# PROJECT PAPER

# ON

# LOAD CALCULATION & SUB-STATION DESIGN FOR ACADEMIC BUILDING-4,DIU ASHULIA CAMPUS

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**LOAD CALCULATION & SUB-STATION DESIGN FOR ACADEMIC BUILDING-4, DIU ASHULIA CAMPUS**

A Project submitted to the Electrical & Electronic Engineering Department of the Engineering Faculty, Daffodil International University (DIU) in partial fulfillment of the requirements for the degree of **Bachelor of Science in Electrical &Electronic Engineering.**


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## DECLARATION

This is to certify that this project is my original work. No part of this work has been submitted elsewhere partially or fully for the award of any other degree or diploma. Any material reproduced in this project has been properly acknowledged.

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# APPROVAL

The Project titled **—"Load calculation & sub-station design for academic building-4, DIU, Ashulia campus"** has been submitted to the following respected members of the Faculty of Engineering, Department of Electrical & Electronic Engineering in partial fulfillment of the requirements for the degree of Bachelor of Electrical and Electronic Engineering on by the following students and has been accepted as satisfactory.

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At first I would like to thank the Almighty who has helped me for completing the project. Then I must thank the people whose names are not included in the list of acknowledgement but helped me to survey and collect valuable information.

We want to pay our utmost respect to our honorable project Co-Supervisor, Engr. Sheikh Mohammad Mostafa, Assistant Engineer (Senior Admin Officer) Electrical, P&D, Daffodil International University who has given me chance to work on our idea and taken care of every issues of development that I will make possible with this concept.

We feel grateful to and wish our profound our indebtedness to supervisor Md. Dara Abdus Satter, Assistant Professor & Associate Head Department of Electrical & Electronic Engineering, Faculty of Engineering & Assistant Proctor Daffodil International University. Deep knowledge & keen interest of our supervisor in the field of Electric power influenced us to carry out this project. His endless patience, scholarly guideline, continual encouragement, constant and energetic supervision, constructive
Criticism, valuable advice at all stage made it possible to complete this project.

We are thankful to our honorable Md. Dara Abdus Satter, Assistant Professor & Associate Head Department of Electrical & Electronic Engineering, Faculty of Engineering & Assistant Proctor Daffodil International University who has given me inspiration to continue my innovative work. With their encouragement and my hard work, this idea or concept has brought to light.

# ABSTRACT

To be a B.Sc. Engineer from Daffodil International University, We have to take a four credit course as EEE-499 (Thesis/project). For our graduation we have taken EEE-499 which is Project. Our Project title is **"Load calculation & sub-station design for academic building-4, DIU Ashulia campus "** We have gathered practical knowledge about Substation, Sub-station Protection, Different types of Protective relays, Bus-Bar System, Sub-Station Installation, Layout Planning, Ring Main Unit (RMU),AVR, Busber Trunking system, Genarator, Power Transformer, Distribution Transformer, Instrument Transformer, Both CT, Isolator, Circuit Breaker, Fuse and Transformer ,Switchgear etc. Before doing this Project we had theoretical and practically knowledge about substation. But now we feel that we have gathered knowledge about this Equipment's comparing to before. In sub-station section we saw the whole process step by step. We learnt how to test a Transformer, What the difference are between Transformer and Instrument Transformer we have also learnt the use of CT and the reasons of using CT at high voltage range. We have also strong knowledge about Substation switchgear HT, LT, PFI, Bus-bar Trunking system and the use of circuit breaker and especially Load Calculation.

# Certification

This is to certify that this project and thesis entitled "**LOAD CALCULATION & SUB-STATION DESIGN FOR ACADEMIC BUILDING-4, DIU ASHULIA CAMPUS**" is done by the following students under my direct supervision and this work has been carried out by them in the laboratories of the Department of Electrical and Electronic Engineering under the Faculty of Engineering of Daffodil International University in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering. The presentation of the work was held on 29 January 2019.

**Signature of the candidates**

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# BOARD OF EXAMINERS

The project and thesis entitled **"LOAD CALCULATION & SUB-STATION DESIGN FOR ACADEMIC BUILDING-4, DIU ASHULIA CAMPUS"** submitted by **Md.Kawsar Ahmed**, ID No:112-33-622, Session: Summer 2019 has been accepted as satisfactory in partial fulfillment of the requirements for the degree of **Bachelor of Science in Electrical and Electronic Engineering** on 19 January 2019.

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# CHAPTER1

# INTRODUCTION OF SUB-STATION

## 1.1 Introduction

An electrical substation is an assemblage of electrical components including busbars, switchgear, power transformers, auxiliaries etc. These components are connected in a definite sequence such that a ckt. Can be switched off during normal operation by manual command and also automatically during abnormal conditions such as short-ckt.

Basically an electrical substation consists of number of incoming ckt. And outgoing ckt. Connected to common Bus-bar systems. A substation receives electrical power from generating station via incoming transmission lines and delivers elect. Power via the outgoing transmission lines.

## 1.2 Function of Substations

The substations apart from the distribution of the electricity have many other functions as follows:

1. Step up and step down of the voltage for transmission and distribution: As for the same power transmitted at a higher voltage the current is lower it results in lower transmission losses, hence is the need of stepping up and stepping down the voltage.
2. Switching and isolating the circuits for maintenance: Switching is also an important function of substations. Closing down a feeder circuit when the load demands are high needs to be done for the safety of the generating plants. Switching high voltages is a dangerous work, and special circuit breakers like air circuit breakers and oil circuit breakers for quenching the arcs have to be used.
3. Load shedding: When the power demand is more than the supply, the substations do load shedding on distribution circuits to maintain balance.

4. Correction of power factors circuits: The power factor has to be kept at the correct value when reactive loads are there to protect the generating plant and increase efficiency.
5. Safety devices like circuit breakers and fuses: These safety devices are provided for protecting the machineries on the distribution circuit as well as in the substation against high short circuit currents.
6. It contains bus bars for splitting the power for distribution: Thick bars of copper to which various distributing circuits are connected by nuts and bolts are known as bus bars.

## 1.3. Single Line Diagram of an Electrical Substation

The single line diagram of the 33kv substation is depicted in the figure below. The connection of the substation is divided as

- Incoming or power feeder connection (33kv Incoming Line)
- Power transformer connection via Lighting Arrestor & Busbar
- Voltage transformer connection for control and metering.
- Outgoing feeder for feeding the other subsequent substations or switchgear.
- Circuit Breaker & Isolator between the incoming and the outgoing lines.

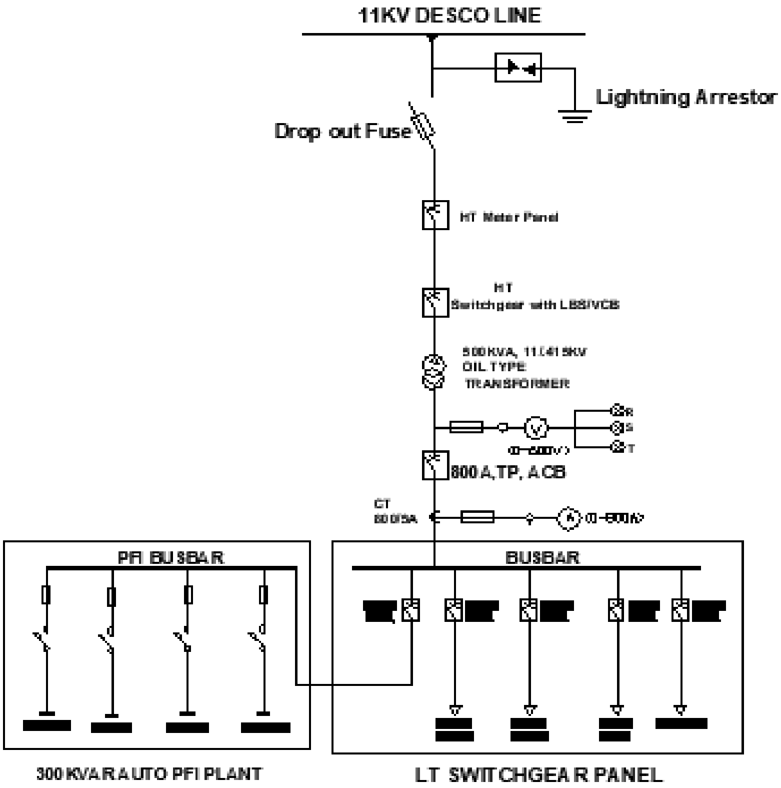



Fig1.3: Single Line Diagram of Substation

On the incoming 33kv incoming feeder line side, the transformer is connected to the bus bar and the lightning or surge arresters are connected as a phase to the ground as the initial connection equipment. A circuit breaker is connected between the 11kv bus-bar and each incoming and outgoing circuit with the support of the isolator being provided on each side of the circuit breaker.

## 1.4. Types of Electrical Substations

There are numerous **types of electrical substations** depending on its nature and power tackling capacities. **Classification of Substations** broadly falls under the following **4 categories** based on various aspects

1. Substation Types based on Application
2. Substation Types based on Service
3. Substation Types based on Operating Voltage Levels
4. Substation Types based on Location/Design

### 1.4.1 Types of Substations based on Applications

The following is the classification of substations based on the application aspect.

**1) Step-up Substation:**

The step-up substations are linked to generating stations directly as generation is achieved in lower voltages. Hence, these voltages are needed to be stepped-up for economical transmission of electrical energy over greater distance. The step-up substation may have circuit breakers which are utilized for transmission and generation circuits in the case when required to be shut down. The specified voltages which are leaving the step-up transmission are to be analyzed through customer’s needs.

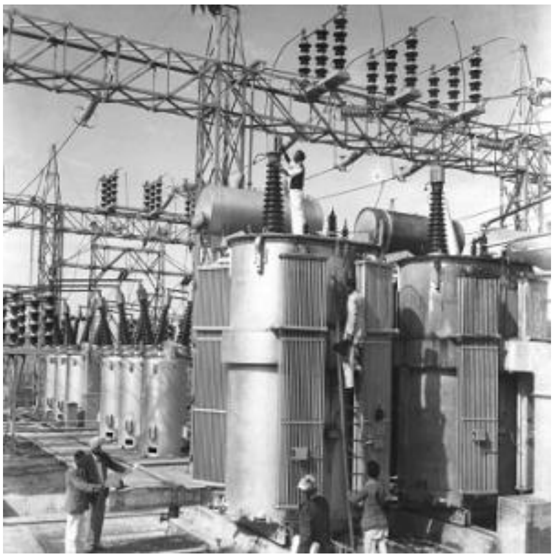


Fig1.4.1.a: Step up Substation

**2) Step-down Substation:**

The step-down substations are linked with load centers as there is a requirement of different voltage levels for various loads. The step-down substations are capable to change the voltage levels of transmission to usually 69kv. The lines of the substation are then serving as a source to that of the distribution substation. Moreover, some of the power is tapped from the substation line to be used for industrial purposes in the way.

Fig1.4.1.b: Step Down Substation

**3) Primary Substation:**

The primary grid substations are linked with bulk load centers alongside primary lines of transmissions. The voltages are stepped-down at various voltage ranges for purpose of secondary transmission.

Fig1.4.1.c: Primary Substation

**4) Secondary Substation:**

The secondary substations are lined alongside secondary transmission lines adjacent to loads. The voltages here are further stepped-down for purpose of distribution.

Fig1.4.1.d: Secondary Substation

**5) Distribution Substation:**

The distribution substations are located at the lace where voltages of primary distribution are being stepped-down. These voltages are for consumers to use for their actual loads. These substations are having high-voltage bearable wires and conductors having one neutral to ground and 4 live wires. The 3 phased voltage is of 34500 volts amid conductors and wires and the voltage is about 19920 volts in single phase when it is considered amid neutral to ground and conductor. Depending on the type of equipment used / Configuration, the substations could be classified as

Fig1.4.1.e: Distribution Substation

- Conventional – Outdoor type with air-insulated equipment
- Indoor type with air-insulated equipment
- SF6 Gas Insulated Substation
    - Outdoor type with gas-insulated equipment
    - Indoor type with gas-insulated equipment
- Composite Substation or Hybrid Substation combination of above two.

### 6) Mobile Substation:

The mobile substations are only for a dedicated purpose and are temporary in nature i.e. mainly for giant constructions. A mobile substation is supposed to fulfill power requirements of the under-construction structures. These substations are a source of temporary electrical supply and its maintenance is very easy. It has vibrant protection from blackouts, fires, weather disturbance, and sabotage etc.


Mobile Substation

### 7) Industrial Substation:

The industrial substations are also known as bulk substations and are traditionally referred to as distributive substation, however, these are for dedicated consumers only e.g. industries requiring bulk power to be supplied.

Fig1.4.1.f: Industrial Substation

**8) Mining Substation:**

The mining substation is of a distinct kind and is needed to be designed carefully as an increased level of precautionary safety measures are to be taken for the operation of its electrical energy. This substation is dedicated for the control of electrical power supply from the surface to mine power station lying underground.

## 1.4.2. Types of Substations based on Service

**Converter Substations–**

As the name suggests, Converter substations contain equipment that changes the frequency of current from higher to lower and can also convert AC to DC or the reverse also.

Fig1.4.2.a: Converter Substation

**Switching Substations–**

A key function of this switching station includes switching the power line without altering the voltages as they are placed in between the transmission lines. It also isolates the faulted portion of the systems and de-energizes faulted equipment which helps the grid operate with stability.

\

**Collector substations–**

These substations are primarily used in distributed power generation projects like wind farms, hydroelectric projects etc. where power flow from multiple power sources can be collected and distributed to the grid by stepping up the transmission voltage.

## 1.4.3. Types of Substations by Operating Voltage Levels

The substations classification below is based on the voltage levels they operate and may vary from region to region

1. **High Voltage Substations (HV Substations)** – Involving voltages between 11 KV and 66 KV.
2. **Extra High Voltage Substations (EHV)**– Involving voltages between 132 kV and 400 kV.
3. **Ultra High Voltage**(UHV) – Operating voltage above 400 KV.
4. **Direct-current high voltage** (dc HV) – ±250 kV, ±400 kV, ±500 kV

Fig1.4.2.b: High Voltage Substations

## 1.4.4. Types based on Locality / Design

The following are types of substations based on locality.

- **Outdoor Substation:** The outdoor substations are constructed in the open air. These are also known as **a 66KV substation**, **132KV substation**, **220KV substation**, and 400KV substation etc. These days gas insulated substations are built for high voltage systems.

Fig1.4.2.c: Outdoor Substation

- **Indoor Substation:** The indoor substations are generally of lower voltages and are built under a roof or closed compartment. These substations are also known as **11KV substation**s and 33KV substations etc.

Fig1.4.2.d: Indoor Substation

- **Pole Mounted Substation:** The **pole mounted substations** are majorly distribution substations which are constructed on the structure of two, four, or sometimes six or more poles. In such substations, there is a need of mounting distribution transformers over poles alongside isolator switches. The single pole is also known as H pole and 4 pole structures are more relevant which are operating at 25KVA, 125KVA, and 225KVA.

Fig1.4.2.e: Pole Mounted Substation

- **Underground Substation:** The underground substations are built in ground or subversive. These substations are built in congested places where building open air/outdoor substations are not possible. However, the design of such substations is very complex. The usual voltage level of such substation varies from 34500/19920 to about 4160/2400 volts.

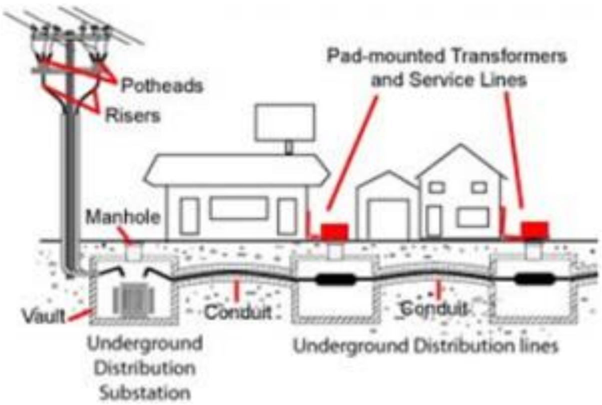



Fig1.4.2.f: Underground Substation

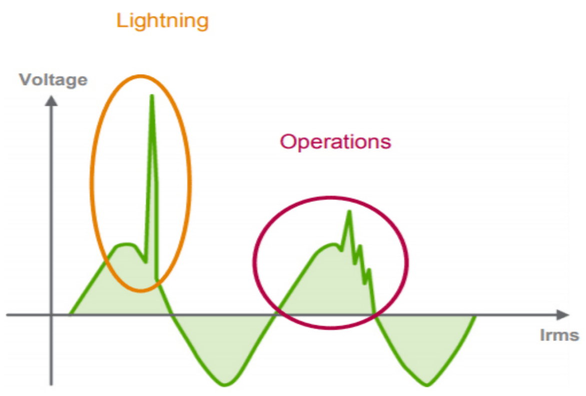
# CHAPTER 2

# SUB-STATION COMPONENTS

## 2.1. Lightning Arresters

### 2.1.1. What is an electrical surge?

A "surge" on an electrical system results from energy being impressed on the system at some point, which can result from lightning strikes or system operations. The impressed energy travels throughout the system in the form of waves, with speed and magnitude that vary along with the parameters of the system.




A "surge" on an electrical system results from energy being impressed on the system at some point, which can result from **lightning strikes** or **system operations**. Photo: Schnider Electric.

Each type of surge can affect the surge arrester and insulation system in a different manner. **Lightning** results in a *fast rate of rise* because it's a true source of coulomb energy, while **switching** operations result in a *relatively slow rate of rise* because it's energy is stored in the magnetic fields of the system.

Along with surge phenomena, a system can also experience a longer term overvoltage from **electrical faults**. Depending on the configuration and grounding of the system, a single line-to-ground fault will cause system voltage on the unaffected phases to escalate.

## 2.1.2Types of Lightning Arresters

The lightning arrestor is mainly classified into twelve types. These types are;

1. Road Gap Arrester
2. Sphere Gap Arrester
3. Horn Gap Arrester
4. Multiple-Gap Arrester
5. Impulse Protective Gap
6. Electrolytic Arrester
7. Expulsion Type Lightning Arrester
8. Valve Type Lightning Arresters
9. Thyrite Lightning Arrester
10. Auto valve Arrester
11. Oxide Film Arrester
12. Metal Oxide Lightning Arresters

**Types of Lightning Arrestors according to Class**

**1. Station Class**

- Station class arrestors are typically used in electrical power stations or substations and other high voltage structures and areas.
- These arrestors protect against both lightning and over-voltages, when the electrical device has more current in the system than it is designed to handle.
- These arrestors are designed to protect equipment **above the 20 mVA range**.

**2. Intermediate Class**

- Like station class arrestors, intermediate class arrestors protect against surges from lightning and over-voltages, but are designed to be used in medium voltage equipment areas, such as electrical utility stations, substations, transformers or other substation equipment.
- These arrestors are designed for use on equipment in the range of **1 to 20 mVA.**

**3. Distribution Class**

- Distribution class arrestors are most commonly found on transformers, both dry-type and liquid-filled.
- These arrestors are found on equipment rated at **1000 kVA or less.**
- These arrestors are sometimes found on exposed lines that have direct connections to rotating machines.

**4. Secondary Class**

- Secondary class lightning arrestors are designed to protect most homes and businesses from lightning strikes, and are required by most electrical codes, according to, Inc., an electrical power protection company.
- These arrestors cause high voltage overages to ground, though they do not short all the over voltage from a surge. Secondary class arrestors offer the least amount of protection to electrical systems, and typically do not protect solid state technology, or anything that has a microprocessor.

## 2.1.3Choosing the right AC Power Surge Arrester

AC power surge protectors are designed to cover all possible configurations in low voltage installations. They are available in many versions, which differ in:

- Type or test class (**1 , 2 or 3**)
- Operating voltage ($\mathbf{U_c}$)
- AC network configuration (**Single/3-Phase**)
- Discharge currents ($\mathbf{I_{imp}}$, $\mathbf{I_{max}}$, $\mathbf{I_n}$)
- Protection level ($\mathbf{U_p}$)
- Protection technology (**varistors, gas tube-varistor, filter**)
- Features (**redundancy, differential mode, plug-in, remote signaling…**)

The surge protection selection must be done following the local electrical code requirements (i.e. minimum rating for $\mathbf{I_n}$) and specific conditions (i.e. high lightning density).

## 2.1.4. Lightning Arrestor Ratings

The Rating of lightning arrestor are given below,

1. *Normal or rated voltage*: It is designated by the maximum permissible value of power frequency voltage which it can support across its line and earth terminal while still carrying effectively and without the automatic extinction of the follow up current. The voltage rating of the arrestors should be greater than the maximum sound phase to ground voltage.

2. *Normal Discharge current*: It is the surge current which flows through the LA after the spark over, expressed in crest value (peak value) for a specified wave shape. Example 10, 5, 2.5, 1.5, 1 kA rating.
3. *Power frequency spark over voltage*: It is the RMS value of the power frequency voltage applied between the line and earth terminals of the arrestor and earth which causes spark over of the series gap. As per IS 3070, the recommended spark over voltage is 1.5 times the rated voltage.

There are also other ratings like maximum impulse spark over voltage, residual or discharge voltage, maximum discharge current etc

### 2.1.5 Selection of Lightning Arrestor

For the protection of substation above 66KV an arrestor of 10kA rating is used.

Voltage rating of LA = Line to line voltage × 1.1 × coefficient of earthing.

Power frequency spark over voltage = 1.5 ×Voltage rating of LA

(Assuming coefficient of earthlings equals 0.8 for effectively earthed system)

**For 220KV side:**

Voltage rating = 1.1 × 220 × 0.8 = 193.6KV

Power frequency spark over voltage = 1.5 ×193.6 = 290.4KV

Rated discharge current = 10 Ka

**For 110KV side:**

Voltage rating = 1.1 × 110×0.8 = 96.8KV

Power frequency spark over voltage = 1.5 × 96.8 = 145.2KV

Rated discharge current = 10kA

**For 66kV Side**

Voltage rating = 1.1 × 66×0.8 = 58.08kV

Power frequency spark over voltage = 1.5 × 58.08 = 87.12kV

Rated discharge current = 10kA

**<u>For 11 KV side</u>**:

Voltage rating = 1.1× 11×0.8 = 9.68KV

Power frequency spark over voltage = 1.5×9.68 = 14.52KV

Nominal discharge current = 5kA

…………………………………………………………………………………………………

# 2.2Fuse

## 2.2.1 What are fuses?

Fuses are the protectors; these are the safety devices which are used to protect the home appliances like televisions, refrigerators, computers with damage by high voltage. The fuse is made up of thin strip or strand of metal, whenever the heavy amount of current or an excessive current flow is there in an electrical circuit, the fuse melts and it opens the circuit and disconnects it from the power supply. Also, it works as a **circuit breaker or stabilizer** which protects the device from damage. In the market, many types, features, and design of fuses are available nowadays. Their strips are made up of aluminum, copper, zinc & it is always connected in series with the **circuit to protect from overcurrent** in the running cables. Here is the basic circuit diagram & symbol of the fuse.

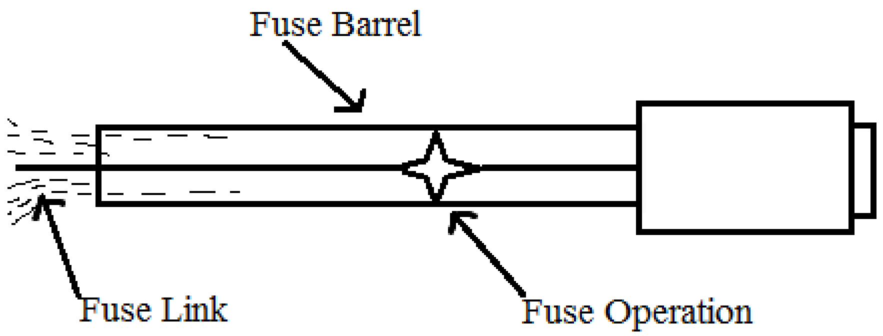
## 2.2.2 Why do we Need Fuse?

Fuses are used for the prevention of home appliances from the short circuit and damage by overload or high current etc. If we don't use fuses, electrical faults occur in the wiring and it burns the wire and electric appliances and may starts fire at home. The lives of television, computers, radios and other home appliances may also put at risk. When the fuse goes, a sudden spark occurs which may lead to turning your home into sudden darkness by disconnecting the power supply which saves any further mishappenings. That's why we need fuses to protect our home appliances from harm.

## 2.2.3 How Does Fuse work?

The fuses work on the principle of the **heating effect of the current**. It's made up of thin strip or strand of metallic wire with noncombustible material. This is connected between the ends of the terminals. Fuse is always connected in series with the electrical circuit.

When the excessive current or heat is generated due to heavy current flows in the circuit, the fuse melts down due to the low melting point of the element and it opens the circuit. The excessive flow may lead to the breakdown of wire and stops the flow of current. The fuse can be replaced or changed with the new one with suitable ratings. The fuse can be made up of the element like zinc, copper, silver &aluminum. They also act as a circuit breaker which is used to break the circuit when the sudden fault occurs in the circuit. This is not only a protector but it is also used as a safety measure to prevent humans from hazards. So, this is how the fuse operates. Here is the figure is shown fuse operation, fuse barrel(container), fuse link.




## 2.2.4 Characteristics of Fuses

There are some of the important characteristics of the fuses in the electrical and electronic system which is as follows:-

- **Current Rating:** The continuously conducting maximum amount of current holds the fuse without melting it is termed as current ratings. It is the current carrying capacity, which is measured in  Amperes. This is the thermal characteristics.

*Current(Cin)=75%Current (rating)*

- **Voltage Rating:** In this characteristic, the voltage connected in series with fuse does not increase voltage rating. i.e.,

  *V(fuse) >V(open ckt)*

- **$I^2t$ Rating:** This is the amount of energy which is carried by fuse element when there is an electrical fault or some short circuit happens. It measures the heat energy(energy due to current flow) of fuse & it is generated when fuse has blown.

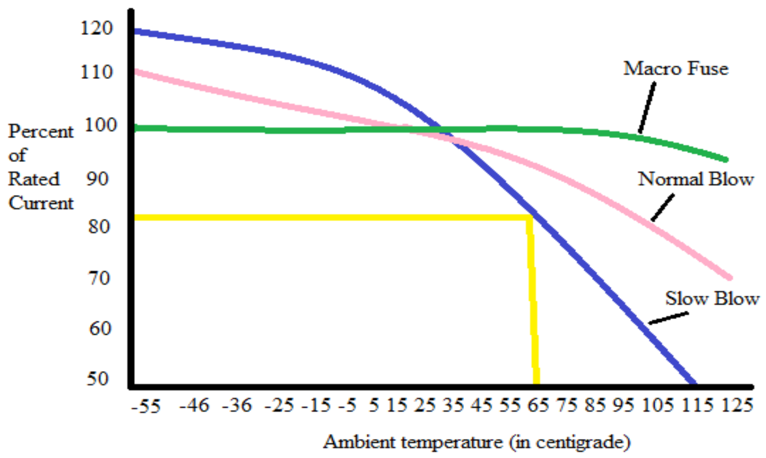
- **Interrupting or Breaking Capacity:** It is the maximum rating of current without harm interrupt by the fuse is known as breaking or interrupting capacity of the fuse.

  *Breaking capacity > maximum rated voltage*

  *Breaking capacity <short ckt current*

- **Voltage Drop**: When excessive current flows, the fuse element melts and opens the circuit. Due to this resistance change and the voltage drop will become lesser.

- **Temperature**: In this, the operating temperature will be higher , therefore the current rating will be lesser, so the fuse melts.

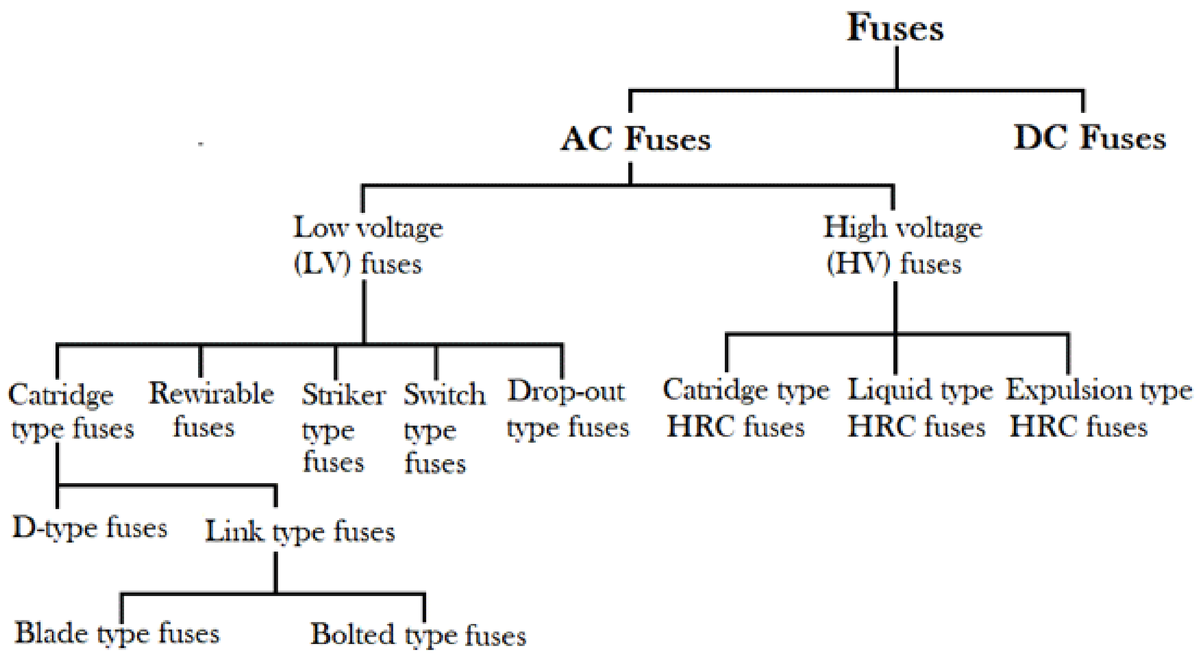


**Fuse characteristic**

*This graph shows the temperature versus the current carrying capacity of the fuse. In this process, at the point where three lines meet at 25 degrees Celsius, the current carrying capacity of the fuse will be 100% and after some time the current capacity decreases at slow blow fuse, it will also decrease up to 82% at 65 degrees C. This results that, increase in temperature will decrease the current carrying capacity of the fuse.*

## 2.2.5 Classification of Fuses

Now we are discussing about **different types of fuses**. They are divided into two parts AC Fuses & DC Fuses. Further, they are divided into many categories given in the flowchart below:-




**Different Types of Fuses**

Fuses are invented first by "Thomas Alva Edison" but nowadays many **types of fuses** are available in the market. Generally, there are two types of fuses:-

- **DC Fuses:** DC fuses have larger in size. DC supply has constant value above 0V so it is hard to neglect and turn off the circuit and there is a chance of an electric arc between melted wires. To overcome this, electrodes placed at larger distances and because of this the size of DC fuses get increased.

- **AC Fuses**: AC fuses are smaller in size. They oscillated 50-60 times in every second from minimum to maximum. So there is no chance of Arc between the melted wires. Hence they can be packed in small size.

AC fuses are further categorized into two parts, i.e., Low voltage fuses and High voltage fuses.

**1. Low Voltage Fuses (LV)**

- **Cartridge Type Fuses:** It is the type of fuses in which they have totally closed containers & has the contact i.e., metal besides.

Cartridge Type Fuses are of two types:-

1. ***D-Type Cartridge Fuses*:-** It is composed of the cartridge, fuse base, cap & adapter ring. The fuse base has the fuse cap, which is fitted with the fuse element with cartridge through adapter ring. The circuit is completed when the tip of the cartridge makes contact with the conductor.
2. ***Link Type Or HRC(High Rupturing Capacity) Fuses*:-** In this type of fuse, the flow of current by fuse element is given under normal condition. To control the arc which is produced by fuse blown we use the fuse which is made up of porcelain, silver &ceramic. The fuse element container filled with silica sand. The HRC type is again divided into two parts that are:-

- *Blade Type/Plug-in Type*:- The body of this fuse is made up of plastic and it is easily replaceable in the circuit without any load.

- *Bolted Type*:- In this type of fuse, the conducting plates are fixed to the fuse base.

- **Rewireable/ Kit-Kat Type:-** In this type of fuse, the main advantage is that the fuse carrier is easier to remove without having any electrical shock or injury. The fuse base acts as an incoming and outgoing terminal which is made up of porcelain & fuse carrier is used to hold the fuse element which is made up of tin, copper, aluminum, lead, etc. This is used in domestic wiring, small industries etc.

- **Striker Type Fuses:-** In this type of fuse, it is used for closing and tripping the circuit. They are having enough force and displacement.

- **Switch Type Fuses:-** In this type of fuse, basically metal enclosed of a switch and a fuse and is far used for low and medium voltage level.

