INTERNSHIP REPORT

ON

[SWITCHGEAR]

By

[Mojahidul Islam.
ID: 2007-1-80-018],
[Md. Iqbal Hossain
ID: 2007-1-80-015],
[Golam kibria
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Submitted to the

Department of Electrical and Electronic Engineering
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in partial fulfillment of the requirements for the degree of
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Approved By

30.01.2011 — 30.01.2011

Academic Advisor — Department Chairperson

[S.M.Shariar Rasid] — [Dr. Anisul Haque]

Power Grid Company of Bangladesh Ltd.

(An Enterprise of Bangladesh Power Development Board)

ISO 9001:2008 CERTIFIED COMPANY

Certificate for Industrial Attachment Training Programme

*This is to certify that **Mr.Mojahidul Islam** bearing student ID: **2007-1-80-018,** Department of Electrical and Electronic Engineering, **East West University**, Dhaka was a candidate for Industrial Attachment Training Programme at Maniknagar PGCB, Dhaka*

Trainer

Company Secretary

Acknowledgment

First of all, we are grateful to Almighty Allah who has blessed us the opportunity to study here in East West University.

Thanks go to our Advisor Mr. S.M.Shariar Rasid (Research Lecturer, East West University) for his insightful and useful suggestion during the preparation of this paper.

Thanks go to Mr. Diponkor Das (Deputy Manager-Maniknagar Substation) and Assistant managers of Maniknagar Substation for provide necessary assistance to us. Thanks are due to our friends Tania Tahmid and Nur Mohammad for doing internship with us. We also remember our family-
now today.

Last but not least, we would also like to thank Mr. Ishfaqur Raja (Associate Professor, East West University), an ever smiling face and guardian like figure in our department, for his various help, sometimes with good humour, sometimes with patience.

Executive Summary

Summary of the internship in Maniknagar substation:

We have done internship program in Maniknagar substation under power Grid Company of Bangladesh (PGCB) .It was 15 days training program. PGCB was incorporated in November 1996 with an authorized capital of Tk.10 billion. Government decision to transfer of transmission assets to PGCB from Bangladesh Power Development Board (BPDB) and Dhaka Power Distribution Company (DPDC), former DESA, PGCB has completed taking over of all the transmission assets on 30.12.2002 and operating them. 76.25% ownership with BPDB & 23.75% with general public. Its Head Office is at Institution of Engineers of Bangladesh Bhaban (New), the 3rd and 4th floor, 8/A Ramna, Dhaka-1000, Bangladesh. Activities of PGCB include. Operation & maintenance of grid sub-station and transmission line, Load dispatching, Operation & maintenance of communication system, Protection, and relay co-ordination, Design & evaluation, Transmission network planning.PGCB also contributes in communication system. O & M of power line carrier communication system of PGCB and OPGW communication in future.

Training in Maniknagar substation can be divided into three parts:

1) Learning about different equipment s and machine such as circuit-breaker, relay, current transformer, voltage transformer and lighting arrester used in the substation.
2)
Arrangement of the Maniknagar substation:. It includes connection established in a substation and single line diagram of the substation .How the incoming and outgoing feeder are connected to the busbar of the maniknagar substation and carefully observed the connection established in maniknagar substation.

3) Operation and maintaince.
We learn how a substation is operated and maintained .Like other substation Maniknagar substation use control circuit of the substation. If any kind of fault occurs then maintaince can be done by control circuit.

DETAIL OF INTERNSHIP WORK

Our working time table:

Date	What we did	Supervisor
02.05.10	Basic Knowledge about Power System. Transmission line of PGCB, Type of Substation, Equipment of Substation and transformer, Basic of Single Line diagram.	Diponkor Das, Deputy Manager-Maniknagar Substation, PGCB.
03.05.10	Different types of conductors used in substation.	Diponkor Das
04.05.10	Transmission line at tower to tower, Sag, supporters or towers, Visit to Switchyard for first time.	Diponkor Das
05.05.10	Detail discussion about different types of insulator.	Diponkor Das
06.05.10	C.T, P.T, Lighting arrester, Wave Trap, PLC.	Diponkor Das
07.05.10	Underground cable.	Diponkor Das
09.05.10	Detail discussion about Maniknagar substation Circuit breakers and their design.	Diponkor Das
10.05.10	Types of circuit breakers	Diponkor Das
11.05.10	Types of circuit breakers	Diponkor Das
12.05.10	Bus bar design scheme	Diponkor Das
13.05.10	Relay panel & AC and DC auxiliary system	Diponkor Das
15.05.10	Total review	Diponkor Das

Table1: Detail of Internship Work

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CHAPTER1

INTRODUCTION

Company Profile:

1.1 Overview of PGCB:

Power Grid Company of Bangladesh (PGCB) was created under the restructuring process of Power Sector in Bangladesh with the objective of bringing about commercial environment including increase in efficiency, establishment of accountability and dynamism in accomplishing its functions. PGCB was incorporated in November 1996 with an authorized capital of Tk.10 billion. It was entrusted with the responsibility to own the national power grid and to operate and expand the same with efficiency. Pursuant to Government decision to transfer of transmission assets to PGCB from Bangladesh Power Development Board (BPDB) and Dhaka Power Distribution Company (DPDC), former DESA, PGCB has completed taking over of all the transmission assets on 30.12.2002 and operating them.

1.2 PGCB Profile:

- A public limited company. Incorporated through sponsorship of chairman, BPDB and its six members.
- 76.25% ownership with BPDB & 23.75% with general public.
- Its Head Office is at Institution of Engineers of Bangladesh Bhaban (New), the 3rd and 4th floor, 8/A Ramna, Dhaka-1000, Bangladesh.

1.3 Prime objective as per memorandum of association as follows:

"To plan, promote, develop, operate and maintain an integrated and efficient power transmission system network in all its aspects including planning, investigation, research, design and engineering, preparation of preliminary feasibility and detailed project reports, construction operation and maintenance of transmission lines, substations, load despatch centres and communication facilities and appurtenant works, co-ordination of integrated operation of regional, national and international grid systems, providing consultancy services in power systems field, execution of turnkey jobs for other utilities / organization, wheeling of power, purchase and sale of power."

1.4 Activities of PGCB:

A. Operation & maintenance of grid sub-station and transmission line.

B. Load dispatching.

C. Operation & maintenance of communication system.

D. Protection, relay co-ordination

E. Design & evaluation.

F. Transmission network planning.

G. Implementation of development projects.

1.4 A. Operation & maintenance of grid sub-station and transmission line.

Under the supervision of General Manager Trans-1 (Dhaka) and Trans-2 (Outside Dhaka), five grid circles headed by Deputy General Managers are performing the following operations:

- Operation & Maintenance of grid substation and Transmission Line
- Regular inspection of line, tower, cutting of trees.
- Preventive maintenance program.
- Inspection of sub-station equipment.
- Annual deadline checking.
- Check list.
- General neat & cleanliness.
- Inspection by different level of officers.

1.4 B. Load dispatching.

Under the supervision of General Manager (System Operation), Load Dispatch Circle is headed by a Deputy General Manager who is performing the following operations:

- Generation planning & schedule preparation
- System control by maintaining load-generation balance
- Operational record keeping
- Telemeter/SCADA system operation
- Operation & maintenance of R.T.U s and A.C.C s.
- Maintenance of Mimic board and console.
- Monthly operational report.
- Monthly interruption report.
- Preparation of economic order of generators (Annual).

1.4 C. Operation & maintenance of communication system.

Under the supervision of General Manager (System Operation), Communication Circle is headed by a Deputy General Manager who is performing the following operations:

- O & M of power line carrier communication system of PGCB and OPGW communication in future.
- O & M of different types of PLC sets used in PGCB.
- O & M of different types of exchanges used in PGCB.
- O & M of coupling system , battery and battery charger etc

1.4 D. Protection, relay co-ordination of Transmission System.

Under the supervision of General Manager (P&D), SPMC is headed by a Deputy General Manager and are performing the following jobs:

- Relay Testing and Co-ordination
- Annual maintenance of Relays
- Troubleshooting of protection and control system,
- Pre commissioning test & commissioning of Grid S/S and transmission lines,
- Auto load shedding scheme planning and implementation,
- Energy meter testing & calibration.

1.4 E. Design & evaluation.

Under the supervision of General Manager (P & D), Design Circle is headed by a Deputy General Manager who is performing the following jobs:

- Preparation of Technical specification of substation equipments, tower, conductors, insulators etc.
- Preparation of Tender Documents, Technical Specifications, Contractor Qualification, Condition for Execution of works etc.
- Evaluation of Tender Documents.
- Drawing approvals.
- Testing and Commissioning.
- O & M Technical Support.

1.4 F. Transmission network planning.

Under the supervision of General Manager (P & D), Planning Circle is headed by a Deputy General Manager is performing the following jobs.

- Load forecasting
- Load flow and short circuit analysis
- Future expansion planning.
- System problem analysis.
- Management Information System (MIS) compilation.
- In house study of new projects.
- Preparation of Development Project Proforma (DPP).
- Annual development program.
- Rolling investment program.
- Progress report of development projects.

1.4 G. Implementation of development projects.

Under the supervision of General Manager (Projects), five Project Offices each headed by a Project Director and Deputy General Manager is performing the following jobs:

- Project implementation planning.
- Finalization of work program which includes the following:
  - Each stage of design
  - Procurement
  - Manufacturer delivery to site
  - Construction

    - Erection
    - Testing and commissioning etc.
- Supervision of progress.
- Approval of drawings and documents.
- Work execution and inspection.
- Testing and Commissioning.
- Preparation of project completion report.

1.5 Substations Category

A) 230 KV SUB-STATIONS

B) 132/33 KV SUB-STATIONS

C) 400/230/132 KV SUB-STATIONS

INTERNSHIP OVERVIEW

1.6 Objective of the Internship

The objective of this internship is to know about how a substation works. How it can be operate. To gain a practical knowledge about circuit breaker, current transformer, voltage transformer, transformer, bus bar, wave trap etc. As well as we want to know about how a transmission line will be setup instead of Bangladesh.

Chapter 02

Substation and their classification

2.1 Sub-station:

The assembly of apparatus used to change some characteristics of electric power supply e.g. voltage, ac to dc, frequency, power factor etc is called sub-station.

2.1.1 Classification of sub-stations:

2.1.1. A) According to the service requirement:

i) Transformer substation: change voltage level.
ii) Switching sub-station: perform switching operation.
iii) Power factor correction substation: Improves power factor.
iv) Frequency changer sub-station: changes frequency.
v) Converting sub-station: ac to dc or dc to ac conversion.
vi) Industrial sub-station: substation for industries.

2.1.1. B) According to constructional feature:

Indoor sub-station: up to 11kv.

Outdoor sub-station:66kv or above.

Underground sub-station: Suitable for densely populated area.

Pole mounted sub-station: usually up to 11kv.

2.2 Comparison between indoor and outdoor substation:

particular	Outdoor substation	Indoor substation
Space requirement	More	less
Time required for erection	Less	More
Future Extension	Easy	Difficult
Fault location	Easy	Difficult
Capital cost	Low	High
operation	Difficult	Easy

Table 2: Comparison between Indoor and Outdoor Substation

2.3 Single

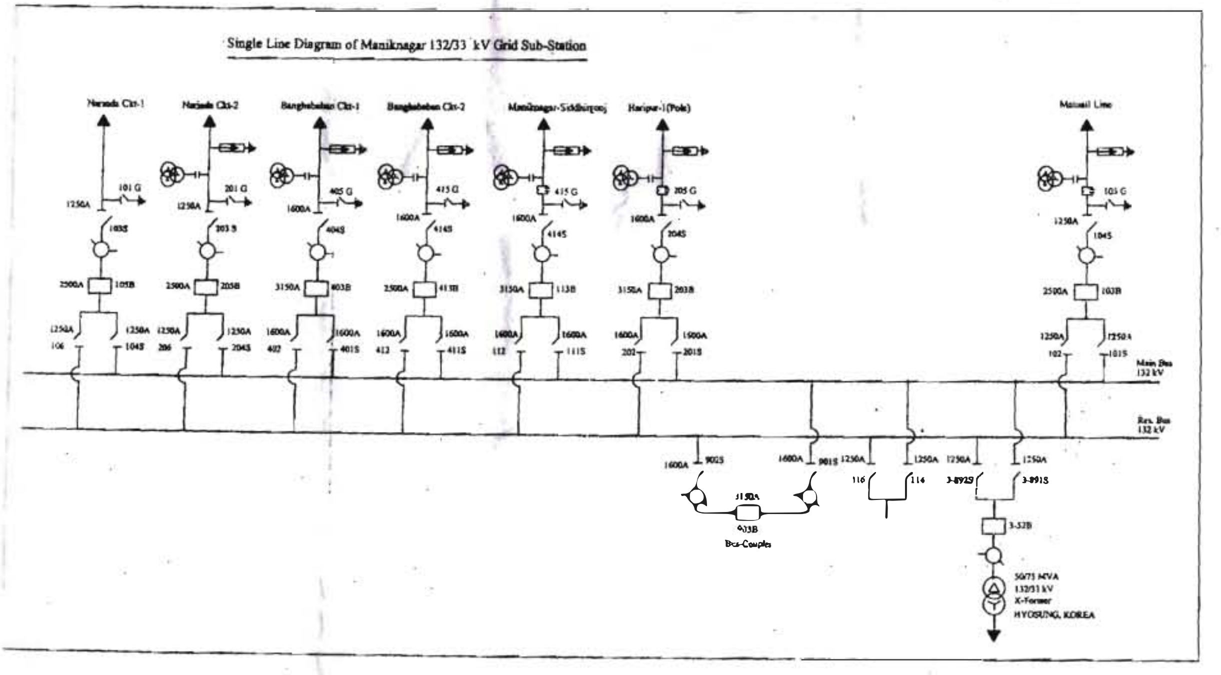

Fig: Single line diagram of Maniknagar 132KV/33KV substation

Single line diagram is the basic circuit diagram of a substation. The relative locations of CB, isolators and bus bars follow the general practice and particular switching requirement and maintenance and protection requirement. The reasoning should be understood and safety operation, maintenance, protection and control requirements must be satisfied.

