THE DESIGN AND CONSTRUCTION OF A 500WATTS, 230/2000/3000V MULTI-TAPED TRANSFORMER.

BY

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NOVEMBER, 2008

DECLARATION

I **AUDU ABDULKADIR**, hereby declare that this dissertation is an original work wholly done by me, under the supervision of **PROF. ORIA USIFO** and as not been submitted before anywhere for the purpose of awarding degree or diploma to the best of my knowledge.

Nov, 2008

Audu Abdulkadir | **Date**

CERTIFICATION

This is to certify that this project work was carried out by **AUDU ABDULKADIR** of matric number **2003/15278EE** of the department of Electrical and computer engineering in Federal University of Technology, Minna.

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H.O.D

Date

External examiner

Date

DEDICATION

This work is dedicated to:

Almighty Allah............................ The giver of knowledge and everything

My lovely Father Mohammed Audu,

My lovely Mother Medinat Mohammed

And

My amiable supervisor Prof. O. Usifo

ACKNOWLEDGMENT

I wish to express my profound gratitude to Almighty Allah for seeing me through this phase of my life. Without him life would have been misery. To my project supervisor, **Prof. O.Usifo**, May Almighty Allah bless and reward you for your guidance and constructive criticism geared towards the success of this project work. **Dr. Y.N. Adediran,** H.O.D Electrical/Computer Engineering, May Almighty Allah increases you in blessings.

My sincere thanks and gratitude to my lovely parents **Mr. and Mrs. Mohammed Audu** for bringing me into this world and nursing me through every stage, My siblings **Lawal, Usman, Aliyu, Hamza** and **Maryam** (First lady), you all will forever remain precious to my heart and may almighty Allah continues to guide and protect you all. **Mr. Peter Butt**, thanks for all the supports rendered. **Anty Bibi** thanks for all your contributions.

The family of **Mr. and Mrs. Elias Odoh**, I'm saying **AYAN!** May almighty Allah continue to bless and reward your kind deeds. The entire lecturers and technicians of the prestigious department of Electrical and Computer Engineering, other lecturers of various departments who in one time or the other impacted knowledge in me, May Almighty Allah continue to grant you all strength and sustenance. **HRH Engr.M.U Zauro**, May all mighty Allah continues to grant you favors.

To my friends: **Pro.Andrew odoh** (Brother! Words can't express's my fillings), **Cletus Attah** (My brother! you know the story), **Engr.Joe Adejo** (you're evergreen in my memory), **Fatima** (So nice knowing you), **My study mates Bendini and Benor** (Multiplexer), Mcvincent, Senator Fred, Joe Melvin, Sunny Finian, Victoria Madaki (you left too sudden), Georgy, Mr. Precious .A., Mr. Taufeek Gbenga Ibrahim, Al-banny, Willy, Bala B, Dan Amama, Saint and to all (not mentioned) who played an important role in my life, May your kind deeds be rewarded by Almighty Allah (Ameen).

ABSTRACT

The project involved the design and construction of a 500Watts multi-tapped power transformer, in which a 230V is transformed into higher voltages of 2000V and 3000V simultaneously. The voltage transformation was achieved with the use of a steel core, copper conductor and paper insulation.

The work involves two stages via design and construction. In the design stage, the volt per turn, Area of the core, Number of turn and cross sectional area of the winding were all derived. At the construction stage, great care was taken to ensure proper and accurate windings on the core limb. The laminated core was properly clamped with bolt and nuts to avoid vibration.

The transformer was tested with good performance. The cost of production was ₦10,920.00 which makes it cheap compare to the service it will rendered

LIST OF ABBREVATION

N_p = Primary winding

S_p = Secondary winding

emf = Electro magnetic force

B_m = Maximum Flux density

E_p = Primary voltage

E_s = Secondary Voltage

E_t =Volt per turn

A_i =Area of core

K_w =window space factor

L_{mc} =Length of main rectangular core

B_{mc} =Width of main rectangular core

ð =Current density

h_w =Window height

b_w =Window width

h_c =Core height

A_y =Yoke area

B_y =Yoke breath

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CHAPTER ONE

1.0 INTRODUCTION

1.1 GENERAL INTRODUCTION

Electrical energy is generated at places where water head, oil, gas and steam are easily accessible for hydro power station and thermal power stations. The energy generated need to be transmitted and distributed at considerable distances for domestic, commercial and industrial purposes in villages, towns and cities. Transmissions of electric energy are required for stepping-up of voltages at point of generation and stepping-down of voltage at point where it is to be used. An electric machine used for this purpose is called a **TRANSFORMER.**

A transformer could be defined as an electromechanical device that transfers electric power from one circuit to another circuit of same frequency purely by magnetic coupling. [3] Transformer operates on the principle of electromagnetic induction and it uses an input source voltage that varies in amplitude. Transformer is a honounary machine in which the flux changes occur by variation in current and not by motion. Owing to the lack of rotating part, there is no friction or winding losses which calls for it high efficiency. Transformers are rugged machines; they require a minimal amount of maintenance and repair [6].

Modern transformers differ considerably from early model, but their operating principle is same. Transformers used in power system ranges in size from small units which are attached to top of distribution poles to unit as large as a small house weighing hundreds of tons. There are myriad of transformers used in the electronic industry, varying in sizes from unit weighing a few pound and used to convert outlet voltage to lower values required by transistorized circuitry to micro-transformers which are deposited directly into silicon substrates via lithographic techniques.

In today's modern society, it would be difficult to imagine this world without the ready access of electricity of transformers plays a critical role.

1.2 INVENTION HISTORY

The success of the transformer is reflected in how ubiquitous and transparent the technology has become in many modern electrical devices. The advent of the transformer revolutionalized the electrical industry [11]. It simplicity, reliability and economy of conversion of voltages by transformers were the principle factor in the selection of alternating current power transmission. The advent of AC power system and transformers occurred about same time.

