Electrical Power Transmission Lab
EE-422

Fall 2016
Experiment Booklet Rev. 00

DEPARTMENT OF ELECTRICAL ENGINEERING

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College of Engineering & Technology

University Of Sargodha

LIST OF EXPERIMENTS:

Lab	Title
1	(a). Familiarization with Energy Analyzer (b). Introduction to the transmission line trainer
2	Familiarization and calculation of transmission line parameters
3	To understand the construction, characteristics and applications of different types of insulators.
4	To Analyze the effect of Resistance on transmission line
5	To Analyze the effect of inductance on transmission line
6	To Analyze the effect of capacitance on transmission line
7	To Calculate the flow of active and reactive power in 3-Phase transmission line at known load
8	To Calculate “Line WATTs” and “Line VARs” absorbed by 3 Phase Transmission line at know load
9	To Calculate Voltage regulation of transmission line as a function of type of Load
10	To understand the construction and technical specifications of different types of OHL conductors
11	To understand main supporting units of OHTL (Transmission Towers)
12	To understand the construction, characteristics, selection and application of Lightening arrestors
13	To Analyze the connection of transmission line with 3 phase feeder
14	To Understand vibration damper and its types used in transmission line
15	To Learn about different types of underground cables

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INTRODUCTION

SAFETY

Engineers are often required to use hand and power tools in constructing prototypes or in setting up experiments. Specifically, electrical engineers use test instruments to measure the electrical characteristics of components, devices, and electronics systems.

These tasks are interesting and challenging, but they may also involve certain hazards if one is careless in his/her work habits. It is therefore essential that students learn the principles of safety at the very beginning of their career and that they practice these principles.

Safe work requires a careful and deliberate approach to each task. Before undertaking an experiment, students must understand "what to do and how to do". They must plan everything, setting out tools, equipment, and instruments on the workbench in a neat and orderly fashion. Extraneous items should be removed, and all cables should be securely fastened.

GENERAL SAFETY RULES

The first rule of personal safety is always**:**

Think First!

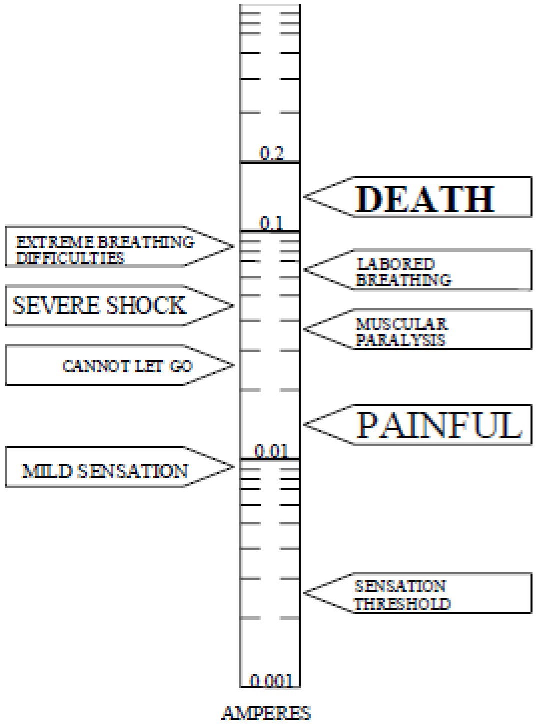
Always study the job at hand and think through your procedures, your methods, and the applications of tools, instruments, and machines before searching. Never permit yourself to be distracted from your work, and never distract another worker engaged in hazardous work. There are generally three kinds of accidents which may occur to electrical students and technicians- electric shock, burns, and equipment-related injuries. Knowing and studying about them, and observing simple rules will make you a safe person to work with. You could personally be saved from painful and expensive experiences.

Electric shocks

What about electric shocks? Are they fatal? The physiological effects of electric currents can generally be predicted with the chart shown in Fig. 1:

Notice that it is the current that does the damage. Currents above 100 mA, or only one tenth of an ampere, are fatal. A workman who has contacted currents greater than 200 mA may live to see another day if given rapid treatment. Currents less than 100 mA can be serious and painful. A safe rule:

"Do not place yourself in a position to get any kind of shock"



Rules for safe practice and avoiding electric shocks:

- Work with one hand behind you or in your pocket. A current between two hands crosses your heart and can be more lethal than a current form hand to foot. A wise technician always works with one hand. Watch your TV serviceman.
- Be sure of the condition of the equipment and the dangers it can present before working on it.
- Never rely on safety devices such as fuses, relays, and interlock systems to protect you. They may not be working and may fail to protect you when most needed.
- Never remove the grounding prong of a three-wire plug. This eliminates the grounding feature of the equipment making it a potential shock hazard.
- Do not work on a cluttered bench. A disorganized mess of connecting leads, components and tools only leads to careless thinking, short circuits, shocks, and accidents. Develop systematized and organized work habits.
- Do not work on wet floors. Your contact resistance to ground is greatly reduced on a wet floor. Work on a rubber mat or an insulated floor.

- Do not work alone. It is just good sense to have someone around to shut off the power, to give artificial respiration, or to call a doctor.
- Never talk to anyone while working. Do not let yourself be distracted. Also, don't talk to someone who is working on dangerous equipment. Do not be the cause of an accident.

EXPERIMENT NO 1

1. **TO BE FAMELARIZTION OF ENERGY ANALYZER**
2. **INTRODUCTION TO TRANSMISSION LINE TRAINER**

Name of Student: ……………………………………………………

Roll No.: ………………………………….Section: …………………

Date of Experiment: ………………………………………………….

Report submitted on: …………………………………………………

Marks obtained: ……………………………………

Instructor's Signature: ……………………………...

COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL ENGINEERING

a. TO BE FAMELARIZTION OF ENERGY ANALYZER
b. INTRODUCTION TO TRANSMISSION LINE TRAINER

OBJECTIVES:

The objective of this experiment is

- To understand the use of Energy analyzer for measuring different electrical quantities.
- To study and analyze the phase to phase and phase to neutral values.
- To analyze the power factor, Active power, Reactive power and Apparent power phases and phase-neutral.
- Introduction to transmission line trainer.

ENERGY ANALYZER:

- Energy analyzer is used to measure dangerous voltages and must be used by trained personnel only.

- The instrument is not protected by fuses therefore, in case of direct connection, make sure that the equipment is protected by fuses or circuit breakers with nominal current lower than 16A. Students use the instrument under the supervision of instructors.
- The instrument is a modern electric power analyzer, suitable to measure voltages, currents, power and energy on single and three phase networks.

TRANSMISSION LINE:

The transmission lines are categorized as three types.

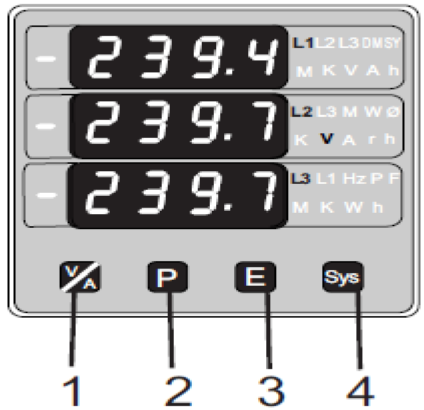
- ☐ Short transmission line (**The line length is up to 80 km**).
- ☐ Medium transmission line (**The line length is between 80km to 160 km**).
- ☐ Long transmission line (**The line length is more than 160 km**).

Whatever may be the category of transmission line, the main aim is to transmit power from one end to another. Like other electrical system, the transmission network also will have some power loss and voltage drop during transmitting power from sending end to receiving end. Hence, performance of transmission line can be determined by its efficiency and voltage regulation.

THEORY:

An instrument for measuring various parameters of an electrical power distribution system is often called an energy analyzer.

It measures electrical parameters like AC voltage, Current, Frequency, Power, Energy (Active / Reactive / Apparent), phase angle, power factor & many more. The instrument integrates accurate measurement technology (All Voltages & current measurements are True RMS up to 15th Harmonic) with 3 line 4 digits Ultra high bright LED display with Clearly Visible Annunciated units with bright LED from Back side.



The front panel has four push buttons for user interface to scroll through the available parameters. These four keys have function as follow:

1.V/A: Selects & Scrolls through Voltage parameters display and phase current parameters display

2.P: Select & Scrolls phase & system Power parameters.

Active power, apparent power, reactive power, phase angle, power factor, then system Apparent, Reactive, Active Power, Phase angle, Power factor, then Current demand, KVA demand, Max current demand, Max KVA demand, Active import demand, Max active import demand, Active export demand, Max active export demand and then back to Phase active power.

3.E: Select & Scrolls through Energy parameters: Active energy (Import), Active energy (Export), Reactive energy (Import), Reactive energy (Export), Apparent energy and then back to Active energy (import).

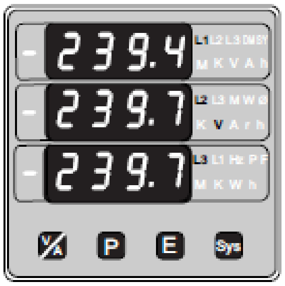
4.Sys: Select & Scroll through System parameters: Voltage-Current-Frequency, Hi values of system voltage and current, Lo values of system Voltage and current, RPM, run Hour, ON hour and no. of interruptions and back to System Voltage-Current Frequency screen.

The Multifunction Meter come with 14mm display and units annunciated from back side, which enables to take reading from long distance. The problem with conventional LED annunciators is overcome with The Multifunction Meter.

