers.

Induction coils with open magnetic circuits are inefficient for transfer of power to loads. Until about 1880, the paradigm for AC power transmission from a high voltage supply to a low voltage load was a series circuit. Open-core transformers with a ratio near 1:1 were connected with their primaries in series to allow use of a high voltage for transmission while presenting a low voltage to the lamps. The inherent flaw in this method was that turning off a single lamp affected the voltage supplied to all others on the same circuit. Many adjustable transformer designs were introduced to compensate for this problematic characteristic of the series circuit, including those employing methods of adjusting the core or bypassing the magnetic flux around part of a coil. [8]

Closed-core lighting transformers

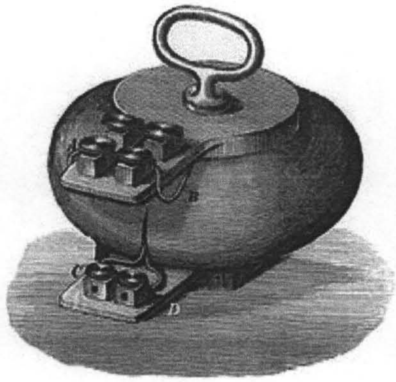


Fig 2.2 A closed-core lighting transformer

Between 1884 and 1885, Ganz Company engineers Károly Zipernowsky, Ottó Bláthy and Miksa Déri had determined that open-core devices were impracticable, as they were incapable of reliably regulating voltage. In their joint patent application for the "Z.B.D." transformers, they described the design of two with no poles: the "closed-core" and the "shell-core" transformers. In the closed-core type, the primary and secondary windings were wound around a closed iron ring; in the shell type, the windings were passed through the iron core. In both designs, the magnetic flux linking the primary and secondary windings traveled almost entirely within the iron core, with no intentional path through air. When employed in electric distribution systems, this revolutionary design concept would finally make it technically and economically feasible to provide electric power for lighting in homes, businesses and public spaces. Bláthy had suggested the use of closed-cores, Zipernowsky the use of shunt connections, and Déri had performed the experiments. Bláthy also discovered the transformer formula, $\frac{V_s}{v_p} = \frac{N_s}{N_p}$ and electrical and electronic systems the world over continue to rely on the principles of the original Z.B.D. transformers. The inventors also popularized the word "transformer" to describe a device for altering the EMF of an electric current, although the term had already been in use by 1882. In 1886, the Ganz Company installed the world's first power station that used AC generators to power a parallel-connected common electrical network, the steam-powered Rome-Cerchi power plant. [5]

2.2 PRINCIPLE OF OPERATION OF THE TRANSFORMER

The operation of the transformer is based on two principles: first, that an electric current can produce a magnetic field (electromagnetism), and, second that a changing magnetic field within a coil of wire induces a voltage across the ends of the coil (electromagnetic induction). Changing the current in the primary coil changes the magnetic flux that is developed. The changing magnetic flux induces a voltage in the secondary coil.

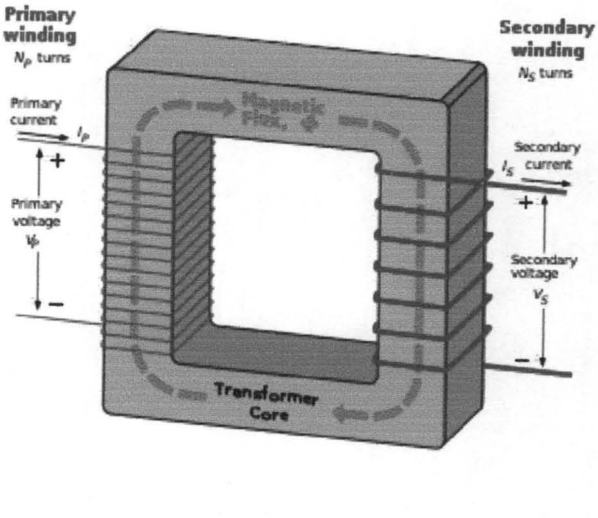


Fig 2.3 An ideal Transformer

In its most basic form a transformer consists of a primary coil winding, secondary winding and a core that supports the coils or windings. This is as shown in figure 2.3.

