Independent University, Bangladesh

Study on Transformer Production of Energypac Engineering Limited

An undergraduate internship report submitted by

Md.Fakhrul Alam Sajib (Student ID: 0920578)

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has been approved on April 16, 2013.

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Dr. M. Abdur Razzak

Internship Supervisor & Associate Professor

Department of Electrical and Electronic Engineering

School of Engineering & Computer Science

Independent University, Bangladesh

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The Author
April 2013
Dhaka, Bangladesh

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 & Electronic Engineering program. This 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; therefore it is an opportunity for the students to know about the real life situation through this program.

The report is broadly categorized in six different parts. At first there is introduction, objectives of the study, scope of the report, methodology of the study, and limitation. Part two describes the overview of Energypac Engineering Ltd (EEL), major works involved, territory, supply chain, mission, vision and strategy, operation, departments of Energypac Engineering Ltd, some other 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 this internship report, transformer manufacturing process of Energypac Engineering Ltd (EEL) as well as switchgear & protective devices is studied.

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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.

Energypac is contributing to the country by saving foreign currency by manufacturing different power products. Energypac was incorporated in 1982 as a private limited business enterprise. At present, Energypac is one of the best power engineering companies not only in Bangladesh but also in South-Asia.Energypac Engineering Ltd.(EEL) is an ISO 9001:2008 and 14000:2004 certified company. Energypac enhances the business of its customers by providing them with complete solutions. While creating better and environmentally compatible technologies, Energypac focuses on the customer's demand with appropriate products and solutions as well as services [2].

1.2 Objective

The particular objectives of internship were as follows:

1) To apply theoretical knowledge in the practical field.
2) To observe the manufacturing process of transformer, testing.
3) Collecting Knowledge regarding Power & Distribution Transformer.
4) To realize the organizational management system of Enegypac.
5) To gain some knowledge in system protection and maintenance of a power system.
6) To gain some knowledge on vector groups of transformer.
7) To find out the success and failure of Energypacin doing its operational activities.

1.3 Scope of the Study

The report covers transformer division, switchgear division of Energypac Engineering Ltd (EEL). This report especially emphasizes on manufacturing of transformer. I had the opportunity to have close view of engineer's activities of Energypac.

1.4 Research Methodology

1.4.1 Nature of the Study

The study was mainly descriptive in nature as it focused mainly on information provided by the different departments of Energypac Engineering Ltd (EEL).

1.4.2 Data Collection

Both primary and secondary data sources had been used in preparing this report.

1.4.2.1 Primary Source:

a) Face to face conversation with the engineers.
b) Direct observations.

1.4.2.2 Secondary Source

a) Website of Energypac and books of different authors.
b) Other different website.

c) Files & Folders.

d) Daily diary (containing my activities)

1.5 Limitations of the Study

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

1) 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.
2) A major portion of the study had been conducted based on the secondary data.
3) 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 The Energypac Engineering Ltd (EEL), personnel did not disclose enough information for the sake of confidentiality rule of the organization.
4) The pain of my journey from Jatrabari to Savar was another limitation restricting this report from being more detailed or analytical.

CHAPTER 2

COMPANY PROFILE

2.1 Energypac Engineering Ltd(EEL)

Energypac is one of the leading power engineering companies in Bangladesh. Continual research and development, state of the art production facility, quality products, competent services, and countrywide operations have made it warmly acceptable to the customers. Energypac was incorporated in 1982 as a private limited business enterprise. It is powered by 1200 skilled manpower of which 150 are graduated engineers. The relentless efforts and dedication of these people are providing continual help to improve technology to innovate and develop new products, just in time delivery, pre and post sales services to maintain a long term business relationship with the customers. To meet countrywide demand of its products and services, Energypac has extensive distribution network throughout Bangladesh with full-fledged offices in the major cities like Chittagong, Khulna, Rajshahi, Sylhet, and Bogura. In an effort to introduce its products globally, Energypac has established its offices in India, and China. Energypac has already experienced its products and service supply to India, Yemen, Ghana, Uganda, Nigeria, Saudi Arabia, and United Kingdom [7].

2.2 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 equipments.
- To provide complete solution to the customers including engineering, procurement and construction.
- Including the checking of all connections and settings of equipments, load management, test run, and finally supplying power to the grid/loads.

2.3 Territory

The manufacturing, testing, research and development facility of Energypac Engineering Limited is situated at Baruipara, Savar, and Dhaka. It is located at a distance of about 24 km to the northwest of Dhaka city. The factory is positioned on a total land area of 288,000.00 square feet. To meet countrywide demand of its products and services, Energypac has extensive distribution network throughout Bangladesh with full-fledged offices in the major cities. In an effort to introduce its products globally, Energypac has established its offices in India, and China. Energypac has already experienced its products and service supply to India, Yemen, Ghana, Uganda, Nigeria, Saudi Arabia, and United Kingdom [2].

2.4 Supply Chain

The flow chart of the supply chain IS shown in Figure 2.1.

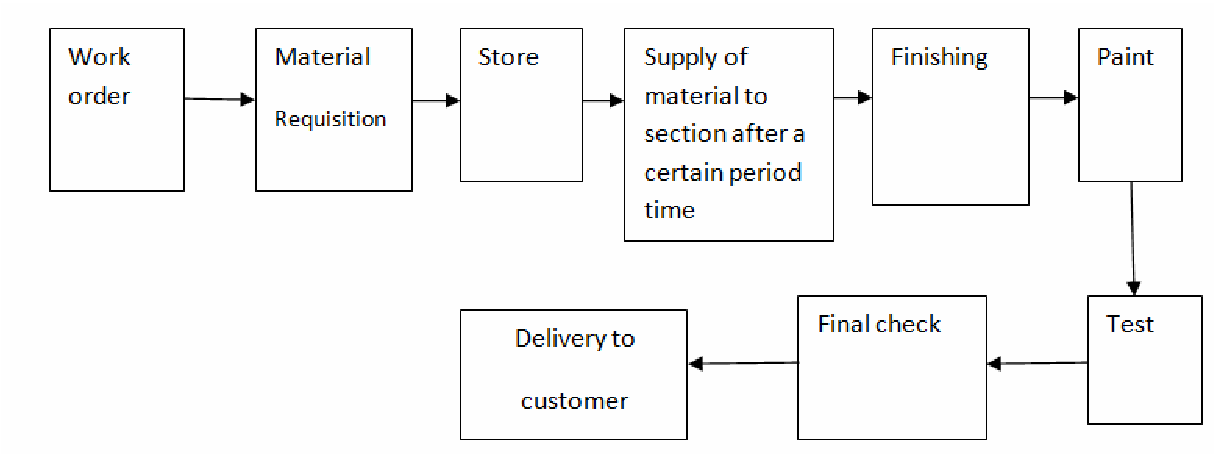

Figure 2.1: Supply chain flow diagram of Energypac Engineering Ltd (EEL)

2.5 Mission, Vision and Strategy

Vision: We will be the most preferred business partner of our customers [7].

Mission: We will provide total power solutions to enhance the business of our customers, concurrently creating better technologies that benefit both the customers and the environment [7].

Strategy: Our strategic aim is to strengthen the leading position we enjoy in our markets, and to ensure continued growth. We rely on our capability to integrate and deliver solutions from our broad equipment and service portfolio which meet the specific needs of our customer segments globally. Our priority is to offer the best efficiency, reliability and value available [7].

2.6 Operation

Energypac Engineering Ltd.(EEL) operates its Sales & Distribution(S& D) division around the country and overseas. EEL created eight numbers of Sales & Distribution (S&D) Divisions [6]. They are:

a) Dhaka S & D Division
b) Chittagong S & D Division
c) Rajshahi S & D Division
d) Khulna S & D Division
e) Sylhet S & D Division
f) Bogra S & D Division
g) India S & D Division
h) China S & D Division

2.7 Departments of Energypac Engineering Ltd.:

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

2.8 Some Other Power Manufacturing Company in Bangladesh

- Powermann Bangladesh Limited
- POWERBREEZE Engineering Limited

CHAPTER 3

LITERATURE REVIEW

3.1 Introduction

This chapter is a basic discussion of the issue of power systems.

3.2 Power System

An electric power system is to connect the generation station to the consumers' loads by means of transmission and distribution system [1]. Therefore, an electric power system can be divided into three components:

a) Generation System
b) Transmission System
c) Distribution System

3.2.1 Generation System

The generation voltage is 11KV. The generation of power is generally prepared by gas in Bangladesh.