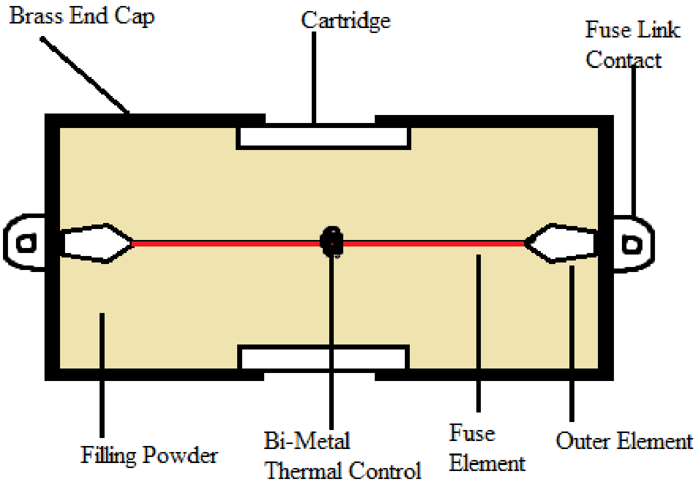
- **Drop Out Fuses:-** In this type of fuse, the melting of fuse causes the element to drop under gravity about its lower support. They are made for the protection of outdoor transformers.

**2. High Voltage Fuses (HV):**

All types of high voltage fuses are used upon the rated voltage up to 1.5 Kv to 138 Kv. High voltage fuses are used to protect the instrument transformers & small transformers. It is made up of silver, copper & tin. When heat generated, the arc produces which causes the boric acid to evolve high amount of gases. That's why these are used in outdoor places.

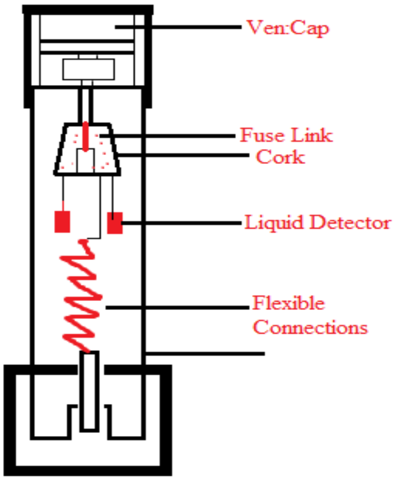
These are of three types which are as follows:-

- **Cartridge Type HRC Fuses:-** It is similar to low voltage type, only some designing features are different.




**Cartridge Type HRC Fuses**

- **Liquid Type HRC Fuses:-** These are used for circuit up to 100A rated current& systems up to 132Kv. These fuses have the glass tube filled with carbon tetrachloride. The one end of the tube is packed and another is fixed by phosphorous bronze wire. When fuse operation starts, the liquid uses in the fuse extinguish the arc. This increase the short circuit capacity.




**Liquid Type HRC Fuse**

- **Expulsion Type HRC Fuses:-** It is the escapable fuse, in which expulsion effect of gases produced by internal arcing. In this, the fuse link chamber is filled with boric acid for expulsion of gases.

- **Resettable Fuses**:- It is the type of fuse, commonly known as self-resetting fuses which uses a thermoplastic conductive type thermistor known as Polymeric Positive Temperature Coefficient (PPTC). If a fault occurs. Current increases, temperature also increase. The increase in resistance is due to increase in temperature. The applications where it is used are military and aerospace where replacement is not possible.


**Resettable Fuses**

## 2.3 Isolator

### 2.3.1 Definition of Isolator

Circuit breaker always trip the circuit but open contacts of breaker cannot be visible physically from outside of the breaker and that is why it is recommended not to touch any electrical circuit just by switching off the circuit breaker. So for better safety, there must be some arrangement so that one can see the open condition of the section of the circuit before touching it. The isolator is a mechanical switch which isolates a part of the circuit from the system as when required. Electrical isolators separate a part of the system from rest for safe maintenance works. So the definition of isolator can be rewritten as an isolator is a manually operated mechanical switch which separates a part of the electrical power. Isolators are used 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. Isolators are generally used on both ends of the breaker so that repair or replacement of circuit breaker can be done without any danger.

### 2.3.2 Types of Electrical Isolators

There are different types of isolators available depending upon system requirement such as

1. Double Break Isolator
2. Single Break Isolator
3. Pantograph type Isolator.

Depending upon the position in the power system, the isolators can be categorized as

1. Bus side isolator – the isolator is directly connected with main bus
2. Line side isolator – the isolator is situated at line side of any feeder
3. Transfer bus side isolator – the isolator is directly connected with transfer bus.

**Constructional Features of Double Break Isolators**

Let's discuss constructional features of Double Break Isolators. These have three stacks of post insulators as shown in the figure. The central post insulator carries a tubular or flat male contact which can be rotated horizontally with a rotation of central post insulator. This rod type contact is also called moving contact.

The female type contacts are fixed on the top of the other post insulators which fitted at both sides of the central post insulator. The female contacts are generally in the form of spring-loaded figure contacts. The rotational movement of male contact causes to come itself into female contacts and isolators becomes closed. The rotation of male contact in the opposite direction makes to it out from female contacts and isolator becomes open.

Rotation of the central post insulator is done by a driving lever mechanism at the base of the post insulator, and it is connected to operating handle (in case of hand operation) or motor (in case of motorized operation) of the isolator through a mechanical tie rod.

**Constructional features of Single Break Isolators**

The contact arm is divided into two parts one carries male contact and other carries female contact. The contact arm moves due to rotation of the post insulator upon which the contact arms are fitted. Rotation of both post insulators stacks in opposite to each other causes to close the isolator by closing the contact arm. Counter rotation of both post insulators stacks open the contact arm and isolator becomes in off condition. This motorized form of this type of isolators is generally used, but an emergency hand driven mechanism is also provided.

### 2.3.3 Operation of Electrical Isolator

As no arc quenching technique is provided in isolator it must be operated when there is no chance current flowing through the circuit. No live circuit should be closed or open by isolator operation. A complete live closed circuit must not be opened by isolator operation, and also a live circuit must not be closed and completed by isolator operation to avoid huge arcing in between isolator contacts. That is why isolators must be open after circuit breaker is open, and these must be closed before circuit breaker is closed. The isolator can be operated by hand locally as well as by motorized mechanism from a remote position. Motorized operation arrangement costs more compared to hand operation; hence decision must be taken before choosing an isolator for the system whether hand operated or motor operated economically optimum for the system. For voltages up to 145 KV system hand operated **isolators** are used whereas for higher voltage systems like 245 KV or 420 KV and above motorized isolators are used.

## 2.4 TRANSFORMER

### 2.4.1Electrical Transformer

**Definition:** The transformer is the static device which works on the principle of electromagnetic induction. It is used for transferring the electrical power from one circuit to another without any variation in their frequency. In electromagnetic induction, the transfer of energy from one circuit to another takes places by the help of the mutual induction. i.e the flux induced in the primary winding is linked with the secondary winding.

## 2.4.2 Transformer parts:

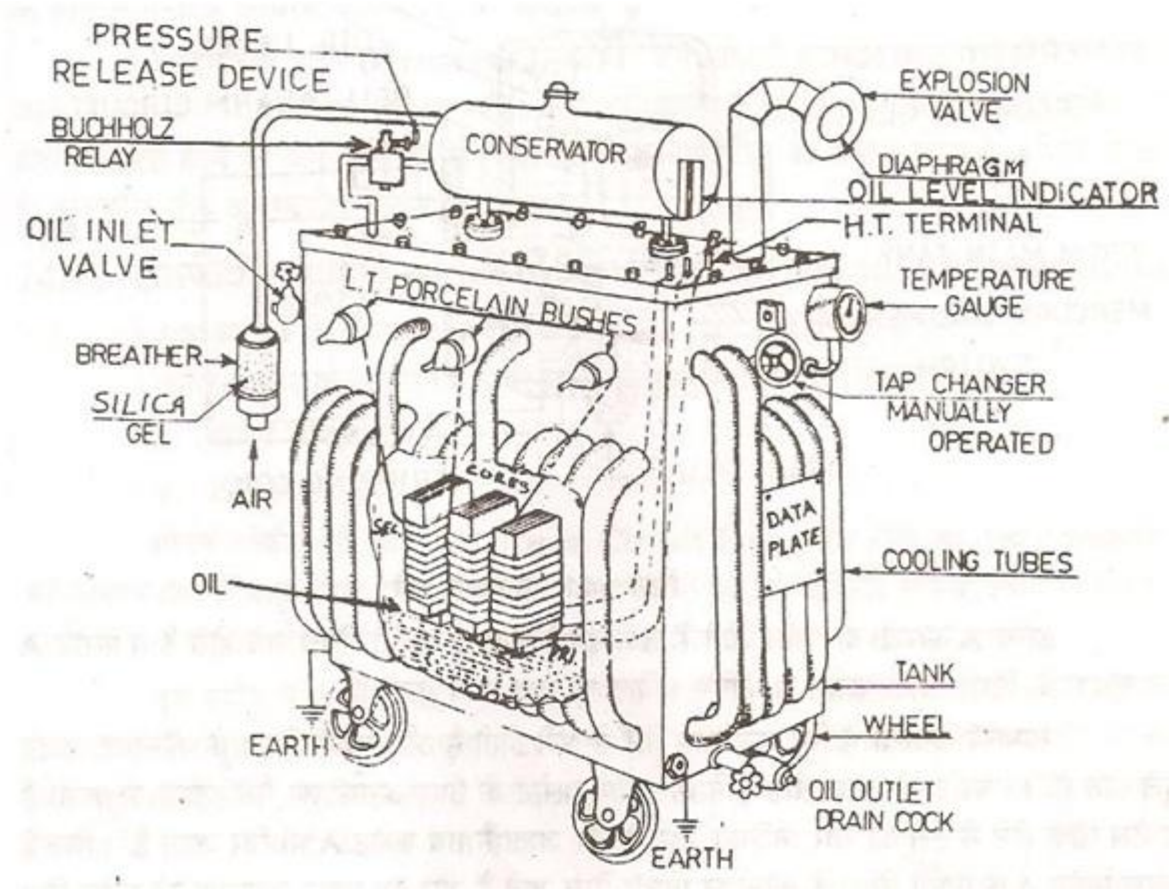



Fig2.4.2.a: Transformer part

## 2.4.3 Types of Transformers

There are two basic Types of Transformers

1. Single Phase Transformer
2. Three Phase Transformer

Below are the more types of transformer derived via different functions and operation etc.

**Types of Transformers w.r.t Cores**

- Core Type Transformer
- Shell Type Transformer

- Berry Type Transformer

**Types of Transformer w.r.t uses**

- Large Power Transformer
- Distribution Transformer
- Small Power Transformer
- Sign Lighting Transformer
- Control & Signaling Transformer
- Gaseous Discharge Lamp Transformer
- Bell Ringing Transformer
- Instrument Transformer
- Constant Current Transformer
- Series Transformer for Street Lighting

**Types of Transformer w.r.t cooling**

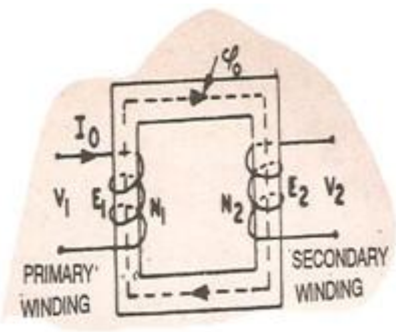
- Self-Air Cooled or Dry Type Transformer
- Air Blast-Cooled Dry Type
- Oil Immersed, Self Cooled (OISC) or ONAN (Oil natural, Air natural)
- Oil Immersed, Combination of Self Cooled and Air blast (ONAN)
- Oil Immersed, Water Cooled (OW)
- Oil Immersed, Forced Oil Cooled
- Oil Immersed, Combination of Self Cooled and Water Cooled (ONAN+OW)
- Oil Forced, Air forced Cooled (OFAC)
- Forced Oil, Water Cooled (FOWC)
- Forced Oil, Self Cooled (OFAN)

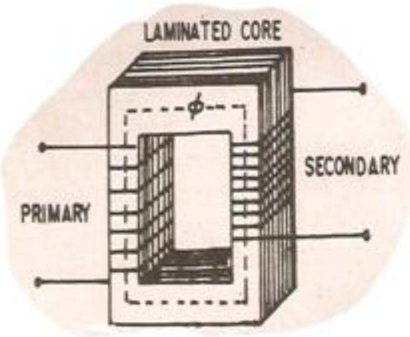
**Types of Instrument Transformer**

- Current Transformer
- Potential Transformer
- Constant Current Transformer
- Rotating Core Transformer or Induction regulator
- Auto Transformer

## 2.4.4Working principle:

A transformer works on the faraday's law of electromagnetic induction. A transformer consists of a laminated magnetic core. It contains two magnetic core. When one of the winding is connected called primary is connected to AC voltage $V_1$ , an alternating flux of the same frequency as that of supply voltage is set up in the magnetic core inducing emf of self-induction $E_1$ primary winding.



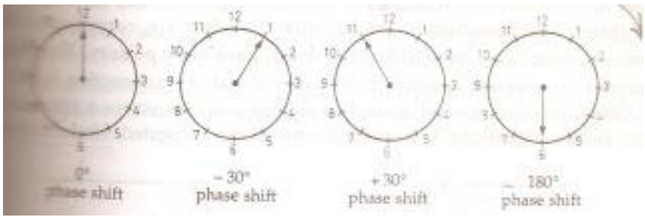

This alternating flux links with the other winding (secondary winding) inducing emf $E_2$ in this winding at the same frequency as that of the supply. This emf is known as emf of mutual induction. If N1 and N2 are number of turns of primary and secondary winding then the ratio is known as transformation ratio of transformer. If a load is connected across secondary winding, a current flows in both the windings. Thus electrical power is transferred magnetically from primary coil to secondary coil.

## 2.4.5 Transformer vector group

**Points to be consider while selecting of Vector Group**

Vector Groups are the IEC method of categorizing the primary and secondary winding configurations of 3-phase transformers. Windings can be connected as delta, star, or interconnected-star (***zigzag***). Winding polarity is also important, since reversing the connections across a set of windings affects the phase-shift between primary and secondary.

Vector groups identify the winding connections and polarities of the primary and secondary. From a vector group one can determine the phase-shift between primary and secondary.




When the hour hand is at 1O'Clockposition, the phase shift is -30 deg. Anti-clock wise direction is negative. A connection designated by Dy 11 is delta-star transformer in which the lv line voltage pharos is at 11 O' clock position that is a phase advance of +30deg. On the corresponding line voltage on hv side.

### Transformer vector group depends upon:

1. **Removing harmonics:** Dy connection – y winding nullifies 3rd harmonics, preventing it to be reflected on delta side.

2. **Parallel operations:** All the transformers should have same vector group & polarity of the winding.
3. **Earth fault Relay:** A Dd transformer does not have neutral. to restrict the earth faults in such systems, we may use zig zag wound transformer to create a neutral along with the earth fault relay..
4. Type of Non Liner Load: systems having different types of harmonics & non linear Types of loads e.g. furnace heaters ,VFDS etc for that we may use Dyn11, Dyn21, Dyn31 configuration, wherein, 30 deg. shifts of voltages nullifies the 3rd harmonics to zero in the supply system.

5. **Type of Transformer Application:** Generally for Power export transformer i.e. generator side is connected in delta and load side is connected in star. For Power export import transformers i.e. in Transmission Purpose Transformer star star connection may be preferred by some since this avoids a grounding transformer on generator side and perhaps save on neutral insulation. Most of systems are running in this configuration. May be less harmful than operating delta system incorrectly. Yd or Dy connection is standard for all unit connected generators.

There are a number of factors associated with transformer connections and may be useful in designing a system, and the application of the factors therefore determines the best selection of transformers.

*For example:*

**For selecting Star Connection:**

A star connection presents a neutral. If the transformer also includes a delta winding, that neutral will be stable and can be grounded to become a reference for the system. A transformer with a star winding that does NOT include a delta does not present a stable neutral.

**Star-star** transformers are used if there is a requirement to avoid a 30deg phase shift, if there is a desire to construct the three-phase transformer bank from single-phase transformers, or if the transformer is going to be switched on a single-pole basis (ie, one phase at a time), perhaps using manual switches.

Star-star transformers are typically found in distribution applications, or in large sizes interconnecting high-voltage transmission systems. Some star-star transformers are equipped with a third winding connected in delta to stabilize the neutral.

**For selecting Delta Connection:**

- A delta connection introduces a 30 electrical degree phase shift.
- A delta connection ‘traps’ the flow of zero sequence currents.

**For selecting Delta-Star Connection:**

- Delta-star transformers are the most common and most generally useful transformers.
- Delta-delta transformers may be chosen if there is no need for a stable neutral, or if there is a requirement to avoid a 30 electrical degree phase shift. The most common application of a delta-delta transformer is as tan isolation transformer for a power converter.

**For selecting Zig zag Connection:**

The Zig Zag winding reduces voltage unbalance in systems where the load is not equally distributed between phases, and permits neutral current loading with inherently low zero-sequence impedance. It is therefore often used for earthing transformers.

Provision of a neutral earth point or points, where the neutral is referred to earth either directly or through impedance. Transformers are used to give the neutral point in the majority of systems. The star or interconnected star (Z) winding configurations give a neutral location.

If for various reasons, only delta windings are used at a particular voltage level on a particular system, a neutral point can still be provided by a purpose-made transformer called a ‘neutral earthing.

**For selecting Distribution Transformer**

The first criterion to consider in choosing a vector group for a distribution transformer for a facility is to know whether we want a delta-star or star-star. Utilities often prefer star-star transformers, but these require 4-wire input feeders and 4-wire output feeders (i.e. incoming and outgoing neutral conductors).

For distribution transformers within a facility, often delta-star are chosen because these transformers do not require 4-wire input; a 3-wire primary feeder circuit suffices to supply a 4-wire secondary circuit. That is because any zero sequence current required by the secondary to supply earth faults or unbalanced loads is supplied by the delta primary winding, and is not required from the upstream power source. The method of earthing on the secondary is independent of the primary for delta-star transformers.

The second criterion to consider is what phase-shift you want between primary and secondary. For example, Dy11 and Dy5 transformers are both delta-star. If we don't care about the phase-shift, then either transformer will do the job. Phase-shift is important when we are paralleling sources. We want the phase-shifts of the sources to be identical.

If we are paralleling transformers, then you want them to have the same the same vector group. If you are replacing a transformer, use the same vector group for the new transformer, otherwise the existing VTs and CTs used for protection and metering will not work properly.

There is no technical difference between the one vector groups (i.e. Yd1) or another vector group (i.e. Yd11) in terms of performance. The only factor affecting the choice between one or the other is system phasing, ie whether parts of the network fed from the transformer need to operate in parallel with another source. It also matters if you have an auxiliary transformer connected to generator terminals. Vector matching at the auxiliary bus bar.

## 2.4.6 Application of Transformer according to Vector Group

**1.) Dyn11, Dyn1, YNd1, YNd11**

- Common for distribution transformers.
- Normally Dyn11 vector group using at distribution system. Because Generating Transformer are YNd1 for neutralizing the load angle between 11 and 1.
- We can use Dyn1 at distribution system, when we are using Generator Transformer are YNd11.
- In some industries 6 pulse electric drives are using due to this 5thharmonics will generate if we use Dyn1 it will be suppress the 5th harmonics.
- Star point facilitates mixed loading of three phase and single phase consumer connections.
- The delta winding carry third harmonics and stabilizes star point potential.
- A delta-Star connection is used for step-up generating stations. If HV winding is star connected there will be saving in cost of insulation.
- But delta connected HV winding is common in distribution network, for feeding motors and lighting loads from LV side.

**2.) Star-Star (Yy0 or Yy6)**

- Mainly used for large system tie-up transformer.
- Most economical connection in HV power system to interconnect between two delta systems and to provide neutral for grounding both of them.
- Tertiary winding stabilizes the neutral conditions. In star connected transformers, load can be connected between line and neutral, only if

  (a) the source side transformers is delta connected or

  (b) the source side is star connected with neutral connected back to the source neutral.
- In this transformers. Insulation cost is highly reduced. Neutral wire can permit mixed loading.
- Triple harmonics are absent in the lines. These triple harmonic currents cannot flow, unless there is a neutral wire. This connection produces oscillating neutral.
- Three phase shell type units have large triple harmonic phase voltage. However three phase core type transformers work satisfactorily.
- A tertiary mesh connected winding may be required to stabilize the oscillating neutral due to third harmonics in three phase banks.

**3.) Delta – Delta (Dd 0 or Dd 6)**

- This is an economical connection for large low voltage transformers.
- Large unbalance of load can be met without difficulty.
- Delta permits a circulating path for triple harmonics thus attenuates the same.
- It is possible to operate with one transformer removed in open delta or" V" connection meeting 58 percent of the balanced load.
- Three phase units cannot have this facility. Mixed single phase loading is not possible due to the absence of neutral.

**4.) Star-Zig-zag or Delta-Zig-zag (Yz or Dz)**

- These connections are employed where delta connections are weak. Interconnection of phases in zigzag winding effects a reduction of third harmonic voltages and at the same time permits unbalanced loading.

- This connection may be used with either delta connected or star connected winding either for step-up or step-down transformers. In either case, the zigzag winding produces the same angular displacement as a delta winding, and at the same time provides a neutral for earthing purposes.
- The amount of copper required from a zigzag winding in 15% more than a corresponding star or delta winding. This is extensively used for earthing transformer.
- Due to **zig-zag** connection (interconnection between phases), third harmonic voltages are reduced. It also allows unbalanced loading. The zigzag connection is employed for LV winding. For a given total voltage per phase, the zigzag side requires 15% more turns as compared to normal phase connection. In cases where delta connections are weak due to large number of turns and small cross sections, then zigzag star connection is preferred. It is also used in rectifiers.

**5.) Zig-zag/ star (ZY1 or Zy11)**

- Zigzag connection is obtained by inter connection of phases.4-wire system is possible on both sides. Unbalanced loading is also possible. Oscillating neutral problem is absent in this connection.
- This connection requires 15% more turns for the same voltage on the zigzag side and hence costs more. Hence a bank of three single phase transformers cost about 15% more than their 3-phase counterpart. Also, they occupy more space. But the spare capacity cost will be less and single phase units are easier to transport.
- Unbalanced operation of the transformer with large zero sequence fundamental mmf content also does not affect its performance. Even with Yy type of poly phase connection without neutral connection the oscillating neutral does not occur with these cores. Finally, three phase cores themselves cost less than three single phase units due to compactness.

**6.) Yd5**

- Mainly used for machine and main Transformer in large Power Station and Transmission Substation.
- The Neutral point can be loaded with rated Current.

**7.) Yz-5**

- For Distribution Transformer up to 250MVA for local distribution system.
- The Neutral point can be loaded with rated Current.

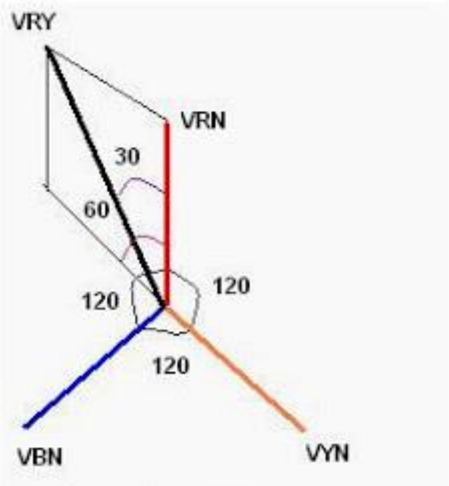
2.4.6 **Application of Transformer according according to Uses**

**Step up Transformer:** – It should be Yd1 or Yd11.
**Step down Transformer:** – It should be Dy1 or Dy11.
**Grounding purpose Transformer:** – It should be Yz1 or Dz11.
**Distribution Transformer:** – We can consider vector group of Dzn0 which reduce the 75% of harmonics in secondary side.
**Power Transformer:** – Vector group is deepen on application for Example: Generating Transformer:Dyn1, Furnace Transformer: Ynyn0.

**Why 30°phase shift occur in star-delta transformer between primary and secondary?**

30 deg phase shift between line voltage and phase voltage

The phase shift is a natural consequence of the delta connection. The currents entering or leaving the star winding of the transformer are in phase with the currents in the star windings. Therefore, the currents in the delta windings are also in phase with the currents in the star windings and obviously, the three currents are 120 electrical degrees apart.




VR,VY,VB = Phase Voltage
VRY = Line Voltage
30 Deg Phase Shift between Line Voltage and Phase Voltage

But the currents entering or leaving the transformer on the delta side are formed at the point where two of the windings comprising the delta come together – each of those currents is the pharos sum of the currents in the adjacent windings.

When you add together two currents that are 120 electrical degrees apart, the sum is inevitably shifted by 30 degrees.

The Main reason for this phenomenon is that the phase voltage lags line current by 30degrees.consider a delta/star transformer. The phase voltages in three phases of both primary and secondary. you will find that in primary the phase voltage and line voltages are same, let it be VRY (take one phase). But, the corresponding secondary will have the phase voltage only in its phase winding as it is star connected. The line voltage of star connected secondary and delta connected primary won't have any phase differences between them. So this can be summarized that "the phase shift is associated with the wave forms of the three phase windings.

This is the HV Side or the Switchyard side of the Generator Transformer is connected in Delta and the LV Side or the generator side of the GT is connected in Star, with the Star side neutral brought out.

The LV side voltage will "lag" the HV side voltage by 30 degrees. Thus, in a generating station we create a 30 degrees lagging voltage for transmission, with respect to the generator voltage.

As we have created a 30 degrees lagging connection in the generating station, it is advisable to create a 30 degrees leading connection in distribution so that the user voltage is "in phase" with the generated voltage. And, as the transmission side is Delta and the user might need three phase, four-wire in the LV side for his single phase loads, the distribution transformer is chosen as Dyn11.

There is magnetic coupling between HT and LT. When the load side (LT) suffers some dip the LT current try to go out of phase with HT current, so 30 degree phase shift in Dyn-11 keeps the two currents in phase when there is dip.

So the vector group at the generating station is important while selecting distribution Transformer.

**Vector Group in Generating-Transmission-Distribution System**

Generating TC is Yd1 transmitted power at 400KV, for 400KV to 220KV Yy is used and by using **Yd** between e.g. 220 and 66 kV, then **Dy** from 66 to 11 kV so that their phase shifts can be cancelled out. And for LV (400/230V) supplies at 50 Hz are usually 3 phase, earthed neutral, so a "Dyn" LV winding is needed. Here GT side -30lag (Yd1) can be nullify +30 by using distribution Transformer of Dy11.

A reason for using **Yd** between e.g. 220 and 66 kV, then **Dy** from 66 to 11 kV is that their phase shifts can cancel out and It is then also possible to parallel a 220/11 kV YY transformer, at 11 kV, with the 66/11 kV (a YY transformer often has a third, delta, winding to reduce harmonics).

If one went Dy11 – Dy11 from 220 to 11 kV, there would be a 60 degree shift, which is not possible in one transformer. The "standard" transformer groups in distribution avoid that kind of limitation, as a result of thought and experience leading to lowest cost over many years.

**Generator TC is Yd1, can we use Distribution TC Dy5 instead of Dy11?**

With regards to theory, there are no special advantages of Dyn11 over Dyn5.

**In Isolation Application:** -In isolated applications there is no advantage or disadvantage by using Dy5 or Dy11. If however we wish to interconnect the secondary sides of different Dny transformers, we must have compatible transformers, and that can be achieved if you have a Dyn11 among a group of Dyn5′s and vice versa.

**In Parallel Connection:** – Practically, the relative places of the phases remain same in Dyn11 compared to Dyn5.

If we use Yd1 Transformer on Generating Side and Distribution side Dy11 transformer than -30 lag of generating side (Yd1) is nullify by +30 Lead at Receiving side Dy11) so no phase difference respect to generating Side and if we are on the HV side of the Transformer, and if we denote the phases as R- Y-B from left to right, the same phases on the LV side will be R-Y -B, but from left to Right.

This will make the Transmission lines have same color (for identification) whether it is input to or output from the Transformer.

If we use Yd1 Transformer on Generating Side and Distribution side Dy5 transformer than -30 lag of generating side (Yd1) is more lag by -150 Lag at Receiving side (Dy5) so Total phase difference respect to generating Side is 180 deg (-30+-150=-180) and if we are on the HV side of the Transformer, and if we denote the phases as R- Y-B from left to right, the same phases on the LV side will be R- Y -B, but from Right to Left.

This will make the Transmission lines have No same color (for identification) whether it is input to or output from the Transformer. The difference in output between the Dyn11 and Dny5 and is therefore 180 degrees.

## 2.4.7 Transformer Protection–

The following protections are used to protect transformersup to 2000KVA, 11/0.415KV:

**Over current & Short circuit (51):** The relay operates when the primary current of the transformer exceeds the limit set in the relay due to overload with inverse time characteristics. Also there is provision for short circuit which trips the feeder instantly due to short circuit. The relay used is CDAG 51.

**Earth Fault (51N):** The relay operates instantly when the fault current exceeds the limit set in the relay. The relay used is CAG 14.

**Transformer Differential (87T):** The transformer feeder is protected from any faults that occur in the primary side of the transformer by using this relay. The relay used is DTH 31. This type of protection is used only in 11/6.6KV transformers.

**WTI (49WTX/49WAX)**: The transformer is protected against increase in winding temperature. The relay is activated by WTI, which gives alarm and also trips the breaker, if it exceeds the limit. The relay used is VAA 34.

**OTI (49TX/49AX):**The transformer is protected against increase in oil temperature. The relay is activated by OTI, which gives alarm and also trips the breaker, if it exceeds the limit. The relay used is VAA 34.

**Buchholz (63TX/63AX):** The transformer is protected against internal faults by providing Buchholz inside. The relay used is VAA 34.

The transformer can be switched on if it trips on over current, WTI and OTI after some interval. If it trips on earth fault, the IR value of the transformer to be checked

**Transformer Over Current protection:**

The over current protection required for transformers is consider for Protection of Transformer only. Such over current protection will not necessarily protect the primary or secondary conductors or equipment connected on the secondary side of the transformer.

**When voltage is switched on to energize a transformer, the transformer core normally saturates.**

This results in a large inrush current which is greatest during the first half cycle (*approximately 0.01 second*) and becomes progressively less severe over the next several cycles (*approximately 1 second*) until the transformer reaches its normal magnetizing current. To accommodate this inrush current, fuses are often selected which have time-current withstand values of **at least 12 times** transformer primary rated current for **0.1 second** and **25 times** for **0.01 second**. Some small dry-type transformers may have substantially greater inrush currents.

To avoid using oversized conductors, over current devices should be selected at about **110 to 125 percent** of the transformer full-load current rating. And when using such smaller over current protection, devices should be of the time-delay type (*on the primary side*) to compensate for inrush currents which reach 8 to 10 times the full-load primary current of the transformer for about 0.1 s when energized initially.

**Protection of secondary conductors has to be provided completely separately from any primary-side protection.**

A supervised location is a location where conditions of maintenance and supervision ensure that only qualified persons will monitor and service the transformer installation. Over current protection for a transformer on the primary side is typically a circuit breaker. In some instances where there is not a high voltage panel, there is a fused disconnect instead.

**It is important to note that the over current device on the primary side must be sized based on the transformer KVA rating and not sized based on the secondary load to the transformer.**

**Over current Protection of Transformers >600V (NEC450.3A)**

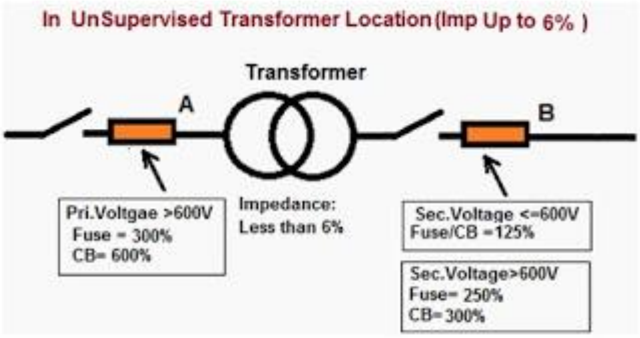



Fig2.4.7: Transformer over current

**1) Unsupervised Location of Transformer (Impedance <6%)**

***<u>OverCurrent Protection at Primary Side (Primary Voltage >600V):</u>***

- Rating of Pri. Fuse at Point A= 300% of Pri. Full Load Current or Next higher Standard size. or
- Rating of Pri. Circuit Breaker at Point A= 600% of Pri. Full Load Current or Next higher Standard size.
- ***<u>OverCurrent Protection at Secondary Side (Secondary Voltage <=600V):</u>***
- Rating of Sec. Fuse / Circuit Breaker at Point B= 125% of Sec. Full Load Current or Next higher Standard size.
- ***<u>OverCurrent Protection at Secondary Side (Secondary Voltage >600V):</u>***
- Rating of Sec. Fuse at Point B= 250% of Sec. Full Load Current or Next higher Standard size. or
- Rating of Sec. Circuit Breaker at Point B= 300% of Sec. Full Load Current.

Example: 500***KVA, 11KV/415V 3Phase Transformer having Impedance of Transformer 5%***

- Full Load Current At Primary side = 750000/(1.732X11000) = 26.2A
- Rating of Primary Fuse = 3X26.2A = 78.6A, So Standard Size of Fuse = 80A.

- OR Rating of Primary Circuit Breaker = 6X26.2A = 157.2A, So standard size of CB = 200A.
- Full Load Current at Secondary side = 500000/(1.732X415) = 695.6A.
- Rating of Secondary of Fuse / Circuit Breaker = 1.25X695.6A = 869.5A, so standard size of Fuse = 1000A.

# CHAPTER 3

# SWITCHGEAR

## 3.1 Introduction

The switchboard and switchgear are two important systems that control how power is delivered to electrical circuits. The two terms are sometimes used interchangeably. However, it is important to note that they perform different functions and usually designed to work together in series so as to provide the maximum coordination and protection.

Since the two have different functions and capabilities, they are suited for different types of installations or at different stages of an electrical network. Whether to use switchgear, a switchboard, or both, depends largely on the design and requirements of the power system. To understand where each fits, we will have a look at their functions and differences.