Those credited with the invention of transformer include;

MICHAEL FARADAY, he invented an induction ring on August 29, 1831. This was the first transformer, but Faraday used it only to demonstrate the principle of electromagnetic induction and did not foresee the use to which it would be eventually be put.

LUCIEN GUALARD AND JOHN DIXIN GIBBS, They first exhibited a device called a secondary generator in London 1881 and then sold the idea to an American company, Westinghouse. They also exhibit the invention in Turin 1884, where it was adopted for an electric lighting system. The former device used a linear iron core which was later abandoned in favor of a more efficient circular core.

OTTO BLATHY, MISKA DERI, AND KAROLY ZIPERNOWSKY, All Hungarian engineers at the Ganz Company in Budapest. They created the efficient ZBD model in 1885, based on Gaulard and Gibbs design.

WILLIAMS STANLEY, An engineer for Westinghouse built the first practical transformer in 1885, after modifying the idea of Gualard and Gibbs. He connected the core in parallel in an enclosed magnetic circuit made from interlocking E-shape iron plates. The design was first used commercially on march 20, 1886.

NIKOLA TESLA, He invented the tesla coil in 1891, which was a high-voltage, air core dual tunned resonant transformer for generating very high voltage at high frequency.

VAN DE GRAAFF, in 1951 invented an insulated core transformer which generates high voltage direct current using magnetic flux.

1.3 AIMS AND OBJECTIVES

- ✓ To design and construct a transformer that could be used for Testing High Voltage devices.
- ✓ To show the procedures involves in designing and constructing a transformer
- ✓ To construct a transformer that is economical and efficient
- ✓ To construct a transformer that output multiple voltages for the optimum use of supply voltage.
- ✓ To construct a transformer that could be used to confirm the high voltage technology of semi-conductor diodes and Field Effect Transistor.
- ✓ To construct a transformer that could supply high voltage in High Fidelity (Hi-fi) loudspeaker and RF amplifier.

1.4 METHODOLOGY

Review of related literatures via internet, textbooks, journals, and technical reports. Application of the universal EMF equation, which stands as the basic equation for the design of any kind of transformer, substituting the most suitable values of constants. Using the best available and necessary materials for the construction. Testing for the duty type, cooling method and installation type.

NEED FOR THE STUDY

1.5 NEED FOR THE STUDY

The pioneer aspiration of every nation is to improve and sustain her economic growth, social development and environmental protection. These are rarely achieved without the readily access of electricity, of which transformer plays an important role. Nigeria economy has been suffering from hug setback, mostly due to lack of power. This does not only lie on generation but also at the transmission and distribution point.

Transformers are been used to improve the availability and quality of electricity. It is practically visible to see an electrical device be it small, medium or large that does not require the service of a transformer.

CHAPTER TWO

2. O LITERATURE REVIEW

2.1 DEFINITION OF A TRANSFORMER

A transformer is an electromechanical device that transfers electric energy from one circuit to another purely by magnetic coupling. The energy is always transferred without a change in frequency, but involves changes in magnitude of voltage and current.

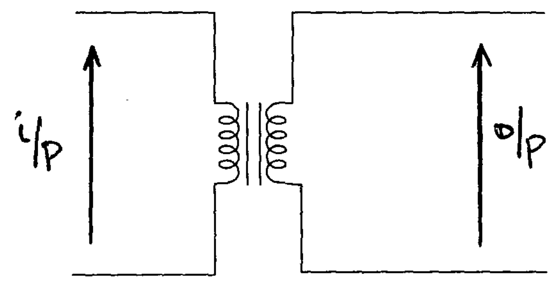

Fig 2.0 Circuit of a transformer

2.2 COMPONENTS OF A TRANSFORMER

Any set of coils of copper or aluminum conductor wounded around a core which are magnetically coupled may be made to function as a transformer.

The principal parts of a transformer include:

Core

Windings

Shielding

Terminals

Insulation

Coolant

Although, larger transformers has components, that makes them more efficient and effective. They include; oil tank, breather, oil gauge, bushings etc. Further explanation will be narrowed to only the principal parts.

2.2.1 CORE

This provides a path for the magnetic line of flux. It also gives support to the coils or windings. The core is made from different materials depending on it application [9].

2.2.1.1 STEEL CORE

They are mainly used in both small and large transformers. A typically laminated steel core is made from E-shaped and I-shaped pieces, leading to the name 'EI transformer'. It major problem is that it retain a static magnetic field when power is removed and when reapplied the residual field may cause the core to temporarily saturate.

2.2.1.2 SOLID CORE

They are also called iron-core. They are used when source frequency is below 20 kHz. Soft iron-core is employed when the transformer is small yet efficient.

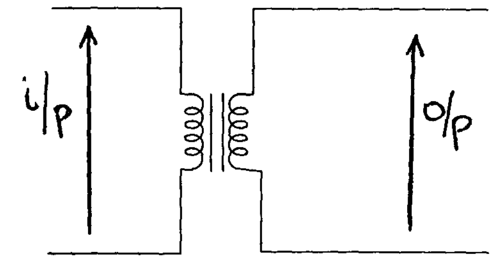

Fig 2.1 Solid core in a transformer

2.2.1.3 AIR CORE

They are used when the transformer is of high frequency. It eliminates the loss due to hysteris in the core material. Such transformer maintains high frequency efficiency by overlapping the primary and secondary windings.

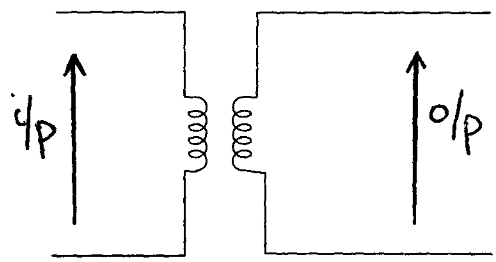

Fig 2.3 Air core in a transformer

2.2.1.4 TOROIDAL CORE

It is used when the transformer frequency is in the range of 20-60 kHz. It is normally built around a ring shape core which is made from long strip of neither silicon steel nor perm-alloy wound into a coil.