2.4 Transformer:

There are two transformer used in Maniknagar substation to transform the voltage from 132kv to 11kv.In the first stage 132kv is transform to 66kv and in the second stage 66kv is transform to 11kv.

Chapter 3

Overhead line

3.1 Components of overhead lines:

1) Conductors.
2) Supporters.
3) Insulator.

3.2 Conductor: Conductor carries electrical power from sending end to receiving end. Conductor cost is the most vital cost of the total transmission cost. Therefore proper choice of the material and size of the conductor is considerable Importance. So, the conductor used for transmission and distributions of electrical power have the following properties:

i) High electrical conductivity.
ii) High tensile strength in order to withstand mechanical stress.
iii) Low cost so that it can be used for long distances.
iv) Low specific gravity so that weight per unit volume is small.

3.2.1 Commonly used conductor material:

1) Copper.

2) Aluminum.

3) Steel cord aluminum.

4) Galvanized steel.

5) Cadmium copper.

3.2.1A) Copper: copper is an ideal materials for overhead lines because of its high electrical conductivity and greater tensile strength. Copper has high current density that is the current carrying capacity of the copper per unit of cross-sectional area is quit large. It has two advantages. Firstly, smaller cross-sectional area is required and secondly, the area offered by the conductor to wind load is reduced.

Due to its higher cost and non availability it is rarely used for this purposes.so, aluminum is used in place of copper.

3.2.1B) Aluminum:

Aluminum is cheap and light as compared to copper but it has smaller conductivity and tensile strength.

3.2.1C) Comparison between aluminum and copper:

1) The conductivity of aluminum is 60 percent of copper. Smaller conductivity means that cross-sectional area of the conductor must be larger in aluminum than in copper. Diameter of the aluminum conductor is about 1.26 times higher than the diameter of the copper conductor.
2) Copper has more weight than the aluminum. So, the supporters or towers made for copper should be stronger.
3) Due to lower tensile strength the sag is greater in aluminum conductors.

Considering cost, conductivity, tensile strength, weight aluminum has greater advantage over copper. That's why it is widely used in heavy current transmission.

3.2.1D) Steel cored aluminum:

Due to low tensile strength, aluminum conductor produces greater sag. To increase sag aluminum conductor is reinforced with a core of galvanized steel wires.

The steel cored aluminum conductors have the following advantages:

i) The reinforced with steel increases the tensile strength but at the same time keeps the composite conductor light. Therefore, steel cored aluminum conductors will produce smaller sag and hence longer spans can be used.

ii) Due to smaller sag with steel cored aluminum conductors, towers of smaller heights can be used.

3.2.1E) Galvanized steel:

Steel has very high tensile strength .Therefore galvanized steel conductor used for long span or for short line section exposed too abnormally high stresses due to climate condition. Due to poor conductivity and high resistance such conductor are not suitable for long distance. They are suitable in rural areas where cheapness is the main consideration. However, they can be used to advantage for transmitting a small power over a small distance where the size of the copper conductor desirable from economic considerations would be too small and thus unsuitable for use because of poor mechanical strength.

3.2.1F) Cadmium copper:

The conductor material now being employed in certain cases is copper alloyed with cadmium. An addition of 1or 2 percent cadmium to copper increases the tensile strength by about 50 percent and the conductivity is only reduced by 15 percent below that of pure copper. Therefore, cadmium copper conductor can be useful for exponentially long spans. Due to high cost of cadmium, such conductors will be economical only for lines of small cross-section where the cost of conductor material is comparatively small compared with the cost of supporters.

3.2.1G) Choice of conductor size and transmission voltage is important:

Choice of the conductor size and transmission voltage is important because it involved the total transmission cost.

Conductor cost is the most vital cost of the total transmission cost. The most economical area of the conductor for which the total transmission cost of minimum is called Kelvin's law.

The total cost of the transmission line can be divided into two parts

Annual charge on capital outlay = p1+p2...... (iii)

Where, p1 = insulation cost.

P2*a = conductor cost.

a = Cross section of the conductor.

Annual cost of energy wasted = p3/a... (iv)

As resistive loss is inversely proportional to the cross-section of the conductor, Therefore,

Total annul cost = p1+p2+ p3/a.

For minimum cost, dc/da = 0

=> d/ da (p1+p2+ p3/a) = 0

=> p2-p3/a^2=0

a = √ (p3/p2).

Graphical Illustration of Kelvin's low:

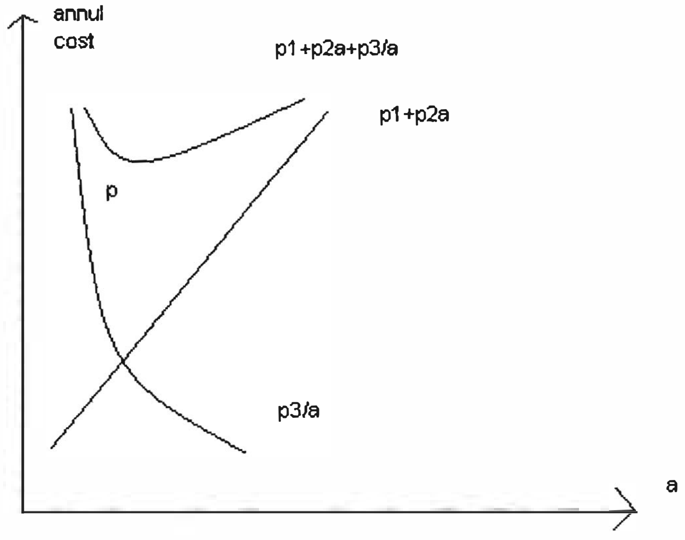

Figure 01: Graphical Illustration of Kelvin's Law

Most economical conductor size is the ap and the corresponding annul cost is p.

.3.3 Line supporters:

The supporting structures for overhead line conductors are various types of poles and towers called line supporters. Line supporters should have the following properties:

i) High mechanical strength to withstand the weight of conductors and wind loads etc.
ii) Light in weight without the loss of mechanical strength.
iii) Cheap in cost and Economical to maintain.
iv) Longer life.
v) Easy accessibility of conductors for maintaince.

There are many types of line supporters or towers are used in transmission line. Most commonly used supporters used in transmission lines are wooden poles, steel poles, and RCC poles.

3.3.1 Wooden poles:

These are made of seasoned wood and are suitable for lines of moderate cross-sectional area and of relatively shorter spans say up to 50meters.such supporters are cheap easily available, provide insulating properties and therefore are widely used for distribution purposes in rural areas as an economical proposition.

But these types of supporters are not suitable all cases because of many reasons. Reasons are:

i) Smaller life.
ii) Can not be used for voltage Higher than 20kv.
iii) Less mechanical strength.
iv) Tendency to root below the ground level.
v) Require periodical Inspection.

3.3.2 Steel poles:

The steel poles are often used as a substitute for wooden poles. They posses greater mechanical strength, longer life and permit longer span to be used. Such poles are generally used for distribution purposes for cities. This type of supports need to be galvanized or pained in order to prolong its life.

3.3.3 RCC (reinforced concrete poles) poles:

These types of poles are very popular and widely used as line supports in recent year. They have greater mechanical strength, longer life and permit longer spans than steel poles. Moreover, they give good outlook; require little maintaince and have good insulating properties. The holes in the poles facilate the climbing of poles and at the same time reduce the weight of line supports.

The main difficulty with the use of these poles is the high cost of transport owing to their heavy weight. Therefore, such poles are often manufactured at the site in order to avoid heavy cost of transportation.

3.3.4 Steel tower:

In practice, wooden poles, steel poles and RCC (reinforced concrete poles) poles are used for distribution purposes at low voltages say up to 11kv.however, for long distance transmission at higher voltage, steel towers are invariably employed. Steel tower have greater mechanical strength, longer life, can withstand most severe climate condition and permit the use of longer span. This minimizes the lighting travel as each tower acts as a lighting conductor.

3.4 Insulator:

The overhead line conductors should be supported on the poles or towers in such way that current from conductor do not flow to the earth through supports that is line conductor must be properly insulated from supports this is achieved by securing line conductor to supports with the help of the insulator.

The insulator provides necessary insulation between line conductors and supports and thus prevents any leakage current from conductors to earth. Insulator should have the following properties:

i. High mechanical strength in order to withstand conductor load, wind load etc.
ii. High electrical resistance of insulator material in order to avoid leakage current.
iii. High relative permittivity of insulator material in order to avoid leakage currents to earth.
iv. The insulator material should be non-porous; free from impurities and cracks otherwise the permittivity will be lowered.
v. High ratio of puncture strength to flashover.

The most commonly used material for insulators of overhead lines is porcelain but glass, steatite and special composition materials are also used to a limit extent. Porcelain is produced by firing at a high temperature a mixture of kaolin, feldspar, quartz. It is stronger mechanically than glass, gives less trouble from leakage and is less affected by changes of temperature.

3.4A) Types of Insulator:

There are many types of insulator. The most commonly used insulators are describe in below:

1. **Pin type insulator:**

Pin type insulators are used for transmission and distribution of electrical power at voltages up to 33kv.Beyond operation of 33kv, the pin type insulators become too bulky and hence uneconomical.

Causes of insulator failure:

Insulators are required to withstand both mechanical and electrical stresses. The latter type is primarily due to line voltage and may cause breakdown of the insulator. The electrical breakdown of insulator can occur by flash over. In flash over an arc occur between the line conductor and insulator pin and the discharge jump across the airgap.In case of flashover, the insulator will continue to act in its proper capacity unless extreme heat produced by the arc destroy the insulator.

In cause of puncture the discharge occur from conductor to pin through the body of the insulator. When such breakdown is involved, the insulator is permanently destroyed due to excessive heat. In practice, sufficient thickness of porcelain is provided in the insulator to avoid puncture by the line voltage. The ratio of puncture strength to flashover the voltage is known as safety factor.

Safety factor of the insulator = puncture strength /flash-over voltage.

It is desirable that the value of safety factor is high so that flash over takes place before the insulator gets punctured. For pin insulators, the value of safety factor is about 10.

2. Suspension type insulators:

The cost of pin type insulator increases rapidly as the working voltage is increased.Therefore, this type of insulator is not economical beyond 33kv.for voltage above 33kv, it is a usual practice to use suspension type insulator. They consist of number of a number of porcelain discs connected in series by metal links in the form of string. The conductor is suspended at the bottom end of this string while the other end of the string is secured to the cross-arm of the tower. Each unit or disc is designed for low voltage; say 11kv.the number of disc in series would obviously depend upon the working voltage.

Advantages of suspension type insulator:

i) Suspension type insulators are cheaper than pin type insulators for voltages beyond 33kv.

ii) Each unit or disc of suspension type insulator is designed for low voltage usually 11kv.Depending upon the working voltage; the desired number of disc can be connected in series.

iii) If any one disc is damaged, the whole string does not become useless because the damaged disc can be replaced by the sound one.

iv) The suspension arrangement provides greater flexibility to the line. The connection at the cross-arm is such that insulator string is free to swing in any direction and can take up the position where mechanical stresses are minimum.

v) In case of increased demand on the transmission line, it is found more satisfactory to supply the greater demand by raising the line voltage than to provide another set of conductors. The additional insulation required for the raised voltage can be easily obtained in the suspension arrangement by adding the desired number of discs.

vi) The suspension type insulators are generally used with steel towers. As the conductors run below the earthed cross-arm of the tower. Therefore, this arrangement provides partial protection from lighting.

