

Internship Report
on
Manufacturing Process of 500kVA, 3-Phase Distribution
Transformer at Basic Power Engineering Ltd.

Bachelor of Science in Electrical and Electronic Engineering

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Certification

This is to certify that this internee ” Manufacturing Process of 500KVA, 3-Phase Distribution Transformer at Basic Power Engineering Ltd.” is done by the flowing student under my direct supervision and this work has been carried out by them in the laboratories of the department of electrical and electronic engineering under the faculty engineering of a Daffodil International University in partial fulfillment of the requirements for the Degree of Bachelor of Science in electrical and electronic engineering. This presentation of the work was held on 27 June 2021.

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List of Abbreviation

A= Ampere

V= Voltage

EMF==Electromotive force

P= Primary

S= Secondary

V_s= Secondary Voltage

V_p= Primary Voltage

N_s=Secondary Turn

N_p=Primary Turn

AC= Alternating Current

DC=Direct Current

Φ= flux

η= Efficiency

MVA= Mega Volt Ampere

kVA= kilo Volt Ampere

CT= Current Transformer

PT= Potential Transformer

ONAN=Oil Natural Air Natural

DAR= Di-electric Absorption Ratio

HV= High Voltage

LV= Low Voltage

HT=High Tension

LT= Low Tension

W=Watt

SWG= Standard Wire Gauge

CCA=Core Coil Assembly

Δ= Delta

Y=Star

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All praise is to the Supreme Being; creator and ruler of the universe, Almighty Allah, whose mercy keeps us alive and to pursue my education in Bachelor of Science in Electrical and Electronic Engineering and to complete the Internee Report which is entitled as “**Manufacturing Process of 400kVA, 3-Phase Distribution Transformer at Basic Power Engineering Ltd**”. In the process of conducting this practicum report, I would like to express my gratitude and respect to some generous persons for their immense help and enormous cooperation.

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ABSTRACT

Basic Power Engineering Ltd. is the pioneer manufacturer of transformers & electrical goods in Bangladesh. The company has always been contributing towards the advancement and development of engineering sector in Bangladesh by introducing a range of quality of distribution transformers with different ranges & other electrical equipment's like-Switchgear equipment's, distribution board etc. I recently have done my internship in Basic Power Engineering Ltd. In which I got training from its transformer section. The internship is basically on manufacturing, assembling, and testing process of distribution transformer.

The starting of this report with some fundamental data about introduction, background, objectives and recommendation are shown. Then I have discussed about distribution transformers, its working procedure, its classifications based on its applicability, its efficiency etc. The report includes manufacturing process step by step with core cutting, HT, LT winding, assembling core and coil, tanking up, bushing, oil filling etc. I have tried to describe the whole calculation process of 500kVA, 3-Phase Distribution Transformer with its testing procedure along with test reports which was observed by me.

In this report, I have given a very brief review of what I saw and learned during in my internship period. I have mentioned all those things which I have learned in my internship period. This report will give its reader the knowledge about the Basic Power Engineering Limited and distribution transformer. I tried my level best to make the report simple but informative.

CHAPTER 1

Introduction

1.1 Background

Electricity is very essential for the development of a nation. The dependence on electricity is so much that it has become a part and parcel of our life. We can say, electricity is considered as the prime mover of a state. Only 40% of the total population of our country has a kind of access to electricity. Problems in the Bangladesh's electric power sector include high system losses, and delays in completion of new plants, low plant efficiencies, erratic power supply, electricity theft, blackouts, and shortages of funds for power plant maintenance. Overall, the country's generation plants have been unable to meet system demand over the past decade [1]. Bangladesh Government is taking huge steps to handle the electricity crisis. Power distribution lines have been expanded to cover more consumers but production of electricity did not increase. It is recognized that the pace of power development has to be accelerated in order to achieve overall economic development of the country because a country's socio-economic development largely depends on it. But currently, consumers cannot be provided with uninterrupted and quality supply of electricity due to the inadequate generation compared to the national demand. There are some problems with the policy that was followed in the power sector. Recently large-scale investment from private sector was encouraged.

Basic Power Engineering Limited is contributing to the country by saving foreign currency by manufacturing different power products. Basic Power Engineering Limited was incorporated in 2007 as a private limited business enterprise. At present, Basic Power Engineering Limited is one of the best power engineering company. Basic Power Engineering Limited is an ISO 9001:2015 certified company. Basic Power Engineering Limited enhances the business of its customers by providing them with complete solutions. While creating better and environmentally compatible technologies, Basic Power Engineering Limited focuses on the customer's demand with appropriate products and solutions as well as services

1.2 Objective

1.2.1 Broad of Objective

The broad objective of this report is mainly to understand the manufacturing, assembling, and testing process of distribution transformer and applying this knowledge for improving the

ability and increasing the capability of the power sector of our country.

1.2.2 Specific objectives

The particular objectives of internship were as follows:

- To apply theoretical knowledge in the practical field.
- Collecting Knowledge regarding Distribution Transformer.
- To know about the calculation process and gain some knowledge about the assembling process of a Transformer.
- To observe the manufacturing process and testing process of Transformer.
- To realize the organizational management system of Basic Power Engineering Limited.

1.3 Scope of the Study

The report covers transformer division of Basic Power Engineering Limited. This report especially emphasizes on manufacturing of transformer. I had the opportunity to have close view of engineer's activities of Basic Power Engineering Limited.

1.4 Data Collection

The study was mainly the Manufacturing, Assembling and Testing of Distribution Transformer. Both primary and secondary data are being collected for the purpose of this report.

1.4.1. Primary Data

Primary Data are collected from the practical work with face to face conversation with the engineers.

1.4.2. Secondary Data

Secondary data was collected from the online internet resources and books of different authors, files & folders, daily diary (containing my activities).

1.5 Limitations of the Study

There were certain limitations while conducting the study. These are summarized below:

- The main obstacle while preparing this report was time. As the tenure of the internship

program was very short, it was not possible to highlight everything deeply.

- A major portion of the study had been conducted based on the secondary data.
- Confidentiality of information was another barrier that hindered the study. Every organization has its own secrecy that is not revealed to someone outside the organization. While collecting data at Basic Power Engineering Limited, personnel did not disclose enough information for the sake of confidentiality rule of the organization.

CHAPTER 2

Organization Overview

2.1 Company Name

Basic Power Engineering Limited.

2.2 Company Overview

Basic Power Engineering Limited is contributing to the country by saving foreign currency by manufacturing different power products. Basic Power Engineering Limited is an ISO 9001:2015 certified company. Basic Power Engineering Limited, a prospective company is running its business since January 2007 under the prominent successful leadership of the company directors [3] to fulfill the domestic electrical requirements of almost every new organization of the country. Basic Power Engineering Limited is now the largest transformer and switchgear manufacturing company in Bangladesh. The company has wide variety of Distribution Transformers, HT-High Tension Switchgear, LT-Low Tension Switchgear, PFI-Power Factor Improvement Panel, DB- Distribution Board etc. All these products are in compliance with internationally recognized standards.

Including,

- ANSI: American National Standards Institute
- NEMA: National Electrical Manufacturing Association
- VDE: Regulation and DIN standard
- ASTM: American Society of Testing Materials
- IEC: International Electro-Technical Commission
- IEEE: Institute of Electrical and Electronics Engineering

The company gives utmost importance to customer satisfaction in all respect is now looking forward to global recognition by adopting internationally recognized quality system.