The primary winding is connected to a 50 hertz ac voltage source. The magnetic field (flux) builds up (expands) and collapses (contracts) about the primary winding. The expanding and contracting magnetic field around the primary winding cuts the secondary winding and induces an alternating voltage into the winding. This voltage causes alternating current to flow through the load. The voltage may be stepped up or down depending on the design of the primary and secondary windings.

The simplified description above neglects several practical factors, in particular the primary current required to establish a magnetic field in the core, and the contribution to the field due to current in the secondary circuit. Such a transformer is called the ideal transformer. Current passing through the primary coil creates a magnetic field. The primary and secondary coils are wrapped around a core of very high magnetic permeability, such as iron, so that most of the magnetic flux passes through both the primary and secondary coils.

Models of an ideal transformer typically assume a core of negligible reluctance with two windings of zero resistance. If a voltage is applied to the primary winding, a small current flows, driving flux around the magnetic circuit of the core. The current required to create the flux is termed the magnetizing current; since the ideal core has been assumed to have near-zero reluctance, the magnetizing current is negligible, although still required to create the magnetic field. The changing magnetic field induces an electromotive force (EMF) across each winding. Since the ideal windings have no impedance, they have no associated voltage drop, and so the voltages V_P and V_S measured at the terminals of the transformer, are equal to the corresponding EMFs. The primary EMF, acting as it does in opposition to the primary voltage, is sometimes termed the "back EMF". This is due to Lenz's law which states that the induction of EMF would always be such that it will oppose development of any such change in magnetic field. [2]

2.3 CLASSIFICATION OF TRANSFORMERS

Since invention of the transformer, there have been several designs for different functions and as such can be classified based on a number of factors. Some of which include:

- By power capacity: from a fraction of a volt-ampere (VA) to over a thousand MVA;
- By frequency range: power-, audio-, or radio frequency;
- By voltage class: from a few volts to hundreds of kilovolts;
- By cooling type: air-cooled, oil-filled, fan-cooled, or water-cooled;
- By application: such as power supply, impedance matching, output voltage and current stabilizer, or circuit isolation;
- By purpose: distribution, rectifier, arc furnace, amplifier output, etc.;
- By winding turns ratio: step-up, step-down, isolating with equal or near-equal ratio, variable, and multiple windings. [1]

2.4 TYPES OF TRANSFORMERS

There are different types of transformers

1. Autotransformer: An autotransformer has a single winding with two end terminals, and one or more terminals at intermediate tap points. The primary voltage is applied across two of the terminals, and the secondary voltage taken from two terminals, almost always having one terminal in common with the primary voltage.
2. Poly-phase transformers: For three-phase supplies, a bank of three individual single-phase transformers can be used, or all three phases can be incorporated as a single three-phase transformer. In this case, the magnetic circuits are connected together, the core thus containing a three-phase flow of flux. A number of winding configurations are possible, giving rise to different attributes and phase shifts. One particular polyphase configuration is the zigzag transformer, used for grounding and in the suppression of harmonic currents.

3. Leakage transformers: A leakage transformer, also called a stray-field transformer, has a significantly higher leakage inductance than other transformers, sometimes increased by a magnetic bypass or shunt in its core between primary and secondary, which is sometimes adjustable with a set screw. This provides a transformer with an inherent current limitation due to the loose coupling between its primary and the secondary windings. The output and input currents are low enough to prevent thermal overload under all load conditions—even if the secondary is shorted. Leakage transformers are used for arc welding and high voltage discharge lamps (neon lamps and cold cathode fluorescent lamps, which are series-connected up to 7.5 kV AC). It acts then both as a voltage transformer and as a magnetic ballast.
4. Resonant transformers: A resonant transformer is a kind of leakage transformer. It uses the leakage inductance of its secondary windings in combination with external capacitors, to create one or more resonant circuits.
5. Audio transformers: Audio transformers are those specifically designed for use in audio circuits. They can be used to block radio frequency interference or the DC component of an audio signal, to split or combine audio signals, or to provide impedance matching between high and low impedance circuits, such as between a high impedance tube (valve) amplifier output and a low impedance loudspeaker, or between a high impedance instrument output and the low impedance input of a mixing console.
6. Instrument transformers: Instrument transformers are used for measuring voltage and current in electrical power systems, and for power system protection and control. Where a voltage or current is too large to be conveniently used by an instrument, it can be scaled down to a standardized, low value. Instrument transformers isolate

measurement, protection and control circuitry from the high currents or voltages present on the circuits being measured or controlled.