2. **Strain Insulators:**

When there is a dead end of the line or there is corner or sharp curve, the line is subjected to greater tension. In order to relieve the line of excessive tension, strain insulators are used. For low voltage lines, shakle insulators are used as strain insulators. However, for high voltage transmission lines, strain insulators consist of an assembly of suspension insulators. The disc of strain insulators are used in the vertical plane. When the tension in lines is exceedingly high, as at long river spans, two or more strings are used in parallel.

3. **Shackle insulators:**

In early days the shackle insulator are used as strain insulator. But now days they are frequently used in low voltage distribution lines. Such insulator can be used either in horizontal position or in a Vertical position.

They can be directly fixed to the pole with a bolt or to the cross arm. The conductor in the groove is fixed with a soft binding wire.

3.4B) Sag in overhead lines:

The difference in level between points of supports and the lowest point on the conductor is called sag.

While erecting an overhead line, it is important those conductors are under tension. If the conductors are too much stretched between supports in a bid to save conductor material then the stress in conductor may be reach unsafe value and in certain cases the conductor may break due to excessive tension. In order to permit safe tension in the conductors, they are not fully stretched but are allowed to have a dip or sag.

Conductor sag and tension:

This is an important consideration in the mechanical design of overhead lines. The conductor sag should be kept to a minimum in order to reduce the conductor material required and to avoid extra pole height for sufficient clearance above ground level. It is also to permit the use of less strong supports. However, low conductor tension and minimum sag are not possible. It is because low sag means a tight wire and high tension, whereas a low tension means o loose wire and increase sag. Therefore in practical case a compromise in made between the two.

Calculation of sag:

In overhead lines, the sag should be adjusted that tension in the conductor is within safe limits. The tension is governed by conductor weight, effects of wind, ice loading and temperature variations.

Sag and tension of a conductor when supports are at equal level:

Consider a conductor between two equalize supports A and B with O as the lowest shown in fig. it can be prove that lowest will be at mid-span.

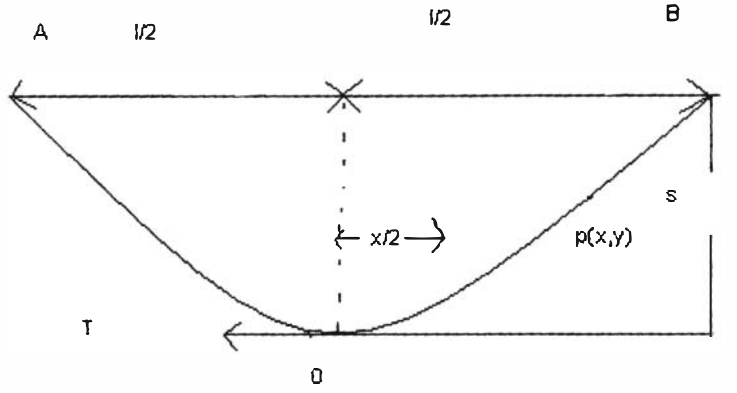

Figure02: Sag Calculation

Let, l = length of span

W= weight per unit length of conductor.

T= tension in the conductor.

Consider a point p on the conductor. taking the lowest point 0 as the origin, let the co-ordinates of point p be x and y.assuming that the curvature is so small that curved length is equal to its horizontal projection, the two forces acting on the portion op of the conductor are :

a) The weight wx of conductor acting at a distancex/2 from 0.
b) The tension t acting at 0.

Equating the moments of above forces about point zero, we get,

$$Ty = wx*x/2$$

Or, $$y= wx^2/2T$$

The maximum sag is represented by the value of y at either of the supports A and B.

At support A, x = l/2;

Y= s.

Sag, $S = w*(l/2)^2/2T$

$= w*l^2/8*T.$

When supports are at unequal levels:

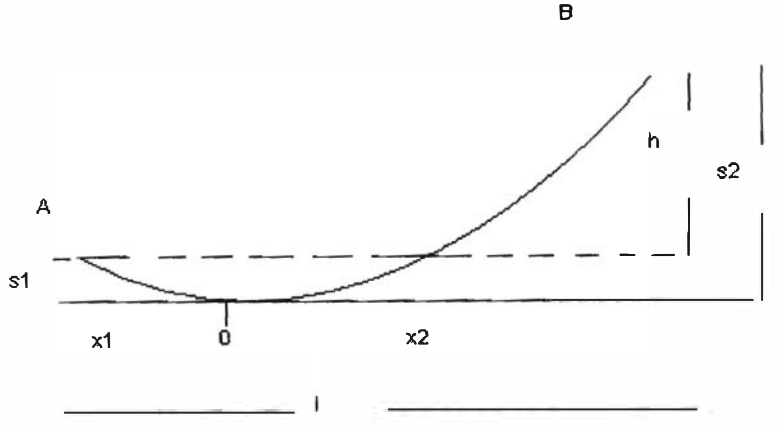

Fig 03: Sag at unequal levels

In hilly areas, we generally come across conductors suspended between supports at unequal levels fig2 shows that a conductor suspended between two supports A and B which are at different levels. The lowest point on the conductor is 0.

Let,

l = span length.

H =difference in levels between two supports.

X1 =distance of support at lower level from 0.

X2=distance of support at higher level from 0.

T = tension in the conductor.

If w is the weight per unit length of the conductor, then,

Sag, s1 $=w*x1^2*/2T$

Sag, s2 $=w*x2^2/2T$

$x1+x2=l$ .... (i)

$*y=w*x^2/2T$

At support A, x=x1 and y=s1

$S1=w*x1^2/2T$

Now, $s2-s1= (w/2*T)*(x2^2-x1^2)$

$= (w/2*T)*(x2+x1)*(x2-x1)$

$= (w*l/2*T)*(x2-x1)$

But, s2-sl = h.

$h = (w*l/2*T)*(x2-x1)$

or, $x2-x1 = (2*T*h)/(w*l)$ . . . . (ii)

Solving equation (i) and (ii),

$x1 = (l/2)-(T*h/w*l)$.

$x2 = (l/2)-(T*h/w*l)$

Having found x1 and x2 values of sl and s2 can be easily calculated.

Chapter4

Current and potential transformer

4.1 Current transformer:

In electrical engineering a current transformer (CT) is used for measurement of electric currents. Current transformers, together with voltage transformers (VT) (potential transformers (PT)), are known as instrument transformers. When current in a circuit is too high to directly apply to measuring instruments, a current transformer produces a reduced current accurately proportional to the current in the circuit, which can be conveniently connected to measuring and recording instruments. A current transformer also isolates the measuring instruments from what may be very high voltage in the monitored circuit. Current transformers are commonly used in metering and protective relays in the electrical power industry

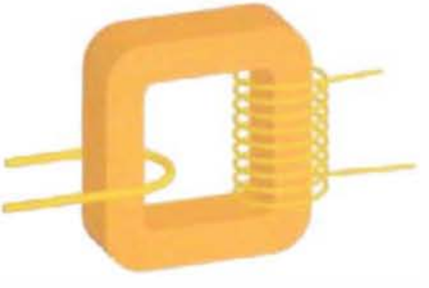

Figure 04: Current Transformer(CT)

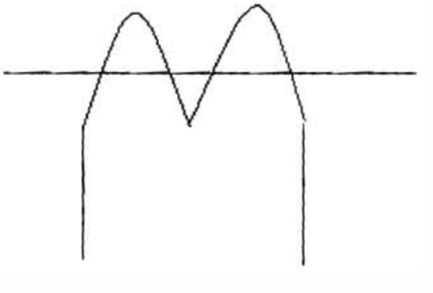

Figure 05: Symbol of a CT

4.2 Instrument Potential Transformer: The instrument potential transformer (PT) steps down voltage of a circuit to a low value that can be effectively and safely used for operation of instruments such as ammeters, voltmeters, watt meters, and relays used for various protective purposes.

Figure6: Potential Transformer (PT).

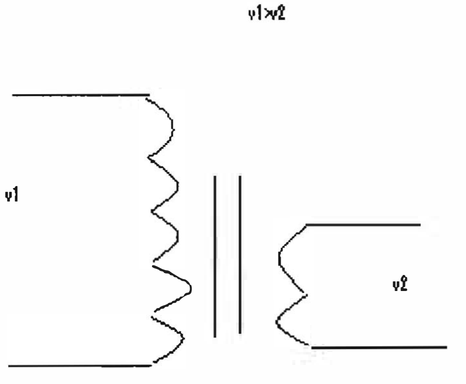

Figure7: Symbol of PT

4.3 Difference between CT (current transformer) and potential transformer (PT):

A transformer is a device that steps up, or steps down voltage. During this process current is also stepped up or down. However, voltage and current are inversely proportional (meaning an increase in voltage results in a decrease in current and vice versa) As an example: A step up transformer of 10:1 ratio with 12 volts and 10 ampere of current applied to the primary will have ten times the voltage (120 volts) and ten times less current (1 ampere) at the secondary...and a step down transformer with the same turns ratio with 120 volts and 1 ampere applied to the primary will have 12 volts and ten ampere available at the secondary. The electricity supplied into homes and business uses wires carrying very high voltage and low current over long distances, then uses step down transformers to step down the voltage and step up the current.

However, in power engineering and protective relaying applications, there are what are called "instrument transformers" which have the specific purpose of providing information to devices (such as relays or meters) about the voltages or currents in the power system. Therefore, there are some differences in construction and connectivity between a Current Transformer (CT) and a Voltage (or Potential) Transformer (PT).

A CT will typically have a toroidal core and evenly distributed secondary windings so as to minimize leakage reactance. The primary is typically the main power line conductor, which passes directly through the toroidal core. This type of transformer is specifically for the purpose of measuring current values, and the secondary windings cannot be left open-circuited, or a large voltage will be produce, resulting in dielectric failure (and often an explosion). If a device is not connected to the CT, its secondary must be short-circuited.

A PT is connected between the main conductor and ground and can be either wound in the normal way, or the voltage can be taken from a subsection of a string of capacitors (this is called a Capacitive Voltage Transformer or CVT, and is usually cheaper than the wound type, but is typically not as accurate). This type of transformer measures voltage values, and the secondary winding cannot be short-circuited, as this will produce excessively high currents, resulting in the failure of the PT or the wires it is connected to. A PT can be left open-circuited.

Chapter5

Underground cable

5.1 Underground cable:

An underground cable essentially consists of one or more conductors covered with suitable insulation and surrounded by a protecting cover.

Underground cable should have the following properties:

(i) Copper or aluminum conductor for good conduction.
(ii) Economical cross-section.
(iii) Proper insulation thickness.
(iv) Armoring may be required for better mechanical strength.
(v) Should not be corrosive.

5.2 Construction of cable:

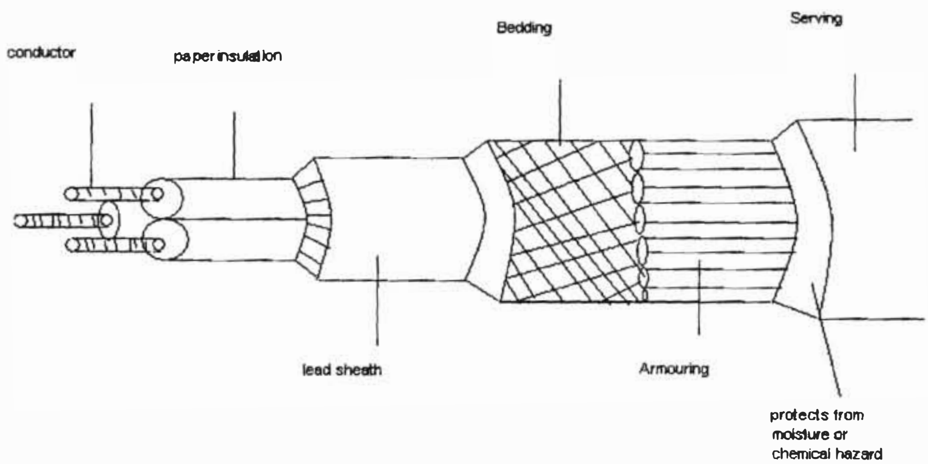

Figure8: Construction of Cable

Conductor:

Conductor may be one core more core depend upon the type of service for which it is intend.

Insulation:

Each core or conductor is provided with a suitable thickness of insulation. The thickness of the layer depends upon the voltage to be withstood by the cable.

