EEE- 160016

STUDY OF ELECTRICAL POWER TRANSMISSION AND DISTRIBUTION IN BANGLADESH

A Thesis report submitted to the department of Electrical & Electronic Engineering (EEE), Sonargaon University, for partial fulfillment of the requirements for the degree of Science in Electrical & Electronic Engineering.

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A THESIS

Candidates' Declaration

It is declared hereby that this thesis paper or any part of it has not been submitted to anywhere else for the award of any degree.

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ACKNOWLEDGEMENT

At first we thank to the Almighty Allah for giving patience to complete the thesis work "STUDY OF ELECTRICAL POWER TRANSMISSION AND DISTRIBUTION IN BANGLADESH". We would like to covey our heartiest felicitation, best gratitude, humblest thanks to our honorable supervisor Mr Shameem Hasan, Lecturer, Department of Electrical and Electronic Engineering, Sonargaon University for his sincere guidance, kind co-operation, supervision, constant encouragement and valuable suggestion. We would also like to express our heartiest gratitude to our honorable teacher Md. Habibur Rahman, Lecturer & Coordinator, Sonargaon University for his valuable advice. Also thanks to our parents, all friends and lab assistants who helped us and inspired us to do the best.

Finally we wish to acknowledge those who directly or indirectly helped us in connection with this work.

ABSTRACT

In this modern world, the dependence on electricity is so much that it has become a part and parcel of our life. The development of any country of the world is based on electricity and its proper generation, transmission and distribution. For the proper utilization, it is required to transmit and distribute the generating electrical power through the proper way.

For proper power generation, we have to consider the selection of power station according to the site selection of the different power station and their advantage and disadvantage.

In this thesis work, we have discussed about different types of power station, their merits & demerits, power generation in Bangladesh, power demand, installed capacity deficiency of power, power plant under construction.

We have also discussed about the transmission and distribution system. We have included mechanical design of transmission system, electrical design of transmission system, different types of transmission loss, remedy of loss. For distribution system, we have included the bhurulia distribution sub-station.

We think that, this study will be very helpful for better understanding about generation and transmission system of Bangladesh.

ABBREVIATIONS & NOTATIONS

BPDB : Bangladesh Power Development Board

PGCB : Power Grid Company of Bangladesh Ltd

DESA : Dhaka Electric Supply Authority

DESCO : Dhaka Electric Supply Company

REB : Rural Electrification Board

LDC : Load dispatch Centre

A.C : Alternating Current

D.C : Direct Current

KVA : Kilo Volt Ampere

Km : Kilometer

KV : Kilo Volt

KW : Kilo Watt

KWH : Kilo Watt Hour

HVDC : High Voltage Direct Current

CB : Circuit Breaker

GS : Generation Station

HEPS : Hydro Electric Power Station

DPS : Diesel Power Station

NPS : Nuclear Power Station

IPP : Independent Power Producer

EHV : Extra High Voltage

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CHAPTER-I

INTRODUCTION

1.1 BACKGROUND

For growing development of a country, electricity has a vital role in all sectors. For the proper utilization, is required to transmit and distribute the electrical power through proper way. During the early years small local generating station supplied power to respective local loads. Each generating station needed enough installed capacity to meet the local peak loads. Bangladesh is an underdeveloped country. Its socio- economic structure is gradually increasing. So the demand of power is extending day by day and thus the importance of Generation, Transmission and Distribution are becoming more complicated.

An electric power system consist of the three principal components are the generation system, transmission system and distribution system. The increasing uses of electric power for domestic, commercial and industrial purposes necessities to provide bulk electric power economically. This is achieved with the help of suitable power generating units, known as power plant. An electric power station is an assembly of equipments in which energy is converted from one form to another into electric energy. Electrical equipments of power station include generators, transformers, switch gears and control gears. The transmission lines are the connecting links between the generating stations and the distribution system and lead to the power system over interconnections. It is required to proper distribute the electric power to the consumer by a network is called the distribution system.

1.2 OBJECTIVES OF THE THESIS

a) To study the different power stations such as hydro electric power station, thermal power station, Nuclear power station, diesel power station and Gas turbine power station.
b) To study the comparative facilities of different power station.
c) To study the comparative productive ability of different power stations.
d) To study the power generation in Bangladesh.
e) To study the transmission system in Bangladesh.

CHAPTER 2

TRANSMISSION SYSTEM

2.1 CLASSIFICATION OF TRANSMISSION SYSTEM

The system by which the electrical power transmitted from generating station to distribution system is known as transmission system. The transmission line divided in two parts:

i. Primary transmission
ii. Secondary transmission

i. PRIMARY TRANSMISSION

The electric power at 132 KV is transmitted by 3-phase 3-wire over head system to the outskirts of the city. This form is the primary transmission.

a. GRID SYSTEM

The entire AC network is interconnected network called national grid. Even neighboring national grid are interconnected to from sub grid. In power system when all generating station line with the operation of substation called grid system of electric power.

In the grid system of Bangladesh power development board, mainly two types of transmission lines are used. These are 230KV and 132KV lines. Also there is another grid line of Bangladesh i.e. 66KV.

b. GRID SUB-STATION

As in Bangladesh there are two types of grid transmission line, one 132KV line and other 230KV line. So we have mainly two categories grid substation. The total number of grid substation operated as of 2012 is 95, of which13 number are 230KV and 82 numbers are

132KV. Capacity of 230KV grid substation is 6675MVA and 132KV is 8587MVA and their transmission length are 2647.3 circuit km and 6071.34 circuit km.

ii. SECONDARY TRANSMISSION

The primary transmission line terminates at the receiving station which usually lies as the outskirts of the city. At the receiving station, the voltages are reduced to 33KV by step down transformers. From this station, electric power is transmitted at 33KV by three phase three wire overhead system to various sub stations located at the strategic points in the city. This form is the secondary transmission.

2.2 CLASSIFICATION OF OVERHEAD TRANSMISSION LINE:

The overhead transmission lines are classified as

- d) Short transmission line
- e) Medium transmission line
- f) Long transmission line

a) **Short transmission line:** When the length of an overhead transmission line is up to 50km and the line voltage is comparatively high (<20KV), it is usually considered as a Short transmission line.

b) **Medium transmission line:** when the length of an overhead transmission line is up to 50-150km and the line voltage is comparatively high(>20KV <100KV), it is usually considered as a medium transmission line.

c) **Long transmission line:** When the length of an overhead transmission line is more than 150Km and the line voltage is comparatively high (>100KV), it is usually considered as a Long transmission line.

2.3 DEFINATION OF IMPORTANT TERMS:

1. *Earthling or grounding*: Connecting to earth or ground.
2. *Neutral earthling*: Connecting to earth, the neutral point i.e. the star point of generator, transformer, rotating machine, neutral point of grounding transformer.
3. *Reactance earthling*: Connecting to the neutral point to earth through a reactance.
4. *Resistance earthling*: Connecting to the neutral point to earth through a resistance.
5. *Non effecting earthling*: when an intentional resistance or reactance is connected between neutral point and earth.

6. *Solid earth or effective earth line*: Connecting to the neutral point to earth without intentional resistance or reactance co-efficient earthling.
7. *Resonant earthling*: Earthling through a reactance of such as value that power frequency current in the neutral to ground connection almost equal opposite to power frequency capacitance current between unsalted line and earth.
8. *Co-efficient of earthling*: it is defined as the ratio of highest r.m.s voltage of healthy line to earth to the line r.m.s voltage.
9. *Petersen coil, suppression coil, ground fault neutralized*: All the three terms have the same meaning the adjustable reactor connected between neutral to earth.
10. *Underground system*: The system whose neutral point is not earth.
11. *Earth fault factor*: It is calculated at the selected point of the system for a given system. It is a ratio of fault factor $=V_1/V_2$.

    Where,

    V_1 = highest r.m.s phase to phase power frequency voltage of sound phase during earth fault on another phase.

    V_2= r.m.s phase to phase power frequency voltage at the same location with fault on the faulty removed.

12. *Bus coupling transformer*: it is a special kind of transformer using in electric power transmission line. It is a bidirectional device that makes injection or taking electric power between two buses. It is also a matching or interfacing transformer between two buses.
13. *Bus*: There are three kinds of buses in power system

    a) PQ bus b) PV bus and c) Stack or swing or reference bus.

For studying and analyzing an electric bus, we have to need for important variables.They are:

a) P-active power b) Q-reactive power

c) V-voltage and d) δ-swing angle

2.4 ADVANTAGE OF HIGH VOLTAGE TRANSMISSION LINE

The transmission of electric power is carried at high voltage due to the following reason:

a) To reduce the volume of conductor material.
b) To increase the transmission efficiency and.
c) To decrease the percentage line drop.