2.2.2. WINDINGS

These are wounds of conductors (wires) round the core that produces the magnetic flux. The winding material depends on it application. Small power and signal transformers are wound with insulated solid copper wire. Large power transformers may be wound with copper or aluminum conductor for heavy current. High frequency transformer operating in 100 kHz will have windings made of litz wire to minimize the skin effect losses in the conductor.

The various types of windings include;

2.2.2.1 CYLINDRICAL WINDING

These windings are layered type and uses either rectangular (strip) or circular conductors. Cylindrical windings using round (circular) conductors are mainly employed for high voltage windings with voltages of 6.6, 11 and 33KV for rating up to 600-1000KVA, whereas those using rectangular conductors are mainly employed for low voltage winding up to 6.6KV for rating of range 600-750KVA.

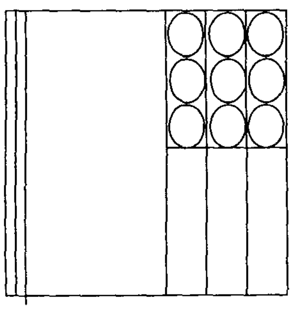

Fig 2.4a Diagram of a rectangular conductor

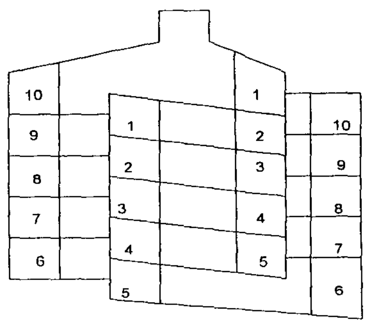

Fig 2.4b Diagram of a circular conductor

2.2.2.2 CROSS-OVER WINDINGS

They are suitable for current not exceeding 20Amps. They are employed for high voltage winding in low rating transformers, where the number of turns may be large but conductors are of small circular section with double cotton covering or paper.

2.2.2.3 HELICAL WINDINGS

They are employed for low coils of medium and high capacity transformer, where the number of coil turns is small but the current is high (as high as 2000amps). They consist of row of parallel rectangular conductors arranged in one radial direction of the winding flat wise and close to each other.

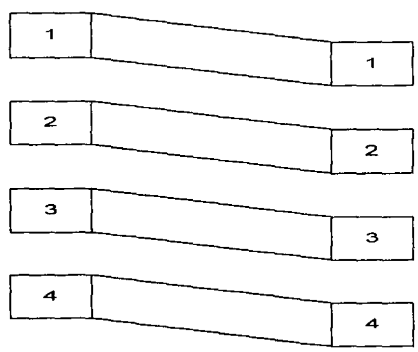

Fig 2.5 Diagram of a helical winding

2.2.2.4 CONTI NOUS DISC WINDINGS

They are used in most modern transformers. It consists of a number of flat coils or disc connected in series or parallel. The coils are formed with rectangular strips wound spirally from centre outward in the radial direction. They are reliable and strong. They are widely employed both as low voltage and high voltage windings in large rating transformer.

2.2.2.5 SANDWICH WINDING

They are common in shell type transformers and allow easy control over leakage reactance. Leakage reactance can be reduce by subdividing the low and high windings into a large number of sections or coils and arranging alternately the high voltage and low voltage sections with the low voltage section nearer to the yoke.

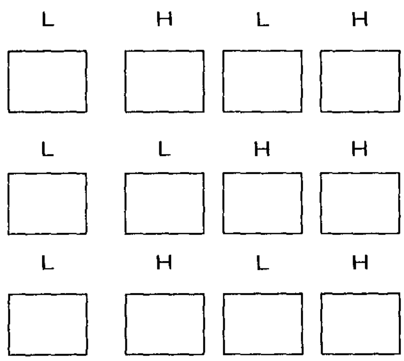

Fig 2.6 Diagram of sandwich windings

2.2.3 TERMINALS

These are inputs and outputs connection point. For very small transformers, the wire leads are directly connected to the end of the coils and brought out to the base of the unit of the circuit connection. Larger transformers, uses heavy bolted terminals, bus bar or high voltage insulated bushing made of polymers or porcelain are used.

2.2.4 INSULATION

The conductor material needs insulation to ensure that the current travels around the core and not through a turn-to-turn short circuit. For small transformers, cotton or paper are often used.

2.2.5 SHIELDING

This serves as a protective device to the transformer from dirt, moisture and mechanical damages. Due to the close proximity of the primary windings, mutual capacitance can be created between the winding. An electrostatic shield can be placed between the circuits for high electrical insulation so as to minimize the effect. It also serves as a cooling system.

2.2.6 COOLANT

This is a medium by which excess heat generated in the core or windings are removed from the transformer. Transformer cooling method depends on it application and the condition at the site of installation. The two major type of cooling methods are

- Dry type cooling
- Oil type cooling

2.3 THEORY OF OPERATION

The physical basis of the transformer is the mutual induction between two or more circuit linked by one common magnetic field. A transformer is sometimes required to pass energy from one circuit to another via a medium of pulsating magnetic field as efficiently and economically possible. The operation is based on Faraday law of electromagnetic induction which states that "An induced emf in any closed circuit is equal to the time rate of change of the magnetic flux through the circuit". That is;

$$E = -N\frac{d\Phi_B}{dt} \qquad (2.1)$$

Consider the simple circuit below

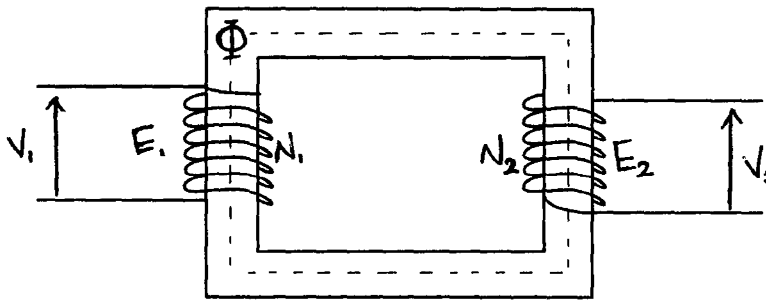

Fig 2.7 Diagram of a transformer showing it windings and magnetic flux

Assuming a sinusoidal time variation of the flux, the induced emf in the primary by Faraday's law will be