Bedding:

Jute or hessian type for the placement of the metallic armoring.

Armoring:

Metal for better mechanical strength.

Serving:

Protects armoring from atmospheric condition.

5.3 Insulating material for cable should have the following properties:

i) High insulation resistance to avoid the leakage current.
ii) High dielectric strength to avoid the electrical breakdown of cable.
iii) High mechanical strength to withstand the mechanical handling of cables
iv) Non-hygroscopic that means it should not absorb moisture from air and soil. In case of insulating material is hygroscopic, it must be enclosed in a waterproof covering like lead sheath.
v) Non-inflammable.
vi) Unaffected by acid or alkalis to avoid any chemical action.

Insulating material those satisfy the requirements:

(i) Rubber: Relative permittivity-varying between 2 and 3.

Dielectric strength is about 3kv/mm

Receptivity of insulation10^17Ωcm.

But the major drawbacks are that it absorbs moisture and maximum safe temperature is low (about 38 deg Celsius).

(ii) Vulcanized India rubber (V.I.R):

Pure rubber cannot be used as insulating material that's why mineral material such as zinc oxide, red lead and 3 to 5% of sulphur is mixed with the pure rubber. The whole process is called vulcanization.vulcanised India rubber has greater mechanical strength, durability and wears resistive proper than India rubber.

Its main drawback is that sulphur reacts very quickly with the copper. VIR is generally use for low and moderate voltage cable.

(iii) Impregnated paper

Impregnated paper has high insulation resistance, high dielectric strength, low cost and low capacitance. The only disadvantage is that paper is hygroscopic. It absorbs moisture and decrease the insulation resistance.

(iv) Varnished cambric:

It is a cotton cloth impregnated and coated with varnish. This type of Insulation is also known as empire tape. Varnished cambric is hygroscopic .Its dielectric strength is about 4kv/mm and permittivity is 2.5 to 3.8.

(vi) PVC(polyvinyl chloride):

PVC (polyvinyl chloride) has high insulation resistance, good dielectric strength and mechanical toughness over a wide range of temperature. This type of insulation is preferred over VIR in extreme environmental condition such chemical factory, cement. As the mechanical property of the PVC are not as good as rubber. Therefore, PVC insulated cables are generally used for low and medium domestic lights and power installations.

5.4 Classification of cable:

i) Low tension(LT) – up to 1kv
ii) High tension(HT) – up to 11kv
iii) Super tension (ST) – 22-33kv.
iv) Extra high tension (EHT) – 33-66kv.
v) Extra super high tension (ESHT) – beyond 132kv.

Chapter6

Circuit breaker

6.1 Circuit breakers:
A circuit breaker is a piece of equipment which can

i) Make or break a circuit either manually or by remote control under normal conditions
ii) Break a circuit automatically under fault conditions
iii) Make a circuit either manually or by remote control under fault conditions.

Thus a circuit breaker incorporates manual as well as automatic control for switching functions. The latter control employs relays and operates only under fault conditions.

6.2 Operating Principle:

A circuit breaker essentially consists of fixed and moving contacts, called electrodes. Under normal operating conditions, these contacts remain closed and will not open automatically until and unless the system becomes faulty. Of course, the contacts can be opened manually or by remote control whenever desired. When a fault occurs on any part of the system, the trip coils of the circuit breaker get energized and the moving contacts are pulled apart by some mechanism, thus opening the circuit.

When the contacts of a circuit breaker are separated under fault conditions, an arc is stuck between them. The current is thus able to continue until the discharge ceases. The production of arc not only delays the current interruption process but it also generates enormous heat which may cause damage to the system or to the circuit breaker itself. Therefore, the main problem in a circuit breaker is to extinguish the arc within the shortest possible time so that heat generated by it may not reach a dangerous value.

6.3 Arc Phenomenon:

When a short circuit occurs, a heavy current flows though the contacts before they are opened by the protective system. At the instant when the contacts begin to separate, the contact area decreases rapidly and large fault current density and hence rise in temperature. The heat produce in the medium between contacts is sufficient to ionize the air or vaporize and ionize the oil. The ionized air or vapor acts as conductor and an arc is stuck between the contacts. The p.d. between the contacts is quite small and is just sufficient to maintain the arc. The arc provides a low resistance path and consequently the current in the circuit remains uninterrupted so long as the arc persists.

During the arcing period, the current flowing between the contacts depends upon the arc resistance. The greater the arc resistance, the smaller the current that flows between contacts. The arc resistance depends upon the following factors;

i) Degree of ionization- the arc resistance increases with the decreases in the number of ionized particles between the contacts.
ii) Length of the arc- the arc resistance increases with the length of the arc i.e., separation of contacts.
iii) Cross-section of arc- the arc resistance with the decreases in area of X-section of the arc.

6.3A) Principles of Arc Extinction:

Before discussing the methods of arc extinction, it is necessary to examine the factors responsible for the maintenance of arc between the contacts. These are:

i) P.d between the contacts.
ii) Ionized particles between contacts.

Taking these in turn,

i) When the contacts have a small separation, the p.d between them is sufficient to maintain the arc. One way to extinguish the arc is to separate the contacts to such a distance the p.d becomes inadequate to maintain the arc. However, this method is impracticable in high voltage system where a separation of many meters may be required.
ii) The ionized particles between the contacts tend to maintain the arc. If the arc path is deionised, the arc extinction will be facilitated. This may be achieved by coding the arc or by bodily removing the ionized particles from the space between the contacts.
iii)

6.3B) Methods of Arc Extinction:

There are two methods of extinguishing the arc in circuit breakers viz.

1. High resistance method.
2. Low resistance or current zero method.

1. **High resistance method:** In this method, the arc resistance is made to increase with time so the current is reduced to a value insufficient to maintain the arc. Consequently, the current is interrupted or the arc is extinguished. The principle disadvantage of this method is that enormous energy is dissipated in the arc. Therefore, it is employed only in d.c. circuit breakers and low-capacity a.c. circuit breakers.

   The resistance of the arc may be increased by:

   i) *Lengthening the arc:* The resistance of the arc is directly proportional to its length. The length of the arc can be increased by increasing the gap between contacts.

ii) *Cooling the arc:* Cooling helps in the deionization of the medium between the contacts. The increases the arc resistance. Efficient cooling may be obtained by a gas blast directed along the arc.

iii) *Reducing X-section of the arc:* If the area of X-section of the arc is reduced, the voltage necessary to maintain the arc is increased. In other words, the resistance of the arc path is increased. The cross-section of the arc can be reduced by lettering the arc pass through a narrow opening or by having smaller area of contacts.

iv) *Splitting the arc:* the resistance of the arc can be increased by splitting the arc into a number of smaller arcs in series. Each one of these arcs experiences the effect of lengthening and cooling. The arc may be split introducing some conducting plates between the contacts.

Low **Resistance or Current zero method**: This method is employed for arc extinction in a.c. circuits only. In this method, arc resistance is kept low until current is zero where the arc extinguishes naturally and is prevented from restriking in spite of the rising voltage across the contacts. All modern high power a.c. circuit breakers employ this method for arc extinction.

In an a.c. system, current drops to zero after every half cycle. At every current zero, the arc extinguishes for brief moment. Now the medium between the contacts contains ion and electrons so that it has small dielectric strength and can be easily broken down by the rising contact voltage known as restiking voltage. If such a breakdown does occur, the arc will persist for another half cycle. If immediately after current zero, the dielectric strength of the medium between contacts is built up more rapidly than the voltage across the contacts, the arc fails to restrike and the current will be interrupted. The rapid increase of dielectric strength of the medium near current zero can be achieved by:

a) Causing the ionized particles in the space between contacts to recombine into neutral molecules.
b) Sweeping the ionized particles away and replacing them by un-ionized particles.

Therefore, the real problem in a.c. arc interruption is to rapidly deionize the medium between contacts as the current becomes zero so that the rising contact voltage or restiking voltage cannot breakdown the space between contacts. The de-ionization of the medium can be achieved by:

i) *Lengthening of the gap:* The dielectric strength of the medium is proportional to the length of the gap between contacts. Therefore, by opening the contacts rapidly, higher dielectric strength of the medium can be achieved.

ii) *High Pressure:* If the pressure in the vicinity of the arc is increased, the density of the particles constituting the discharge also increases. The increases density of the particles cause higher rate of de-ionisation and consequently the dielectric strength of the medium between contacts is increased.

iii) *Cooling:* Natural combination of ionized particles takes place more rapidly if they are allowed to coo. Therefore, dielectric strength of the medium between contacts can be increased by cooling the arc.

iv) *Blast effect:* If the ionized particles between the contacts are swept away and replaced by un-ionized particles, the dielectric strength of the medium can be increased considerably. This may be achieved by a gas blast directed along the discharge or by forcing oil into the contact space.

Important Terms:

The following are the important terms much used in the circuit breaker analysis:

i) **Arc voltage:** It is the voltage that appears across the contacts of the circuit breaker during the arcing period.

As soon as the contacts of the circuit breaker separate, the arc is formed. The voltage that appears across the contacts during arcing period is called the arc voltage. Its value is low expected for the period the fault current is at or near zero current point. At current zero, the arc voltage rises rapidly to peak value and this peak voltage tends to maintain the current flow in the form of arc.

ii) **Restriking voltage:** It is the transient voltage that appears across the contacts at or near current zero during arcing period.

At current zero, a high frequency transient voltage appears across the contacts and is caused by the rapid distribution of energy between the magnetic and electric fields associated with the plant and transmission lines of the system. This transient voltage is known as resriking voltage. The current interruption in the circuit depends upon this voltage. If the restriking voltage rises more rapidly than the dielectric strength of the medium between the contacts, the arc will persist for another half cycle. On the other hand, if the dielectric strength of the medium builds up more rapidly than the restriking voltage, the arc fails to restrike and the current will be interrupted.

iii) **Recovery voltage:** It is the normal frequency (50Hz) R.M.S. voltage that appears across the contacts of the circuit breaker after final arc extinction. It is approximately equal to the system voltage.

When contacts of circuit breaker are opened, current drops to zero after every half cycle. At some contact zero, the contacts are separated sufficiently apart and dielectric strength of the medium between the contacts attains a high value due to the removal of ionized particles. At such an instant, the medium between the contacts is strong enough to prevent the breakdown by the restriking voltage. Consequently, the final arc extinction takes place and circuit current is interrupted. Immediately after final current interruption, the voltage that appears across the contacts has a transient part. However, these transient oscillations subside rapidly due to the damping effect of system resistance and normal circuit voltage appears across the contacts. The voltage across the contacts is of normal frequency and is known as recovery voltage.

-.4 Types of circuit breaker:

F..nt panel of a 1250 A air circuit breaker manufactured by ABB. This low voltage power . rcuit breaker can be withdrawn from its housing for servicing. Trip characteristics are . nfigurable via DIP switches on the front panel.

Many different classifications of circuit breakers can be made, based on their features such as . oltage class, construction type, interrupting type, and structural features.

-.4A) Low voltage circuit breakers:

_ow voltage (less than 1000 V_{AC}) types are common in domestic, commercial and industrial application, include:

- MCB (Miniature Circuit Breaker)—rated current not more than 100 A. Trip characteristics normally not adjustable. Thermal or thermal-magnetic operation. Breakers illustrated above are in this category.
- MCCB (Molded Case Circuit Breaker)—rated current up to 2500 A. Thermal or thermal-magnetic operation. Trip current may be adjustable in larger ratings.
- Low voltage power circuit breakers can be mounted in multi-tiers in LV switchboards or switchgear cabinets.

The characteristics of LV 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.

Large low-voltage molded case and power circuit breakers may have electrical motor operators, allowing them to be tripped (opened) and closed under remote control. These may form part of an automatic transfer switch system for standby power.

Low-voltage circuit breakers are also made for direct-current (DC) applications, for example DC supplied for subway lines. Special breakers are required for direct current because the arc does not have a natural tendency to go out on each half cycle as for alternating current. A direct current circuit breaker will have blow-out coils which generate a magnetic field that rapidly stretches the arc when interrupting direct current.

Small circuit breakers are either installed directly in equipment, or are arranged in a breaker panel.

