A Briefly Concept on the Features of Switchgears, PFI and Transformer

A Project and Thesis submitted in partial fulfillment of the requirements for the Award of Degree of Bachelor of Science in Electrical and Electronics Engineering.

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DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

FACULTY OF ENGINEERING

DAFFODIL INTERNATIONAL UNIVERSITY

Letter of Transmittal

August, 2019

To

The Supervisor

Department of EEE

Daffodil International University

Dattapara, Ashulia,

Savar, Dhaka.

Subject: Submission of Intern Report.

Dear Sir,

Please find enclosed the intern report entitled "A Briefly Concept on the Features of Switchgears, PFI and Transformer" .The study has been carried out in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronics Engineering.

In carrying out the study, I have followed supervisor's advice and collected.

Required information from several text books, reference books, web sites and other sources. I think you will find it useful and informative; I would be glad to furnish you explanations or clarifications if required.

Sincerely yours,

_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

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Declaration

I do hereby cheerfully declare that the work presented in this report entitled "A Briefly Concept on the Features of Switchgears, PFI and Transformer" has been carried out by us and has not been previously submitted to any other university, college or organization for an academic qualification, certificate or diploma/degree.

I hereby warrant that the work that has been presented here does not breach any existing copyright. I further undertake to indemnify the university against any loss or damage arising from breach of the foregoing obligations.

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Certificate

This to certify that the report entitled “A Briefly Concept on the Features of Switchgears, PFI and Transformer” is the valid record of the work done by Md. Rafiqul Islam, Md. Masud Rana & Md. Mobinul Islam for Partial fulfillment of the requirement of the degree of B.Sc. in Electrical and Electronics Engineering (EEE) from Daffodil International University.

This work has been carried out under my guidance and is a bonfire record of valid works carried out successfully.

Countersignature

Abu Bakar Siddique

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APPROVAL

This Thesis titled "A Briefly Concept on the Features of Switchgears, PFI and Transformer" submitted by Md. Rafiqul Islam, Md. Masud Rana & Md. Mobinul Islam to the Department of Electrical & Electronics Engineering, Daffodil International University has been found as satisfactory & accepted for the partial fulfillment of the requirement for the degree of Bachelor of Science in Electrical & Electronics Engineering.

Board of Examiners:

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ABSTRACT

The internship program is very helpful to bridge the gap between the theoretical knowledge and real life experience as part of Bachelor of Science in Electrical & Electronics Engineering program. Their internship report has been designed to have a practical experience through the theoretical understanding. Classroom discussion alone cannot make a student perfect in handling the real engineering situation; therefor it is an opportunity for the students to know about the real life situation through their program.

The report is broadly categorized in six different parts. At first time is introduction, objectives of the study, scope of the report, methodology of the study, and limitation. Part two describes the overview of Tokai Power Product Ltd (TPPL), major works involved, territory, supply chain, mission, vision and strategy, operation, departments of Tokai Power Product Ltd, some of power manufacturing company in Bangladesh. Part three focuses on Literature Review. Part four focuses on transformer manufacturing. Part five focuses on switchgear. It includes circuit breaker, isolator and switch, importance of power factor, transformer fault and protection. Part six narrates a concluding summery, future work and references.

In their internship report, transformer manufacturing process of Tokai Power Product Ltd (TPPL) as well as switchgear & protective devices were studied. I learn here how

Can transformer work? Also know how power factor is calculated.

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Table of Contents

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List of Figure

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List of Tables

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CHAPTER 1

INTRODUCTION

1.1 Background of Bangladesh power sector

In 1972, the first Government of Bangladesh, in an effort to speed up the investment in the sector issued an Ordinance creating the Bangladesh Power Development Board (BPDB) as the successor organization of the power side of EWAPDA. At first BPDB used to generate transmit and distribute power. BPDB started generating power and transmission responsibility was given to PGCB. During 1972 to 1995, BPDB has increased the generating capacity in the country to 2818 MW, and the length of its 230 and 132 KV transmission networks to 419 KM and 2469 KM. For the first time in December 1982, the eastern and western halves of the country were electrically connected through the commissioning of double circuit 230 KV transmission line across the Jamuna River energized at 132 KV between Ishurdi and Tongi called the first East-West Interconnector. Generation sources were diversified to include a 230 MW hydropower station at Kaptai on the Karnaphuli River and natural gas and imported fuel based, open and combined cycle power plants at different locations of Eastern and Western part of the country. The distribution networks of all major towns and cities had been linked through 230 KV and 132 KV inter-cities. In order to intensify the pace of rural electrification, the Government issued as ordinance in 1977 establishing the Rural Electrification Board (REB), a semi-autonomous agency charged with the responsibility of planning, developing, financing and construction of rural distribution networks, promoting the establishment of Rural Electric Cooperatives (Palli Bidyut Samities), handing over the constructed rural networks to them, assisting the PBSs to operate and maintain the rural networks and monitoring their financial performance. The REB has so far constructed over 46,000 Km of distribution lines and provided over 950,000 consumers connections in the rural areas (As of June, 1995). Usually, BPDB used to distribute power to mainly the urban areas except the metropolitan city of Dhaka. The responsibility of distributing power in Dhaka was given to Dhaka Electric Supply Authority (DESA). Later, DESA went through lots of controversies and corruption. Then Bangladesh government formulated National Energy Policy in 1996 and segregated power generation, transmission, and distribution functions in to separate services. Government created a new subsidiary named Dhaka Electric Supply Company Ltd. (DESCO) and

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1.2 History of TOKAI Power Products Ltd

Founded in 1997, Tokai Power Products Ltd. (TPPL) has been playing a part in the steady growth of Bangladesh economy by contributing in various aspects of power generation, transmission and distribution. The company envisions a prosperous Bangladesh and strives to complement the public and private sector initiatives by providing total power solutions to our valued customers. Maximizing customer value being our prime focus, Tokai Power Products Ltd. has earned profound name and reputation in last two decades through their quality service delivery and customer centric approach. Run by vastly experienced veteran engineers, the company incorporates the effective balance of youth and experience; and operates uncompromisingly with ethical management practice along with its core engineering expertise.

Besides offering turnkey engineering solutions, TPPL applies appropriate technology and efficient process in their manufacturing and testing facilities which is well-equipped to produce and assemble power and distribution transformers, HT and LT switchgear panels, PFI and other equipment's associated with electrical power transmission and distribution.

TPPL, with its highest order of manufacturing and administrative standard, has been certified as an ISO 9001:2008 company and we also give utmost importance to the health and safety of our prized employees. With quality, reliability and customer service at the heart of our values, Tokai Power Products Ltd. boasts a rich clientele featuring a host of giant conglomerates and power utilities steering the forward-moving Bangladesh.

1.3 Objective of the Internship

The first objective is to complete EEE441 and EEE457 course which is an essential part of completing Bachelor in EEE at Daffodil International University (DIU). Before doing this internship we had only theoretical knowledge over these topics but on completion of internship in TOKAI Power Products Ltd we have earned practical knowledge also. The following list summarizes our internship goals.

- ✓ Understanding company management.
- ✓ Understanding industrial environment.
- ✓ Acquiring practical knowledge about transformer and relay protection.
- ✓ Idea about safety

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1.4 Scope of the Study

The major goal of this study was to know the manufacturing process of transformer, switchgear, PFI LT panel and HT panel. Without good understanding about the manufacturing process from foreman, technician and worker it is not possible for me to know the design criteria etc. This is my first time to publicize myself in the practical world. The report covers the manufacturing, designing and assembling of transformer, switchgear and PFI panel of Tokai Power Products Ltd (TPPL).

1.5 Research Methodology

The report is mainly based on information provided by different department of TOKAI Power Products Ltd and my own study. I have to used many data source to fulfill this internship report. Both primary and secondary data sources had been used in preparing this report.

1.5.1 Primary Source

The information is gathered by personal observation and direct conversation with the engineers at TOKAI

1.5.2 Secondary Source

The company website and various single line diagram provided by the engineers whom we worked with.

1.5.3 Limitations of the study

Data collection was not that tough but there were some limitations in collecting information. The limitations are given below:

- Although the permission has been taken but as it’s an organization it has some limitations of providing information. It was difficult to make the report as per the requirement.
- As a fresh graduate I have some lacking of collecting information or the procedures of collecting prime information.
- The time three month is not enough for a research or study the whole organization. But I have tried my best to complete my report as per the requirements.
- The engineer in charge of the factory was not available all the time due to busy in official work; therefore I had to depend on the information from the technicians and workers. Although the engineers and the supervisor were too helpful to share the Information’s which are required for this report.