2.3 Major Works Involved

- To provide large KVA rating power transformer to customer.
- To acquaint with the installation and commissioning of thousands of transformers, switchgears, and complete substations.
- To involve with the service and maintenance of its own supplied equipment.
- To provide complete solution to the customers including engineering, procurement and construction.

- Working hard and aiming high.
- Serving and devoting to through customers.

2.4 Supply Chain

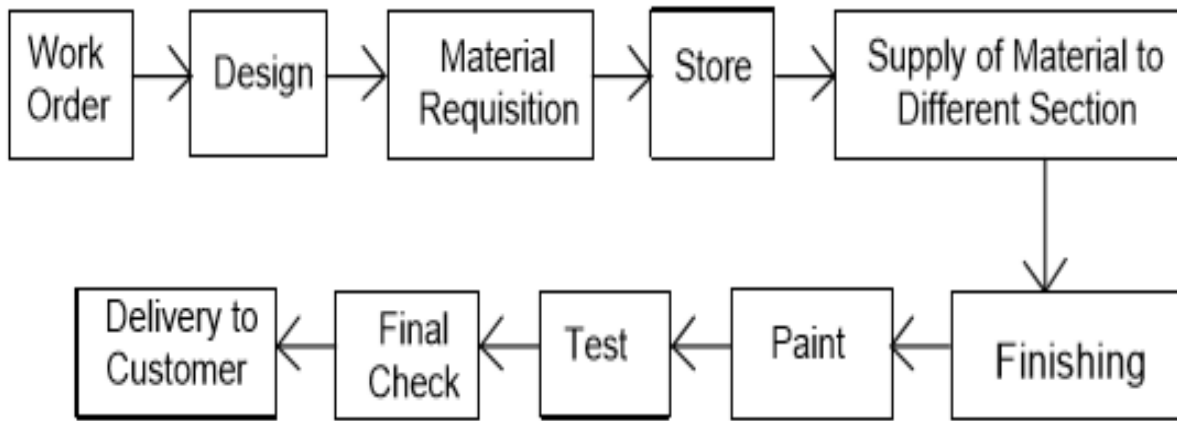


Figure 2.1: Supply chain flow diagram of Basic Power Engineering Limited

2.5 Vision

Our vision is to become the leading Power engineering solutions provider in Our Country [2].

2.6 Mission

We are committed to maintain our leading role in Power Sector, Power Transmission & Distribution with the help of our skilled & professional staff members in order to execute the challenging projects in timely manner with customer focused policy [3].

2.7 Quality and Environmental Policy

Basic Power Engineering Limited, believe that the establishment of an effective quality and environmental management system will help our company achieve its vision of becoming a highly respected fabricator and manufacturer of various internal and external electrification products /items. The company is strongly determined to lead in this industry by providing satisfaction to our customers and complying with all applicable environmental laws and other requirements that we subscribe [2].

2.8 Scope

This report has been prepared through the assistance of the help of practical knowledge and broad discussion of my selected supervisor, technical engineer and employees of this organization. While Preparing this report, I had a great opportunity to have an in depth

knowledge of Manufacturing and Testing procedure of Distribution Transformer. This practical knowledge will help me to apply my knowledge to related field.

2.9 Achievements and Awards

Since its inception in 2007, Basic power Engineering Limited has through its dedication and service, achieved distinction as the Leading Power Engineering Company in Bangladesh. They have earned the respect and trust of globally renowned companies. We are also in the process of getting certified by ISO 14000 and ISO 18000. Throughout the journey till this point they have achieved both materialistic and abstractive recognition, certification, award and records that have only inspired them to achieve even bigger.

2.10 Departments of Basic Power Engineering Limited

- Transformer Division
- Switchgear Division
- Instrument Transformer Division
- Breaker & Isolator Division
- Administration Division
- Research & Development Division
- Human Resource Management Division

CHAPTER 3

Transformer & Its Parts

3.1 Basic Function of Transformer

If we arrange two electrically isolated coils in such a way that the time varying flux due to one of them causes an electromotive force (EMF) to be induced in the other, they said to form a transformer. In other words, a transformer is a device that involves magnetically coupled coils. If only a fraction of the flux produced by one coil links the other, the coils are said to be loosely coupled. In this case, the operation of the transformer is not very efficient. In order to increase the coupling between the coils, the coils are wound on a common core. The transformer is called an air-core transformer when the core is made of a nonmagnetic material. When the core is made of a ferromagnetic material with relatively high permeability, the transformer is referred to as an iron-core transformer [4].

Only rotating component in transformer operation is flux, which moves electromagnetically (not physically), rest everything is stationary and hence transformer is a static electrical equipment. A transformer consists of two coils that are electrically isolated from each other but are wound on the same magnetic core. A time varying current in one coil sets up a time varying flux in the magnetic core. Owing to the high permeability of the core, most of the flux links to the other coil and induces a time-varying emf (voltage) in that coil. The frequency of the induced emf in the other coil is the same as that of the current in the first coil. If the other coil is connected to the load, the induced emf in the coil establishes a current in it. Thus, the power is transferred from one coil to the other via the magnetic flux in the core. The coil to which the source supplies the power is called the primary winding. The coil that delivers power to the load is called the secondary winding.

The voltage induced across the secondary coil may be calculated from Faraday's law of induction, which states that:

$$V_s = N_s \frac{d\Phi}{dt} \quad (1)$$

where V_s is the instantaneous voltage, N_s is the number of turns in the secondary coil and Φ is the magnetic flux through one turn of the coil. Since the same magnetic flux passes through both the primary and secondary coils in an ideal transformer, the instantaneous voltage across the primary winding equals

$$V_p = N_p \frac{d\Phi}{dt}$$

Taking the ratio of the two equations (1) and (2) for V_s and V_p gives the basic equation for stepping up or stepping down the voltage

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} \quad (3)$$

The ratio N_p/N_s is known as the transformation ratio. Now by appropriate selection of the ratio of turns, a transformer thus enables an alternating current voltage to be "stepped up" by making N_s greater than N_p , or "stepped down" by making N_s less than N_p .

3.2 Uses of Transformer

The most important uses and application of Transformer are:

- It can rise or lower the level of the level of voltage or current (when voltage increases, current decreases and vice versa because $P=VI$, and Power is same) in AC circuit.
- It can increase or decrease the value of capacitor, an inductor or resistance in an AC circuit. It can thus act as an impedance transferring device.
- It can be used to prevent DC from passing from one circuit to the other.
- It can isolate two circuits electrically.

Transformer is the main reason to transmit and distribute power in AC instead of DC, because Transformer not work on DC so there are too difficulties to transmit power in DC. in the DC Transition and distribution, the level of voltage Step up by Buck and Boost Converter but it is too costly and not suitable economically.

The main application of Transformer is to Step up (Increase) or Step down (Decrease) the level of voltage. In other words, increase or decrease the level of current, while power must be same [6].

3.2.1 Other uses and application of Transformer

It step up the level of voltage at generation side before transmission and distribution. in distribution side, for commercial or domestic use of electricity, transformer step down (decries) the level of voltage for example from 11kV to 220 V single phase and 440 V three phase.