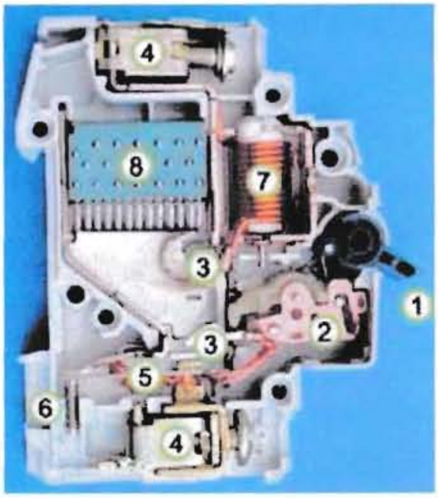

Figure9: side view of a circuit breaker

The 10 ampere DIN rail-mounted thermal-magnetic miniature circuit breaker is the most common style in modern domestic consumer units and commercial electrical distribution boards throughout Europe. The design includes the following components:

1. Actuator lever - used to manually trip and reset the circuit breaker. Also indicates the status of the circuit breaker (On or Off/tripped). Most breakers are designed so they can still trip even if the lever is held or locked in the "on" position. This is sometimes referred to as "free trip" or "positive trip" operation.
2. Actuator mechanism - forces the contacts together or apart.
3. Contacts - Allow current when touching and break the current when moved apart.
4. Terminals
5. Bimetallic strip
6. Calibration screw - allows the manufacturer to precisely adjust the trip current of the device after assembly.
7. Solenoid
8. Arc divider/extinguisher

6.4B) Magnetic circuit breaker:

Magnetic circuit breakers use a solenoid (electromagnet) whose pulling force increases with the current. Certain designs utilize electromagnetic forces in addition to those of the solenoid. The circuit breaker contacts are held closed by a latch. As the current in the solenoid increases beyond the rating of the circuit breaker, the solenoid's pull releases the latch which then allows the contacts to open by spring action. Some types of magnetic breakers incorporate a hydraulic time delay feature using a viscous fluid. The core is restrained by a spring until the current exceeds the breaker rating. During an overload, the speed of the solenoid motion is restricted by the fluid. The delay permits brief current surges beyond normal running current for motor starting, energizing equipment, etc. Short circuit currents provide sufficient solenoid force to release the latch regardless of core position thus bypassing the delay feature. Ambient temperature affects the time delay but does not affect the current rating of a magnetic breaker.

6.4C) Thermal magnetic circuit breaker:

Thermal magnetic circuit breakers, which are the type found in most distribution boards, incorporate both techniques with the electromagnet responding instantaneously to large surges in current (short circuits) and the bimetallic strip responding to less extreme but longer-term over-current conditions.

Common trip breakers:

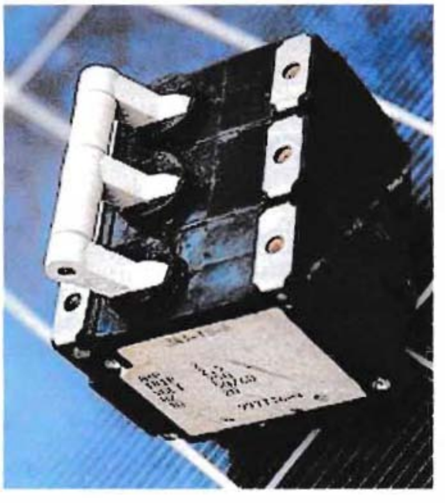

Figure 10: Three pole common trip breaker for supplying a three-phase load. This breaker has a 2A rating

When supplying a branch circuit with more than one live conductor, each live conductor must be protected by a breaker pole. To ensure that all live conductors are interrupted when any pole trips, a "common trip" breaker must be used. These may either contain two or three tripping mechanisms within one case, or for small breakers, may externally tie the poles together via their operating handles. Two pole common trip breakers are common on 120/240 volt systems where 240 volt loads (including major appliances or further distribution boards) span the two live wires. Three-pole common trip breakers are typically used to supply three-phase electric power to large motors or further distribution boards.

Two and four pole breakers are used when there is a need to disconnect the neutral wire, to be sure that no current can flow back through the neutral wire from other loads connected to the same network when people need to touch the wires for maintenance. Separate circuit breakers must never be used for disconnecting live and neutral, because if the neutral gets disconnected while the live conductor stays connected, a dangerous condition arises: the circuit will appear de-energized (appliances will not work), but wires will stay live and RCDs will not trip if someone touches the live wire (because RCDs need power to trip). This is why only common trip breakers must be used when switching of the neutral wire is needed.

4D) Medium-voltage circuit breakers:

Medium-voltage circuit breakers rated between 1 and 72 kV may be assembled into metal-enclosed switchgear line ups for indoor use, or may be individual components installed outdoors in a substation. Air-break circuit breakers replaced oil-filled units for indoor applications, but are now themselves being replaced by vacuum circuit breakers (up to about 35 kV). Like the high voltage circuit breakers described below, these are also operated by current sensing protective relays operated through current transformers. The characteristics of MV breakers are given by international standards such as IEC 62271. Medium-voltage circuit breakers nearly always use separate current sensors and protection relays, instead of relying on built-in thermal or magnetic overcurrent sensors.

Medium-voltage circuit breakers can be classified by the medium used to extinguish the arc:

- Vacuum circuit breaker—with rated current up to 3000 A, these breakers interrupts the current by creating and extinguishing the arc in a vacuum container. These are generally applied for voltages up to about 35,000 V,[4] which corresponds roughly to the medium-voltage range of power systems. Vacuum circuit breakers tend to have longer life expectancies between overhaul than do air circuit breakers.

- Air circuit breaker—rated current up to 10,000 A. Trip characteristics are often fully adjustable including configurable trip thresholds and delays. Usually electronically controlled, though some models are microprocessor controlled via an integral electronic trip unit. Often used for main power distribution in large industrial plant, where the breakers are arranged in draw-out enclosures for ease of maintenance.

- SF_6 circuit breakers extinguish the arc in a chamber filled with sulfur hexafluoride gas.

Medium-voltage circuit breakers may be connected into the circuit by bolted connections to bus bars or wires, especially in outdoor switchyards. Medium-voltage circuit breakers in switchgear line-ups are often built with draw-out construction, allowing the breaker to be removed without disturbing the power circuit connections, using a motor-operated or hand-cranked mechanism to separate the breaker from its enclosure.

High-voltage circuit breakers:

Figure11: 400 kV SF_6 live tank circuit breakers

Figure12: 115 kV bulk oil 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 breakers are nearly always solenoid-operated, with current sensing protective relays operated through current transformers. In substations the protection scheme can be complex, protecting equipment and busses from various types of overload or ground/earth fault.

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

- Bulk oil
- Minimum oil
- Air blast
- Vacuum
- SF_6

Some of the manufacturers are ABB, GE (General Electric) , AREVA, Mitsubishi Electric, Pennsylvania Breaker, Siemens, Toshiba, Končar HVS, BHEL, CGL.

Due to environmental and cost concerns over insulating oil spills, most new breakers use SF_6 gas to quench the arc.

Circuit breakers can be classified as *live tank*, where the enclosure that contains the breaking mechanism is at line potential, or *dead tank* with the enclosure at earth potential. High-voltage AC circuit breakers are routinely available with ratings up to 765 kV. 1200KV breakers are likely to come into market very soon.

High-voltage circuit breakers used on transmission systems may be arranged to allow a single pole of a three-phase line to trip, instead of tripping all three poles; for some classes of faults this improves the system stability and availability.

6.5 Classification of circuit breakers:

There are several ways of classifying the circuit breakers. However, the most general way of classification is on the basis of medium used for arc extinction is usually oil, air, sulpher hexafluoride (SF_6) or vacuum. Accordingly, circuit breakers may be classified into:

i) *Oil circuit breakers* which employ some insulating oil for arc extinction.

ii) *Air blast circuit breakers* in which high pressure air blast is used for extinguishing the arc.

iii) *Sulpher hexafluoride circuit breakers* in which sulpher hexafluoride (SF_6) gas is used for arc extinction.

iv) *Vacuum circuit a breaker in which vacuum is* used for arc extinction.

Each type of circuit breaker has its own advantages and disadvantages. In the following sections, we shall discuss construction and working of these circuit breakers with special emphasis on the way the arc extinction is facilitated.

.5A) Sulpher hexafluoride (SF_6) circuit breakers:

In such circuit breakers, sulpher hexafluoride (SF_6) gas is used as the arc quenching medium. The SF_6 is an electro-negative gas and has a strong tendency to absorb free electrons. The contacts of the breaker are opened in a high pressure flow of SF_6 gas and an arc is stuck between them. The conducting free electrons in the arc are rapidly captured by the gas to form relatively immobile negative ions. The loss of conducting electrons in the arc quickly builds up enough insulation strength to extinguish the arc. The SF_6 circuit breakers have been found to be very effective for high power and high voltage service.

Why SF_6:

Sulfur Hexafluoride (SF6) is an excellent gaseous dielectric for high voltage power applications. It has been used extensively in high voltage circuit breakers and other switchgears employed by the power industry. Applications for SF6 include gas insulated transmission lines and gas insulated power distributions. The combined electrical, physical, chemical and thermal properties offer many advantages when used in power switchgears. Some of the outstanding properties of SF6 making it desirable to use in power applications are:

- ✓ High dielectric strength.
- ✓ Unique arc-quenching ability.
- ✓ Excellent thermal stability.
- ✓ Good thermal conductivity.

Constrnction:

The parts of a typical SF_6 circuit breaker. It consists of fixed and moving contacts enclosed in a chamber containing SF_6 gas. This chamber is connected to SF_6 gas reservoir. When the contacts of breaker are opened, the valve mechanism permits a high pressure SF_6 gas form the reservoir to flow towards the arc interruption chamber. The fixed contact is a hollow cylindrical current carrying contact fitted with the arc horn. The moving contact is also a hollow cylindrical with rectangular holes in the sides to permit the SF_6 gas to let out though these holes after flowing along and across the arc. The tips of fixed contact, moving contact and arcing horn are coated with copper-tungsten arc resistat material. Since SF_6 gas is costly, it sis reconditioned and reclaimed by suitable auxiliary system after each operation of the breaker.

Working principle:

In the closed position of the breaker, the contacts remain surrounded by SF_6 gas at a pressure of about 2.8kg/cm^2. When the breaker operates, the moving contact is pulled apart and an arc is stuck between the contacts. The movements of the moving contact s synchronized with the opening of a valve which permits SF_6 gas at 14 kg/cm^2 pressure from the reservoir to the arc interruption chamber. The high pressure flow of SF_6 rapidly absorbs the free electrons in the arc

...th to form immobile negative ions which are ineffective as charge carries. The result is that the ...edium between the contacts quickly builds up high dielectric strength and causes the extinction ...the arc. After the breaker operation, the valve is closed by the action of a set of springs.

...Mechanical Life and Maintenance of the Mechanism:

...imsan breaker mechanism can perform 10.000 opening-closing operations without changing ...y component. The mechanical life of the circuit breaker is minimum lO'.OOO operations. ...owever, it needs a periodical maintenance depending on its environment. In ideal working ...onditions, lubrication once a year or after every 1000 operations is sufficient. In dusty and damp ...nvironment, the mechanism should be lubricated once every 3 - 6 months or after every 250 - ...00 operations. Thin machine oil and grease with molybdenum must be used for lubricating. ...wing to mechanism's capability of operating between -5°C and + 40 °C, it does not require a ...eater.

Auxiliary Switch:

...he auxiliary switch mounted on the circuit breaker has 12 contacts. One of them is for ...ntidumping circuit; four of them are allocated for opening and closing coils. The remaining 7 contacts are spare. Three of them are normally opened and four are normally closed. When it is ...ecessary, the number of the contacts can be increased.

Rapid Automatic Reclosing:

The circuit breaker which opens due to a short circuit failure can be re-closed automatically after a pre selected time by arc closing relay, assuming the fault is temporary. Thus, we avoid long time power loss in case of temporary short circuits. But, if the fault lasts after re-closure, the protection relay will trip to open the circuit breaker again.

Advantages: Due to the superior arc quenching properties of SF_6 gas, the SF_6 circuit breakers have many advantages over oil or air circuit breakers. Some of them are listed below:

i) Due to the superior are quenching properties of SF_6 such circuit breakers have very short arcing time.
ii) Since the dielectric strength of SF_6 gas is 2 to 3 times that of air, such breakers can interrupt much large currents.
iii) The SF_6 circuit breakers give noiseless operation due to its closed gas circuit and no exhaust to atmosphere unlike the air blast circuit breaker.
iv) The closed gas enclosure keeps the interior dry so that there is no moisture problem.
v) There is no risk of fire in such breakers because SF6 gas is non inflammable.
vi) There is no carbon deposits so that tracking and insulation problems re eliminated.
vii) The SF_6 breakers have low maintenance cost, light foundation requirements and minimum auxiliary equipment.
viii) Since SF_6 breakers are totally enclosed and sealed from atmosphere, they are particularly suitable where explosion hazard exists e.g., coal mine.