7. Current transformer: A Current transformer is a transformer designed to provide a current in its secondary coil proportional to the current flowing in its primary coil.
8. Voltage transformers (VTs): also referred to as "potential transformers" (PTs), are designed to have an accurately known transformation ratio in both magnitude and phase, over a range of measuring circuit impedances. A voltage transformer is intended to present a negligible load to the supply being measured. The low secondary voltage allows protective relay equipment and measuring instruments to be operated at lower voltages. [6]

2.5 ENERGY LOSSES IN A TRANSFORMER

An ideal transformer would have no energy losses, and would be 100% efficient. In practical transformers energy is dissipated in the windings, core, and surrounding structures. Larger transformers are generally more efficient, and those rated for electricity distribution usually perform better than 98%.

Experimental transformers using superconducting windings achieve efficiencies of 99.85%. The increase in efficiency can save considerable energy, and hence money, in a large heavily-loaded transformer; the trade-off is in the additional initial and running cost of the superconducting design.

Losses in transformers (excluding associated circuitry) vary with load current, and may be expressed as "no-load" or "full-load" loss. Winding resistance dominates load losses, whereas hysteresis and eddy currents losses contribute to over 99% of the no-load loss. The no-load loss can be significant, so that even an idle transformer constitutes a drain on the electrical supply and a running cost; designing transformers for lower loss requires a larger core, good-quality silicon steel, or even amorphous steel, for the core, and thicker wire, increasing initial cost, so that there is a trade-off between initial cost and running cost. (Also see energy efficient transformer). [9]

Transformer losses are divided into losses in the windings, termed copper loss, and those in the magnetic circuit, termed iron loss. Losses in the transformer arise from:

(1) Winding resistance

Current flowing through the windings causes resistive heating of the conductors. At higher frequencies, skin effect and proximity effect create additional winding resistance and losses.

(2) Hysteresis losses

Each time the magnetic field is reversed, a small amount of energy is lost due to hysteresis within the core. For a given core material, the loss is proportional to the frequency, and is a function of the peak flux density to which it is subjected.

(3) Eddy currents

Ferromagnetic materials are also good conductors, and a core made from such a material also constitutes a single short-circuited turn throughout its entire length. Eddy currents therefore circulate within the core in a plane normal to the flux, and are responsible for resistive heating of the core material. The eddy current loss is a complex function of the square of supply frequency and Inverse Square of the material thickness. Eddy current losses can be reduced by making the core of a stack of plates electrically insulated from each other, rather than a solid block; all transformers operating at low frequencies use laminated or similar cores.

(4) Magnetostriction

Magnetic flux in a ferromagnetic material, such as the core, causes it to physically expand and contract slightly with each cycle of the magnetic field, an effect known as magnetostriction. This produces the buzzing sound commonly associated with transformers, and can cause losses due to frictional heating.

(5) Mechanical losses

In addition to magnetostriction, the alternating magnetic field causes fluctuating forces between the primary and secondary windings. These incite vibrations within nearby metalwork, adding to the buzzing noise, and consuming a small amount of power.