The Current Transformer and Potential Transformer also used power system and in the

industry. Also, it is used for impedance matching. So these were the simple uses and application of transformer [6].

3.3 Efficiency of a Transformer

The amount or the intensity of Power loss in a transformer, determines the efficiency of the transformer. The efficiency can be understood in terms of power loss between primary and secondary of a transformer. Hence, the ratio of power output of secondary winding to the power input of primary winding can be stated as the Efficiency of the transformer. This can be written as,

$$Efficiency = \frac{Output\ Power}{Input\ Power} \times 100\%$$

Efficiency is generally denoted by η . The above given equation is valid for an ideal transformer where there will be no losses and the whole energy in the input gets transferred to the output. Hence, if losses are considered and if the efficiency is calculated in practical conditions, the below equation is to be considered,

$$Efficiency = \frac{Output\ Power}{Output\ Power + Copper\ Losses + Core\ Losses} \times 100\%$$

It is to be noted that the input, output and losses are all expressed in terms of power, i.e., in It

It is to be noted that the input, output and losses are all expressed in terms of power, i.e., Watts [7].

3.4 Classifications of Transformer

3.4.1 Mainly two types of construction are in common use for the transformers

- Core type
- Shell type

In a core type transformer, each winding may be evenly split and wound on both legs of the rectangular core. In a shell type transformer, the two windings are usually wound over the same leg of the magnetic core [5]. Basic Power Engineering ltd. mainly produces core type transformers because it is cheaper than shell type. Hence core type is widely used in

industries.

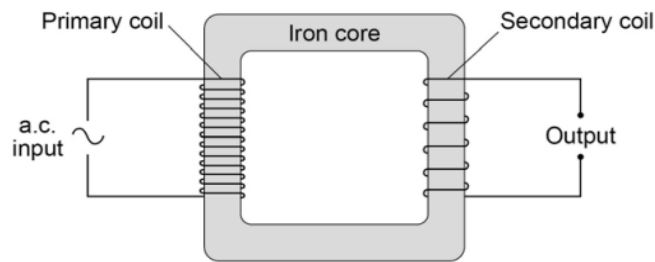


Figure 3.1: Core type Transformer

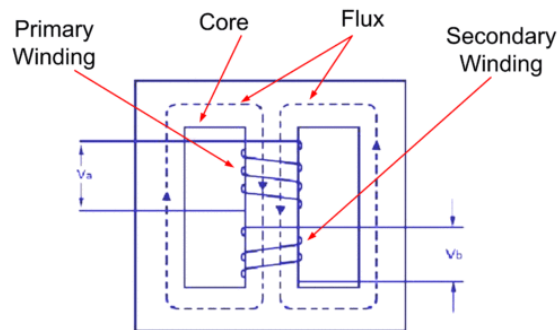


Figure 3.2: Shell type Transformer

3.4.2 Depending upon the type of service, in the field of power system, they are classified as

- Power Transformers and
- Distribution Transformers

3.4.2.1 Power Transformer

Power transformers are used in electronic circuits and come in many different types and applications. Electronics or power transformers are sometimes considered to be those with ratings of 300 volt-amperes and below. These transformers normally provide power to the power supply of an electronic device, such as in power amplifiers in audio receivers [9].

3.4.2.2 Distribution Transformer

A distribution transformer is also known as a typical kind of isolation transformer. The main function of this transformer is to alter the high voltage to the normal voltage like 240/120 V to

use in electric power distribution. In the distribution system, there are different kinds of transformers available like single phase, 3-phase, underground, pad-mounted, pole-mounted transformer [10].

3.5 Technical Specification of 500kVA, 3-Ø Distribution Transformer

Table 3.1: Specification of Transformer

Brand	Basic Power Engineering Ltd.	
Type of Transformer	Step down	
Serial No	500-013	
Rated power	500 KVA	
Rated voltage	HV side – 11 KV	LV side – 415 V
Rated current	HV side –26.24 A	LV side –695.6A
Phase	3	
Rated Frequency	50 Hz	
Connection type	HT side – Δ	LT side – Y
Cooling type	ONAN	
Insulation Level		
Impulse (Peak)	HV Side- 75KV	
Power Frequency	HV Side -28 KV	LV Side -3 KV
Temperature Rise		
In Oil	60°C	
In Windings	65°C	
No Load Loss	1000W	
Load Loss	5500W	
Impedance voltage	4%	
Total Weight	1765Kg.	
Oil Quantity Ltr.	415	
MFG Year	2020	

3.6 Major Components of a Transformer

- Core
- Copper wire for (HT and LT side)
- Insulation paper
- Bushing
- Tap Changer
- Channel

- Separator
- Transformer Tank
- Radiator
- Transformer Oil
- Oil Level Indicator
- Conservator Tank
- Breathers
- Horn Gap

3.6.1 Core

A transformer core always creates a path into its core channels towards the magnetic flux. The correct use of highly permeable material helps to achieve very low reluctance to remain within the core in the path of magnetic flux. Usually, it is made of several thin electrical steel sheets known as lamination sheets. There are many types core is available such as steel laminated, solid and air core as well as variations of each within their respective categories.



Figure 3.3: Core

3.6.2 Copper wire for HT and LT side

Copper and aluminum are the only two winding material used in transformer there are no other winding material that are able to be used as efficiently and economically.



HT Copper wire

Figure 3.4: Copper wire for HT



LT Copper wire

Figure 3.5: Copper wire for LT

It is not considered that there is any significant material improvement available here. They use of larger winding conductor cross section to reduce winding resistance and hence load loss is a possible option for improvement. However larger cross section conductor will also have the undesired effect of increasing eddy current loss when harmonic current is present in the winding with nonlinear load. They will also add to the weight and cost. Lower temperature operation and the attendant lower winding resistance would reduce load loss, but would mean lower power capacity for the same size transformer unit.

3.6.3 Insulation Paper

Electrical insulation papers are paper types that are used as electrical insulation in many applications due to pure cellulose having outstanding electrical properties. Cellulose is a good insulator, having a dielectric constant significantly greater than one.



Figure 3.6: Insulation Paper

3.6.4 Bushings

Bushings are used for terminating windings on the tank body. In oil type transformer, terminal means of bringing the electrical connection from the inside to the outside of the tank. Terminal device in form of bushings brings the connection from the transformer insulation medium to the external insulation medium which in most cases is air, but can also be oil. The bushings are the things that have the electrical wires connected to them on top of the transformer. Transformer bushings are needed to carry the electrical charge completely through the grounding and on as a voltage output. The bushing is very important to the overall transformer because without it, conduction would not be achievable



Figure 3.7: HT and LT Bushing

3.6.5 Tap Changer

The purpose of a tap changer is to regulate the output voltage of a transformer. Tap changer substituting the quantity of turns in a single winding and there by changing the turn proportion of the transformer. The tapings shall be selected by an 'off load' tapping switch with an external hand wheel with provision for locking on to a selected tapping. The voltage operating positions, together with tap change positions might be clearly and permanently checked. This will also have an impact on transformer losses.