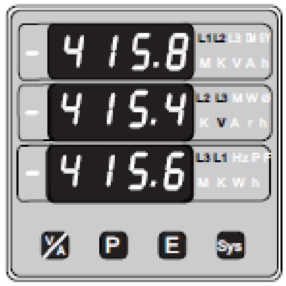
Measurement Reading Screens:

a. "V/A" Key:

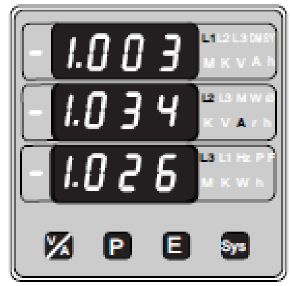
Screen 1 : Voltage Line to Neutral
(For 3Ph4 Wire only)



Screen 2 : Voltage Line to Line
(For 3Ph 4Wire & 3 Wire)



Screen 3 : Line Currents

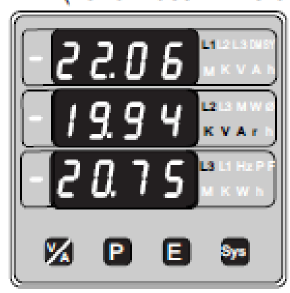


b. "P" Key:

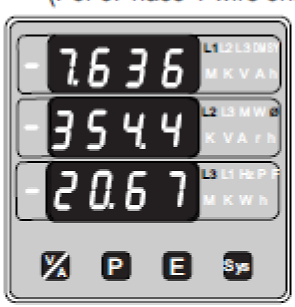
Screen 1 : Phase Active power
(For 3Phase 4 wire only)

Screen 2 : Phase Apparent power
(For 3Phase 4 wire only)

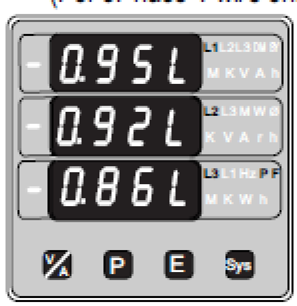
Screen 3 : Phase Reactive power
(For 3Phase 4 wire only)



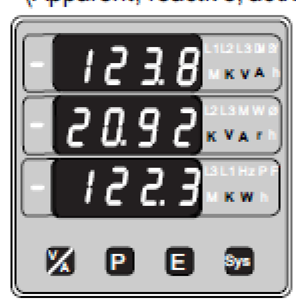
Screen 4 : Phase Angle
(For 3Phase 4 wire only)



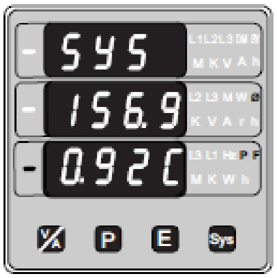
Screen 5 : Phase power factor
(For 3Phase 4 wire only)



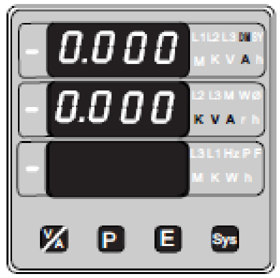
Screen 6 : System powers
(Apparent, reactive, active)



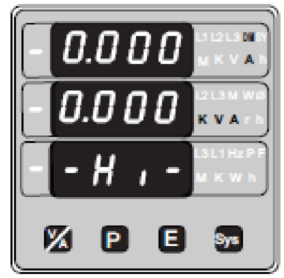
Screen 7 : System Phase Angle & power factor (3P4W &3W)



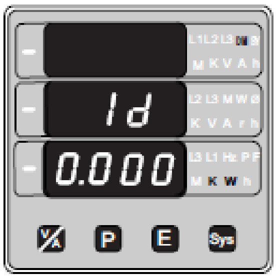
Screen 8 : Current Demand/ kVA Demand



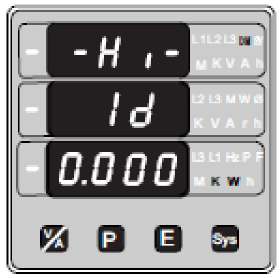
Screen 9 : Max Current Demand/ Max kVA Demand



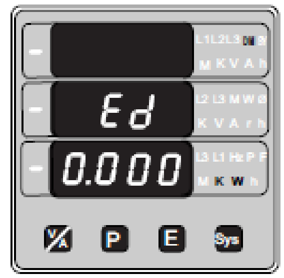
Screen 10 : Import kW Demand



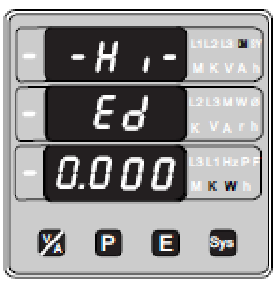
Screen 11 : Max Import kW Demand



Screen 12 : Export kW Demand

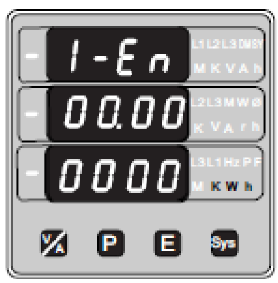


Screen 13 : Max Export kW Demand

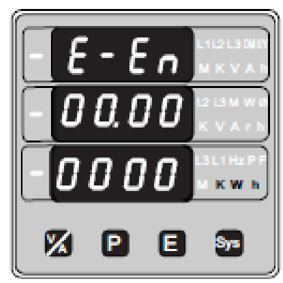


c. “E” Key:

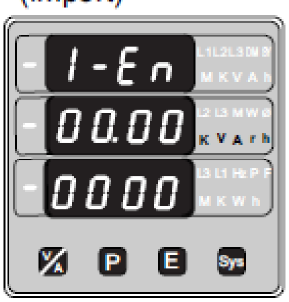
Screen 1 : Active Energy(Import)



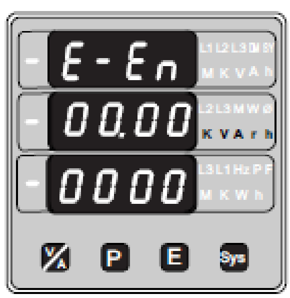
Screen 2 : Active Energy (Export)



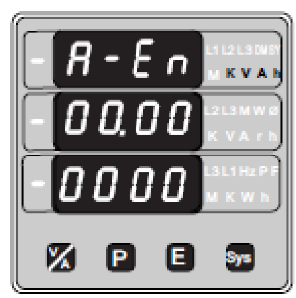
Screen 3 : Reactive Energy (Import)



Screen 4 : Reactive Energy (Export)

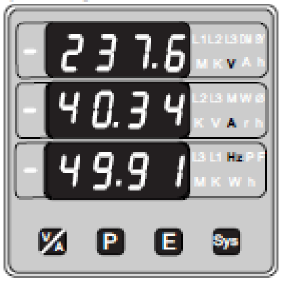


Screen 5 : Apparent Energy

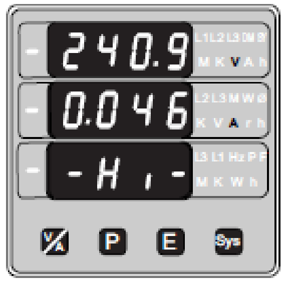


d. “Sys” Key:

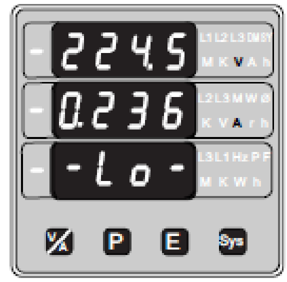
Screen 1 : System Values (Voltage, Current, Frequency)



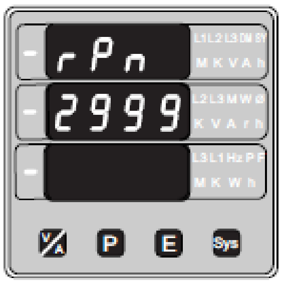
Screen 2 : Max. Values



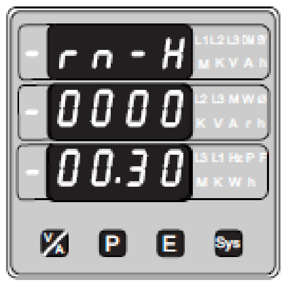
Screen 3 : Min. Values



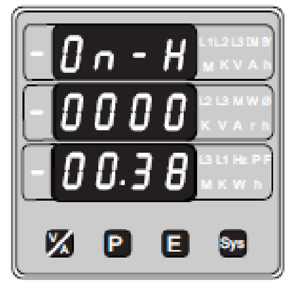
Screen 4 : RPM Measurement



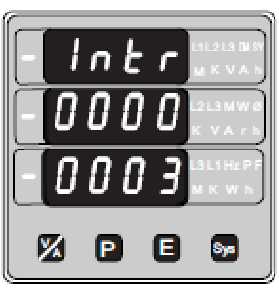
Screen 5 : Run Hours



Screen 6 : ON Hours



Screen 7 : No. of Interruptions



SPECIFICATIONS:

Direct connection or through adapters to single and three phase 3 or 4 wire circuits.

Voltage:	300/500V	Precision:	± 0.5%, ± 1 digit
Current:	6A	Precision:	± 0.5%, ± 1 digit
Power:	4,000W	Precision:	± 1%, ± 1 digit
Active Energy:	up to 999,999 +/-	Resolution:	1Wh
Reactive Energy:	up to 999,999 +/-	Resolution:	1varh or 1kvarh
Frequency:	48 to 62Hz		
Max. Peak factor	3		

In presence of harmonics, operation is still correct with an additional 1% error.

PROCEDURE:

To make and understand connections of transmission line follow the steps given below.

1. First connect main supply to the input of energy analyzer.
2. And also make both neutral same.
3. Then connect input of energy analyzer 1 to the input of transmission line.
4. Note all the readings of main supply through energy analyzer 1.

CONNECTION DIAGRAM:

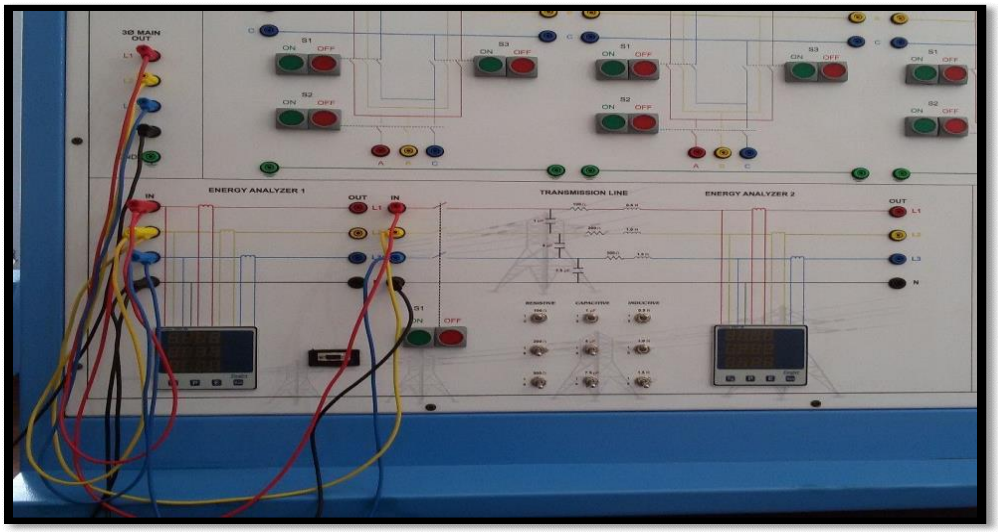


TABLE:

Sr. NO.	Characteristics	Readings without load	Readings with load	Remarks
1				
2				
3				
4				
5				

Sr. NO.	Characteristics	Readings without load	Readings with load	Remarks
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				

Sr. NO.	Characteristics	Readings without load	Readings with load	Remarks
18				
19				
20				
22				
23				
24				
25				

OBSERVATION/OPINION:

EXPERIMENT NO 2

FAMELIRIZATION AND CALCULATION OF TRANSMISSION LINE PARAMETERS

Name of Student: ……………………………………………………

Roll No.: ……………………………….Section: …………………

Date of Experiment: ………………………………………………….

Report submitted on: …………………………………………………

Marks obtained: ……………………………………

Instructor’s Signature: ……………………………...

COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL ENGINEERING

FAMELIRIZATION AND CALCULATION OF TRANSMISSION LINE PARAMETERS

OBJECTIVE:

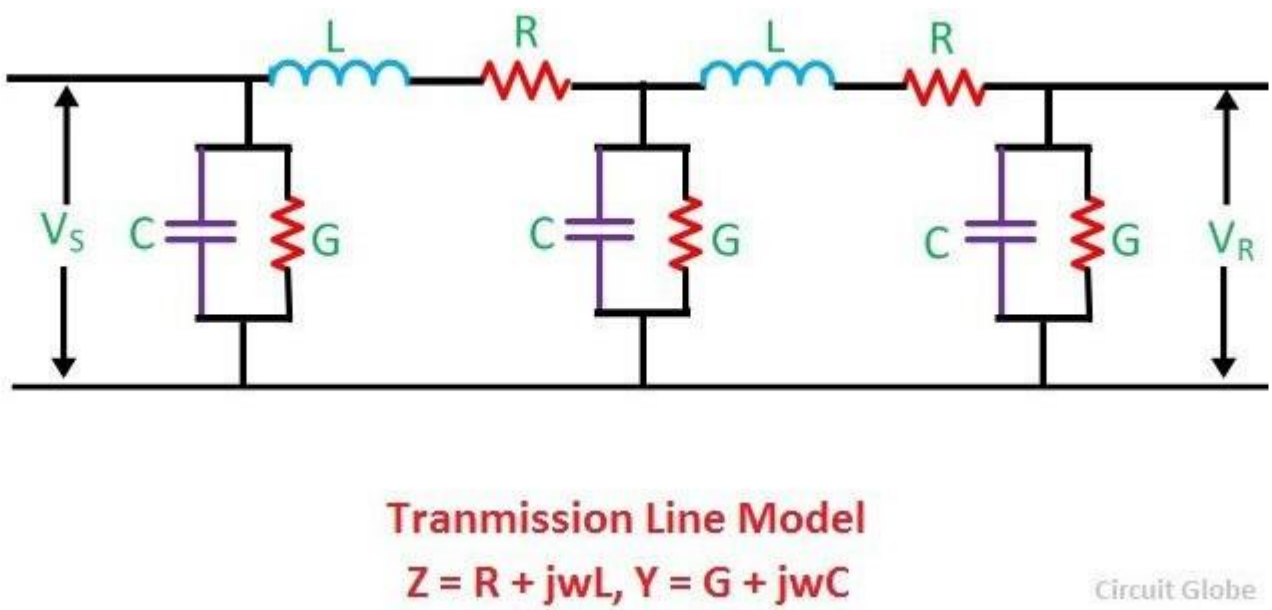
Objective of this experiment is to get knowledge about the transmission line parameters.

THEORY:

The transmission lines are modeled by means of the parameters resistance, inductance, capacitance and conductance. Resistance and inductance together is called transmission line impedance. Also capacitance and conductance in parallel is called admittance Here we are not going to derive the formulas rather to develop some concepts about the transmission line parameters. It will help us understand the transmission line modelling and in analyzing the power system. In this article we will discuss about the line resistance and inductance. In the next article we will discuss about line capacitance and conductance.

PARAMETERS OF TRANSMISSION LINE:

The performance of transmission line depends on the parameters of the line. The transmission line has mainly four parameters, resistance, inductance, capacitance and shunt conductance. These parameters are uniformly distributed along the line. Hence, it is also called the distributed parameter of the transmission line.



The inductance and resistance form series impedance whereas the capacitance and conductance form the shunt admittance. Some critical parameters of transmission line are explained below in detail.

RESISTANCE:

The conductors of the transmission lines have small resistance. For short lines, resistance plays an important role. As the line current increases so do the ohmic loss (I2R loss). When the current exceeds a certain value the heat generated due to ohmic loss starts to melt the conductor and the conductor becomes longer that results in more sag. The current at which this condition of conductor is irreversible is called thermal limit of conductor. Short overhead lines should be operated well within this limit.

The resistance R of a conductor of length ‘l’ and cross section ‘a' is given by the formula

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

Here ρ is the resistivity of the conductor material which is a constant. Transmission lines usually use ACSR conductors with spirally twisted strands. So the actual length of the conductor is about 2 % more than the ACSR conductor length. So from the above formula, the resistance of the line is proportionately 2% more than the conductor length. Another important factor is that when the frequency of current increases the current density increases towards the surface of conductor and current density at the center of conductor is less. That means more current flows towards the surface of conductor and less towards the center. This is well known skin effect. Even at power frequency (60/50 Hz) due to this skin effect the effective cross sectional area of conductor is less. Again from the above equation it is clear that the conductor resistance is more for higher frequency. So AC resistance of conductor is more than the DC resistance. Temperature is another factor that influences the resistance of conductor. The resistance varies linearly with temperature. The manufacturers specify the resistance of the conductor and one should use the manufacturer’s data.

LINE INDUCTANCE:

The current flow in the transmission line induces the magnetic flux. When the current in the transmission line changes, the magnetic flux also varies due to which Emf induces in the circuit. The magnitude of inducing Emf depends on the rate of change of flux. Emf produces in the transmission line resist the flow of current in the conductor, and this parameter is known as the inductance of the line.

LINE CAPACITANCE:

In the transmission lines, air acts as a dielectric medium. This dielectric medium constitutes the capacitor between the conductors, which store the electrical energy, or increase the capacitance of the line. The capacitance of the conductor is defined as the present of charge per unit of potential difference.

Capacitance is negligible in short transmission lines whereas in long transmission; it is the most important parameter. It affects the efficiency, voltage regulation, power factor and stability of the system.

SHUNT CONDUCTANCE:

Air act as a dielectric medium between the conductors. When the alternating voltage applies in a conductor, some current flow in the dielectric medium because of dielectric imperfections. Such current is called leakage current. Leakage current depends on the atmospheric condition and pollution like moisture and surface deposits.

Shunt conductance is defined as the flow of leakage current between the conductors. It is distributed uniformly along the whole length of the line. The symbol Y represented it, and it is measured in Siemens.

PERFORMANCE OF TRANSMISSION LINES:

The term performance includes the calculation of sending end voltage, sending end current, sending end power factor, power loss in the lines, efficiency of transmission, regulation and limits of power flows during steady state and transient conditions. Performance calculations are helpful in system planning. Some critical parameters are explained below

VOLTAGE REGULATION:

Voltage regulation is defined as the change in the magnitude of the voltage between the sending and receiving ends of the transmission line.

$$\% \, Voltage\ regulation = \frac{Sending\ end\ voltage - Receiving\ end\ voltage}{Sending\ end\ voltage} \times 100$$

THE EFFICIENCY OF TRANSMISSION LINES:

Efficiency of the transmission lines is defined as the ratio of the input power to the output power.

$$\% \, Transmission\ line\ efficiency = \frac{Power\ delieverd\ at\ receiving\ end}{Power\ sent\ from\ the\ sending\ end} \times 100$$

IMPORTANT POINTS:

- Admittance measures the capability of an electrical circuit or we can say it measures the efficiency of a transmission line, to allows AC to flow through them without any obstruction. It SI unit is Siemens and denoted by the symbol Y.
- Impedance is the inverse of the admittance. Its measure the difficulty occurs in the transmission line when the AC flow. It is measured in ohms and represented by the symbol z.

FORMULATION:

OBSERVATION/OPINION:

EXPERIMENT NO 03

TO INVESTIGATE THE CONSTRUCTION, CHARACTERISTICS AND APPLICATIONS OF DIFFERENT TYPES OF INSULATORS

Name of Student: ……………………………………………………

Roll No.: …………………………………Section: …………………

Date of Experiment: ……………………………………………….

Report submitted on: ………………………………………………

Marks obtained: ……………………………………

Instructor's Signature: ……………………………...

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TO INVESTIGATE THE CONSTRUCTION, CHARACTERISTICS AND APPLICATIONS OF DIFFERENT TYPES OF INSULATORS

INSULATORS

The overhead line conductors should be supported on the poles or towers in such a way that currents from conductors do not flow to earth through supports i.e., line conductors must be properly insulated from supports. This is achieved by securing line conductors to supports with the help of insulator. The insulators provide necessary insulation between line conductors and supports and thus prevent any leakage current from conductors to earth. In general, the insulators should have the following desirable characteristics:

(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 currents to earth.

(iii) High relative permittivity of insulator material in order that dielectric strength is high.

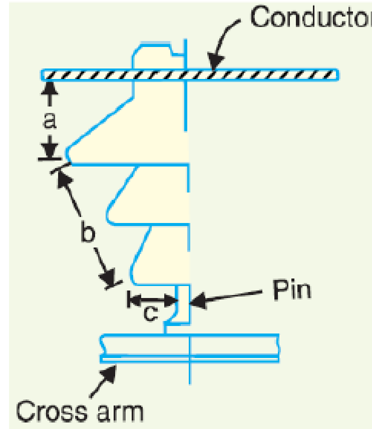
(iv) The insulator material should be non-porous; free from impurities and cracks otherwise the permittivity will be lowered.

(v) High ratio of puncture strength to flashover.

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

Flashover and Puncture of Insulator:

Insulators are required to withstand both mechanical and electrical stresses. The electrical breakdown is primarily due to line voltage and may cause the breakdown of the insulator. The electrical breakdown of the insulator can occur either by flash-over or puncture. In flashover, an arc occurs between the line conductor and insulator pin (i.e., earth) and the discharge jumps across the air gaps, following shortest distance. Figure shows the arcing distance (i.e. a + b + c) for the insulator. In case of flash-over, the insulator will continue to act in its proper capacity unless extreme heat produced by the arc destroys the insulator. In case of puncture, the discharge occurs 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 voltage is known as safety factor i.e.:

Safety factor of 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 type insulators, the value of safety factor is about 10.

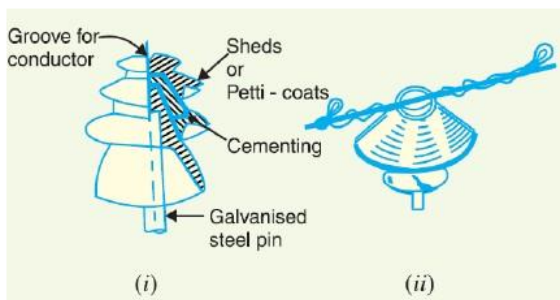
TYPES OF INSULATORS:

The successful operation of an overhead line depends to a considerable extent upon the proper selection of insulators. There are several types of insulators but the most commonly used are:

(i) Pin type (ii) Suspension type (iii) Strain insulator (iv) Shackle insulator

PIN TYPE INSULATOR:

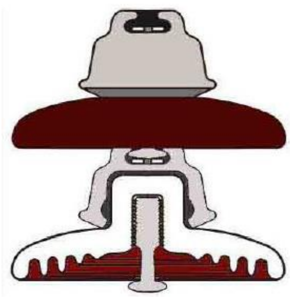
Pin insulator is earliest developed overhead insulator, but still popularly used in power network. The pin type insulator is secured to the cross-arm on the pole. There is a groove on the upper end of the insulator for housing the conductor. The conductor passes through this groove and is bound by the annealed wire of the same material as the conductor. As the leakage path of insulator is through its surface, it is desirable to increase the vertical length of the insulator surface area for lengthening leakage path. In order to obtain lengthy leakage path, one, two or more rain sheds or petticoats are provided on the insulator body. In addition to that rain shed or petticoats on an insulator serve another purpose. These rain sheds or petticoats are so designed, that during raining the outer surface of the rain shed becomes wet but the inner surface remains dry and non-conductive. So there will be discontinuations of conducting path through the wet pin insulator surface.