$$E_1(t) = \frac{N_1 d\Phi p}{dt} \qquad (2.2)$$

For a sinusoidal flux

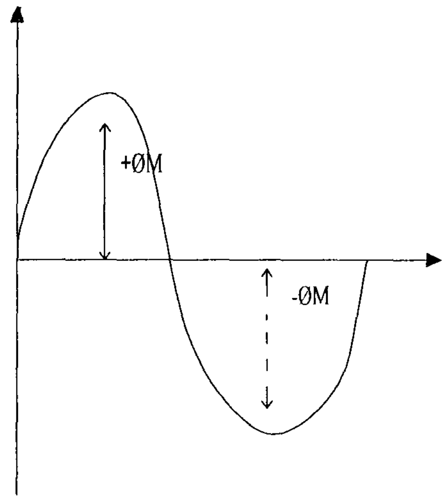

Fig 2.8 Sinusoidal wave of a magnetic flux

$\Phi = \Phi_m \mathrm{Sin} 2\pi ft$ (2.3)

Substituting eqt (2.4) into eqt (2.2)

$$E_1 = -\frac{N_1 d(\Phi_m \mathrm{Sin} 2\pi ft)}{dt}$$

Eqt 2.4 becomes

$E_1 = -N_1 2\pi ft \Phi_m \mathrm{Cos} 2\pi ft$

Rms value for $\mathrm{Cos} 2\pi ft = \frac{1}{\sqrt{2}}$ (2.6)

Thus

$$E_1(\mathrm{rms}) = 2\pi ft N_1 \Phi_m . \frac{1}{\sqrt{2}}$$

$$\frac{E_1}{E_2} = \frac{4.44 f N_1 \Phi_m}{4.44 f N_2 \Phi_m} .(\mathrm{volts})$$ (2.7)

$$\frac{E_1}{E_2} = \frac{N_1}{N_2} \qquad (2.10)$$

Furthermore, At no-Load the secondary voltage $V_2 = E_2$, as there is no voltage drop in the secondary. At normal load, the secondary flux produced weakens the main flux momentarily.

Thus,

$$F_{net} = N_pI_p - N_sI_s \qquad (2.11)$$

The net MMF produces a net flux in the core

$$F_{net} = N_pI_s - N_sI_s = \Phi R \qquad (2.12)$$

For a well designed transformer, the core reluctance is small (nearly zero) until the core is approximately saturated.

Therefore,

$$F_{net} = N_pI_p - N_sI_s = 0 \qquad (2.13)$$

As long as the core is unsaturated

$$N_pI_p = N_sI_s$$

$$\frac{I_p}{Is} = \frac{N_s}{Np} \qquad (2.14)$$

2.4 REAL AND IDEAL TRANSFORMER

2.4.1 IDEAL TRANSFORMER

An ideal transformer is a transformer that has a perfect magnetic coupling between its coils and it dissipates no energy. The eqtns (2.10) and eqtn (2.14) previously derived, apply to the ideal transformer. Practical transformers are designed to approach the ideal transformer very closely.

The following assumptions are made for ideal transformers:

- Voltage on each sides of the transformer is proportional to the number of turns.
- Current on each sides of the transformer are inversely proportional to the number of turns.
- Impedances on each side of the transformer are directly proportional to the square of the ratio of the number of turns.
- Power in volt amperes remain the same and unchanged

2.4.2 REAL TRANSFORMER

Non of the characteristics assumed for an ideal transformer can be obtained in practice. The following are obtainable in a real transformer

- The magnetic coupling between the coils is imperfect
- There are power losses in the winding and core
- At high magnetic field, the core material exhibit saturation.

2.5 CLASSIFICATION OF TRANSFORMER

Transformer is often classified based on their construction. This distinguished the manner in which the primary and secondary coils are placed around the laminated core. The major types of transformer construction are:

- Core type
- Shell type
- Spiral Core type

2.5.1 CORE TRANSFORMER

The core transformer consist of two legged core with the windings wrapped round the two limbs. It has an advantage of easy construction and maintenance. It major setback is it low efficiency due to large magnetic flux leakage.

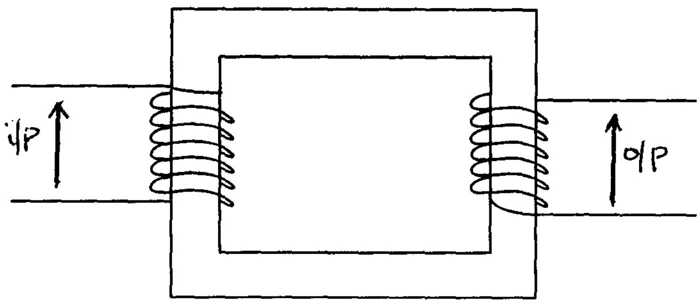

Fig 2.9 diagram of a core type transformer

2.5.2 SHELL TRANSFORMER

The shell type transformer consists of three legged core with the windings wrapped around the centre leg (both secondary and primary winding). It major advantages include high efficiency due to the concentration of magnetic flux within the core, protection provided by the core of the winding against mechanical damage. It major setback is the difficulty in repair.

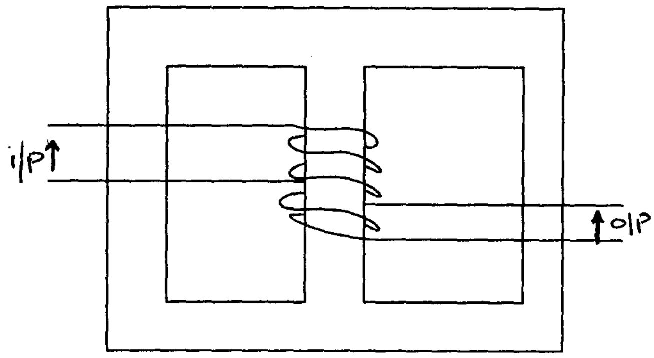

Fig 2.10 Diagram of a shell type transformer

2.5.3 SPIRAL CORE TRANSFORMER

For the spiral core type transformer, the core is assembled in a continuous strip or ribbon of transformer steel wound in the form of a circular or elliptical cylinder. It advantages include; rigid core, low manufacturing cost and lower iron losses at higher operating flux densities.