3.2.2 Transmission System

Transmission lines are the connecting link between the generation station and the distribution system. For economical reasons, electric power has to be transmitted through transmission lines at a very high voltage which is 230KV. When higher voltages are supplied, there is less current in the wire for the same amount of power. By reducing the current allows to use smaller conductor sizes. It saves money. At the distribution side voltage reduces to 440V (line voltage) [3].

3.2.3 Distribution System

Distribution system are responsible for delivering electrical energy from the distribution substation to the service entrance equipment located at residential, commercial, and industrial consumer facilities. Distribution system connects all the loads in a given locality to the transmission lines [3].

3.3 Important Terms of Power System

3.3.1 Electrical grid

An electrical grid is an interconnected network for delivering electricity from suppliers to consumers [6]. It consists of generating stations that produce electrical power, high-voltage transmission lines that carry power from distant sources to demand centers, and distribution lines that connect individual customers.

3.3.2 Sub-Station

The assembly of apparatus used to change some characteristic (e.g. voltage, a.c.to d.c., frequency, power factor etc.) of electric supply is called a sub-station. Sub-stations are important part of power system. The continuity of supply depends to a considerable extent upon the successful operation of sub-stations. It is, therefore, essential to exercise utmost care while designing and building a sub-station [3]. The following are the important points which must be kept in view while laying out a sub-station:

a) It should be located at a proper site. As far as possible, it should be located at the centre of gravity of load.
b) It should provide safe and reliable arrangement. For safety, consideration must be given to the maintenance of regulation clearances, facilities for carrying out repairs and maintenance, abnormal occurrences such as possibility of explosion or fire etc. For reliability, consideration must be given for good design and construction, the provision of suitable protective gear etc.
c) It should be easily operated and maintained.
d) It should involve minimum capital cost.

3.3.3 Bus-Bar

Electrical bus-bar is the collector of electrical energy at one location. When a number of lines operating at the same voltage have to be directly connected electrically, bus-bar are used, it is made up of copper or aluminum bars and operate at constant voltage. Some important bus-bars arrangements used for power stations and sub-stations. They are:

a) Single Bus-bar System

The single bus-bar system has the simplest design and is used for power stations. It is also used in small outdoor stations having relatively few outgoing or incoming feeders and lines. The chief advantages of this type of arrangement are low initial cost, less maintenance and simple operation. There is also a disadvantage. If a fault occurs on the bus-bar itself, there is complete interruption of supply .

b) Single bus-bar system with Sectionalisation

In large generating stations where several units are installed, it is a common practice to sectionalize the bus so that fault on any section of the bus-bar will not cause complete shutdown. Three principal advantages are claimed for this arrangement. Firstly, if a fault occurs on any section of the bus-bar, that section can be isolated without affecting the supply to other sections. Secondly, if a fault occurs on any feeder, the fault current is much lower than with unsectionalised bus-bar. This permits the use of circuit breakers of lower capacity in the feeders. Thirdly, repairs and maintenance of any section of the bus-bar can be carried out by deenergising that section only, eliminating the possibility of complete shutdown.

c) Duplicate bus-bar system

In large stations, it is important that breakdowns and maintenance should interfere as little as possible with continuity of supply. In order to achieve this objective, duplicate bus-bar system is used in important stations. Such a system consists of two bus-bars,
a “main bus-bar’’ and a “spare” bus-bar. Three principal advantages are claimed for this arrangement. Firstly, if repair and maintenance it to be carried on the main bus, the supply need not be interrupted as the entire load can be transferred to the spare bus. Secondly, the testing of feeder circuit breakers can be done by putting them on spare bus-bar, thus keeping the main bus-

bar undisturbed. Thirdly, if a fault occurs on the bus-bar, the continuity of supply to the circuit can be maintained by transferring it to the other bus-bar [3].

3.3.4 Voltage Surge

There are several instances when the elements of a power system (e.g. transformers) are subjected to overvoltages. Voltages are greater than the normal value. These overvoltages on the power system may be caused due to many reasons such as lightning, the opening of a circuit breaker, the grounding of a conductor etc. Most of the overvoltages are not of large magnitude but may still be important because of their effect on the performance of circuit interrupting equipment and protective devices. A sudden rise in voltage for a very short duration on the power system is known as a voltage surge [3].

3.3.5 Lightning Arrestor

A lightning arrester is a protective device which conducts the high voltage surges on the power system to the ground. I have given the picture of the lightning arrestor as shown in Figure 3.1. Lightning arrester also known as surge arrester has a high voltage terminal and a ground terminal.

Figure 3.1: Lightning arrestors

Lightning arresters are installed on many different pieces of equipment such as power poles and towers, power transformers, circuit breakers, bus structures, and steel superstructures in substations. Two things must be taken care of in the design of a lightning arrester. Firstly, when the surge is over, the arc in gap should cease. If the arc does not go out, the current would continue to flow through the resistor and both resistor and gap may be destroyed. Secondly, IR drop (where I is the surge current) across the arrester when carrying surge current should not exceed the breakdown strength of the insulation of the equipment to be protected [3].

3.3.6 Short-Circuit Currents

Whenever a fault occurs on a network such that a large current flows in one or more phases, a short-circuit is said to have occurred. When a short circuit occurs, a heavy current called short circuit current flows through the circuit. Most of the failures on the power system lead to short-circuit fault and cause heavy current to flow in the system. The calculations of these short-circuit currents are important for the following reasons:

a) A short-circuit on the power system is cleared by a circuit breaker or a fuse. It is necessary, therefore, to know the maximum possible values of short-circuit current so that switchgear of suitable rating may be installed to interrupt them.

b) The magnitude of short-circuit current determines the setting and sometimes the types and location of protective system.

c) The magnitude of short-circuit current determines the size of the protective reactors which must be inserted in the system so that the circuit breaker is able to withstand the fault current.

d) The calculation of short-circuit currents enables us to make proper selection of the associated apparatus (e.g. bus-bars, current transformers etc.) so that they can withstand the forces that arise due to the occurrence of short circuits.

3.4 Faults in a Power System

A fault occurs when two or more conductors that normally operate with a potential difference come in contact with each other. These faults may be caused by sudden failure of a piece of equipment, accidental damage or short-circuit to overhead lines or by insulation failure resulting from lightning surges. Irrespective of the causes, the faults in a 3-phase system can be classified into two main categories:

(i) **Symmetrical faults**

That fault which gives rise to symmetrical fault currents (i.e. equal faults currents with 120 degree displacement) is called a symmetrical fault. The most common example of symmetrical fault is when all the three conductors of a 3-phase line are brought together simultaneously into a short-circuit condition. The following points may be particularly noted:

a) The symmetrical fault rarely occurs in practice as majority of the faults are of unsymmetrical nature.
b) The symmetrical fault is the most severe and imposes more heavy duty on the circuit breaker.

(ii) Unsymmetrical faults

Those faults which give rise to unsymmetrical currents (i.e. un-equal line currents with unequal displacement) are called unsymmetrical faults. On the occurrence of an unsymmetrical fault, the currents in the three lines become unequal and so is the phase displacement among them. It may be noted that the term ‘unsymmetry’ applies only to the fault itself and the resulting line currents. However, the system impedances and the source voltages are always symmetrical through its main elements viz. generators, transmission lines etc. There are three ways in which unsymmetrical faults may occur in a power system .The unsymmetrical faults may take one of the following forms:

a) Single line-to-ground fault
b) Line-to-line fault
c) Double line-to-ground fault

The great majority of faults on the power system are of unsymmetrical nature; the most common type being a short-circuit from one line to ground .

CHAPTER 4

TRANSFORMER

4.1 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:

$$V_s = N_s \frac{d\varphi}{dt} \qquad (1)$$

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

$$V_p = N_p \frac{d\varphi}{dt} \qquad (2)$$

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

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

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.

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

a) core type
b) 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 [2]. Energypac mainly produces core type transformers because it is cheaper than shell type. Hence core type is widely used in industries. I have given the picture of the power transformer as shown in Figure 4.1 and distribution transformer as shown in Figure 4.2.

The following points may be noted carefully:

(i) The transformer action is based on the laws of Faraday's law of Electromagnetic Induction.
(ii) There is no change in frequency.

(iii)The losses that occur in a transformer are:

a) core losses

b) copper losses

Figure 4.1: Power Transformer

Figure 4.2: Distribution Transformer

4.2 Major Components of a transformer

a. Core
b. HT coil
c. LT coil
d. Main Tank
e. Buchholz relay
f. Bushing
g. Conservator Tank
h. Tap Changer
i. Radiators
j. Breathers

The brief description of these components is given below:

- **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 [9].