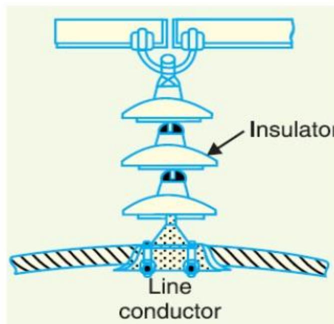


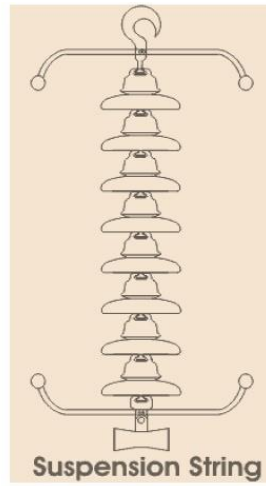
Pin type insulators are used for transmission and distribution of electric power at voltages up to 33 kV. Beyond operating voltage of 33 kV, the pin type insulators become too bulky and hence uneconomical.

SUSPENSION TYPE INSULATOR:

The cost of pin type insulator increases rapidly as the working voltage is increased. Therefore, this type of insulator is not economical beyond 33 kV. For high voltages (>33 kV), it is a usual practice to use suspension type insulators shown in Fig. 8.7. They consist of a number of porcelain discs connected in series by metal links in the form of a 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 11 kV. The number of discs in series would obviously depend upon the working voltage.







Advantages of Suspension insulator

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

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

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

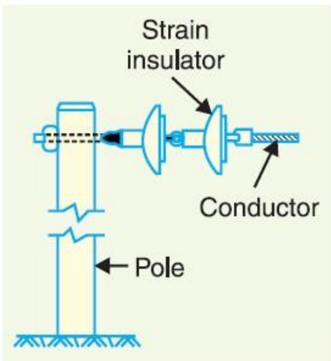
iv. The suspension arrangement provides greater flexibility to the line. The connection at the cross arm is such that insulator string is free to swing in any direction and can take up the position where mechanical stresses are minimum.

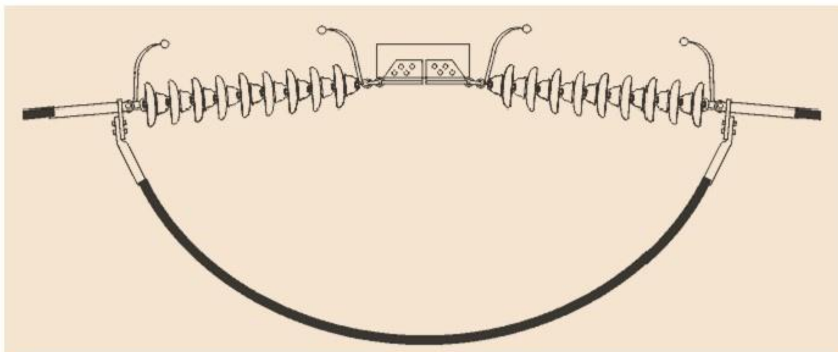
v. In case of increased demand on the transmission line, it is found more satisfactory to supply the greater demand by raising the line voltage than to provide another set of conductors. The additional insulation required for the raised voltage can be easily obtained in the suspension arrangement by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

STRAIN INSULATOR:

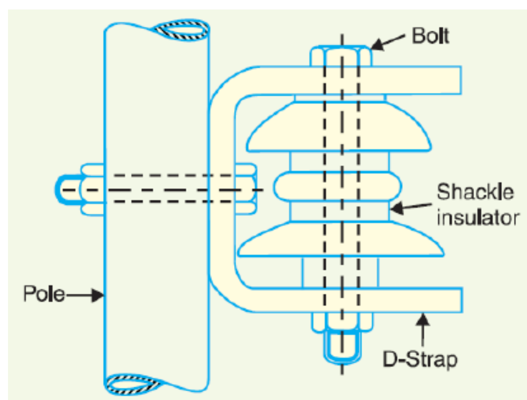
When there is a dead end of the line or there is corner or sharp curve, the line is subjected to greater tension. In order to relieve the line of excessive tension, strain insulators are used. For low voltage lines (< 11 kV), shackle insulators are used as strain insulators. However, for high voltage transmission lines, strain insulator consists of an assembly of suspension insulators as shown in Fig. 8.8. The discs 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.

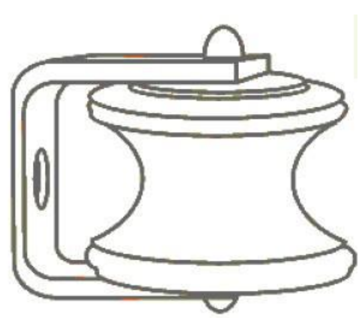




SHACKLE INSULATOR

The shackle insulator or spool insulator is usually used in low voltage distribution network. It can be used both in horizontal and vertical position. The use of such insulator has decreased recently after increasing the using of underground cable for distribution purpose. The tapered hole of the shackle insulator distributes the load more evenly and minimizes the possibility of breakage when heavily loaded. The conductor in the groove of shackle is fixed with the help of soft binding wire. They can be directly fixed to the pole with a bolt or to the cross arm. Figure shows a shackle insulator fixed to the pole.





REVIEW QUESTIONS:

Q-1: Why are insulators used with overhead lines?

Q-2: Discuss the desirable properties of insulators.

Q-3: Explain, how the electrical breakdown can occur in an insulator?

OBSERVATION/OPINION:

EXPERIMENT NO 04

TO ANALYZE THE EFFECTS OF RESISTANCE ON TRANSMISSION LINE

Name of Student: …………………………………………………

Roll No.: ………………………………Section: …………………

Date of Experiment: ……………………………………………….

Report submitted on: …………………………………………………

Marks obtained: ……………………………………

Instructor's Signature: ……………………………...

COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL ENGINEERING

TO ANALYZE THE EFFECTS OF RESISTANCE ON TRANSMISSION LINE

OBJECTIVE:

Objective of this experiment is to study and analyze the effect of resistance on transmission line using energy analyzer.

TOOLS REQUIRED:

Transmission board.
Connecting wires.
Power supply.
Built in resistors.

THEORY:

The conductors of the transmission lines have small resistance. For short lines, resistance plays an important role. As the line current increases so do the ohmic loss (I2R loss). When the current exceed a certain value the heat generated due to ohmic loss starts to melt the conductor and the conductor becomes longer that results in more sag. The current at which this condition of conductor is irreversible is called thermal limit of conductor. Short overhead lines should be operated well within this limit.

The resistance R of a conductor of length 'l' and cross section 'a' is given by the formula

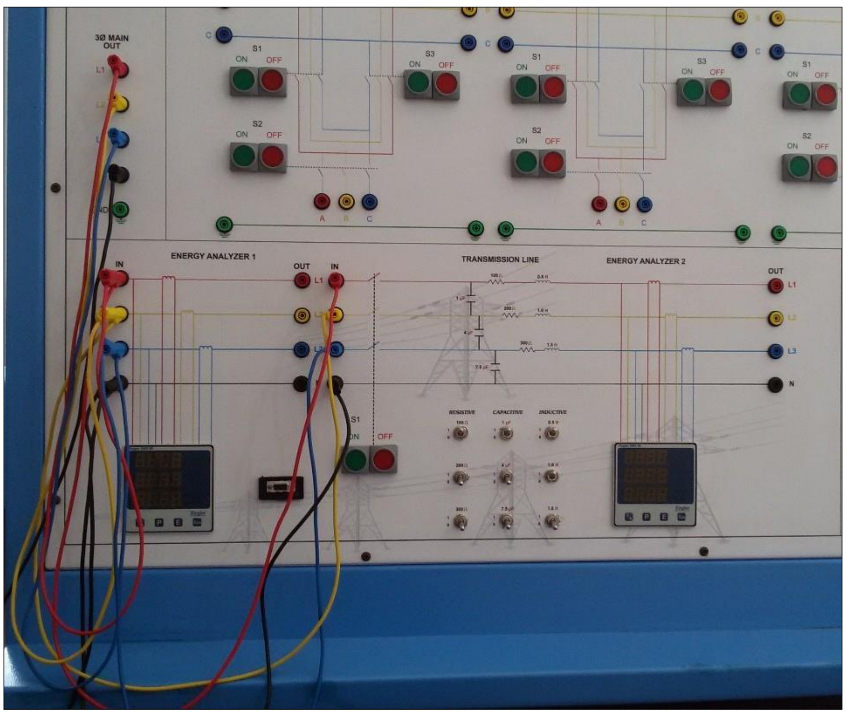
$$R = \rho \frac{l}{a}$$

Here ρ is the resistivity of the conductor material which is a constant. Transmission lines usually use ACSR conductors with spirally twisted strands. So the actual length of the conductor is about 2 % more than the ACSR conductor length. So from the above formula, the resistance of the line is proportionately 2% more than the conductor length. Another important factor is that when the frequency of current increases the current density increases towards the surface of conductor and current density at the center of conductor is less. That means more current flows towards the surface of conductor and less towards the center. This is well known skin effect. Even at power frequency (60/50 Hz) due to this skin effect the effective cross sectional area of conductor is less. Again from the above equation it is clear that the conductor resistance is more for higher frequency. So AC resistance of conductor is more than the DC resistance. Temperature is another factor that influences the resistance of conductor. The resistance varies linearly with temperature. The manufacturers specify the resistance of the conductor and one should use the manufacturer's data.

PROCEDURE:

1. First connect main supply to the input of energy analyzer.
2. And also make both neural same.
3. Than connect input of energy analyzer 1 to the input of transmission line.
4. Add 100 ohm resistor and note its effect.
5. Than add 200 ohm in addition with 100 ohm and note readings.
6. At the end add 300 ohm in addition with both 100 ohm and 200 ohm and note its effect.

CONNECTION DIAGRAM:



ANALYSIS:

S.NO	RESISTANCE	VOLTAGE (V)	CURRENT (I)	KW	KVAR	KVA	PHASE ANGLE	POWER FACTOR
1	100 Ω							
2	200 Ω							
3	300 Ω							

OBSERVATION/OPINION:

EXPERIMENT NO 05

TO ANALYZE THE EFFECTS OF INDUCTANCE ON TRANSMISSION LINE

Name of Student: ……………………………………………………

Roll No.: …………………………………Section: …………………

Date of Experiment: ………………………………………………….

Report submitted on: …………………………………………………

Marks obtained: ……………………………………

Instructor's Signature: ……………………………...

COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL ENGINEERING

TO ANALYZE THE EFFECTS OF INDUCTANCE ON TRANSMISSION LINE

OBJECTIVE:

Objective of this experiment is to study and analyze the effect of inductance on transmission line using energy analyzer.

TOOLS REQUIRED:

Transmission board.
Connecting wires.
Power supply.
Built in inductors.