2.6 DESIGN CONSIDERATION

2.6.1 SPECIFIC MAGNETIC LOADING

This is the maximum flux density (B_m) in the core. When voltage is supplied to one of the winding, the transformer will be excited and a flux is produced in the core. This helps to obtain the cross-section of the core by choosing a flux density. The flux density used depends on the type of material used for the core construction, thickness of the material, etc so that the core does not get over saturated.

2.6.2 SPECIFIC ELECTRIC LOADING

This is the current used in selecting the size of the conductor to be used in the winding. It should be such that the winding can carry the current safely and not overheated.

2.6.3 NOISE

Transformer with rating in excess of 100VA emits some noise (humming) during service under no-load condition. This hum originates in transformer core where laminations vibrate under the influence of magnetic forces. The major causes include

magnatitostriction: this is the principle whereby a specimen changes dimensions on being magnetized.

Core plate vibration: this depends on the tightness of the lamination (i.e. the effectiveness of the clamping) size, gauge of associated structure parts. The noise emitted from the core can be minimize by

- Minimizing the maximum flux density (B_m)
- Quality clamping of lamination
- Sound insulating the transformer from the tank by using cushion or padding
- Cooling of the transformer

2.6.4 THERMAL RATING

The design of a transformer is ultimately affected by the type of service it is to perform. The rating of a transformer is quoted always in volt-ampere. The rating being limited to the maximum temperature of the operation of which the transformer has a reasonably long life.

In most transformer designs, the average winding temperature is (at maximum) one hundred degree centigrade (100°C). A transformer designed to operate well below the specified limit is capable of over load for a restricted period of time, while that kept at it temperature limits fails in overload condition.

2.7 TYPES OF TRANSFORMER

2.7.1 PULSE TRANSFORMER

This is a transformer that is optimized for transmitting rectangular electrical pulses (pulse with fast rise and fall time). Small power versions called signal type are used in digital control and telecommunication circuits for matching logic drivers to transmission line. Medium power versions are used in power control circuits such as camera flash controllers. Lager power versions are used in the electrical power distribution industry to interface low-voltage control circuitry to the high-voltage gates of power semi-conductors.

2.7.2 INSTRUMENT TRANSFORMER

They transformers used for measuring high voltage and high current in AC circuit. They include; current transformer and voltage (potential) transformer.

CURRENT TRANSFORMER: This is design to provide a current in the secondary which is accurately proportional to the current flowing in the primary. They are commonly used to measure large current which are difficult to measure directly.

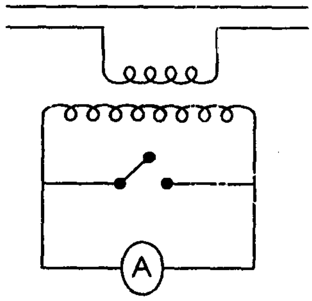

Fig 2.11 Diagram of a current transformer.

POTENTIAL (VOLTAGE) TRANSFORMER: They are used in the electrical supply industry to measure accurately the voltage being supplied. They are design to present negligible load to the voltage being measured.

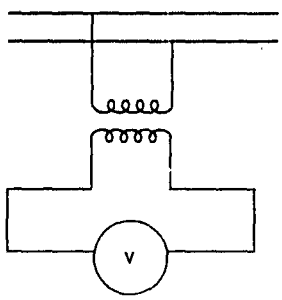

Fig 2.12 Diagram of a potential transformer

2.7.3 RF TRANSFORMER

They are used in radio frequency to give an extremely wide bandwidth. The transformers are made from configuration of transmission line wound around ferrite core. The windings are sometime bifilar and sometime made from coaxial cable. This style of transformer is frequently used as an impedance matching balun to convert from 300ohms balanced to 75ohm unbalance in FM receivers.

2.74 AUTO-TRANSFORMER

These are transformers which have both the primary and secondary on a single coil and tapped on some point along the winding. The both coils are not electrically isolated from each other. Auto transformers are used to compensate for voltage drop in a distribution system or for matching two transmission voltages.

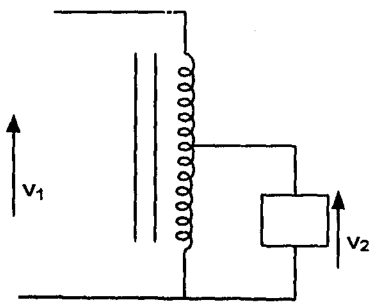

Fig 2.13 Diagram of an auto-transformer.

2.7.4 RESONANT TRANSFORMER

A resonant transformer is one that operates at the resonance frequency of one or more of its coil. The resonant coil, usually the secondary acts as an inductor and its connected in series with a capacitor. Resonance causes high voltage to develop across the secondary unit and limited by some process as electrical breakdown. They find applications in voltage regulating transformers, flyback transformer of a CTR television set and coupling between stages of super heterodyne receivers.

2.8 TRANSFORMER LOSSES

Transformer loss mainly has two components: No-load and load loss.

No-load loss results from steel materials, used for magnetizing core laminations. It include hysteresis and eddy current loss, dielectric loss and copper loss due to no-load current.

Load loss arises from the resistive components used for building the primary and secondary windings. It comprises I^2R loss of windings due to eddy current and stray loss in the tank and core clamp.

2.8.1 COPPER LOSSES

This is the loss of energy in form of heat dissipated by the resistance of the primary and secondary winding. This occurs as a result of overloading the transformer or using a transformer on a lower frequency of supply below that which it was designed.