2.5 ADVANTAGES OF HIGH VOLTAGE DC TRANSMISSION

i. It requires only two conductors as compared to three for ac transmission.

ii. There is no inductance, capacitance, phase displacement and surge problem in dc transmission.

iii. A dc transmission. Line has better voltage regulation as compared to the line for same load and sending voltage.

iv. There is no skin effect in dc system.

v. A dc line requires less insulation as compared to ac line for the same working voltage.

vi. A dc line has less corona loss and interference with communication circuit.

vii. The high voltage dc transmission is free from the dielectric losses, particularly in the case of cables and

viii. In dc transmission, there is no stability problem and synchronizing difficulties.

2.6 DISADVANTAGES OF HIGH VOLTAGE DC TRANSMISSION

i. Electric power cannot be generated at high voltage dc due to commutation problems.

ii. The dc voltage cannot be stepped up for transmission of power at high voltages and

iii. The dc switches and circuit breaker have their own limitations.

CHAPTER 3

CONDUCTORS' MATERIALS

The most commonly used conductor materials for overhead lines are: -

a) Copper.
b) Aluminum.
c) Steel-cored aluminum.
d) Galvanized steel.
e) Cadmium copper.

In the early days of the transmission of electric power, conductors were usually copper, but aluminum conductors have completely replace copper because of the much lower cost and lighter weight of an aluminum conductor compared with a copper conductor of the same resistance. The fact that an aluminum conductor has a larger diameter than a copper conductor of the same resistance is also an advantage. With a larger diameter the lines of electric flux originating on the conductor will be farther apart at the conductor surface.

But in our countries in overhead transmission line copper materials are used because it is an ideal material for overhead lines owing to its high electric conductivity and greater tensile strength. It is always use in the hard drawn form as standard copper has high current density. The current carrying capacity of copper per unit of cross-section area is quite large.

3.1 TYPES OF CONDUCTOR

There are four type of aluminum conductors used in transmission and distribution line. Symbols identifying different types of aluminum conductors are as follows: -

(iv) All-Aluminum Conductors (AAC).
(v) Aluminum Conductor Steel-Reinforced (ACSR).
(vi) All-Aluminum-Alloy Conductor (AAAC).
(vii) Aluminum Conductor Alloy-Reinforced (ACAR).

(i) All-Aluminum Conductors (AAC):

All-aluminum conductors are the most favored type for use in the construction of relatively short span distribution schemes and are in common use on lines for voltage up to 60 KV. Another frequent application for all-aluminum conductor is in flexible bus bar connections. Although aluminum-to-copper connections can be made, it is better to use aluminum conductors for service connections, as various forms of covered cable being available for this purpose. The data sheets show the most common sizes of conductors but other sizes, to any recognized standards or customer specification can also be supplied. AAC insulated with XLPE or PVC can be supplied as per the customers' requirement.

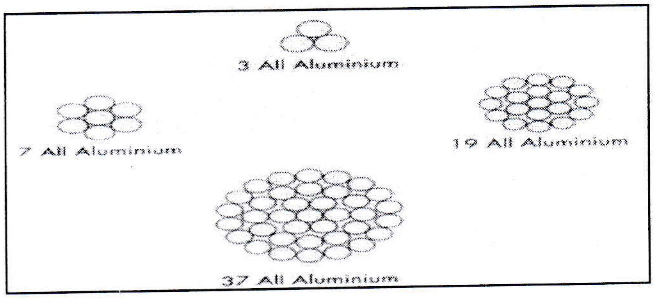


***Fig.-3.1**: Conductor Section of AAC.*

(ii) Aluminum Conductor, Steel-Reinforced (ACSR):

The mixed construction of ACSR makes it a very flexible medium from a design point of view. By varying the relative proportions of aluminum and steel the ideal conductor for any particular application can be produced. Generally, ACSR consists of a galvanized steel core of 1 wire, 7 wires or 19 wires surrounded by concentric layers of aluminum wire. When a conductor with a high current carrying capacity and comparatively low strength is required, special constructions are available with high aluminum content. A coating of non-oxidizing grease is normally applied to the steel cores of all conductors, in addition to the protection offered by the galvanizing of the steel wires. One or more layers of the aluminum wires can, if required, be supplied partially or fully greased. OCI ensures complete freedom from contamination by other metals during the entire manufacture of ACSR conductors.

(iii) All-Aluminum-Alloy Conductor (AAAC):

This section deals with heat-treatable magnesium silicon type aluminum alloys to BS EN 50182, the electrical and mechanical properties of which all fall within the values suggested by Publication 104 of the international Electro technical Commission. Conductors to all other recognized specifications can also be supplied. The alloys referred to have higher strength but lower conductivity than pure aluminum. Being lighter, alloy conductors can sometimes be used to advantage in place of the more conventional ACSR; having lower breaking loads than the latter, their use becomes particularly favorable when ice and win loadings are low.

CHAPTER 4

LINE SUPPORT

Line supports may be defined as the support which mechanically supported the conductor on the tower and support the conductor to ground. In general, the line supports should have the following properties: -

(i) Light in weight without of the loss of mechanical strength.

(ii) Easy accessibility of conductors for maintenance.

(iii) High mechanical strength to withstand the weight of conductor and load etc.

(iv) Cheap in cost and economical to maintain.

(v) Longer life.

4.1 TYPES OF LINE SUPPORT

There are four types of transmission and distribution: -

1) **Wooden Pole: -** Wooden poles used for low voltage distribution purpose. The wooden poles generally tend to rote the ground level, causing foundation failure. Double pole structures of the 'A' or 'H' type are often used to obtain a higher transverse strength than could be economically provided by means of single poles.

2) **Steel Tubular Pole: -** It is use instead of wooden pole in urban area of town for increasing vision satisfactory. It is also stronger than the wooden pole. Such poles are generally used for distribution purpose in the cities. In BPDB steel tubular poles are used distribution system.

3) **Reinforced Concrete (RCC) Poles: -** RCC poles have greater mechanical strength, linger life and permit longer spans than steed poles. They require little maintenance and have good insulating properties. In BPDB, RCC poles are used in 11kV and 33kV transmission systems.

4) **Steel Tower: -** For long distance transmission at higher voltages, steel towers are invariably employed. Steel towers have greater mechanical strength, longer life, can withstand most severe climatic conditions and permit the use of linger spans. In BPDB,steel towers are used in single circuit and double circuit transmission line. This has voltage about 132 kV and 230 kV.

CHAPTER 5

INSULATORS

Insulators are used to 'isolate' conductors form towers on overhead lines and to support high voltage devices from the ground or others structures.

5.1 TYPES OF INSULATORS

There are several types of insulators but the most commonly used are: -

1) Pin Type Insulators: Pin type insulators are used for transmission and distribution of electric power at voltage up to 33 kV. Beyond operating voltage of 33 kV, the pin type insulators become too bulky and hence uneconomical.

2) Suspension type insulators: - This type of insulator is not economical beyond 33 kV. For high voltage transmission line suspension type insulator used. This type insulator consists of a number of porcelain discs connected in series by metal links in the form of strength. 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 voltage. The number of discs in series would obviously depend upon the working voltage.

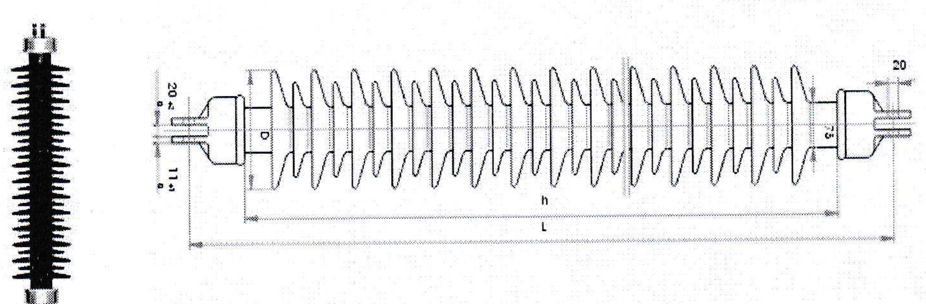


Fig.-5.1: Pin type Insulator

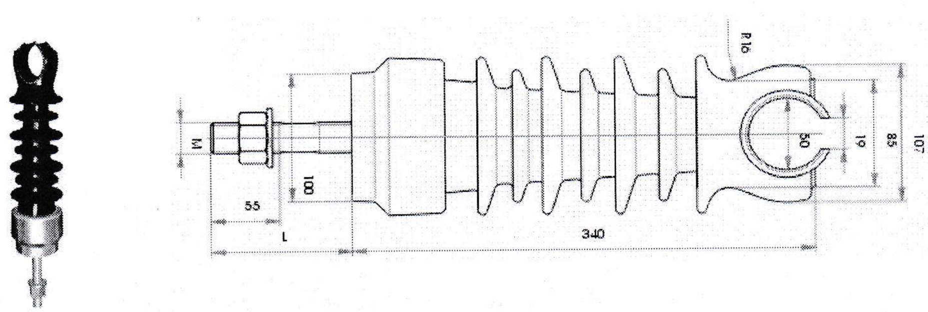


Fig.-5.2: Outside and inside constructional diagram of long rod insulators.