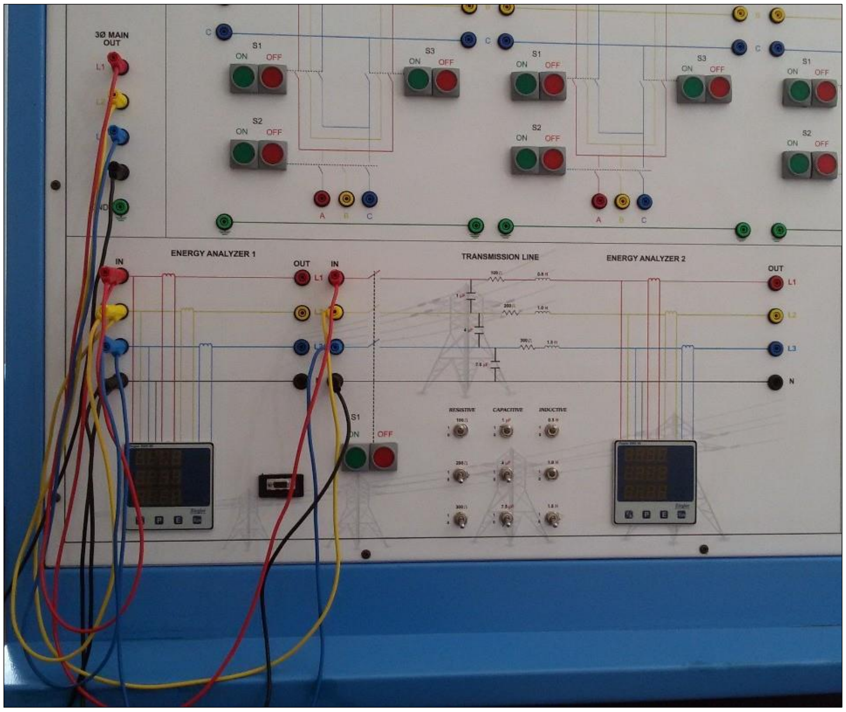
THEORY:

The current flow in the transmission line induces the magnetic flux.When the current in the transmission line changes, the magnetic flux also varies due to which emf induces in the circuit. The magnitude of inducing emf depends on the rate of change of flux. Emf produces in the transmission line resist the flow of current in the conductor, and this parameter is known as the inductance of the line.

PROCEDURE:

1. First connect main supply to the input of energy analyzer.
2. And also make both neural same.
3. Than connect input of energy analyzer 1 to the input of transmission line.
4. Add 0.5H inductor and note its effect.
5. Than add 1H in addition with 0.5H inductor and note readings.
6. At the end add 1.5H inductor in addition with both 0.5H and 1H and note its effect.

CONNECTION DIAGRAM:



ANALYSIS AND RESULTS:

INDUCTIVE LOSS:

S.NO	INDUCTANCE	VOLTAGE (V)	CURRENT (I)	KW	KVAR	KVA	PHASE ANGLE	POWER FACTOR
1	0.5H							
2	1H							
3	1.5H							

OBSERVATION/OPINION:

EXPERIMENT NO 06

TO ANALYZE THE EFFECTS OF CAPACITANCE ON TRANSMISSION LINE

Name of Student: ……………………………………………………

Roll No.: …………………………………Section: …………………

Date of Experiment: ………………………………………………….

Report submitted on: …………………………………………………

Marks obtained: ……………………………………

Instructor's Signature: ……………………………...

COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL ENGINEERING

TO ANALYZE THE EFFECTS OF CAPACITANCE ON TRANSMISSION LINE

OBJECTIVE:

Objective of this experiment is to study and analyze the effects of capacitance on transmission line using energy analyzer.

TOOLS REQUIRED:

Transmission board.
Connecting wires.
Power supply.
Built in capacitors.

THEORY:

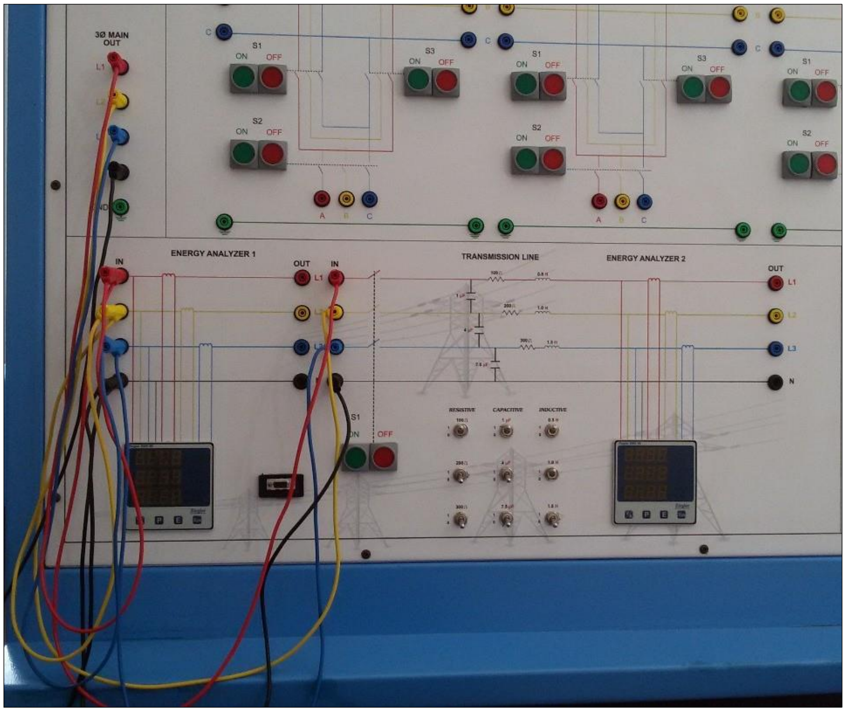
In the transmission lines, air acts as a dielectric medium. This dielectric medium constitutes the capacitor between the conductors, which store the electrical energy, or increase the capacitance of the line. The capacitance of the conductor is defined as the present of charge per unit of potential difference.

Capacitance is negligible in short transmission lines whereas in long transmission; it is the most important parameter. It affects the efficiency, voltage regulation, power factor and stability of the system.

PROCEDURE:

1. First connect main supply to the input of energy analyzer.
2. And also make both neural same.
3. Than connect input of energy analyzer 1 to the input of transmission line.
4. Add 1uF capacitor and note its effect.
5. Then add 4uF in add with 1uF capacitor and note readings.
6. At the end add 7.5uF capacitor in addition with both 1uF and 4uF and note its effect.

CONNECTION DIAGRAM:



ANALYSIS AND RESULTS:

CAPACITIVE LOSS:

S.NO	CAPACITANCE	VOLTAGE (V)	CURRENT (I)	KW	KVAR	KVA	PHASE ANGLE	POWER FACTOR
1	1μF							
2	4μF							
3	7.5μF							

OBSERVATION/OPINION:

EXPERIMENT NO 07

OBSERVE THE FLOW OF ACTIVE AND REACTIVE POWER IN 3-Ø TRANSMISSION LINE AT KNOWN LOADS

Name of Student: …………………………………………………

Roll No.: …………………………………Section: …………………

Date of Experiment: ……………………………………………….

Report submitted on: ………………………………………………

Marks obtained: ……………………………………

Instructor's Signature: ……………………………...

COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL ENGINEERING

OBSERVE THE FLOW OF ACTIVE AND REACTIVE POWER IN 3-Ø TRANSMISSION LINE AT KNOWN LOADS

OBJECTIVE:

Objective of this experiment is to observe the flow of Active and Reactive power in 3-Ø Transmission line at known loads.

COMPONENTS REQUIRED:

- Energy analyzer
- Known loads
- 3 phase transmission line

THEORY:

REAL POWER:

In direct current circuits the real power (in watts) supplied to a load is always equal to the product of the voltage and the current. In alternating current circuits, however, this product is usually greater than the real (or active) power which the load consumes. For this reason, watt meters are used to measure the real power.

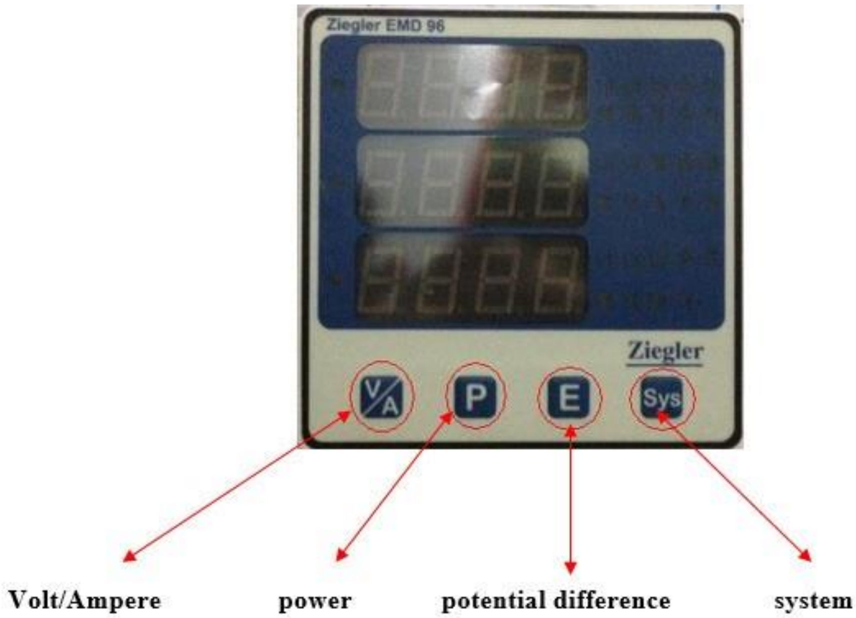
3 phase energy analyzer is an instrument connected into power line to measure the real power which flows in the line if no power flows, the power will indicate zero. In case we have analog watt meter then, If power in the line flows from left to right the pointer will be deflected to the right conversely if power flows from right to left the pointer will be deflected to the left.

In case of digital meter positive and negative signs will show the same thing as mentioned above.

REACTIVE POWER:

Reactive power is the power associated with the charge and discharge of condensers and the increase and decrease of the magnetic fields of inductors when they are part of an alternating current circuit. The same terminology can be applied to meters which measure reactive power such as the mega var-meter.

ENERGY ANALYZER:



Q#1: Draw the power triangle and prove the different formula by using power triangle.

Q#2 Prove the formula of three phase active power reactive power and apparent power.

OBSERVATION/OPINION:

EXPERIMENT NO 08

CALCULATE 'LINE WATTS' AND 'LINE VARS' ABSORBED BY 3-Ø TRANSMISSION LINE AT KNOWN LOADS

Name of Student: …………………………………………………

Roll No.: …………………………………Section: …………………

Date of Experiment: ……………………………………………….

Report submitted on: ………………………………………………

Marks obtained: ……………………………………

Instructor's Signature: ……………………………...

COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL ENGINEERING

CALCULATE 'LINE WATTS' AND 'LINE VARS' ABSORBED BY 3-Ø TRANSMISSION LINE AT KNOWN LOADS

OBJECTIVE:

To calculate 'line watts' and 'line vars' absorbed by 3-Ø Transmission line at known loads.