2.8.2 HYSTERESIS LOSSES

This is the heating of the core as a result of internal molecular structure reversals which occurs as the magnetic flux alternates. An amount of energy proportional to the area of the hysteresis is dissipated during each cycle. The loss is not simply proportional to the stage, since the shape of hysteresis loop changes as the maximum flux is changed. The loss is proportional to the area of the hysteresis loop.

2.8.3 EDDY CURRENT LOSSES

This is the heating of the core due to emf being induced not only in the transformer winding but also in the core. The induced emf set-up circulating current called the eddy current. The amount of energy lost due to eddy is proportional to the size of the paths they follow within the core.

2.8.4 STRAY LOSSES

These occur as a result of eddy current induced by the leakage fluxes in the tank and other part of the structure. The sum of the copper and stray losses is called load losses.

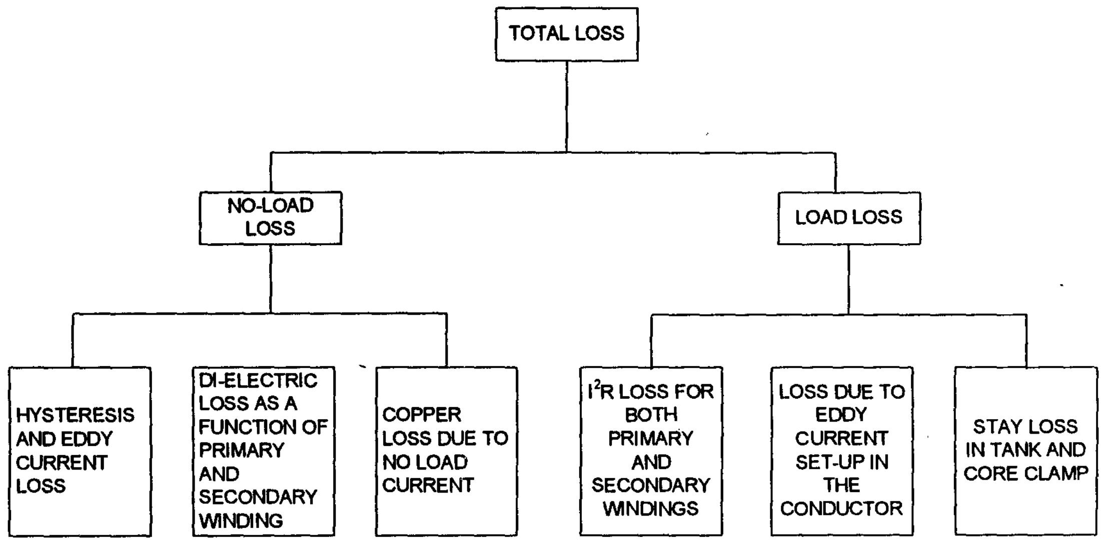

Fig 2.14 Chart showing losses in a transformer.

2.9 USES OF TRANSFORMER

It is seen that transformer has wide applications in the field of electrical engineering, common importance are

- Electric power transmission over long distances.
- High-voltage direct-current power transmission system
- Large specially constructed power transformers are used for electric arc furnaces used in steelmaking.

- Small transformers are often used to isolate and link different parts of radio receivers and audio amplifiers.
- Rotating transformers are used to pass power or signals from a stationary mounting to a rotating mechanism, or radar antenna

CHAPTER THREE

3.0 DESIGN ANALYSIS

A 500W with 230V input voltage stepping-up to 2000 and 3000v output voltage.

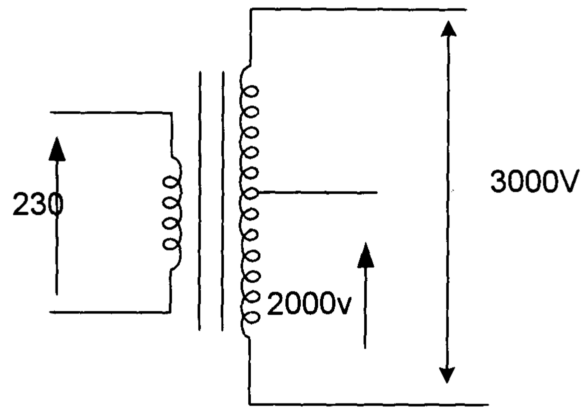

Fig 3.0 Circuit of a multi-tapp transformer

Fig 3.0

3.1 DESIGN PARAMETERS

Material for the magnetic frame	= Hot rolled silicon steel (HRS)
Section of transformer core and yoke	= rectangular
Factor K for single phase shell power transformer	= 1.1
Maximum flux density in core or yoke, B_m	= 0.9
Window space factor	= 0.17
Average current density	= $3.2 \times 10^6 A/m^2$
Thickness of core sheet	= 0.03mm

Proportions of the rectangular core = 2:1

Window proportion = 2:1

Density of steel = 7.55×10^3 kg/m^3

k for core diameter = 0.45

Power Rating = 500W

3.2 MAIN DIMENSION

The emf per turn

$$Et = 1.1\sqrt{0.5}$$

$$= 0.78\text{volt}$$

Net cross sectional area of core

$$Et = 4.44fBmAi$$

$$Ai = \frac{Et}{4.44fBm}$$

$$= \frac{0.78}{4.44 \times 50 \times 0.9}$$

$= 0.0039m2$

$= 39.0cm2$

Diameter of the core

$A_i = kd^2$

$d = \sqrt{A_i\,(net)/k}$

$= \sqrt{\frac{39cm2}{0.45}}$

$= 9.3cm$

Gross area of the core

$A_i\,(gross) = \frac{A_i\,(net)}{K}$

$= \frac{39cm^2}{0.9}$

$= 43.3cm2$

Gross area 43.3cm2 with core proportion of 2:1

This implies,

Length of the main rectangle core, $\mathbf{L_{mc}}$ = 9.30cm

Width of main rectangular core, $\mathbf{B_{mc}}$ = 4.65cm

Window area, Aw

$S = 2.22fB_m\,K_w\delta A_iA_w$

$Aw = \frac{S}{2.22.f.Bm.Ai.\,\delta.Kw}$

$= \frac{500}{}$

$2.22 \times 50 \times 0.0039 \times 0.9 \times 3.3\mathbf{e}6 \times 0.17$

$= 24cm^2$

Window area $24cm^2$ with window proportion 2:1

This implies,

Window height, $\mathbf{h_w}$ = 6.9cm

Window width, $\mathbf{b_w}$ = 3.5cm

Core height = window height, $\mathbf{h_c}$ = 6.9cm

For a small transformer, the section yoke and side core carries only half the total flux.