(6) Stray losses

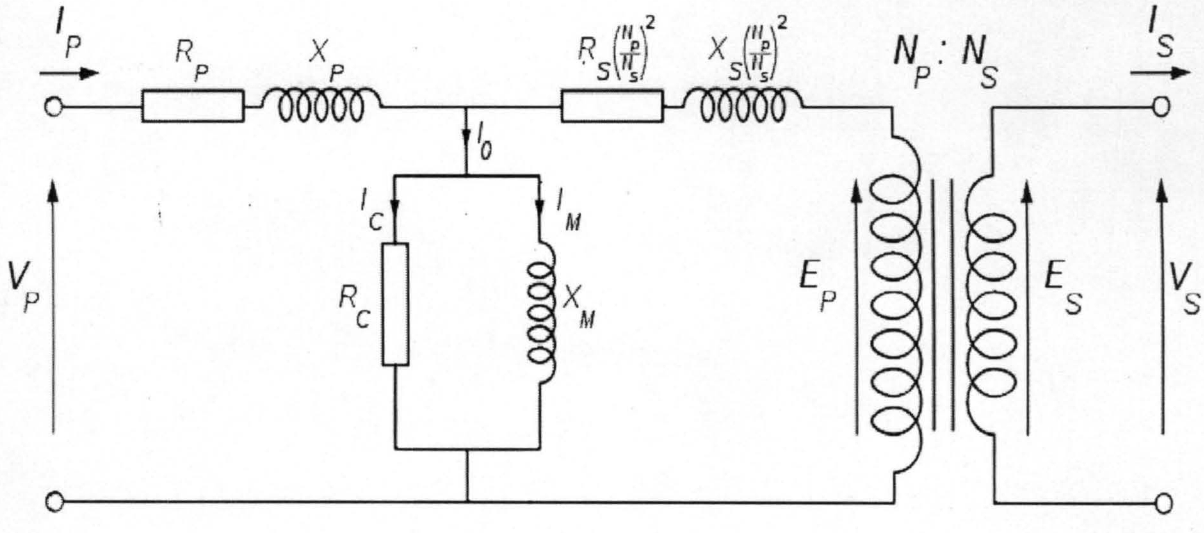
Leakage inductance is by itself largely lossless, since energy supplied to its magnetic fields is returned to the supply with the next half-cycle. However, any leakage flux that intercepts nearby conductive materials such as the transformer's support structure will give rise to eddy currents and be converted to heat. There are also radiative losses due to the oscillating magnetic field, but these are usually small. [5]

2.6 EQUIVALENT CIRCUIT OF A PRACTICAL TRANSFORMER

The physical limitations of the practical transformer may be brought together as an equivalent circuit model (shown below) built around an ideal lossless transformer. Power loss in the windings is current-dependent and is represented as in-series resistances R_p and R_s. Flux leakage results in a fraction of the applied voltage dropped without contributing to the mutual coupling, and thus can be modeled as reactance of each leakage inductance X_p and X_s in series with the perfectly coupled region.

Iron losses are caused mostly by hysteresis and eddy current effects in the core, and are proportional to the square of the core flux for operation at a given frequency. Since the core flux is proportional to the applied voltage, the iron loss can be represented by a resistance R_C in parallel with the ideal transformer.

A core with finite permeability requires a magnetizing current I_m to maintain the mutual flux in the core. The magnetizing current is in phase with the flux; saturation effects cause the relationship between the two to be non-linear, but for simplicity this effect tends to be ignored in most circuit equivalents. With a sinusoidal supply, the core flux lags the induced EMF by 90° and this effect can be modeled as a magnetizing reactance (reactance of an effective inductance) X_m in parallel with the core loss component. R_c and X_m are sometimes together termed the magnetizing branch of the model. If the secondary winding is made open-circuit, the current I_0 taken by the magnetizing branch represents the transformer's no-load current. The secondary impedance R_s and X_s is frequently moved (or "referred") to the primary side after multiplying the components by the impedance scaling factor, $\frac{N_s}{N_p}$.



Transformer equivalent circuit, with secondary impedances referred to the primary side

The resulting model is sometimes termed the "exact equivalent circuit", though it retains a number of approximations, such as an assumption of linearity.[44] Analysis may be simplified by moving the magnetizing branch to the left of the primary impedance, an implicit assumption that the magnetizing current is low, and then summing primary and referred secondary impedances, resulting in so-called equivalent impedance.

The parameters of equivalent circuit of a transformer can be calculated from the results of two transformer tests: open-circuit test and short-circuit test. [3]

CHAPTER THREE

DESIGN

In this chapter, the different steps taken in designing the transformer shall be explained. All assumptions and parameters taken into consideration will also be explained. Basic calculations such as sheet packing, magnetic core thickness, number of laminations, etc will be carried out.