COMPONENTS REQUIRED:

- Energy analyzer
- Known loads
- 3 phase transmission line

THEORY:

REAL POWER:

In direct current circuits the real power (in watts) supplied to a load is always equal to the product of the voltage and the current. In alternating current circuits, however, this product is usually greater than the real (or active) power which the load consumes. For this reason, watt meters are used to measure the real power.

3 phase energy analyzer is an instrument connected into power line to measure the real power which flows in the line if no power flows, the power will indicate zero. In case we have analog watt meter then, If power in the line flows from left to right the pointer will be deflected to the right conversely if power flows from right to left the pointer will be deflected to the left.

In case of digital meter positive and negative signs will show the same thing as mentioned above.

REACTIVE POWER:

Reactive power is the power associated with the charge and discharge of condensers and the increase and decrease of the magnetic fields of inductors when they are part of an alternating current circuit. The same terminology can be applied to meters which measure reactive power such as the mega var-meter.

PROCEDURE:

Caution:

High voltages are present in this Laboratory Experiment! Do not make any connections with the power on!

Take readings before load and write below.

W1= ______________________________

var 1=______________________________

1. Connect inductive load of per phase, take readings and record in table.
2. Now Apply a three phase resistive load per phase, take readings and record in table.
3. Apply a three phase capacitive load per phase, take reading and record in table.
4. Calculate the real and reactive power which is absorbed by the transmission line in previous experiment and record in table.

Load	V1	W1	Var1	V2	W2	Var2	V3	W3	Var3
Resistive									
Inductive									
Capacitive									
R+L+C									

REVIEIW QUESTIONS:

Q-1. Write down the effect of active and reactive power on system by using resistive, inductive and capacitive load .

Ans:

____

____

____

____

____

____

Q-3: A three-phase transmission line having a reactance of 120 ohms per phase is connected to a wye-connected load whose resistance is 160 ohms per phase. If the supply voltage is 70kV line to line calculate.

a) The line-to-neutral voltage per phase.

40.41 kV

---

b) The line current per phase.

202.5 A

---

c) The real and reactive power supplied to the load.

6.53 MW, 0 VAR

---

d) The real and reactive power absorbed by the line.

4.897 MVAR, 0 W

---

e) The voltage drop per phase in the line.

24.24 kV

---

f) The total apparent power supplied by the source.

8.16 MVA

---

g) The total real and reactive power supplied by the source.

6.53 MW, 4.897 MVAR

OBSERVATION/OPINION:

EXPERIMENT NO. 09

CALCULATE THE VOLTAGE REGULATION OF TRANSMISSION LINE AS A FUNCTION OF TYPE OF LOAD

Name of Student: …………………………………………………

Roll No.: …………………………………Section: …………………

Date of Experiment: ……………………………………………….

Report submitted on: ………………………………………………

Marks obtained: ……………………………………

Instructor's Signature: ……………………………...

COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL ENGINEERING

EXPERIMENT NO.9

CALCULATE THE VOLTAGE REGULATION OF TRANSMISSION LINE AS A FUNCTION OF TYPE OF LOAD

OBJECTIVE:

To calculate the voltage regulation at the receiving end of transmission line as a function of type of load.

COMPONENTS REQUIRED:

- Energy analyzer
- Known loads
- 3 phase transmission line

THEORY:

Voltage regulation of a transmission line is the change in voltage at the receiving end, expressed in percent of full-load voltage, when full load at a specified power factor is removed while the sending-end voltage is held constant.

$$\text{Regulation percentage} = \frac{E_{\text{no-load}} - E_{\text{full-load}}}{E_{\text{full-load}}} (100\%)$$

A resistive or inductive load at the end of a transmission line produces very large voltage drop, which would be quite intolerable under practical conditions. Motor, relays and electric lights work properly only under stable voltage conditions, close to the potential for which these devices are rated. We must, therefore, regulate the voltage at the receiving end of the transmission line in such a way as to keep it as constant as possible. One approach is to connect capacitors parallel to the load which delivers the required reactive power to the inductive loads thus lowering the need of high line current through the transmission line which results in a lower voltage drop at the load terminals.

PROCEDURE:

Caution: High voltages are present in this Laboratory Experiment! Do not make any connections with the power on!

Take readings before load and write below.

W1= ______________________________

var 1=_____________________________

1. Connect inductive load of per phase, take readings and record in table.
2. Now Apply a three phase resistive load per phase, take readings and record in table.
3. Apply a three phase capacitive load per phase, take reading and record in table.
4. Calculate the real and reactive power which is absorbed by the transmission line in previous experiment and record in table.

READINGS:

Load	E1 (V)	W1 (W)	Var1 (var)	Regulation%
No load				
Resistive				
Inductive				
Capacitive				

OBSERVATION/OPINION:

EXPERIMENT NO.10

INVESTIGATE THE CONSTRUCTION, TECHNICAL SPECIFICATION OF DIFFERENT TYPES OF OVERHEAD LINE CONDUCTORS

Name of Student: …………………………………………………

Roll No.: …………………………………Section: …………………

Date of Experiment: ……………………………………………….

Report submitted on: ………………………………………………

Marks obtained: ……………………………………

Instructor's Signature: ……………………………...

COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL ENGINEERING

EXPERIMENT NO.10

INVESTIGATE THE CONSTRUCTION, TECHNICAL SPECIFICATION OF DIFFERENT TYPES OF OVERHEAD LINE CONDUCTORS

OBJECTIVE:

Objective of this experiment is to investigate the construction, technical specification of different types of overhead line conductors (AAC, ACSR)

THEORY:

OVERHEAD LINE CONDUCTOR:

In overhead power line is a structure used in electric power transmission and distribution to transmit electrical energy along large distances. It consists of one or more conductors (commonly multiples of three) suspended by towers or utility poles. Since most of the insulation is provided by air, overhead power lines are generally the lowest-cost method of power transmission for large quantities of electric energy.

Towers for support of the lines are made of wood (as-grown or laminated), steel (either lattice structures or tubular poles), concrete, aluminum, and occasionally reinforced plastics. The bare wire conductors on the line are generallymade of aluminum (either plain or reinforced with steel, or composite materials such as carbon and glass fiber), though some copper wires are used in medium-voltage distribution and low-voltage connections to customer premises. A major goal of overhead power line design is to maintain adequate clearance between energized conductors and the ground so as to prevent dangerous contact with the line, and to provide reliable support for the conductors, resilient to storms, ice load, earthquakes and other potential causes of damage. Today overhead lines are routinely operated at voltages exceeding 765,000 volts between conductors, with even higher voltages possible in some cases.

PROPERTIES OF OVERHEAD BARE CONDUCTORS:

- Current Carrying Capacity
- Strength
- Weight
- Diameter
- Corrosion Resistance
- Creep Rate
- Thermal Coefficient of Expansion
- Fatigue Strength
- Operating Temperature
- Short Circuit Current/Temperature
- Thermal Stability
- Cost

CATEGORIES OF OVERHEAD CONDUCTORS:

- VR (Vibration Resistance)
- Non-Specular
- ACSR / SD• (Self Damping)

CHOICES OF OVERHEAD DEPEND UPON:

POWER DELIVERY REQUIREMENTS:

- Current Carrying Capacity
- Electrical Losses

LINE DESIGN REQUIREMENTS:

- Distances to be Spanned
- Sag and Clearance Requirements

ENVIRONMENTAL CONSIDERATIONS:

- Ice and Wind Loading
- Ambient Temperatures

CATEGORIES OF OVERHEAD CONDUCTORS:

HOMOGENEOUS CONDUCTORS:

- Copper
- AAC (All Aluminum Conductor)
- AAAC (All Aluminum Alloy Conductor)
- The core consists of a single strand identical to the outer strands. Since all the strands are the same diameter, one can show that the innermost layer always consists of 6 strands, the second layer of 12 strands, etc., making conductors having 1, 7, 19, 37, 61, 91, or 128 strands.

NON HOMOGENEOUS CONDUCTORS:

- ACAR (Aluminum Conductor Alloy Reinforced)
- ACSR (Aluminum Conductor Steel Reinforced)
- ACSS (Aluminum Conductor Steel Supported)
- AACSR (Aluminum Alloy Conductor Steel Reinforced.
- The strands in the core may or may not be of the same diameter. In a 30/7
- ACSR conductor the aluminum and steel strands are of the same diameter. In a 30/19
- ACSR they are not. Within the core or within the outer layers, however, the number of strands always increases by 6 in each succeeding layer. Thus, in 26/7 ACSR, the number of layers in the inner layer of aluminum is 10 and in the outer layer 16

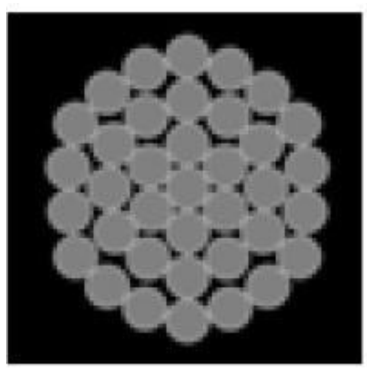
CLASSIFICATION BY OPERATING VOLTAGE:

Overhead power transmission lines are classified in the electrical power industry by the range of voltages:

- Low voltage (LV) – less than 1000 volts, used for connection between a residential or small commercial customer and the utility.
- Medium voltage (MV; distribution) – between 1000 volts (1 kV) and to about 33 kV, used for distribution in urban and rural areas.
- High voltage (HV; sub transmission less than 100 kV; sub transmission or transmission at voltage such as 115 kV and 138 kV), used for sub-transmission and transmission of bulk quantities of electric power and connection to very large consumers.
- Extra high voltage (EHV; transmission) – over 230 kV, up to about 800 kV, used for long distance, very high power transmission.
- Ultra high voltage (UHV) – higher than 800 kV.

1. AAC (ALL ALUMINUM CONDUCTORS):

- AAC is made up of one or more strands of hard drawn 1350 Aluminum Alloy.
- AAC has had limited use in transmission lines and rural distribution because of the long spans utilized.
- Good Conductivity -61.2% IACS
- Good Corrosion Resistance
- High Conductivity to Weight Ratio.
- Moderate Strength

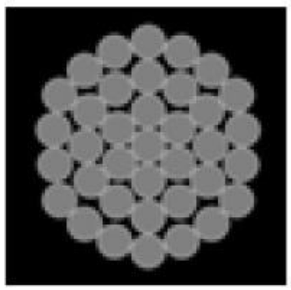


TYPICAL APPLICATION:

- Short spans where maximum current transfer is required.
- The excellent corrosion resistance of aluminum has made AAC a conductor of choice in coastal areas.
- Because of its relatively poor strength-to-weight ratio, AAC has seen extensive use in urban areas where spans are usually short but high conductivity is required.
- These conductors are used in low, medium and high voltage overhead lines.