## 3.2 What is Switchgear?

The apparatus used for switching, controlling and protecting the electrical circuits and equipment is known as switchgear.

The term 'switchgear' is a generic term encompassing a wide range of products like circuit breakers, switches, switch fuse units, off-load isolators, HRC fuses, contactors, earth leakage circuit breakers (ELCBs), etc…

## 3.3 Essential Features of Switchgear

The essential features of switchgear are:

1. **Complete reliability**: With the continued trend of interconnection and the increasing capacity of generating stations, the need for reliable switchgear has become of paramount importance. This is not surprising because it is added to the power system to improve the reliability. When fault occurs on any part of the power system, they must operate to isolate the faulty section from the remainder circuit.

2. **Absolutely certain discrimination**: When fault occurs on any section of the power system, the switchgear must be able to discriminate between the faulty section and the healthy section. It should isolate the faulty section from the system without affecting the healthy section. This will ensure continuity of supply.
3. **Quick operation**: When fault occurs on any part of the power system, the switchgear must operate quickly so that no damage is done to generators, transformers and other equipment by the short-circuit currents. If fault is not cleared quickly, it is likely to spread into healthy parts, thus endangering complete shutdown of the system
4. **Provision for manual control**: Switchgear must have provision for manual control. In case the electrical (or electronics) control fails, the necessary operation can be carried out through manual control.

## 3.4 Classification of Switchgear

Switchgear can be classified on the basis of voltage level in to the following

1. Low voltage (LV) Switchgear
2. Medium voltage (MV) Switchgear
3. High voltage (HV) Switchgear

**1. Low Voltage Switchgear**

They are generally rated upto 1 kV (1000 V).

They includes low voltage circuit breakers, switches, off load electrical isolators, HRC fuses, earth leakage circuit breaker, Residual Current Protective Devices (RCCB & RCBO), miniature circuit breakers (MCB) and molded case circuit breakers (MCCB) etc i.e. all the accessories required to protect the LV system.
The most common use of this is in LV distribution board.

**2. Medium Voltage Switchgear**

From 3 kV to 36 kV the system is categorized as medium voltage switchgear or MV switchgear.

They are of many types. They may metal enclosed indoor type, metal enclosed outdoor type, outdoor type without metal enclosure, etc. The interruption medium may be oil, SF and vacuum.
The main requirement of MV power network is to interrupt current during faulty condition irrespective of what type of CB is used in the system. Although it may be capable of functioning in other conditions also.
A medium voltage switchgear, should be capable of,

1. Normal ON/OFF switching operation.
2. Short circuit current interruption.
3. Switching of capacitive currents.
4. Switching of inductive currents.
5. Some special application.

**3. High Voltage Switchgear**

The power system deals with voltage above 36kV, is referred as high voltage.
As the voltage level is high the arcing produced during switching operation is also very high. So, special care to be taken during designing of high voltage switchgear.
High voltage circuit breaker, is the main component of HV switchgear, hence high voltage circuit breaker should have special features for safe and reliable operation.
Faulty tripping and switching operation of high voltage circuit are very rear. Most of the time these circuit breakers remain, at ON condition, and may be operated after a long period of time. So CBs must be reliable enough to ensure safe operation, as when required.

# 3.5 Switchgear Equipment

## 3.5.1 Circuit Breaker

### 3.5.1.1 What is Circuit Breaker?

A circuit breaker is a switching device that interrupts the abnormal or fault current. It is a mechanical device that disturbs the flow of high magnitude (fault) current and in additions performs the function of a switch. The circuit breaker is mainly designed for closing or opening of an electrical circuit, thus protects the electrical system from damage.

### 3.5.1.2 **Types of Circuit Breakers**

Circuit breakers are classified into different types based on the following criteria.

1. Based on the voltage level
    1. Low voltage circuit breaker
    2. Medium voltage circuit breaker
    3. High voltage circuit breaker
2. Based on where is installed
    1. Outdoor circuit breaker
    2. Indoor circuit breaker
3. Based on the actuating mechanism
    1. Spring Operated Circuit breaker
    2. Pneumatic circuit breaker
    3. Hydraulic circuit breaker
4. Based on the arc interrupting medium
    1. Vacuum circuit breaker
    2. SF6 circuit breaker
    3. Oil circuit breaker
    4. Air blast circuit breaker
5. Based on External characteristic design
    1. Live tank circuit breaker
    2. Dead tank circuit breaker

*Circuit Breaker Types based on Voltage Level*

Firstly we classify the circuit breakers according to the voltage levels they can operate on. So there are three most used types of circuit breakers in this category. These are:

1. Low Voltage Circuit Breakers (< 1 kV)
2. Medium Voltage Circuit Breakers (1-72 kV)
3. High Voltage Circuit Breakers (> 72 kV)

**1. Low Voltage Circuit Breakers**

A low – voltage circuit breaker is one which is suited for circuits rated at 1000 volts or lower.

Fig3.5.1.2.a: Low Voltage Circuit Breakers

Low-voltage circuit breakers are common in domestic, commercial and industrial applications. Most commonly used low-voltage circuit breakers are, miniature circuit breaker, molded case circuit breaker, earth leakage circuit breaker, and Residual current protective devices.

- MCB (Miniature Circuit Breaker)—rated current not more than 100 A.
- MCCB (Molded Case Circuit Breaker)—normal rated current is up to 2,500A with the thermal or thermal-magnetic operation.

The characteristics of low-voltage circuit breakers are given by international standards such as IEC 947. These circuit breakers are often installed in draw-out enclosures that allow removal and interchange without dismantling the switchgear.

**2. Medium Voltage Circuit Breaker**

Medium-voltage circuit breakers rated between 1 and 72 kV may be assembled into metal-enclosed switchgear lineups for indoor use, or may be individual components installed outdoors in a substation.

The characteristics of MV breakers are given by international standards such as IEC 62271.

**3. High Voltage Circuit Breaker**

Electrical power transmission networks are protected and controlled by high-voltage breakers.

The definition of high voltage varies but in power transmission work is usually thought to be 72.5 kV or higher, according to a recent definition by the International Electrotechnical Commission (IEC).

High-voltage circuit breakers are broadly classified by the medium used
to extinguish the arc:

1. Bulk oil circuit breaker
2. Minimum oil circuit breaker
3. Air blast circuit breaker
4. Vacuum circuit breaker
5. SF6 circuit breaker
6. CO2 circuit breaker

**Circuit Breaker Types based on Installation**

Another very important category is where to use the circuit breaker. This may seem a bit weird at first, but when installing a breaker, you must have to take care if it will be used inside your home or any other building or it has to be installed somewhere outdoors. This is because the outer mechanical body of the breaker has to be designed accordingly for it to be tough and protective to prevent the internal circuitry from damaging. So two more types can be:

1. Outdoor circuit breaker
2. Indoor circuit breaker

**Indoor Circuit breaker**

Indoor Circuit breakers are designed for use only inside buildings or weather-resistant enclosures. Generally, indoor circuit breakers are operated at a medium voltage with a metal clad switchgear enclosure.

Fig3.5.1.2.b: Indoor Vacuum Circuit Breaker

**Outdoor Circuit Breaker**

Outdoor Circuit breakers are designed to use at outside without any roof. So these breakers external enclosure arrangement will be strong compared to indoor breakers to withstand wear and tear.

Fig:3.5.1.2.c: Outdoor Circuit Breaker

**Circuit Breaker Types based on Actuating Mechanism**

There is another category which is based on the mechanism used to actuate the circuit breaker, which specifies the mechanism of operation of the breaker, there are three further types:

1. Spring operated circuit breaker
2. Pneumatic circuit breaker
3. Hydraulic circuit breaker

A spring-operated mechanism is one driven by the mechanical energy stored in springs. Typically, the “closing spring” is mechanically charged by a motor and is held in its compressed position by a closing latch.

A hydraulic-operated mechanism uses pressurized gas to direct the flow of oil, thus actuating the linkage(s) connected to the interrupter(s).

A pneumatic-operated mechanism uses compressed air as the energy source for closing and tripping.

**Circuit Breaker Types based on Interrupting Medium**

Now considering the medium in which a circuit breaker can operate. The most general way of classification is on the basis of the medium used for arc extinction. The medium used for arc extinction is usually oil, air, sulfur hexafluoride (SF6) or vacuum.

Accordingly, circuit breakers may be classified into:

1. Oil circuit breaker which employs some insulating oil (eg., transformer oil) for arc extinction
2. Air Blast circuit breaker in which high-pressure air-blast is used for extinguishing the arc.
3. SF6 circuit breaker in which sulfur hexafluoride (SF6) gas is used for arc extinction.
4. Vacuum circuit breaker in which vacuum is used for arc extinction.

**Circuit Breaker Types based on External Design**

Based on their structural design the circuit breakers are classified as

1. dead tank circuit breakers and
2. Live tank circuit breakers.

A breaker which has its enclosed tank at ground potential is called as dead tank circuit breakers.


Live tank and Dead tank circuit breaker

A Breaker which has its tank housing the interrupter is at potential above the ground is called as a live tank circuit breaker.

**Other Types of Circuit Breaker**

The following are some other types of circuit breakers classified based on various criteria.

Interrupting medium– Air, Air blast, Magnetic blast, Vacuum, Oil circuit breaker, Gas insulated circuit breaker (GIS)

**According to service**– Indoor or outdoor circuit breaker

**Way of operation**– Gravity opened, gravity closed and horizontal break circuit breaker

**Action**– Automatic and non-automatic circuit breaker

**Method of control**– Direct control or remote (manual, pneumatic or electrical) control

**Way of mounting**– Panel mounted rear of panel or remote from panel type.

**Tank construction**– Separate tank for each pole type or one tank for all poles type, Live tank or Dead tank

**Contacts**– Butt, Wedge, Laminated flat contacts

**Important Circuit Breaker Types**

Here is a brief description of the most important types of circuit breakers used in different places.

## Air Blast circuit breaker

3200A, 75KA, TP, 415V, 50Hz  Air Circuit breaker (ACB)
with under voltage release and  micro processor protection unit.

The micro processor protection unit meets the requirement of the IEC 947.2 standard. This unit is powered by the current transformers & performs all the necessary three or four pole overcurrent protection.

**Standard Protection:**

*Overload Relay Setting switch
*Short-Circuit & time delay rotary setting switches
*Earth Fault & time delay rotary setting switches
*Manual/automatic reset buttob (selactablea)
*Over load / short circuit trip curve symbol
*Earth fault protection curve symbol
* Healthy Light Emiting diod
*Multi-pin socket for text box / protable power box

**ACB Auxiliary:**
Shunt opening, Shunt closing Release, Under Voltage Release and Gear Motor.

Air blast circuit breakers employ a high-pressure air blast as an arc quenching medium. Under normal condition, the contacts are closed. When a fault occurs contacts are opened and an arc is struck between them. The opening of contacts is done by a flow of air blast established by the opening of blast valve (located between air reservoir and arcing chamber ).

The air blast cools the arc and sweeps away the arching products into the atmosphere. Thus the dielectric strength of the medium is increased, prevents from re-establishing the arc. The arc gets extinguished and flow of current is interrupted.

The circuit breakers are classified on the basis the direction of air blast to the arc. They are classified into:

1. Axial Blast Type – air blast is directed along the arc path.

2. Cross Blast Type – air blast is directed at right angles to the arc path.

3. Radial Blast Type – air blast is directed radially.

**SF6 Circuit Breakers**

In SF6 Circuit Breakers, sulfur hexafluoride gas (SF6) is used as the arc quenching medium.

The sulfur hexafluoride gas (SF6) is an electronegative gas and has a strong tendency to absorb free electrons. The contacts of the breaker are opened in a high high-pressure sulfur hexafluoride (SF6) gas and an arc is struck between them. The gas captures the conducting free electrons in the arc to form relatively immobile negative ions.

This loss of conducting electrons in the arc quickly builds up enough insulation strength to extinguish the arc. The sulfur hexafluoride (SF6) circuit breakers have been found to be very effective for high power and high voltage service.

**Vacuum Circuit Breaker***:*

**01) 11KV HT SWITCHGEAR ( Vmax VCB)PANEL:**

This specification covers the supply of 11KV indoor, metalclad, switchgear according to IEC publication 298, BSS227,2631,3659 and VDE 0670 /6.

The medium voltage switchgear panel shall be used for secondary distri- ibution sub – station up to 12KV and suitable for an ambient temperature of 45 Deg. C and rated rupture capacity of 350 MVA complete with all accessories , diagrams, levels, wiring & terminals.

The 11KV, 350MVA rated switchboard would comply compulsory electricity regulations by standards. All cubicles are fitted with security interlocks and earthing switch.

The erection of the panel can be done directly on the leveled floor. Cable trenches are necessary. Cables can easily installed from the bottom side of the panel.

The design is done to allow safe operation in extremely tropical climate conditions.

**TECHNICAL DATA :**

| | |
|---|---|
| Service voltage | : 11KV |
| Rated Voltage | : 12 KV |
| Rated current of Busbars | : 800A |
| Rated current of circuit breaker | : 630A |

**INSULATION LEVEL :**

| | |
|---|---|
| Impulse withstand voltage 1.2 / 50 micro – sec | : 75KV  Peak) |
| Power frequency withstand voltage / 1 min. | : 28KV rms. |

In vacuum circuit breakers, the vacuum is used as the arc quenching medium. Vacuum offers the highest insulating strength. So it has far superior arc quenching properties than any other medium.

For example, when contacts of a breaker are opened in the vacuum, the interruption occurs at first current zero with dielectric strength between the contacts building up at a rate thousands of times higher than that obtained with other circuit breakers.

The technology is suitable for mainly medium voltage application. For higher voltage vacuum technology has been developed but not commercially viable.

### 3.5.2 CURRENT TRANSFORMER (CT)

**3.5.2.1 Definition–**A current transformer is a device that is used to produce low ac current in the secondary winding which is proportional to the high ac current in the primary winding.

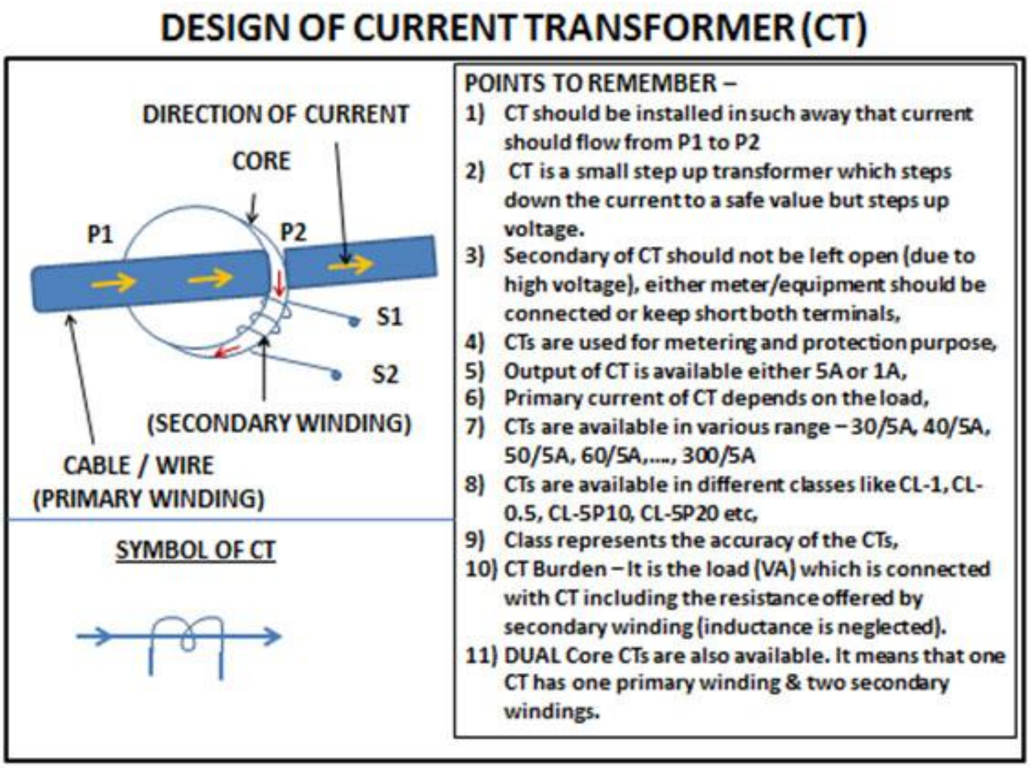
It is used for both metering & protection system. So, with the help of CT, high value of current can be measured easily by using low value meters.

**3.5.2.2 Construction** –

It consist of a primary winding & secondary winding. The primary winding may be a conductor, strip etc whose current is to be reduced. The secondary winding is wounded on a core. The number of turns of secondary winding depends on the primary current & output of secondary current. Standard secondary output current is either 1A or 5A.

**3.5.2.3 Working principle** –

It works on the principle of transformer; It is just like a small step-up transformer which reduces the current in secondary winding & increases the secondary voltage. In CT, primary winding has few turns only such as either one turn or two turn etc.



### 3.5.2.4 CTR (CURRENT TRANSFORMER RATIO)–

CTR stands for Current Transformer Ratio. It is the ratio between primary & secondary current of a CT. For example, a CT is available of 100/5A where 100A represents maximum value of primary current & 5A represents maximum value of secondary current. Value of secondary current varies in proportion to the primary current. So, here CTR is 20 (100/5 = 20). It means primary current is 20 times greater than the secondary current.

For CT 400/5A, CTR = 80 (which is 400/5 = 80), it means primary current is 80 times greater than secondary current. As CT is just like any other transformer, it must satisfy following equation –

T.R = Np/Ns = Is/Ip

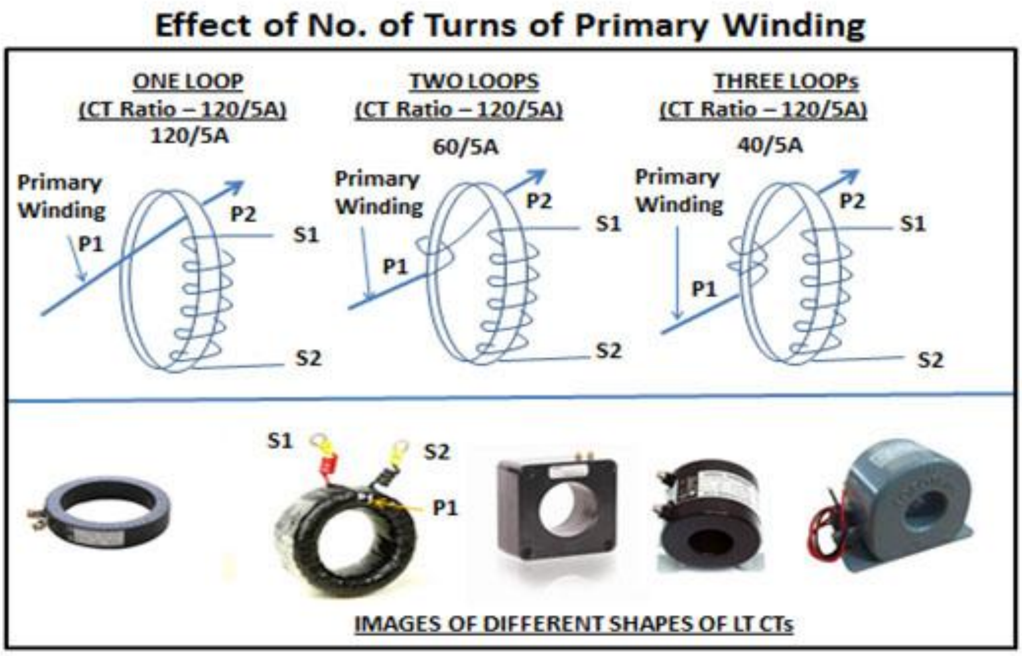
Where Np = No of turns of primary winding,

Ns = No of turns of secondary winding,

Ip = Current in primary winding,

Is = Current in secondary winding,

### 3.5.2.5 Effect of Number of Turn of Primary Winding –



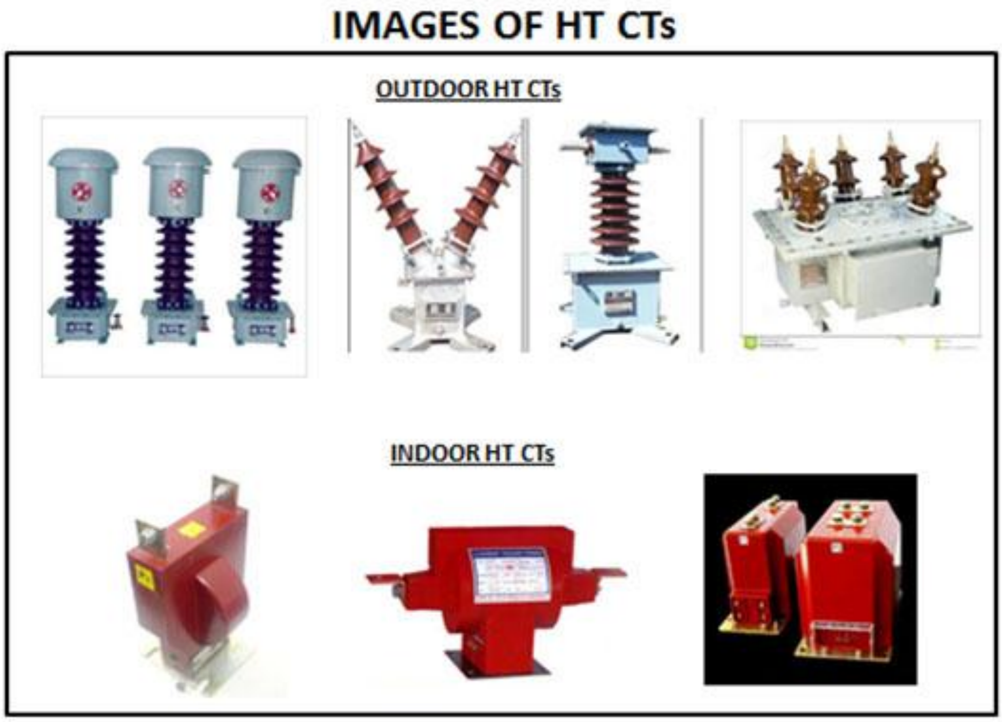



Fig3.5.2.5: Images of HT CTs

**3.5.2.6 Type of Current Transformer–**

There are three types of Current Transformer available – a) Wound CT, b) Toroidal CT & c) Bar-type CT –

- **Wound Current Transformer**– The transformers primary winding is physically connected in series with the conductor that carries the measured current flowing in the circuit. The magnitude of the secondary current is dependent on the turn ratio of the transformer.
- **Toroidal Current Transformer**– These do not contain a primary winding. Instead, the line that carries the current flowing in the network is threaded through a window or hole in the toroidal transformer. Some current transformers have a "split core" which allows it to be opened, installed, and closed, without disconnecting the circuit to which they are attached.
- **Bar-type Current Transformer**– This type of current transformer uses the actual cable or bus-bar of the main circuit as the primary winding, which is equivalent to a single turn. They are fully insulated from the high operating voltage of the system and are usually bolted to the current carrying device.

**3.5.2.7 Important Teams Related With CT –**

**CT Burden –** The burden of a CT is defined by the load of the device which is connected with CT and impedance offered by the secondary winding of CT. It is represented by the VA.The rated VA indicates the load that transformer can take.

The CT should never be 100% loaded as the burden of CT can increase with age due to increase of resistance of connecting wires, change in temperature, loosening of connections etc.

**Accuracy of CTs** – Accuracy defines the highest permissible percentage error at the rated current. CTs are classified into two categories –a) metering CTs & protection CTs.

**Metering CT** – High accuracy CTs are used for metering as they have low saturation point. CTs are available in following **accuracy class** – 0.1, 0.2, 0.5,1,3,5. These values indicate percentage error at the rated primary current. It means a CT of 50/5A with 0.1 accuracy will have a max error of 0.1 when 50A current passes through the primary.

Metering CTs are designed in such a way that CT is not damaged by high current during fault. During fault, CT gets saturated & output stays in the range of measuring instruments.

**Protection CT** – Protection CTs have different characteristics than metering CT. Protection CTs have high saturation point as it has to continuously sense fault current even during fault also. These CTs have low accuracy & are classified as 5P10, 10P10 etc.

Example – CT with class 10P10 – Where first letter 10P indicates the maximum(10%) percentage error & last number 10 indicates the number of times the rated current.

**3.5.2.8 Application of CTs –**

- Class 0.1 or 0.3 – for Process metering,
- Class 0.5 or 1.0 – for Commercial metering,
- Class 1 or 3 – for ammeters,
- Class 5P10 or 5P20 – for protection,

**3.5.2.9Knee Point Saturation Voltage** –

**Definition**– It is defined as the voltage at which 10% increase in voltage of CT secondary results in 50% in secondary current.

Let us understand this by this method – An AC voltage applied to the secondary of the CT with primary open, when voltage increased by 10% which causes 50% increase in magnetizing current. This happens because $E_2$άØ (magnetic flux) as $E_2$= 4.44 ØfT2 where Ø is produced by exciting current (Ie). There is a nonlinear relationship between Ø &Ie, after a certain period of exciting current, flux will not increase so rapidly further as the core of CT is made up of CRGO steel material which has its own saturation level.

It is an important factor for protection CTs & protection CTs are also termed as PS (Protection Class). This is related with the saturation of core. Knee point is very important for **differential & restricted earth fault protection** schemes because there should not be tripping of transformer when fault occurs outside the protection zone. Even If normal CTs are provided with high accuracy (not PS rated) & fault occurs outside the protection zone, the fault current will travel towards protected zone (from secondary side) then due to different Knee point saturation voltage of both normal CTs, Power transformer may trip. That is whyit is very important that for differential & REF protection only same PS rated should be used.

## 3.5.3 Potential Transformers

It is not an easy way to measure the high voltage and currents associated with power transmission and distribution systems, hence instrument transformers are often used to step-down these values to a safer level to measure. This is because measuring meters or instruments and protective relays are low voltage devices, thereby cannot be connected directly to high voltage circuit for the purpose of measurement and protection of the system.

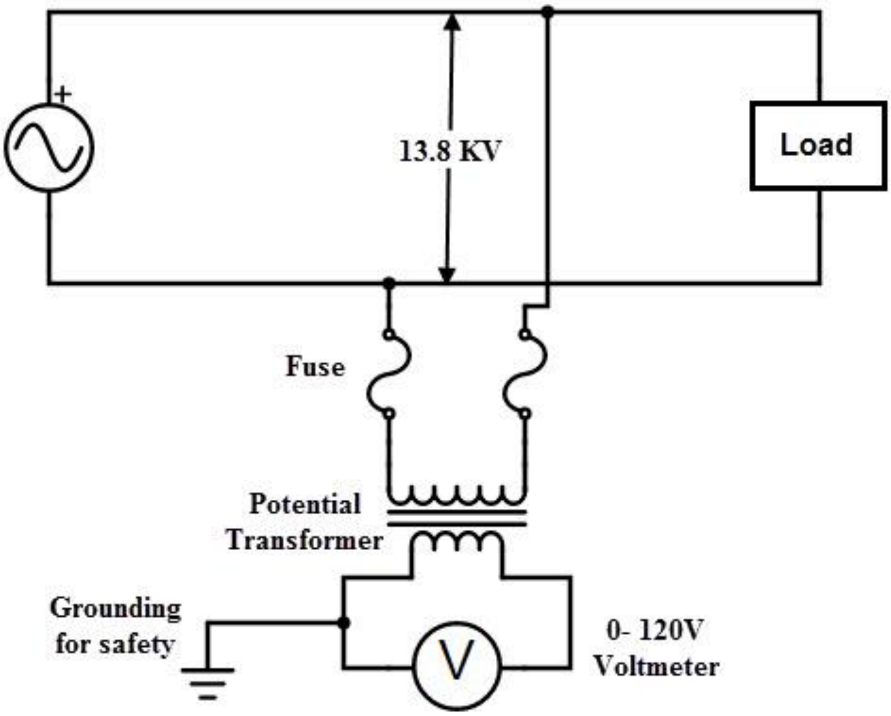
In addition to the reduction of voltage and current levels, these transformers isolate the measuring or protective circuit from the main circuit which is operating at high power levels.

The current transformers reduce the level of current to the instrument or relay operating range, whereas potential transformers transforms the high voltage to a circuit operating low voltage. In this article we are going to discuss in detail about the potential transformers.

### 3.5.3.1 What is Potential Transformer

Potential transformer is a voltage step-down transformer which reduces the voltage of a high voltage circuit to a lower level for the purpose of measurement. These are connected across or parallel to the line which is to be monitored.

The basic principle of operation and construction of this transformer is similar to the standard power transformer. In common, the potential transformers are abbreviated as PT.




The primary winding consists of a large number of turns which is connected across the high voltage side or the line in which measurements have to be taken or to be protected. The secondary winding has lesser number of turns which is connected to the voltmeters, or potential coils of wattmeter and energy meters, relays and other control devices. These can be single phase or three phase potential transformers. Irrespective of the primary voltage rating, these are designed to have the secondary output voltage of 110 V.

Since the voltmeters and potential coils of other meters have high impedance, a small current flows through the secondary of PT. Therefore, PT behaves as an ordinary two winding transformer operating on no load. Due to this low load (or burden) on the PT, the VA ratings of PTs are low and in the range of 50 to 200 VA. On the secondary side, one end is connected to the ground for safety reasons as shown in figure.

Similar to the normal transformer, the transformation ratio is specified as

$V1/V2 = N1/N2$

From the above equation, if the voltmeter reading and transformation ratio are known, then high voltage side voltage can be determined.

### 3.5.3.2 Construction

Compared to the conventional transformer, potential transformers or PTs use larger conductor sizes and core. PTs designed for ensuring the greater accuracy and hence, at the time of designing economy of the material is not considered as main aspect.

PTs are made with special high quality core operating at lower flux densities in order to have small magnetizing current so that no load losses are minimized. Both core and shell type constructions are preferred for PTs. For high voltages, core type PTs are used while shell type is preferred for low voltages.

To reduce the leakage reactance, co-axial windings are used for both primary and secondary. For reducing the insulation cost, low voltage secondary winding is placed next to the core. And for high voltage PTs, high voltage primary is divided into sections of coils to reduce the insulation between coil layers. For these windings, vanished cambric and cotton tape are used as laminations. In between the coils, hard fiber separators are used.

These are carefully designed to have minimum phase shift between the input and output voltages and also to maintain a minimum voltage ratio with variation in load. Oil filled PTs are used for high voltage levels (above the range of 7KV). In such PTs, oil filled bushings are provided to connect the main lines.

### 3.5.3.3 Types of Voltage or Potential Transformers

Majorly these are classified into outdoor and indoor potential transformers.

#### 1. Outdoor Potential Transformers

These can be single or three phase voltage transformers available for different range of operating voltages that are used for outdoor relaying and metering applications. Up to 33KV, these are of electromagnetic type single and three phase voltage transformers. Above 33KV single phase outdoor potential transformers can be two types electromagnetic type and capacitive voltage transformer (CVT).

Electromagnetic or Wound Type Conventional Potential Transformer

These are similar to the conventional oil filled wire wound transformers. The figure below shows the electromagnetic type of PT wherein tap tank is connected to the line terminal. A plug is provided on the tank to fill the oil and this tank is mounted on an insulator support.

At the base, ground terminal and oil drain plug is provided. In this, primary is connected between the two phases or between one phase and ground. So one end of the primary is connected to main line at the top and the other end is brought out at the bottom and is grounded with other ground terminals.

The secondary terminals including earth terminal are located in the terminal box at the bottom, further these are connected to the metering and relay circuits. These are used up to or below 132 KV operating voltages due to insulation aspects.

**Capacitive Voltage Transformers (CVTs)**

It is a capacitive potential divider connected between the phase of main line and ground. These can be coupling capacitor or bushing type CVTs. These two types are electrically less or more similar, but the difference is that the formation of capacitance which further decides their rated burden (or load).

A coupling capacitor type consists of a stack of series connected capacitors which are made up of oil-impregnated paper and aluminum foil. For desired primary and secondary voltages, primary and secondary terminals are connected across the capacitors.

The bushing type CVT uses condenser type bushings provided with tapping. CVTs are also used for power line carrier communication and hence more economical.

**2.IndoorPotential Transformers**

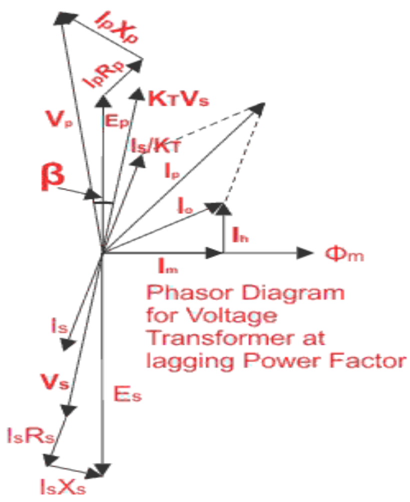
These are also available as single or three phase PTs which are of moulded, magnetic type. The mounting mechanism can be fixed or drawout type. In this type of PTs, all parts of primary winding are insulated from earth at its rated insulation capacity. These are designed to operate relays, measuring instruments, and other control devices in indoor service with high accuracy.

Fig3.5.3.3: Indoor Potential Transformers

Based on the function, PT or voltage transformers are classified into metering voltage transformers and protection voltage transformers.

### 3.5.3.4 Errors in Voltage Transformer

For an ideal voltage transformer, the voltage produced in the secondary winding is an exact proportion to the primary voltage and are exactly in phase opposition. But in actual PTs this is not so because of the presence of voltage drops in primary and secondary resistance and also due the power factor of the burden on secondary. This causes to occurrence of ratio and phase angle errors in voltage transformers. Let us know in detail.