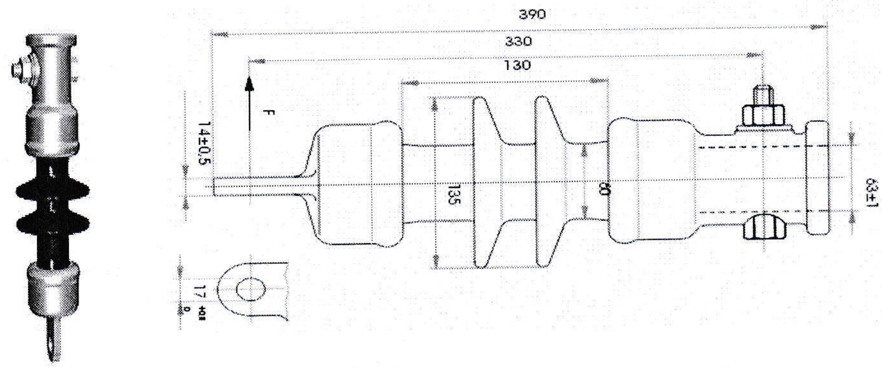


***Fig.-5.3**: Outside and Inside constructional diagram of line-post insulators*

CHAPTER 6

ELECTRICAL DESIGN OF TRANSMISSION LINE

6.1 ELECTRICAL DESIGN ASPECTS

The electrical design involves the following aspects

i) Choice of transmission voltage.
ii) Choice of conductor configuration.
iii) Voltage control and reactive power compensation.
iv) Corona losses and radio interference.
v) Transient stability, auto reclosing.
vi) Abnormal operating conditions and protection systems.
vii) Insulation coordinating surge arrester protection.
viii) Neutral grounding.
ix) Power line communication.
x) Sub-station grounding.
xi) Overhead shielding wires and lightning protection.
xii) Telephone interference.
xiii) Radio interference.
xiv) Television interference.
xv) Audible noise.

An A.C. transmission line has resistance, inductance and capacitance uniformly distributed along its length. These are known constants of parameters of transmission lines.

6.1.1 CONSTANTS OF TRANSMISSION LINE

The transmission lines having distributed constants. These constant are:-

(a) Resistance.
(b) Inductance.
(c) Capacitance.

A transmission line has resistance, inductance & capacitance uniformly distributed along the whole length of the line. Before we pass on to the methods of finding these constants for a transmission line, it is profitable to understand then thoroughly.

(a) **Resistance:** It is the opposition of line conductors to current flow. The resistance is distributed uniformly along the whole length of the line. The performance of a transmission line can be analyzed conveniently if distributed resistance is considered as lumped. The resistance R is given by,

$$R = \frac{\rho l}{a}$$

Where,

a = Cross section area.

l = Length of conductor.

ρ = Resistivity.

(b) **Inductance:** When an alternating current flows through a conductor, changing flux is set up which links the conductor. Due to these flux linkages, the conductor possesses inductance. Mathematically, inductance is defined as the flux linkages per ampere,

Inductance $L = \frac{\varphi}{I}$ henrys

Where,

Ψ = flux linkages in Weber-turns

(c) **Capacitance:** We know that any two conductors separated by an insulating material constitute a capacitor. As any two conductors of an overhead transmission line are separated by air which acts as an insulation therefore, capacitance exists between any two overhead line conductors. The capacitance between the conductors is the per unit potential difference, Capacitance, $C = \frac{q}{v}$ farad.

Where,

q = charge in the line in coulomb.

v = potential difference between the conductors in volts.

6.1.2 CALCULATION OF CONSTANTS':

(a) **Resistance:** The variation of resistance of metallic conductors with temperature is practically linear over the normal range of operation. Suppose R_1 and R_2 are the resistance of a conductor $t_1{}^0C$ and $t_2{}^0C(t_2 > t_1)$ respectively. It α_1 is the temperature coefficient at $t_1{}^0C$ then,

$$R_2 = R_1 [1+\alpha_1 (t_2-t_1)]$$

Where $\alpha_1 = \dfrac{\alpha_0}{1+\alpha_0 t_1}$

α_0 = temperature co-efficient at 0^0 C

a) In a single phase or 2 wire D.C lines, the total resistance is equal to double the resistance of either conductor.

b) In case of a 3-phase transmission, resistance per phase is the resistance of one conductor.

(b) Inductance:

(i) Equilateral Spacing: - Inductance of three phase lines with equilateral spacing. If we assume balanced 3-phase phasor currents,

$I_a + I_b + I_c = 0$

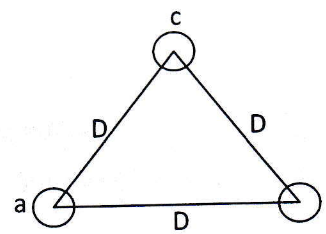


***Fig.-6.1**: Equilateral Spacing (inductance).*

Flux linkages of a conductor 'a',

$$\lambda_a = 2\times10^{-7}\left(I_a \ln\frac{1}{D_s} + I_b \ln\frac{1}{D} + I_c \ln\frac{1}{D}\right) wb-T/m$$

Since $I_a = -(I_b + I_c)$ so we get,

$$\lambda_a = 2\times10^{-7}\left(I_a \ln\frac{1}{D_s} - I_a \ln\frac{1}{D}\right) wb-T/m$$

$$=\rangle\ 2\times10^{-7} I_a \ln\frac{D}{D_s}\ wb-T/m$$

Therefore, $L_a = 2\times10^{-7} \ln\dfrac{D}{D_s}\ H/m$

(ii) Unsymmetrical: The calculation of inductance of three phase lines shown in figure with unsymmetrical spacing. Assume that there is no neutral wire,

$I_a + I_b + I_c = 0$

Unsymmetrical spacing causes the flux linkages and therefore the inductance of each phase to be different resulting in unbalanced receiving-end voltages even when sending-end voltages and line currents are balanced. So there are introducing a problem. To remove these problem transposition (i.e- Exchange the position of the conductors) process is apply. This is shown in figure –

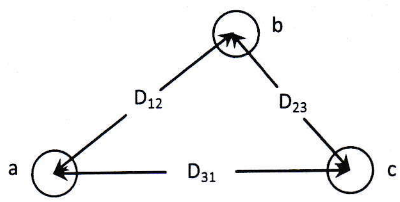


Fig.-6.2(a): Unsymmetrical Spacing (inductance).

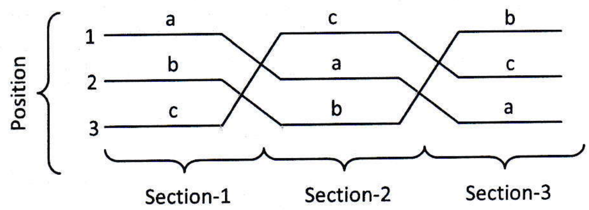


Fig.-6.2(b): Unsymmetrical Lines (inductance).

To find the average inductance of each conductor of a transposed line, the flux linkages of the conductor are found for each position.