3.1 DESIGN PARAMETERS

Transformer type: Single phase transformer

Rated power (An): 2000VA

Primary voltage (V_{in}): 230V

Secondary voltage (V_{out}): 530V

Frequency: f = 50Hz

Cooling type: Natural convention

Preliminary value of efficiency: $\eta = 0.85$

3.2 CALCULATION OF THE SHEET PACK

Preliminary choice of the values of B and of the packing factors Kg selected on the basis of service type:

For continuous service: B [T]	$0.8 \div 1 = 0.8$
For continuous service: K_S	0.9
For intermittent service: B [T]	$0.9 \div 1.1 = 1.1 = 0.82$
For intermittent service: K_S	0.94

3.3 FLUX CALCULATION

Where $W = 2536x10^3$

$$\text{From } \varphi = W.10^{-2}x\sqrt{\frac{A_n x10^{-3}}{f}} = W\,x10^{-2}\,x\sqrt{\frac{2000x10^{-3}}{50}} = 5072 \text{ wb}$$

3.4 CALCULATION OF CENTRAL COLUMN AREA

Section required by the flux:

$$R_f = \frac{\varphi}{B} = \frac{5072}{0.8} = 6340\text{mm}^2$$

Gross section calculated with packing factor:

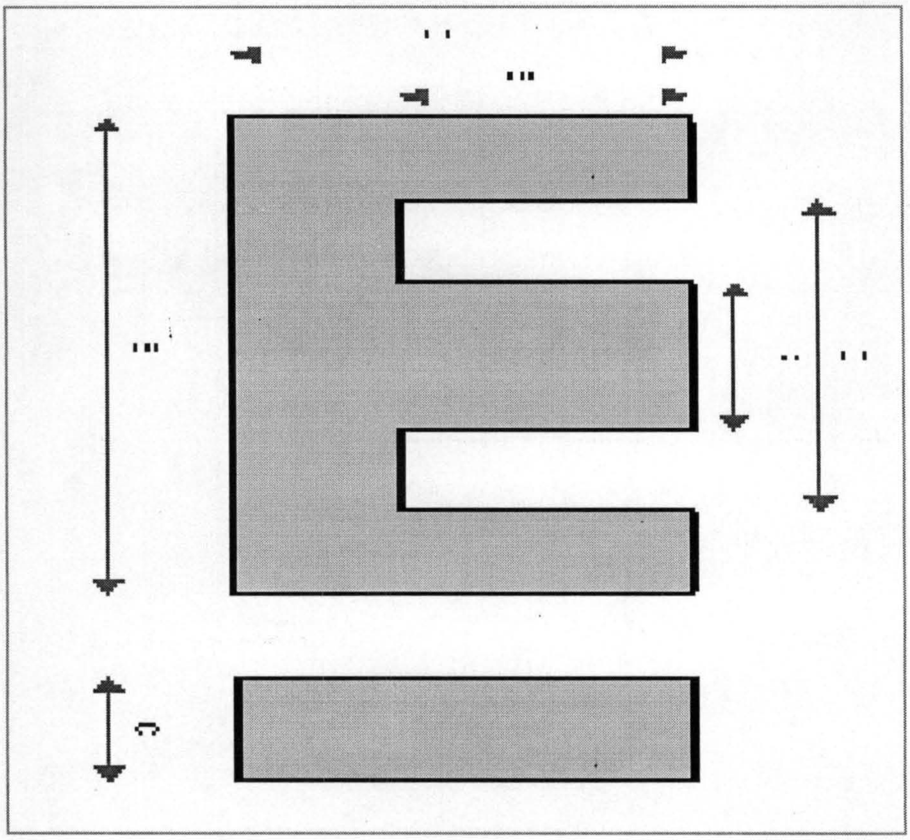
$$Z_c = \frac{R_f}{K_s} = \frac{6340}{0.9} = 7044.44\text{mm}^2$$

Approximate dimension of the column:

$$P = \sqrt[4]{A_n} \quad = \sqrt[4]{2000} = 6.687\text{mm}$$

3.5 CHOICE OF THE TRADE TYPE LAMINATION

We must select an available lamination in the market with dimensions that will provide a minimum number of sheets required to accommodate the produced flux.