Errors in Voltage Transformer

Consider the phasor diagram of potential transformer shown above,

where

Io = No load current

Im = magnetizing component of no load current

Iu = Wattful component of no load current

Es and Ep = Induced voltages in secondary and primary windings respectively

Np and Ns = Number of turns in primary and secondary windings respectively

Ip and Is = Primary current and secondary current

Rp and Rs = Resistances of primary and secondary windings respectively

Xp and Xs = Reactance of primary and secondary windings respectively

β = Phase angle error

The primary induced voltage or EMF Ep is derived by subtracting the primary resistive (IpRp) and reactive drop (IpXp) from the primary voltage Vp. And also, secondary terminal voltage Vs is derived by subtracting secondary winding resistance drop (IsRs) and reactance drop (IsXs) vector ally from secondary induced EMF Es. Due to these drops nominal ratio of the potential transformer is not equal to the actual ratio of the PT, hence introduces a ratio error.

**Ratio Error**

The ratio error of the potential transformer is defined as the variation in actual ratio of transformation from nominal ratio.

Percentage Ratio Error = (Kn – R) / R × 100

Where

Kn is the nominal or rated transformation ratio and is

Kn = Rated primary voltage / Rated secondary voltage

Phase Angle Error

In ideal PT, there should not exist any phase angle between the primary voltage and reversed secondary voltage. But in practice, there exist a phase difference between Vp and Vs reversed (as we can observe in above figure), thereby, introduces phase angle error. It is defined as the phase difference between the primary voltage and reversed secondary voltage.

In order to reduce these errors such that the accuracy is improved by designing the transformers in such a way that they windings have appropriate magnitudes of internal resistance and reactances. In addition to this, the core should require minimum magnetizing and core loss components of exciting current.

**3.5.3.5 Applications of Voltage Transformers**

- Electrical Metering systems
- Electrical protection systems
- Distance protection of feeders
- Synchronizing generators with grid
- Impedance protection of generators

The class of potential transformers used for metering is called as measurement voltage or potential transformers. On other hand PTs used for protection called as protection voltage transformers. In some cases PTs are used for both metering and protection purposes, in such cases, one secondary winding is connected to metering and other secondary winding is used for protection.

# Chapter 4

# EARTHING SYSTEM

## 4.1 What is Grounding or Earthing?

To connect the metallic (conductive) Parts of an Electric appliance or installations to the earth (ground) is called Earthing orGrounding.

In other words, to connect the metallic parts of electric machinery and devices to the earth plate or earth electrode (which is buried in the moisture earth) through a thick conductor wire (which has very low resistance) for safety purpose is known as *Earthing or grounding.*

To earth or earthing rather, means to connect the part of electrical apparatus such as metallic covering of metals, earth terminal of socket cables, stay wires that do not carry current to the earth. Earthing can be said as the connection of the neutral point of a power supply system to the earth so as to avoid or minimize danger during discharge of electrical energy.

## 4.2 Difference between Earthing, Grounding and Bonding.

Let me clear the confusion among earhing, grounding and bonding.

Earthing and Grounding is the same terms used for earthing. Grounding is the commonly word used for earthing in the North American standards like IEEE, NEC, ANSI and UL etc while, Earthing is used in European, Common wealth countries and Britain standards like IS and IEC etc.The word Bonding used for jointing two wires (as well as conductors, pipes or appliances together. Bonding is known as connecting the metallic parts of different machines which is not considered to be carrying electric current during normal operation of the machines to bring them at the same level of electric potential.

## 4.3 Purpose of Earthing

**1. Safety for Human life / Building /Equipment**

- To save human life from danger of electricalshock or death by blowing a fuse i.e. To provide an alternative path for the fault current to flow so that it will not endanger the user
- To protect buildings, machinery & appliances under fault conditions.
- To ensure that all exposed conductive parts do not reach a dangerous potential.
- To provide safe path to dissipate lightning and short circuit currents.
- To provide stable platform for operation of sensitive electronic equipment i.e. To maintain the voltage at any part of an electrical system at a known value so as to prevent over current or excessive voltage on the appliances or equipment .

**2. Over voltage protection**

Lightning, line surges or unintentional contact with higher voltage lines can cause dangerously high voltages to the electrical distribution system. Earthing provides an alternative path around the electrical system to minimize damages in the System.

**3. Voltage stabilization**

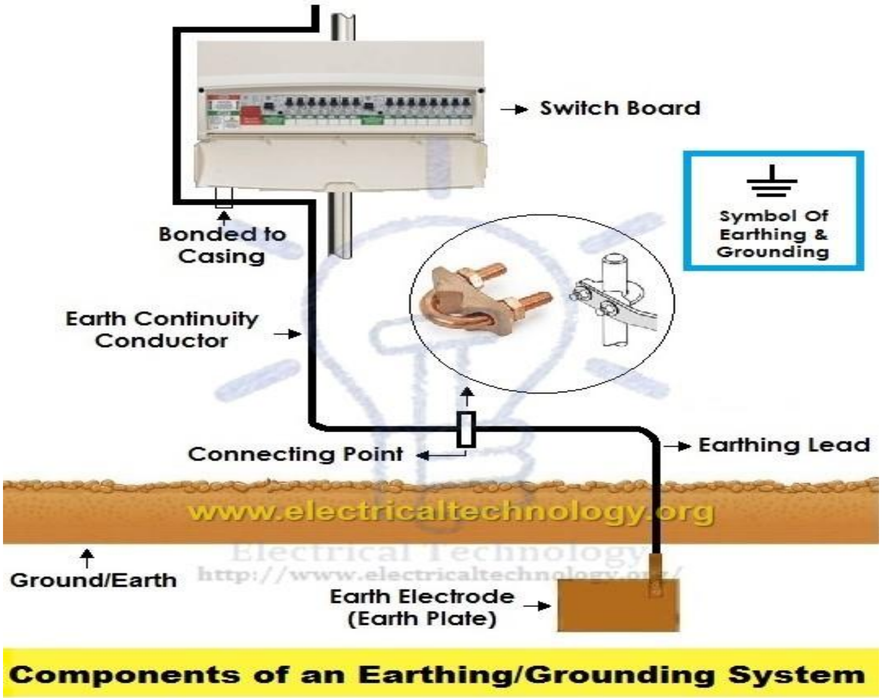
There are many sources of electricity. Every transformer can be considered a separate source. If there were not a common reference point for all these voltage sources it would be extremely difficult to calculate their relationships to each other.

*The earth is **the most omnipresent conductive surface**, and so it was adopted in the very beginnings of electrical distribution systems as a nearly universal standard for all electric systems.*

## 4.4 Components of Earthing System

A complete electrical earthing system consists on the following basic components.

- Earth Continuity Conductor
- Earthing Lead
- Earth Electrode




## 4.5 Earth Continuity Conductor or Earth Wire

That part of the earthing system which interconnects the overall metallic parts of electrical installation e.g. conduit, ducts, boxes, metallic shells of the switches, distribution boards, Switches, fuses, Regulating and controlling devices, metallic parts of electrical machines such as, motors, generators, transformers and the metallic framework where electrical devices and components are installed is known as earth wire or earth continuity conductor as shown in the above fig.

The resistance of the earth continuity conductor is very low. According to IEEE rules, resistance between consumer earth terminal and earth Continuity conductor (at the end) should not be increased than 1Ω. In simple words, **resistance of earth wire should be less than 1Ω**.

Size of the Earth Continuity Conductor or Earth Wire depends on the cable size used in the wiring circuit.

**Size of Earth Continuity Conductor**

The cross sectional area of the **Earth Continuity Conductor** should not be less than the half of the cross sectional area of the thickest wire used in the **electrical wiring installation**.

Generally, the size of the bare copper wire used as earth continuity conductor is 3SWG. But keep in mind that, don't use less than 14SWG as earth wire. Copper strip is also can be used as earth continuity conductor instead of bare copper wire but don't go for it until manufacture recommend it.

**Size of the Earthing Lead**

The size or area of earthing lead should not be less than the half of the thickest wire used in the installation.

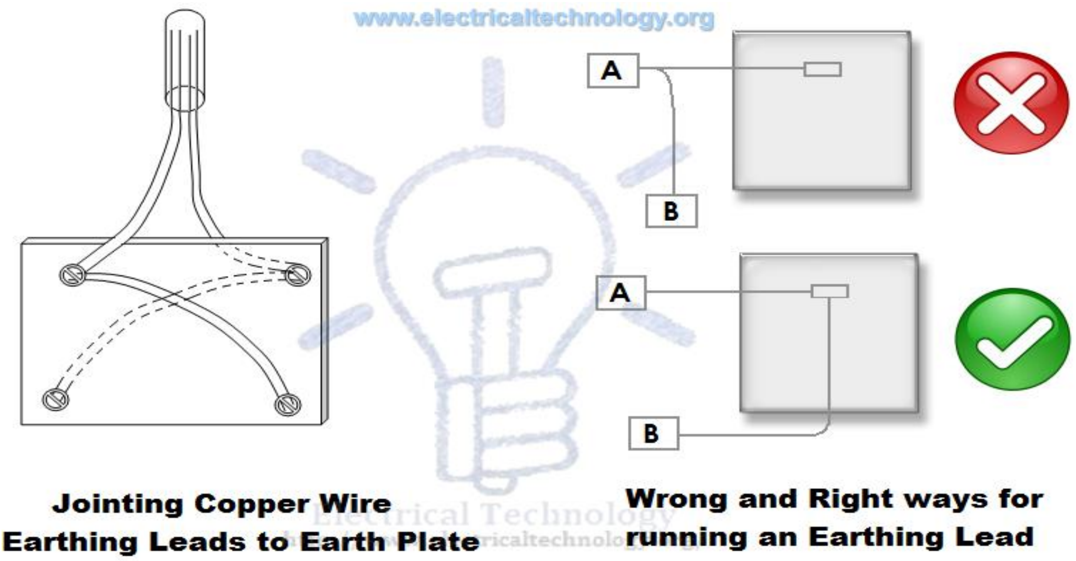
The largest size for earthing lead is 3SWG and the minimum size should not be less than 8SWG. If 37/.083 wire is used or the load current is 200A from the supply voltage, then it is recommended to use copper strip instead of double earthing lead. The earth lead connection methods is shown in the above fig.

Note: We will post additional article about Earth Plate size with simple calculations… Stay tune.

## 4.6 Earthing Electrode or Earth Plate

A metallic electrode or plate which is buried in the earth (underground) and it is the last part of the electrical earthing system. In simple words, the final underground metallic (plate) part of the earthing system which is connected with earthing lead is called earth plate or earth electrode.

A metallic plate, pipe or rode can be used as an earth electrode which has very low resistance and carry the fault current safely towards ground (earth).




**Size of Earthing Electrode**

Both copper and iron can be used as earthing electrode.

The size of earth electrode (In case of copper)

2×2 (two foot wide as well as in length) and 1/8 inch thickness.. I.e. 2’ x 2’ x 1/8”. (600x600x300 mm)

In case of Iron

2’ x2’ x ¼” = 600x600x6 mm

It is recommended to bury the earth electrode in the moisture earth. If it is not possible, then put water in the GI (Galvanized Iron) pipe to make possible the moisture condition.

In the earthing system, put the earth electrode in vertical position (underground) as shown in the above fig. Also, put a 1 foot (about 30cm) **layer of powdered charcoal and lime mixture** around the earth plate (don’t confuse with earth electrode and earth plate as both are the same thing).

This action makes the possible increase in the size of the earth electrode which leads a better continuity in the earth (earthing system) and also helps to maintain the moisture condition around earth plate.

**P.S:** We will post Example calculation about Earth Electrode Sizing… Stay tune.

**Good to know:**

*Don't use coke (after burning coal in the furnace to emit all the gases and other components, the remaining 88% carbon is called coke) or stone coal instead of charcoal (wood coal) because it causes to corrosion in the earth plate.*

*Since, the water level is different in the different areas; therefore, the depth for earth electrode installation is also different in various areas. But, the depth for earth electrode installation should not be less than 10ft (3 meter) and should below 1 foot (304.8mm) from the constant water level.*

***Motors**, **Generator**, **Transformers** etc should be connected from to earth electrode two different places.*

## 4.7 Earth Plate or Earth Electrode Size for Small installation

In small installation, use metallic rod (diameter = 25mm (1inch) and length = 2m (6ft) instead of earth plate for earthing system. The metallic pipe should be 2 meter below from the surface of ground. To maintain the moister condition, put 25mm (1inch) coal and lime mixture around the earth plate.

For effectiveness and convenience, you may use the copper rods 12.5mm (0.5 inch) to 25mm (1 inch) diameter and 4m (12ft) length. We will discuss the installation method of rod earthing latter.

## 4.8Methods of Earthing | Types of Earthing

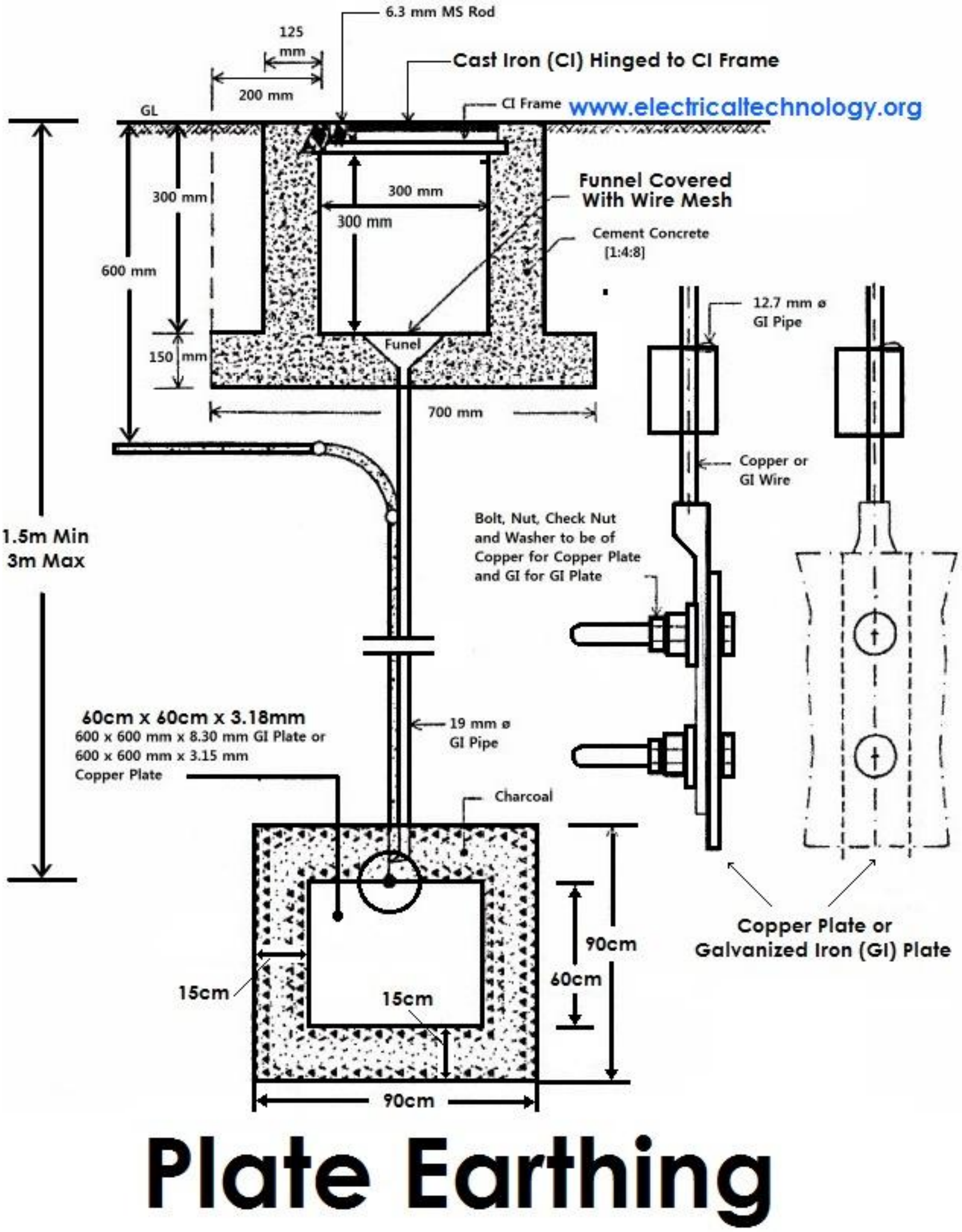
Earthing can be done in many ways. The various methods employed in earthing (in house wiring or factory and other connected electrical equipment and machines) are discussed as follows:

### 4.8.1 Plate Earthing:

In plate earthing system, a plate made up of either copper with dimensions 60cm x 60cm x 3.18mm (i.e. 2ft x 2ft x 1/8 in) or galvanized iron (GI) of dimensions 60cm x 60cm x 6.35

mm (2ft x 2ft x ¼ in) is buried vertical in the earth (earth pit) which should not be less than 3m (10ft) from the ground level.

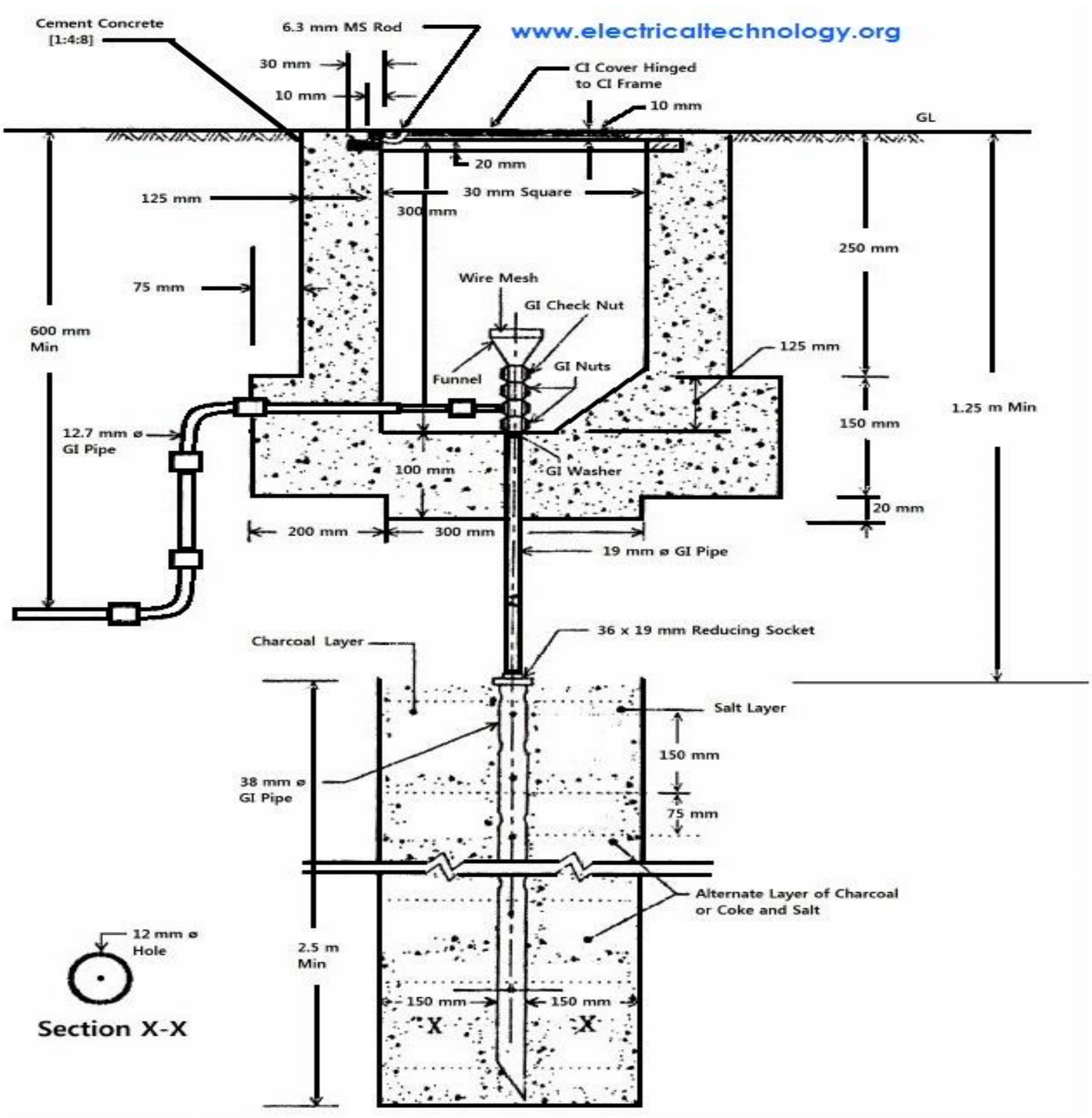
For proper earthing system, follow the above mentioned steps in the (Earth Plate introduction) to maintain the moisture condition around the earth electrode or earth plate.



## 4.8.2 Pipe Earthing:

A galvanized steel and a perforated pipe of approved length and diameter is placed vertically in a wet soil in this kind of system of earthing. It is the most common system of earthing.

The size of pipe to use depends on the magnitude of current and the type of soil. The dimension of the pipe is usually 40mm (1.5in) in diameter and 2.75m (9ft) in length for ordinary soil or greater for dry and rocky soil. The moisture of the soil will determine the length of the pipe to be buried but usually it should be 4.75m (15.5ft)




Pipe Earthing

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## 4.8.3 Rod Earthing

it is the same method as pipe earthing. A copper rod of 12.5mm (1/2 inch) diameter or 16mm (0.6in) diameter of galvanized steel or hollow section 25mm (1inch) of GI pipe of length above 2.5m (8.2 ft) are buried upright in the earth manually or with the help of a pneumatic hammer. The length of embedded electrodes in the soil reduces earth resistance to a desired value.

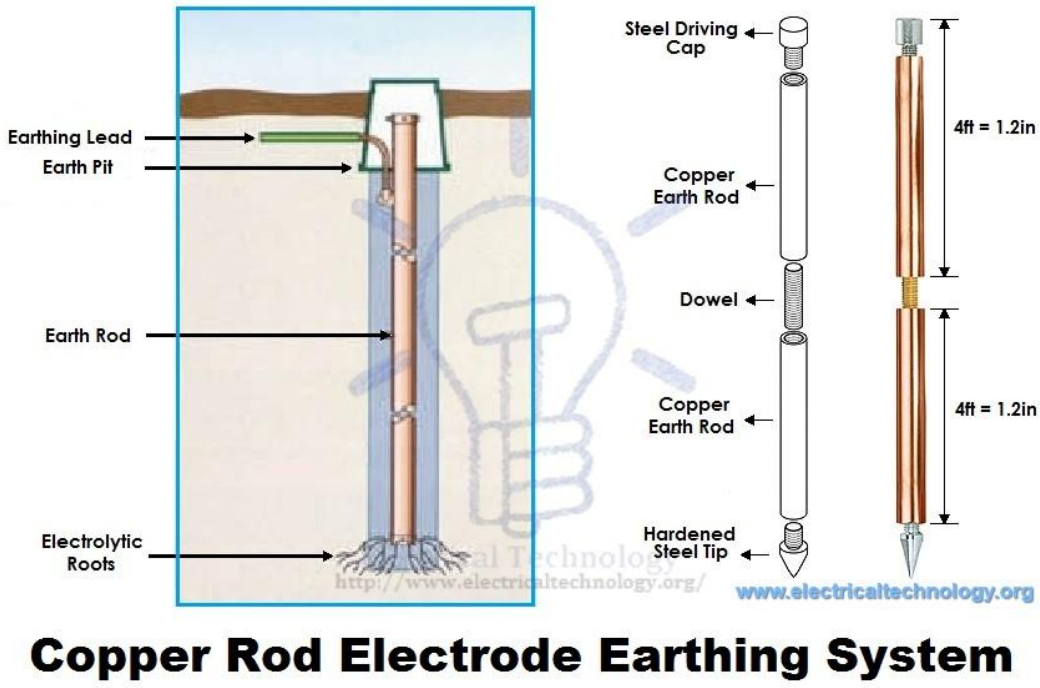



Fig4.8.3: Copper Rod Electrode Earthing System

## 4.8.4 Earthing through the Waterman

In this method of earthing, the waterman (Galvanized GI) pipes are used for earthing purpose. Make sure to check the resistance of GI pipes and use earthing clamps to minimize the resistance for proper earthing connection.

If stranded conductor is used as earth wire, then clean the end of the strands of the wire and make sure it is in the straight and parallel position which is possible then to connect tightly to the waterman pipe.

### 4.8.5 Strip or Wire Earthing:

In this method of earthing, strip electrodes of cross-section not less than 25mm x 1.6mm (1in x 0.06in) is buried in a horizontal trenches of a minimum depth of 0.5m. If copper with a cross-section of 25mm x 4mm (1in x 0.15in) is used and a dimension of 3.0mm$^2$ if it's a galvanized iron or steel.

If at all round conductors are used, their cross-section area should not be too small, say less than 6.0mm$^2$ if it's a galvanized iron or steel. The length of the conductor buried in the ground would give a sufficient earth resistance and this length should not be less than 15m.

## 4.9 General method of Earthing / Proper Grounding Installation (Step by Step)

The usual method of earthing of electric equipments, devices and appliances are as follow:

1. First of all, dig a 5x5ft (1.5×1.5m) pit about 20-30ft (6-9 meters) in the ground. (Note that, depth and width depends on the nature and structure of the ground)
2. Bury an appropriate (usually 2' x 2' x 1/8" (600x600x300 mm) copper plate in that pit in vertical position.
3. Tight earth lead through nut bolts from two different places on earth plate.
4. Use two earth leads with each earth plate (in case of two earth plates) and tight them.
5. To protect the joints from corrosion, put grease around it.
6. Collect all the wires in a metallic pipe from the earth electrode(s). Make sure the pipe is 1ft (30cm) above the surface of the ground.
7. To maintain the moisture condition around the earth plate, put a 1ft (30cm) layer of powdered charcoal (powdered wood coal) and lime mixture around the earth plate of around the earth plate.
8. Use thimble and nut bolts to connect tightly wires to the bed plates of machines. Each machine should be earthed from two different places. The minimum distance between two earth electrodes should be 10 ft (3m).

9. Earth continuity conductor which is connected to the body and metallic parts of all installation should be tightly connected to earth lead.

10. At last (but not least), test the overall earthing system through earth tester. If everything is going about the planning, then fill the pit with soil. The maximum allowable resistance for earthing is 1Ω. If it is more than 1 ohm, then increase the size (not length) of earth lead and earth continuity conductors. Keep the external ends of the pipes open and put the water time to time to maintain the moisture condition around the earth electrode which is important for the better earthing system.

## 4.10SI specification for Earthing

Various specifications in respect to earthing as recommended by Indian Standards are given below. Here are few;

- An earthing electrode should not be situated (installed) close to the building whose installation system is being earthed at least more than 1.5m away.
- The earth resistance should be low enough to cause the flow of current sufficient to operate the protective relays or blow fuses. It's value is not constant as it varies with weather because it depends on moisture (but should not be less than 1 Ohm).
- The earth wire and earth electrode will be the same material.
- The earthing electrode should always be placed in a vertical position inside the earth or pit so that it may be in contact with all the different earth layers.

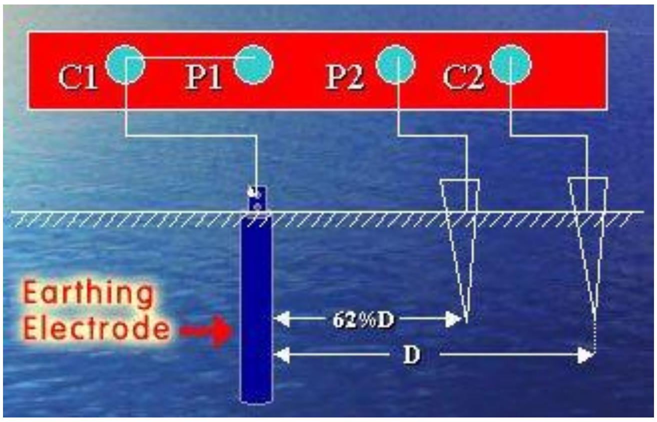
## 4.11 Measurement of Earth Resistance by use of Earth Tester

**For measuring soil resistivity Earth Tester is used. It is also called the "MEGGER".**

- It has a voltage source, a meter to measure Resistance in ohms, switches to change instrument range, Wires to connect terminal to Earth Electrode and Spikes.
- It is measured by using Four Terminal Earth Tester Instrument. The terminals are connected by wires as in illustration.
- P=Potential Spike and C=Current Spike. The distance between the spikes may be 1M, 2M, 5M, 10M, 35M, and 50M.

- All spikes are equidistant and in straight line to maintain electrical continuity. Take measurement in different directions.
- **Soil resistivity =2πLR.**
- R= Value of Earth resistance in ohm.
- Distance between the spikes in cm.
- π = 3.14
- P = Earth resistivity ohm-cm.
- Earth resistance value is directly proportional to Soil resistivity value

### 4.11.1 Measurement of Earth Resistance (Three point method)




### 4.11.2 Measurement of Earth Resistance (Three point method)

n this method earth tester terminal C1 and P1 are shorted to each other and connected to the earth electrode (pipe) under test. Terminals P2 and C2 are connected to the two separate spikes driven in earth. These two spikes are kept in same line at the distance of 25 meters and 50 meters due to which there will not be mutual interference in the field of individual spikes.

Normally, the length of wires should be **10 and 15 meters or in proportion of 62% of 'D'**.

Suppose, the distance of Current Spike from Earth Electrode D = 60 ft, Then, distance of Potential Spike would be 62 % of D = 0.62D i.e. 0.62 x 60 ft = 37 ft.

### 4.11.3 Four Point Method

In this method 4 spikes are driven in earth in same line at the equal distance. Outer two spikes are connected to C1 & C2 terminals of earth tester. Similarly inner two spikes are connected to P1 & P2 terminals. Now if we rotate generator handle with specific speed, we get earth resistance value of that place.

In this method error due to polarization effect is eliminated and earth tester can be operated directly on A.C.

## 4.12GI Earthing Vs Copper Earthing

- As per IS 3043, the resistance of Plate electrode to earth **(R) = (r/A) X under root(P/A).**
- Where r = Resistivity of Soil Ohm-meter.
- A=Area of Earthing Plate m3.
- The resistance of Pipe electrode to earth **(R) = (100r/2πL) X loge (4L/d).**
- Where L= Length of Pipe/Rod in cm
- d=Diameter of Pipe/Rod in cm.
- The resistivity of the soil and the physical dimensions of the electrode play important role of resistance of Rod with earth.
- The material resistivity is not considered important role in earth resistivity.
- Any material of given dimensions would offer the same resistance to earth. Except the sizing and number of the earthing conductor or the protective conductor.

## 4.13Pipe Earthing Vs Plate Earthing

- Suppose Copper Plate having of size 1.2m x 1.2m x 3.15mm thick. soil resistivity of 100 ohm-m,
- The resistance of Plate electrode to earth (R)=( r/A)X under root(π/A) = (100/2.88)X(3.14/2.88)=**36.27 ohm**
- Now, consider a GI Pipe Electrode of 50 mm Diameter and 3 m Long. soil resistivity of 100 Ohm-m,
- The resistance of Pipe electrode to earth (R) = (100r/2πL) X loge (4L/d) = (100X100/2X3.14X300) X loge (4X300/5) =**29.09 Ohm.**

- From the above calculation the GI Pipe electrode offers a much lesser resistance than even a copper plate electrode.
- As per IS 3043 Pipe, rod or strip has a much lower resistance than a plate of equal surface area.

## 4.14Maximum allowable Earth resistance

- Major power station = **0.5 Ohm**
- Major Sub-stations = **1.0 Ohm**
- Minor Sub-station = **2 Ohm**
- Neutral Bushing = **2 Ohm**
- Service connection = **4 Ohm**
- Medium Voltage Network = **2 Ohm**
- L.T.Lightening Arrestor = **4 Ohm**
- L.T.Pole = **5 Ohm**
- H.T.Pole = **10 Ohm**
- Tower = **20-30 Ohm**

# Chapter 5

# Busbar Trunking System

## 5.1 Busbar trunking systems (BTSs)

In electrical installations for industrial environments, busbar trunking systems(BTSs) optimize the power distribution despite the inevitable modifications that are carried out (additions, displacements, replacement of loads) and to facilitate maintenance work and safety verifications.They are mainly used for:

- supplying sources of light, safety and low power distribution;
- Lighting lines (medium power);
- Power supply and distribution (medium and large power);

### 5.1.1 Busbar trunking systems are subject to the following Standards:

- IEC 60439 – 1 “Low-voltage switchgear and control gear assemblies – Part 1:
Type-tested and partially type-tested assemblies”
- IEC 60439 – 2 “Low-voltage switchgear and control gear assemblies – Part 2:
Particular requirements for busbar trunking systems (bus ways)”.

### 5.1.2 BTSs consist of:

**Conductors/busbars;**
**Coupling:** electrical and mechanical connecting elements for different elements;
**Straight elements:** base elements of the line for carrying energy from the source to the loads;
**Routing elements:** flexible joints for the creation of curves or overcoming Obstacles, horizontal and vertical angles, tee joints and cross elements to Create any type of route;
**Pull boxes:** elements that enable lamps or operating machines to be supplied Directly with integrated protection (fuses or circuit breakers);
**Suspensions/accessories:** hanging and fixing elements for BTS and for any Support required for special loads (lighting components, etc),

### 5.1.3 Dimensioning of a BTS

To dimension a BTS, the load current must be determined using the following data:
Power supply

- General type of load supply:
  - single-phase
  - Three-phase.
- Type of BTS supply:
  - from one end;
  - from both ends;
  - Central power supply.
- Rated voltage
- Short-circuit current at the supply point
- Ambient temperature.