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CHAPTER 2

COMPANY PROFILE

2.1 Tokai Power Product Limited (TPPL)

Tokai Power Products Ltd. (TPPL) started its journey in 1997. Since then Tokai Power Products Ltd. (TPPL) has continued to carry on the business of manufacturing assembling and marketing of all types of power products to meet the demands of our changing times. By successful planning and providing quality products and services it has been possible to satisfy the various needs of the customers. As a result, TPPL has been able to achieve steady growth. Initially TPPL started assembling and marketing of electrical equipment for Apartment and Industrial application. IT has steadily expanded and now providing Electrical, Mechanical and Electronic products for Apartment, Commercial and Industrial applications. Today, this company has achieved a sound position in this area of manufacturing. TPPL is dedicated for developing integrated controlling system and new applications of advanced electronic technology for heavy electrical machinery. In short, TPPL is committed for superior performance and constantly advancing towards a goal to meet the users need perfectly. In 2001 Modernization of Gazipura factory for manufacturing of Transformer and different types of electrical equipment's completed. 2002 Started marketing of forklift, escalator, elevator, air compressor, soundproof canopy, best qualities have house electrical accessories for multipurpose uses. In 2003 Completed Supply and Installation of 5MVA Sub-Station Equipment at Barendra Multipurpose Project.

2.2 Location & Contact Information

Today, the factory is established on a land of 2 acres, consisting of 35 technicians and helpers in total the factory has separate departments for PFI and Switchgear and transformers. The factory is complete with all the machineries required to manufacture transformer. Even the tank of the transformer and other small materials or equipment is built inside the factory, so there is no outside assistance required for this factory to manufacture their products. The expansion process of the factory is going on.

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152/1/H, Green Road (8th Floor) Panthapath,
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Phone: 880-2-8141875, 9146149
Fax: 880-2-9111267
E-mail: tokai_powers@yahoo.com, tokai@citech.net

The link for the dedicated website of TOKAI Power Products is given below:
www.tokaipower.com

2.3 Design, Supply & Services by Tokai

- Industrial, commercial, residential electric
- Electrical Lift
- Power Station
- Sub-station work
- Rewiring and upgrading electric works
- Turnkey project
- KWH/ Energy Meter

2.4 Manufactured by Tokai

- Distribution transformer
- High tension switchgear work
- Low tension switchgear
- Motor control center
- Diesel & Gas generating set
- Power factor improvement plant

2.5 Major Work Involved

To provide distribution transformer, Low tension switchgear (LT), High tension switchgear (HT) and power factor improvement (PFI) to customer.

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CHAPTER 3

LITERATURE REVIEW

3.1 Introduction

Electricity is a phenomenon that begins in the quantum state of elements, and is associated with the flow of electrical charge naturally present in elements. Electricity can disperse a number of effects, such as static electricity, lighting and electromagnetic induction very prominently. Electrical energy is easier to transport from one place to another, put more simply put, electrical energy can be transported via electrical wires, where transfer of mechanical, heat and chemical energy require massive transport facility. To make the transfer of electrical energy from the generation plant to our drawing room possible and to extend the electrical power to the all people, hence this complex system is divided into three parts:

a. Generation System

b. Transmission System

c. Distribution System

3.2 Generation

As by the law of conservation of energy states that; "energy cannot be created nor destroyed; only it can be changed from one form to another". The generation of electricity is bound by this principle. Generation of electricity requires some other form of energy to be converted into electrical energy since electrical energy does not occur naturally that can be harvested. So other forms of energy such as mechanical, chemical are used as a source to harvest electrical energy. These energies are converted into electrical energy by means of complex machineries. The fundamentals were discovered by Michael Faraday during the early 1830's. His basic concepts are still used today; electricity is produced by the movement of a loop of wire, between magnetic poles, much like an electric motor. The first commercial generation of electricity began in 1882. The generation units are also known as power plants, where the very first power plants ran on water (Hydroelectricity) or coal (heat engine).

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Sources of generation include:

- Coal
- Natural Gas
- Nuclear
- Hydroelectricity Other

Renewable energy sources

3.3 Transmission

The next step after the generation is the transmission. Usually the generation plant is quite distant from the consumers, so here the voltage level for transmission is raised since high voltage has its own advantages, discussed on later.

Generally, transmission is divided into two categories they are:

a) Primary Transmission

b) Second Transmission

3.3.1 Primary Transmission

The primary transmission line is the longest line connecting the generator to the primary. So in order to facilitate the transmission with minimum loss of power, the voltage level is at its peak at 132KV. It is transmitted by a 3-phase, 3-wire delta connected overhead system. This forms the primary transmission. In Bangladesh and also abroad, these are usually located outside the city.

3.3.2 Secondary Transmission

The primary transmission connects to the receiving stations. Here the voltage is reduced 132KV to 33KV by transformers. From here, the electric power is transmitted to other substations located at various parts of the city. This forms the secondary transmission.

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3.4 Distribution

The last step for providing the power to our homes is the distribution system. The distribution system consists of subsystems and distribution systems. This can be further classified as:

3.4.1 Primary Distributor

Here the secondary transmission line terminates at the substation; here the voltage is farther step down from 33KV to 11KV, in a three phase delta connected system. In Bangladesh, industrial consumers directly tap their power lines from which they have their own sub-stations.

3.4.2 Secondary Distributor

This is the final pit stop for the electrical energy line. The power from primary distributor (11kv) is connected to distribution sub stations. These sub-stations are comparatively smaller in size and located near residential areas. More transformers are used to further step down the voltage to 440V. Here the transmission line system is changed to star connected line. This has its own advantages. In a star connected system, one neutral line is taken out and treated as a single phase line and the voltage between any phases to neutral is 240V that is the standard voltage for house hold appliances and machines in Bangladesh. The phase to phase voltage is 440V which is called a three phase line. This is also required for large and medium office and apartment complexes where heavy machineries such as elevators, escalators, central air conditioning systems and large motors are used. The requirement of line is based on the connected load directly.

3.5 Need for High Voltage

Transmission of electric power is carried out in a very high voltage. There are reasons why this transformer is used to step up the voltage where needed. They are:

- Higher voltage reduces the required volume of conductors.
- Higher voltage increases transmission efficiency.
- It decreases the line drop percentage.

3.6 Importance of Power System Protection

Electricity is generated, transmitted, and then distributed to industrial, commercial and domestic consumers. It is important to protect the large investment in equipment, and to ensure

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the safety of operators and consumers. Considering our need for uninterrupted power, protection is a mandatory part of any power system. Protection has been in practice, ever since the introduction of power systems more than a century ago. In that sense power system protection is a general knowledge of power systems. The engineers should be familiar with fundamental protection systems of three phase system, used in almost all generation, transmission and distribution.

3.7 Protection Equipment

In TOKAI power products we saw this company assemble the transformers and switchgear protection. To assembling this products, they care about protection and they follow:

3.7.1 Need of Transformers

As discussed earlier, it is seen that for the sake of efficient transmission and distribution, step up and step down of voltage is required in almost every stage of it. This action is done by transformers of different capacity. In general, transformer has the ability to step up and down the voltage levels ideally without any loss of energy in the process. In transmission and distribution systems, according to necessity, the voltage levels are stepped up and down. Voltage is stepped up in primary transmission because since loss is denoted by W=I2R, high current will result in higher loss. To minimize the loss, current is brought down and in turn, voltage is raised. But voltage level near to consumers are stepped down because the rated voltage level for most of the consumer appliances are low, so high voltage will result damage to the appliances.

3.7.2 Importance of Switchgear

The equipment in the transmission and distribution system handles a large amount of voltage and current. It is very likely for faults to occur and it can have devastating effects on the equipment both technically and financially. So to offer some kinds of protection to these devices, switchgear system is introduced. A combination of disconnect switches and breakers used to isolate equipment in substations. Switchgear system consists of many individual equipment put together to function as a unit

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CHAPTER 4

TRANSFORMER

4.1 Introduction

Transformer is a static device which transforms electrical energy from one circuit to another without any direct electrical connection and with the help of mutual induction between two windings. It transforms power from one circuit to another without changing its frequency but may be in different-voltage-level. Transformer is a device that is used to transfer electric energy from one circuit to another, especially a pair of multiply wound, inductively coupled wire coils that effect such a transfer with a change in voltage, current, phase, or other electric characteristic.

4.2 Basic Theory of a Transformer

Whenever we apply alternating current to an electric coil, there will be an alternating flux surrounding that coil. Now if we bring another coil near the first one, there will be an alternating flux linkage with that second coil. As the flux is alternating, there will be obviously a rate of change in flux linkage with respect to time in the second coil. Naturally emf will be induced in it as per Faraday's law of electromagnetic induction. This is the most basic concept of the theory of transformer.

The winding which takes electrical power from the source, is generally known as primary winding of transformer. Here in our above example it is first winding. Transformer basic winding flux is show in Fig 4.1[1].

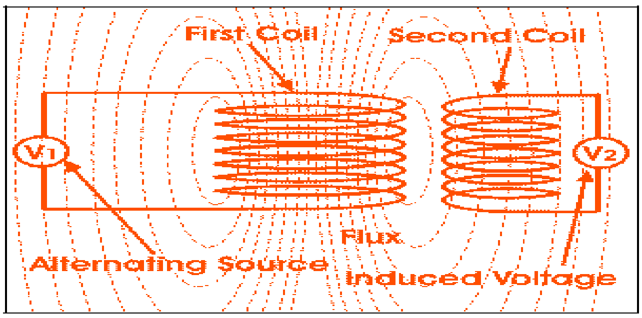

Figure 4.1: Transformer Winding Flux [1]

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The winding which gives the desired output voltage due to mutual induction in the transformer, is commonly known as secondary winding of transformer. Here in our example it is second winding. Transformer winding is show in Fig 4.2.