Thus,

Cross-sectional area of yoke, $\mathbf{A_y}$ = ½ Ai(net)

= ½ x 39cm2

= 19.5cm2

Width of side core, $\mathbf{b_y}$ = ½ bmc

= ½ x 4.65cm

= 2.3cm

Height of yoke, $\mathbf{h_y}$ = $\mathbf{b_y}$ = 2.3cm

Length of yoke, **Ly** $= \mathbf{h_y} + \mathbf{b_w} + \mathbf{b_{mc}} + \mathbf{b_w} + \mathbf{h_y}$

= (2.3 + 3.5 + 4.65 + 3.5 + 2.3)cm

= 16.25cm

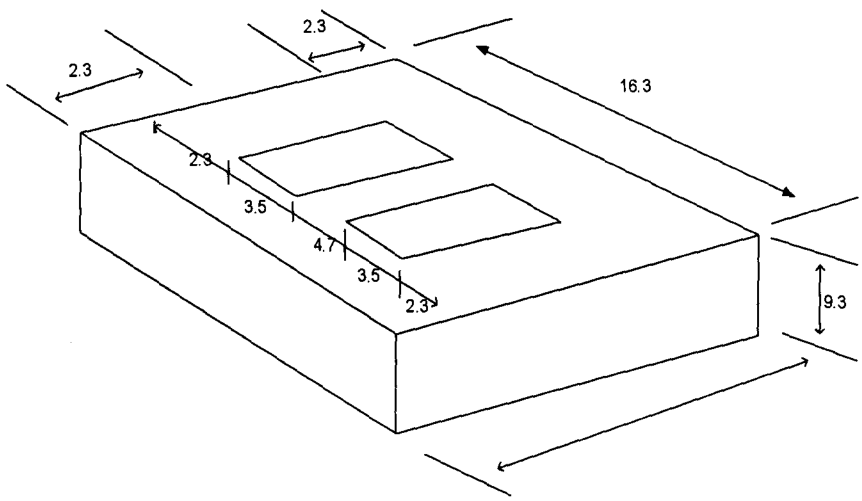

Fig. 3.1 Diagram of a steel core.

3.2 MAGNETIC CIRCUIT

Volume of central core, $\mathbf{V_c}$ = Ai x hc

$= 43.3cm^2 \times 6.9cm$

$= 298.77cm^3$

Volume of 2 sides core, $V_{c2} = 2(A_y \times h_w)$

$= 2(19.5cm^2 \times 6.9cm)$

$= 269.1cm^3$

Total volume of all the cores,

Volume of central core + Volume of 2sides core

$= 269.1cm^3 + 269.77cm^3$

$= 567.87cm^3$

Volume of the yokes, $\mathbf{V_y} = 2(A_y \times L_y)$

$= 2(19.5 \times 16.25)$

$= 633.75cm3$

Volume of all the cores and yokes,

Volume of the core + Volume of the yokes

$= 567.87 + 633.75$

$= 1210.5cm^3$

3.3.1 LOSSES

Core volume

$= 1201.5cm^3$

$= 1201.5 \times 10^{-6}m^3$

Weight of all the cores and yoke

$= 1201 \times 10^{-6}m^3 \times 7.55 \times 10^3kg/m^3$

$= 9.07kg$

From design data sheet of a transformer, specific core loss at 0.9tesla for HRS

$P = 1.1W/kg$

Iron loss

$= 1.1W/kg \times 9.07kg \qquad = 9.97W$

Iron losses calculated above are increased by 5% to take account mechanical workings of laminations and joints.