Disadvantages:

SF_6 breakers are costly due to the high cost of SF_6.

Since SF_6 has to be reconditioned after every operation of the breaker, addition equipment is required for this purpose.

Application:

A typical SF_6 circuit breaker consists of interrupter units each capable of dealing with currents up to 60kVA and voltages in the range of 50-80-kV. A number of units are connected in series according to the system voltage. SF_6 circuit breakers have been developed for voltages 115kv to 230kV, power ratings 10MVA to 20 MVA and interrupting time less than 3 cycles.

6.5B) Air Blast Circuit Breakers:

These breakers employ a high pressure air blast as an arc quenching medium. The contacts are opened in a flow of air-blast established by the opening of blast valve. The air-blast cools the arc and sweeps away the arcing products to the atmosphere. This rapidly increases the dielectric strength of the medium between contacts and prevents from re-establishing the arc. Consequently, the arc is extinguished and flow of current is interrupted.

Advantages:

An air blast circuit breaker has the following advantages over an oil circuit breaker:
i) The risk of fire is eliminated.

ii) The arcing products are completely removed by the blast whereas the oil deteriorates with successive operations; the expense of regular oil replacement is avoided.

iii) The growth of dielectric strength is so rapid that final contact gap needed for arc extinction is very small. This reduces the size of the device.

iv) The arcing time is very small due to rapid buildup of dielectric strength between contacts. Therefore, the arc energy is only a fraction of that in oil circuit breakers, thus resulting in less burning of contacts.

v) Due to lesser arc energy, air-blast circuit breakers are very suitable for conditions where frequent operation is required.

vi) The energy supplied for arc extinction is obtained from high pressure air and is independent of the current to be interrupted.

Disadvantages:

The use of air as the arc quenching medium offers the following disadvantages:

i) The air has relatively inferior arc extinguishing properties.

ii) The air blast circuit breakers are very sensitive to the variations in the rate of rise of restriking voltage.

iii) Considerable maintenance is required for the compressor plant which supplies the air blast.

The air blast circuit breakers are finding wide applications in high voltage installations. Majority of the circuit breakers for voltages beyond 110kV are of this type.

6.5C) Low oil Circuit Breakers:

In the bulk oil circuit breakers discussed so far, the oil has to perform two functions. Firstly, it acts as an arc quenching medium and secondly, it insulates the live parts from earth. It has been found that only a small percentage of oil is actually used for arc extinction while the major part is utilized for insulation process. For this reason, the quantity of oil in bulk oil circuit breakers reaches a very high figure as the system voltages increases. This not only increases the expenses, tank size and weight of the breaker but it also increase the fire risk and maintenance problems.

The fact that only a small percentage of oil in the bulk oil circuit breaker is actually used for arc extinction leads to the question as to why the remain of the oil, that is not immediately surrounding the device, should not be omitted with consequent saving in bulk, weight and fire risk. This led to the development of low oil circuit breaker. A low oil circuit breaker employs solid materials for insulation purposes and uses a small quantity of oil which is just sufficient for arc extinction. As regards quenching the arc, the oil behaves identically in bulk as well as low oil circuit breaker. By using suitable arc control devices, the arc extinction can be further facilitated in a low oil circuit breaker.

Construction: The cross section of a single phase low oil circuit breaker. These are two compartments separated from each other but filled with oil. The upper chamber is the circuit breaking chamber while the lower one is the supporting chamber. The two chambers are separated by a portion and oil from one chamber is prevented from mixing with the other chamber. This arrangement permits two advantages. Firstly, the circuit breaking chamber requires a small volume of oil which is just enough for ac extinction. Secondly, the amount of oil to be replaced is reduced as the oil in the supporting chamber does not get contaminated by the arc.

i) Supporting chamber: It is a porcelain chamber mounted on a metal chamber. It is fille with oil which is physically separated from the oil in the circuit breakin compartment. The oil inside the supporting chamber and the annual space forme between the porcelain insulation and bakelised paper is employed for insulatio purposes only.

ii) Circuit breaking chamber: It is a porcelain enclosure mounted on the top of supportin compartment. Its filled with oil and has the following parts:

a) Upper and lower fixed contacts

b) Moving contacts

c) Turbulator.

To moving contact is hollow and includes a cylinder which moves down over a fixed piston. Th tabulator is an arc controller device and has both axial and vents. The axial venting ensures th interruption of low current whereas radial venting helps in the interruption of heavy currents.

iii) *Top chamber:* It is the metal chamber and is mounted on the circuit breaking chamber. I provides expansion space for the oil in the circuit breaking component. The to chamber is also provide with a separator which provide any loss of oil by centrifuga action caused by circuit breaking action caused by circuit breaker operation durin fault conditions.

Operation: Under the normal operation condition, the moving conduct remains engaged wit the upper fixed contact. When a fault occurs the moving conduct pull down by the trippin springs. And the arc is struck. The arc energy vaporizes the oil and produces gases under hig pressure. This action constrains the oil to pass through a central hole in the moving contact an results in forcing series of oil though the respective passages of the tabulator. The process o turbulation is orderly one, in which the sections of the arc successively quenched by the effect o separate streams of oil moving across each section in turn and bearing away its gases.

Advantages: A low oil circuit breaker has the following advantages over a bulk oil circui breaker.

i) It requires lesser quantity of oil.

ii) It requires smaller space.

iii) There is reduced risk of fire.

iv) Maintenance problems are reduced.

Disadvantages: A low oil circuit breaker has the following disadvantages as compared to a bulk oil circuit breaker.

i) Due to smaller quantity of oil, the degree of carbonization is increased.

ii) There is difficulty of removing the gases from the contact space in time.

iii) The dielectric strength of the oil deteriorates rapidly due to high degree of carbonization.

Chapter 7

BUS-BAR

7.1 Introduction of Bus-bar and Bus-bar equipment:

The Buses concerned with switchgear do not have an wheels, not do an transport people. However, they called busses, perhaps due to their commonness with omnibuses that do not have any conductor and do only transport of electricity. Conductors to which a number of circuits are connected are called Buses. And Bar means rod or metals which help current to flow.

Rating of Bus-bar:

The standard rms value of current and Voltage which the bus-bar can carry continuously with temperature rise within specified limits are given bellow.

Voltage (KV rms)	Current (amperes)
0.415	220
11	800
33	1600
132	2000
220	2400
400	3000

Table 3: Voltage and Current data of the bus bar

7.2 Bus-Bar arrangement:

Bus-Bar arrangement is the important component in substation. There are several ways in which he switching equipment can be connected in electrical layout of generating station, receiving station or a distribution station. The selection of scheme is in general affected by following aspects:

1. Degree of Flexibility of operations desired.
2. Importance of load and local conditions. Freedom from total shut down and its period desired.
3. Economic consideration, availability and cost.
4. Technical consideration.
5. Maintenance, safety op personnel.
6. Simplicity.
7. Provision of extension.

There are several Bus-bar arrangements that can be used in substation. Like

- Single Bus-bar
- Double Bus-bar
- Sectionalization of Bus
- Ring Bus.

- One and half scam Bus-bar.

NOTE: Maniknagar substation arrangement Double bus-bar. So we discussed only Double bus-bar scheme

7.3 Double Bus-bar or Main and reserved Bus-bar

A Double Bus-bar configuration consists of two independent buses, one of which, the main bus, is normally energized. Under normal operating conditions, all incoming and outgoing circuits are fed from the main bus through their associated circuit breakers and switches. If it becomes necessary to remove a circuit breaker from service for maintenance or repairs, the integrity of circuit operation can be maintained through use of the bypass and bus tie equipment. The bypass switch for the circuit breaker to be isolated is closed, the bus tie breaker and its isolation switches are closed, and the bypassed breaker and its isolation switches are opened to remove the breaker from service. The circuit is then protected by the bus tie breaker.

Note: But Maniknagar substation energized two bus-bars simultaneously. Because this is very risky for one bus-bar to transmit 200MW power and there is a possibility to overloading.

Advantages:

1. Accommodation of circuit breaker maintenance while maintaining service and line protection
2. Reasonable in cost
3. Fairly small land area
4. Easily expandable

Disadvantages:

1. An additional circuit breaker is required for bus tie.
2. since the bus tie breaker, have to be able to be substituted for any line breaker, its associated relaying may be somewhat complicated.
3. Failure of a circuit breaker or a bus fault causes loss of the entire substation.
4. Somewhat complicated switching is required to remove a circuit breaker from service for maintenance.

Chapter8
Protection relay

8.1 Introduction of relays:

In a power system consisting of generation transformers, transmission, and distribution circuit, it is inevitable that sooner or later some failure will occur somewhere in the system. When the failure is occur on any part of the system, it must be quickly detected and disconnected from the system. There are two systems for it. Firstly, if the fault is not cleared quickly, it may cause unnecessary interruption of service to customer. Secondly, rapid disconnection of faulted apparatus limits the amount of damage to it and prevents the effect of fault from spreading into system. The detection of a fault and disconnection of fault section or apparatus can be achieved by using fuses or relays in conjunction with circuit breaker.

The relays are compact, self-contained device which respond to abnormal condition. The relays distinguish between normal and abnormal condition. Whenever an abnormal condition developed, the relays close its contacts. There by the trip circuit of the circuit breaker is closed.

8.2 Design Objectives:
The principle function of protective relaying is to cause the promote removal from service of any element of the power system when the it start to operate in an abnormal manner or interfere with the effective operation of the rest of the system. In order that protective relay system may perform this function satisfactorily, it should have following qualities.

- Selectivity
- Speed
- Sensitivity
- Reliability
- Simplicity
- Economy

8.2A) Selectivity: It is the ability of the protective system to select correction that part of the system in trouble and disconnection that fault part without disturbing rest of the system. A well design and efficient relay should be selective. It should be able to detect the point at which the fault occur and cause the opening of the circuit breakers close to the fault with minimum or no damage to the system.

8.2B) Speed: Speed means clearing all faults in the shortest possible time with all due regard to dependability and security. The relay system should disconnect the faulty section as first as possible for the following reasons

a. Electrical apparatus may be damage if they are carrying the fault current for a long time.

b. A failure on the system leads to a great reduction in the system voltage. If the faulty section is not disconnected quickly, then the low voltage created by the fault may shut down consumer system.
c. The high speed relay system decreases the possibility of development of one type of fault into other more severe type.

8.2C) Sensitivity: It is the ability of the relay system to operate with the low value of actuating quantity. Sensitivity of a relay is a function of volt-amperes input to the coil of the relay necessary to cause its operation. The smaller the volt-ampere input required to causes the relay operation, the more sensitive is the relay. Thus, a 1VA relay is more sensitive then a 3 VA relay. It is desirable that relay system should be sensitive so that it operates with low values of volt-ampere input

8.2D) Reliability: Reliability is the certainty of correct operation in response to system troubles. Dependability includes the reliable operation of the relay system operating when it is supposed to and selectivity of the relay system operating to isolate the minimum amount of the system necessary to provide continuity of service.

8.2E) Security: Security is the ability to avoid miss operations between faults. Every relay system has to be designed to either operate or not operate selectively with other systems.

8.2F) Simplicity: A relaying system should be no more complex than is required for any given application. Adding more equipment into a scheme than is necessary for good coverage adds to the possibility of equipment failure and disoperation.

8.2G) Economy: the most important factor in the choice of a particular protection scheme is economical aspect. Sometime it is economically unjustified to use an ideal scheme of protection and a compromise method has to be adopted. As a result the protective gear should not cost more than 5% of total cost.

8.3 Indications of Defective Equipment or Abnormal Conditions

Short Circuits: A short circuit is an abnormal connection of relatively low resistance between two or more points of differing potential in a circuit. If one of these points is at ground potential, it is referred to as a "ground fault." If ground potential is not involved, it is referred to as a "phase fault." Phase faults cause excessive currents and low voltages. Ground faults may or may not cause excessive currents or abnormal voltages, depending on whether the system is normally ungrounded, high- or low resistance grounded, or effectively grounded.

Excessive Heating: Equipment is designed to deliver full-rated capacity with the temperature maintained below a value that will not be damaging to the equipment. If operating temperature becomes excessive, the life of the equipment (generator, motor, transformer, etc.,) will be reduced. Excessive heating may be caused by overloading, high ambient temperatures, improper cooling, or failure of cooling equipment.

Overvoltage: Equipment is designed for normal operating voltages as stated on its nameplate with a slight allowance (usually about 5 percent) for normal overvoltage. Abnormal overvoltage may cause:
1. Insulation failure
2. Shortening of the equipment life
3. Excessive heating as a result of greatly increased excitation currents where electromagnetic devices are used
4. Excessive heating in resistors used in controls
5. Failure of transistors and other electronic devices

Under voltage: Continued under voltage will likely cause overheating of motors and dropping out of contactors, and lead to the failure of electrical equipment.