- Total width = a = 96mm
- Column width = f = 31mm
- Width d = 64mm
- Column height = e = 48mm
- Side height = b = 64mm

- Lamination thickness, s = 0.5mm

3.6 CALCULATION OF THE MAGNETIC CORE THICKNESS

$$\mathrm{U} = \frac{\mathrm{Zc}}{\mathrm{f}} = \frac{7044.44}{31} = 227.24\mathrm{mm}$$

3.7 CALCULATION OF THE TOTAL NUMBER OF LAMINATION

$$\mathrm{n} = \frac{\mathrm{u}}{\mathrm{s}} = \frac{227.24}{0.5} = 454.48 \approx 455$$

3.8 CALCULATION OF THE CURRENTS IN THE WINDINGS

We fix a preliminary value for the efficiency $\eta = 0.85$

$$\mathrm{I}_1 = \frac{\mathrm{A_n}}{\mathrm{V_{in}x\eta}} = \frac{2000}{230\mathrm{x}0.85} = 10.2\mathrm{A}$$

$$\mathrm{I}_2 = \frac{\mathrm{A_n}}{\mathrm{V_{2n}x\eta}} = \frac{2000}{530\mathrm{x}0.85} = 4.44\mathrm{A}$$

3.9 CALCULATION OF THE CONDUCTOR SECTIONS AND OF THE RELATIVE DIAMETERS

We fix a value of the current density in conductors

J = 3.5 A/mm^2

$$\mathrm{S_{cu}} = \frac{\mathrm{I_n}}{\mathrm{J}}$$

Where $\mathrm{S_{cu}}$ is the cross sectional area of conductors and $\mathrm{I_n}$ is the current flowing through the conductor.

(1) Copper size for primary side:

$S_{cu1} = \frac{10.2}{3.5} = 2.91mm^2$

(2) Copper size of secondary side:

$S_{cu2} = \frac{4.44}{3.5} = 1.27mm^2$

(3) Copper diameter for primary winding:

$$d_{c1} = \sqrt{\frac{4xS_{cu1}}{\pi}} = \sqrt{\frac{4x2.91}{\pi}} = 1.925mm$$

(4) Copper diameter for secondary winding

$$d_{c2} = \sqrt{\frac{4xS_{cu2}}{\pi}} = \sqrt{\frac{4x1.27}{\pi}} = 1.270mm$$

3.10 DETERMINATION OF THE PRIMARY AND SECONDARY TURN NUMBER

Voltage per turn:

Let K be the design constant ranging from 0.37 to 0.45. Our assumed value of K is 0.44

And Q is a value in hundreds chosen depending on the power rating of this transformer (2000VA).

K= 0.44 and Q= 20

The volt per turn at the primary winding of the transformer is given by:

e = volt per turn = K x $\sqrt{Q}$

= 0.44 x $\sqrt{20}$

= 1.968 v/turn

Thus the numbers of turns are given by:

(1) Primary number of turns:

Since 1.968volt exit in 1 (one) turn, then

$230 \div 1.968 = 116.87 \approx 117$ Turns of primary winding

(2) Secondary number turns:

From $E_2/E_1 = N_2/N_1$

Where E_2 is secondary voltage

E_1 is primary voltage

N_2 is secondary number of turns

N_1 is primary number of turns

$N_2 = (530 \times 117)/230$

= 270 turns

CHAPTER FOUR

TEST AND RESULT

In this chapter, the entire procedure followed in testing the designed and constructed device were discussed. The results obtained from these tests were also presented.

4.1 STEPS TAKEN TO TEST FOR RESULT

(1) The transformer's primary and secondary windings were insulated from each other and as such a test was carried out to ensure that they were properly insulated

(2) The basic parameters of the transformer were then measured and recorded. They were also compared with the real life values to determine the accuracy of design.

(3) The transformer was then used to power a heating element and the values of each of the parameters observed for any discrepancies and also determine power efficiency.

4.2 TEST FOR OPEN AND SHORT CIRCUIT

On completing the construction, the primary and secondary windings were tested by use of a digital multi-meter for an open circuit. This was accomplished by setting the meter to measure resistance and the resistances of both windings taken and shown on table 4.1.

WINDING TYPE	RESISTANCE (Ω)
PRIMARY WINDING	890
SECONDARY WINDING	512

Table 4.1 Resistances of primary and secondary windings

The results shown above clearly indicate that there is no open circuit in any of the windings as their resistances are not infinite.