For the first section,

$$\lambda_{a1} = 2\times10^{-7}\left(I_a \ln\frac{1}{r_a^{'}} + I_b \ln\frac{1}{D_{12}} + I_c \ln\frac{1}{D_{31}} \right) wb-T/m$$

For the second section,

$$\lambda_{a2} = 2\times10^{-7}\left(I_a \ln\frac{1}{r_a^{'}} + I_b \ln\frac{1}{D_{23}} + I_c \ln\frac{1}{D_{12}} \right) wb-T/m$$

For the third section,

$$\lambda_{a3} = 2\times10^{-7}\left(I_a \ln\frac{1}{r_a^{'}} + I_b \ln\frac{1}{D_{13}} + I_c \ln\frac{1}{D_{23}} \right) wb-T/m$$

Average flux linkages of conductor an area,

$$\lambda_a = \frac{\lambda_{a1} + \lambda_{a2} + \lambda_{a3}}{3}$$

$$= 2\times10^{-7}\left(I_a \ln\frac{1}{r_a^{'}} I_b \ln\frac{1}{(D_{12}D_{23}D_{31})^{1/3}} + I_c \ln\frac{1}{(D_{12}D_{23}D_{31})^{1/3}} \right)$$

But, $I_b + I_c = -I_a$, hence

$$\lambda_a = 2\times10^{-7} I_a \ln\frac{(D_{12}D_{23}D_{31})^{1/3}}{r_a^{'}}$$

Let, $D_{eq} = (D_{12}D_{23}D_{31})^{1/3}$ = equivalent equilateral spacing

Then

$$L_a = 2\times10^{-7}\ln\frac{D_{eq}}{r_a'} = 2\times10^{-7}\ln\frac{D_{eq}}{D_s}\ H/m$$

This is the same relation where $D_m = D_{eq}$ the mutual GMD between the three phase conductors. If $r_a = r_b = r_c$, we have $L_a = L_b = L_c$

(c) Capacitance:

(i) Equilateral Spacing: - Three phase line composed of three identical conductors of radius 'r' placed in equilateral configuration,

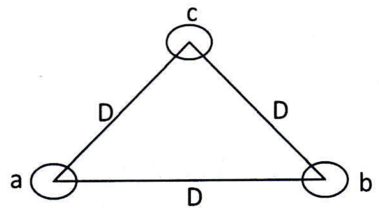


Fig.-6.3:*Equilateral Spacing (capacitance).*

Potential difference between conductors 'a' and 'b' is,

$$V_{ab} = \frac{1}{2\pi k}\left[q_a\ln\frac{D}{r} + q_b\ln\frac{r}{D} + q_c\ln\frac{D}{D}\right]$$

$$V_{ac} = \frac{1}{2\pi k}\left[q_a\ln\frac{D}{r} + q_b\ln\frac{D}{D} + q_c\ln\frac{r}{D}\right]$$

Adding V_{ab} and V_{ac}, we get

$$V_{ab} + V_{ac} = \frac{1}{2\pi k}\left[2q_a\ln\frac{D}{r} + (q_b + q_c)\ln\frac{r}{D}\right]$$

The sum of charges on the three conductors is zero. Thus $q_b + q_c = -q_a$

$$V_{ab} + V_{ac} = \frac{3q_a}{2\pi k}\ln\frac{D}{r}$$

With balanced three phase voltages applied to the line, it follows from the phasor diagram.

$V_{ab} + V_{ac} = 3V_{an}$.

So, we have $V_{an} = \frac{q_a}{2\pi k}\ln\frac{D}{r}$

The capacitance of line to neutral immediately follows as,

$$C_n = \frac{q_a}{V_{an}} = \frac{2\pi k}{\ln(D/r)}$$

(ii) Unsymmetrical Spacing: - Assume that the line is fully transposed. So the conductors are rotated cyclically in the three section of the transposition cycle.

For the first section of the transposition cycle,

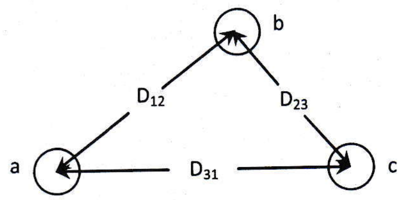


***Fig.-6.4:** Unsymmetrical Spacing (capacitance).*

$$V_{ab1} = \frac{1}{2\pi k}\left(q_{a1}\ln\frac{D_{12}}{r} + q_{b1}\ln\frac{r}{D_{12}} + q_{c1}\ln\frac{D_{23}}{D_{31}}\right)$$

For the second section of the transposition cycle,

$$V_{ab2} = \frac{1}{2\pi k}\left(q_{a2}\ln\frac{D_{23}}{r} + q_{b2}\ln\frac{r}{D_{23}} + q_{c2}\ln\frac{D_{31}}{D_{12}}\right)$$

For the third section of the transposition cycle,

$$V_{ab3} = \frac{1}{2\pi k}\left(q_{a3}\ln\frac{D_{31}}{r} + q_{b3}\ln\frac{r}{D_{31}} + q_{c3}\ln\frac{D_{12}}{D_{23}}\right)$$

With the usual spacing of conductors sufficient accuracy is obtained by assuming,

$$q_{a1} = q_{a2} = q_{a3} = q_a \;;\; q_{b1} = q_{b2} = q_{b3} = q_b \;\;;\;\; q_{c1} = q_{c2} = q_{c3} = q_c$$

The solution can be considerably simplified by taking V_{ab} as the average of three voltages (V_{ab1}, V_{ab2}, V_{ab3})

$$V_{ab}\,(avg) = \frac{1}{3}(V_{ab1} + V_{ab2} + V_{ab3})$$

$$\Rightarrow V_{ab} = \frac{1}{6\pi k}\left[q_a\ln\left(\frac{D_{12}D_{23}D_{31}}{r^3}\right) + q_b\ln\left(\frac{r^3}{D_{12}D_{23}D_{31}}\right) + q_c\ln\left(\frac{D_{12}D_{23}D_{31}}{D_{12}D_{23}D_{31}}\right)\right]$$

$$= \frac{1}{2\pi k}\left(q_a\ln\frac{D_{eq}}{r} + q_b\ln\frac{r}{D_{eq}}\right)$$

Where, $D_{eq} = (D_{12}D_{23}D_{31})^{1/3}$

Similarly, $V_{ac} = \frac{1}{2\pi k}\left(q_a\ln\frac{D_{eq}}{r} + q_c\ln\frac{r}{D_{eq}}\right)$

Now adding V_{ab} and V_{ac},

$$V_{ab} + V_{ac} = \frac{1}{2\pi k}\left[q_a \ln\frac{D_{eq}}{r} + (q_b + q_c)\ln\frac{r}{D_{eq}} \right]$$

For balanced three phase voltages, $V_{ab} + V_{ac} = 3V_{an}$

And also, $q_b + q_c = -q_a$

Therefore, $V_{an} = \frac{q_a}{2\pi k}\ln\frac{D_{eq}}{r}$

The capacitance of line to neutral of the transposed line is then given by,

$$C_n = \frac{2\pi k}{\ln\left(D_{eq}/r\right)} \; F/m \text{ to neutral}$$

6.2 CHARACTERISTICS OF DIFFERENT TRANSMISSION LINE

Line characteristic means the nature of parameters, such as Resistance, Inductance, Capacitance, Identity etc.

Transmission line can be modeling & analysis by two port network.

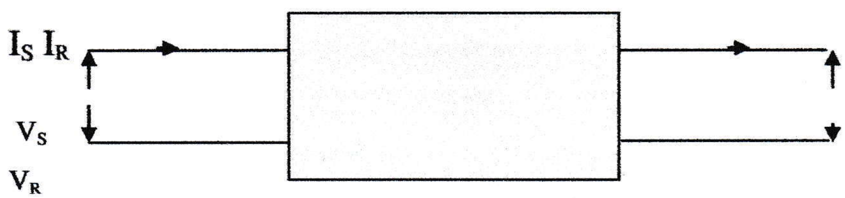


Fig.-6.5: Two port network.

Let,

$V_S = AV_R + BI_R$, $I_S = CV_R + DI_R$

Where A, B, C, D are constants.

So the matrix,

$$\begin{bmatrix} V_S \\ I_s \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

And $AD - BC = 1$ be an identity.

6.2.1 SHORT TRANSMISSION LINE:

The lengths of these lines are less than 100km. Only for resistance & inductance are the effective parameters. Capacitance is very negligible.

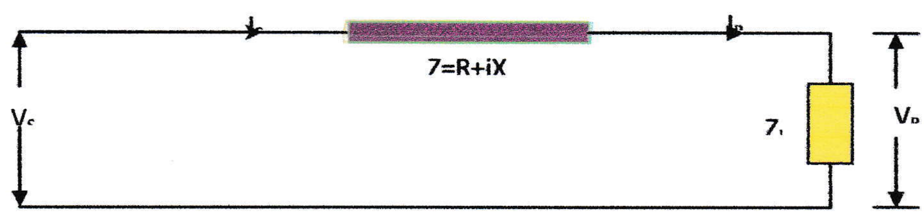


Fig.6.6: Short Transmission line.

Here,

$V_s = V_R + ZI_R, I_s = I_R$.

So the matrix,

$$\begin{bmatrix} V_s \\ I_s \end{bmatrix} = \begin{bmatrix} 1 & Z \\ 0 & 1 \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

Also AD – BC =1-0 = 1, is the identity

6.2.2 MEDIUM TRANSMISSION LINE:

If we consider the length of the lines are more than 100Km but less than 250Km, then these will be called medium transmission line. Capacitance also consider with resistance & inductance in these types of line.