Unbalanced Phase Conditions: On balanced three-phase systems with balanced three-phase Loads, a sudden unbalance in the current or the voltages usually indicates an open or a partially shorted phase. An unbalanced voltage condition is especially serious for three-phase motors because negative sequence currents can lead to considerable overheating within the motor. On balanced three-phase systems with single-phase loads, the loading on each phase may normally vary, depending on the magnitude of each single-phase load. However, it is desirable to keep this unbalance to a minimum to maintain balanced voltages for three-phase loads. Unbalanced conditions, which include single-phase and double-phase faults with or without ground, can be detected with the use of negative and zero sequence relay elements.

Reversed Phase Rotation: Reversed phase rotation can occur after circuit changes have been made or during an open phase condition. Reversed rotation of motors may cause considerable damage to the facility driven by the motors, such as a conveyor.

Abnormal Frequency: Abnormal frequencies can occur when the load does not equal the generation. The frequency may be above or below the system normal frequency. Many facilities such as electric clocks, synchronous motors, etc., are frequency sensitive.

Over speed: Considerable mechanical damage can be done to generators and motors because of over speed. Excessive over speed may cause parts of the generator or motor to be thrown for considerable distances, which is dangerous to personnel as well as to other facilities. Generators or series connected motors may reach dangerous over speeds when loads are suddenly removed.

Abnormal Pressure: In electrical equipment, such as transformers, that use liquid as an insulating fluid, high internal pressures can be created during internal faults.

Abnormal Impedance: Electrical equipment has impedance associated with it that either has definite known values or values that may vary within a known range during known varying operating conditions. These values are normally determined during the manufacture and installation of equipment. Substantial deviations in the impedance of the equipment can indicate a failure of the equipment.

-of-Step Conditions: Electric power systems in Bangladesh operate at a frequency of ertz. All the generators and rotating equipment on the system rotate at an rpm to maintain the ertz frequency. As such, each machine on the electrical system maintains a relative position, hase angle, with respect to every other machine on the system. Once a machine exceeds a cal phase angle, it can no longer stay in phase with the system. It is said to have moved out ep with the system, and has to be removed from the system and resynchronized to the system rder to establish operation. Out of-step conditions are typically monitored through the use of edance relays and set to trip or block the trip of breakers in order to segment the system at etermined locations based on system stability studies.

essive System Phase Angles (Synchronism Check): The closing of a circuit breaker on a em connects the electrical systems on either side of the circuit breaker. The closing of the ker will cause any difference of voltage and phase angle across the breaker to be reduced to , causing current flow from one system to the other to equalize the system voltages, currents, phase angles. If the voltage and phase angle differences across the breaker are too much, ssive currents can flow, resulting in a disturbance to the system, possibly damaging the ker or adjacent rotating equipment. Typically, the voltage and phase angle across the breaker compared to confirm the systems are within proper limits before the breaker is closed.

The protective relay use in sub station:

r current Relay

over current relay responds to a magnitude of current above a specified value. There are four c types of construction:

- Plunger,
- Rotating disc,
- Static,
- Microprocessor.

he plunger type, a plunger is moved by magnetic attraction when the current exceeds a ified value. In the rotating induction-disc type, which is a motor, the disc rotates by tromagnetic induction when the current exceeds a specified value. Static types convert the ent to a proportional dc mill volt signal and apply it to a level detector with voltage or act output. Such relays can be designed to have various current-versus-time operating acteristics. In a special type of rotating induction-disc relay, called the voltage restrained current relay, the magnitude of voltage restrains the operation of the disc until the nitude of the voltage drops below a threshold value. Static over current relays are equipped multiple curve characteristics and can duplicate almost any shape of electromechanical y curve. Microprocessor relays convert the current to a digital signal. The digital signal can be compared to the setting values input into the relay. With the microprocessor relay, ous curves or multiple time-delay settings can be input to set the relay operation. Some relays w the user to define the curve with points or calculations to determine the output acteristics.

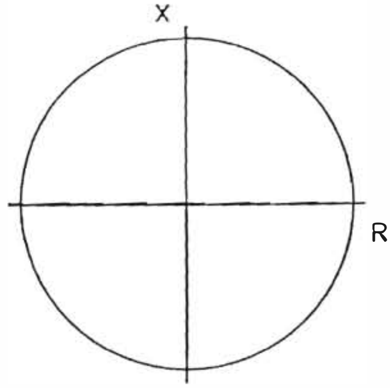

Fig13: R-X diagram (voltage remains constant)

...e protective characteristic of the over current relay, in terms of the impedance diagram, is a ...cle, assuming a constant voltage, with the relay located at the origin of the R-X coordinate ...gram. The relay operates on the simple magnitude of current passing through it according to ... settings applied to the relay.

...tance Relay:

...e distance relay responds to a combination of both voltage and current. The voltage restrains ...eration, and the fault current causes operation that has the overall effect of measuring ...pedance. The relay operates instantaneously (within a few cycles) on a 60-cycle basis for ...ues of impedance below the set value. When time delay is required, the relay energizes a ...arate time-delay relay or functions with the contacts or output of this time-delay relay or ...ction performing the desired output functions.

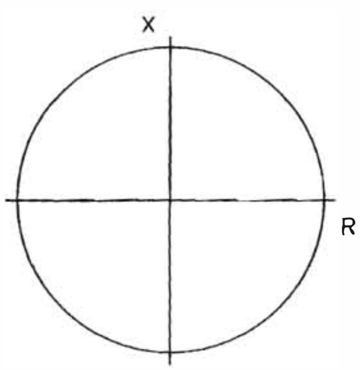

Figure 14: Over current Protect Characteristic

...e protective characteristic of the distance relay, in terms of the impedance diagram, is a circle ...h the relay located at the origin of the R-X coordinate diagram. The relay operates on the ...gnitude of impedance measured by the combination of restraint voltage and the operating ...rent passing through it according to the settings applied to the relay. When the impedance is ...h that the impedance point is within the impedance characteristic circle, the relay will trip. ... relay is inherently directional. The line impedance typically corresponds to the diameter of ... circle with the reach of the relay being the diameter of the circle. Distance Protective cteristic Since the relay responds directly to the value of impedance represented by the urrent and voltage applied to the relay, it will discriminate more correctly between the ns of faults since the electric power system also may be represented by its impedance. The ce relay may be used more successfully on an electric power system when the magnitudes lt current do not provide adequate location differentiation to be able to accurately trip c breakers and isolate a fault.

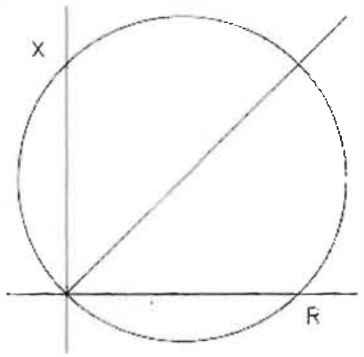

Figure 15: Distant Protect Characteristic

the relay responds directly to the value of impedance represented by the fault current and e applied to the relay, it will discriminate more correctly between the locations of faults the electric power system also may be represented by its impedance. The distance relay e used more successfully on an electric power system when the magnitudes of fault current provide adequate location differentiation to be able to accurately trip specific breakers and a fault.

istance element in a relay may be used when a component of the electric power system, s a transmission line, has defined impedance characteristics. Several distance elements are used, with the circles passing through the origin of the R-X diagram, to provide several of protection for the system component. Additional zones of protection will be used with to provide direct protection or without timers and used in pilot protection schemes ing communications from all remote terminals of the transmission line. Distance elements e used for out-of-step protection with the first zone impedance characteristic passing h the R-X impedance coordinate diagram origin and the remaining zones concentric l the first zone.

ential Relay:

fferential relay is a current-operated relay that responds to the difference between two or currents above a set value. The relay works on the basis of the differential principle that goes into the device has to come out. If the current does not add to zero, the "error" (fault) t flows to cause the relay to operate and trip the protected device.

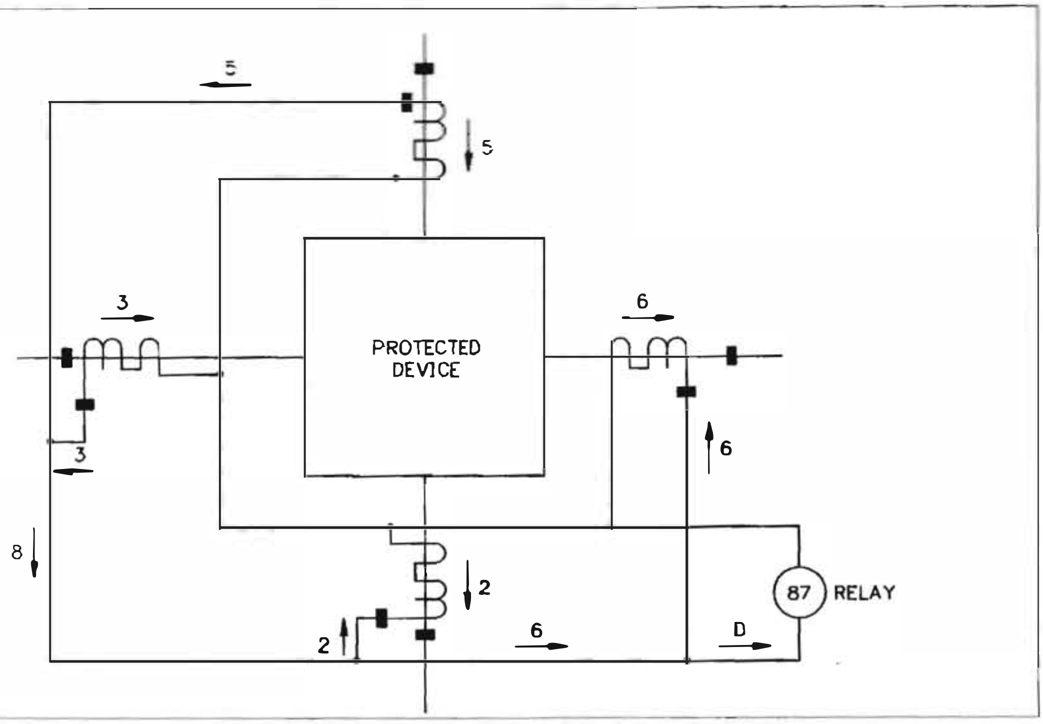

Figure 16: Differential Relay Principle

lifferential relay is used to provide internal fault protection to equipment such as ɔrmers, generators, and buses. Relays are designed to permit differences in the input ts as a result of current transformer mismatch and applications where the input currents from different system voltages, such as transformers. A current differential relay provides nt coils on the incoming current circuits. The restraint coils in combination with the ing coil provide an operation curve, above which the relay will operate. Some of the relays ecific equipment, such as transformers, use additional restraint proportional to the nics sensed in the incoming currents. Setting levels are based on the characteristics of the ted equipment.

ential relays are often used with a lockout relay to trip all power sources to the device and it the device from being automatically or remotely re-energized. The relays are very ve. The operation of the device usually means major problems with the protected nent and the likely failure in re-energizing the equipment.

oltage Relay & under voltage Relay:

vervoltage and under voltage relay responds to a magnitude of voltage above a specified for over voltage relay and below for under voltage relay.

Relay:

er relay responds to the product of the magnitude of voltage, current, and the cosine of the angle between the voltage and current, and is set to operate above a specified value. The c construction includes the rotating induction-disc, static, or microprocessor relay. The relay herently directional since the normally open contacts close for power flow in one direction ve a set value but remain open for power flow of any amount in the opposite direction.

ectional over current Relay:

irectional over current relay operates only for excessive current flow in a given direction. ctional over current relays are available in electromechanical, static, and microprocessor structions. An electromechanical over current relay is made directional by adding a ctional unit that prevents the over current relay from operating until the directional unit has rated. The directional unit responds to the product of the magnitude of current, voltage, and phase angle between them, or to the product of two currents and the phase angle between n. The value of this product necessary to provide operation of the directional unit is small, so it will not limit the sensitivity of the relay (such as an over current relay that it controls). In t cases, the directional element is mounted inside the same case as the relay it controls. For mple, an over current relay and a directional element are mounted in the same case, and the bination is called a directional over current relay. Microprocessor relays often provide a ice as to the polarizing method that can be used in providing the direction of fault, such as lying residual current or voltage or negative sequence current or voltage polarizing functions e relay.

quency Relay:

equency relay responds to frequencies above or below a specified value. The basic types are tromechanical relays with a vibrating reed or rotating induction-disc with a frequency-itive circuit, static relays, and microprocessor relays.

rmal Relay:

thermal relay responds to a temperature above a specified value. There are two basic types: ct and replica.