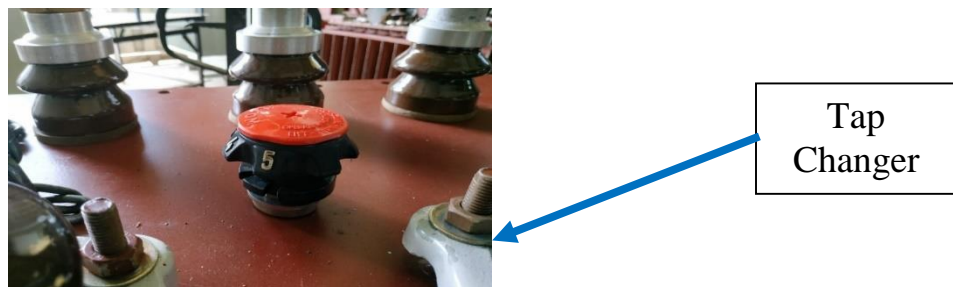


Figure 3.8: Off Load Tap Changer

3.6.6 Channel

Channel is a long pole which is sliced by the size required. Basic Power Engineering Ltd. Bought the channel from different companies. After the channel reached it sent to the hole drilling section. After completing the drilling channel, it sent to the core section to assemble the core on the channel. Four channels are needed to make one complete transformer.



Figure 3.9: Channel

3.6.7 Pressboard/Supporter

Amongst Channel and the core, a separator is used for protection. This Guarantees not to pass any immediate electric current between them. Hard board is used this for this kind of protection. This additionally have some other great things like this gives additional cushion to the core to get any harm by the channel. 5mm thick separator is used for ensuring the tight bonding between the channel and core. It is sufficiently hard that it we not break.



Figure 3.10: Channel to Core Supporter

3.6.8 Transformer Tank

The transformer tank should be manufactured from steel and might be of hearty development. Care should be taken at the assembling stage so as not have leaks during transportation or when the transformer is continuously worked at rated power. Transformer tank envelop the active part, filled with completely with oil. The body has no contact with the active part. The paint at the inward side is oil resistive and the external paint is hostile to consumption. Even if it just a container but required much consideration during design. Except for radiator components, every outside joint should be crease welded. The bearing surface of the tank to which bushings are clamped should be significantly level. Every single coordinating face of joints should be made oil tight and completed with a smooth surface to guarantee that the casketing materials make a satisfactory joint.



Figure 3.11: Transformer Tank

3.6.9 Radiator

The function of radiator is to dissipate heat generated in a transformer by way of radiation. Radiators are used in a transformer to cool the transformer oil through natural air or forced air flowing in these radiator fins. As the transformer oil temperature goes down due to cooling it goes to the transformer tank from bottom, cool the windings and gets heated, and then returns to the radiator for next cooling. This cycle repeats as the oil flow is also natural due difference in temperature of oil on bottom and top.



Figure 3.12: Transformer Radiator

3.6.10 Transformer Oil

Transformer oil or protecting oil will be oil that is stable at high temperatures and has superb electrical protecting properties. Transformer oil forms an exceptionally critical part in the transformer protection system. Breakdown voltage strength is the basic parameter of the transformer oil. Breakdown voltage should not be less than 50 kV after filtration. The fundamental crude material for the creation of transformer oil is crude Petroleum.



Figure 3.13: Transformer Oil

3.6.11 Oil Level Indicator

Oil level Indicator gives nonstop sign of the fluid level within a transformer's primary tank,
 ©Daffodil International University 20

conservator tank or load tap changer compartment. This device is needed to give a visual indication about the insulation fluid level. This device has been designed to give an alarm in case the fluid reaches the minimum or the maximum level according to the preset values.

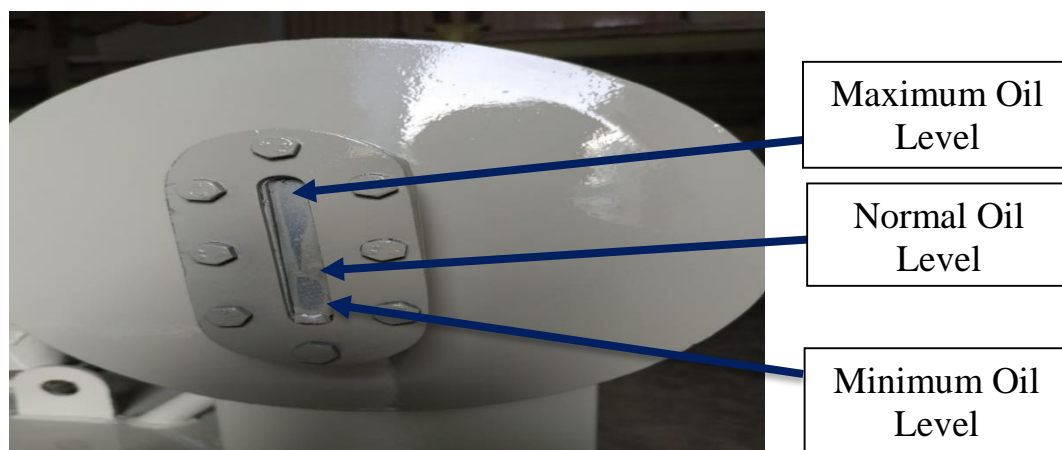


Figure 3.14: Oil Level Indicator

3.6.12 Conservator Tank

The conservator is located at the top of the transformer. The Conservator is designed to act as a tank for the transformer oil. The level of the oil in the transformer can rise and fall due to temperature. The increase of temperature can be caused either by a rise in ambient temperature or due to increased load on the transformer. An increase in temperature causes the oil in the transformer to expand. The conservator provides space for this expansion of the oil. The oil level indicator in the conservator needs to be monitored to ensure that the level of oil does not fall below the alarm limit. As the level of oil rises and falls inside the conservator, air enters and leaves the chamber. The air may carry moisture which may cause the oil to deteriorate.



Figure 3.15: Conservator Tank

3.6.13 Breathers

During reduction of oil, the outside air gets into transformer through breather. The breather has silica gel which absorbs the moisture. Also, the breather has an oil cap to stop entering the particles such as dust enter the transformer. Breather contributes to safe and reliable operation of the transformer.

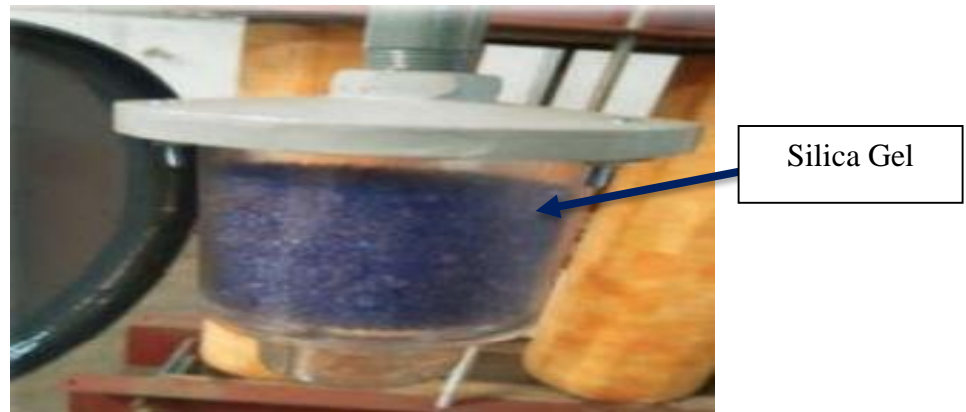


Figure 3.16: Breathers

3.6.14 Horn Gap

Arcing horn basically protected conductors used the insulators in high voltage. Transmission Line may damage during flashover. Over voltage on transmission line may occurs due to various reasons like- lightning strike, sudden load variation, fault etc. Due to this high voltage a flash over may take place which will blast the insulator. Horns are normally paired on either side of the insulator, one connected to the high voltage part and the other to ground. The horns can take different forms, for example simple cylindrical rods, circular guard rings.