A short circuit occurs when there is a bridge between the primary and secondary windings of the transformer. This was prevented by use of a masking tape to completely isolate them. It was tested for by use of the continuity tester of a digital meter and there was no continuity between any of the primary and or the secondary windings.

4.3 TEST FOR PRIMARY AND SECONDARY VOLTAGE VALUES

After constructing the device, analog meters were provided to measure the primary input voltage and secondary output voltage. These meters were used to determine the corresponding output voltages at different values of primary voltages and at each instance the voltage ratio was calculated and compared to the desired turn ratio so as to determine the efficiency of designed techniques. The results are as shown on table 4.2.Figure 4.1illustrate the results as read on the analog meters.

PRIMARY VOLTAGE VALUE (v)	SECONDARY VOLTAGE VALUE (v)	VOLTAGE RATIO
180	409	2.27
140	315	2.25
230	524	2.28

Table 4.2 Summary of input and output voltages

The results of the table clearly show that the device transforms the primary voltage accurately.

4.4 TESTS FOR TRANSFORMER EFFICIENCY

The transformer was used to power a heating element with a range of resistance: $R = \frac{V^2}{P} = \frac{530^2}{2000} = 140.5$

A 150Ω heating element was used and a digital meter connected in series with the input and output terminals to measure their current.

The input power is thus given as: $P_{in} = IV = 230v \times 9.13 \ = 2099W$

The output power is also given as: $P_{out} = IV = 530v \times 3.70A = 1961W$

Thus the efficiency of the transformer which is given as

e= $\frac{P_{out}}{P_{in}} \times 100 = \frac{1961}{2099} \times 100 = 93.4\%$

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

In this chapter, conclusions reached from the results obtained were stated alongside appropriate recommendations.

5.1 CONCLUSION

From the results obtained, it is clear that a transformer of any capacity and voltage ratio can be constructed by calculating the diameters of primary and secondary conductors, the number of turns on each winding, the dimension of lamination sheets as well as the number of such sheets required. This has promoted trade of electronics between different countries as a transformer can easily be provided to match the voltage requirements of both countries. It has also enabled power to be transmitted at a very high efficiency by allowing transmission at a very high voltage and low current thereby reducing the diameters of cables required and minimizing heat loss due to current.

5.2 RECOMMENDATION

For better design and construction of transformers in the future, the following are recommended:

(1) Better cooling methods such as the use of cooling oil should be adopted as it will increase the durability of the transformer.

(2) An ammeter should be connected to both input and output to measure power consumed by load as well as by the transformer.

(3) A protective device should be incorporated with the transformer to prevent overload of transformer as well as short circuit fault from damaging the windings of the transformer

REFERENCES

[1] B.L Theraja and A.K Theraja, "A TEXTBOOK OF ELECTRICAL TECHNOLOGY". S CHAND LTD, pp 865-886

[2] Daniels, A.R. (1985), "INTRODUCTION TO ELECTRICAL MACHINES. MACMILLAN". ISBN 0-333-19627-9

[3] Flanagan, William (1993), "HANDBOOK OF TRANSFORMER DESIGN AND APPLICATIONS". McGraw-Hill. ISBN 0-0702-1291-0.

[4] Gottlieb, Irving (1998)," PRACTICAL TRANSFORMER HANDBOOK. ELSEVIER". ISBN 0-7506-3992-X.

[5] Hammond, John Winthrop. Men and Volts, the Story of General Electric, published 1941 by J.B.Lippincott, pp 106-107

[5] Harlow, James (2004). ELECTRIC POWER TRANSFORMER ENGINEERING. CRC Press. ISBN 0-8493-1704-5.

[6] Hindmarsh, John (1977). ELECTRICAL MACHINES AND THEIR APPLICATIONS, 4th edition. Exeter: Pergammon. ISBN 0-08-030573-3.

[7] Pansini, Anthony (1999). ELECTRICAL TRANSFORMERS AND POWER EQUIPMENT. CRC Press. p. 23. ISBN 0-8817-3311-3.

[8] Ryan, H.M. (2004). HIGH VOLTAGE ENGINEERING AND TESTING. CRC Press. ISBN 0-8529-6775-6.

[9] Say, M.G. (1983). ALTERNATING CURRENT MACHINES, fifth edition. London: Pitman. ISBN 0-273-01969-4.