Thus,

Total iron loss

$= 10.47W$

Yoke weight

$633.75cm^3 \times 7.55 \times 10^{-3}kg/cm^3$

$= 4.78kg$

Net yoke

$= 0.9 \times 633.75cm^3$

$= 570.38cm^3$

Net core

$= 0.9 \times 567.87cm^3$

$= 511.08cm^3$

Flux density

$$= 0.9 \times \frac{511.08}{570.38}$$

$= 0.8wb/m^2$

Specific core loss at $0.8wb/m^2$

$P = 0.9W/kg$

Core loss

$= 0.9W/kg \times 4.78kg$

$= 4.302W$

Total losses

$= 10.47 + 4.3$

$= 14.77W$

3.3 WINDING ARRAGEMENT

First high voltage winding

$E_t = 0.78$

$V_3 = 3000v$

$N_3 = ?$

$$N_3 = \frac{V_3}{E_t}$$

$$N_3 = \frac{3000}{0.7}$$

$N_3 = 3846$ turns

$$I_3 = \frac{500}{3000V}$$

$I_3 = 0.17A$

Current density, $\eth_3 = 2.3A/mm^2$

Cross sectional area for V_3 conductor

$$A_3 = \frac{I_3}{\eth_3}$$

$$= \frac{0.17A}{2.3A/mm}$$

$A_3 = 0.074mm^2$

$$A_3 = \frac{\Pi d_3^2}{4}$$

$d_3 = 0.301mm$

From SWG data table, SWG 30 fit for V_3

Second high voltage windings

$$N_2 = \frac{V_2}{E_t}$$

$$= \frac{2000}{0.78}$$

$$\mathbf{N_2} = 2564 \text{ turns}$$

$$I_2 = \frac{500}{2000}$$

$$I_2 = 0.25A$$

$$A_2 = \frac{I_2}{\eth_3}$$

$$= \frac{0.25A}{2.3A/mm^2}$$

$$A_2 = 0.109 \text{ mm}^2$$

$$A_2 = \frac{\Pi d_2^2}{4}$$

$$\mathbf{d_2} = 0.372mm$$

From SWG data sheet, SWG 28 fits for V_2

Low voltage windings

Using the relationship

$$\frac{V_3}{V_1} = \frac{N_3}{N_1}$$

$N_1 = N_3 \times \frac{V_1}{V_3}$

$= 3846 \times \frac{230}{3000}$

$\mathbf{N_1} = 294$ turns

$I_1 = \frac{500}{230}$

$I_1 = 2.17A$

$ð_1 = 3.2A/mm^2$

$A_1 = \frac{I_1}{ð_1}$

$= \frac{2.17A}{3.2A/mm^2}$

$A_1 = 0.68mm^2$

$A_1 = \frac{\Pi d_1^2}{4}$

$d_1 = 0.93mm$

From SWG data table, SWG 19 fits for V_1

CHAPTER FOUR

4.0 CONTRUCTION, TESTING AND DICURSSION OF RESULT

4.1 CONSTRUCTION

This process is done after the design has been finally analyzed. This stage precedes the testing stage. The dimension of materials derived from the design is put into application.

- The steps taking for the construction are as follows: All materials were tested.
- The core limb was constructed using a rubber insulator.
- The turns of coils was wounded on the core limb, starting with the primary then followed by the secondary.
- Paper was inserted between the primary and secondary windings to provide insulation.
- At the tip of each winding, two wires (positive and negative) are connected to serve as source in and source out (terminals).
- The core sheets were fixed into the limbs until the whole space was occupied.
- A thick insulated paper was used to wrap the exposed windings, to avoid mechanical damages, moist and dust from affecting the transformer.
- The core was properly clamped, using bolts and nut to avoid vibration.

4.1 TESTING

The transformer was tested at no load condition. For the output voltage to be easily measured, the input was connected to a 24V supply. A multi-meter was used to measure the voltage across the winding. The transformer was left to serve for 1 hour so as to know the working temperature.

4.2.1 CALCULATION OF RESULTS

Supplying a 24V to the input terminal, the following voltage values would be expected at the two outputs.

$V_1 = 24$

$V_2 =?$

$N_1/N_2 = 0.1147$

$V_1/V_2 = N1/N2$

$24/V_2 = 0.1147$

$\mathbf{V_2 = 209V}$

$V_1 = 24$

$V_3 =?$

$N_1/N_3 = 0.076$

$24/V_3 = 0.076$

$\mathbf{V_3 = 314V}$

Due to some factors, the values obtained did not tally with the expected values.

$V_2 = 190V$

$V_3 = 211V$

From the obtained result, it implies that

$V_2 = 1820V$

$V_3 = 2022V$

Expected current at the outputs will be

$I_2 = 0.25amps$

$I_3 = 0.17amps$

Obtained currents at the outputs are

$I_2 = 0.23amps$

$I_3 = 0.11amps$

Input Power $P_1 = 500W$

Power at output was calculated to be

$P_2 = 0.23 \times 1820$

$= 418.6watts$

$P3 = 0.11 \times 2022$

= 222.42watts

Efficiency of the transformer

$= P_{out}/P_{in} \times 100$

$$P_{out} = \frac{418.6 + 222.42}{2}$$

= 320.51watts

Thus, efficiency will be

$= 320.51/500 \times 100$

= 64%

4.2.2 TECHNICAL SPECIFICATION

The table below shows the expected technical result and result obtained.

Technical specification	Expected Result	Result Obtained
Power Rating	500watts	222.42 – 418.6watts
Output Voltage Range	2000 – 3000V	1820 – 2022V
Main Input Range	230V	190 – 230V
Efficiency	99.9%	64%
Frequency	50Hz	50Hz

Table 4.0 Result Obtained and Expected Result.

4.2 DISCUSSION OF RESULT

The goal of the project was to design and construct a transformer of 500W capacity, taking an input of 230V with output voltages of 2000V and 3000V simultaneously. Due to some factors, the expected results were not achieved. Some factor responsible include

- Non availability of correct dimension of core.
- Usage of locally made material.
- Constant values not been feasible.

CHAPTER FIVE

6.0 COST ANALYSIS

This is an important aspect in every engineering project management. It tells the extent in which the project would be achieved for a dedicated market force.

Materials cost would be directly considered since the project is a prototype model. The table below shows the quantity, unit price and cost of the components used in the construction of the transformer.

S/No.	ITEMS	QUANTITY	UNIT PRICE (#)	COST (#)
1	STEEL CORE	1	4000	4000
2	CORE LIMB	1	200	200
3	SWG 30	1KG	400/KG	400
4	SWG 28	1KG	400/KG	400
5	SWG 19	1KG	400/KG	400
6	BOLTS AND NUTS	4	250	1000
7	LABOUR	LOT	3000	3000
8	TRANSPORTATION	LOT	1000	1000
	SUB TOTAL			**10400**
	5% CONTINGENCY			520
	GRAND TOTAL			**10,920**

Table 5.0 Bill of Quantity

CHAPTER SIX

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

This project has been subjected to a series of test during and after construction. The basic objective of this project was achieved by transforming a 230V into a higher voltage. It was also seen that from our earlier theory about a real and an ideal transformer, the characteristics observed in an ideal transformer can not be same when compared to a real transformer.

5.2 RECOMMENDATIONS

After carrying out the design and construction of the transformer, the following were drafted for further advancement.

- One of the paramount objectives of the design and production engineer is to produce a device that work efficiently and effectively using or occupying minimal space. So for such transformer, special research on how a special circuitry could effect the change should be embarked on.
- The department could get one for testing high voltage devices.
- If encouraged to produce in large quantity, it will not only serve as an income source but also help to empower and reduce the cry for unemployment.
- With the currently adopted High Voltage Distribution System (HVDS) by PHCN, which requires installation of large number of transformers, the ease of maintenance as well as construction could be done within Nigeria.

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