- **Conservator**

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 [10].

- **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 a oil cap to stop entering the particles such as dust enter the transformer. Breather contributes to safe and reliable operation of the transformer.

- **Radiators**

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 [8].

4.3 Important Raw Materials

a. Copper
b. Aluminum
c. Silicon Steel
d. Transformer Oil
e. Mild Steel Sheet
f. Stainless Steel Sheet

4.4 Transformer manufacturing procedures

Here I have given the transformer manufacturing flow chart as shown in Figure 4.3.

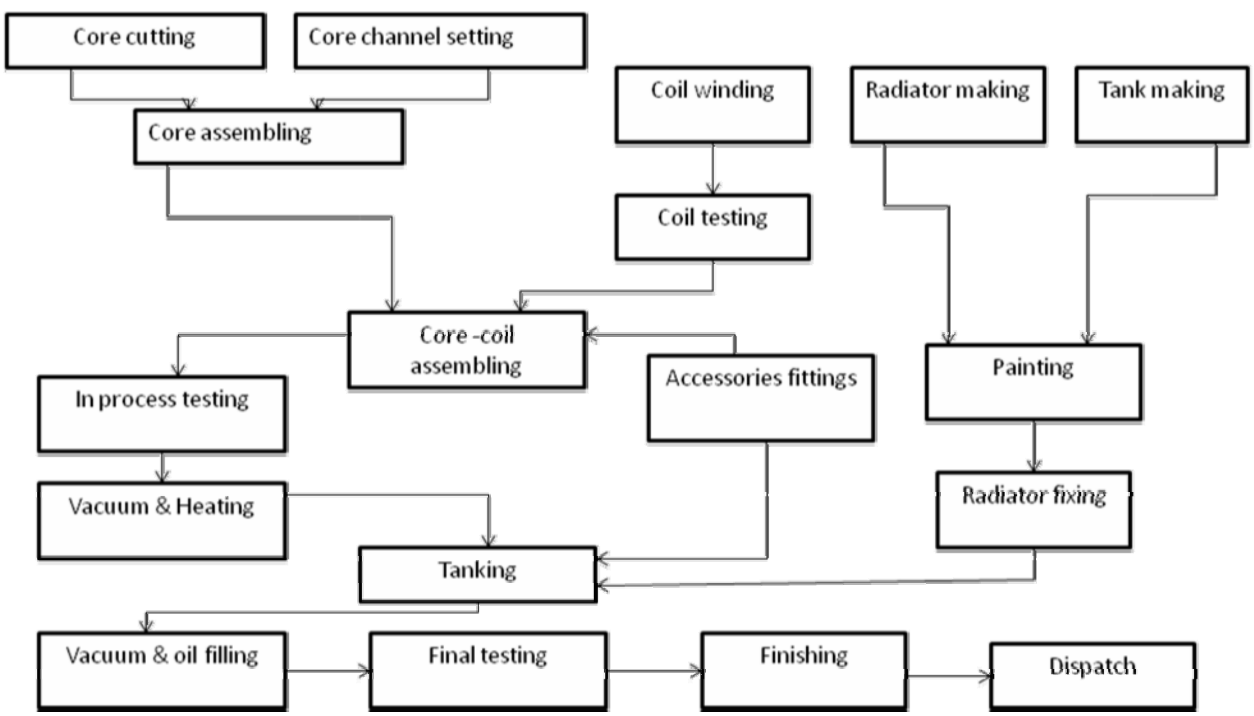

Figure 4.3: Transformer manufacturing flow chart.

4.5 Transformer Core cutting & Channel setting

CRGO (Cold Rolled Grain Oriented) steel with silicon lamination is used as core material in transformers. CRGO is an alloy steel which contain certain percentage of silicon. This material has excellent magnetic property of high permeability and low hysteresis loss at reasonable operating flux density. Core is laminated in order to reduce eddy current loss. These features considerably reduce the iron losses and no load current. Two types of core cutting used in transformer. They are:

a) Manual core cutting
b) Auto Core Cutting

Manual core cutting is used in Distribution transformer. Auto Core Cutting unit is used in Power transformer. An Auto Core Cutting unit where cores are cut to give the right size for the transformer. There is a PLC (Programmable Logic Controllers) which actually controls the machine which cuts the core to the desired size and number. This total machinery is imported from Micro Tool and Machine Ltd, Canada (www.mtm-coreshears.com).The technicians just set the required size and number of cores through the software of PLC and the machine does the rest. Here I have taken the yoke length =1480 mm and leg length= 1600mm of the core for 10-12.5 MVA as shown in Figure 4.4. Core type is three legs and thickness of a single core is 0.27mm. Here Feeding delay is 0.9sec and Arm delay is 0.2sec.

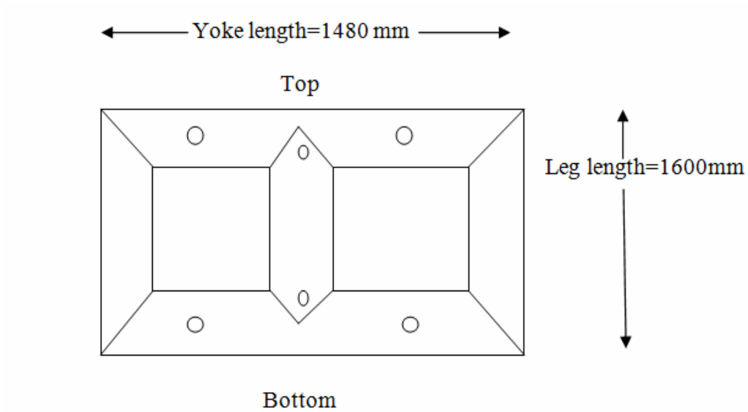

Figure 4.4: Core for 10-12.5MVA(Geometric view of Core cutting)

At first one of the top and one of the bottom channels is set horizontally.Four channels is to set, two in top and two in bottom.I have given a picture of channel setting as shown in Figure 4.5

Figure 4.5:A snapshot of channel setting

4.6 Core Assembling

Starting from the lower stack the core assembling for bottom stack is started. One stack consist of three metal core sheet. I have given a picture of core assembling at primary stage as shown in Figure 4.6(a) and core assembled as shown in Figure 4.6(b)

Figure 4.6(a):Core assembling at primary stage

Figure 4.6(b): Core assembled

4.7 Coil Winding

A completed coil assembly with taps is often called a winding. Coil Winding is the process of making an electromagnetic coil. Coil Winding basically consists of winding wire (usually copper or aluminium) around a core. The whole process from beginning to end product is generally referred to as Coil Winding. Various types of winding are done depending on the client's requirement. Types of coil manufactured at Energypac :

(i) Disk winding

The most popular winding type is the disk winding. I have given a picture of disk winding as shown in Figure 4.7.These are used for HV windings of power transformers. Several numbers of turns are wound like a disk and several disks are covered through the core. For a 40/45 MVA, 11/230KV transformer there is 94 disks with 13 turns in each disk.

Figure 4.7: Disk winding

(ii) Cross-over winding

The second popular winding type is the cross over coil. These are used for HV windings of distribution transformers. Copper wire is used as a coil which is wound one after another across the core. These turns are wound in several layers.

(iii) Spiral winding

This is commonly used for LV winding. I have given a picture of spiral winding as shown in Figure 4.8.This winding is done spirally around the core and two layers are given on it. It is also used to reduce number of turns.

Figure 4.8: Spiral winding

(iv) Foil winding

This is similar as cross-over winding. But Copper wire is not used in this winding. Aluminium wire is used as a coil.

4.8 Insulators

There are many types of insulators used in a transformer. Energypac imported insulators from other countries. The names of the insulators are given below:

1. Double Paper Cover (DPC) paper (Over copper wire)
2. Crepe paper (Over copper wire)
3. Press board (Used in between each coil)
4. Pharma wood (Between the channel and coil)

4.9 Core Coil assembly

Press board is surrounded around the core in circle making way. LT coil is putted over the press board. I have given a picture of core coil assembly in progress as shown in Figure 4.9(a) and core coil assembly completed as shown in Figure 4.9(b). Again, for insulation, press board is surrounded over the LT coil. HT coil is putted over the press board.

Figure 4.9(a): Core coil assembly in progress

Figure 4.9(b): Core coil assembly completed

4.10 Vacuum Drying Plant

The whole active part of the transformer is put into the Vacuum Drying Plant as shown in Figure 4.10. It is kept there for three days with a continuous heating temperature of 100^0 C to clean the moistures in it.