Figure 3.17: Horn Gap

CHAPTER 4

Calculation and Manufacturing Process

4.1 Basic Calculation of a Transformer

We calculate all the things of 500kVA Transformer:

Table 4.1: Data table for Transformer

	HV	LV
Connection type	Delta	Star
Line Voltage	11000V	415V
Line Current	$= (\text{kVA} \times 1000) / (\sqrt{3} \times \text{line voltage})$ $= (500 \times 1000) / (\sqrt{3} \times 11000)$ $= 26.24 \text{A}$	$= (\text{kVA} \times 1000) / (\sqrt{3} \times \text{line voltage})$ $= (500 \times 1000) / (\sqrt{3} \times 415)$ $= 695.6 \text{A}$
Phase Voltage	Line Voltage=Phase Voltage	$415 / \sqrt{3} = 239.6 \text{ V}$ $\approx 240 \text{V}$
Phase Current	$26.65 / \sqrt{3} = 15.38 \text{ A}$	Line Current=Phase Current

Power P= 500kVA

Primary /line voltage =11000 Volt

Secondary / line voltage = 415 Volt

At first we need to find out the Diameter of a Transformer

Diameter $= 3.94 * (\text{kVA})^{1/4}$ [it can vary from 3.5-4]

$$= 3.94 * (400)^{1/4}$$

$$= 18.63 \text{ cm}$$

$$= 18.63 * 10 \text{mm} [1 \text{cm} = 10 \text{mm}]$$

$$= 186.33 = 186 \text{mm}$$

We can consider 186mm for rounding process

Let, Core width=180mm

The thickness of each stack pertaining to a particular core step is calculated as follows:

We consider step=S

$$S_1 = \sqrt{((186)^2 - (180)^2)}$$

$$=46\text{mm}$$

Let, Core width=165mm

$$S_2 = \sqrt{((186)^2 - (165)^2)} - S_1$$

$$= (85.85 - 46) \text{ mm}$$

$$=40\text{mm}$$

Let, Core width=150mm

$$S_3 = \sqrt{((186)^2 - (150)^2)} - (S_1 + S_2)$$

$$= (109.98 - 86) \text{ mm}$$

$$=24\text{mm}$$

Let, Core width=135mm

$$S_4 = \sqrt{((186)^2 - (135)^2)} - (S_1 + S_2 + S_3)$$

$$= (127.94 - 110) \text{ mm}$$

$$=18\text{mm}$$

Let, Core width=120mm

$$S_5 = \sqrt{((186)^2 - (120)^2)} - (S_1 + S_2 + S_3 + S_4)$$

$$= (142.12 - 128) \text{ mm}$$

$$=14\text{mm}$$

Let, Core width=105mm

$$S_6 = \sqrt{((186)^2 - (105)^2)} - (S_1 + S_2 + S_3 + S_4 + S_5)$$

$$= (153.52 - 142) \text{ mm}$$

$$=12 \text{ mm}$$

Let, Core width=90mm

$$S_7 = \sqrt{((186)^2 - (90)^2)} - (S_1 + S_2 + S_3 + S_4 + S_5 + S_6)$$

$$= (162.77 - 154) \text{ mm}$$

$$=9 \text{ mm}$$

Let, Core width=75mm

$$S_8 = \sqrt{((186)^2 - (75)^2)} - (S_1 + S_2 + S_3 + S_4 + S_5 + S_6 + S_7)$$

$$= (170.20 - 163) \text{ mm}$$

$$=7\text{mm}$$

$$S_9 = \sqrt{((186)^2 - (60)^2)} - (S_1 + S_2 + S_3 + S_4 + S_5 + S_6 + S_7 + S_8)$$

$$= (176.05 - 170) \text{ mm}$$

$$=6\text{mm}$$

Now, we need to select the Area,

At first we need to find out per core Area, $A_1 = \text{Width} * \text{thickness}$

$$= 180 * 46$$

$$= 8280$$

$$A_2 = 165 * 40$$

$$= 6600$$

$$A_3 = 150 * 24$$

$$= 3600$$

$$A_4 = 135 * 18$$

$$= 2430$$

$$A_5 = 120 * 14$$

$$= 1680$$

$$A_6 = 105 * 12$$

$$= 1800$$

$$A_7 = 90 * 9$$

$$= 810$$

$$A_8 = 75 * 7$$

$$= 525$$

$$A_9 = 60 * 6$$

$$= 360$$

Area = Total Area / 100

$$= (A_1 + A_2 + A_3 + A_4 + A_5 + A_6 + A_7 + A_8 + A_9)$$

$$= 26085 / 100$$

$$= 260.85 \text{ mm}$$

Per turns voltage = $4.44 * f * B_m * A * 10^{-4}$ [we can select B_m from 1.5-1.7]

$$= 4.44 * 50 * 1.60 * 260.85 * 10^{-4}$$

$$= 9.265 \text{ V}$$

Where, f = frequency

B_m = Flux density

A = Area

LT Turns = Secondary phase voltage / Per turns voltage

$$= 240 / 9.266$$

$$= 25.90$$

= 26 turns

Conductor Area Selected for 500kVA Transformer

Secondary Coil/LT Winding

Secondary Winding type=Helical Winding

Secondary Current, $P = \sqrt{3}VI$

$$I = P / \sqrt{3}V$$

$$I = KVA * 1000 / \sqrt{3} * 415$$

$$I = 00 * 1000 / \sqrt{3} * 415$$

$$= 695.6A$$

Current density for Cu in Oil Maximum 3.5

Let, We Consider,

Cu Current density = 3.03

Here,

We need LV side current = 695.6A

[We select conductor which current capacity is 695.7 which comes from this equation calculating value = $8.9 * 4.3 * 6 * 3.03$]