**Loads**

- Number, distribution, power and cosϕ and type of loads supplied by the same BTS

**BTS geometry**

Type of installation:

- Flat,
- edge-on,
- vertical,

Length.

**NOTE:** BTSs shall be placed at a distance from the walls and the ceilings in such a way as to enable visual inspection of connections during assembly and to facilitate insertion of the branch units.

If possible, it is preferable to install the BTS edge-on so as to improve mechanical resistance and reduce any possible deposit of powder and polluting substances that might affect the level of internal insulate

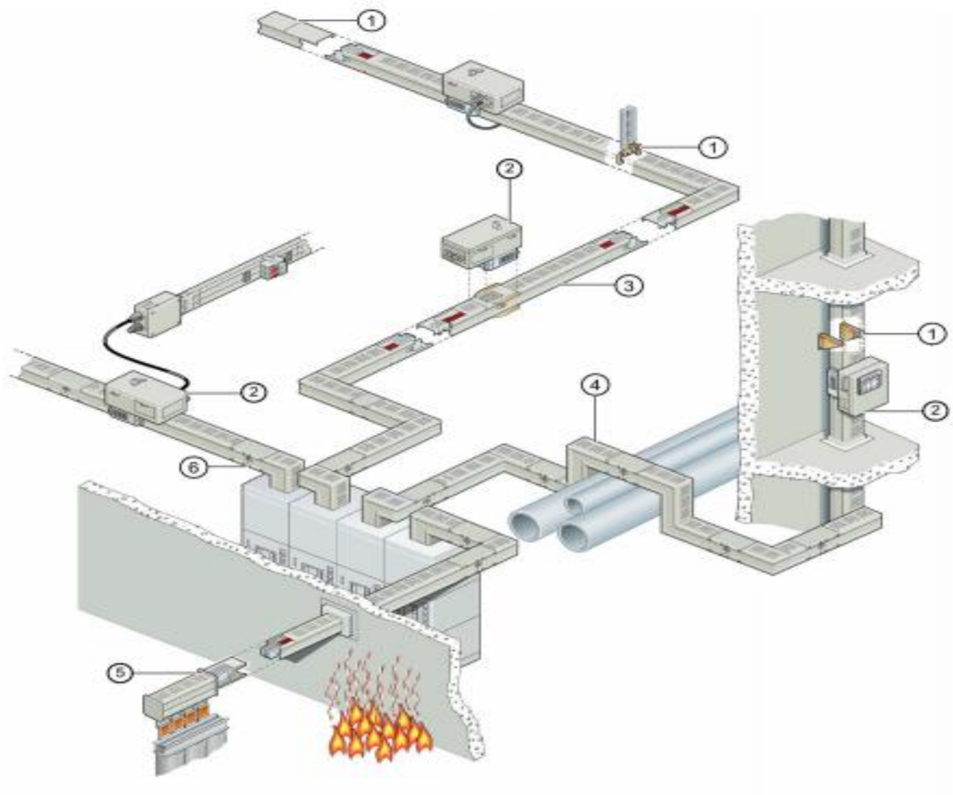
- supplying moving equipment (bridge cranes),

## 5.2 A comparison of busbar trunking systems and cable trunking

**Table 5.2: Comparison of busbar trunking systems and cable trunking**

| Feature | Busbar trunking unit | Cable trunking |
|---|---|---|
| Type-tested system | x | — |
| Mechanical safety | High | Low |
| Fire load | Low | High |
| Thermal characteristics | Ambient temperature compliant with IEC / EN 61439-1 and-6 max. +40°C and +35°C average over 24 hours | Cable loads are related to +30 °C in accordance with DIN 57298-4, Chap. 5.3.3.1 / DIN VDE 0298-4/2.88. |
| Protective devices for loads | In the tap-off unit: facilitating direct and immediately traceable assignment to load locally. | Centrally in the distribution board: this means that assignment to the load cannot be verified directly. You have to rely on the cable and load being labeled correctly |
| Space requirements | Low | High, |
| Planning and configuration | Quick and easy using computer-assisted planning tools Configuration is time-consuming and complex (distribution board and cable dimensioning, cable diagrams, etc.) | Configuration is time-consuming and complex (distribution board and cable dimensioning, cable diagrams, etc. |
| Dimensioning (current, voltage drop, neutralization conditions) | Complex | Very complex |
| Troubleshooting expenditure | Low | High |
| Fireproof barrier | Type-tested, factory-built | Dependent upon installation quality on site |
| Electromagnetic interference | Low | Relatively high for standard cables |
| Installation | Few installation accessories and tools, short installation times | Extensive installation accessories and numerous tools, long installation time |
| Weight | Weighs up to 1/3 of comparable cable weight | Up to 3 times the weight of the busbar trunking system |
| Halogen-free, PVC-free | All tap-off units are halogen-free and PVC-free. | Standard cables are not halogen-free and PVC-free. |

## 5.3System description



① **Additional equipment**

② **Tap-off unit's**

③ **Straight trunking units**

④ **Junction units**

⑤ **Infeeds**

⑥ **Distribution board connection units**

**Fig 5.3: Overview of LD busbar trunking system**

The LD busbar trunking system is used for both power transmission and distribution. The system offers a high short-circuit rating and is particularly suited for the connection of transformers to low-voltage main distribution boards and sub-distribution boards.In applications where high powers are required, conventional systems frequently require the use of parallel cables. The LD system offers optimal power distribution for both horizontal and vertical busbar runs. Coded plug-in tap-off units up to 1250 A that meet extremely high safety standards are available for this purpose.

# 5.4Important planning information:

The nominal mounting position of the busbar trunking system is horizontal and edgewise for The busbars. In very rare cases, due to a specific trunking run or the option of connecting tap-off units on the side, the busbars might have to be laid flat. The resulting increase in the Internal heat rise of the system necessitates a reduction in rated current. The same applies to vertical height rises > 1.3 m (see the table in the chapter "Type code (Page 108)").

The LD busbar trunking system is a ventilated system. When the degree of protection is Increased from IP34 to IP54 (enclosed system), the rated current must be derated as Specified in the tables in the next chapter

Ordering type

Basic type | Fire protection

LD ☐ ☐ ☐ ☐ ☐ - ... +LD - L ☐ - ☐

Conductor material

| | |
|---|---|
| Al | A |
| Cu | C |

Rated current $I_{sA}$ [A]

| IP34 | | | | | | IP54 | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Horizontal edgewise incl. height rises | | | | | | Horizontal Edgewise and vertical | | Horizontal Flat | | |
| < 1,3m | | > 1,3m | | Vertical | | | | | | |
| Al | Cu | Al | Cu | Al | Cu | Al | Cu | Al | Cu | |
| 1100 | | 950 | | 950 | | 900 | | 700 | | 1 |
| 1250 | 2000 | 1100 | 1650 | 1100 | 1650 | 1000 | 1600 | 750 | 1200 | 2 |
| 1600 | 2600 | 1250 | 2100 | 1250 | 2100 | 1200 | 2000 | 1000 | 1550 | 3 |
| 2000 | | 1700 | | 1700 | | 1500 | | 1200 | | 4 |
| 2500 | | 2100 | | 2100 | | 1800 | | 1700 | | 5 |
| 3000 | 3400 | 2300 | 2700 | 2300 | 2700 | 2000 | 2600 | 1800 | 2000 | 6 |
| 3700 | 4400 | 2800 | 3500 | 2800 | 3500 | 2400 | 3200 | 2200 | 2600 | 7 |
| 4000 | 5000 | 3400 | 4250 | 3400 | 4250 | 2700 | 3600 | 2350 | 3000 | 8 |

Version

| | |
|---|---|
| 4-conductor | 4 |
| 5-conductor | 6 |

N / PEN

| | |
|---|---|
| $\frac{1}{2}$ L | 1 |
| L | 2 |

Degree of protection

| | |
|---|---|
| IP 34 | 3 |
| IP 54 | 5 |

Fire protection

| | |
|---|---|
| LDA1 - LDA3<br>LDC2 - LDC3 | 120A |
| LDA4 - LDA8<br>LDC6 - LDC8 | 120B |

Fire protection

| | |
|---|---|
| Positioning (X*, Y*, Z*) | |

Fig 5.4: Important planning information

### 5.4.1 Selection example

A rated current of 2500 A is calculated for a project. Aluminium conductors shall be used. A 4-pole system also has to be used. The cross section of the protective conductor needs to be equal to the cross section of the phase conductor. The required degree of protection is IP34. The mounting position is horizontal, edgewise, without height rises. Use of the above table results in the selection of the following type:

**LDA 5423**

| Ordering type | LI | - | | | | | - | | - ... - | |
|---|---|---|---|---|---|---|---|---|---|---|

| Conductor material | |
|---|---|
| Al | A |
| Cu | C |

| Insulation material | |
|---|---|
| Mylar foil | M |
| Epoxy hybrid[1] | E |
| No selection | N |

| Rated current $I_{nA}$ [A] | |
|---|---|
| 800 (Al only) | 0800 |
| 1000 | 1000 |
| 1250 | 1250 |
| 1600 | 1600 |
| 2000 | 2000 |
| 2500 | 2500 |
| 3200 | 3200 |
| 4000 | 4000 |
| 5000 | 5000 |
| 6300 (Cu only) | 6300 |

| Configuration of the conductors | |
|---|---|
| L1 + L2 + L3 + PE[2] | 3B |
| L1 + L2 + L3 + PEN[3] | 4B |
| L1 + L2 + L3 + N + PE[2] | 5B |
| L1 + L2 + L3 + N + N[4] + PE[2] | 5C |
| L1 + L2 + L3 + N + PE[3] (PE bar 50 %) | 5G[1] |
| L1 + L2 + L3 + N + PE[3] (PE bar 100 %) | 5H |
| L1 + L2 + L3 + N + (PE)[5] + PE[2] | 6B |
| L1 + L2 + L3 + N + N[4] + (PE)[5] + PE[2] | 6C |

| Degree of protection | |
|---|---|
| IP00 | 00 |
| IP40 | 40 |
| IP55 | 55 |
| IP66[5] | 66 |

| Busbar ends | |
|---|---|
| Hook - bolt | HB |
| Hook | H |
| Bolt | B |

### Selection example

A rated current of 2500 A is calculated for a project. Aluminum shall be used as the conductor material, and Mylar as the insulation material. A 5-pole system has to be used. The cross section of the neutral conductor needs to be equal to the cross section of the phase conductor.

**The following type is obtained:**

**LI-AM25005B**

### 5.4.2 Sizes

Sizes are dependent upon rated current and conductor material. In total, there are ten sizes. Six sizes are set up as single systems and three as double systems for the version with aluminium and copper.

Single systems comprise one enclosure with between 3 and 6 aluminium or copper bars.

Double systems have between 6 and 12 bars in two enclosures.

The precise number of bars is determined by the required conductor configuration.

**Sizes (H x W), single system**

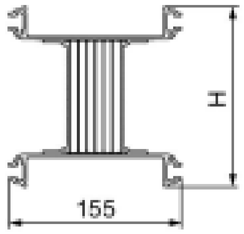



Figure 5-3 Sizes, single system SB

**Table 5.2.2.a: AL/Cu Bus-bar Sizes(Single System):**

| Height H [mm] | System |
|---|---|
| 111 | LI-A.800 |
| 132 | LI-A.1000 |
| 146 | LI-A.1250 |
| 182 | LI-A.1600 |
| 230 | LI-A.2000 |
| 297 | LI-A.2500 |

**The width W is always 155 mm.**

**Table5- 2 CU system**

| | |
|---|---|
| **Height H [mm]** | **System** |
| 111 | LI-C.800 |
| 132 | LI-C.1000 |
| 146 | LI-C.1250 |
| 182 | LI-C.1600 |
| 230 | LI-C.2000 |
| 297 | LI-C.2500 |

**The width W is always 155 mm**

**<u>Sizes (H x W), double system</u>**

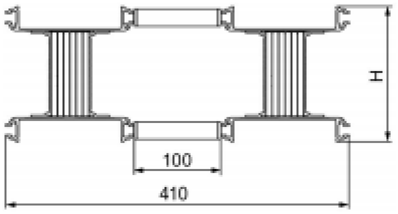



Figure 5-4 Sizes, double system DB

**Table 5.2.2.b:AL/Cu Bus-bar Sizes(Single System):**

| Height H [mm] | System |
|---|---|
| 182 | LI-A.3200 |
| 230 | LI-A.4000 |
| 297 | LI-A.5000 |

**The width W is always 410 mm**

**<u>Table5- 4 CU system</u>**

| Height H [mm] | System |
|---|---|
| 174 | LI-C.4000 |
| 213 | LI-C.5000 |
| 280 | LI-C.6300 |

**The width W is always 410 mm.**

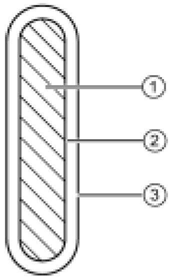
## 5.5Structure of the busbars:

The bars in the LI busbar system are usually tinned and enclosed in a sleeve made of highly resistant insulating material. The LI-A system features aluminum conductors and the LI-C system copper conductors. In addition to tinning, aluminum bars are also coated with a layer of nickel.

① Aluminum bar (LI-A), copper bar (LI-C)

②Nickel layer, tinning (LI-A), tinning (LI-C)

③Insulating material sleeve with high heat resistance or epoxy resin coating and insulating material sleeve with high heat resistance (on request)




## 5.5.1 Junction units:

**Junction units for horizontal installation, horizontal and vertical installation:**

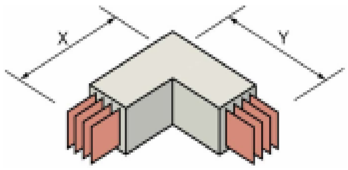
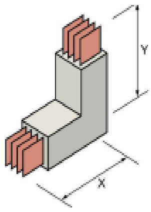
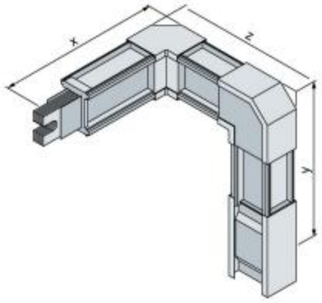
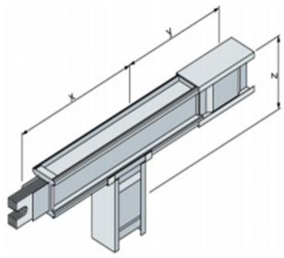
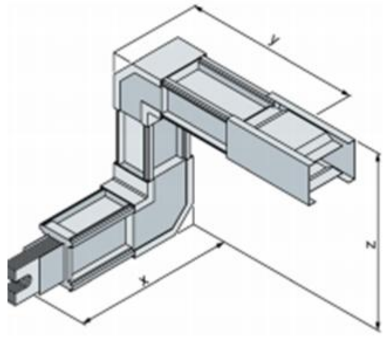
| | |
|---|---|
|   |   |

Fig 1: Elbow LI

| Length | System |
|---|---|
| X = 0.48… 1.90m<br>FY= 0.27m<br>Y = 0.48… 1.90m<br>FY = 0.27 m | LI-A.0800… LI-A.2500<br>LI-C.1000 … LI-C.3200 |
| X = 0.74… 1.90m<br>FY= 0.525m<br>Y = 0.74… 1.90m<br>FY = 0.525 m | LI-A.3200… LI-A.5000<br>LI-C.4000… LI-C.6300 |

| | | |
|---|---|---|
|  Fig 5: Knee offset LI |  Fig 6: T unit LI |  Fig 3: Elbow Offset LI |
| X = 0.74… 1.20 m / Y= 0.56… 1.20m<br>Z=0.89…1.20m<br>Max. X + Y + Z = 3000 mm<br>LI-A.4000 , LI-C.5000 | X / Y min = 0.60m Z = 0.430m<br>Z = 0.413 m Max. X, Y = 1500mm<br>Max. X + Y + Z = 2500 mm<br>LI-A.4000, LI-C.5000 | X = 0.62… 1.20 m / Y= 0.74… 1.20m, Z = 0.95 … 1.20 m<br><br>LI-A.4000/ LI-C.5000 |

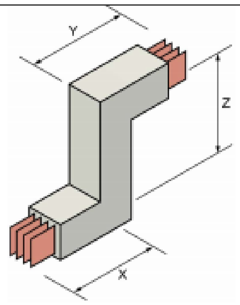
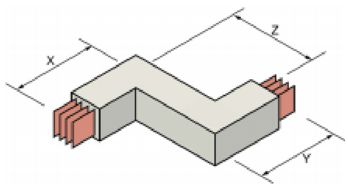
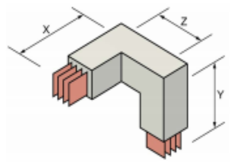
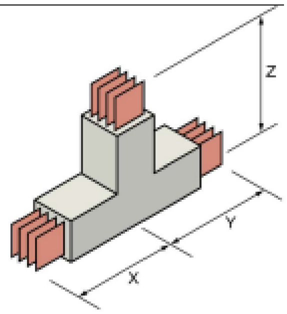
| | | | |
|---|---|---|---|
|  |  |  |  |

Fig 5.5.1: Z units , Offset knee . T units units LI

| Length | System |
|---|---|
| X/Y min = 0.40m<br>Z min. = 0.38 m | LI-A.0800… LI-A.2500<br>LI-C.1000 … LI-C.3200 |
| X/Y min = 0.50m<br>Z min. = 0.63 m | LI-A.3200… LI-A.5000<br>LI-C.4000 … LI-C.6300 |

Max. X + Y + Z = 2800mm

Max. Z = 1200mm

### 5.5.2 Straight trunking units:

**Straight trunking units for horizontal and vertical installation without tap points and joint unit:**

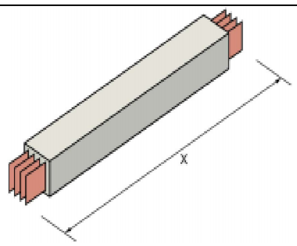
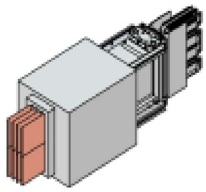
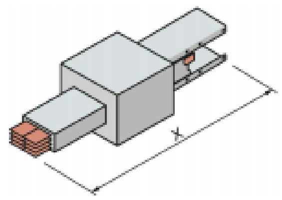
| Straight trunking units for horizontal and vertical installation without tap points and joint unit | Straight trunking units to adapt to LI systems for indoor applications | Straight trunking units to adapt to LD systems for indoor applications |
|---|---|---|
|  Configurable lengths X from 0.30 m to 3.00 m in 0.01 m steps available<br>Straight trunking units for tap-off units on request |  LR-LI adapter element (x = 0.8 m or 0.95m) |  Adapter element (X = 1.0m) |

Fig5.5.2: Straight trunking units

## 5.6 Distribution board connection for distribution boards:

**Connection to power distribution systems as type-tested low-voltage switchgear assemblies compliant with DIN EN 61439-1 and DIN EN 61439-6**

The distribution board and LI busbar trunking system are connected using an integrated busbar trunking connection unit for rated currents up to 6300 A (Ie = 6300 A on request). The busbars can be connected:

- From above
- From below (on request)

This enables a flexible arrangement. The link between the busbar trunking system and the SIVACON S8 distribution systems ensures high short-circuit strength backed up by type testing and a high level of reliability as regards power transmission.

Fig 5.6: Distribution board link

## 5.7Installation of the bus-bar connection unit:

The busbar connection unit in the distribution board must be copper-plated by the board manufacturer or in compliance with that manufacturer's specifications. The board manufacturer must ensure that the required short-circuit strength is achieved and the permissible temperature limit of the busbar connection unit for distribution boards is not exceeded.

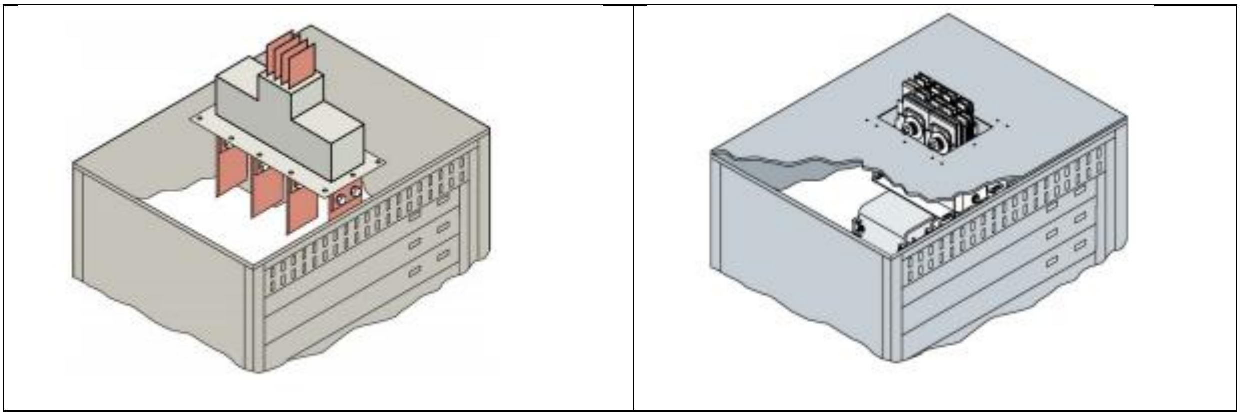


Fig 5.7: Busbar connection unit for distribution boards

## 5.8 Connection unit for transformers and distribution boards:

The wide variety of transformer types reflects the variety of rated currents and the different phase sequences and clearances. This type variety requires high flexibility as regards transformer connection in busbar trunking systems.You can also use the universal connection unit for connecting distribution boards.For LI busbar trunking systems up to 6300 A, transformer connection units are available with busbar connection on the side (LI.....-TCE.) and on the top (LI.....-TCET.).

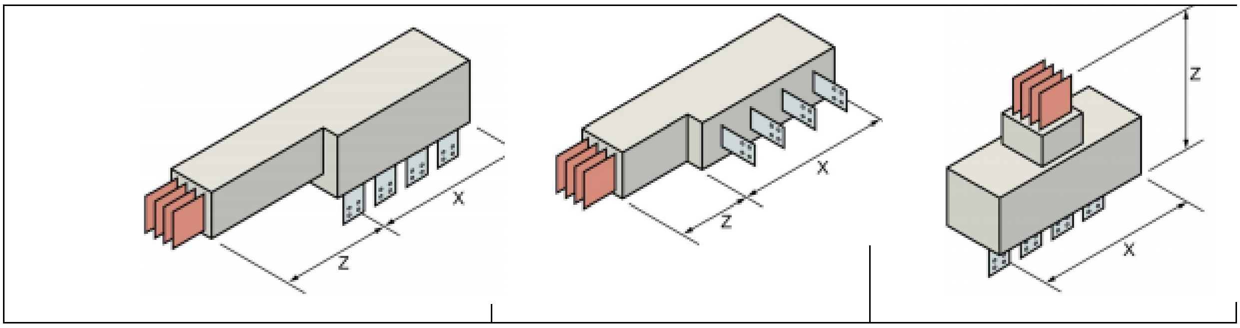



Fig 5.8.a Fig 5.8.bFig5.8.c

**Fig 5.8.a: Bus-bar connection on the side and customer connection on the bottom**.

**Fig5.8.b: Bus-bar connection on the side and customer connection on the side.**

**Fig5.8.c: Bus-bar connection on the top and customer connection on the bottom.**

The total length is calculated from the phase clearances of the connection units to be

Table5.8: Planned (approx. 3 x phase clearance + 300 mm).

| Connection unit type | Selectable phase clearance |
|---|---|
| LI......-TCEL | 135 … 800 mm |
| LI......-TCER | 135 … 800 mm |
| LI......-TCETL | 135 … 800 mm |

# 5.9Tap-offs for power distribution:

## 5.9.1 Characteristics of tap-off units:

For a comprehensive power distribution structure, tap-off units are available in seven sizes:

- Tap-off units up to 160 A
- Tap-off units for 250A
- Tap-off units for 400A
- Tap-off units for 630A
- Tap-off units for 800 to 1250 A (on request)

The rated operating voltage Ue is 400 V. Regardless of the mounting position, the closed enclosures ensure degree of protection IP55. As a general rule, they are equipped with:

- Fuse bases, fuse switch disconnectors, switch disconnectors with fuses or circuit breakers with handle or motorised operating mechanism
- Bolts for cable connection

**Conductor configurations in acc:**

For conductor systems with insulated PE conductor, the tap-off units are supplied with the addition of a separate PE connection.

**Circuit breaker with manual operating mechanism:**

This type of tap-off unit has a circuit breaker which can be controlled from the outside using a handle.

**Degree of protection**

The tap-off units have IP54 degree of protection.

**Opening the tap-off unit**

The contact compartment and the copper connections between the contact mechanism and the circuit breaker are encapsulated in a finger-proof casing. The cover can only be opened if the breaker has been deactivated. This ensures voltage-free load when the cover is removed.

**Cable connection**

On the load side, the outgoing cables are routed directly via the circuit breaker. The PE/PEN conductor is fixed to a bolted connection as appropriate for the cross section. Single-core or multi-core cables can be fed in from the side or via the front face. The sectional flange plate facilitates the laying of the cables.

## 5.9.2 Tap-off units:

- Tap-off via tap-off point
- Anti-rotation feature prevents incorrect mounting
- IP20 touch protection whilst the unit is being connected to the tap-off point

**Note: Hot plugging:**

In accordance with DIN EN 50110-1 (VDE 0105-1), national regulations must be observed. Country-specific regulations may prohibit plugging when the busbar run is not switched off and energized with electrical power.

**Cable entry**

You can insert the cables optionally from the side or the front. Integrated flange with cable grommets facilitates multi-core cable entry. Aluminium plates are used for single-core cable entry; you have to fit these with cable glands locally. Blanking plates are attached at the side for delivery.

**Safety during operation**

To open the tap-off units, you must switch the breaker off either by actuation of the handle or at the motorised operating mechanism of the breaker. Once this is done, the cable connection area is no longer energized. The part of the contact device in the front of the tapoff unit is "finger-safe".

**Implementing the tap-offs:**

Tap-offs are required for different amperages depending on the size and type of loads involved. These are implemented by means of plug-in tap-off units up to 1250 A.

### 5.9.3 Tap-off units with fuse base up to 630 A:

**Rated currents**

Plug-in tap-off units in four sizes are available for selection:

- For 160 A
- For 250 A
- For 400 A
- For 630 A

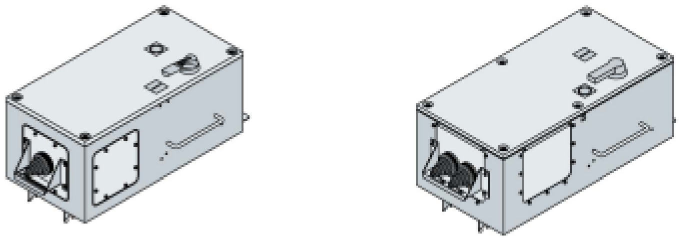


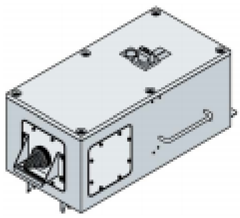
Fig5.9.3a:Tap-off unit with switch disconnector with fuses up to 250 A and 400 A to 630 A

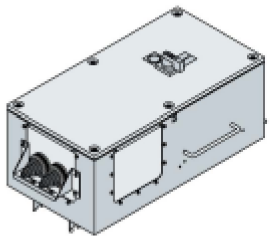
## 5.9.4 Tap-off units with circuit-breaker up to 1250 A:

**Rated current:**

Tap-off units up to 630 A in six sizes are available for selection:

- For 160 A
- For 250 A
- For 400 A
- For 630 A
- For 800 A
- For 1250A





Tap-off unit with circuit breaker up to 400 A        Tap-off unit with circuit breaker up to 630

**The tap-off unit permits rated currents of up to 630 A:**

An equipment compartment is built onto thetap-off unit. Project-specific switchgear (e.g. circuit breakers) is installed in the compartment and connected- both electrically and mechanically - to the tap-off unit.Tap-off units are not designed forconnection whilst the LRC system is live. All other characteristics and technical data can only be provided on request for specific projects.

## 5.9.5 Tap-off units with circuit-breaker:

**Short-circuit rating**:

If you use circuit breakers, the conditional rated short-circuit current of the tap-off units with switching capacity N is 55 kA, with switching capacity H 77 kA, and with switching capacity L 110 kA.

**Installed equipment**:

The circuit breakers have the switching capacity N, H and L. They can come optionally with 3 or 4 poles.

**Cable connection**:

Bolts are used to connect cables with pre-fabricated cable lug. For the small size the maximum compatible cross section per phase is up to 150 mm2, for the medium size up to 240 mm2, and for the large size up to 4 x 240 mm2.

## 5.10 Incoming cable connection unit:

If power needs to be supplied to the busbar trunking system via cables, you should use an LI.-KE incoming cable connection unit.

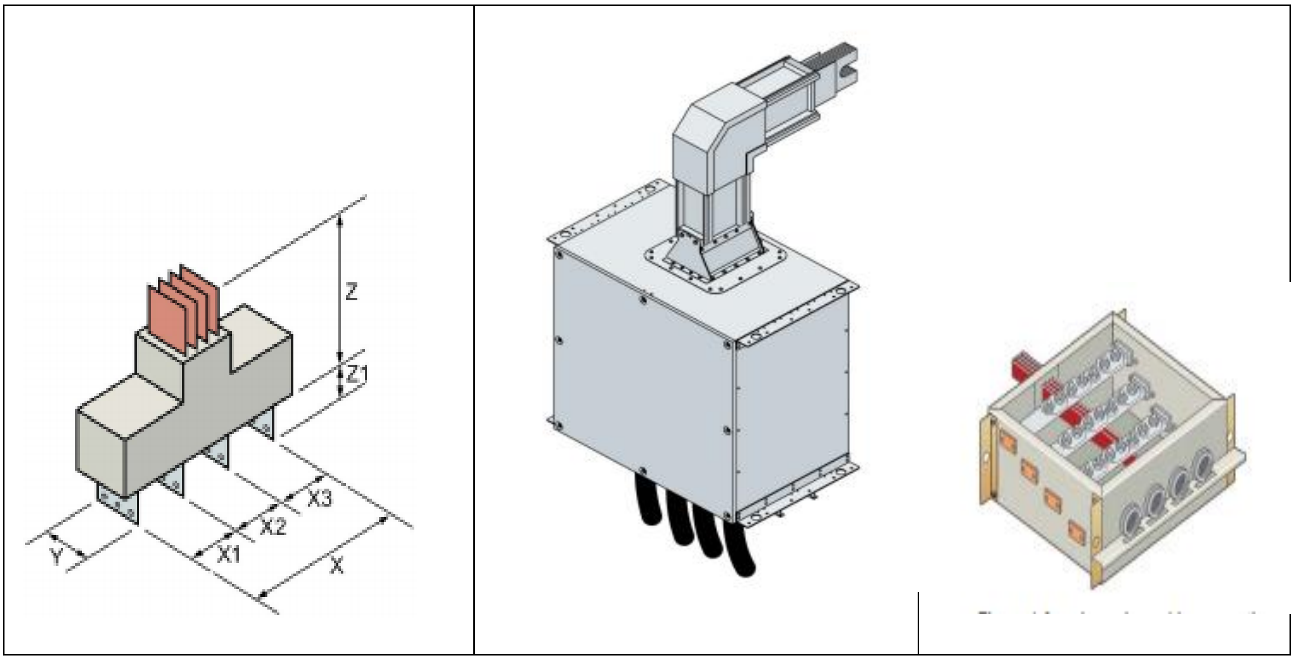



**Fig 5.10: Incoming cable connection unit**

The maximum dimensions are 1000 mm x 950 mm x 655 mm (W x H x D).You can connect single-core or multi-core cables. You can connect cross-sections up to 300 mm2 (bolted connection) directly to the connection bars of the incoming cable connection unit**.**

## 5.11 Connection unit for transformers and distribution boards:

There are four different transformer connection pieces (LD.....-AS.) available for all rated current ranges to connect various transformers to a busbar trunking system:

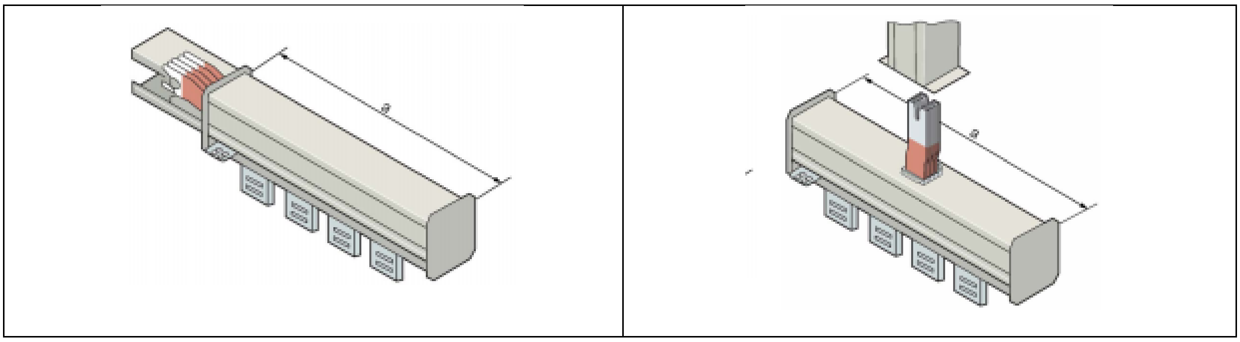


Fig5.11: Connection unit for transformers and distribution boards

We recommend a maximum clearance of 200 mm between the tags on the connection unit. The universal connection unit can also be used to connect distribution boards.