Figure 4.10: Vacuum Drying Plant

4.11 Transformer Tap Changer

Energypac imports tap changers from some reputed companies of the world like ABB, HUAMING and MR etc. There are two types of transformers:

1. On load – Plus/minus, Linear.
2. Off load.

A tap changer is a device fitted to transformers for regulation of the output voltage to required levels. This is normally achieved by changing the ratios of the transformers on the system by altering the number of turns in one winding of the appropriate transformers. Supply authorities are under obligation to their customers to maintain the supply voltage between certain limits. Tap changers offer variable control to keep the supply voltage within these limits [14]. Tap changers are always connected with the HV side to minimize the current handling requirements of the contacts. HV side carries lower current. That's why tap changers are connected with this side.

4.11.1 On Load Tap-Changing Transformer

I have discussed about two types of on load tap changers here.

Plus/Minus:

Figure 4.11(a) is Plus/Minus type of on load tap changing transformer.In figure-1, we can observe secondary consists of two equal parallel windings. In the normal working condition, switches a, b and tappings with the same number remain closed and each each secondary winding carries one-half of the total current. Referring to the figure, voltage will be maximum when switches a, b and 5a, 5b are closed. However, the secondary voltage will be minimum when switches a, b and 1a, 1b are closed.

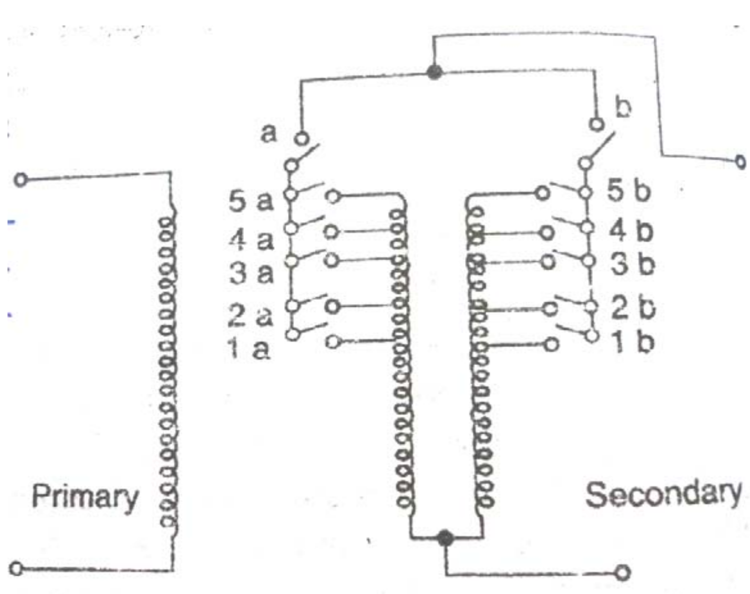

Figure 4.11(a): Plus / Minus type on load tap changing Transformer .

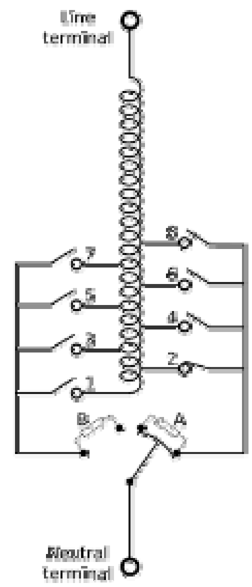

Figure4.11(b): Linear type on load tap changing Transformer

Suppose the transformer is operating with tapping position at 4a, 4b and it is desired to alter its position to 5a, 5b. for this purpose, one of the switches a and b, say a, is opened. This takes secondary windiong controlled by switch a out of the cicuit. Now, the winding controlled by switch b carried the total current which is twice its rated capacity. Then the tapping on the disconnected winding is changed to 5a and switch a is closed. After this, switch b is opened to disconnect its winding, tapping position on this winding is changed to 5b and then switch b is closed. In this way, tapping position is changed without interruting the supply .

Disadvantages:

1) There are double as many tappings as the voltage steps.

2) During swiching , the impedence of transformer is increased.

Linear:

Figure 4.11(b) is linear type of on load tap changing transformer In figure-2, we can observe that even and odd number of tap positions are taken from a single winding. Even positions are connected with terminal A and the odd positions are with terminal B. We can see the figure that it is working with tap position 2. If it desires to change its position to 3, then the contact of 3 will be connected through the signal from a motor drive unit. Then the magnetic contact of neutral terminal will be moved from switch A to B. Then the contact 2 will be opened as well. That’s how it works [1].

4.11.2 Off load Tap-Changing transformer

In this type of transformer, the load is kept open and that’s why the name off load tap-changing transformer .

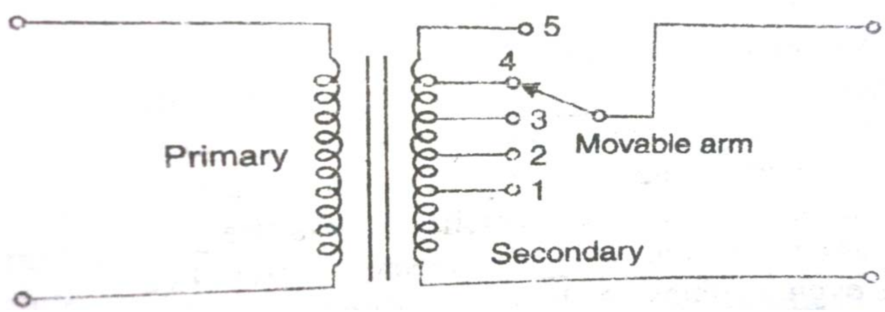

Figure 4.12: Off load Tap Changer.

The Figure 4.12 shows the arrangement where tappings have been provided on the secondary. As the position of the tap is varied, the effective number of turns is varied and hence the output voltage of the secondary can be changed. Thus referring to the above figure when the movable arm makes the contact with tap position 1, the secondary voltage is minimum and when with position 5, it is maximum. During the period of a light load, the voltage across the primary is not much below the alternator voltage and the movable arm is placed on tap position 1.

When the load increases, the voltage across the primary drops, but the secondary voltage can be kept at the previous value by placing the movable arm on to a higher tap position.

Off load tap-changing transformer circuit arrangement shown to the above figure cannot be used for tap-changing on load. Assume for a moment that tapping is changed from position 1 to position 2 when the transformer is supplying load. If contact with position 1 is broken before contact with position 2 is made, there is break in the circuit and arcing results. On the other hand, if contact with position 2 is made before contact with position 1 is broken, the coils connected between these two tappings are short-circuited and carry damaging heavy currents. For this reason, the above circuit arrangement cannot be used for tap-changing on load [1].

4.12 Vector Groups

The vector group indicates the way in which the primary & secondary windings are connected and the phase difference between the primary and secondary sides of the transformer. It consists of code letters that specify the connection of the phase windings and a code number that defines the phase displacement. The transformer vector group is indicated on the Name Plate of transformer by the manufacturer.

The most commonly used vector groups available for a transformer are shown below:

a. Yd1/ YNd1
b. Yd11/ YNd11
c. Dy1/ Dyn1
d. Dy11/ Dyn11
e. Dd0/ Yy0
f. Zig Zag

Now I am explaining the physical meaning which is given below:

First symbol (Capital letter): Primary side connection of transformer.

Second symbol (Lower case letter): Secondary side connection of transformer.

Third symbol (Number): Phase displacement expressed as the clock hour number.

Capital letter:

Mesh or Delta = D

Star or Wye = Y

Zigzag or Interconnected star = Z

Neutral = N

Lower case letter:

Mesh or Delta = d

Star or Wye =y

Zigzag or Interconnected star =z

Neutral =n

The vector for the high voltage winding is taken as the reference vector. Displacement of the vectors of other windings from the reference vector, with anticlockwise rotation, is represented by the use of clock hour. We have to use the hour indicator as the indicating phase displacement angle. According to International Electrotechnical Commission (IEC) standards, phase rotation is always anti-clockwise. Because there are 12 hours on a clock, and a circle consists out of 360°, each hour represents 30°.

Thus 1 = 30°, 2 = 60°, 3 = 90°, 6 = 180° and 12 = 0° or 360°.The minute hand is set on 12 o'clock and replaces the line to neutral voltage (sometimes imaginary) of the HV winding. This position is always the reference point. Because rotation is anti-clockwise, 1 = 30° lagging (LV lags HV with 30°) and 11 = 330° lagging or 30° leading (LV leads HV with 30°)[11].I have given a picture of all vector groups connections as shown in Figure 4.13.

I saw Dy1 and Dyn11 connection mainly in the energypac.