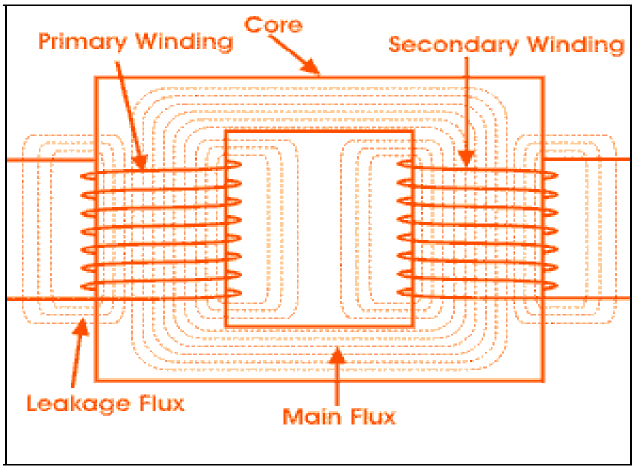

Figure 4.2: Transformer Winding [1]

The above mentioned form of transformer is theoretically possible but not practically, because in open air very tiny portion of the flux of the first winding will link with second; so the current that flows through the closed circuit of later, will be so small in amount that it will be difficult to measure. The rate of change of flux linkage depends upon the amount of linked flux with the second winding. So, it is desired to be linked to almost all flux of primary winding to the secondary winding. This is effectively and efficiently done by placing one low reluctance path common to both of the winding. This low reluctance path is core of transformer, through which maximum number of flux produced by the primary is passed through and linked with the secondary winding. This is the most basic theory of transformer. Transformer Emf direction show in Fig 4.3.[1]

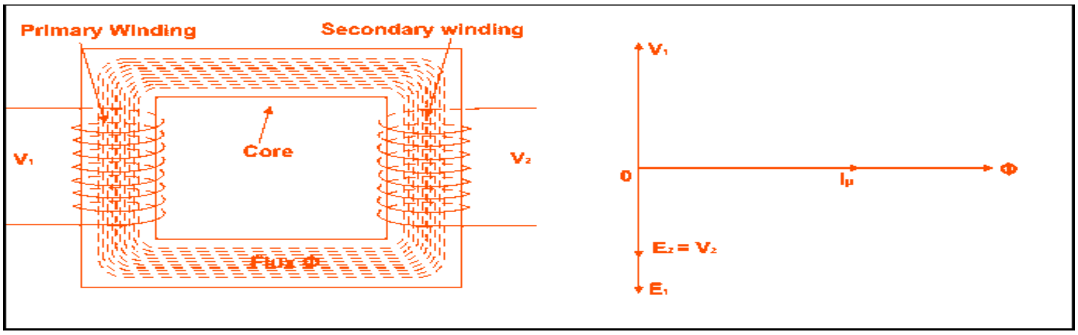

Figure 4.3: Transformer Emf Direction [1]

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Let's say, T is number of turns in a winding,

Φm is the maximum flux in the core in Wb.

As per Faraday's law of electromagnetic induction,

$$emf,\ e = -T\frac{d\phi}{dt}$$

Where φ is the instantaneous alternating flux and represented as,

$$\phi = \phi_m sin\, 2\pi f t$$
$$Hence,\ e = -T\frac{d(\phi_m sin 2\pi f t)}{dt}$$
$$\Rightarrow e = -T\phi_m cos(2\pi f t)\ \times 2\pi f$$
$$\Rightarrow e = -T\phi_m \times 2\pi f cos(2\pi f t)$$

As the maximum value of cos2πft is 1, the maximum value of induced emf e is,

$$e_m = T\phi_m \times 2\pi f$$

To obtain the rms value of induced counter emf, divide this maximum value of e by √2.

$$Then,\ E = \frac{2\pi}{\sqrt{2}} \times \phi_m f T$$

$$E = 4.44\phi_m f T\ Volts\ \ (\ Since\ \frac{2\pi}{\sqrt{2}} = 4.44)$$

This is EMF equation of transformer.

If E1 & E2 are primary and secondary emfs and T1 & T2 are primary and secondary turns then, voltage ratio or turns ratio of transformer is,

$$\frac{E_1}{E_2} = \frac{4.44\phi_m f T_1}{4.44\phi_m f T_2} = \frac{T_1}{T_2}$$

$$\Rightarrow \frac{E_1}{E_2} = \frac{T_1}{T_2}$$

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4.3 Transformer Losses

The different losses in the transformer are as follows:

i. Copper losses

ii. Core losses

4.3.1 Copper losses (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.

4.3.2 Core or Iron Losses

There are two types of core or iron losses in a Transformer.

i. Hysteresis losses

ii. Eddy current Losses

4.3.2.1 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 transformer losses are proportional to the frequency, and is a function of the peak flux density to which it is subjected.

We can find Hysteresis losses by this formula.

$$W_h = K_h f (B_m)^{1.6} \; watts$$

4.3.2.2 Eddy Current Losses

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 using laminated or similar cores.

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4.4 Category of Transformer

The categories of transformer are given below:

- Variable Autotransformer
- Induction Regulator
- Grounding Transformer
- Leakage (or stray field) Transformers
- Resonant Transformer
- Constant Voltage Transformer
- Instrument Transformer
- Current Transformer
- Potential Transformer (Voltage Transformer)
- Combined Instrument Transformer
- Pulse Transformer
- RF Transformer
- Air-core Transformer
- Ferrite-core Transformer
- Transmission-line Transformer

4.5 Types of Transformers

Transformers can be categorized in different ways, depending upon their purpose, use, construction etc. The types of transformer are as follows:

- Step Up Transformer & Step Down Transformer- A transformer that increases voltage from primary to secondary (more secondary winding turns than primary winding turns) is called a step-up transformer. Conversely, a transformer designed to do just the opposite is called a step down transformer. Generally used for stepping up and down the voltage level of power in transmission and distribution power system network.
- Three Phase Transformer & Single Phase Transformer- Former is generally used in three phase power system as it is cost effective than later. But when size matters, it is preferable to use a bank of three single phase transformer as it is easier to transport than one single

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three phase transformer unit.

- Electrical Power Transformer, Distribution Transformer & Instrument Transformer- Power transformers are generally used in transmission network for stepping up or down the voltage level. It operates mainly during high or peak loads and has maximum efficiency at or near full load. Distribution transformer steps down the voltage for distribution purpose to domestic or commercial users. It has good voltage regulation and operates 24 hrs a day with maximum efficiency at 50% of full load. Instrument transformers include C.T and P.T which are used to reduce high voltages and current to lesser values which can be measured by conventional instruments.
- Two Winding Transformer & Auto Transformer- Former is generally used where ratio between high voltage and low voltage is greater than 2. It is cost effective to use later where the ratio between high voltage and low voltage is less than 2.
- Outdoor Transformer & Indoor Transformer- Transformers that are designed for installing at outdoor are outdoor transformers and transformers designed for installing at indoor are indoor transformers.

4.6 Distribution Transformer

TPP Transformers are manufactured in accordance to the requirement of individual customer request to one or more internationally recognized standard including IEC-76, BSS-171 ANSI-C.57 and VDE-0532. TPP makes the conventional / sealed oil/ immersed, natural cooled, single phase & three phase distribution transformers suitable for outdoor and indoor installation.

Power Range

5KVA to 500KVA (Single Phase)

RATED VOLTAGE

Single phase: 6.35/0.24kV

Three phase: 11/0.415kV

Vector Group

Single phase: 1/1-0 Three phase: Dyn11

FREQUENCY: 50 Hz Cooling: ONAN

BIL HV: 75kV LV: 3kV

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Temperature Rise

(Above ambient of 40 C)

winding: 60 C, Oil: 50 C

4.7 Transformer Construction

Basically depending on construction types, there are two types of transformer constructions. This variation depends on the arrangement of winding around the core. They are:

a. Shell type

b. Core type

a. Shell Type

For shell type construction, when windings are surrounded by the core, the transformer is in shell form. For this type, the windings are in rectangular shape. The different layers are insulated by paper. One of the major advantages of shell type transformers is that they are much more protected from the winding because it is surrounded by the cores. Another advantage would be that they cost roughly 5% less.

b. Core Type

The other form of construction is the core type transformer, the basic of this technique is, and the windings are places around the core. The both high voltage and low voltage are wound around, usually placing the high voltage on the inner part and separated from each other by heavy insulation. The shape of windings may be rectangular, circular or oval, depending on size of the transformer. Mostly, circular windings are used to construct higher rating transformers. Core type transformers have better insulation due to their design and easier to construct then shell type.