Arrangement of conductor = $3 * 2$

Conductor = $8.9 * 4.3$

Insulation = 0.5mm

Overall Size of Conductor = $9.4 * 4.8$

Total Turns = 26

Layer = 2

Per layer turns = $26 / 2$

$$= 13$$

Inter layer insulation = 0.5mm

In Diameter of coil LV = $(186 + 6)$ mm

$$= 192mm$$

Height of the Coil = $(9.4 * 3) * (13 + 1)$ [1 coil Extra for Helical Windings]

$$= 393 + (17 + 17 + 6) \quad \text{[Side ring/side gear upper 17mm and lower 17mm]}$$

$$= 393 + 40 \quad \text{Conductor per turn air gap = 6}$$

\therefore Height of the Coil = 433mm

Out Diameter of LV = $\{(4.8 * 2) * 2 + (4.8 * 2) * 2\} + \text{In diameter}$

$$\begin{aligned}
&=38.4+192 \\
&=230.4 +0.6 \text{ [layer insulation 0.8]} \\
&=231
\end{aligned}$$

$$\begin{aligned}
\text{Conductor Weight} &= (\text{In diameter} + \text{Out diameter}) / 2 \text{ [Mid diameter} = \text{In dia} + \text{Out dia} / 2] \\
&= (192 + 231) / 2 \\
&= 211.5 \\
&= 211.5 * 3.1416 * 26 \quad [\text{Length} = \text{mid diameter} * \pi * \text{LT Turns}] \\
&= 17275.65 * 8.9 * 4.3 * 6 \quad [\text{width} = 8.9, \text{thickness} = 4.3, \\
&\quad \text{Conductor number} = 6] \\
&= 3966836.682 * 0.0000089 \text{ [0.000089} = \text{constant density of copper]} \\
&= 35.30 * 3 \quad [3 \text{ coil}] \\
&= 105.91 + 10 [10 = \text{starting and finishing lead}] \\
&= 115.91 \text{ kg}
\end{aligned}$$

Primary Coil/HT Winding

In Diameter= 254 [LT to HT gap 23mm, but we can take maximum 25

\therefore Out diameter of LT + gap=231+23=254 in diameter of HT]

Current density= 3.11 Primary Current, $P = \sqrt{3} VI$

$$\begin{aligned}
\therefore I &= P / \sqrt{3} V \\
&= 500 * 1000 / 11000 * \sqrt{3} \\
&= 26.24 \\
&= 26.24 \text{ A [Line Current]} \\
&= 26.24 / \sqrt{3} \\
&= 15.15 \text{ [Phase Current]}
\end{aligned}$$

Table 4.2: Size of Wire

SWG	In	mm	SWG	In	mm
1	.300	7.620	21	.032	.813
2	.276	7.010	22	.028	.711
3	.252	6.401	23	.024	.610
4	.232	5.893	24	.022	.559
5	.212	5.385	25	.020	.5080
6	.192	4.877	26	.018	.4572
7	.176	4.470	27	.0164	.4166
8	.160	4.064	28	.0148	.3759
9	.144	3.658	29	.0136	.3454

10	.128	3.251	30	.0124	.3150
11	.116	2.946	31	.0116	.2946
12	.104	2.642	32	.0108	.2743
13	.092	2.337	33	.0100	.2540
14	.080	2.032	34	.0092	.2337
15	.072	1.829	35	.0084	.2134
16	.064	1.626	36	.0076	.1930
17	.056	1.422	37	.0068	.1727
18	.048	1.219	38	.0050	.1524
19	.040	1.106	39	.0052	.1321
20	.036	.914	40	.0048	.1219

For this Transformer,

We use 12.5 SWG(TPC) = 2.49mm [from the table]

Conductor area= $\pi D^2/4$

$$= 3.1416 \cdot (2.49)^2 / 4$$

$$= 4.86$$

Current density= 3.11A [Maximum current density=3.5]

Tapping for 2.5% to -7.5%

Primary turns =LV turns* Ratio

$$= 26 \cdot 45.9 \text{ [Ratio} = \sqrt{3} V_p / V_C = 1.732 \cdot 11000 / 415 = 45.9 \text{]}$$

$$= 1193.4$$

$$= (1193.4 \cdot 2.5\%) + 1193.4$$

$$= 29.83 + 1193.4$$

$$= 1223.23 = 1223$$

Turns /section =1223/6

$$= 203.87 = 204$$

Type of Coil=6 [normal coil 4, Tap coil =2]

We use paper covering Copper Wires,

Insulation=0.5mm

$$\text{Overall Size} = 2.49 + 0.5$$

$$= 2.99$$

Arrangement of Conductor = 1

Height of coil = 59

Layer = 11

In diameter = 254

$$\text{Out diameter} = \text{Conductor thickness} * \text{layer} + \text{Inter layer insulation}$$

$$= (2.99 * 2) * 11 + 1.08$$

$$= 43.92 + 1.08$$

$$= 66.86 + 254 \quad [254 = \text{HT In diameter}]$$

$$= 320.86 = 321 \text{ mm}$$

$$\text{Conductor Weight} = (\text{In diameter} + \text{Out Diameter}) / 2 \quad [\text{Mid diameter} = (\text{In Dia} + \text{Out Dia}) / 2]$$

$$= (254 + 321) / 2$$

$$= 287.5$$

$$= 287.5 * 3.1416 * 204 \quad [\text{Length} = \text{Mid diameter} * \pi * \text{HT Turns}]$$

$$= 184254.84 * 4.86 \quad [\text{Area of Wire} = 4.86]$$

$$= 895478.52 * 0.0000089 \quad [0.0000089 = \text{Constant density of copper}]$$

$$= 7.97 * 18 \quad [18 \text{ coil}]$$

$$= 143.46 \text{ kg}$$

4.2 Core Calculation

Window height = 453 mm [20mm more than LT coil]

Limb center = 332 mm [11mm extra from out diameter of HT; it can take maximum 20]

Diameter of core = 186mm

Table 4.3: Core plates dimension with quality

S/N	Length ₁	Width	Length ₂	Stack
A Core				

A ₁	453	180	813	46
A ₂	453	165	783	40
A ₃	453	150	753	24
A ₄	453	135	723	18
A ₅	453	120	693	14
A ₆	453	105	663	12
A ₇	453	90	633	9
A ₈	453	75	603	7
A ₉	453	60	573	6

B Core

B ₁	453	180	633	23
B ₂	453	165	618	20
B ₃	453	150	603	12
B ₄	453	135	588	9
B ₅	453	120	573	7
B ₆	453	105	558	6
B ₇	453	90	543	4.5
B ₈	453	75	528	3.5
B ₉	453	60	513	3

C Core

C ₁	152	180	844	46
C ₂	167	165	829	40
C ₃	182	150	814	24
C ₄	197	135	799	18
C ₅	212	120	784	14
C ₆	227	105	769	12
C ₇	242	90	754	9
C ₈	257	75	739	7
C ₉	272	60	724	6

4.3 Transformer Manufacturing Process

Here I have given the transformer manufacturing flow chart as shown in Figure 3.3.