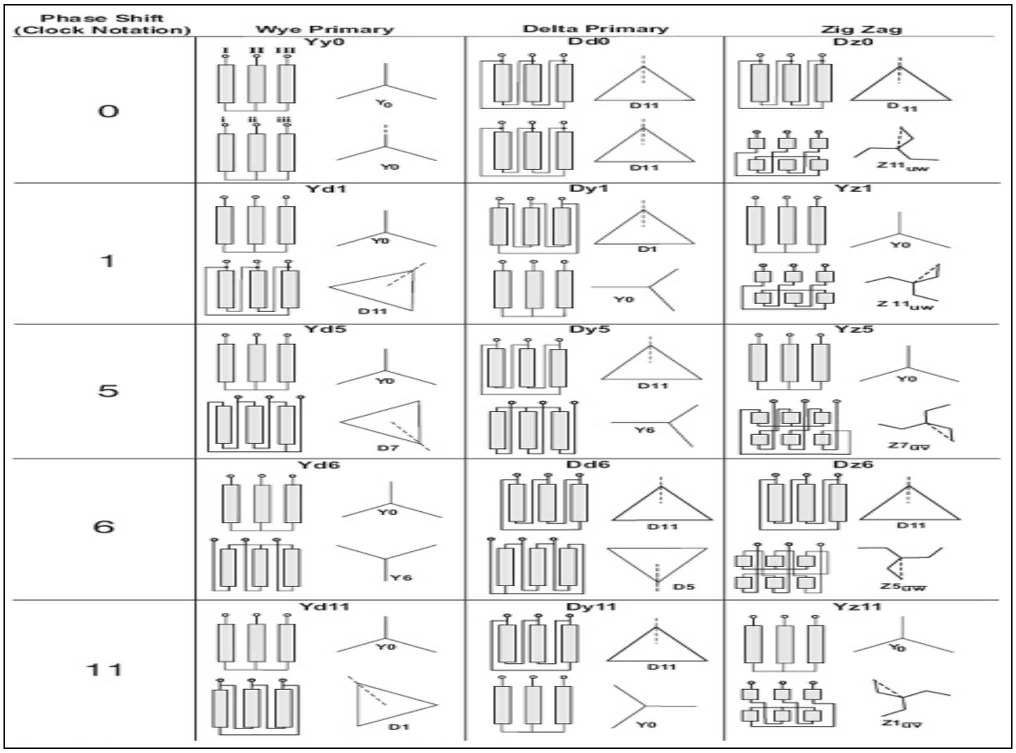

Figure 4.13: All Vector groups connection

Dy1: A transformer with a vector group of Dy1 has a Delta connected HV winding and star connected LV winding. LV is lagging HV with 30°. For Dyn1, there is neutral brought out.

Dyn11: A transformer with a vector group of Dyn11 has a Delta connected HV winding and star connected LV winding with neutral brought out. HV is lagging LV with 330° and other way we can say LV is leading HV with 30°. For Dy11, there is no neutral brought out.

4.13 Transformer Testing

The test on finished transformer is a part of quality assurance. I always tried to learn the transformer testing. There are two types of tests done on a transformer.

a) In process test- Continuity test, Magnetizing current test, Ratio test, Magnetic balance test, Insulation resistance test.
b) Routine test- No load test, full load test.

Now I am explaining these all test.

- **Continuity test**

This test is designed to determine the coil continuity after the completion of coil winding and core coil assembly. It is done with the help of a multi meter. We know that a close circuit can conduct electricity and an open circuit cannot conduct electricity. This continuity is the basic concept of this test.

- **Magnetizing current test**

The core of a nonideal transformer has finite permeability and core loss. Therefore, even when the secondary is left open the primary winding draws some current, known as the excitation current. The excitation current is the sum of core-loss current and the magnetizing current. Magnetizing current test of transformer is performed to locate defects in the magnetic core structure, shifting of windings, failure in turn to turn insulation or problem in tap changers. These conditions change the effective reluctance of the magnetic circuit, thus affecting the electric current required to establish flux in the core. First of all we have to keep the open high tension side. Then apply three phase 415V supply on the line terminals of low tension side for three phase transformers and single phase 230V supply on single phase transformers. After that we measure the supply voltage and electric current in each phase. Magnetizing current measure by the clamp on meter. I have given here an observed result that I found while doing this test.

Rating: 10/12.5 MVA, 33/11.55KV, Power Transformer

Table 4.1 Parameters of Magnetizing current test

Measured Voltage	Measured Current	Meter Name	Remarks
V a-b= 394.2V	Ia= 32.6 mA	Clamp on Meter	Satisfactory
V b-c= 394.8V	Ib= 29.5 mA		
Vc-a= 395.1V	Ic= 39.4 mA		

- **Ratio test**

The performance of a transformer largely depends upon perfection of specific turns or voltage ratio of transformer. So transformer ratio test is an essential test of transformer**.** This test is done after core coil assembly under in process test. The ratio of the HT & LT winding of the transformer is measured by Automatic Transformer Ratio Tester (ATRT) as shown in Figure 4.14. It gives the values of the ratio for both the LT and HT windings. I have given here an observed result that I found while doing this test.

Figure 4.14: Transformer Turn Ratio Tester

Rating: 10/12.5 MVA, 33/11.55KV, Power Transformer

Table 4.2 Parameters of Ratio Test

Tap Position	Actual Ratio	Measured Ratio		
		Phase A	Phase B	Phase C
1	5.196	5.193	5.192	5.194
2	5.072	5.072	5.073	5.071
3	4.949	4.951	4.950	4.952
4	4.824	4.831	4.829	4.827
5	4.701	4.705	4.704	4.711

- **Magnetic balance test**

This test is designed to determine the magnetic imbalance. A two phase supply of 220V is applied across two phase, another phase is kept open. The voltage is then measured twice, each between one of the first two phases and open phase. The sum of these two voltages should give the applied voltage. I have given here an observed result I found while doing this test.

Rating: 10/12.5 MVA, 33/11.55KV, Power Transformer

Table 4.3 Parameters of Magnetic balance test

Supply Voltage (V)		Measured Voltage (V)		Sum of measured Voltage (V)	Measured Current (mA)	
V_{an}	230	V_{bn}	150	234	I_a	55.8
		V_{cn}	84			
V_{bn}	230.6	V_{an}	115.2	230.8	I_b	47.5
		V_{cn}	115.6			
V_{cn}	230.2	V_{an}	84	233.8	I_c	55.5
		V_{bn}	149.8			

This test result is satisfactory as per my instructor's saying and I understood the reasons behind it as well.

- **Insulation resistance test**

Insulation resistance test is measured by KYORITSU High Voltage insulation Tester (KHVIT- Model 3125) as shown in Figure 4.15. I have given the picture of KHVIT. A DC voltage 5000 V is given and reading is taken after 15 and 60 seconds. In this test, the insulation of LT-E (Earth), HT-E and HT-LT is checked. Here an example is given of it.

Figure 4.15: KYORITSU High Voltage insulation Tester

Rating: 10/12.5 MVA, 33/11.55KV, Power Transformer

Table 4.4 Parameters of Insulation resistance test

Time (Seconds)	Insulation Resistance (Mega Ohms)		
	LT-E	HT-E	HT-LT
15	9.24 GΩ	6.51 GΩ	9.71GΩ
60	20.7 GΩ	8.00 GΩ	19.1 GΩ

This test result is satisfactory. After these in process tests the transformer tank is filled with oil and then the routine tests are done on it.

- **Open Circuit Test or No Load 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 as shown in Figure 4.16. A wattmeter is connected to the primary. An ammeter is connected in series with the primary winding. A voltmeter is optional since the applied voltage is same as the voltmeter reading. The frequency of the applied voltage must be the rated frequency of the transformer.