2. AAAC (ALL ALUMINUM ALLOY CONDUCTORS):

- AAAC are made out of high strength Aluminum-Magnesium-Silicon alloy.
- AAAC with different variants of electrical grade Alloys type 6101 and 6201.
- These conductors are designed to get better strength to weight ratio and offers improved electrical characteristics, excellent sag-tension characteristics and superior corrosion resistance when compared with ACSR.
- Equivalent aluminum alloy conductors have approximately the same ampacity and strength as their ACSR counterparts with a much improved strength-to-weight ratio, and also exhibit substantially better electrical loss characteristics than their equivalent single layer ACSR constructions. The thermal coefficient of expansion is greater than that of ACSR.
- As compared to conventional ACSR, lighter weight, comparable strength & current carrying capacity, lower electrical losses and superior corrosion resistance have given AAAC a wide acceptance in the distribution and transmission lines.



FEATURES:

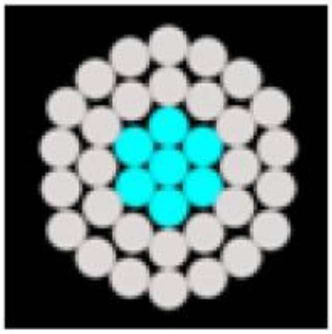
- High strength to weight ratio
- Better sag characteristics
- Improved electrical properties
- Excellent resistance to corrosion
- Specifications
- Higher Tensile Strength
- Excellent Corrosion Resistance
- Good Strength to Weight Ratio
- Lower Electrical Losses
- Moderate Conductivity –52.5% IACS

TYPICAL APPLICATION:

Transmission and Distribution applications in corrosive environments, ACSR replacement.

3. ACAR (ALUMINUM CONDUCTOR AL. ALLOY REINFORCED):

- Aluminum Conductor Alloy Reinforced (ACAR) is formed by concentrically stranded Wires of Aluminum 1350 on high strength Aluminum-Magnesium-Silicon (AlMgSi) Alloy core.
- The number of wires of Aluminum 1350 & AlMgSi alloy depends on the cable design.
- Even though the general design comprises a stranded core of AlMgSi alloy strands, in certain cable constructions the wires of AlMgSi Alloy strands can be distributed in layers throughout the Aluminum 1350 strands. ACAR has got a better mechanical and electrical properties as compared to an equivalent conductors of ACSR, AAC or AAAC.
- A very good balance between the mechanical and electrical properties therefore makes ACAR the best choice where the ampacity, strength, and light weight are the main consideration of the line design.
- These conductors are extensively used in overhead transmission and distribution line.



FEATURES:

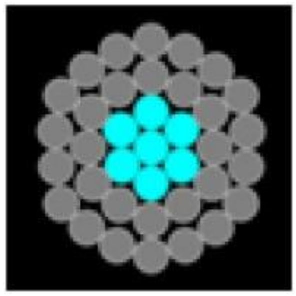
- Improved strength to weight ratio
- Improved mechanical properties
- Improved electrical properties
- Excellent resistance to corrosion Specifications
- Balance of Mechanical & Electrical
- Excellent Corrosion Resistance
- Variable Strength to Weight Ratio
- Higher Conductivity than AAAC
- Custom Designed, diameter equivalent to ACSR most common.

TYPICAL APPLICATION:

Used for both transmission and distribution circuits.

4. AACSR - ALUMINUM ALLOY CONDUCTOR STEEL REINFORCED

- AACSR is a concentrically stranded conductor composed of one or more layers of Aluminum-Magnesium-Silicon alloy wire stranded with a high-strength coated steel core.
- The core may be single wire or stranded depending on the size. Core wire for AACSR is available with Class A, B or C galvanizing; or aluminum clad (AW).
- Additional corrosion protection is available through the application of grease to the core or infusion of the complete cable with grease.

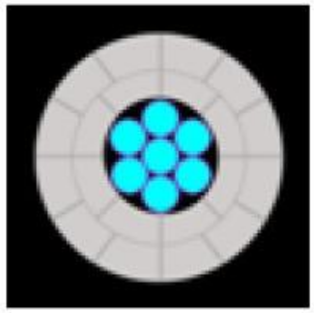


FEATURES:

- Offers optimal strength for line design
- Improved strength to weight ratio
- Ideal for extra long spans and heavy load conditions
- Excellent resistance to corrosion

5. ACSS - ALUMINUM CONDUCTORS STEEL SUPPORTED:

- ACSS is a composite concentric-lay stranded conductor with one or more layers of hard drawn and annealed 1350-0 aluminum wires on a central core of steel.
- In an ACSS, under normal operating conditions, the mechanical load is mainly derived from the steel core as aluminum in fully annealed stage does not contribute much towards the mechanical strength.
- Steel core wires are protected from corrosion by selecting an appropriate coating of the wire like galvanizing, mischmetal alloy coating or aluminum clad. The type of coating is selected to suit the environment to which the conductor is exposed and operating temperature of the conductor
- ACSS are suitable for operating at high temperature without losing the mechanical properties.
- The final sag-tension performance is not affected by the long term creep of aluminum.



FEATURES:

- Improved conductivity
- High current carrying capacity
- Very low sag at high temperature
- High degree of immunity to vibration fatigue
- Better self-damping property

6. ACCC - ALUMINUM CONDUCTOR COMPOSITE CORE:

- With one or more layers of trapezoidal shaped hard drawn and annealed 1350-0 aluminum wires on a central core of high strength Carbon and glass fiber composite.
- The ACCC Conductor uses a carbon fiber core that is 25% stronger and 60% lighter than a traditional steel core.
- This allows with the help of trapezoidal shaped strands the ability to increase the conductor's aluminum content by over 28% without increasing the conductor's overall diameter or weight.

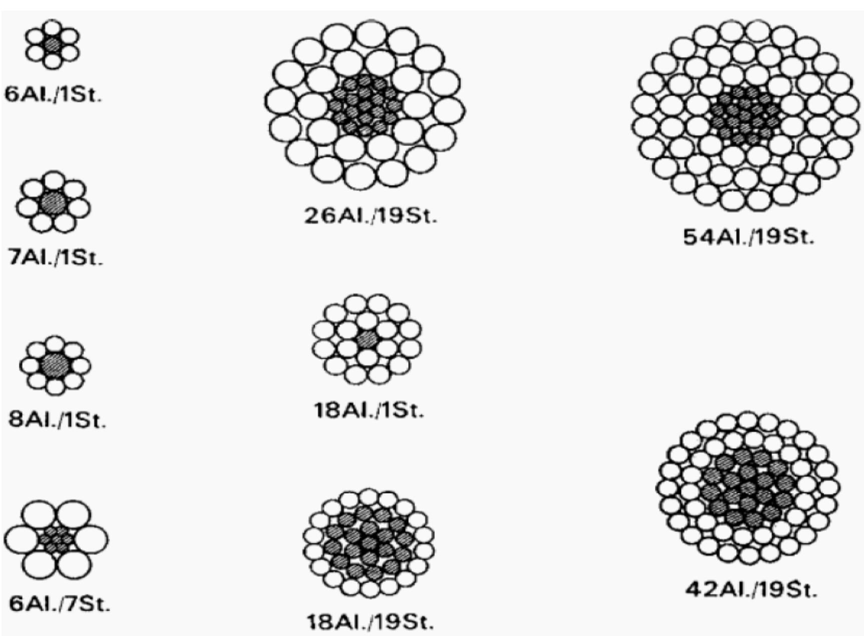
FEATURES:

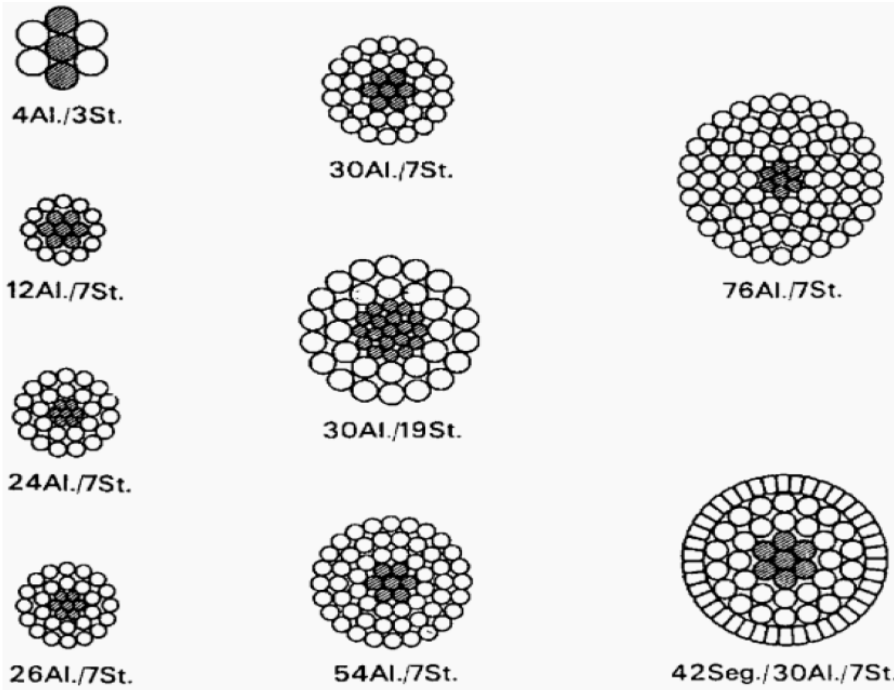
- Excellent Sag properties
- Increased current carrying capacity
- High operating temperature
- Excellent strength to weight ratio
- Highly energy efficient

7. ACSR (ALUMINUM CONDUCTOR STEEL REINFORCED):

- Aluminum Conductor Steel Reinforced (ACSR) is concentrically stranded conductor with one or more layers of hard drawn 1350-H19 aluminum wire on galvanized steel wire core.
- The core can be single wire or stranded depending on the size.
- Steel wire core is available in Class A ,B or Class C galvanization for corrosion protection.
- Additional corrosion protection is available through the application of grease to the core or infusion of the complete cable with grease.

- The proportion of steel and aluminum in an ACSR conductor can be selected based on the mechanical strength and current carrying capacity demanded by each application.
- ACSR conductors are recognized for their record of economy, dependability and favorable strength / weight ratio. ACSR conductors combine the light weight and good conductivity of aluminum with the high tensile strength and ruggedness of steel.
- In line design, this can provide higher tensions, less sag, and longer span lengths than obtainable with most other types of overhead conductors.
- The steel strands are added as mechanical reinforcements.
- ACSR conductors are recognized for their record of economy, dependability and favorable strength / weight ratio.
- ACSR conductors combine the light weight and good conductivity of aluminum with the high tensile strength and ruggedness of steel.
- In line design, this can provide higher tensions, less sag, and longer span lengths than obtainable with most other types of overhead conductors.
- The steel strands are added as mechanical reinforcements.
- The cross sections above illustrate some common stranding.
- The steel core wires are protected from corrosion by galvanizing.
- The standard Class A zinc coating is usually adequate for ordinary environments.
- For greater protection, Class B and C galvanized coatings may be specified. The product is available with conductor corrosion resistant inhibitor treatment applied to the central steel component. Figure illustrates typical stranding's of ACSR. The conductor, with an outer layer of segmented strands, has a smooth surface and a slightly reduced diameter for the same





FEATURES:

- High Tensile strength
- Better sag properties
- Economic design
- Suitable for remote applications involving long spans
- Good Ampacity
- Good Thermal Characteristics
- High Strength to Weight Ratio
- Low sag
- High Tensile Strength

TYPICAL APPLICATION:

- Commonly used for both transmission and distribution circuits.
- Compact Aluminum Conductors, Steel Reinforced (ACSR) are used for overhead distribution and transmission lines.