For calculation it is assumed that capacitance is concentrated in one end, Middle or both end i.e. load end, nominal T section, nominal Π section.

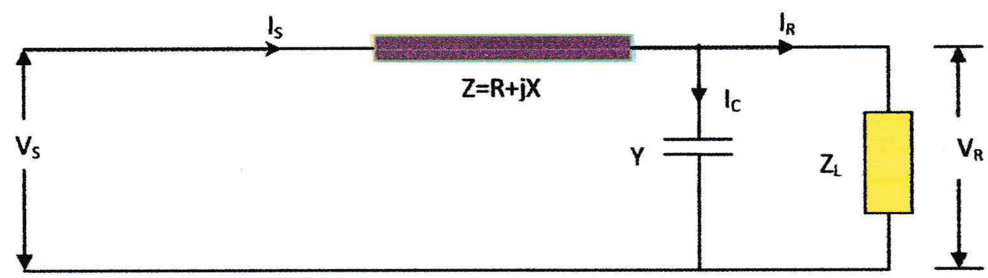


Fig.-6.7: Medium Transmission Line.

Here,

$I_c = YV_R$,

$I_s = I_R + YV_R$,

$V_s = V_R + I_sZ = V_R + Z(I_R + YV_R) = V_R(1+YZ) + ZI_R$.

The current –voltage relationship can be written with matrix,

$$\begin{bmatrix} V_S \\ I_S \end{bmatrix} = \begin{bmatrix} 1+YZ & Z \\ Y & 1 \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

Here, AD – BC = 1 also identity.

i. Nominal - T Representation:

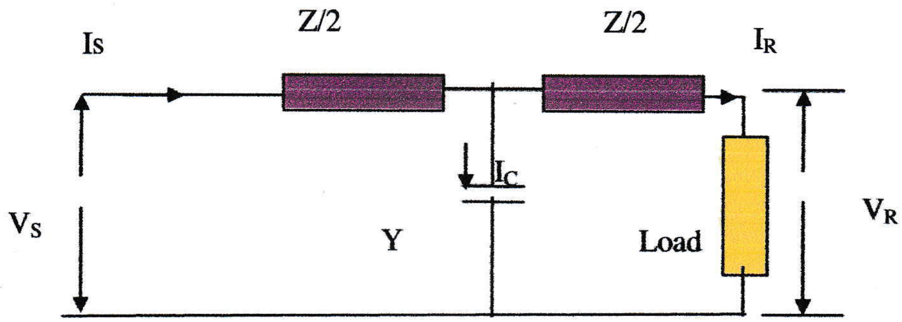


Fig.-6.8: Nominal –T representation.

Also the V-I relationship,

$V_s = V_R(1 + YZ) + I_R \{ Z(1 + YZ/4)\}.$

$I_s = V_R Y + I_R (1 + YZ/2).$

The matrix,

$$\begin{bmatrix} V_S \\ I_S \end{bmatrix} = \begin{bmatrix} 1+YZ & Z(1+YZ/4) \\ Y & 1+YZ/2 \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

AB – DC = 1 be the identity.

ii. Nominal π Representation:

In this method total capacitance is divided into two equal parts which are lumped at the shedding and receiving end resulting in the nominal π representation as shown in fig 5.9.

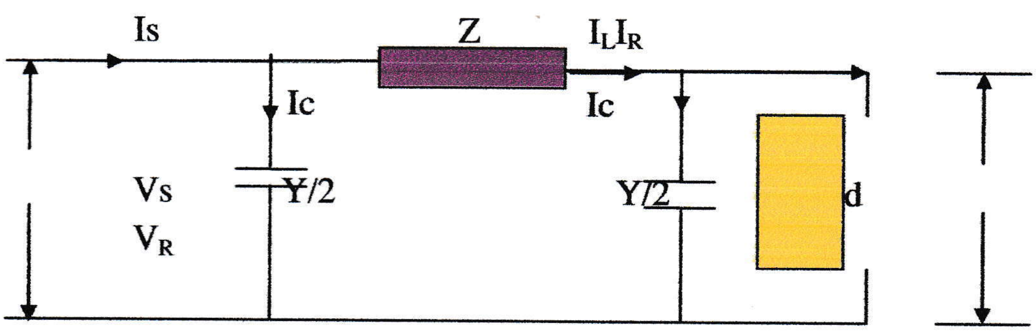


Fig.-6.9: Nominal π representation.

The V-I equation,

$V_s = V_R (1 + YZ/2) + I_R Z$

$I_s = V_R \{Y(1 + YZ/2)\} + I_R(1 + YZ/2)$

The matrix,

$$\begin{bmatrix} V_s \\ I_s \end{bmatrix} = \begin{bmatrix} 1+YZ/2 & Z \\ Y(1+YZ/2) & (1+YZ/2) \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

$AD - BC = (1 + YZ/2)^2 - ZY(1 + YZ/2) = 1$ be the identity.

6.2.3 THE LONG TRANSMISSION LINE:

For lines over 250Km the fact that the parameters of a line over are not lumped but distributed uniformly throughout its length, must be considered. Capacitance varies with distance which is more considerable than short & medium transmission line.

The rigorous solution of long transmission line:

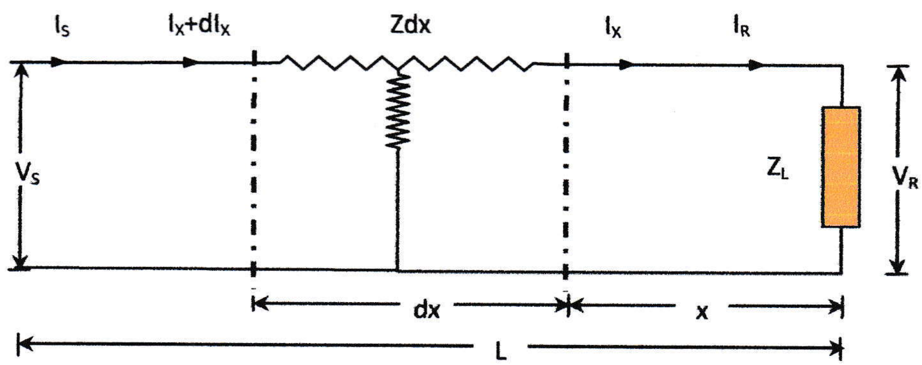


Fig.-6.10: *Long Transmission Line.*

Let dx be an elemental section of the line at a distance X from the receiving end having series impedance Zdz and shunt admittance Ydx. The riswe in voltage over elemental section.

$dV_x = I_x Zdz$

$dV_x/dx = ZI_x$ (1)

$dI_x = V_x Ydx$

$dI_x/dx = V_x Y$ (2)

Differentiating (1) w.r.t 'x'

$D^2V_x/dx^2 = ZdI_x/dx$ (3)

From (2) & (3) we get,

$D^2V_x/dx^2 = YZV_x$

Let, $\gamma^2 = YZ$ then,

$D^2V_x/dx^2 - \gamma V_x = 0.$

The general solution is,

$Vx = C_1 e^{\gamma x} + C_2 e^{-\gamma x}$ (4)

Again differentiating (4) w.r.t. 'x',

$dV_x/dx = C_1\gamma e^{\gamma x} + C_2\gamma e^{-\gamma x}$ (5)

Where $Z_c=(Z/Y)^{1/2}]$

The constant C1 & C_2 may be evaluated by using the end conditions. i.e. when x = 0, Vx = V_R & Ix = I_R. Substituting these values in equation (4) & (5) gives

$V_R = C_1 + C_2$

$I_R = 1/Z_C (C_1 - C_2)$

Which upon solving yield;

$C_1 = ½ (V_R + Z_C I_R)$

$C_2 = ½ (V_R - Z_C I_R)$

Substituting C_1& C_2 on (4) & (5)

$V_X= \{(V_R + Z_C I_R) /2\}e^{YX} + \{(V_R - Z_C I_R) /2\}e^{-YX}$

$I_X = \{(V_R/ZC + I_R) 2\}e^{YX} – \{(V_R/Z_C - I_R) /2\}e^{-YX}$

These can be written after introducing hyperbolic function as,

$V_X = V_R \cosh Yx + I_R Z_C \sinh Yx$

$I_X = I_R \cosh Yx + V_R (1/Z_C) \sinh Yx$

The matrix,

$$\begin{bmatrix} V_X \\ I_X \end{bmatrix} = \begin{bmatrix} \cosh Y_X & Z_C \sinh Y_X \\ (1/Z_C)\sinh Y_X & \cosh Y_X \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

Here, A = D = coshYx

B = Z_C sinhYx

C = $(1/Z_C)$ sinhYx

The identity be the AD – BC = 1

If X = L, then $V_X = V_s$, $I_X = I_S$

6.3 STANDARDIZATION OF TRANSMISSION VOLTAGE

There is much variation in transmission voltages in different countries. A country adopts a voltage or a system of voltage levels to suit its requirements of load. Where long distance transmission is involved, the use of EHV becomes inevitable, earlier; individual attempts were made to fix voltage levels for high power transmission but such an adoption of individual voltage levels resulted in waste of time. the design due to their varied nature was costly. It was realized to standardize the transmission voltages for the following reasons.

i) Standardization provides better facilities for research and development.

ii) The equipment can be manufactured economically with greater reliability.

iii) The maximum possible use of EHV for transmission and interconnection of EHV systems can be made.