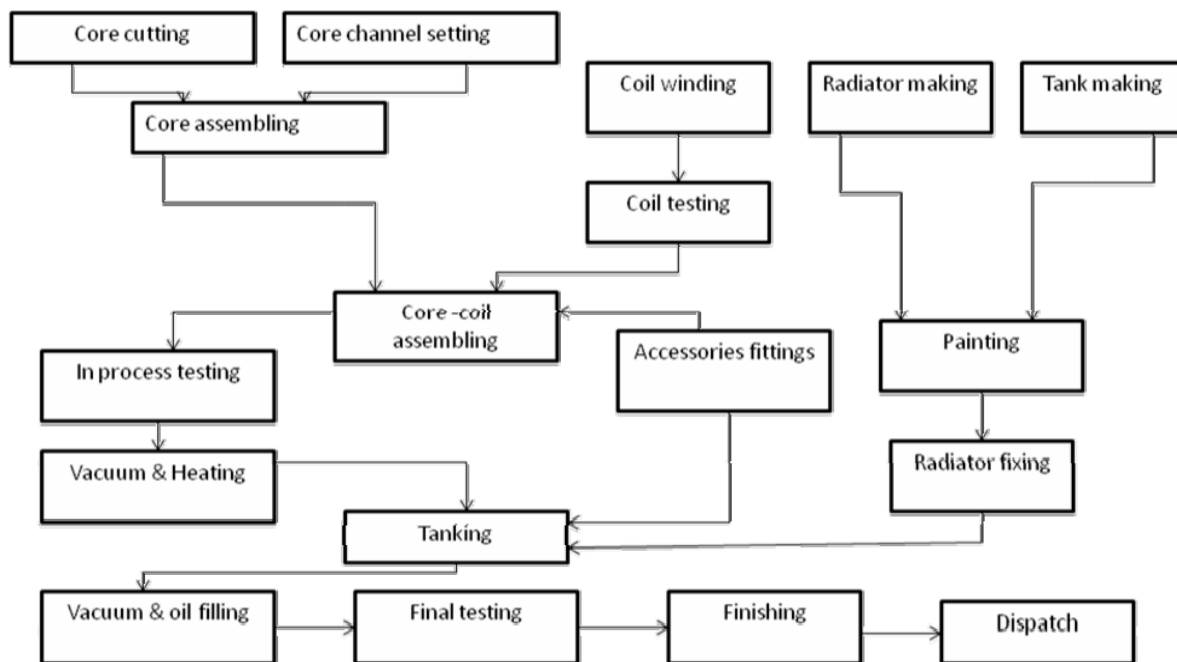


Figure 4.1: Transformer manufacturing flow chart

4.3.1 Core Cutting

After calculating the measurement of core we cut the core by using different machine to get our required shape. The core is made of Cold-Rolled High Grained Oriented (CRGO) silicon steel. The core cut of an angle 900 in rectangular shape and 450 for MITRED shape also cut “V” notch. Staking and Wound core 0.27 mm thick M4 grade silicon steel.



Figure 4.2: Cutting core 90°



Figure 4.3: Cutting “V” notch in Core B



Figure 4.4: Cutting Core 450 for MITRED shape

4.3.2 Core Assembling

The cores mitered and assembled in step lap formation. The mitered joints are provided with minimum gap. The clamping structure is a fabricated steel frame made from standard angle, channels or plate construction.

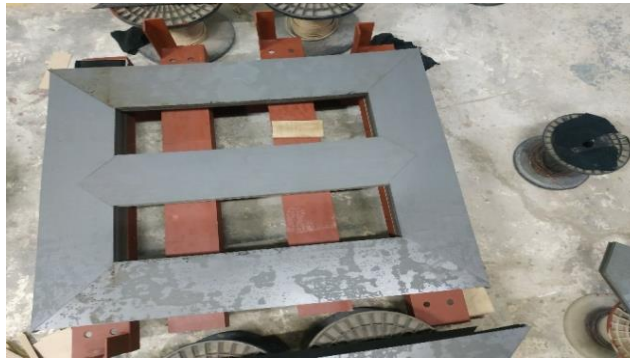


Figure 4.5: Core Arrangement

After arranging the core, we tight up the core with 4 channel and tie the rods and screw them shown in fig 5. After tight up the core cotton tape will be sprayed shown in fig 6. After tighten up the core, the upper two channels and C core is open for placing the two coils (LT and HT) into the core. Before placing the core, above the cotton tape there is 6mm insulation paper is wrapped into two parts (3mm+3mm); which is used for insulation between core and coil and give a bottom separator inside the three cores which separated between coil and channel shown in fig 7



Figure 4.6: Tighten the arranged Core



Cotton Tape

Figure 4.7: Cotton tape sprayed above core



Figure 4.8: Insulation paper and bottom Separator

4.3.3 Coil Windings

There are two windings wound over the transformer core which is protected from each other. Windings consists of few turns of copper coils packaged together, every package are associated in series to form of windings.

The low voltage winding is in cylindrical shape; the high voltage winding is in cylindrical or foil type. HT & LT windings are nothing but the calculated coil form of copper wire. So it will have sufficient capacity secured against short circuit and make the magnetic circuit more reasonable. The winding conductor is drawn to various sizes in round and rectangular shapes. The choice of conductor and insulation covering depend on the voltage class, current, cooling and insulation clearances. The cross section of the winding provides the necessary area to handle the current. The conductor is wound into coils.

The windings are such designed so as to ensure reduced axial stresses in Short Circuit conditions and also to withstand impulse and over-voltages. Some standard forms of coil windings are spiral, helical, interleaved disc and plain disc. For Power Transformers, both low voltage and high voltage windings are disc type, which give highest resistance against short circuit forces. It is ensured that proper tension is given on the winding for rigidity.



Figure 4.9: Coil Windings Machine

4.3.4 Core Coil Assembling

The transformer experiences dynamic forces due to frequent loading and unloading. The sudden loading and withdrawal of load creates a tensile stress on the winding in form of buckling forces or bursting forces. The construction of the CCA (Core Coil Assembly) by providing sufficient radial and axial supports prevents the stress from causing any damage to the windings.



Figure 4.10: Core Coil (HT & LT) Assembling

After placing the coil in the core it looks like fig 10. Head of the leg is tight by cotton and then again press board is placed top of the coil for insulation between coil and upper channel. Press board is cut according to the space between one core legs to other leg. After placing the press board C type of core is placed in the core legs to complete core designs.

4.3.5 Tap changer:

Tap change from + 2.5% to -7.5%

For our 1st value we pick up tap after 2.5% of total turns for 10V more or less. Because we know primary voltage always not same sometimes it may vary. It will regulate the output voltage by altering the number of turn and thereby changing the turn's ratio of the transformer. We brought out 1 wire after every 32 turns from the total turns of High tension winding, after turn out six wires form four steps we will connect those by a tap changer from 1 to 5 tap.

Generally, the Transformers are either Δ to Y or Y to Δ connected. If High voltage side Delta connected, then low voltage side Y connected and vice versa. We connected HT side is Delta connection and LT side is star connection.

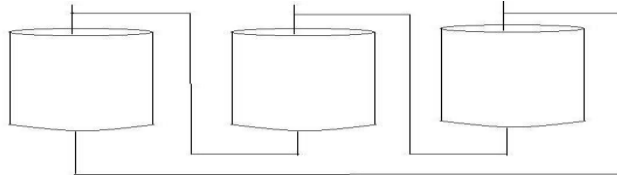


Figure 4.11: Delta connection Diagram



Figure 4.12: Delta Connection

For making star connection in LT side, we need to make 3 phase connection and common neutral with three coils. For that reason, we need to contact wire & contact material to connect with bushing.

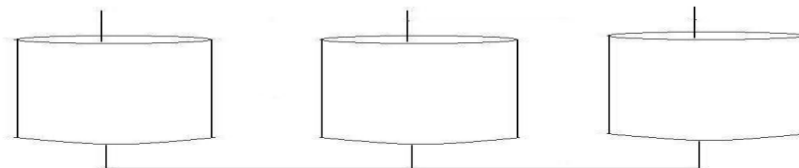


Figure 4.13: Star Connection Diagram



Figure 4.14: Star Connection

After Δ to Y Connection, we connect HT side with HT side Bushing and LT side with LT Side Bushing.