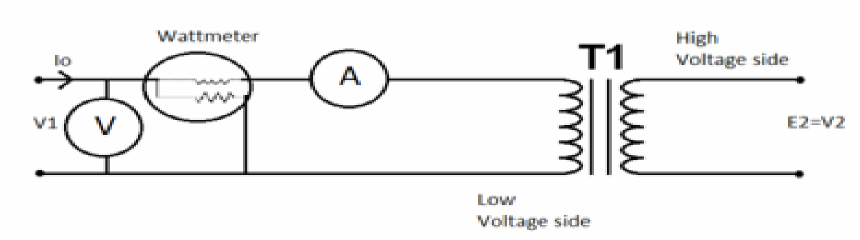

Figure 4.16: Open Circuit Test or No Load Test

If the applied voltage is normal voltage then normal flux will be set up. As the Iron loss is a function of applied voltage, normal iron loss will occur. Hence the iron loss is maximum at rated voltage. This maximum iron loss is measured using the wattmeter. Since the impedance of the series winding of the transformer is very small compared to that of the excitation branch, all of the input voltage is dropped across the excitation branch. Thus the wattmeter measures only the iron loss. It should be noted that the iron losses consist of the hysteresis loss and the eddy current loss. This test only measures the combined loss. Although the hysteresis loss is less than the eddy current loss, it is not negligible. The two losses can be separated by driving the transformer from a variable frequency source since the hysteresis loss varies linearly with supply frequency and the eddy current loss varies with the square. Since the secondary of the transformer is open, the primary draws only no load current which will have some copper loss. This no load current is very small and because the copper loss in the primary is proportional to the square of this current, it is negligible. There is no copper loss in the secondary because there is no secondary current [12].

Rating: 10/12.5 MVA, 33/11.55KV, Power Transformer

Table 4.5 Parameters of Open Circuit Test

Test Voltage KV	No- Load Current I_0 (A)	Watt Meter Reading - W1 (KW)	Watt Meter Reading – W2 (KW)	Watt Meter Reading – W3 (KW)	Remark
Van = 6.59	Ia = 0.82	1.66	2.42	3.83	CT Ratio = 2 PT Ratio = 55
Vbn = 6.74	Ib = 0.676				
Vcn = 6.66	Ic = 0.848				

No load loss= (W1+W2+W3) = 7.91KW.

It is reminded that iron losses are the same at all loads. Of course, iron losses will be the same if measured on either winding. But if measurement is made on high-voltage winding, the no load current would be inconveniently small and the applied voltage inconveniently large.

- **Short Circuit Test or Full load test**

This test is designed to determine the winding resistance and leakage reactances. In this test, the secondary is short circuited by a thick conductor and variable low voltage is applied to the primary as shown in Figure 4.17. The supply voltage required to circulate rated current through the transformer is usually very small and is of the order of a few percent of the nominal voltage and this voltage is applied across primary. The core losses are very small because applied voltage is only a few percentage of the nominal voltage and hence can be neglected [13].

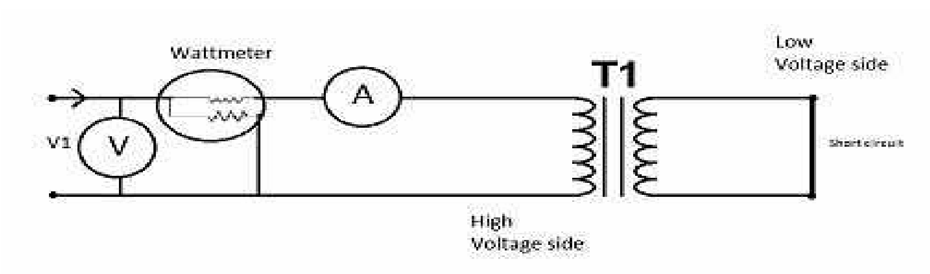

Figure 4.17: Short Circuit Test or Full load test

Thus the wattmeter reading measures only the full load copper loss.
For carrying short circuit test on power transformer we have to consider following things:

- Isolate the power transformer from service.
- Remove HV/LV jumps and disconnect neutral from earth/ground.
- Short LV phases and connect these short circuited terminals to neutral
- Energize HV side by LV supply.
- Measure current in neutral, LV line voltages, HV voltage and HV line currents.

I have given a test result for following specification where 3 watt meter method is used.

Rating: 10/12.5 MVA, 33/11.55KV, Power Transformer

Table 4.6 Parameters of Short Circuit Test

Rated Current (A)	Applied Current (A)	Applied Voltage (V)	Watt meter Reading (W1) (KW)	Wattmeter Reading (W2) (KW)	Watt meter Reading (W3) (KW)	Remarks
175	$I_A = 175.21$ $I_B = 172.66$ $I_C = 177$ $I_{avg}=174.96$	$V_{A-N} = 1125$ $V_{B-N} = 1143$ $V_{C-N} = 1145$ $V_{AVG}=1137.67$	11.83	14	13.07	CT Ratio=300 PT Ratio=10

Full Load Loss = (W1+W2+W3)= 38.9KW

These two tests are done through a panel as shown in Figure 4.18.

Figure 4.18: Loss Measurement Panel [6].

The Open Circuit Test and Short Circuit Test offer the following advantages:

a) These tests enable us to determine the efficiency of the transformer accurately at any load and power factor without actually loading the transformer.

b) The power required to carry out these tests is very small as compared to the full load output of the transformer.

Another type of test which is called the high voltage test/ impulse test is done for some special clients. It is basically done to test whether the transformer withstand the high voltage during heavy thunder occurs.

4.14 Instrument Transformer

Energypac introduced its indigenously developed Instrument Transformers in 1995. Since then Energypac is the only manufacturer of instrument transformers in Bangladesh. Energypac manufactures outdoor/indoor, oil cooled/cast resin Current Transformers (CT) ranging from 11 kV to 230 kV[6]. Available products at Energypac

- Indoor type (Dry) resin cast CT up to 11 KV
- Indoor type (Dry) resin cast PT up to 11 KV
- Outdoor type (Oil cooled) CT up to 230 KV
- Outdoor type (Oil cooled) PT up to 230 KV

4.14.1 Current Transformers (CT)

Direct measurement of current in high voltage system is not possible because of insulation problem of measuring instruments. It is also not possible to use current flowing through the system directly for protection purpose due to its high value and high insulation problem. I have given the picture of oil type CT as shown in Fig 4.19(a), LT coil of oil type CT as shown in Fig 4.19 (b)and dry type CT as shown in Fig 4.19 (c).

Fig 4.19(a): Oil type CT

Fig4.19 (b): LT coil of oil type CT

Fig4.19(c): Dry type

CT can be designed for Single or Multi ratio. The ratio selection can be achieved by providing two or four sections or primary for series/parallel connection, the current ratio shall be in proportion of 1:2:4. The advantage of this type of ratio is that output from each secondary remains constant for any type of ratio.

CT Basic functions of current transformers are:

- To reduce the line current to a value which is suitable for standard measuring instruments, relays, etc.
- To isolate the measuring instruments namely meters, relays, etc. from high voltage side of an installation.
- To protect measuring instruments against short circuit currents.
- To sense abnormalities in current and to give current signals to protective relays to isolate the defective system [6].

Outdoor type (Oil cooled) CT:

Oil type CT is named because of their cooling process. In oil type CT secondary coil is conducted metering. In oil type CT primary coil is surrounded manually and P1 and P2 are taken out.

Indoor type (Dry) resin cast CT:

CRGO silicon steel is used as core material .Core is inside a cast resin which confirms the insulation between the windings inside it. Secondary winding is done automatically and distributed equally on the periphery of the core to minimize leakage reactance. Primary winding is of braided electrolytic copper conductors with double cotton covering. Varnished fiber glass sleeve is provided as an additional insulation on this conductor. High quality crepe insulating paper is used to build up main insulation of the CT. brown/white glazed porcelain bushing with different shade profiles to suit different pollution conditions are used [6]. Here no cooling oil is needed as those are indoor types with low ratings.

CT can be used as:

1) Protection Class
2) Metering Class

4.14.2 Potential Transformers (PT)

Direct measurement of voltage in high voltage system is not possible because of insulation problem of measuring instruments. It is also not possible to use direct voltage for the system protection purpose due to its high value and high insulation problem of protective relays.

Therefore, Voltage Transformers or Potential Transformers (PT) is used to step-down the high system voltage to low standard value accurately in proportion to their ratio. . I have given the picture of oil type PT as shown in Figure 4.20(a) and dry type PT as shown in Figure 4.20(b).

Basic functions of potential transformers are:

- To reduce the line voltage to a value which is suitable for standard measuring instruments, relays, etc.
- To isolate the measuring instruments, meters, relays, etc. from high voltage side of an installation.
- To sense abnormalities in voltage and give voltage signals to protective relays to isolate the defective system.

Figure 4.20(a): Oil type PT

Figure 4.20(b): Dry type PT

Copper enameled wire is used for winding. Primary is wound with multilayer and graded insulation. Secondary is separately wound and inserted in the primary winding as per the requirement. Winding and tapping of PT is done in dust-free atmosphere. CRGO silicon steel is used for building up electromagnetic core. Shell type construction is used to minimize leakage reactance. Bottom/dead tank and oil expansion chamber are made of MS sheet which is the bottom portion of outdoor type PT. Brown/white glazed porcelain bushing with different shed profiles to suit different pollution condition is used. These bushings are hollow cylindrical type conforming to IEC 815/IS 5621. High quality electrical grade Kraft paper and crepe paper is used for insulating primary and secondary of PT [7].