## 5.12Coupling units:

Coupling units are used if devices or sections of the power supply need to be disconnected or connected accordingly. To adapt the busbar trunking system to the actual load, the busbar cross section can be reduced and protected against short circuits and overloads with a coupling unit.

Coupling units can be fitted with switch disconnectors or circuit breakers as appropriate for their application. Coupling units resistant to accidental arcs can be supplied as an option

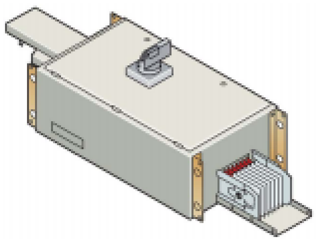


Fig5.12: Coupling units

**Rated currents**

Rated currents adapted to the systems between 1100 and 3000 A can be supplied as appropriate for the application.

**Operator control**

The coupling units can be operated using a handle or even a motor drive.

**Dimensions**

The installation length in the busbar trunking run is 1600 mm.

The dimensions are dependent on the device type and the current size and must be obtained project-specifically.

## 5.13Additional equipment:

**End cap:**

If a busbar run is not to continue to another distribution board, you will need to fit an end cap. You will need to install an end cap with a hook or a bolt at the end of a busbar run depending on the version of the trunking unit.

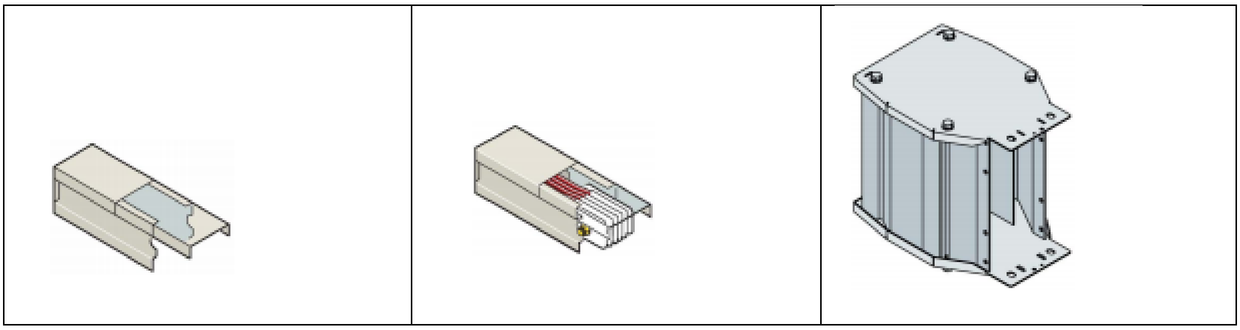


Fig5.13: End cap with hook, End cap with bolt, End Cap

## Suspension bracke:

The LD-B1/B2 suspension bracket is used to mount the busbar trunking system in a horizontal installation.

- B1 for enclosure dimensions 180 mm x 180 mm
- B2 for enclosure dimensions 240 mm x 180 mm

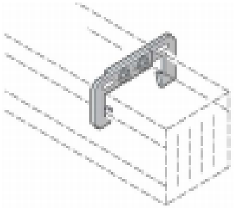
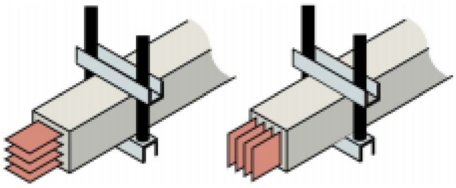
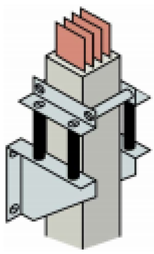
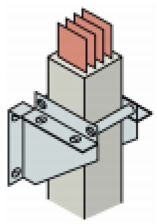
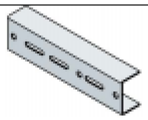
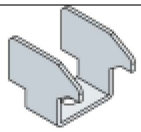
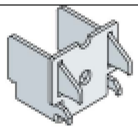
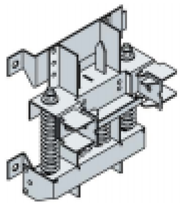
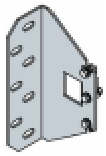


Fig: Suspension bracke

## Fixing bracket:

| Fixing brackets for horizontal installation | Fixing brackets for vertical installation |
|---|---|
|  |   |
|    |   |

## Joint block :

The joint block is used for the trunking units' electrical and mechanical connections. LR trunking units are usually supplied without joint units (junction blocks or monoblocks, as they are also known). Accordingly, you need to make provision to plan and order joint blocks separately as appropriate for the number of trunking unit connections.

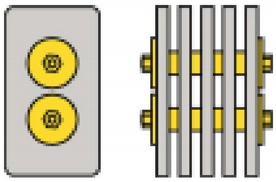
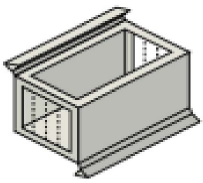


Fig: Joint unit

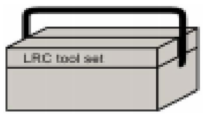
**Accessories for busbar connections with joint blocks:**

Once the electrical link with the joint block has been established, it needs to be cast with epoxy resin. For this purpose, moulding casts, cast resin mix, separators and various tools are provided as accessories.



Casting mould


Cast resin mix




Tool set

# 5.14 CALCULATION:

## 5.14.1 Determining the Voltage drop:

With long trunking runs it may be necessary to calculate the Voltage drop:

$\therefore \Delta V = K.\sqrt{3}.Ib.l.(R1.\cos\theta+X1.\sin\theta).10\text{-}3$

Where, $\Delta V$ = Voltage drop (V)

Ib = Rated current (A)

l = Total length of the system

K = Total distribution factor

R1 = ohmic resistance (mΩ/m) with busbar final heating

X1 = Inducative resistance (mΩ/m) ” ” ” ”

Cosθ = power factor

The load distribution factor K for calculating the voltage drop at the ed of the busbar trunking system is defined ad follows.

* K = 1, If the load is connected at the end of the busbar trunkin system (power transmission).
* K = (n+1)/(2×n), if the load is distributed across n taps.

To calculate the voltage drop in distance (d) between the start of the tap and the start of the busbar system. proced as follows:

K = (2×n+1 - n×d/L)/(2×n)

**Voltage drope diagram:**

Taking into account the final heating resistances

With a load distribution factor

K = 1 for hog current 4000 – 6300 A

K = 0.5 ” low and medium current 8000-3200A

at rated current load.

**Table5.14.1 Thermal characteristics: Standard:**

| Ambient temperature 24-hour aveg. | 200C | 250C | 300C | 350C | 400C | 450C | 500C |
|---|---|---|---|---|---|---|---|
| Correction factor | 1.075 | 1.05 | 1.025 | 1 | 0.95 | 0.9 | 0.85 |

## 5.14.2 Voltage Drop (outgoing):

It a BTS is particularly long, the value of the voltage drop must be verified. For there phase system with a power factor (cosθ) not lower than 0.8, the voltage drop can be calculated by using the formula:

$$\Delta v = \frac{a \times \sqrt{3} \times I_b \times L \times (r_t \cos\theta + x \sin\theta)}{1000} [v]$$

Where, a is the current distribution factor, which depends on the circuit supply and the arrangement of the electric loads along the BTS, Table:

Table5.14.2:Current distribution factor:

| Type of Supply | Arrangement of Loads | Current distribution factor |
|---|---|---|
| From one end only | load concentrated at the end | 1 |
| | Evenly distributed load | 0.5 |
| From both ends | Evenly distributed load | 0.25 |
| Central | load concentrated at the end | 0.25 |
| | Evenly distributed load | 0.125 |

$I_b$ = is the load current (A);

L = is the BTS length (m);

$r_t$ = is the resistance per unit of length of BTS, measured under thermal steady state condition (mΩ/m)

x = is the phase reactance per unit of the length of BTS (mΩ/m)

cosθ = is average power factor of the loads.

Percentage voltage drop is obtained from:

$$\Delta v\% = \frac{\nabla u}{v_r} \times 100$$

Where $v_r$ is the rated voltage.

### 5.14.3 Calculation of voltage drop for unevenly distributed load:

If the load cannot be considered to be evenly distributed, the voltage drop can be calculated more aceueately by using formula:

For the distribution of the three phase shown is the fig, the Voltage drop can be calculated by the following formula if the BTS has a constant cross section (as usual):

$$\Delta u = \frac{\sqrt{3} r_t \sum I_i L_i \cos\theta_i + x \sum I_i L_i \sin\theta_i}{1000} [v]$$

Where, $r_t$ = is the phase resistance per unit of length of BTS, measured under thermal steady-state conditions (mΩ/m)

x = is the phase reactance per unit of the length of BTS (mΩ/m)

$\cos\theta_i$ = is average power factor of the i th load.

$I_i$ = is the i-th load current (A)

$L_i$ = is the distance of the i-th load from the beginning of the BTS (m).

**Table 5.14.4 Rated Current and short Circuit current of standard transformers:**

| Rated Voltage | 400/230v, 50 Hz | | |
|---|---|---|---|
| Rated short circuit Voltage value | | 4% | 6% |
| Rated Power ( KVA) | Rayed current $I_r$ (A) | Initial symetrical short circuit current $I_k$ (A) | Initial symetical short circuit current $I_k$ (A) |
| 50 | 72 | 1933 | 1306 |
| 100 | 144 | 3871 | 2612 |
| 150 | 230 | 6209 | 4192 |
| 200 | 288 | 7749 | 5239 |
| 250 | 360 | 9716 | 6552 |
| 315 | 455 | 12247 | 8259 |
| 400 | 578 | 15506 | 10492 |
| 500 | 722 | 19438 | 12020 |
| 630 | 910 | 24503 | 16193 |
| 800 | 1154 | - | 20992 |
| 1000 | 1444 | - | 26224 |
| 1250 | 1805 | - | 32791 |
| 1600 | 2310 | - | 39818 |
| 2000 | 2887 | - | 52511 |
| 2500 | 3608 | - | 65547 |
| 3150 | 4550 | - | 82656 |

N.B. Ukr = 4% (100-630 KVA)

Ukr = 6%  630 Avobe

**Formula:**

Transformer Rated current: $I_N$ (A) = K × $S_{NT}$

Transformer short circuit AC current: $I_K = \frac{I_N}{I_{UK} \times 100}(A)$

400V : K = 1.45

690V : K = 0.84

∴ 1 KVA =? current

K = $\frac{1 \times 1000}{1.732 \times 400}$

∴ 3150 KVA = 3150 × 1.45

= 4567 A

## Table 5.14.5 Technical data for LD System:

| | | | |
|---|---|---|---|
| 1. | Rated operating voltage $U_e$ | AC | 1000V |
| 2. | Standard degree of protection | | IP4.IP54 |
| 3. | Rated current $I_{nA}$ | A | 1100-5000 |
| 4. | Rated short time withstand current $I_{cw}$ (1s) | KA | 55-116KA |
| 5. | Conditional circuit rating $I_{ce}$ for TU 800A and above | | 100kA |
| 6. | Dimensions width×hight for copper | mm x mm | (240×180) |
| 7. | Fire load per tap-off point | kwh/m | 7.8-10.8 |
| 8. | Voltage drop (ΔV) | mv/m/A | 0.03 |
| 9. | Magnetic fields | µT | 14.4 |
| 10. | Max. fixing distance | m | 2-3 |
| 11. | Top off unit can be plugged into tap-off points at 3m intervals<br>315A-630A<br>800A-1250A | units | <br><br>3<br>2 |

N.B: 1. PE = clean Earth

2. Cosθ 0.9, Voltage drop for 50HZ, 3-∅

3. Magnetic field values measured with symmetrical load 0.5m away the BBT

4. Tap off units can only be connected between two busbar trunkings with a bolt-on joint block (tixed tap-off unit)

5. IP34 = Ventilated (with busbars installed horizontally and edgewise)

IP54 = enclosed

## 5.15 Planning example:

1. Power distribution board
2. Busbar trunking system
3. Tap-off pont.

| | |
|---|---|
| No. off floor | :15 ( 8 residential units) |
| Effective installed loads Per residential Unit | : 26 KW |
| Rated operating voltage $U_e$ | :400V |
| Power factor cosθ | : 0.9 |
| Load factor ∝ | : 0.6 |
| utilization fator β | : 0.5 |
| Supply transformers | : 1×1250 KVA, $U_k$ = 6% |
| Degree of protection | :1P30/1P54 |
| Line system configuration | :TN-S |

N.B: Torque for single bolt terminal = 80N

### 5.15.1 Determining the rated current per floor:

$$I_{BS} = \frac{Pinst.\alpha}{\sqrt{3}.U_e.\cos\theta}$$

$$= \frac{26 \times 0.6}{1.732 \times 400 \times 0.9}.10^3$$

= 25 A

∴ 8 residential × 25A = 200A

$I_{BS}$ = Rated current per storey (A)

$U_e$ = Rated operating voltage (V)

cosθ = power factor

Pinst = Instaled power rating (Kw)

α = Rated diversity factor

### 5.15.2 Determining the rated current of the trunking run:

IN = N. IBS.β [N = number of floor)

=15×200×0.5

= 1500 A

∴ $I_N < I_e$

The rated diversity factor in accordance with IEC/EN 61439-1 applies for the total number of loads and the demand factor for the type of load. In the absence of precise figures for the demand factor, reliable empirical values can be obtained from local utility compares, However, these vary from region to region. Average values are listed in the table below:

### 5.15.2 Table Utilization factor:

| Type of load | β<br>Utilization factor |
|---|---|
| Residential accommodation with electric ovens and water heaters | 0.1-0.2 |
| off-peas storage heating | 0.8-1 |
| Lighting in office blocks and commercial building | 0.7-09 |
| Lifts and general facilities | 0.6-0.8 |
| Small offices | 0.5-0.7 |
| Conference Rooms | 0.6-0.8 |
| Large offices | 0.4-0.8 |

In accordance with the system Selection criteria based technical data and areas of application. The LI high voltage system is used in the planning for the example power distribution in multi-story buildings with primarily vertical trunking Layout.

Combining the assessment criteria and calculation results an LI-A busbar system being selected with 5 conductor and full neutral conductor cross section, a current carrying capacity of 1600 A and a short circuit rating $I_{cw}$ (t=1s) = 65 KA

Selected busbar system LI-A.1600

Top-off Units with 3-pole 250A fuse

(designed for use with NH1 fuse link) are used to supply power to the distribution boards on each floor.

Selected tap-off units: LI-T-0250-5H55-FSF-IEC-3-RD-G-BD-00

### 5.15.3 Load current calculation for three-phase system:

Load current $I_b$ for a three phase system is calculated by the following formula:

$$I_b = \frac{P_t \times b}{\sqrt{3} \times V_r \times \cos\theta} \text{ [A]}$$

Where, Pt = he Sum of the active power of all the installed load [W]

b = The supply factor which is

b = 1 if the BTS is supplied from one side only.

b = 0.5 if the BTS is supplied from the centre or from both ends simultaneously;

$V_r$ = The overrating Voltage (v)

cosθ = The average power factor of the load.

### 5.15.4 Choice of BTS current carrying capacity:

The following formula : $I_b < I_{zo} \times K_t = I_z$

Where,

$I_{zo}$ = The current that the BTS can carry for an indefinite time at the reference temperature ($40_0$C)

$I_b$ = The load current

$K_t$ = is the correction factor for ambient temperature values other than Table 1.

$I_z$ = The continuous current carrying capacity of BBT.

| aperature oc | 15 | 20 | 25 | 35 | 40 | 45 | 50 |
|---|---|---|---|---|---|---|---|
| Kt | 1.2 | 1.17 | 1.08 | 1.05 | 1 | 0.95 | 0.85 |

5.15.4 The following tables show typical parameters of the BTS present on the market:

| Generic Type | Number of conductors | Izo (A) | rph (mΩ/m) | Xph (mΩ/m) | Vr (V) |
|---|---|---|---|---|---|
| 5000A Cu | 4 | 5000 | 0.008 | 0.005 | 1000 |
| 5000A Cu | 5 | 5000 | 0.008 | 0.023 | 1000 |

* phase resistance at rph

* Izo current carrying capacity

### 5.15.5Technical data of BTS (CU):

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Rated Current (A) | 1000 | 1250 | 1600 | 2000 | 2500 | 3200 | 4000 | 5000 |
| Casting Dimension lateral | 85 | 85 | 130 | 160 | 200 | 266 | 326 | 406 |
| Height of the bar | 50 | 75 | 120 | 150 | 190 | 120 | 150 | 190 |
| Verall dismension (mm) | 140× 85 | 140× 85 | 140× 130 | 140× 160 | 140× 200 | 140× 266 | 140× 326 | 140× 406 |
| ** and Nutral cross section | 300 | 450 | 720 | 900 | 1140 | 1440 | 1800 | 2280 |
| **cross section (mmFe) | 1071 | 1071 | 1206 | 1416 | 1966 | 1794 | 2100 | 2280 |
| ** between Pt/phase section | 45% | 30% | 21% | 20% | 17% | 16% | 15% | 13% |
| **/Insulation Voltage | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| ** resistance $20^{0}$C (mΩ/m) | 0.06 | 0.04 | 0.03 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 |
| ** resistance @ 50% load c (mΩ/m) | 0.06 | 0.04 | 0.03 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 |
| ** resistance @ thermal conditions (mΩ/m) | 0.07 | 0.05 | 0.03 | 0.02 | 0.02 | 0.02 | 0.01 | 0.00 |
| ** reatance (mΩ/m) | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| ** @ $20^{0}$C and 50% load | 0.06 | 0.04 | 0.03 | 0.02 | 0.02 | 0.01 | 0.01 | 0.01 |
| **Sistance of protective conductor (mΩ/m) | 0.12 | 0.12 | 0.11 | 0.09 | 0.08 | 0.07 | 0.06 | 0.06 |
| ** Short time current ** Phase nutral fault (1s) KA | 24 | 30 | 33 | 36 | 48 | 60 | 60 | 72 |
| ** Short-time current ** Phase-PE fault (1s) KA | 24 | 30 | 33 | 36 | 48 | 60 | 60 | 72 |
| ** Peak current for ** Phase fault (KA) | 88 | 110 | 121 | 132 | 176 | 220 | 220 | 264 |
| ** Peak Peak current for Phase-PE fault (KA) | 53 | 66 | 73 | 79 | 106 | 132 | 132 | 158 |
| **/Insulation Voltage | 53 | 66 | 73 | 79 | 106 | 132 | 132 | 158 |

Physical data:

| | | | |
|---|---|---|---|
| 5000 A | 3000 mm-or-3 m | (406×140) mm | straight line |
| 5000 A | 200 mm-or-2 m | (406×140) mm | straight line |
| 5000 A | 400 mm | (406×140) mm | Left dihedral elbow |
| 5000 A | 400 mm | (406×140) mm | Right dihedral elbow |
| 5000 A | 800 mm | (406×140) mm | left or Right flat elbow. |

## 5.16BTS Testing:

1. Insulation/Megar test by applying 2.5KV for 1 minute
2. Temperature rise test
3. High voltage test-3.5 KV
4. Voltage withstand test.

## 5.17 Voltage drop calculation for outgoing cable:

For an electrical conductor with impedancez, the voltage drop is calculated by the following formula:

$\Delta u = KZI_b = KI_P \frac{L}{n}$ (rcosθ+xsinθ) (v)

Where,

K = is a coefficient equal to:

- 2 for Single Phase and two phase system

$\sqrt{3}$ for three-phase systems;

$I_b$ = is the load current; if no information are available, the cable carrying capacity $I_s$ shall be considered;

L = is the I ength of the conductor km)

n = is the number of conductors in parallel per phase;

r = (Ω/km) is the resistance of the single cable per kilometer;

x = (Ω/km) is the reactance of the single cable per kilometer;

cosθ = is the power factor of the load, sinθ = $\sqrt{1 - cos^2\theta}$

$\Delta V\% = \frac{\nabla u}{v_r} \times 100$

Normally, the percentage value of in  relation to the rated value $v_r$ is calculated by

NB: Resistance and reactance values per unit of length are set out on the following table by cross sectional area and cable formate, for 50HZ, in case of 60HZ, the reactance value shall be multiplied by 1.2.

### 5.17.1 Resistance and reactance per unit of length of copper cables:

| Area (S) sqmm | Single Core Cable r(ohm/km) | Single core Cable x(ohm/km) | Two/three core Cable r(ohm/km) | Two/three core cable x(ohm/km) |
|---|---|---|---|---|
| 1.5 sqmm | 14.8 | 0.168 | 15.1 | 0.118 |
| 2.5 sqmm | 8.9 | 0.156 | 9.08 | 0.109 |
| 4 sqmm | 5.57 | 0.143 | 5.68 | 0.101 |
| 6 sqmm | 3.71 | 0.135 | 3.78 | 0.0955 |
| 10 sqmm | 2.24 | 0.119 | 2.27 | 0.0861 |
| 16 sqmm | 1.41 | 0.112 | 1.43 | 0.0817 |
| 25 sqmm | 0.889 | 0.106 | 0.907 | 0.0813 |
| 35 sqmm | 0.6411 | 0.101 | 0.654 | 0.0783 |
| 50 sqmm | 0.473 | 0.101 | 0.483 | 0.0779 |
| 70 sqmm | 0.328 | 0.0965 | 0.334 | 0.0751 |
| 95 sqmm | 0.236 | 0.0975 | 0.241 | 0.0762 |
| 120 sqmm | 0.188 | 0.0939 | 0.191 | 0.074 |
| 150 sqmm | 0.153 | 0.0928 | 0.157 | 0.0745 |
| 185 sqmm | 0.123 | 0.0908 | 0.125 | 0.0742 |
| 240 sqmm | 0.0943 | 0.0902 | 0.0966 | 0.0752 |
| 300 sqmm | 0.0761 | 0.895 | 0.078 | 0.075 |

### 5.17.2 Current carrying capacity of sqmm cable:

| mm | (A) PVC | (A)XLPE/ EPR | PVC (A) | XLPE/EPR (A) |
|---|---|---|---|---|
| 1.5 sqmm | 22 A | 26 A | - | - |
| 2.5 sqmm | 30 A | 36 A | - | - |
| 4 sqmm | 39 A | 49 A | - | - |

| | | | | |
|---|---|---|---|---|
| 6 sqmm | 50 A | 63 A | - | - |
| 10 sqmm | 69 A | 86 A | - | - |
| 16 sqmm | 94 A | 115 A | - | - |
| 25 sqmm | 125 A | 149 A | 131 A | 161 A |
| 35 sqmm | 160 A | 185 A | 162 A | 200 A |
| 50 sqmm | 195 A | 225 A | 196 A | 242 A |
| 70 sqmm | 245 A | 289 A | 251 A | 310 A |
| 95 sqmm | 300 A | 352 A | 304A | 377 A |
| 120 sqmm | 350 A | 410 A | 352A | 437A |
| 150 sqmm | 405 A | 43 A | 406 A | 504 A |
| 185 sqmm | 460A | 542 | 463 A | 575A |
| 240 sqmm | 555 A | 641 | 546 A | 679 A |
| 300 sqmm | 640 A | 741 | 629 A | 783 A |
| 400 sqmm | 770 A | - | 754 A | 940 A |
| 500 sqmm | 900 A | - | 868 A | 1083 A |
| 630 sqmm | 1030 A | - | 1005 A | 1254 A |
| 800 sqmm | 1165 A | - | - | - |
| 1000 sqmm | 1310 A | - | - | - |

### 5.17.3Specific Voltage drop at cosθ = 0.9 for copper cables:

**(cosθ = 0.9. 0.85)**

| Area | Single-core cable | | Two or Three core cable | |
|---|---|---|---|---|
| S(sqmm) | Single Phase | three phase | Single phase | Three phase |
| 1.5 sqmm | 26.79 | 23.20 | 27.28 | 23.63 |
| 2.5 sqmm | 16.17 | 14.01 | 16.44 | 14.24 |
| 4 sqmm | 10.15 | 8.79 | 10.31 | 8.93 |
| 6 sqmm | 6.80 | 5.89 | 6.89 | 5.96 |
| 10 sqmm | 4.14 | 3.58 | 4.16 | 3.60 |
| 16 sqmm | 2.64 | 2.28 | 2.65 | 2.29 |
| 25 sqmm | 1.69 | 1.47 | 1.70 | 1.48 |
| 35 sqmm | 1.24 | 1.08 | 1.25 | 1.08 |
| 50 sqmm | 0.94 | 0.81 | 0.94 | 0.81 |

| | | | | |
|---|---|---|---|---|
| 70 sqmm | 0.67 | 0.58 | 0.67 | 0.58 |
| 95 sqmm | 0.51 | 0.44 | 0.50 | 0.43 |
| 120 sqmm | 0.42 | 0.36 | 0.41 | 0.35 |
| 150 sqmm | 0.36 | 0.31 | 0.35 | 0.30 |
| 185 sqmm | 0.30 | 0.26 | 0.29 | 0.25 |
| 240 sqmm | 0.25 | 0.22 | 0.24 | 0.21 |
| 300 sqmm | 0.22 | 0.19 | 0.21 | 0.18 |

**Example 1:**

To calculated a voltage drop on a three-phase cable with the following specification:

* Rated voltage: 400V

* Cable length: 25 m

* Cable formation: Single-core copper cable, 3×50 $mm^2$

* Load current: 100 A

* Power factor: cosθ = 0.9

From the table, 50 $mm^2$ = 0.81

$\therefore \Delta U = \Delta U_x . I_b . L$

$= 0.81 \times 100 \times 0.025$

$= 2.03$ V

$I_b = 100$ A

$\Delta U_x = 0.81$

$L = 25 \text{ m} = \frac{25}{1000} \text{ km}$

$= 0.025$ km

Which corresponds to this percentage Value:

$\Delta u\% = \frac{\nabla u}{V_r} \times 100$

$= \frac{2.03}{400} \times 100$

$= 0.51$ %

**Example 2**:

To calculate a Voltage drop on a three-phase cable with the following specification:

- Rated Voltage: 690 V
- Cable length: 50 m
- Cable formation: multi-core copper cable 2×(3×10) $mm^2$
- load current: 50A
- power factor: cosθ = 0.85

From the table: 10$mm^2$ = 3.60

$\therefore \Delta U = \Delta U_x \times I_b \times \frac{L}{2}$

$= 3.60 \times 50 \times \frac{0.05}{2}$

= 4.5 V

$I_b$ = 50 A

$\Delta U_x$ = 3.60

I = 50 m

= 0.05

for

multicore $\frac{L}{2} = \frac{0.05}{2}$

Which corresponds to this percentage value:

$\Delta u\% = \frac{\nabla u}{V_r} \times 100$

$= \frac{4.5}{690} \times 100$

= 0.65%

**Example 3: For long cable: or cable Selection:**

Supply of a three phase load with $P_u$ = 35 kw ($U_r$ = 400v, $f_r$ =80 Hz, cosθ = 0.9) with a 140 m cable insulated on a perforated tray, consisting of a multi-core copper cable with EPR insulation.

maximum permitted voltage drop 2%, $\mathbf{\Delta U_{m\ max}} = \frac{\nabla V\% \times V_r}{100 \times I_b \times L}$

Load current $I_b = \frac{Pu}{\sqrt{3}V\cos\theta} = \frac{35000}{\sqrt{3} \times 40 \times 0.9}$ = 56 A

From the table: 10 $mm^2$ = 3.60 $I_b$ = 56 A

$\therefore \Delta U = \Delta U_x \times I_b \times L = 3.60 \times 56 \times 0.14$ $\Delta U_x$ = 3.60

= 28.2 V L = 140 m

= 0.14 km

Which corresponds to this percentage value:

$$\Delta V\% = \frac{\nabla V}{V_r} \times 100 = \frac{28.2}{400} \times 100 = 7.05\%$$

This value is too high, Another Formula

$$\Delta U_{m\ max} = \frac{\nabla V\% \times V_r}{100 \times I_b \times L} = \frac{2\% \times 400}{100 \times 56 \times 0.14} = 1.02\ (V/A.Km)$$

From table: Cross Section of 50 $mm^2$ can be chosen.

For this cross Section $\Delta U_x$ = < 1.02 V/(A.km)

By using this value it results:

$\Delta U = \Delta U_x \times I_b \times L$

$= 0.81 \times 56 \times 0.14$

= 6.35 V

This corresponds to a percentage Value of:

$$\Delta U\% = \frac{\nabla u}{V_r} \times 100$$

$$= \frac{6.35}{400} \times 100$$

= 1.6%

# Chapter 6

# DIU SUB-STATION

## 6.1 HT Side Equipment Selection & Calculation

### 6.1.1 Transformer Information

Transformer Rating =3150 KVA

Insulation Class= 12 KV

Short-circuit voltage Uk(%) = 6

No-load current $I_0$(%) = 0.4

No-load loss $P_o$= 3800 W

legrand®

| $S_n$ [kVA] | Series (Reg548) | Item | Uk [%] | Primary voltage [kV] | Secondary voltage [V] | Po [W] | Pk [W] a 120 °C | Io [%] | LwA-Acoustic power [dB (A)] | Length (A) [mm] | Width (B) [mm] | Height (C) [mm] | Ic - wheel centre line [mm] | R - wheel diameter (0) [mm] | Weight [kg] | Enclosure type* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3150 | AoAk | FP2AAACBA | 6 | 10 | 400 | 3800 | 22000 | 0,4 | 74 | 2150 | 1400 | 2450 | 1070 | 200 | 7000 | 8 |

### 6.1.2 Primary Current of Transformer:

We Know, $P = \sqrt{3}VI$

$$\therefore I = \frac{P}{\sqrt{3}V}$$

$$= \frac{3150 \times 1000}{1.732 \times 1100}$$

$$= \frac{3150000}{19052}$$

**= 165 A**

P = 3150 KVA = 3150 × 1000

= 3150000 VA

V = 11 KV = 11 × 1000 =11000 V

$\sqrt{3} = 1.732$

### 6.1.3 Short CKT Primary Current of Transformer:

Short circuit current,

$$I_{SC} = \frac{3150}{1.734 \times 11 \times \%Z}$$

Transformer Rating =3150 KVA

Transformer Impedance=6%

$$= \frac{3150}{1.732 \times 11 \times 0.06}$$

$$= \mathbf{2755.616\ A}$$

### 6.1.4 HT Cable Calculation and Selection Indoor to Outdoor Sub-Station

**<u>According to Thoum Rule</u>**

Primary Current of Transformer= 165A

Safety factor 125% of full load current

∴ 165 of 125%

= 165 × 1.25

**= 206 A**

**# 1mm$^2$= 1.2A/1.6A (for copper)**

$$\therefore Rm = \frac{206}{1.2}$$

**=172mm$^2$**

So, we have to select next higher cable

Next higher cable size is **185 $mm^2$**

### 6.1.5 Cable Short CKT Current

we know,

$I_{SC} = \frac{S \times K}{\sqrt{t}}$

$= 185 \times 0.143$

=**26.455 Ka**(**Short CRK Current of 185mm2 cable)**

S = Nominal Cross sectional area of the conductor in mm of XLPE cable.

K = Conductor rang constant

Copper = 0.143, Aluminum = 0.094

t = Fault clearing time in Second (1 sec)

..................................................................................................................................................................

### 6.1.6HT Cable Calculation and Source to Outdoor Sub-Station

System Current=165×2=**330A**

Safety factor 125% of full load current

∴ 330 of 125%

= 330 × 1.25

**= 413 A**

**[1mm$^2$= 1.2A-1.6A (for copper)]**

$\therefore$ Rm $= \frac{413A}{1.6} = \mathbf{258\ mm^2}_{\mathbf{So, we have to select next higher cable}}$

**There is no cable in this rating. That's why next higher rating cable has to be select**

$\therefore \mathbf{300\ mm^2}$

## 6.2 Underground Cable Calculation and Selection for Tx

Underground Cable Calculation and Selection with the following specification-

- system voltage **11 V three phase**

- Cable length=**80 m** (**Sub-station1 to Sub-station2**)
- Primary Current $\mathbf{T_x}$=**165 A**
- Ground Temperature **$25^0$ C**
- Depth of laying **105 cm**
- 1 Run Three Core Cable in Horizontal Formation in Touching
- permissible voltage dropis **5%**
- power factor is **0.8**

**Correction Factors=** $\boldsymbol{K2 \times K3 \times K4}$

**=1×.99×.69**

**=.683**

Selection of cable – Case #1

*Let's select **3 core 150** $\boldsymbol{mm^2}$ cables for single run.*

- Current capacity of **150**$\boldsymbol{mm^2}$ cable is: **436 Amp**,

  Resistance = 0.1240 Ω/Km and

  Reactance = 0.304 mH/Km

- Total de-rating current of $\mathbf{150}\boldsymbol{mm^2}$cable = 436 × 0.683 = 297.788 Amp.