4.8 Transformer Construction Procedures

For the simple construction of a transformer, you must need two coils having mutual inductance and a laminated steel core. The two coils are insulated from each other and from the steel core. The device will also need some suitable container for the assembled core and windings, a medium with which the core and its windings from its container can be insulated. In order to insulate and to bring out the terminals of the winding from the tank, apt bushings that are made from either porcelain or capacitor type must be used. In all transformers that are used commercially, the core is made out of transformer sheet steel laminations assembled to provide a continuous magnetic path with minimum of air-gap included. The steel should have high permeability and low

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hysteresis loss. For this to happen, the steel should be made of high silicon content and must also be heat treated. By effectively laminating the core, the eddy-current losses can be reduced. The lamination can be done with the help of a light coat of core plate varnish or lay an oxide layer on the surface. For a frequency of 50 Hertz, the thickness of the lamination varies from 0.35mm to 0.5mm for a frequency of 25 Hertz. Laminated core transformer is show in Fig 4.4[2]

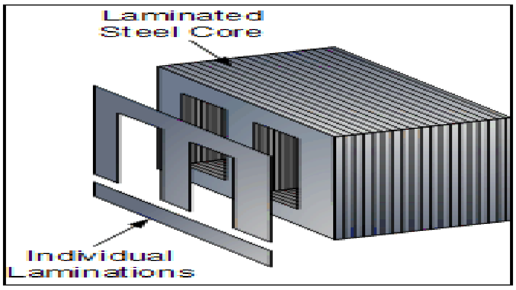

Figure4.4: Transformer Laminated Core [2]

4.8.1 Construction of the Core

Generally, the name associated with the construction of a transformer is dependent upon how the primary and secondary windings are wound around the central laminated steel core. The two most common and basic designs of transformer construction are the closed-core transformer and the shell-core transformer. In the "closed-core" type (core form) transformer, the primary and secondary windings are wound outside and surround the core ring. In the "shell type" (shell form) transformer, the primary and secondary windings pass inside the steel magnetic circuit (core) which forms a shell around the windings as shown below in fig 4.5[2]

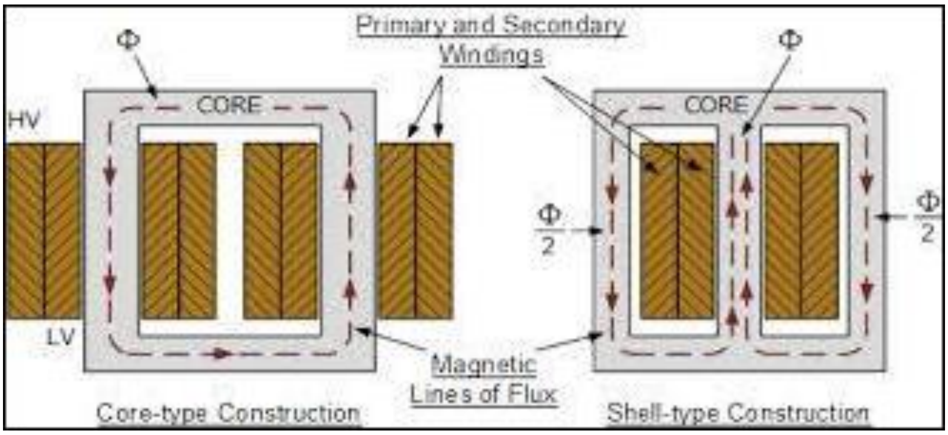

Figure 4.5: Core Type & Shell Type Transformer [2]

In both types of transformer core design, the magnetic flux linking the primary and secondary windings travels entirely within the core with no loss of magnetic flux through air. In the core type transformer construction, one half of each winding is wrapped around each leg (or limb) of the

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transformers magnetic circuit as shown above. The coils are not arranged with the primary winding on one leg and the secondary on the other but instead half of the primary winding and half of the secondary winding are placed one over the other concentrically on each leg in order to increase magnetic coupling allowing practically all of the magnetic lines of force go through both the primary and secondary windings at the same time. However, with this type of transformer construction, a small percentage of the magnetic lines of force flow outside of the core, and this is called "leakage flux". Shell type transformer cores overcome this leakage flux as both the primary and secondary windings are wound on the same center leg or limb which has twice the cross-sectional area of the two outer limbs. The advantage here is that the magnetic flux has two closed magnetic paths to flow around external to the coils on both left and right hand sides before returning back to the central coils. This means that the magnetic flux circulating around the outer limbs of this type of transformer construction is equal to $\Phi/2$.

4.8.2 Core Clamping

After the core arranging has been completed, it is clamped on tightly at both the top and bottom ends. The purpose of it is to keep the core tightly bolted and to keep its physical structure strong, because on the latter part, much movement is necessary to be made in order to finish its construction. The figure below shows the clamped core. Core insulation after the clamping has been completed, pillars of the core is properly insulated by insulation grade paper and wrapped around by cotton thread. The purpose of it is to provide extra protection in case of failure of the winding that may result in short circuit. A figure below comprises the following:

4.8.3 Bushings

Larger transformers are provided with high-voltage insulated bushings made of polymers or porcelain. The bushing must be able to provide the insulation and the control of the electric gradient without letting out the transformer oil out. Both the insulators are made of similar material, but only differ in size and shape but possess similar characteristics. Two types of bushings are used in the transformer construction. They are:

1. Pin type
2. Shackle type

The pin type insulator is used in the Low Tension side (LT).Where the shackle type is used in the High tension side (HT).Pin type and shackle type bushing show in Fig 4.6 and 4.7.

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Figure 4.6: Pin Type Bushing

Figure 4.7: Shackle Type Bushing

4.8.4 Tank

The tank is the outermost physical support of the transformer that inertly supports the core, windings, cooling system, bushings, comprising everything. The tank and cabinet system has to be compact but has to support the entire system. Precise construction of shape and size is important as well as the materials used to construct the tanks and cabinet. Slight miscalculation of dimension or poor quality of construction may result in severe financial losses. The materials used to constructers: Mild steel, stainless steel, composites.

4.9 Transformer Laminations

But you may be wondering as to how the primary and secondary windings are wound around these laminated iron or steel cores for these types of transformer constructions. The coils are firstly wound on a former which has a cylindrical, rectangular or oval type cross section to suit the construction of the laminated core. In both the shell and core type transformer constructions, in order to mount the coil windings, the individual laminations are stamped or punched out from larger steel sheets and formed into strips of thin steel resembling the letters “E’s”, “L’s”, “U’s” and “I’s” as shown below.

4.9.1 Transformer Core Types

Lamination Shell type and Core type transformer show in fig 4.8.

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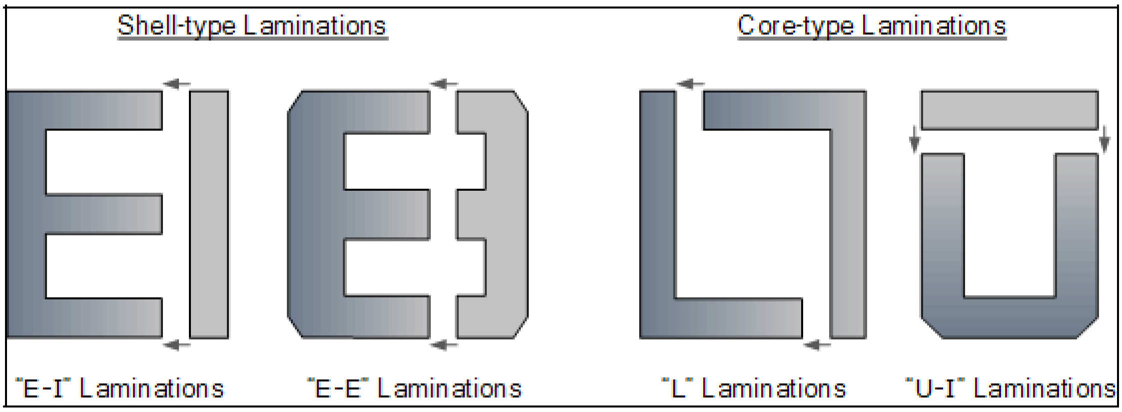

Figure 4.8: Shell Type and Core Type Lamination of Transformer[2]

These lamination stampings when connected together form the required core shape. For example, two "E" stampings plus two end closing "I" stampings to give an E-I core forming one element of a standard shell-type transformer core. These individual laminations are tightly butted together during the transformers construction to reduce the reluctance of the air gap at the joints producing a highly saturated magnetic flux density. Transformer core laminations are usually stacked alternately to each other to produce an overlapping joint with more lamination pairs being added to make up the correct core thickness. This alternate stacking of the laminations also gives the transformer the advantage of reduced flux leakage and iron losses. E-I core laminated transformer construction is mostly used in isolation transformers, step-up and step-down transformers as well as auto transformers.

4.9.2 Transformer Winding Arrangements

Transformer windings form another important part of a transformer construction, because they are the main current-carrying conductors wound around the laminated sections of the core. In a single-phase two winding transformer, two windings would be present as shown. The one which is connected to the voltage source and creates the magnetic flux called the primary winding, and the second winding called the secondary in which a voltage is induced as a result of mutual induction. If the secondary output voltage is less than that of the primary input voltage the transformer is known as a "Step-down Transformer". If the secondary output voltage is greater than the primary input voltage it is called a "Step-up Transformer".