4.15 Transformer Oil

Use of oil as an insulating and cooling medium has greatly helped in the rise of transformer rating. Both the core loss and the copper loss in a transformer generate heat, which, in turn, increases the operating temperature of the transformer. In small transformer, natural air cooling is used. This method of cooling is termed as AN (Air Natural). In distribution transformer, natural air circulation is not enough, a transformer are generally cooled by housing them in tanks filled with oil. This method of cooling is termed as ON (Oil Natural). The oil serves a double purpose, carrying the heat from the windings to the surface of the tank and insulating the primary from the secondary. The scientific name of the oil that is been put in the tank is Ascarol Piron. For large power transformers, external radiators are added to increase the cooling surface of the oil filled tank. The oil circulates around the transformer and moves through the radiators where the heat is released to surrounding air. Sometimes cooling fans blow air over the radiators to accelerate the cooling process. This method of cooling is termed ONAF (Oil Natural Air Forced). In many large sized transformers the cooling method is matched with the amount of heat that is required to be removed. As the load on the transformer changes the heat generated within also changes. Suitable cooling method can be pressed into service at that time. This gives rise to the concept of mixed cooling technique.

4.16 Transformer Ratings

The nameplate of a transformer provides information on the apparent power (volt-ampere) and the voltage handling capacity of each winding. The range of power rating, voltage rating and frequency rating for the transformers of Energypac provides the following information:

Power Rating: 50 MVA/ 75 MVA

Voltage Rating: 132 KV/33 KV

Frequency: 50Hz

From the nameplate of a 4.5-MVA, 11/0.415-KV, 50Hz, step-down transformer we can say that it’s nominal or full load power rating is 4.5 MVA or it can deliver 4.5 MVA on a continuous basis. Since it is a step down transformer then primary voltage is 11 KV and secondary voltage is 415 V. The rated currents of the transformer windings are not usually given on the nameplate but can be calculated from the KVA rating and voltage ratings of the windings [4].

4.17 Applications of Transformers

There are three principle applications of transformer.

a) Power Transformers

They are designed to operate with an almost constant load which is equal to their rating. The maximum efficiency is designed to be at full-load. This means that full-load winding copper losses must be equal to the core losses.

b) Distribution Transformers

These transformers have variable load which is usually considerably less than the full-load rating. Therefore, these are designed to have their maximum efficiency at between one half and one fourth of full load.

c) Instrument transformers

Voltage and current transformers are used to extend the range of a.c. instrument [4].

CHAPTER 5
SWITCHGEAR

5.1 Basics of Switchgear:

Energypac Engineering Limited manufactures low voltage switchgear (hereafter called LT Panel) which is applied for power control and distribution systems of AC 50Hz, rated working voltage up to 440V. It's mainly used in power station, industrial enterprise, Commercial/Residential Buildings for power distribution and can be used to control, protect and inspect the circuit. LT Switchgear is considered as the heart of the system. One of the major components of LT panel is the Power Factor Improvement (PFI) panel. Medium voltage switchgear ranges up to 33KV and high voltage switchgear up to 230KV. Vacuum Circuit Breaker (VCB), Air Circuit Breaker (ACB), Load Break Switch (LBS) those are the main panels of medium and high voltage switchgear [6].

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. This is achieved by an apparatus called switchgear.

The apparatus used for switching, controlling and protecting the electrical circuits and equipments is known as switchgear [1]. In an electric power system, switchgear is the combinations of electrical disconnect switches, fuses or circuit breakers used to control, protect and isolate electrical equipment. Switchgear is used both to de-energize equipment to allow work to be done and to clear faults downstream. This type of equipment is important because it is directly linked to the reliability of the electricity supply. Typically, the switchgear in substations is located on both the high voltage and the low voltage side of large power transformers. The switchgear on the low voltage side of the transformers may be located in a building, with medium-voltage circuit breakers for distribution circuits, along with metering, control, and protection equipment.

Switchgear equipments mainly consist of:

- Fuse
- Circuit Breaker
- Switch
- Relay

a) Fuse

A fuse is a short piece of wire or thin strip which melts when excessive current flows through it for sufficient time. It is inserted in series with the circuit to be protected. When a short circuit or overload occurs then the current through the fuse element increases beyond its rated capacity. Thus raises the temperature and the fuse element melts or blows out disconnecting the circuit protected by it. In this way, a fuse protects the machines and equipment from damage due to excessive currents.

b) Switch

A switch is a device which is used to open or close an electrical circuit in a convenient way. It can be used under full-load or o-load conditions but it cannot interrupt the fault currents. When the contacts of a switch are opened, an arc is produced in the air between the contacts. This is particularly true for circuits of high voltage and large current capacity.Energypac mainly produces air-break switch and isolator switch.

(i) Air-break switch

It is an air switch and is designed to open a circuit under load. In order to quench the arc that occurs on opening such 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. Consequently, the arc is lengthened, cooled and interrupted. 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.

(ii) **Isolator switch**

Isolator switch means disconnecting switch. It is essentially a knife switch and is designed to open a circuit under no load. Its main purpose is to isolate one portion of the circuit from the other and is not intended to be opened while current is flowing in the line. Such switches are generally used on both sides of circuit breakers in order that repairs and replacement of circuit breakers can be made without any danger. They should never be opened until the circuit breaker in the same circuit has been opened and should always be closed before the circuit breaker is closed.

c) Relay

A relay is a device which detects the fault and supplies information to the breaker for circuit interruption.

d) Circuit Breaker

A circuit breaker is equipment which can open or close a circuit under all conditions like no load, full load and fault conditions. Even in instances where a fuse is adequate, as regards to breaking capacity, a circuit breaker may be preferable. It is because a circuit breaker can close circuits, as well as break them without replacement and thus has wider range of use altogether than a fuse. The circuit breaker is labeled with the rated current in Amperes.

5.2 Vacuum Circuit Breaker (VCB)

Energypac is the first and only company in Bangladesh to introduce vacuum circuit breaker in the country way back in 1998. Energypac mainly produces 11 KV and 33 KV VCBs as shown in Figure 5.1. The construction is of metal clad type and uses high grade CRCA steel of adequate thickness ensuring safety and security. HHV 12 employs rated vacuum interrupters for arc extinction. The interrupters are procured from most renowned and the best quality manufacturer of the world, CUTLER-HAMMER (EATON), USA [6].

Special characteristics of VCBs are:

a) Very low arcing time
b) Quick recovery of dielectric strength
c) Small contact gap

d) Trouble free service
e) Low energy mechanism

Repair life of Vacuum Circuit Breaker is much longer than other types of circuit breakers. A vacuum circuit breaker is such kind of circuit breaker where the arc quenching takes place in vacuum. When the breaker operates, the moving contact separates from the fixed contact and an arc is struck between the contacts. The production of arc is due to the ionisation of metal ions and depends very much upon the material of contacts.

Figure 5.1: Vacuum circuit breaker

The arc is quickly extinguished because the metallic vapours, electrons and ions produced during arc are diffused in a short time and seized by the surfaces of moving and fixed members and shields. Since vacuum has very fast rate of recovery of dielectric strength, the arc extinction in a vacuum breaker occurs with a short contact separation [1].
The outdoor VCBs are larger in size but works exactly same as the indoor ones.

Advantages of VCB:

a) They can interrupt any fault current.
b) The vacuum interrupters have long life.

c) They have low arc energy.
d) Vacuum circuit breakers are almost maintenance free.
e) There are no fire hazards.

Disadvantages of VCB:

The main disadvantage of VCB is that it is uneconomical for use of VCB at voltages exceeding 38 kV. The cost of the breaker becomes prohibitive at higher voltages. This is due to the fact that at high voltages (above 38 kV) more than two numbers of interrupters are required to be connected in series.

5.3 Load Break Switch (LBS) Panel

This protective equipment is used at 11 kV sub-station. The main Load Break Switch (LBS) mechanism is available for 630A & the over current protection scheme is done through HRC fuse. The panel includes 3 numbers of CT (Current Transformer) & 2/3 numbers of PT (Potential Transformer) for measuring system current & voltage respectively & 3 numbers of HRC (High Rupturing Capacity) Fuses for protection of overload. The scheme is so designed that if fault occurs in any phase it will isolate the whole three phases from the system instantly. The panel also includes 3 numbers of Ampere meters & one number of Voltmeter with selector switch for monitoring system current & voltage. The standard panel size is 900x900x1800 mm & weight is around 450 kg [6]. I have given the picture of load break switch as shown in Figure 5.2.