- $\boldsymbol{Voltage\ Drop\ of\ Cable} = \frac{(1.732 \times Current \times (Rcos\emptyset + jsin\emptyset) \times Cable\ length \times 100)}{(Line\ voltage \times No\ of\ run \times 1000)}$

$$= \frac{(1.732 \times 165 \times (0.1240 \times .309 + .304 \times .6) \times 80 \times 100)}{(11 \times 1 \times 1000)}$$

$$= \frac{285.78 \times 0.220716 \times 80 \times 100}{11 \times 1 \times 1000}$$

$= \mathbf{0.04587\%}$

**Table 6.2 Correction factor:**

## CORRECTION FACTORS

### (1) Cables laid direct in Ground:

(a) Correction factors for variation in Ground Temperature : K1

**Table : A**

| Ground Temperature (°C) | 15 | 20 | 25 | 30 | 35 | 40 | 45 |
|---|---|---|---|---|---|---|---|
| Rating Factor | 1.04 | 1.00 | 0.96 | 0.93 | 0.89 | 0.85 | 0.81 |

(b) Correction factors for variation in Thermal Resistivity of Soil : K2

**Table : B**

| Thermal Resistivity of Soil (°C.cm/W) | 100 | 120 | 150 | 200 | 250 | 300 |
|---|---|---|---|---|---|---|
| Rating Factor | 1.00 | 0.94 | 0.84 | 0.75 | 0.68 | 0.62 |

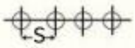
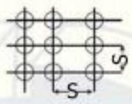
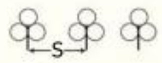
(c) Correction factors for various depth of Laying: K3

**Table : C**

| Depth of Laying (cm) | Upto 6 / 10 Kv | 8.7 / 15 kV & above |
|---|---|---|
| 90 | 1.00 | - |
| 105 | 0.99 | 1.00 |
| 120 | 0.98 | 0.99 |
| 150 | 0.96 | 0.97 |
| 180 and above | 0.95 | 0.96 |

(d) Group Rating Factors : K4

**Table : D**

| Naumber of Cables/ circuits. in group | Multicore cables in horizontal formation   | | | Multicore cables in trefoil touching formation   | | | Single core cables in trefoil touching formation   (Three Cables per circuit | | |
|---|---|---|---|---|---|---|---|---|---|
| | Touching | s=15 cm | s = 30 cm | Touching | s = 15 cm | s = 30 cm | Touching | s = 15 cm | s = 30 cm |
| 2 | 0.79 | 0.82 | 0.86 | - | - | - | 0.78 | 0.82 | 0.85 |
| 3 | 0.69 | 0.72 | 0.76 | - | - | - | 0.68 | 0.71 | 0.76 |
| 4 | 0.62 | 0.66 | 0.72 | 0.60 | 0.64 | 0.69 | 0.61 | 0.65 | 0.71 |
| 6 | 0.54 | 0.59 | 0.65 | 0.51 | 0.55 | 0.60 | 0.53 | 0.57 | 0.64 |

### (2) Cables laid on racks in air

(a) Rating factors for variation in ambient air temperature

**Table : E**

| Ambient Air tempereatre (°C) | 20 | 25 | 30 | 35 | 40 | 45 | 50 |
|---|---|---|---|---|---|---|---|
| Rating Factor | 1.07 | 1.04 | 1.00 | 0.96 | 0.91 | 0.86 | 0.83 |

(b) Group Rating factors

**Table : F**

| Number of Cables/ circuits. in group | Multicore cables (touching) 30 cm — Number of racks | | | | Multicore cables in (Spacing between cables equal diameter of cable) 30 cm — Number of racks | | | | Single core cables in trefoil touching formation (Spacing between circuits equal to twice the diameter of cable) 30 cm — Number of racks | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 6 | 1 | 2 | 3 | 6 | 1 | 2 | 3 | 6 |
| 1 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 2 | 0.84 | 0.80 | 0.78 | 0.76 | 0.98 | 0.95 | 0.94 | 0.93 | 0.98 | 0.95 | 0.94 | 0.93 |
| 3 | 0.80 | 0.76 | 0.74 | 0.72 | 0.96 | 0.93 | 0.92 | 0.90 | 0.96 | 0.93 | 0.92 | 0.90 |
| 6 | 0.76 | 0.71 | 0.70 | 0.68 | 0.93 | 0.90 | 0.89 | 0.87 | - | - | - | - |

THREE CORE GALVANISED STEEL TAPE ARMOURED CABLE : IEC-60502-2 (2xSEYBY) > 3 core, XLPE Insulated, Galv. Steel tape armoured Cable, 6/10 (12) & 8.7/15 (17.5) kV.

**TYPE : 2xSEYBY**
Specification : IEC 60502-2
Uo/U (Um) = 6 / 10 (12) kV.;
Permissible Service Voltage 6.35 / 11 kV.


1. CONDUCTOR – COPPER
2. COND. SEMI – CONDUCTING SCREEN
3. XLPE INSULATION
4. INS. SEMI – CONDUCTING SCREEN
5. METALLIC SCREEN
6. FILLER
7. INNER COVERING
8. STEEL TAPE ARMOUR
9. OVER SHEATH – PVC

**Table : 39**

| Nominal Conductor Area | Nominal Insulation Thickness | Nominal Thickness of steel tape armour | Nominal Over sheath Thickness | Approx O/Dia. of cable | Approx Weight of Cable | Max. DC resistance of conductor at 20°C | Capacitance of Cable | Inductance of Cable | Current Rating in Ground at 20°C | Current Rating in Air at 30°C |
|---|---|---|---|---|---|---|---|---|---|---|
| No. x mm² | mm | mm | mm | mm | Kg/Km | Ohm/Km | Micro F/Km | mH/Km | Amp | Amp |
| 3 x 25 | 3.4 | 2 x 0.5 | 2.3 | 48.0 | 3340 | 0.7270 | 0.21 | 0.410 | 145 | 147 |
| 3 x 35 | 3.4 | 2 x 0.5 | 2.3 | 51.0 | 3860 | 0.5240 | 0.23 | 0.391 | 182 | 183 |
| 3 x 50 | 3.4 | 2 x 0.5 | 2.4 | 54.0 | 4450 | 0.3870 | 0.26 | 0.364 | 218 | 218 |
| 3 x 70 | 3.4 | 2 x 0.5 | 2.6 | 57.5 | 5440 | 0.2680 | 0.29 | 0.344 | 269 | 270 |
| 3 x 95 | 3.4 | 2 x 0.5 | 2.7 | 61.5 | 6560 | 0.1930 | 0.33 | 0.327 | 324 | 333 |
| 3 x 120 | 3.4 | 2 x 0.5 | 2.8 | 65.5 | 7450 | 0.1530 | 0.35 | 0.314 | 362 | 378 |
| 3 x 150 | 3.4 | 2 x 0.5 | 2.9 | 69.0 | 8590 | 0.1240 | 0.38 | 0.304 | 411 | 436 |
| 3 x 185 | 3.4 | 2 x 0.5 | 3.0 | 73.0 | 10070 | 0.0991 | 0.42 | 0.295 | 455 | 503 |
| 3 x 240 | 3.4 | 2 x 0.5 | 3.2 | 78.5 | 12210 | 0.0754 | 0.46 | 0.284 | 527 | 580 |
| 3 x 300 | 3.4 | 2 x 0.5 | 3.3 | 84.0 | 14570 | 0.0601 | 0.50 | 0.275 | 567 | 611 |

**TYPE : 2xSEYBY**
Specification : IEC 60502-2
Uo/U (Um) = 8.7 / 15 (17.5) kV.
Permissible Service Voltage : 9.2 / 16.3 kV.

**6.2.bTable of Voltage Drop**

**VOLTAGE DROP PER CORE / PER AMP. / PER KM:**

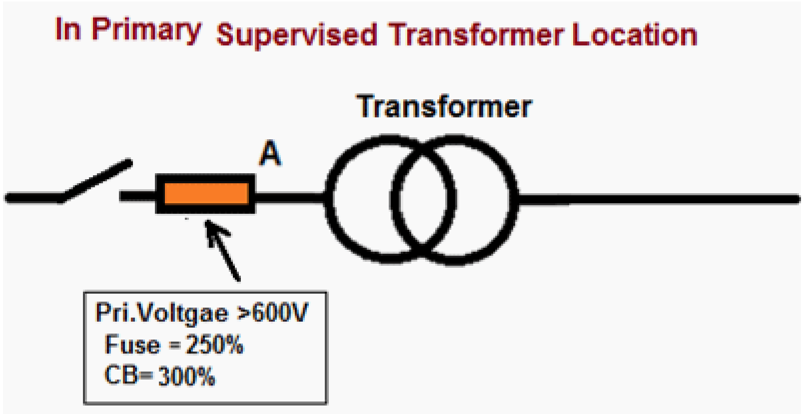
| Conductor Area | 3.6/6(7.2) kV | | 6/10(12)kV | | 8.7/15(17.5)kV | | 12/20(24) kV | | 18/30(36) kV | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Un-Armoured | Armoured | Un-Armoured | Armoured | Un-Armoured | Armoured | Un-Armoured | Armoured | Un-Armoured | Armoured |
| No.xSqmm | V/core/A | V/core/A | V/core/A | V/core/A | V/core/A | V/core/A | V/core/A | V/core/A | V/core/A | V/core/A |
| 3x25 | 0.946 | 0.946 | 0.947 | 0.947 | 0.948 | 0.948 | - | - | - | - |
| 3x35 | 0.686 | 0.686 | 0.687 | 0.687 | 0.688 | 0.688 | 0.690 | 0.690 | - | - |
| 3x50 | 0.511 | 0.511 | 0.512 | 0.512 | 0.514 | 0.514 | 0.515 | 0.515 | 0.519 | 0.519 |
| 3x70 | 0.360 | 0.360 | 0.362 | 0.362 | 0.364 | 0.364 | 0.366 | 0.366 | 0.370 | 0.370 |
| 3x95 | 0.267 | 0.267 | 0.269 | 0.269 | 0.272 | 0.272 | 0.274 | 0.274 | 0.279 | 0.279 |
| 3x120 | 0.218 | 0.218 | 0.221 | 0.221 | 0.223 | 0.223 | 0.225 | 0.225 | 0.231 | 0.231 |
| 3x150 | 0.184 | 0.184 | 0.186 | 0.186 | 0.189 | 0.189 | 0.192 | 0.192 | 0.198 | 0.198 |
| 3x185 | 0.155 | 0.155 | 0.158 | 0.158 | 0.161 | 0.161 | 0.164 | 0.164 | 0.170 | 0.170 |
| 3x240 | 0.130 | 0.130 | 0.132 | 0.132 | 0.135 | 0.135 | 0.138 | 0.138 | 0.145 | 0.145 |
| 3x300 | 0.114 | 0.114 | 0.116 | 0.116 | 0.119 | 0.119 | 0.122 | 0.122 | 0.129 | 0.129 |

| Duration of short circuit current | Area of Alu conductor | Short circuit current I (kA) = (K*A)/ √ t | Area of Cu conductor | Short circuit current I (kA) = (K*A)/ √ t |
|---|---|---|---|---|
| Time (t) | Area (A) | I=(0.094 x A)/√(t) | Area (A) | I=(0.144 x A)/√(t) |
| second | sq mm | kA | sq mm | kA |
| 1 | 10 | 0.94 | 10 | 1.44 |
| 1 | 16 | 1.50 | 16 | 2.30 |
| 1 | 25 | 2.35 | 25 | 3.60 |
| 1 | 35 | 3.29 | 35 | 5.04 |
| 1 | 50 | 4.70 | 50 | 7.20 |
| 1 | 70 | 6.58 | 70 | 10.08 |
| 1 | 95 | 8.93 | 95 | 13.68 |
| 1 | 120 | 11.28 | 120 | 17.28 |
| 1 | 150 | 14.1 | 150 | 21.60 |
| 1 | 185 | 17.39 | 185 | 26.64 |
| 1 | 240 | 22.56 | 240 | 34.56 |
| 1 | 300 | 28.2 | 300 | 43.20 |
| 1 | 400 | 37.6 | 400 | 57.60 |
| 1 | 500 | 47.0 | 500 | 72.00 |
| 1 | 630 | 59.22 | 630 | 90.72 |
| 1 | 800 | 75.2 | 800 | 115.20 |
| 1 | 1000 | 94.0 | 1000 | 144.00 |

## 6.3 Protection of Primary Side of Transformer

### 6.3.1 Circuit Breaker Selection forTx Primary Side(Indoor Sub-Station):

Supervised Location (in Primary side only) of Transformer




Supervised Location (in Primary side only) of Transformer

- **OverCurrent Protection at Primary Side (Primary Voltage >600V):**
- Rating of Pri. Fuse at Point A= 250% of Primary Full Load Current or Next higher Standard size.
- Rating of Pri. Circuit Breaker at Point A= 300% of Primary Full Load Current or Next higher Standard size.

$\therefore P_{FLC} = \mathbf{165\ A}$

$P_{FLC}$= Primary Full Load Current

Circuit Breaker Rating= $P_{FLC} \times 3$ = 165× 3

**=495A**

### 6.3.2Circuit Breaker/FuseSelection forTx Primary Side (Outdoor Sub-Station)

System Current =165×2=**330A**

$\therefore$ Circuit Breaker Rating $= 330 \times 3$

**=990A**

$\therefore Fuse\ Rating = 330 \times 2.5$

**=825A**

### 6.3.3 Lighting Arrester Selection

Since the arrestor is connected from phase to ground, phase voltage is used rather than line to line voltage:

$$V_P = \frac{V_{L-L}}{\sqrt{3}}$$

$V_P = Phase\ Voltage$

$V_{L-L} = Line\ to\ Ling\ Voltage$

$$V_P = \frac{11kv}{1.732} = \mathbf{6.351kv\ (RMS)}$$

$$V_{peak} = V_{rms} \times \sqrt{2}$$

$$= 6.351 \times 1.414$$

$$= \mathbf{8.98\ KV}$$

**Howeve**r, the maximum overvoltage permitted isn't necessarily the nominal voltage rating-it could be up to 5–10% over that, so:

$$V_{max} = V_{peak} \times 1.1$$

$$= 8.98 \times 1.1$$

$$= \mathbf{9.878\ KV}$$

**So, we have to select next higher rating of "LA"**

## 6.4 LT Side Equipment Selection & Calculation

### 6.4.1 Secondary Current of Transformer:

We Know, $P = \sqrt{3}VI$

$\therefore I = \frac{P}{\sqrt{3}V}$

$= \frac{3150 \times 1000}{1.732 \times 415}$

$= \frac{3150000}{719}$

**= 4382.425 A**

P = 3150 KVA = 3150 × 1000

= 3150000 VA

V = 415 V

$\sqrt{3} = 1.732$

### 6.4.2 Short CKT Current of Transformer Secondary Side:

Short circuit current,

$$\boldsymbol{I}_{SC} = \frac{3150000}{1.734 \times 415 \times \%Z}$$

Transformer Rating =3150 KVA

Transformer Impedance=6%

$$= \frac{3150000}{1.732 \times 415 \times 0.06}$$

$$= \mathbf{73040.4}\ \boldsymbol{A}$$

### 6.4.3 LT Cable Calculation and Selection

**<u>According to Thumb Rule</u>**

$\therefore I_{FLC}$= **4382.425 A**

$I_{FLC}$= Full Load Current Secondary Current of Transformer

Safety factor 125% of full load current

$\therefore$ 4382.425 A of 125%

= 4382.4 A × 1.25

**= 5478 A**

∴ $1mm^2$= 1.2A-1.6A (for copper)

$$\therefore Rm = \frac{5478}{1.6}$$

**=3424 $mm^2$**

So, we have selected **500$mm^2$**cables

$$= \frac{3424}{500}$$

$$= 6.848\ Runs$$

So, we have selected **500$mm^2$** cable and 7 Runs ($7\times 1C - 500mm^2$)

### 6.4.4Circuit Breaker Selection forTx Secondary Side (Indoor Sub-Station)

$I_{FLC}$= **4382.425 A**

Safety factor 125% of full load current

∴ 4382.425 A of 125%

= 4382.4 A × 1.25

**= 5478 A**

**Therefore, there is no ACB in this rating. So, we have to select next higher rating ACB is 6300 A.**

### 6.4.5Bus-bar Calculation for LT Panels

We know, Line current,

∴ $I_{FLC}$= 4382.425 A

Safety factor 125% of full load current

 4382.425 A of 125%

= 4382.4 A × 1.25

= **5478 A**

$I_{FLC}$= Full Load Current SecondaryCurrent of Transformer

$1mm^2$ = 1.2A-1.6 A (Copper)

$1mm^2$ = 0.8 A (Aluminum)

$\therefore Busbar\ Side = \frac{5478}{1.2}$

= **4565 mm²**

We know that, height (H) is multiplied with copper width (w) to select bus-bar copper.

According to bus-bar size, $(120\times10)\ mm^2 = 1200\ mm^2$

$\therefore\ 4\times(120\times10) = 4800\ mm^2$

$\therefore$ 4 Runs $(120\times10)\ mm^2$ copper Busbar will be need for LT panel

### 6.4.6Available Busbar Size:

| (H×W) | (H×W) | (H×W) |
|---|---|---|
| $(25\times5) = 125mm^2$ | $(60\times5) = 300\ mm^2$ | $(100\times8) = 800\ mm^2$ |
| $(25\times10) = 250mm^2$ | $(60\times8) = 480\ mm^2$ | $(100\times10) = 1000\ mm^2$ |
| $(30\times5) = 150\ mm^2$ | $(60\times10) = 600\ mm^2$ | $(110\times8) = 880\ mm^2$ |
| $(30\times8) = 240\ mm^2$ | $(70\times5) = 350\ mm^2$ | $(110\times10) = 1100\ mm^2$ |
| $(20\times10) = 200\ mm^2$ | $(70\times8) = 560\ mm^2$ | $(110\times12) = 1320\ mm^2$ |
| $(35\times5) = 175mm^2$ | $(70\times10) = 700\ mm^2$ | $(120\times8) = 960\ mm^2$ |
| $(40\times5) = 200\ mm^2$ | $(70\times12) = 840\ mm^2$ | $(120\times10) = 1200\ mm^2$ |
| $(40\times8) = 320\ mm^2$ | $(80\times5) = 400\ mm^2$ | $(120\times12) = 1440\ mm^2$ |
| $(40\times10) = 400\ mm^2$ | $(80\times8) = 640\ mm^2$ | |
| $(50\times5) = 250\ mm^2$ | $(80\times10) = 800\ mm^2$ | |
| $(50\times10) = 500\ mm^2$ | $(80\times12) = 960\ mm^2$ | |

## 6.5 P.F.I/A.P.F.C CALCULATION

### 6.5.1 KVAR Selection for 3150 KVA Transformer

We are to get KVAR of 60% of KVA

$\therefore$ P = 3150 KVA

= 3150 × 60%

= **1890 KVAR**

We know that, 2 set PFI are used to 12 steps (2000-4000) KVA

$\therefore \frac{1890}{2}$ = **945 KVAR.**

$\therefore$ (945+945) KVAR.

### 6.5.2 Current Calculation for PFI Line:

$P = \sqrt{3}VI\sin\theta$

$\Rightarrow \; I = \frac{P}{\sqrt{3}V\sin\theta}$

$\sin\theta = 1$

P = 1 KVAR

= 1000 VAR

$= \frac{1\times1000}{1.732\times415\times1}$

$\therefore$ 1 KVAR = 1.39=1.4 A

$\therefore$ 1890×1.4 = 2646 A.

$I_{FLC}$=**2646 A** (for 1890 KVAR)

### 6.5.3 Calculation of PFI Incoming circuit Breaker:

$\therefore I_{FLC}$= 2646 A

Safety factor 150% of full load current

2646 A of 150%

= 2646 A × 1.5

= **3969A**

Hence nearest higher size of circuit Breaker 4000 A ACB is required.

### 6.5.4 Bus-bar Calculation for P.F.I

∴ $I_{FLC}$= 2646 A

Safety factor 150% of full load current

2646 A of 150%

= 2646 A × 1.5

= **3969A**

$1mm^2$ = 1.2A-1.6 A (Copper)

$1mm^2$ = 0.8 A (Aluminum)

$$\therefore Busbar\ Side = \frac{3969}{1.2}$$

= **3308 $mm^2$**

We know that, height (H) is multiplied with copper width (w) to select bus-bar copper.

According to bus-bar size, (120×10) $mm^2$ = 1200 $mm^2$

∴ 3× (120×10) = 3600 $mm^2$

∴ 3 Runs (120×10) $mm^2$ copper Busbar will be need for P.F.I panel

### 6.5.5 Incoming Cable Selection for PFI:

∴ $I_{FLC}$= 2646 A

Safety factor 150% of full load current

2646 A of 150%

= 2646 × 1.5

= **3969A**

$$\therefore Cable\ Side = \frac{3969}{1.6}$$

= **2480 $mm^2$**

So, we have selected 500$mm^2$cables

$$= \frac{2480}{500}$$

=4.96 Runs

So, we have selected 500$mm^2$ cable and 5 Runs (5×1C-500mm2)

## 6.6 Outgoing of load current, Circuit Breaker and Cable Selection:

We know,

KVA = $\frac{KW}{\cos\theta}$ [∴ Angle between Total power and Apparent power. ∴ cosθ = 0.8]

∴ KW = KVA × cosθ

= 3150×0.8

= 2520 KW

Therefore, our load line is four (4). So, we will distribution three load line,

1st load line = 1010 KW

2nd load line = 1010 KW

3rd load line = 500 KW

4th load line Spare.

## * 1010 KW load : (1st and 2nd load line):

We know, P = $\sqrt{3}VIcos\theta$

⇨ I = $\frac{P}{\sqrt{3}V\cos\theta}$

= $\frac{1010000}{1.732\times415\times0.8}$

= $\frac{1010000}{575}$

= 1756 A

Here

P =1010 KW

= 1010000 W

$\sqrt{3} = 1.732$

V = 415 Volt

Cosθ = 0.8

∴ Current I = 1756 A

Hence nearestr higher size of circuit Breaker against current.

So, We will Selected circuit Breaker 2000A ACB

Circuit Braker = 2000A, AB, 65KA

## Cable Selection:

Sqmm = $\frac{1756}{1.8}$ [$\therefore$ 1mm = 1.8A copper]

= 976 sqmm

300 $mm^2$ Cable can be current Carrying Capacity 475A So, If we Select 300 mm2 Cable we will have to 4 run.

$\therefore$ 300×4 = 1200 mm2

$\therefore$ 4×5(1c – 300 $mm^2$) cable for PVC Cable

4 = run

5 = TPN + PE

1c = Single core.

## * 500 KW load:

We know, P = $\sqrt{3}VIcos\theta$

⇨ I = $\frac{500000}{1.732\times415\times0.8}$

= $\frac{500000}{575}$

= $870A$

P = 500 KW = 500000 W

V = 415 V

$\sqrt{3} = 1.732$

cosθ = 0.8

**Circuit Breaker:**

Current I = 870 A

Hence nearest higher size of circuit Breaker against current.

So, we will do select circuit Breaker 1000 A ACB or MCCB.

$\therefore$ Circuit Breaker = 1000A MCCB

Cable Selection: $\frac{870}{1.8}$ =484 Sqmm [$\therefore$ 1$mm^2$ = 1.8 A copper)

300 mm$^2$ cable can be current carrying capacity 475A.

So, If we Select 300 mm$^2$ cable we will have to 2 run.

$\therefore$ 2× (1c – 300 mm$^2$) cable for PVC cable.

2 = run

5 = TPN + PE

1c = Single core.

### 6.6.1 Short Circuit Current for XLPE and PVC Insulated Cables:

Voltage 450/750V and 600/1000V

| Copper Conductor | Max. Conductor Resistance At $20^0$C ohm/km | Short Circuit Current Rating At 1 Second | |
|---|---|---|---|
| sqmm | | XLPE Cable (KA) | PVC Cable (KA) |
| 1.5 | 12.1 | 0.215 | 0.173 |
| 2.5 | 7.41 | 0.358 | 0.288 |
| 4 | 4.61 | 0.572 | 0.46 |
| 6 | 3.08 | 0.858 | 0.69 |
| 10 | 1.83 | 1.43 | 1.15 |
| 16 | 1.15 | 2.288 | 1.84 |
| 25 | 0.727 | 3.575 | 2.875 |
| 35 | 0.524 | 5.005 | 4.025 |
| 50 | 0.387 | 7.15 | 5.75 |
| 70 | 0.268 | 10.01 | 8.05 |
| 95 | 0.193 | 13.585 | 10.925 |
| 120 | 0.153 | 17.16 | 13.8 |
| 150 | 0.124 | 21.45 | 17.25 |
| 185 | 0.0991 | 26.455 | 21.275 |

| | | | |
|---|---|---|---|
| 240 | 0.0754 | 34.32 | 27.6 |
| 300 | 0.0601 | 42.9 | 34.5 |
| 400 | 0.047 | 57.2 | 41.2 |
| 500 | 0.0366 | 71.5 | 51.5 |
| 630 | 0.0283 | 90.09 | 64.89 |
| 800 | 0.0221 | 114.4 | 82.4 |
| 1000 | 0.0176 | 143 | 103 |

$\therefore$ XLPE Cable I = $\dfrac{0.143A(mm^2)}{\sqrt{t}}$

PVC Cable I = $\dfrac{0.115A(mm^2)}{\sqrt{t}}$ for equal and less than 300 $mm^2$

I = $\dfrac{0.103A(mm^2)}{\sqrt{t}}$ for A greater than 400 $mm^2$

I : Short circuit current in KA

A: Conductor cross Section area in $mm^2$

t : Time of short circuit in second.

# 6.7 Circuit & Panel Diagram For DIU,Building-4,Ashulia Campus:

## 6.7.1(2×3150)KVA Single Line Diagram Of DIU,Building-4 ASHULIA Campus:

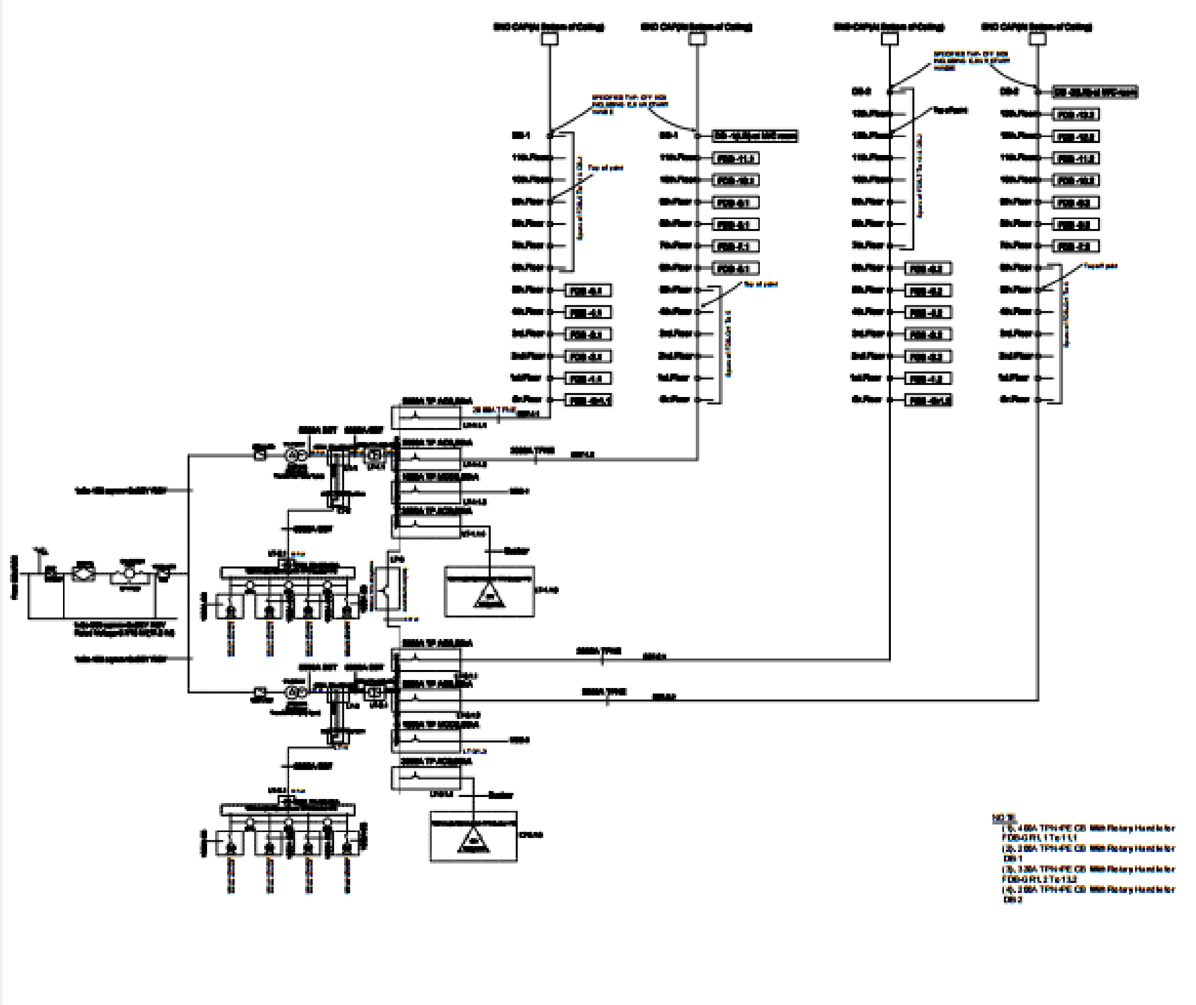


Fig:Single line diagram of 2x3.15 MVA Sub-Station and BBT Design including full load standby supply

# 6.7.2 (2×3150)KVA  Layout Of DIU,Building-4 Campus:

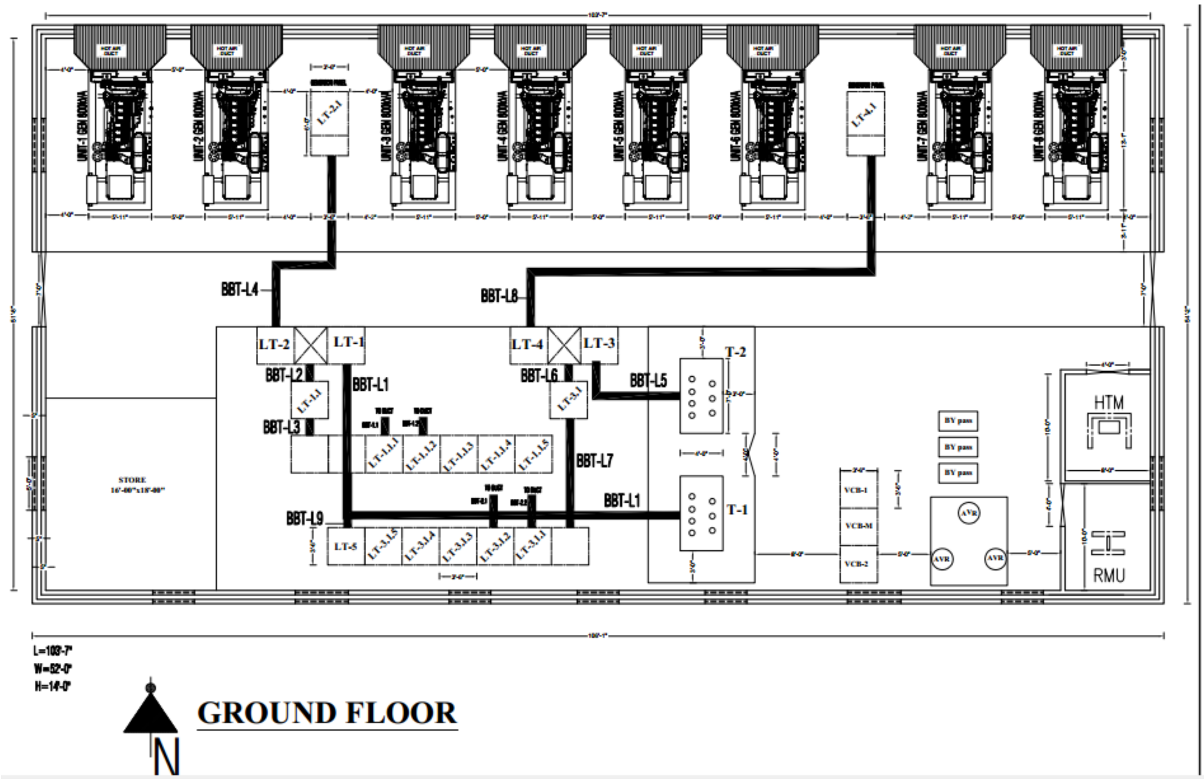
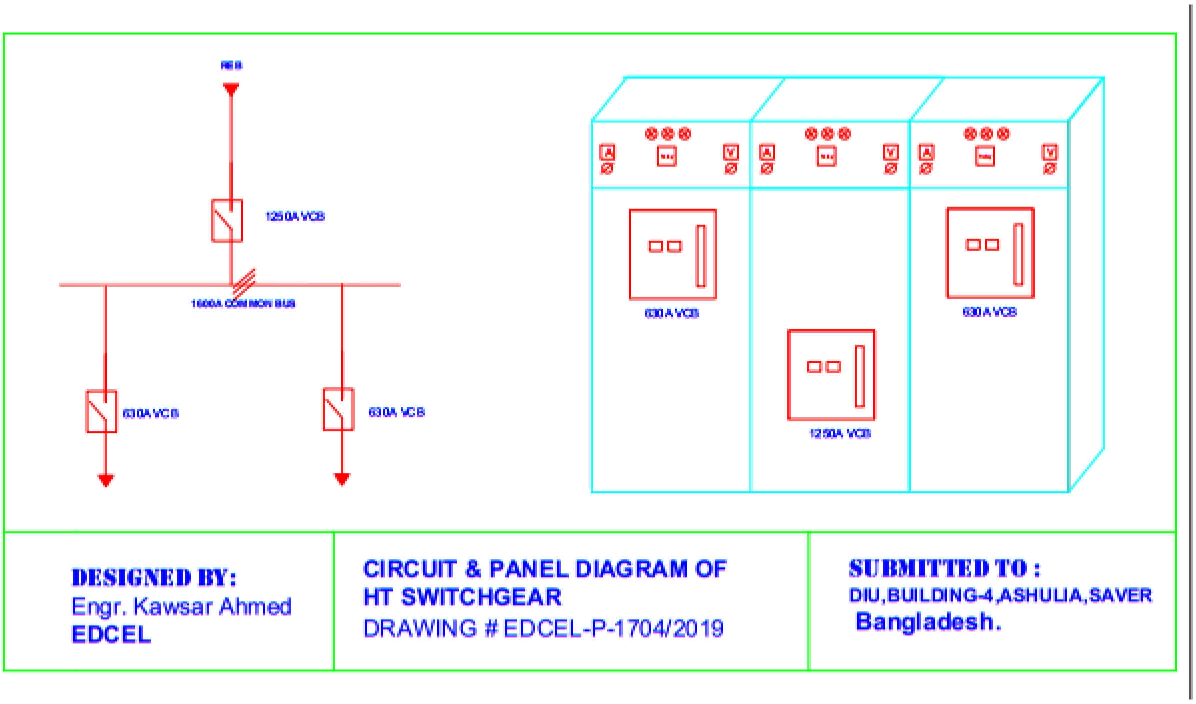



Fig 6.7.2 (2×3150)KVA  Layout Of DIU,Building-4 Campus

## 6.7.3 Circuit & Panel Diagram of HT Switchgear:



**11KV HT SWITCHGEAR WITH VCB :** **1 Set**

This specification covers the supply of 11KV indoor, metalclad, switchgear according to IEC publication 298, BSS227,2631,3659 and VDE 0670 /6.