The standardization would, therefore avoid independent attacks to tackle EHV problems in different countries to find the optimum economic voltage and thus, a lot of time is saved by standardizing the equipment the higher voltage can be adopted for a reasonable period of time before the next change and thus the number of lines will also be lesser.

One of the difficulties encountered within the standardization was to adopt the maximum continuous voltage or the nominal voltage to fix up a standard of a system voltage. Again there is a discrepancy in the margin between these values in European and American practices. In the former case, the maximum value in ten percent higher than nominal value, while in the later this difference is only five percent. It was proposed to compensate the nominal values in such a way as to have the same maximum value in both the systems in order to avoid this margin. It was preferred to have the criterion of maximum value rather than the nominal value for the standardization purpose.

Earlier, standardization was very successfully up to a voltage level of 230KV. This voltage was the standard voltage used in many countries above 230KV and the international standardization was not so successful.

6.4 EXTRA HIGH VOLTAGE TRANSMISSION

There has been a constant drive in the power system field to achieve the most economical design. The adoption of higher voltage level is also a step in this direction. The advantages claimed by EHV have given incentives to many countries to go for the higher voltage levels.

With the rapid growth in the system size some new problems are also coming in the way while others already percent at lower voltages are becoming more acute. Three main problems are associated with EHV.

a. Radio interference

b. Line insulation

c. Equipment insulation

CHAPTER 7

TRANSMISSION LINE LOSSES

Whole produced effective power is not useable for any system. The loss which is occurred to transmit the power from the generation end to grid sub-station end and the use of power for the system own is called transmission loss.

7.1 TYPES OF LOSSES

There are several types of losses are introduce on overhead transmission line. In this section transmission lines losses actually occur in all lines. Line losses may be any of three types: -

(a) Copper Losses.

(b) Dielectric Losses.

(c) Radiation or Induction Losses.

7.1.1 COPPER LOSSES:

One type of copper loss is I^2R loss. In transmission lines the resistance of the conductors is never equal tozero. Whenever current flows through one of these conductors, some energy is dissipated in the form ofheat. This heat loss is a power loss. With copper braid, which has a resistance higher than solidtubing, this power loss is higher.Another type of copper loss is due to skin effect. Since resistance is inverselyproportional to the cross-sectional area, the resistance will increase as the frequency is increased. Also,since power loss increases as resistance increases, power losses increase with an increase in frequencybecause of skin effect.

These losses can be minimized and conductivity increased in an transmission line by plating the line withsilver. Since silver is a better conductor than copper, most of the current will flow through the silver layer.The tubing then serves primarily as a mechanical support.

7.1.2 DIELECTRIC LOSSES:

These Losses result from the heating effect on the dielectric material between theconductors. Power from the source is used in heating the dielectric. The heat produced is dissipated intothe surrounding medium. When there is no potential difference between two conductors, the atoms in thedielectric material between them are normal and the orbits of the electrons are circular. When there is apotential difference between two conductors, the orbits of the electrons change. The excessive negativecharge on one conductor repels electrons on the dielectric toward the positive conductor and thus distortsthe orbits of the electrons. A change in the path of electrons requires more energy, introducing a powerloss. The atomic structure of rubber is more difficult to distort than the structure of some other dielectricmaterials. The atoms of materials, such as polyethylene, distort easily. Therefore, polyethylene is oftenused as a dielectric because less power is consumed when its electron orbits are distorted.

7.1.3 RADIATION AND INDUCTION LOSSES:

These losses are similar in that both are caused by the fieldssurrounding the conductors. Induction losses occur when the electromagnetic field about a conductor cutsthrough any nearby metallic object and a current is induced in that object. As a result, power is dissipatedin the object and is lost.Radiation losses occur because some magnetic lines of force about a conductor do not return to theconductor when the cycle alternates. These lines of force are projected into space as radiation and these results in power losses. That is, power is supplied by the source, but is not available to the load.

7.2 SKIN EFFECT

The tendency of alternating current to concentrate near surface of a conductor is known as skin effect.

The skin effect depends upon the following factors:

(1) Nature of material.
(2) Diameter of wire –increases with the diameter of wire.
(3) Frequency –increases with the increase in frequency.
(4) Shape of wire-less for stranded conductor than the solid conductor.

It may be note that skin effect is negligible when the supply frequency is low & conductor diameter is small.

7.3 MINIMIZATION OF TRANSMISSION LOSS

1) By increase the transmission voltage.
2) By change the old x-former & switchgear.
3) By set up generating station nearby the load center.
4) By fulfill the local demand by small plants.

CHAPTER 8

DISTRIBUTION SYSTEM

8.1 SUB-STATION

8.1.1. DEFINITION:

The assembly of apparatus used to change some characteristic (e.g. voltage, ac to dc, frequency, p.f. etc) is called the sub-station.

8.1.2 IMPORTANCE OF SUBSTATION

Substation is an important part of power system. The continuity of supply depends to a considerable extent upon the successful operation of sub-station. It is therefore essential to exercise utmost care while designing and building substation. The following parts are important point which must be kept in view while laying out a substation.

1. It should be located at a proper site as far as possible it should be at the center of load.
2. It should be easily operated and maintenance.
3. It should involve minimum capital cost.

8.1.3 EQUIPMENTS OF SUBSTATION

- Transformer
- CT,PT
- Bus bar
- Isolator
- Protective fuse
- Main switch
- Incoming feeder
- Outgoing feeder
- Energy meter
- P.F meter
- Maintenance tools
- Bus bar chamber

8.1.4 CLASSIFICATION OF SUBSTATION

According to constructional feature the substation are classified as:

1. Indoor substation.
2. Out door substation.
3. Underground substation.
4. Pole mounted substation.

1. Indoor substation

For voltage up to 11kv the equipment of the substation is installed indoor because of economic consideration .However when the atmosphere is contain with impurities these substation can be erected for voltage unto 66kv .

Advantage:

a. Less space is required.

b. Operation is easier than outdoor substation.

Disadvantage:

a. Future extension is difficult.

b. Capital cost is high.

c. More possibility of escalation.

2. Outdoor substation

For voltage beyond 66kv ,equipment is invariably installed out door .It is because for such voltage the clearance between conductor and the space required for switch , circuit breaker and equipment becomes so great it is not economical to install the equipment indoor

Advantage:

a. Easy to future extension.
b. Low capital cost.
c. Easy to fault location.

Disadvantage:

a. More space is required.

b. Operation is difficult.

3. Pole–mounted substation

This is an outdoor subs station with equipment installs over head on H-pole or 4-pole structure. It is cheapest from of substation for over voltage not exceeding 11KV (or 33 KV in the some case. Electric power is almost distributed in localities through such substation. For complete discussion on pole mounted substation.

8.2 DEFINITION OF DIFFERENT EQUIPMENTS USED IN THE DISTRIBUTION SUB-STATION:

8.2.1 TRANSFORMER

A transformer is a static device that transfer the electrical energy from one circuit to another circuit at a constant frequency on the basis of mutual induction between two circuits linked by a common magnetic flux

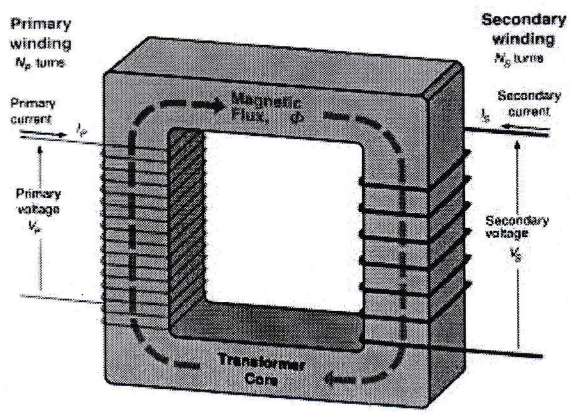


Figure 8.1: Transformer.

i. Power Transformer

A power Transformer is used in a substation to step-up or step-down the voltage. Except at the Power Station, all the subsequent substations use step-down transformers to gradually reduce the voltage of electric supply and finally deliver it at utilization voltage. The modern practice is to use 3-phase transformer in substation, although 3-phase bank of transformer can also be used.

ii. Instrument Transformer

The lines in substations operate at high voltages and carry current of thousands of amperes. The measuring instruments and protective devices are designed for low voltage (generally 110) and currents (about 5A). Therefore, they will not work satisfactorily if mounted directly on the power lines. The function of these instrument transformers is to transfer voltages or currents in the power lines to values which are convenient for the operation of measuring instruments and relays.