- **Direct:** In the direct type of thermal relay, a device such as a thermocouple is embedded in the equipment. This device converts temperature to an electrical quantity such as voltage, current, or resistance. The electrical quantity then causes a detecting element to operate.

- **Replica:** In the replica type of thermal relay, a current proportional to the current supplied to the equipment flows through an element, such as a bimetallic strip, that has a thermal characteristic similar to the equipment. When this element is heated by the flow of current, one of the metallic strips expands more than the other, causing the bimetallic strip to bend and close a set of contacts.

ssure Relay:

pressures relay responds to sudden changes of either fluid or gas pressure. It consists of a sure sensitive element and a bypass orifice located between the equipment to which the relay onnected and a chamber that is part of the relay. During slow pressure changes, the bypass ice maintains the pressure in the chamber to the same value as in the equipment. During den pressure changes, the orifice is not capable of maintaining the pressure in the chamber at e value as in the equipment, and the pressure-sensitive element mechanically operates a ntacts.

ry Relay:

y relays perform such functions as time delay, counting, and providing additional upon receiving a signal from the initiating relay. These relays are necessary to provide d variety of schemes required by a power system.

ay Schemes:

ission Line Protection

ission lines provide the links between the various points of the power system and deliver rom the point of generation to the ultimate user. The lines operate at the differing included in the power system. The significance of a line to the electric power system ccording to the voltage level, the location of the line in the system, the loads carried by and other factors specific to the cooperative. Schemes for the relay protection of the line cording to the significance of the line in the system, the characteristics of faults on the speed at which a line fault has to be cleared, and the preferences of the relay engineer utility's practices. The protection schemes available for transmission line relay protection

Over current, instantaneous, no directional
Over current, timed with either inverse curves or discrete times, no directional
Over current, instantaneous, directional
Over current, timed with either inverse curves or discrete times, directional
Current differential using over current
Distance, instantaneous and timed
Pilot with a communication channel between all terminals

on schemes may include the use of the schemes individually or in combinations to lines with primary and secondary protection schemes. The following in determining the y is used for designing a protection scheme of transmission line:

The configuration of the transmission line
The number of line terminals
Whether the line is radial or looped in the system
How many taps, if any, are on the line
How the line will be loaded
Fault levels associated with the line
Any other transmission line-specific data peculiar to the system
Load-specific information such as specified outage times, temporary power levels, etc.
System constraints such as out-of-step relay requirements
Coordination requirements with relay systems of the remote line terminals

oltage transmission lines tend to have more sophisticated relay protection systems often loted schemes (the use of communications channels providing information from the nd of the line) to provide more security. Transmission lines at 132 kV normally utilize nary relay schemes with pilot protection. However, the voltage of the line is not the factor in determining the types of relay protection that may be used. Rather, it is the nce of the line in the power system and the effect of faults on the line that will determine d in which the line has to be removed from the system when a fault occurs. Some lower systems are in operation where extremely sophisticated relay schemes are in place, and 2 kV systems operate with simplistic schemes because of the characteristics of the the location of the line.

above information about the system, the relay engineer can make a decision as to the relay schemes that may be used. The following are schemes used for transmission line n.

ot Schemes:
oted schemes involve the use of relays to provide protection without the use of ications channels providing information from the remote end of the line. The relay s the input quantities, makes the action decision based on those quantities, and provides t to the circuit breakers or circuit logic at the site of application based on the input and logic. All the inputs and outputs are local to the site of application.

)ver current Relaying: Over current relay protection is the simplest form of protection sually applied on lower voltage lines or on radically supplied feeders. It is used ccasionally as backup relay protection for some transmission lines. In its most basic orm, no directional inverse time over current relays are applied on radial feeders with wo phase devices and one ground device. The fault current is reduced by increased line mpedance the further out on the line the fault occurs, resulting in a longer time for the elay to trip the feeder.

urrent Differential with over current Relay: This circuit uses the differential rinciple in connecting the CT circuits and an over current relay instead of a differential elay. The scheme has limited use since the CTs from all terminals of the line, line egment, or bus has to be connected by the hardwire circuits back to the over current elay. This connection is more secure and can be set more sensitively than a simple over urrent relay application. It also can keep one more over current relay from being in a tring of over current relays that have to be set with increasing time delay.

he circuit is typically used within a substation or generation plant facility where short ine segments or buses require protection that does not need the speed of a differential elay. In applying the circuit, the relay engineer has to be aware of the CT error and nismatch that may occur in the differential circuit to the relay and set the relay over any nismatch that may occur.

.. it can more easily be coordinated and used when the coordination of over current ... not work. The distance relay is more costly than the over current relay and requires ... of line potential sources, adding cost to the scheme. Advantages of distance relays ...xed reach based on the impedance of the protected device, regardless of the system ... current changes; the ability to operate at fault currents less than load current; and ...ent overreach.

... are used to protect the total length of the line, providing protection referred to as ...e 1 relay is typically set for 85 to 95 percent of the line impedance. Zone 1 tripping ... for instantaneous tripping, that is, with no intentional time delay. Zone 2 is typically ... to 150 percent of the line impedance. Zone 2 needs to extend past the line being ...to the adjacent lines, not reaching past the far end terminal of the adjacent lines, yet ...e line in question is covered. Zone 2 tripping time is typically set with 18 to 30 cycles ...y.

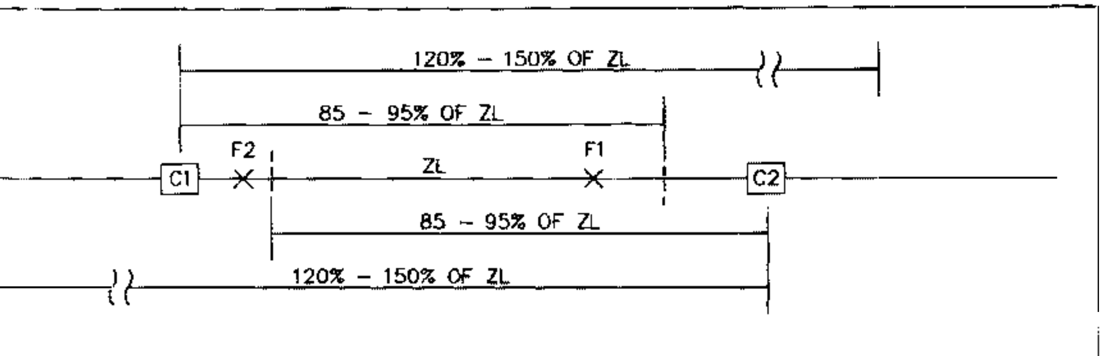

Figure 17: Distant Relay Zones 1 and 2

...me provides instantaneous tripping for 70 to 90 percent of the transmission line for a ... Figure 12-6) located within Zone 1 reach for both ends of the line. For the remainder of ... fault (F2, Figure 12-6) near each line terminal is cleared in the time delay used for ... fault located near a line terminal will be sequentially cleared by the near breaker ...irst and the remote terminal breaker tripping after the Zone 2 trip time delay.

...one of protection, Zone 3, is often used in step distance relaying. Zone 3 is usually set to ...ugh the next line to cover breaker failures. The reach for the Zone 3 relay is usually in ... of 200 to 225 percent of the line impedance. Zone 3 tripping time is typically set with ... cycles. The impedance setting will vary depending on the length of the adjacent lines. ...of the reach of the
...haracteristic, it often encroaches on the load impedance and is susceptible to power ...wings. Use caution when incorporating Zone 3 relays since long settings can result in ...n load.

...ay be reversed to look in the opposite direction of the line to which step distance relays ... applied. This is the case when carrier schemes are applied. Occasionally, a reverse-set ...elay is used as a local breaker failure relay, indicating failure of adjacent circuit ance relaying may be difficult to apply when the transmission lines are short, with little ice. The settings for the distance relays may be very small, near the limits of the design relay reach, resulting in the possibility of the relay's overreaching and tripping for line faults. Three te minal lines will often use distance relays as fault detectors, but will require the implementation of a pilot scheme to ensure tripping for all fault conditions.

chemes: Pilot schemes simultaneously measure and monitor system parameters at all s of a transmission line, local and remote, and then respond according to their mined functions. These schemes require the use of a communications channel that may ided through pilot wires, microwave, fiber, or power line carrier. If the measured ers exceed threshold values, appropriate actions are initiated.

hemes can generally be broken into two primary categories. Those categories are al comparison and phase comparison. Directional schemes use directional distance r phase fault detection and either directional distance relays or directional over current r ground fault detection. The decision to trip is based on relay setting thresholds being d and the faults being located in the predetermined direction for trip.

our internship we dill with pilot wire which is a phase comparison. So we only discuses t wire.

Pilot Wire

This scheme is a form of phase comparison since it compares current direction at each terminal. The difference between this scheme and others is that a pair of telephone wires is used as the communication channel. A special filter in the relay converts the three-phase currents to a single-phase voltage and applies this voltage to the wires. When current flows through the protected section, the voltages at each end oppose each other and no current flows in the operate coils. When current enters the line from each end, the voltage on the pilot wire reverses to allow current to circulate through the operate coils and consequently trip both ends. Special monitor relays sound an alarm if the pilot wire pair becomes open or shorted. The wire line has to have enough protection against induced voltages and a rise in station ground potential but may not use carbon block protectors because the line has to remain in service while the protection is operating. Neutralizing transformers and gas tubes with mutual drainage reactors, all with sufficient voltage ratings, comprise the preferred pilot wire protection package.

This relaying has the advantage of simplicity and does not require a potential source. It does not provide backup protection. Its application is limited to short lines a mile or so in length because of pilot wire cost and increased exposure. Recently, pilot wire systems have been replaced with fiber-optic systems providing the communications systems, using a module to convert the output voltage to a light signal. These modified systems have provided a more dependable and secure protection system.

Chapter 9
AC and DC AUXILIARY SYSTEM for sub station

System:

al Loads Supplied:

ac auxiliary systems are typically used to supply loads such as:
rmer cooling, oil pumps, and load tap changers
breaker air compressors and charging motors
r device heaters
r lighting and receptacles
house
g and receptacles
g, ventilating, and air conditioning
charger input
well pump
-operated disconnecting switches.

gn Requirements:

ritical Loads: Some low-voltage loads have to be maintained at all times:
chargers which, through the batteries, supply breaker trip and close circuits as well as
cation circuits
ormer cooling
circuit breaker compressors and motors
le light receptacles in the station yard
ty lighting
er control circuits
arm circuit(s)
ic heating
tion automation circuitry

uxiliary System:

r supply heart of the substation. Without a Dc supply the substation is fully unprotected.

Loads Supplied:

n dc auxiliary systems are typically used to supply loads consisting of the following:
ing, supervisory, alarm, and control equipment
ency control house lighting
t breaker trip and close circuits

ry:

one of the backup sources of Dc supply. There is 84 Nickel cadmium battery cell and 24 cell for SCADA operation. Each cell is almost 1.5 Volt. All of this battery is tured by Rahim Afroz.

EMS AND RECOMMENDATION:

: :rt we want to mansion two kind of problem that we face and learn during our

'echnical problem

eneral problem

nical problem

- **Mutual capacitauce:**

s the flow of charge. When the transmission line disconnected from load or source then an't flow. But the cable still carries some charge. Now in case of high voltage ion line this storage charge is huge and this might be the cause of death of any people dy is connected with earth ground. Now the most important thing is when two parallel ent is there they create a mutual capacitor due to the storage charge. And this storage good enough to breakdown the air dielectric strength. And in this case the transmission s as a capacitor metal path. During this time if anyone wants to work in transmission he just grounded only one phase but he could not grounded others he will be face a ctric shook for mutual capacitor.

oid this best solution is to disconnect the line isolator and connected to the ground. In ay the storage charge goes to the ground and there is no mutual capacitor anymore. But mission line man also takes extra protection like the grounded the pole body to the vearing plastic gumboot.

problem:

Student should complete the core course and elective course like switch gear

ourse if some one interested to do his internship in a power plant.

There should be internship course curriculum for those student who want to do there internship in substation.

LUSION:

ent decision to transfer of transmission assets to PGCB from Bangladesh Power ment Board (BPDB) and Dhaka Power Distribution Company (DPDC), former DESA, as completed taking over of all the transmission assets on 30.12.2002 and operating ernship program in the Maniknagar substion is very helpful to understand the switchgear the transmission system is designed to transmit power. How the incoming and outgoing re connected can be understand easily by single line diagram.

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