4.10 Assemble:

After receiving the design requirements, the workers follow these steps separately, each is designated to perform a particular job for the construction. The assembly line of each of the parts is:

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- Core Assembly
- Coil Assembly
- Body Building

4.10.1 Core Assembly

The core line consists of five employees. The core material is composed of 97% steel and 3% silicon, compositely known as silicon steel. The silicon steel is directly imported from India by their requirements. The basic cutting and shaping of the steel is done in India and then sent to Bangladesh. If they are responsible for the certain steps to follow:

4.10.2 Core Arranging

This is the first step of the construction of transformer. The core is assembled by a group of 4 employees. The core is arranged in such a manner that the core gets a rounded shape. It is achieved by a arranging silicon steel with smaller width under, proportionally increasing the width of the steel as stacking goes up, on reaching the center, the steel with smaller width is stacked, just as opposite. This action gives a rounded shape. Transformer Core arranging show below in Fig 4.9

Figure 4.9: Core Arranging

4.10.3 Coil Assembly

The coil line consists of 4 regular employees and two rolling machines at TPPL. The material used to make the coil is formally known as:

1. Super Wire
2. Electric Copper

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The super wire is alloy of 60% copper and 40% steel and is pre insulated by industrial grade paper insulation. Even though alloy of steel reduces conductivity, it is provided to increase the Mechanical strength of the wire since copper by only itself is weak. Physical shape of this wire is flat type and is mostly used in the secondary side for lower capacity transformer, and used in both for higher capacity. The electric copper the electric copper and it is insulated not by paper, but by an insulating polymer, layered around the wire. The insulation layer is more prone to physical damage and it has lower insulation class than paper insulation. It is thinner than super wire and deals with less current. It is usually round type. Principally, the size, wound and grade of the wire is determined in the design section. The coil building is one of the most laborious task in the transformer construction, as mentioned before, it consists of four employees at TPPL. The complete roll of the coil has to be made hollow in order to be fitted around the core. After receiving the design criteria, and determining the number of turns required, the employees start a difficult task of coil winding. At first the core circumference is measured, now a two piece wooden filling is put together and clamped on the roller. The winding will be around these wooden fillings, after the clamping, according to requirements, the windings will rest on the fillings. The roller is motor driven which has a brake in order to sync the rolling, upon releasing the brake, the filling rotates, and the wires begin to wrap around the filling. According to the design, the tapings are taken out of the coil accordingly. After each layer is completed, paper insulation is placed before the next layer. Usually, there are segments of windings built to ease the difficulty of dealing with a larger one piece of coil; it is segmented to manufacturing and handling easier. The method is similar for both primary and secondary windings. After building the coils, the next following step is to place the windings into the core, in order to do so, the top clamp and top side core is removed. This process is laborious and time consuming. Then the primary coil is put inside first, after is a gap is created by inserting pieces of wood and paper inside to make the air gap for flux linkage. Then the secondary coil is put around the first coil. It is made sure that the coil does not come in contact with the base of the core, as it might result in a short circuit. The top core is again arranged back and clamped on again. Making coil progress in factory is show in Fig 4.10.

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Figure 4.10: Coil Building Process

4.10.4 Body Building

Now the third and difficult process of body line is commenced. This part includes.

1. HT and LT connections
2. Tap changer
3. De moisturizing
4. Tank and cabinet building
5. Radiator and conservator assembling
6. Placement inside the tank
7. Oil loading
8. Conservator placement and oil loading
9. Testing

LT & HT Connections

The low tension (LT) and high tension (HT) connections for transformer built at the TPPL are Wye connected and Delta connected respectively. These connections serve their own characteristics. The high tension side or (HT) is the delta connected side, this is because the

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transmission lines are usually three wired. In this system, the phase and the line voltages are equivalent and equal to the voltage induced across each coil. For wye connected system, if at one point at which all the terminal are connected is called the neutral point. If a conductor is not attached from this pint the load the system is Y connected three phase three-wire generator. If the neutral is connected the system is a y connected there phase four wire systems. HT and LT connection show below in Fig 4.11 and Fig 4.12

Figure 4.11: HT Connection

Figure 4.12: LT Connection

4.11 Tap Changer

In this simple example, the primary tap changes are calculated for a supply voltage change of ±7.5%, but any value can be chosen. Some transformers may have two or more primary or two or more secondary windings for use in different applications providing different voltages from a single core. The tap changer mechanism serves the purpose that, if in certain scenario, the voltage level of the transformer has to be changed, either decreased or increased, the number of windings can be varied to obtain the certain result. The maximum is 2.5 above the preset level and -2.5 under the present level. The tap changer is usually imported directly from India by TPPL according to requirements. This tap changer has a five position option. The tap changer is associated with the HT side. The tap changer consists of knob, slider and connection bar. Since the tap changer is connected to the HT side, the connections tapping are taken from the primary side and connected as the delta system. The system consists of three sets of six wire system. From each phase, six wires are taken from the windings that are connected to the changer. During the changes, the knob is rotated to the desired percentage, and the slider allows the set to move in desired direction, all the three phases at the same time. Practical tap changer show in Fig 4.13

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Figure 4.13: Tap Changer

4.12 Tank

The tank and cabinet provides the outermost physical supports for the transformer. There are separate sections for tank and cabinet building. As mentioned before, the tank is built by mild steel and joints are made by arc welding. As the fuel, mixture of LPG and Oxygen is used. It takes about 5-20 days to build a tank. The shape and size depends on the capacity of the transformer. The physical connections of the bushings, radiator, conservator and oil for cooling in incorporated in the cabinet. Transformer tank is show in Fig 4.14

Figure4.14: Transformer Tank

4.13 Radiator and Conservator Tank

The concept of radiator is like on any other device, it is used for assisting the cooling mechanism. Since the transformer gets heated up fast, it has to be rapidly cooled down in order of the safety of the machine. The operation of radiator is rather simple, the radiators are hollow pipes that connect the top and bottom end of the tank. When the inside of the transformer heats up, the oil heats up and rises to the top, then it travels to the hollow radiators the outer part of which is contact with air, the air removes the heat from the body of the radiator, thus cooling the oil down, now cooler oil travels down and back to the bottom of the transformer. This is a cylindrical tank mounted on supporting structure on the roof the transformer main tank. The main function of conservator tank of transformer is to provide

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adequate space for expansion of oil inside the transformer. When transformer is loaded and ambient temperature rises, the volume of oil inside transformer increases. A conservator tank of transformer provides adequate space to this expanded transformer oil. It also acts as a reservoir for transformer insulating oil. Radiator and Conserver tank Fig 4.15 and Fig 4.16

Figure 4.15: Radiator

Figure 4.16: Conserver Tank

Placement inside the Tank

After completing the core assembling, coil assembling the main structure of the transformer becomes ready to place inside the tank. It has been mentioned before that the body of the tank is made depending upon the KVA rating of the transformer. The inside structure of the transformer is placed inside the tank by using electric crane. Placing transformer sown in figure: 4.17

Figure 4.17: Placing Transformer inside the Tank

4.14 Oil Loading

After the body has been put to its place, the inside of the tank is filled with oil. This oil is primarily refined petroleum namely naphthenic mineral oil, which stays stable at high temperature. For the TPPL, this oil is imported from India. The oil has to have the following properties.

- Mostly inert, non-reactive, high breakdown ability and non-inflammable, minimum

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Vaporization of metal

- It must have high di electric strength

- High specific heat capacity so minimum temperature rise

Figure 4.18: Transformer Oil

4.15 Buchholz Relay

Buchholz relay in transformer is an oil container housed the connecting pipe from main tank to conservator tank. It has mainly two elements. The upper element consists of a float. The float is attached to a hinge in such a way that it can move up and down depending upon the oil level in the Buchholz relay Container. One mercury switch is fixed on the float. The alignment of mercury switch hence depends upon the position of the float. The lower element consists of a baffle plate and mercury switch. This plate is fitted on a hinge just in front of the inlet (main tank side) of Buchholz relay in transformer in such a way that when oil enters in the relay from that inlet in high pressure the alignment of the baffle plate along with the mercury switch attached to it, will change. The image of Buchholz Relay is show in Fig 4.19

Figure 4.19: Buchholz Relay

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4.16 Silica Gel

Whenever electrical power transformer is loaded, the temperature of the transformer insulating oil increases, consequently the volume of the oil is increased. As the volume of the oil is increased, the air, above the oil level in conservator, will come out. Again at low oil temperature the volume of the oil is decreased, which cause, the volume of the oil to be decreased which again causes air to enter into conservator tank. The natural air always consists of more or less moisture in it and this moisture can be mixed up with oil if it is allowed to be entered into the transformer. The air moisture should be resisted during entering the air into the transformer, because moisture is very harmful for transformer insulation. A silica gel breather is most commonly used as a mean of filtering air from moisture. Silica gel breather for transformer is connected with conservator tank by means of breathing pipe. The image of Silica Gel Breather is show in Fig 4.20