Figure 4.15: HT side with HT Bushing



Figure 4.16: LT Side with LT Side Bushing

After arranging all these things finally, the input and output points are connected with the copper bars. Copper bars are covered very tightly with cotton tape after welding. Then the transformer is ready to go for the next step of attaching bushing materials and for going to heat chamber.

4.3.6 Heat Chamber

Heating chamber is a place where heat generates. It can control temperature inside the heat of the transformer. Transformer is placing inside heat chamber because of increasing insulating resistance.



Figure 4.17: Heat Chamber

Inside the transformer, coil creates magnetic flux so that heat will produce. If inside of the transformer is not dry enough, then dielectric strength breaking down because of heat and power losses occurs. For that reason, it needs to dry enough the transformer. Transformer is kept inside the heat chamber for 48 hours at 900C. This heat chamber temperature ranges 80 to 1000C. After that prepared to delivery this transformer to customer shown in figure 18.



Figure 4.18: Ready Transformer

CHAPTER 5

Testing

5.1 Testing Process of Transformer

A number of tests are required to physically determine the electrical characteristics of power and distribution transformer.

Following test are done by Basic Power Engineering are given below:

- Oil Test
- Measurement of Voltage Ratio Test
- Resistance Test
- No Load loss
- Full Load loss
- Megger Test
- High Voltage test

5.1.1 Oil Test

Testing Method: Electric Breakdown Voltage

Oil Brand Name: Spiranol

At the time of oil testing we takes oil in a pot then give it to oil test machine. It shows the oil breakdown voltage. We do the same things 5 times and find out the Mean Breakdown voltage.

Table 5.1: Oil test Statics

Sample No	Breakdown Voltage in KV	Withstand Time	Average Value in KV	Remark
01	41.50	30 Sec	48.55	Satisfactory
02	45.11	30 Sec		
03	49	30 Sec		
04	52.31	60 Sec		
05	55.26	60 Sec		

Remark: Breakdown Voltage 32kV is considered to be satisfactory. Below this level oil is prescribed to be centrifuged.



Figure 5.1: Oil Test

5.1.2 Measurement of Voltage Ratio

Measuring the voltage ratio, we use voltage ratio test machine. At first we need to set the ratio meter and multiplier. Then we connect the wire in three phase off the transformer and match the measured ratio with the calculated ratio.

Tap Position	HT Voltage	LT Voltage	Calculative Ratio	Measured Ratio		
				Phase-H1	Phase-H2	Phase-H3
1	11275	415	27.16	15.27	15.25	15.26
2	11000	415	26.5	15.65	15.64	15.65
3	10725	415	25.84	16.05	16.04	15.06
4	10450	415	25.18	16.48	16.47	16.49
5	10175	415	24.51	16.92	16.91	16.95

Table 5.2: Voltage Ratio Test

Remarks: The Voltage Ratio between HT & LT side of the Transformer for every Tap position is OK Polarity of the Transformer is Subtractive.



Figure 5.2: Voltage Ratio Test

5.1.3 Resistances Test

For resistance test, firstly we need to conduct the meter to measure HT side resistance then we just hold on the probe of the clamp on meter to the HT lead like - AB, BC, CA and find the result for this side. We should repeat same procedure for getting the result of LT side also.

Table 5.3: LT Side Resistance (Principle Tap 3)

Phase to Neutral Connection	Measured Value (m ohm)
X1-N	0.00126
X2-N	0.00125
X3-N	0.00126
Average	0.001256

Table 5.4: HT Side Resistance (Principle Tap 3)

Phase to Neutral Connection	Measured Value (m ohm)
H1-H2	5.06
H2-H3	4.08
H3-H1	5.11
Average	5.083

Remark: Result is Satisfactory.



Figure 5.3: Resistance Test

5.1.4 Measurement of No-Load Loss

No load test is known as open circuit test. This test has been done without load. In this test LT neutral terminal and HT terminal are kept open. For testing the no load at first we connect three phase supply to LT terminals and we need a watt meter and clamp meter.

Table 5.5: No-Load loss test

Applied Voltage(V)	Rated RMS Voltage (V)	No-Load Current (A)	Wattmeter Reading (W)
415	415	$I_1=4.95$	551.43
		$I_2=4.82$	537.01
		$I_3=4.94$	550.38
		Average	546.27

No Load Loss = 546.27 W

Remark: Result is Satisfactory.



Figure 5.4: No Load Test

5.1.5 Measurement of Full Load Loss

Full load is also known as short circuit test. This test is used for measuring copper loss. The test

is conducted on the high voltage (HV) side of the transformer where the low voltage (LV) side or the secondary side is shorted. For this test we need a watt meter and clamp meter.

Table 5.6: Full Load loss test

Rated Current (A)	Applied Current (A)	Impedance Voltage (V)	Wattmeter Reading (W)
20.99	$I_1=20.99$	$V_1=441$	4600
	$I_1=20.98$	$V_2=457$	
	$I_1=20.99$	$V_3=448$	

Full Load Loss = 4.6 KW

Remark: Result is Satisfactory.



Figure 5.5: Full Load Test

5.1.6 Megger Test

When we do the megger test of a transformer at first we hold on the probe of HV side with Earthing then LV side with Earthing and then HV side with LV side for 30 second. We do the same things again for 60 second. By doing this process we get the values which is shown in the table 5.6

Table 5.7: Megger Test

Megger Test (Gega Ohms)			
Time	HT-E	LT-E	HT+LT
30 Sec	9.99	12.9	16.8
60 Sec	11.57	14.69	20.32

Remark: Result is Satisfactory.



Figure 5.6: Megger Test

5.1.7 High Voltage Test

For doing High Voltage test at HV winding we need to shorted the three-phase terminal of HV side, LV side and body/tank with the main earthing. At first, we have given 28kV from High Voltage test bench, then it come to barrier. After that it was gone through HT side of transformer. We have to apply 28kV for 1 min to the Transformer. If the transformer remains withstand after keeping this voltage for 1 min then it proves that the transformer keeps secure in voltage surges which may be caused by lightning or other over voltage.



Figure 5.7: High Voltage Test

Remark: Result is Satisfactory.

CHAPTER 6

Supplementary Part

6.1 Recommendation

Within my internship period, I gather all practical knowledge about transformers manufacturing from Basic Power Engineering Limited. Although, they need to increase some facilities:

- They should increase the manufacturing quality.
- They have not enough technicians and manpower as a result they can't deliver huge amount of products at a time. So, they should appoint more manpower.
- They should increase their testing number for more accurate efficiency.
- They did not have sufficient amount of testing meters. So, they should increase the amount of testing meters.

6.2 Conclusion

This internship has given me very crucial practical experience about transformer manufacturing which gives me confidence about practical field. I have gained new knowledge, skills and met so many new people. I got insight into professional practice. Demand of practical work experience has no other alternative in today's job market. This was a great opportunity for me to achieve this experience. The internship was also good to find out what my strengths and weaknesses are. I feel very proud to be an intern of Basic Power Engineering Limited. It is a great chance to gather knowledge of corporate world before entering the job field. I think that, the practical experience that I gathered in Basic Power Engineering Limited will help me in my professional life.

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