There are two types of instrument transformer as follows:

a) Current transformer (C.T).

b) Potential transformer (P.T)

a) Current transformer (C.T)

A current transformer is essentially a step-up transformer which steps down the current to a consists by a spark gape in series with non-linear resistor. Its upper terminal connects the power circuit and lower terminal are grounded.

Its action is occurs by this three step.

1. Where the power system is normal is operation then the lighting arrester obtains off states.
2. When the surge voltage apply on the apply on the power system then the spark gap get contact by this high voltage and current.
3. Its non-linear resistance prevents the effect of short circuit after high resistance this resistance makes the spark gap.

8.2.4 INSULATOR

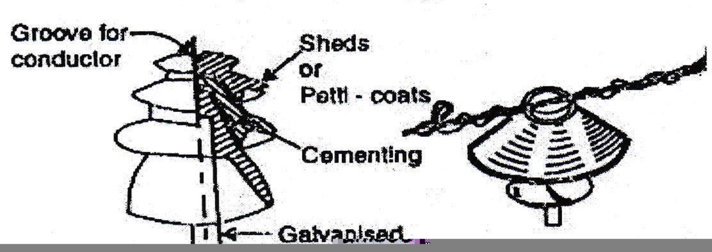
The insulator serves two purposes. They support the conductor and confined the current in the conductors. The most commonly used material for the manufacture of insulator porcelain. There are several kinds of insulator (e.g. pin type, suspension type, post insulator etc.) and their use in the sub-station will depend upon the service requirement. For example, post Insulator is used for bus bars. a post insulator consists of a porcelain body, cast iron cap.

Types of line insulator

- ❖ Pin type insulators.
- ❖ Suspension type insulators
- ❖ Strain insulators.

i. Pin type insulators:

Pin type insulators are used for transmission and distribution of electric power voltage up to 33KV



ii. Suspension type insulators

For high voltage i.e. beyond 33KV transmission line, Suspension type insulators used. This type insulator consists of a number of porcelain discs connected in series by the metal links in the form of strength. 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 discs is designed for 11KV. The number of discs in series would obviously depend upon the working voltage.

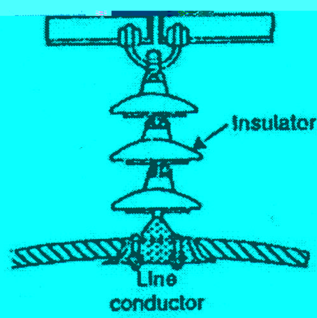


Fig 8.4: Suspension type insulator.

iii. 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 shackle insulators are used as strain insulators. For high voltage transmission lines, strain insulator consists of an assemble of suspension insulators.

The discs of strain insulators are used in vertical plane.

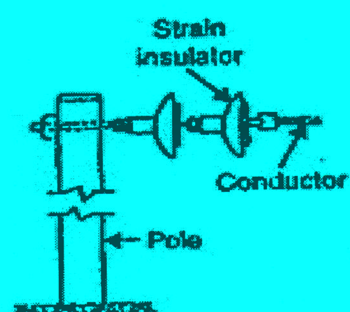


Fig 8.5: Strain insulator

8.2.5 BUS-BAR

When a number of generator or feeders operating at the same voltage have to be directly connected electrically, bus-bar are used as the common electrical component.

Bus-bars are copper rods or thin walled tubes and operated at constant voltage. Thus electrical bus bar is the collector of electrical energy from one location.

The selection of any bus bar system depends upon the following:

1. Amount of flexibility required in operation.
2. Immunity from total shut-down.
3. Initial cost of the installation.
4. Load handled by the bus bar.

Classification of bus bar:

1. Single bus bar system.
2. Sectionalized bus bar.
3. Duplicate bus bar.
4. Ring bus bar.

1. Single Bus bar:

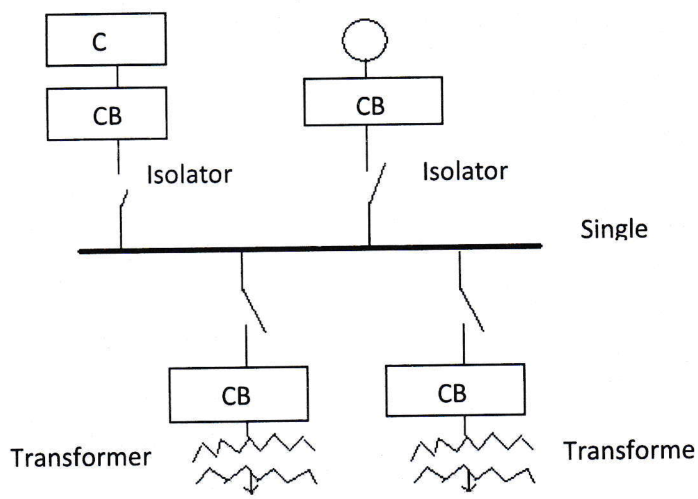


***Fig 8.6:** Single Bus bar.*

- **Advantages:**

i. It is cheapest arrangement as only one circuit breaker for each outgoing circuit breaker is required.
ii. Due to the absence of the transfer breaker and disconnections, the operation has become simple. For de-energizing a circuit only the associated circuit breaker is to be opened.
iii. The maintenance cost, which is only dependent upon the number of breakers, will be appreciably low for a single bus bar system.

- **Disadvantages:**

i. The biggest disadvantages of this system is complete shut-down of the line in case of a bus bar fault.

ii. It is not possible to have any regular maintenance work on the energized bus bar.

iii. For maintaining or repairing a circuit breaker, the circuit is required to be disconnected from the bus bar.

iv.

2. Single Bus bar system with Sectionalisation:

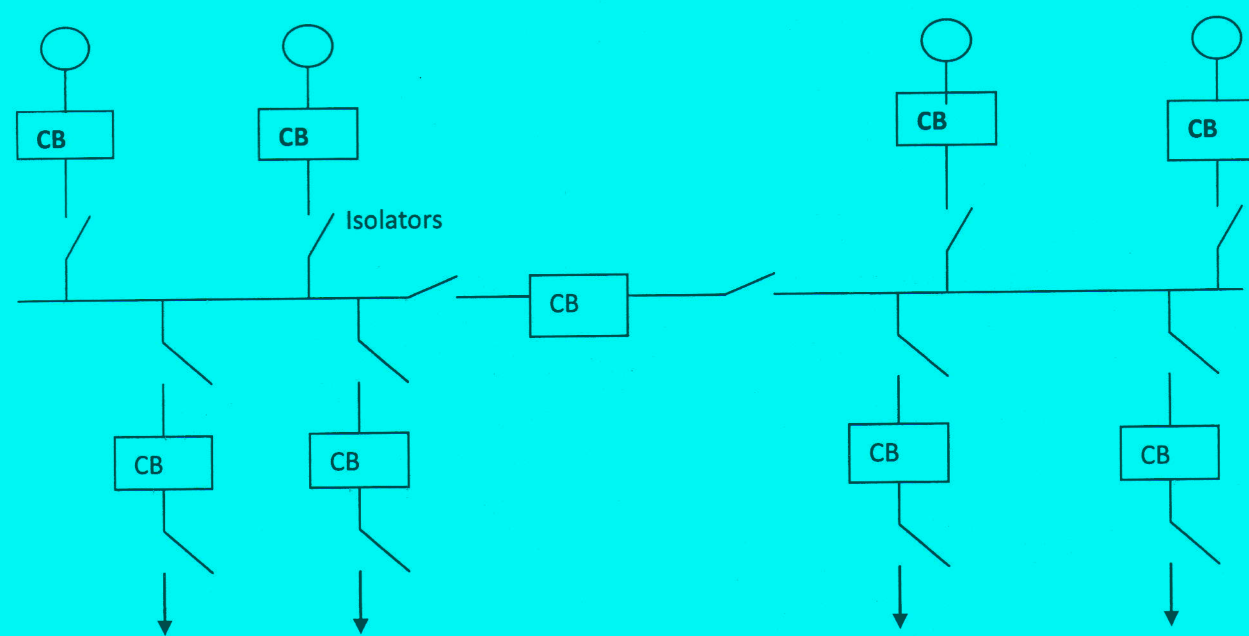


Fig 8.7: Single Bus bar system with Sectionalisation.