Figure 4.20: Construction of Silica Gel Breather

4.17 The Rating Plate

The rating plate carries all the important specification of the transformer. The common specifications are, KVA rating, voltage rating, connection type, vector group, tapping, cooling type, and ambient temperature. It also bears the manufacturing date and model. Apart from this, there are other specifications which are usually in the manual. The real transformer rating plate of TPPL is show in Fig 4.21

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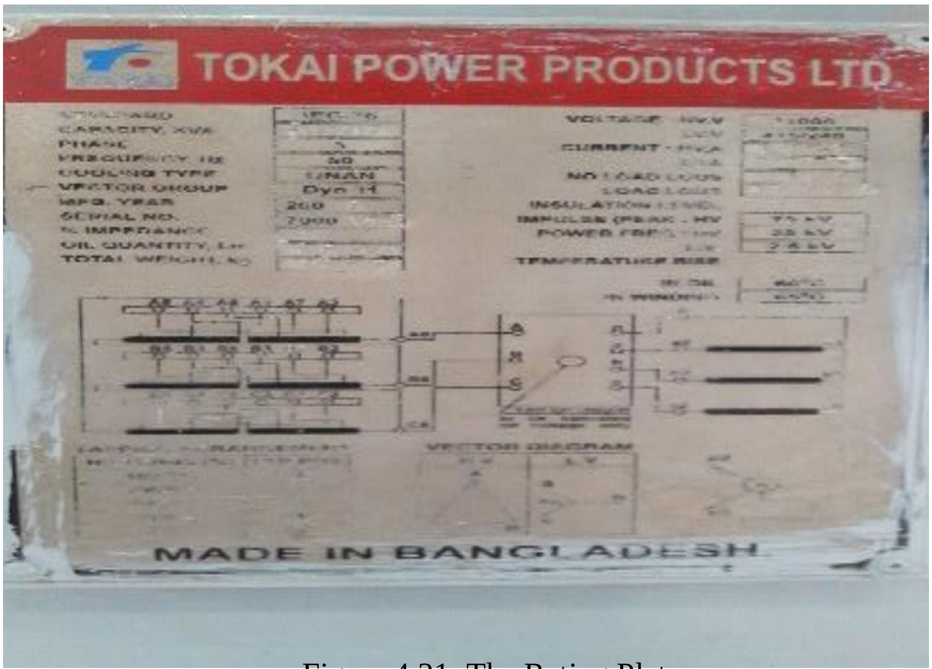

Figure 4.21: The Rating Plate

4.18 Price list of Transformer (TPPL):

TPPL applies appropriate technology and efficient process in their manufacturing and testing facilities which is well equipped to produce and distribution transformer, HT and LT switchgear panels, PFI and other equipment's associated with electrical transmission and distribution.

Table 4.1: Price List of Transformer (TPPL)

Sl.	**Size of Transformers**		**Net. Selling price**
1	100KVA transformer	=	250,000
2	150KVA transformer	=	300,000
3	200KVA transformer	=	350,000
5	250KVA transformer	=	400,000
6	315KVA transformer	=	513,000
7	400KVA transformer	=	573,000
8	500KVA transformer	=	700,000
9	630KVA transformer	=	800,000
10	With Buchhloz +Dial therm	=	820,000
11	750KVA transformer	=	1,013,000
12	With Buchhloz +Dial therm	=	1,033,000
13	800KVA transformer	=	1,020,000
14	With Buchhloz +Dial therm	=	1,040,000

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15	1000KVA transformer	=	1,216,000
16	1250KVA transformer	=	1,492,000
17	1500-1600KVA transformer	=	1,850,000
18	2000KVA transformer	=	2,310,000
19	2500KVA transformer	=	2,728,000
20	3000-3150KVA transformer	=	3,500,000

4.19 Transformer Testing done by Tokai

Before the delivery of a product, the testing of a product is very essential and it's not any different in TPPL. There are a number of tests that is done on a transformer, such as:

- Winding Resistance Test
- Insulation Test
- Ratio Test
- Open Circuit Test
- Short-circuit Test
- Load Test
- Insulation Test

At TPPL, due to lack of proper testing units, only a few tests are run on the transformers, and the following tests are discussed below:

4.19.1 Insulation Test

The insulation test is the first test done on the transformer at TPPL. It is carried out to find out whether the transformer is safe to be tested for applied voltage. It is done by a DC high voltage power device simply called the "insulation tester". It is done to determine the dryness of the winding insulation system. This test requires connection from individual windings to the ground. The thumb rule of readings acquired to farther forward the transformer to voltage test is considered to be 1MΩ. This test is also called Medgar test.

4.19.2 Voltage Test

It is just a simple test to verify that, whether the stepping of voltage are properly done or not. Since the lack of 11KV industrial line in the factory, the technicians attach the 440V line to the secondary side and observe whether the voltage steps up to 11KV or not. It is tested for all of the three phases. Also in parallel, the phase to phase voltages are also measured and verified

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4.19.3 Load Test

Load Test helps to determine the total loss that takes place, when the transformer is loaded. At TPPL, the voltage is supplied to the LT side and current is assessed from the primary side. The purpose of the test is:

a) To determine the rated load of the machine and the temperature rise
b) To determine the voltage regulation and efficiency of the transformer.

Rated load is determined by loading the transformer simultaneously by the load steering installed in the transformer testing unit and observing the temperature rise. The losses that occur display as the heat, temperature rise of the transformer. It is very carefully done because if overloading occurs, it may cause the transformer to leak oil, and go in flames. The following date table contains load test report for a 200 KVA transformer performed at Tokai.

Table 4.2: Parameters for Load Test

Apply voltage	HV.A	LV.A, N- 3A	Watt
415 V	10.44	281	816
415 V	10.58	282	840
413 V	10.41	275	810
			Total loss = 2466

4.19.4 No Load Test or Open Circuit Test

This test is conducted to determine the core losses (or iron losses). In this test, the rated voltage is applied to the primary while the secondary of the transformer is left open-circuited. For safety precautions at TPPL rated voltage i.e. 11 KV is not applied, rather 415 V is applied to the primary. The following table shows the data for open circuit test for 200 KVA (11 KV /415 V) transformers. [10]

Table 4.3: Parameter for No Load Test

Apply voltage	Loss-A	Watt
415V	2.80	96
415V	2.20	96
417V	2.58	234
		Total loss = 426 W

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4.19.5 Short Circuit Test

In this test secondary side of the transformer is short circuited by using a metallic conductor and then variable low voltages are applied to the primary. After reaching at rated current of secondary side, voltage, current and amount of load are measured. Thus the short circuit test mainly gives the copper loss of the transformer [6].

4.19.6 Ratio Test

The performance of a transformer largely depends upon perfection of specific turns or voltage ratio of transformer. So transformer ration test is an essential type test of transformer. The voltage should be applied only in the high voltage winding in order to avoid unsafe voltage.

Procedure of Transformer Ratio Test

- First, the tap changer of transformer is kept in the lowest position and LV terminals are kept open.
- Then apply 3-phase 415 V supply on HV terminals. Measure the voltages applied on each phase (Phase-phase) on HV and induced voltages at LV terminals simultaneously.
- After measuring the voltages at HV and LV terminals, the tap changer of transformer should be raised by one position and repeat test.
- Repeat the same for each of the tap position separately [7].

The following table contains the data for ratio test of a 200 KVA (11 KV/415 V) transformer done by Tokai.

Actual ratio = HT side voltage/LT side voltage

= 11000/415

= 26.5

4.20 Parameter for Ratio Test

Table 4.4: Parameter for Ratio Test

	Applied voltage	**Ratio**	**Applied voltage**	**Ratio**	**Applied voltage**	**Ratio**
Tap Position	416 V		416V		416V	
Position -1	15.2	27.3	15.1	27.5	15.1	27.5
Position -2	15.5	26.8	15.3	27.2	15.5	26.8
Position -3	15.9	26.2	15.7	26.5	15.9	26.2
Position -4	16.3	25.5	16.2	25.6	16.4	25.4
Position -5	16.8	24.8	16.6	25.1	16.7	24.9

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4.21 Specifications of Transformers at TPPL

Table 4.5: Specifications of Transformers at TPPL

KVA	Ratio	Total Kg	Oil Liter	LV-A	HV-A	No load loss	Load loss	Impedance %
50	11KV/415V	450	110	69.56	2.62	175	890	4
100	11KV/415V	690	190	139.1	5.24	280	1480	4
150	11KV/415V	775	200	208.6	7.87	320	1890	4
200	11KV/415V	1050	256	278.24	10.49	475	2525	4.5
250	11KV/415V	1080	280	347.8	13.12	530	2525	4.5
315	11KV/415V	1440	420	438.2	16.53	650	3260	4.5
400	11KV/415V	1600	420	556.4	21	720	3560	4.5
500	11KV/415V	1850	520	695.6	26.24	860	4220	5
630	11KV/415V	2340	560	876.24	33.06	1090	5100	5
750	11KV/415V	2680	810	1043.4	39.36	1150	6800	6
800	11KV/415V	2680	810	1112.9	41.98	1150	6800	6
1000	11KV/415V	3600	850	1391.2	52.48	1330	8200	6
1250	11KV/415V	4200	1200	1739	65.6	1490	12100	6

The following table shows an extended form of the metal requirements of transformer according to their rating. These calculations were directly adopted from TPPL.