The medium voltage switchgear panel shall be used for secondary distri-ibution sub – station up to 12KV and suitable for an ambient temperature of 45 Deg. C and rated rupture capacity of 350 MVA complete with all accessories , diagrams, levels, wiring & terminals.

The 11KV, 350MVA rated switchboard would comply compulsory electricity regulations by standards. All cubicles are fitted with security interlocks and earthing switch.
The erection of the panel can be done directly on the leveled floor. Cable trenches are necessary. Cables can easily installed from the bottom side of the panel.

The design is done to allow safe operation in extremely tropical climate conditions.

**TECHNICAL DATA :**

| | |
|---|---|
| Service voltage | : 11KV |
| Rated Voltage | : 12 KV |
| Rated current of Busbars | : 1000A |
| Rated current of circuit breaker | : 630A |

**INSULATION LEVEL :**

| | |
|---|---|
| Impulse withstand voltage 1.2 / 50 micro – sec | :75KV (Peak) |
| Power frequency withstand voltage / 1 min. | : 28KV rms. |

## 6.7.4 HT panel shall comprising of :

**1 -** **Vmax-12.06.20**
11KV, 630A, 20KA, triple pole, fixed type,Vacuum circuit breaker(VCB) with auxiliary contacts, shunt trip coil, and operating mechanism with visible disconnect & grounding feature with earth switch.
**Origin : ABB of ITALY.**

3 - Cast resin insulated dry type 11KV double core current Transformer with ratio 100/5/5A.
Core –1 : 30V, class 0.5M5
Core – 2 : 30VA, class 10P10
**Siemens of germany**

1 – Ammeter scaled 0 –300A with selector switch.
**Rise sun of Taiwan**

3 – Dry type cast resin insulated potential transformer for open delta connection with primary switch.
Ratio : 11000/110V
Burden : 100VA, Class : 0.5
**Siemens of germany**

1 – MCB for PT secondary protection.
**Origin : ABB OF Italy**

1 – Voltmeter scaled (0 –11KV ) with selector switch.
**Rise sun of Taiwan**

1 – Microprocessor based triple pole, IDMT relay with over, current, earth fault and under voltage provision.
**Origin : Mikro.**

3 – Indicating lamp RED/YELLOW/BLUE.
**Origin : Telemaccnique.**

1 – Panel heater.
2 - Set Cooling fan with filter.
1 – set TP busbar suitably sized & air insulated.

Fig 6.7.3 Circuit & Panel Diagram of HT Switchgear

## 6.7.5 5000A ATS PANEL:

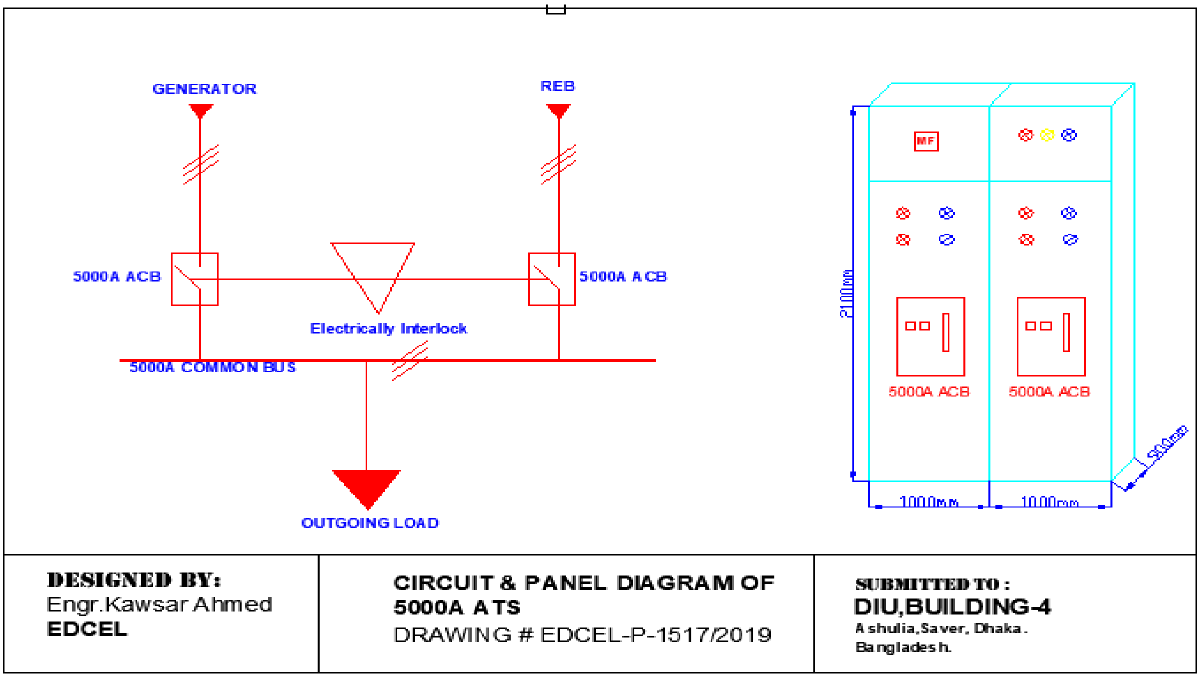



Fig6.7.5 5000A ATS Circuit & Panel Diagram

**<u>5000A CHANGE-OVER PANEL :</u>** **2 Set**

16SWG Sheet steel fabricated, floor mounting, tropicalized design, indoor low tension switchgear for 3 phase, 4 wire, 50Hz, 380 /415 AC system and shall be supplied complete with TPN + PE bus-bars suitability sized and properly insulated arrange to withstand & short current 50KA, of 1 sec.

The boards are designed & constructed in accordance with BS5486/IEC439.

The boards are factory assembled complete with all wiring, metal parts bonded grounded points & finished with **two coats of powder coated paint.**

Busbars and other live parts are spaced and insulated in accordance with European standards IEC158, UTE C20 – 040, VDE –C110 for 660V.

All MCCB units & panel boards shall fully comply regulations of the 15th edition IEE wiring regulation for isolation & switching.

## 6.7.6 ATS panel shall comprising of : 2 SETS

**<u>INCOMING :</u>**

2 - **E3N 5000 PR121/P-LI In =5000A 3p F HR**

5000A, 85KA, TP, 415V, 50Hz Air Circuit breaker (ACB) with under voltage release and micro processor protection unit.

The micro processor protection unit meets the requirement of the IEC 947.2 standard. This unit is powered by the current transformers & performs all the necessary three or four pole overcurrent protection.

**Standard Protection:**

*Overload Relay Setting switch
*Short-Circuit & time delay rotary setting switches
*Earth Fault & time delay rotary setting switches

*Manual/automatic reset buttob (selactablea)

*Over load / short circuit trip curve symbol

*Earth fault protection curve symbol

* Healthy Light Emiting diod

*Multi-pin socket for text box / protable power box

**ACB Auxiliary:**

Shunt opening, Shunt closing Release, Under Voltage Release and Gear Motor

**Origin : ABB fo Italy.**

6

\- Current transformer ratio : 5000/5A with suitable accuracy & burden.

2 - Disital Ammeter scaled (0-5000A) with selector switch.

2 - Disital Voltmeter scaled ( 0 – 500V) with selector switch.

6 - Phase indicating lamp RED /YELLOW/ BLUE.

2 - Set control fuse.

2 - ON Indicating Lamp

2 - OFF Indicating Lamp

2 - ON/OFF push switch

**4 – Set (120X10)MM Copper Busbar with Tube insulated for ACB terminal.**

**4 – Set (120X10)MM Copper Busbar for Nutural**

**1 – Set (100X10)MM Copper Busbar for Earthing**

**2 – Set (2100X900x1000)MM Powder Coated Panel**

## 6.7.7 Synchronizing Panel for Genarator:

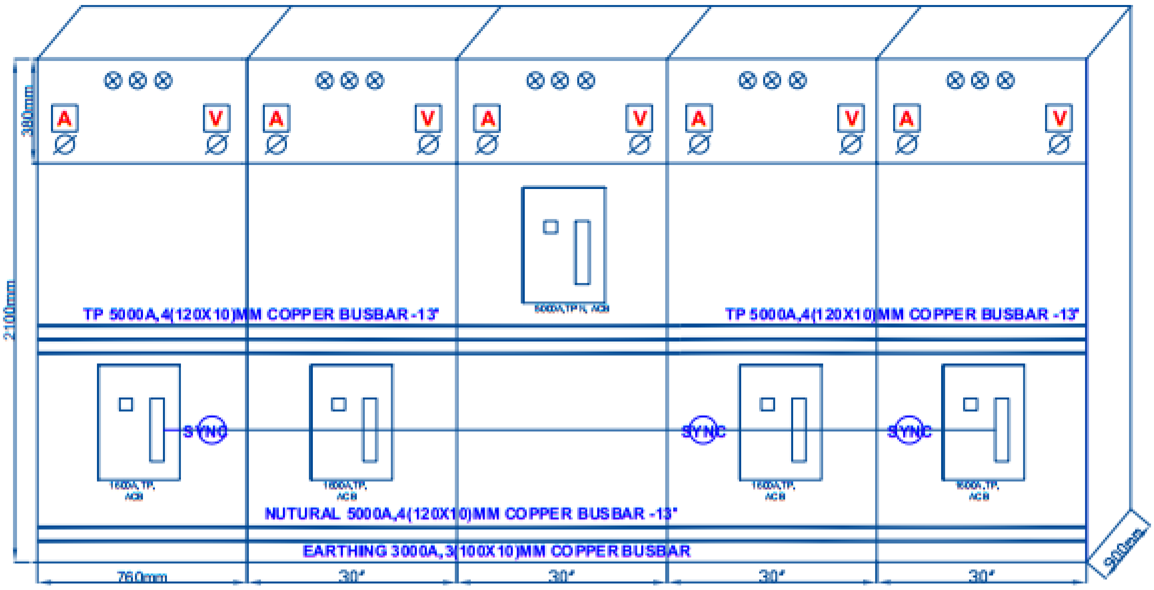



Fig 6.7.7 Synchronizing Panel for Generator

### Technical Specification of 4 x 800 KVA diesel generators with auto synchronization, auto load sharing including 1 x 5000 Amp common Auto Transfer Switch.

### Specification of generator:

4 units power generator sets - engine 4 stroke water cooled diesel engines close coupled to brushless single bearing, AVR. controlled self excited alternator and droop kit, rated @ specific kVA, 400/230V, 3 Ph, 0.8PF, 1500 RPM, 50Hz Prime duty Prime rating allows continuous operation with 10% overload for any one hour in twelve.

Each engine is water cooled with tropicalied radiator with fan guard/stone guard and dry charged 24V DC lead acid battery system.

Each genset is mounted on a steel welded baseframe with inbuilt fuel tank including fuel feed and return lines, fill, vent and drain points and a contents gauge. Heavy duty compressed rubber anti-vibration mounts are supplied inbuilt.

## Specification of Engine:

Turbo-charged, water cooled, multi-cylinder direct-injection. Electronic or electronic engine management governing. Replaceable elements for fuel, oil and air filters (where appropriate). Requiring only lubricating oil, coolant, inhibitor, battery acid and fuel for immediate start up. Manual start/stop operation, with heavy-duty dry-charged lead acid battery pack with connecting leads and charging system. Heavy duty tropicalised radiator with fan and stone-guards for water-cooled range.

Brand of Engine: Perkins/Cummins

Origin: UK/ Japan.

## Specification of Alternator:

Alternator of single bearing design close-coupled to the engine to provide accurate alignment. Brushless, self or magnet exciting, self regulating and solid state AVR controlled. Regulation under full load is maintained to +/- 0.5 - 1.5% depending upon AVR type. Enclosed in fabricated steel shell with drip-proof air ducts.

Tropically insulated windings to class 'H', built in accordance with BS 5000, VDE 0530, IEC 34, UTE 5100 and NEMA MG1-22 regulations.

Brand of Alternator: Stamford/Mecc-alte

Origin & Shipment: UK/ Japan

## Specification of Synchronization:

On each generator, the following equipments should be available in vibration isolated control panel.

1 x Oil pressure gauge

1 x Engine temperature gauge

1 x Battery voltmeter

1 x Emergency stop button

1 x Set of fuses, terminations, relays and transformers (as appropriate)

The power system is controlled via a suite of freestanding sheet steel cubicles. Front access to controls and components is via lockable and hinged doors.

Genset controls (per unit)

3 x Ammeters

1 x Genset voltmeter with selector switch - phase to phase and phase to neutral

1 x Frequency meter

1 x Speed control potentiometer

1 x Voltage control potentiometer

1 x Set of contactor / circuit breaker open/close push buttons

1 x Mains fed 3 Amp battery charger with on/off switch and ammeter / voltmeter

1 x Auto / manual contactor / circuit breaker control switch

1 x Emergency stop button

1 x Automatic/manual synchronising switch

1 x Microprocessor controlled automatic engine control module  with inbuilt timers,

## and safety protections: -

Pushbutton control for: - Automatic / Manual /Stop (Reset) / Start

LCD display for: - Oil Pressure / Engine Temperature / Hours Run / Battery Volts /

LCD and LED display for: - Fail to Start / Reverse Power / Low Oil Pressure /High

Engine Temperature / Overspeed / Auto mode / Manual mode / Low water level /

1 x Automatic synchronising relay / Load share relay c/w reverse power protection

1 x Set of protection circuit mcb’s, terminations, relays and transformers (as appropriate)

1 x Output rated 3-pole motorised circuit breaker with thermal and magnetic overload trips

3 x Instrumentation / load share current transformers 5 Amp secondary class 1 Common Equipment includes

1 x LED type synchroscope with inbuilt check synch relay and on/off switch

1 x Synchroscope switch on / off

1 x Duty selector switch G1 / G2/G3/G4 (or more as system is set up)

1 x Load level demand / Load Shed control via Kw sensing relays

1 x Earth bar running the horizontal length of the panel.

1 x TP &N (half size neutral) hard drawn high conductivity air insulated copper bus / cable

system running the horizontal length of the panel

## Specification of ATS changeover switch comprising:

1 x Mains failure and under voltage relay

1 x Mains return timer

1 x Set of LED indications for Mains Available

Mains on Load

Generator Available

Generator on Load

1 x Set of engine start/stop contacts

1 x Set of protection circuit mcb's, terminations, relays and transformers (as appropriate)

1 x Pair of output rated Amp rated motorised circuit breakers with electrical and

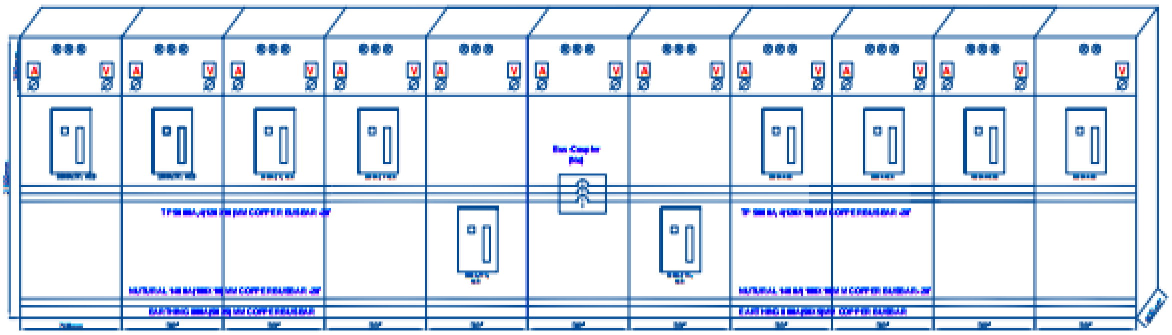
mechanical safety interlocking and including thermal and magnetic overload trips,

under voltage release (with time delay on mains side)

Origin of module : Japan/UK

Origin of Circuit Breaker: Japan/UK/Italy/India

## 6.7.8 Circuit & Panel Diagram LT Switchgear:



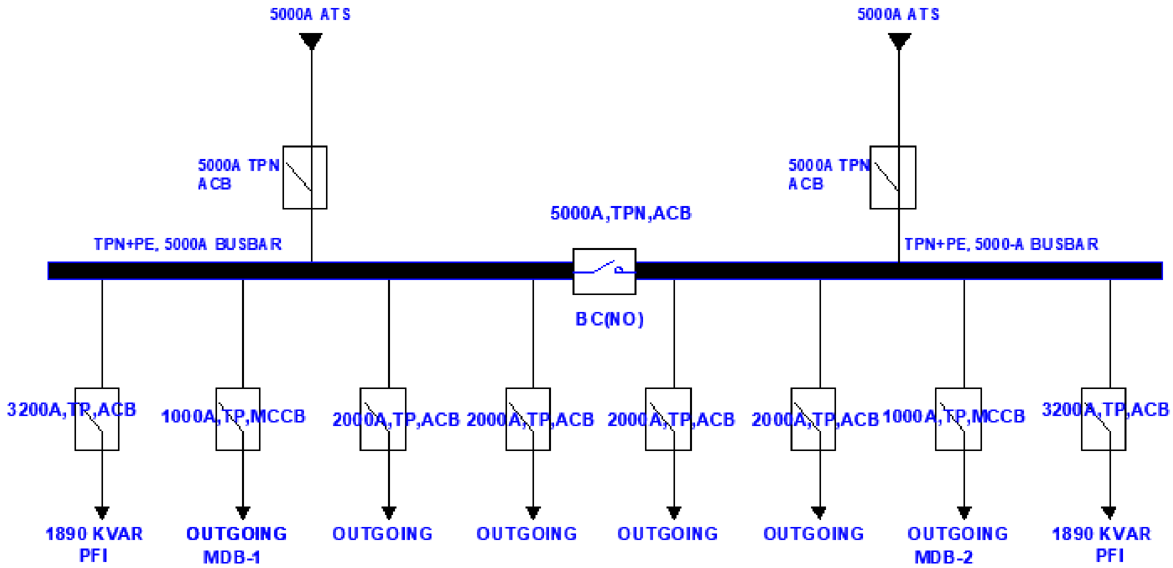



Fig 6.7.8 Circuit & Panel Diagram LT Switchgear

## 5000A LT SWITCHGEAR : **2 Set**

16/14 SWG Sheet steel fabricated, floor mounting,tropicalized design,indoor low tension switchgear for 3 phase, 4 wire, 50Hz, 380 /415 AC system and

properly insulated arrange to withstand & short current 50KA of 1 sec.

The boards are designed & constructed in accordance with BS5486/IEC439.

The boards are factory assembled complete with all wiring, metal parts bonded grounded points & finished with **two coats of powder coated paint.**

Busbars and other live parts are spaced and insulated in accordance with European standards IEC158, UTE C20 – 040, VDE –C110 for 660V.

All MCCB units & panel boards shall fully comply regulations of the 15th edition IEE wiring regulation for isolation & switching.

**6.7.9 LT panel shall comprising of :**

**INCOMING :**

1 - **E3S 5000 PR121/P-LI In =5000A 4p F HR** **2 SET**
5000A, 85KA, TP, 415V, 50Hz Air Circuit breaker (ACB)
with under voltage release and micro processor protection unit.

The micro processor protection unit meets the requirement of the IEC 947.2 standard. This unit is powered by the current transformers & performs all the necessary three or four pole overcurrent protection.

**Standard Protection:**

*Overload Relay Setting switch
*Short-Circuit & time delay rotary setting switches
*Earth Fault & time delay rotary setting switches
*Manual/automatic reset buttob (selactablea)
*Over load / short circuit trip curve symbol
*Earth fault protection curve symbol
* Healthy Light Emiting diod
*Multi-pin socket for text box / protable power box

**ACB Auxiliary:**
Shunt opening, Shunt closing Release, Under Voltage Release and Gear Motor
**Origin : ABB of Italy.**

3 - Current transformer ratio : 5000/5A with suitable accuracy & burden.
1 - Ammeter scaled (0-5000A) with selector switch.
1 - Voltmeter scaled ( 0 – 500V) with selector switch.
3 - Phase indicating lamp RED /YELLOW/ BLUE.
1 - Set control fuse.
2 - Set Cooling fan with filter.

**Origin :Rise sun of Taiwan.**

**<u>OUTGOING :</u>**

**1 -** **E2N 3200 PR121/P-LI In =3200A 3p F HR FOR PFI**
3200A, 65KA, TP, 415V, 50Hz Air Circuit breaker (ACB)
with under voltage release and micro processor protection unit.

**2 -** **E2N 2000 PR121/P-LI In =2000A 3p F HR FOR FLOOR**
2000A, 65KA, TP, 415V, 50Hz Air Circuit breaker (ACB)
with under voltage release and micro processor protection unit.

The micro processor protection unit meets the requirement of the IEC 947.2 standard. This unit is powered by the current transformers & performs all the necessary three or four pole overcurrent protection.

**Standard Protection:**

*Overload Relay Setting switch
*Short-Circuit & time delay rotary setting switches
*Earth Fault & time delay rotary setting switches
*Manual/automatic reset buttob (selactablea)
*Over load / short circuit trip curve symbol
*Earth fault protection curve symbol
* Healthy Light Emiting diod
*Multi-pin socket for text box / protable power box

**ACB Auxiliary:**
Shunt opening, Shunt closing Release, Under Voltage Release and Gear Motor
**Origin : ABB of Italy.**

**1 –** **T7S 1000 PR231 In = 1250A F F - For MDB**
1000A, TP, 50KA, 415V, 50Hz MCCB with adjustable
thermal overload and magnetic short circuit protection.
**Origin : ABB of Italy.**

**1 –** **Set, TPN+PE 5000A Copper Busbar with tube Insulation.**
**1 –** **No. Panel Size : (HXWXD) = (2000X2250X750)mm.**

## 6.7.10 Circuit & Panel Diagram of PFI :

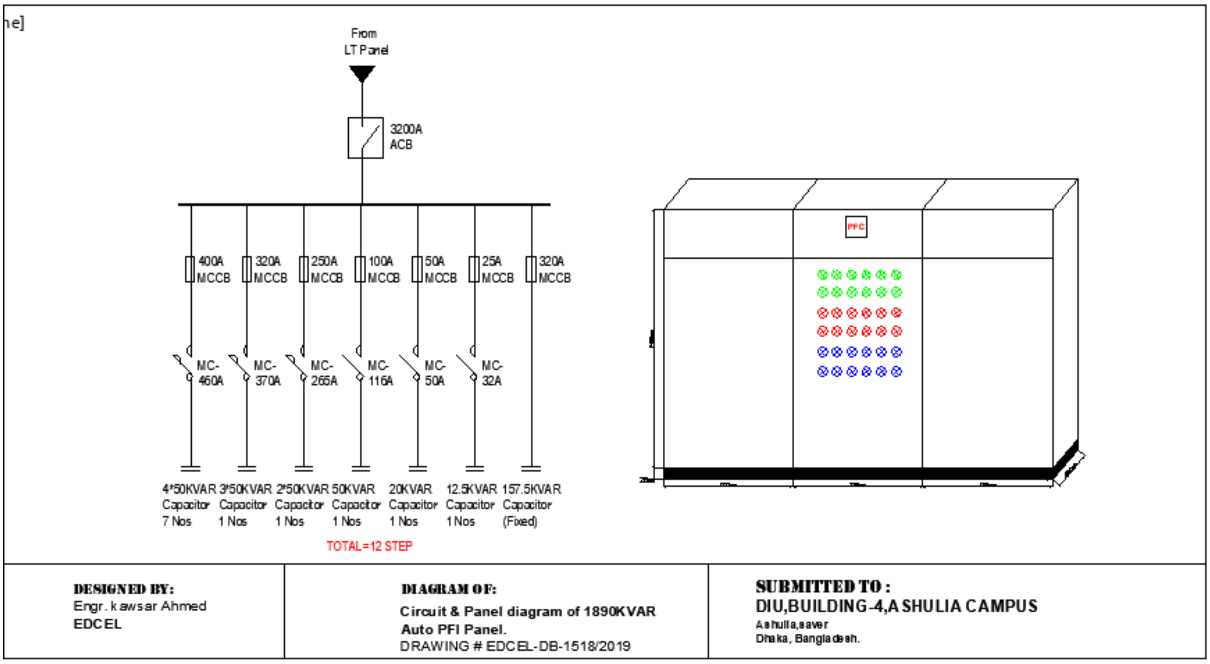



Fig 6.7.10 Circuit & Panel Diagram of PFI

**<u>1890KVAR AUTO PFI PLANT</u> :** **2 Set**

Auto/manual power factor improvement plant, 750KVAR in 12 steps. 16 SWG Sheet steel fabricated, floor mounting, tropicalized design, indoor type, Power factor imrovement panel for 3 phase, 4 wire, 50 Hz 380/415V AC system and shall be supplied complete with TP + N busbar short current of 50 KA for 1 sec.

The boards are designed & constructed in accordance with BS5486/ IEC439.

The boards are factory assembled complete with all wiring, metal parts bonded grounded points & finished with **two coats of powder coated paint.**

Busbars & other live parts are spaced & insulated in accordance with European standards IEC158, UTE, C20 – 040, VDE –C110 for 660V.

The panel shall fully comply regulations of the 15th edition IEE wiring regulation for isolation & switching.

### 6.7.11 PFI panel shall comprise of :

7 - 4x50KVAR, 415VAC, 50Hz, 3 Phase, **dry type,** self healing compact PF capacitors bank with discharge resistor.
**Origin : Epcos of Germany.**

1 - 3x50KVAR, 415VAC, 50Hz, 3 Phase, **dry type,** self healing compact PF capacitors bank with discharge resistor**.**
**Origin : Epcos of India.**

1 - 2x50KVAR, 415VAC, 50Hz, 3 Phase, **dry type,** self healing compact PF capacitors bank with discharge resistor**.**
**Origin : Epcos of Germany.**

1 - 50KVAR, 415VAC, 50Hz, 3 Phase, **dry type,** self healing compact PF capacitors bank with discharge resistor**.**
**Origin : Epcos of Germany.**

1 - 20KVAR, 415VAC, 50Hz, 3 Phase, **dry type,** self healing compact PF capacitors bank with discharge resistor**.**
**Origin : Epcos of Germany.**

1 - 12.5KVAR, 415VAC, 50Hz, 3 Phase, **dry type,** self healing compact PF capacitors bank with discharge resistor**.**
**Origin : Epcos of Germany.**

1 - 157.5(50+50+50+7.5)KVAR, 415VAC, 50Hz, 3 Phase, **dry type,** self healing compact PF capacitors bank with discharge resistor**.(Fixed)**
**Origin : Epcos of Germany.**

7 - **MC- 460A**
Capacitor Switching Magnetic Contactor for 200( 4X50)KVAR capacitor.
**Origin : ABB of India.**

1 - **MC-370A**
Capacitor Switching Magnetic Contactor for 150(3×50)KVAR capacitor.
**Origin : ABB of India.**

1 - **MC-265A**
Capacitor Switching Magnetic Contactor for 100(2×50)KVAR capacitor.
**Origin : ABB of India.**

1 - **MC-116A**
Capacitor Switching Magnetic Contactor for 50KVAR capacitor.
**Origin : ABB of India.**

1 - **MC-50A**
Capacitor Switching Magnetic Contactor for 20KVAR capacitor.
**Origin : ABB of India.**

1 - **MC-32A**
Capacitor Switching Magnetic Contactor for 12.5KVAR capacitor.
**Origin : ABB of India.**

7 - 400A, TP, 50Hz, 36KA MCCB for 200KVAR
**Origin : ABB of Italy.**

1 - 320A, TP, 50Hz, 36KA MCCB for 150KVAR
**Origin : ABB of Italy.**

1 - 250A, TP, 50Hz, 36KA MCCB for 100KVAR
**Origin : ABB of Italy.**

1 - 100A, TP, 50Hz, 36KA MCCB for 50KVAR
**Origin : ABB of Italy.**

1 - 50A, TP, 50Hz, 36KA MCCB for 20KVAR
**Origin : ABB of Italy.**

1 - 25A, TP, 50Hz, 25KA MCCB for 12.5KVAR
**Origin : ABB of Italy.**

1 - 320A, TP, 50Hz, 36KA MCCB for 157.5KVAR(Fixed)
**Origin : ABB of Italy.**

1 - 12 steps reactive power regulator which performs the switching of capacitor bank in automatic power factor correction equipments depending on changes of reactive power complete with p.f. luminescent indicators and digital power factor meter.
**MIKRO of Malaysia.**

1 - LT current transformer of adequate rating & burden.
2 - Set Cooling fan with filter.
1 - Set TP busbar suitably sized & air insulated.
**3 – No. Panel Size : (HXWXD) = (2100X700X600)mm.**

# LIST OF ABBREVIATIONS

1. RMU = Ring Main Unit
2. LA = Lighting Arrestor
3. DOF = Drop Out Fuse
4. AVR = Automatic Voltage Regulator
5. DG = Diesel Generator
6. HT Switchgear = High Tension Switchgear (Transformer HT Side)
7. LT Switchgear = Low Tension Switchgear
8. BBTs = Bus-bar Trunking System
9. AB Switch = Air Break Switch
10. VCB = Vacuum Circuit Breaker
11. SF6 Circuit breaker = Sulphur Hexafluoride Circuit Breaker
12. ACB = Air Circuit Breaker
13. OCB = Oil Type Circuit Breaker
14. ACDB = Alternating Current Distribution Board
15. DCDB = Direct Current Distribution Board
16. PDB = Power Distribution Board
17. MPDB = Main Power Distribution Board
18. PCC = Power Control Centre
19. MCC = Motor Control Centre
20. MCP = Motor Control Panel
21. VVVF = Variable Voltage Variable Frequency Drive
22. VSD = Variable Speed Drive
23. DOL = Direct On Line
24. RDOL = Reverse Duty On Line
25. MLDB = Main Lighting Distribution Board
26. SLDB = Secondary Lighting Distribution Board
27. EMLDB = Emergency Lighting distribution board
28. CPSS = Construction Power Sub-Station
29. DSS = Distribution Power Sub-Station
30. RCC = Remote Control Cables

31. MCB = Miniature Circuit Breaker
32. MCCB = Moulded Case Circuit Breaker
33. MPCB = Motor Protection Circuit Breaker
34. EMPR = Electronic Motor Protection Relay
35. RCCB = Residual Current Circuit Breaker
36. RCBO = Residual Current Circuit Breaker With Over Current Protection
37. ELCB = Earth Leakage Circuit Breaker
38. HRC = High Rupting Capacity Fuse
39. OLTC = On Load Tap Changer
40. UPS = Un-Interrupted Power Supply
41. JB = Junction Box
42. PB= Push Button
43. TB = Terminal Box
44. LCB = Local Control Board
45. SPNDB = Short Circuit Protection Neutral Distribution Board
46. TPN = Three Phase & Neutral
47. PE = Protective Earth
48. CT = Current Transformer
49. PT = Potential Transformer
50. SCIM = Squirrel Cage Induction motor
51. FDA = Fire Detection &Alarm
52. NO = Normally Open
53. NC = Normally Close
54. GI BUS-BAR = Galvanized Iron Bus Bar( For Earthing)ACVS

## Conclusion:

This is one and only company in Bangladesh which work with power transmission.PGCV is an established company and has a good repution.Here Engineers play great role.This attachment makes our theoritical knowledge strong.We are learn practicaly how a sub- station is protected equipment.We also learn about bus bar arrangement.A sub-station takes power from a power generation company or from a grid and then according to the consumer demand They step down the power and supply the power.Between the taking and distribution of power there are a lot of procedure to do all the pwe procedure.Within the short time we have tried my best to acquire knowledge about the transmission system,system protection planning of sub-station.We have also learnt about the sub-station and the working principle of all sub-station equipments.Bo th Engineer and suprvisor in all sectors were helpful to us.We hope that the practical experience whice we have gained from PGCB will be helpful for my future job sector.

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