- **Advantages:**
  i. In this system, only one additional breaker will be needed, thus its cost in comparison to single bus bar system will not be much.
  ii. The operation of this system is as simple as that of single bus bar.
  iii. The maintenance cost of this system is comparable with the single bus bar.
- **Disadvantages:**

i. On the bus bar fault, one half of the station will be switched off.

ii. For regular maintenance also, one of the bus bar is required to be de-energized.

8.2.6 CIRCUIT BREAKER

A circuit breaker is a piece of equipment, which can-

- ❖ **Make or break a circuit either manually or by remote control under normal condition.**

- **To Brake a circuit automatically under fault condition.**
- To make a circuit either manually or remote control under fault conditions.

Basic principles of operation of circuit breaker

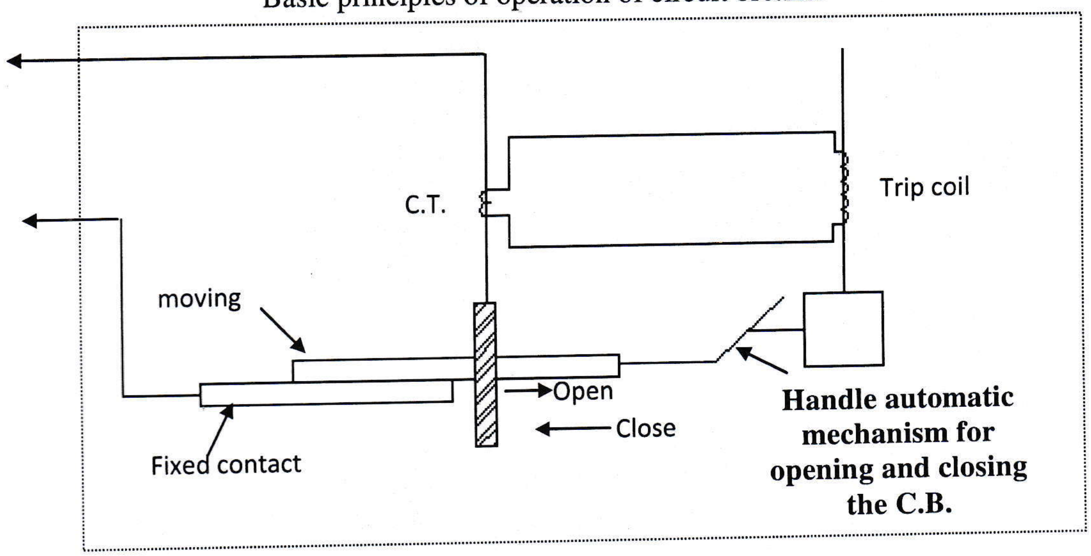


Fig 8.8: ***Basic operation of circuit breaker***

The figure represents an elementary schematic diagram of CB. It consists of fixed contact and a sliding contact in to which mores a moving contact. The end of the moving contact is attached to a handle which can be manually or it can be operate automatically with the help of a mechanism which has trip coil energized by the secondary of the current Transformer generally called current transformer. The power supply is brought to the terminals the emf induced of the C.B. Under mn and aids the de

cing products from the

ength of the medium is

se in length by

- **Advantage:**

The arc extinction is facilitated by the following processes:

i. The hydrogen gas bubble generated around the arc cools the arc colu ionization of the medium between the contacts.

ii. The gas sets up turbulence in the oil and helps in eliminating the ar arc path.

iii. As the arc lengthens due to the separating contacts, the dielectric str increased.

- **Disadvantage:**

i. There is no special control over the arc other than the increa

✓ **Sulphur Hexa Fluoride Circuit Breaker (SF6)**

Working Principle:

In which sulphur hexa Fluoride (SF6) gas is used for arc extinction. In the closed position of the breaker, the contacts remain surrounded by SF6 gas at a pressure of about 2.8 Kg/cm2. When the breaker operates, he moving contact is pulled apart and an arc is struck between the contacts. The movement of the moving contact is synchronized with the opening of a valve which permits SF6 gas at 14Kg/cm2 pressure from the reservoir to the arc interruption chamber. The high pressure flow of SF6 rapidly absorbs the free electrons in the arc path to form immobile negative ions which are ineffective as charge carriers. The result is that the medium between the contacts quickly builds up high dielectric strength.

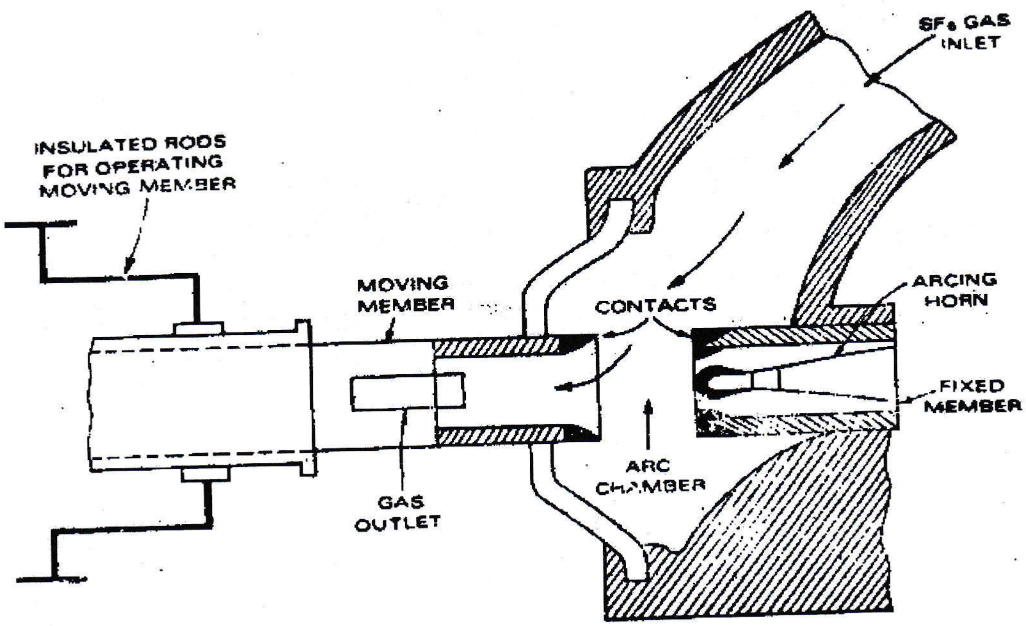


Fig 8.9: Sulphur Hexa Fluoride(SF_6) Circuit Breaker

- **Advantage:**

i. The possibility to obtain the highest performances, up to 63 KA, with a reduced number of interrupting chambers.

ii. Short break time of 2 to 2.5 cycle

iii. Reliability and availability.

iv. Low noise level.

v. Sulphur Hexa Fluoride CB is used in high voltage up to 245 K

8.3 CALCULATION OF POWER FACTOR

8.3.1 Power triangle:

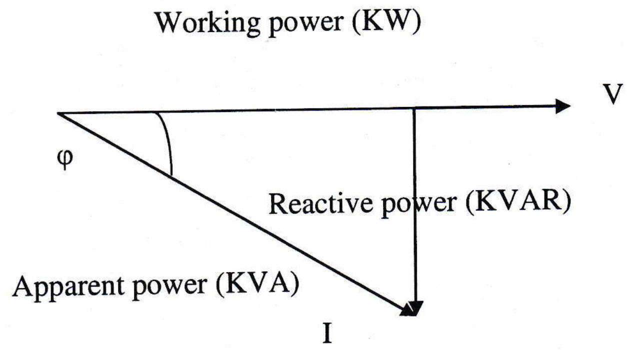


Fig 8.10: Power Triangle

Power Factor = Active power/Apparent power

Usually

1. Real power (KW) -Measured

2. Reactive power (KVAR) -Measured

3. Apparent power (KVA) -Calculated

CONCLUSION

The electrical energy has a vital rule in the development of civilization. There has been a universal basic drive towards better living through expended utilization of energy. The advancement of a country is measured in terms of capital consumption of electrical energy. The study of generation and transmission system is of great important. Bangladesh power development board (BPDB) evolved on May 1, 1972 as an integrated utility with responsibility of power generation, transmission and distribution. BPDB supplies electrical power through transmission and distribution system to the consumers of Bangladesh.

In this thesis we have studied the electrical power a generation and transmission system. For the

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