4.22 Transformer Ratings

Most important term of transformer is its rating. Transformers have a name plate fixed on them on which rated output, rated voltages, the rated frequency, cooling method are recorded. The interesting fact is that its output rating is expressed in KVA (kilovolts ampere) rather than KW (kilowatt). This is due to the fact that the transformer rated output is limited by heating and hence losses in the transformer. The two types of losses in a transformer are core loss and Hysteresis losses. These losses depend on transformer voltage and current and are almost unaffected by the load power factor, therefore transformer rated output is expressed in VA or in KVA and not in KW.

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CHEPTER 5

SWITCHGEAR AND POWER FACTOR IMPROVEMENT

5.1 Introduction

A great demand for electrical energy is a notable feature of modern civilization. Most of this energy is needed for lighting, heating, domestic appliances, industrial electrical machinery and electric traction. The importance of electric supply in everyday life has reached such a stage that it is desirable to protect the power system from harm during fault conditions and to ensure maximum continuity of supply. For this purpose, means must be provided to switch on or off generators, transmission lines, distributors and other equipment under both normal and abnormal conditions. This is achieved by an apparatus called switchgear. Switchgear consists of switching and protecting devices such as switches, fuses, circuit breakers, relays etc. During normal operation, switchgear permits to switch on or off generators, transmission lines, distributors and other electrical equipment. However, the switchgear detects the fault and disconnects the unhealthy section from the system. In this way, switchgear protects the system from the damage and ensures continuity of supply. In this chapter, we shall present the elementary introduction to switchgear .The switchgear is classified into two types according to their voltage:

i. High Tension Switchgear (HT)
ii. Low Tension Switchgear (LT)

Figure 5.1: HT Switchgear

Figure 5.2: LT Switchgear

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5.2 Switchgear Equipment

Switchgear covers a wide range of equipment concerned with switching and interrupting currents under both normal and abnormal conditions. It includes switches, fuses, circuit breakers, relays and other equipment.

5.3 Switchgear Types

Switchgear along with control panels are installed in generating stations, transformer stations, distribution systems, and almost all types of industries. Nowadays. Now according to their types, switchgears can be

- Outdoor type- above 66KV
- Indoor type-below 66KV

It can operate under both are:

- Normal condition
- Abnormal condition

The switchgear is classified into two types according to their voltage:

i. High Tension Switchgear (HT)
ii. Low Tension Switchgear (LT)

5.4 High Tension Switchgear

TPPL high tension switchgear comprises of SF6 Circuit Breaker, Vacuum Circuit Breaker, Minimum Oil Circuit Breaker, Load Break Switch, Vacuum Contactor, disconnect etc. to meet individual requirement which comply with IEC/ BS and other relevant international standard. TPPL high tension switchgears are suitable for inexpensive electrical substation with transformer feeder, measuring, sectionalizing, auto change over and motor protection. HT switchgear is shown in below figure 5.3.[6]

Figure 5.3: HT Switchgear [6]

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5.5 Low Tension Switchgear

TPP Low tension switchgear, DB & MCC panels are specially designed to control and distribute power for diverse installations such as power station, industries, mills & factories, irrigation, tea gardens, housing complex and other different loads. Switchgear panels are designed and manufactured for indoor and outdoor of fixed type or fully draw out type with frame structure of modular construction for easy extension & coupling depending on the condition of installation. The Low Tension Switchgear comprises of Air Circuit Breaker, Molded Case Circuit Breaker, Fuse, Switch, unit, Disconnect etc, to meet individual requirement which comply with IEC/ BS and relevant international standard. LT switchgear is shown in below figure 5.4.[6]

Figure 5.4: LT Switchgear [6]

5.6 Circuit Breaker

Protective electrical switch that turns itself off (trips) to interrupt flow of electricity,if the current exceeds a preset limit. When the current returns to normal, the circuit breaker is either manually or automatically reset for reuse. The circuit breakers are classified by the following parameters:

- Low voltage: Less than 1KV
- High voltage: Higher than 1KV

5.6.1 Circuit Breaker used at TPPL

TPPL has a range of different products they assemble, completely depending on the demand of the customer. But mostly, there are some products that receive the most demands. During my stay in TPPL I witnessed the assembly of these products most frequently. Most of these orders were in response to the customers of industries, some of which include the best industries of the country. TPPL mostly uses vacuum circuit breaker (VCB), air circuit breaker (ACB) mostly for the construction of their products. From my experience, vacuum circuit breakers are mostly used.

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The products are imported from China, Italy, Germany, USA and Japan. Although the ranges of assembled products are high, my focus is going to stay on the assembly of the products I have witnessed.

5.6.2 Vacuum Circuit Breaker

The vacuum circuit breaker is classified as a medium voltage circuit breaker, with a current up to 6300 A and is generally applied to voltage level of about 40KV. As it is known that, vacuum is a great perhaps the best insulator, it uses the same principle. The breaker is confined in a vacuum container, or bottle. One of the contacts is fixed and one is movable. When the circuit breaker detects a fault, the movable contact pulls away from the fixed contact, interrupting the current. It usually moves away 6-10 mm of length. Now since the contacts are in a vacuum, arcing between the contacts is suppressed, ensuring that the circuit remains open. Automated vacuum circuit breakers will reset automatically once the fault is cleared. But there are also manual circuit breakers where an operator has to manually reset the reclose, in this case, maximum safety measures has to be taken.

The prefer ability of vacuum circuit breakers are high because, there are certain advantages of such a device. They are:

- Compact, reliable, longer life
- No fire
- No gas produce
- Can handle all fault current, VCB shown in Fig 5.5

Figure 5.5: Vacuum Circuit Breaker (VCB)

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5.6.3 .Air Circuit Breaker (ACB)

It is an air switch and is designed to open a circuit under load. In order to quench the arc that occurs on opening suc h a switch, special arcing horns are provided. Arcing horns are pieces of metals between which arc is formed during opening operation. As the switch opens, these horns are spread farther and farther apart. Air-break switches are generally used outdoor for circuits of medium capacity such as lines supplying an industrial load from a main transmission line or feeder. Air Circuit Breaker (ACB) is shown below in Fig 5.6.

Figure 5.6: Air Circuit Breaker (ACB)

5.6.4 Miniature Circuit Breaker (MCB)

Now a day, more commonly, miniature circuit breaker or MCB is used instead of fuse. There are some certain advantages of MCB over fuse and there are some definite advantages to it also It automatically switches off the electrical circuit during abnormal conditions, both overload and faulty condition.

- It is much more sensitive than fuse
- Quick restoration of MCB is possible, restoration can be simply done by turning a switch
- Handling of MCB is electrically safer than fuse

There are two operating principles of MCB. For overload current, thermal effect works. The bimetal strip is heated during the overload current, and it deflects by bending away. This releases the mechanical latch which is attached to the operating mechanism that opens the MCB. Secondly for short circuit current, electromechanical current works. As a result of short circuit, if there is sudden rise in current, a mechanical displacement of plunger occurs, tripping the coil. The only disadvantage of MCB over fuse is, it is more expensive than fuse. Miniature Circuit Breaker (MCB) is show below in Fig 5.7.

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Figure 5.7: Miniature Circuit Breaker (MCB)

5.6.5 Molded Case Circuit Breaker (MCCB)

The MCCB is circuit breaker is a plastic that interrupts an electrical current if the current exceeds the trip rating of a breaker. The plastic encloses the mechanism in the breaker box, and also separates conductors from each other and from metal grounds. It is most commonly used in switchboards, starters and control panels. It has an operating range of current 25-1600 A and a fault level of (16-50KA). In the case for TPPL, it is used in the switching panels. Molded Case Circuit Breaker (MCCB) is shown in Fig 5.8.