Figure 5.2: Load break switch [6].

Load break switch can deenergize circuits under normal operating conditions. It should be capable of making and breaking normal load currents. The load break switch must be able to perform making operations under short-circuit conditions, since this is a possible operation condition when energising a medium voltage circuit under short-circuit conditions.

At the bottom of the figure we could see the three CTs. Those are connected in series with the 3 load break switches. The HRC fuses are put with these LBSs. There are PTs as well on the head of the fuses to assist the voltmeters to take the reading. Load break switches are not used that much. These are basically used instead of VCBs sometimes. It depends on the client's need.

Advantage of LBS:

It is very economical compare to the VCB panel. Hence many clients order it to reduce the cost.

Disadvantage of LBS:

There are lots of disadvantages involved in it. Here fuses need to be replaced after once it is damaged. It should have to be done in presence of an engineer. Its manual operation is not very user friendly like VCB as well.

5.4 Control, Metering and Relay panels

Energypac designs of control, metering & relay panels are based on the concept of unit assembly from standard parts. Control, Metering and Relay panels facilitate centralized control of the related controlled equipment in power stations, switching stations and industrial plant. I have given the picture of control, metering & relay panels as shown in Figure 5.3.The panel is built up of separate sheets which consist of front panel, two side panels, door frame, door and roof providing rigidly and strength. The panel has a standard dimension of height: 2350 mm, Width: 400 mm to 900 mm and depth: 500 mm to 1200 mm. Design and manufacture control & relay panel based on Customer's requirement. The enclosure is constructed by using sheet steel and is equipped with interior lamp, anti-condensation facilities. It is suitable for floor mounting and bottom entry of auxiliary power and multicore cable.

Figure 5.3: Control, metering & relay panels [6].

Major Compartments/Components of Control Relay Panel:

a) Metering
b) Window alarm fascia
c) Protection relay

Metering is used to see and measure the flowing current and existing voltage. Many types of metering can be used based on the necessity of the system. They are:

a) Ammeter (to measure the current)
b) Voltmeter (to measure the voltage of the system)
c) KWH meter (to measure the used power)

The protection relays are equipped for fault protection of system operation. Protection relays are designed and applied to provide maximum discrimination between faulty and healthy circuits. Facilities are provided to give remote signal and audible alarm alerting the control room attendant of the operation of protection devices and mal-operation of power equipment[6].

5.5 Power Factor Improvement (PFI) Plant

We know that the power factor of a circuit is the ratio of the active power to the apparent power. In other words, the cosine of angle between voltage and current in an a.c. circuit is known as power factor. If the circuit is inductive, the current lags behind the voltage and the power factor is referred to as lagging. However, in a capacitive circuit, current leads the voltage and power factor is said to be leading. Power factor of the system is degraded due to inductive load of different industries and big apartments. I have given the picture of Power Factor Improvement Plant as shown in Figure 5.4. Energypac manufacture PFI (Power Factor Improvement) Plant for improving the degraded Power Factor of the system. They have microprocessor based PFC (Power Factor Correction) relay up to 16 stages. The Capacitors they use are of different ratings (2.5, 5, 7.5, 10, 20, 25, 50 KVAR…. etc) and corresponding Magnetic Contactor for suitable stepping of the Capacitor bank. Sometimes they also use detuned Reactor with the Capacitors for harmonic filtration of the system. The standard panel size is 600x600x1700 mm (single unit) and the weight is around 200 kg [6].

Figure 5.4: Power Factor Improvement (PFI) Plant [6].

5.5.1 Benefits of Improving Power factor

- To decrease the price of electricity
- To increase the earning capacity of the power station
- To decrease transmission loss.
- To decrease voltage drop
- To improve voltage quality
- To increase in available power

5.5.2 Disadvantages of low power factor

The disadvantages of low power factor in a 3-phase system are:

a. Large Copper Losses

The large current at low power factor causes more I^2R losses in all elements of the supply system which results in poor efficiency.

b. Large KVA Rating

The electrical machinery (transformers, switchgear) is always rated in KVA. Now,

$$KVA = KW / \cos\Phi$$

So, the KVA rating of the equipment is also inversely proportional to power factor. Therefore at low power factor, the KVA rating of the equipment has to be made more, making the equipment larger and expensive.

c. Greater Conductor Size

We know that load current in three phase system is

$$I_L = P / (3^{1/2} V_L \cos\Phi)$$

So, load current is inversely proportional to power factor. That means lower the power factor, higher is the load current and vice-versa. To transmit or distribute a fixed amount of power at constant voltage; the conductor will have to carry more current at low power factor. This necessitates large conductor size.

d. Poor voltage regulation

The large current at low lagging power factor causes greater voltage drops in alternators, transformers, transmission lines and distributors. This results in the decreased voltage available at the supply end, thus impairing the performance of utilisation devices. In order to keep the receiving end voltage within permissible limits, extra equipment is required.

5.6 Transformer Fault and protection:

Transformers are expensive component of the power system. Due to the long lead time for repair of and replacement of transformers, a major goal of transformer protection is limiting the damage to a faulted transformer.

The types of faults that the transformers are subjected to are classified as:

- **Internal Faults**

Internal faults on the transformer arise from deterioration of winding insulation due to overheating or mechanical injury. When an internal fault occurs, the trans-former must be disconnected quickly from the system because a prolonged arc in the transformer may cause oil fire. Therefore, relay protection is absolutely necessary for internal faults.

- **External Faults:**

These are due to failure of the cooling system, overload conditions and external short circuits. Time graded Over current & Earth Fault relays are employed for external short circuit conditions. Fuses are provided instead of circuit breaker for Distribution transformers.

The following relays are used for transformer protection:

- Buchholz relays
- Over current and earth fault relays

5.6.1 Buchholz relay

Buchholz Relay is a gas detection relay. It is installed in oil immersed transformers for protection against all kinds of faults. It is used to give an alarm in case of slow-developing faults in the transformer and to disconnect the transformer from the supply in the event of severe internal faults. It is usually in-stalled in the pipe connecting the conservator to the main tank.

Under normal conditions the relay is completely full of oil. Whenever a fault in transformer develops slowly, heat is produced locally, which begins to decompose solid of liquid insulated materials and thus to produce inflammable gas and oil flow. Gas gets accumulated in the Buchholz relay and replaces the oil in the relay. For minor fault, upper float operates the alarm.

If a serious fault occurs in the transformer, an enormous amount of gas is generated in the main tank. The oil in the main tank rushes towards the conservator via the Buchholz relay. These gases create a rise in pressure in the transformer tank due to which the oil is forced through the connecting pipe to the conservator. The oil flow develops a force on the lower float and over trips it causing its contacts to complete the trip circuit of the transformer breaker [5].

5.6.2 Over Current and Earth Fault Protection

The earth fault protection is used to provide protection against any earth fault in the windings of the transformer. It works on the principle that when the transformer winding is sound the currents in all the three phases will balance and no current will spill into the earth fault relay. The arrangement is such that the relay does not respond to any out of balance current between windings caused by tap changing arrangement.

The overload relays have high current setting and are arranged to operate against faults between the phases. Over current protection includes the protection from overloads. This is most widely used protection. Overloading of a machine or equipment generally means the machine is taking more current than its rated current. Hence with overloading, there is an associated temperature rise. The permissible temperature rise has a limit based on insulation class and material problems. Over- current protection of overloads is generally provided by thermal relays. Over current protection includes short-circuit protection. Short circuits are phase faults, earth faults or winding faults. The basic element in Over-current protection is an Over-current relay which picks up when the magnitude of current exceeds the pick up level. The over-current relays are connected to the system, normally by means of CT's. The over current protection is needed to protect the transformer from sustained overloads and short circuits. Induction type over current relays are used which in addition to providing overload protection acts as back up relays for protection of transformer winding fault.

CHAPTER 6

SUMMARY & FUTURE WORK

6.1 Conclusion

This internship was very successful to me. 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. Internship is a great opportunity to achieve this experience. The internship was also good to find out what my strengths and weaknesses are. This helped me to define what skills and knowledge I have to improve in the coming time. I feel very proud to be an intern of Energypac. I left Energypac but the memory still haunts my mind. Energypac is really helpful those who actually want to learn. 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 Energypac will help me in my professional life.

6.2 Future Work

- Energypac Engineering Ltd should hire more theoretical and practical experienced electrical design engineer. If the company desired to produce above 75 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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