Figure 5.8: Molded Case Circuit Breaker (MCCB)

5.7 High-Rupturing Capacity (H.R.C.) Cartridge Fuse

The primary objection of low and uncertain breaking capacity of semi-enclosed rewire able fuses is overcome in H.R.C. cartridge fuse. High-Rupturing Capacity (H.R.C.) Cartridge Fuse is shown in Fig 5.9[7]

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Figure 5.9: High-Rupturing Capacity (H.R.C.) Cartridge Fuse [7]

5.8 Power Factor

As a commercial customer, it is important to understand how power factor is calculated, since you may be charged a reactive power fee if your facility's power factor is below 95%. The power factor triangle below illustrates how real power, reactive power and apparent power relate to each other to get the power factor angle. One way to get the power factor is by getting the cosine of the power factor angle.[8]

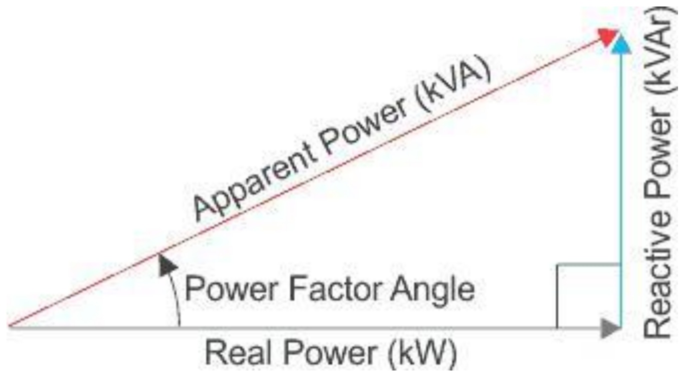

Figure 5.10: Power Factor Angle [8]

5.9 Power Factor Improvement

Mathematically it is cosine of the phase difference between source voltage and current. It refers to the fraction of total power (apparent power) which is utilized to do the useful work called active power Real power is given by $P = VI \cos\varphi$. To transfer a given amount of power at certain voltage, the electrical current is inversely proportional to $\cos\varphi$. Hence higher the pf lower will be the current flowing. A small current flow requires less cross sectional area of conductor and thus it saves conductor and money. TPPL Power Factor Improvement Plant has been designed to meet the needs of all forms of power factor correction by Capacitor banks from small unit to a large plant. PFI Plant are preferably designed to eliminate the penalties for consumption of reactive

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power, reduction of voltage drop, increase in transformer capacity with some losses (load), reduction line losses. The PFI Plant supplied in Cubicles of sheet metal clad, dust & vermin proof, free standing and floor mounting (wall mounting in special cases.) Automatic PFI plant comprises of Capacitor Banks Power Factor Improvement Relay / Regulator, Contactors, HRC Fuses, Manual

/ Automatic change over switch, reactors for large plant comply with IEC/B5 and other relevant international standard. The automatic PFI Plant are available in steps of 5KVAR to 120KVAR are capacitor banks and up to a maximum output of 10,000 KVAR.

5.9.1 Capacitor Combination

The major aspect of a PFI panel is capacitor to provide necessary power when needed to maintain the power factor near to unity power factor, 5 KVAR, 10 KVAR, 20 KVAR and 25 KVAR rating capacitors are combining in different stages to make the desire power combination in a PFI panel. Stages depend of required rating of PFI panel. Before the first stage one fixed capacitor is connected to bus bar to reduce the eddy current loss coming out from transformer. The rating of this fixed capacitor is also depends on the eddy current loss.

For30 KVR capacitor ratings are- (written on capacitor body)

- 415 volt
- 600 Hz
- 42 A

For 25 KVR capacitor ratings are- (written on capacitor body)

- 415 volt
- 50 Hz
- 35 A

5.9.2 Contactor

A contactor is an electrically controlled switch used for switching a power circuit. In a PFI panel contactors are used for switching between required capacitor to support the improvement of power factor. Contactor connects the busbar with capacitor in the PFI panel. The fixed capacitor in the PFI panel is directly connected with busbar without the contactor.

5.9.3 Fuse

Fuse is another important aspect in PFI panel to protect the component from access flow of current. Fuses are connected between busbar and contactor. For every single line one fuse is needed. For the fixed capacitor which is connected to busbar without contactor, there are also three Fuses for every single line of three phase connection.

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5.9.4 Busbar

Busbar is made of copper and the size of busbar varies depend on cost estimation and setup area of a PFI panel. Current flowing through $1mm^2$ is 1.6A.

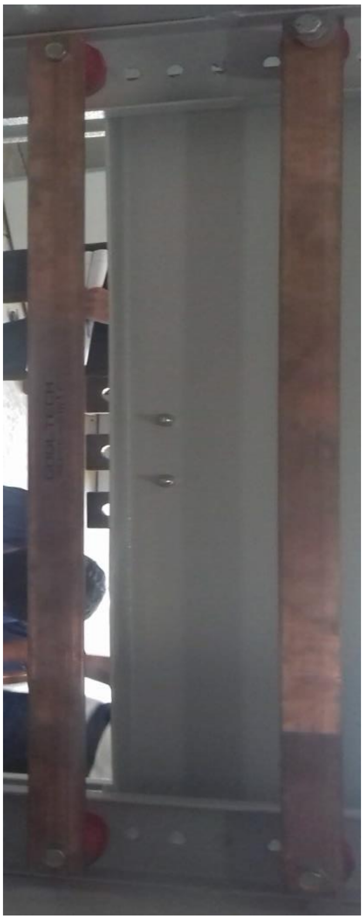

Figure 5.11: Bus bar.

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CHAPTER 6

CONCLUSION & FUTURE WORK

6.1 Conclusion

This internship was extremely helpful to me. I have gained practical knowledge, skills and met so many people**.** TPPL has allowed me to venture into the world of manufacturing and assembling power products which is effectively, a major contribution to the power system industry of our country. During this three months of industrial attachment, I have learnt the techniques, steps, methods, precautions, rules and regulations to construct such complex products namely transformers, switchgears and PFI. I have had the opportunity to see the various machineries and tools used to constructs these products. I have seen how the complex work core assembly of transformer is done carefully done by hand, the winding rolling are done by roller and how it is controlled and done, and how the core and windings are put into place. I have seen the construction of transformer body and putting the core and windings into the body and finally finishing the process completely. As simple as loading the oil and connecting the bushings seemed amazing to me. From a simple tool such as a gas cutter to the complex machinery of transformer testing unit, I have learnt how to use these tools and became familiar with the various uses of different tools. These tool sets were very unfamiliar to me and seeing them in use was a great experience. I have also learnt about the safety measurements in an industry and the safety materials that are used for the protection of the workers to avoid any undesired accidents.

I have achieved the immediate experience of manufacturing procedures of transformers, switchgear and PFI units. These experiences cannot be learnt in text books or the in class. Although I have found that, these technical aspects are in contrast with the studies done inside of the classroom, so I have seen how the theories learned in the class is directly used in the manufacturing of the goods. The calculations, measurements are exactly similar to the ones done in the class. It was a good experience to learn the theories and to see them put into use. The manufacturing of transformers, switchgear and PFI are one experience that will help me guide my way to the career as an Electrical Engineer. I think our four years' course will be fruitless if we do not learn the manufacturing of electrical devices.

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6.2 Future Work

In the modern world, no country can achieve their long term economic goals without having a sustainable power sector. Though the generation capacity of our power sector is limited but an efficient distribution system can mitigate the problem a great extent. A customer focused distribution system can relieve the miseries of the common people. For poverty alleviation and socio-economic development electricity is very much essential for a nation. Without providing continuous electricity it is impossible to develop a country. The power sectors of Bangladesh are not satisfactory. It has numerous problems like supply capacity, frequent power cuts and unacceptable quality of supply. For removing those problems proper PFI, LT, HT panel, transformer and insulation property should be accurate. Both government and company should take some steps to increase the power sector and sustainable equipment for power side. They also look to the cost of production; cause due to maintain the own power plant they need to pay some extra cost. If our power development board can produce enough power to serve the industries, then the production cost can come down than the present situation. However, our government encourages the proprietor for various sustainable, efficient and low cost power production systems.

- Tokai Power Product Ltd should hire more theoretical and practical experienced electrical design engineer. If the company desired to produce above 5 MVA power transformer and above 33KV circuit breaker.
- Some accessories come in from foreign country. If the company manufactured that product in Bangladesh, then the turnover of the company will be enriched.
- Every division should be provided more training facilities for manufacturing purpose.

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REFERENCE

[1] http://www.electrical4u.com/what-is-transformer-definition-working-principle-of-transformer/

[2] www.electrical4u.com/open-and-short-circuit test for a transformer

[3] http://www.thehindu.com/features/kids/importance-of-electricity/article216311.ece

[4] http://www.banglajol.info/

[5] http://www.tokaipower.com/

[6] S. Khan, "Power System Protection", First Reprint, Dhaka 2013

[7] www.electrical4u.com/voltage-turns-ratio-test-of-transformer

[8] https://www.scribd.com/doc/69726440/A-Report-on-Transfrmer-Part-2

[9] http://www.canadatransformers.com/transformer-efficiency-losses-heat/

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APPENDIX

A

ACB: Air Circuit Breaker

C

CT: Current Transformer

D

DIU: Daffodil International University

E

EMF: Electro Motive Force

H

HRC: High-Rupturing Capacity

HT: High Tension

K

KVA: Kilo Volt Ampere

KVAR: Kilo Volt Ampere Reactance

L

LT: Low Tension

M

MCB: Miniature Circuit Breaker

MCCB: Molded Case Circuit Breaker

MVA: Mega Volt Ampere

O

OCB: Oil Circuit Breaker

P

PFT: Power Factor Improvement

PT: Potential Transformer

T

TPPL: Tokai Power Product Limited

V

VCB: Vacuum Circuit Breaker

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