CALCULATION OF NO. OF STRANDS:

No of strands can be calculated by formula that is given below.

$$\text{Total No. of Strands} = 3n(n-1) + 1$$

Where n is the no. of layers.

OBSERVATION/OPINION:

EXPERIMENT NO. 11

INVESTIGATE MAIN SUPPORTING UNIT OF TRANSMISSION LINE (TRANSMISSION TOWERS)

Name of Student: ……………………………………………………

Roll No.: …………………………………Section: …………………

Date of Experiment: ………………………………………………….

Report submitted on: …………………………………………………

Marks obtained: ……………………………………

Instructor's Signature: ……………………………...

COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL ENGINEERING

EXPERIMENT NO. 11

INVESTIGATE MAIN SUPPORTING UNIT OF TRANSMISSION LINE (TRANSMISSION TOWERS)

OBJECTIVE:

Objective of this experiment is to investigate main supporting unit of transmission line (transmission towers).

THEORY:

The main supporting unit of overhead transmission line is transmission tower. Transmission towers have to carry the heavy transmission conductor at a sufficient safe height from ground. In addition to that all towers have to sustain all kinds of natural calamities. So transmission tower designing is an important engineering job where all three basic engineering concepts, civil, mechanical and electrical engineering concepts are equally applicable. A power transmission tower consists of the following parts,

- Peak of transmission tower
- Cross arm of transmission tower
- Boom of transmission tower
- Cage of transmission tower
- Transmission Tower Body
- Leg of transmission tower
- Stub/Anchor Bolt and Base plate assembly of transmission tower.
- The main parts among these are shown in the pictures.

PEAK OF TRANSMISSION TOWER:

The portion above the top cross arm is called peak of transmission tower. Generally earth shield wire connected to the tip of this peak.

CROSS ARM OF TRANSMISSION TOWER:

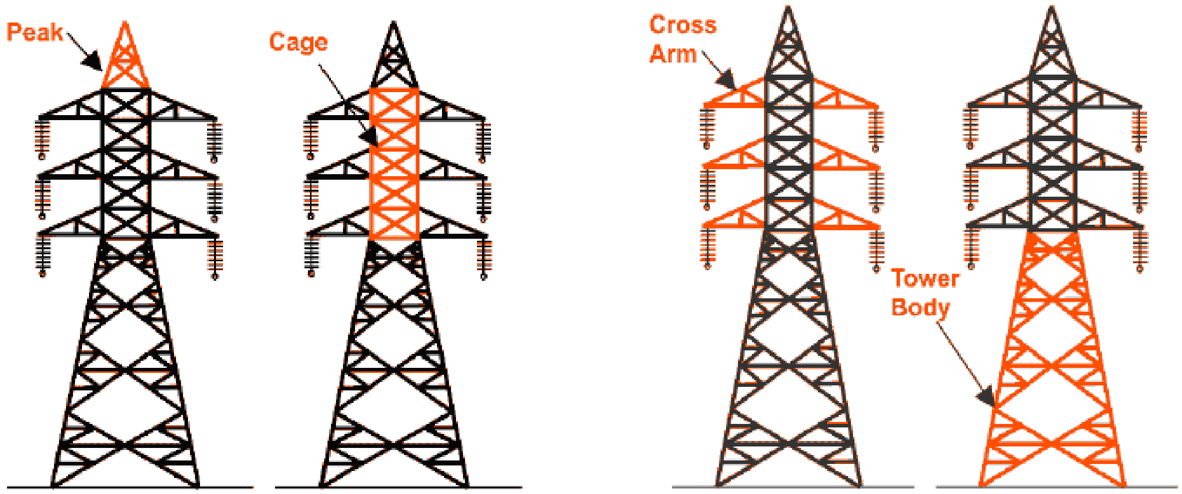
Cross arms of transmission tower hold the transmission conductor. The dimension of cross arm depends on the level of transmission voltage, configuration and minimum forming angle for stress distribution.

CAGE OF TRANSMISSION TOWER:

The portion between tower body and peak is known as cage of transmission tower. This portion of the tower holds the cross arms.

TRANSMISSION TOWER BODY:

The portion from bottom cross arms up to the ground level is called transmission tower body. This portion of the tower plays a vital role for maintaining required ground clearance of the bottom conductor of the transmission line.



DESIGN OF TRANSMISSION TOWER:

During design of transmission tower the following points to be considered in mind,

- The minimum ground clearance of the lowest conductor point above the ground level.
- The length of the insulator string.
- The minimum clearance to be maintained between conductors and between conductor and tower. The location of ground wire with respect to outer most conductors.
- The mid span clearance required from considerations of the dynamic behavior of conductor and lightening protection of the line.

To determine the actual transmission tower height by considering the above points, we have divided the total height of tower in four parts,

- Minimum permissible ground clearance (H1)
- Maximum sag of the conductor (H2)
- Vertical spacing between top and bottom conductors (H3)
- Vertical clearance between ground wire and top conductor (H4).

TYPES OF TRANSMISSION TOWER:

According to different considerations, there are different types of transmission towers. The transmission line goes as per available corridors. Due to unavailability of shortest distance straight corridor transmission line has to deviate from its straight way when obstruction comes. In total length of a long transmission line there may be several deviation points. According to the angle of deviation there are four types of transmission tower.

1. A – Type tower – angle of deviation 0o to 2o.
2. B – Type tower – angle of deviation 2o to 15o.
3. C – Type tower – angle of deviation 15o to 30o.
4. D – Type tower – angle of deviation 30o to 60o.

As per the force applied by the conductor on the cross arms, the transmission towers can be categorized in another way.

1. Tangent suspension tower and it is generally A – type tower.
2. Angle tower or tension tower or sometime it is called section tower. All B, C and D types of transmission towers come under this category.

Apart from the above customized type of tower, the tower is designed to meet special usages listed below,

These are called special type tower

1. River crossing tower
2. Railway/ Highway crossing tower
3. Transposition tower

Based on numbers of circuits carried by a transmission tower, it can be classified as-

1. Single circuit tower
2. Double circuit tower
3. Multi circuit tower.

OBSERVATION/OPINION:

EXPERIMENT NO 12

EVALUATE THE CONSTRUCTION, CHARACTERISTICS, SELECTION AND APPLICATION OF LIGHTENING ARRESTOR

Name of Student: ……………………………………………………

Roll No.: …………………………………Section: …………………

Date of Experiment: ……………………………………………….

Report submitted on: ………………………………………………

Marks obtained: ……………………………………

Instructor's Signature: ……………………………...

COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL ENGINEERING

EXPERIMENT NO. 12

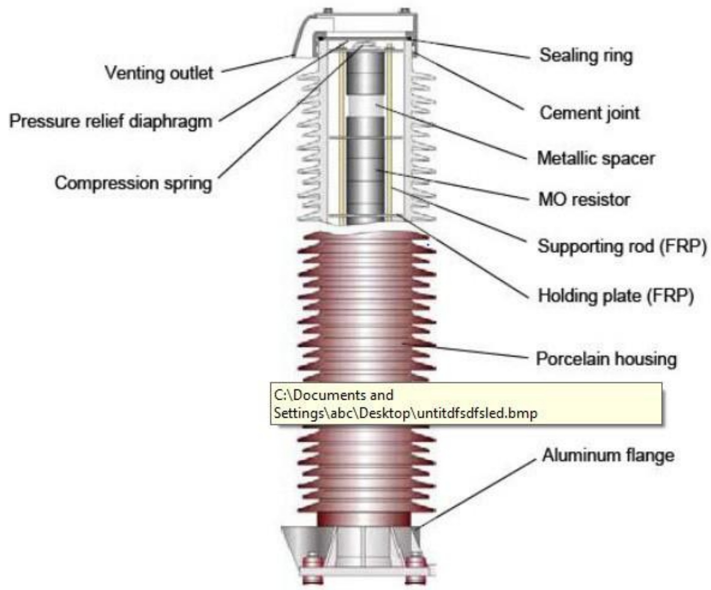
EVALUATE THE CONSTRUCTION, CHARACTERISTICS, SELECTION AND APPLICATION OF LIGHTENING ARRESTOR

OBJECTIVE:

Objective of this experiment is to evaluate the construction, characteristics, selection and application of lightening Arrestor as a protective device in power system.

THEORY:

A surge arrester is defined as: "A protective device for limiting surge voltages by discharging or bypassing surge current" Surge protection has been a primary concern when connecting devices and equipment to low-, medium-, or high-voltage electrical systems.



TYPES/CLASSIFICATIONS

TYPES:

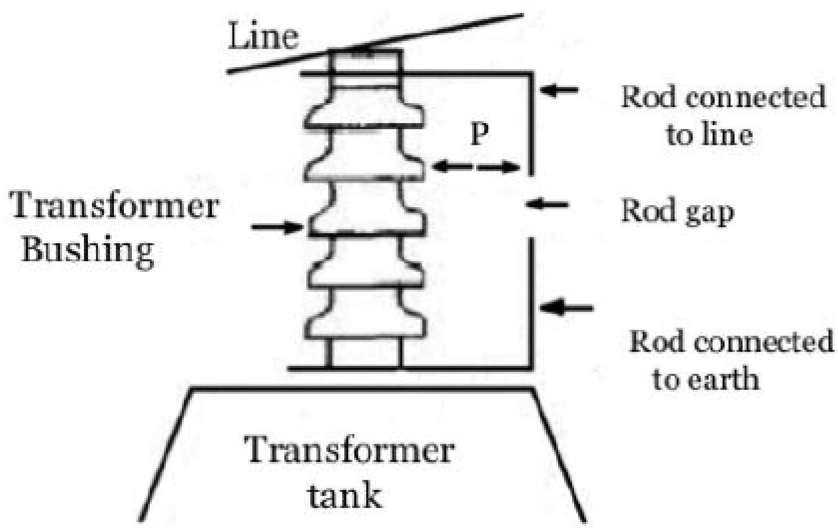
There are two types of arrestors as given below:

1. Gaped surge Arrestors

a. Rod gap type surge Arrestors
b. Horn gap type surge Arrestors
c. Multi gap type surge Arrestors
d. Expulsion type surge Arrestors
e. Valve type surge Arrestors (Non-linear resistor type)
f. Silicon type surge Arrestors

Rod gap type surge Arrestors:

It is a very simple type of diverter and consists of two 1.5 cm rods, which are bent at right angles with a gap in between as shown in Fig. One rod is connected to the line circuit and the other rod is connected to earth. The distance between gap and insulator (i.e. distance P) must not be less than one third of the gap length so that the arc may not reach the insulator and damage it.Generally, the gap length is so adjusted that breakdown should occur at 80% of spark-voltage in order to avoid cascading of very steep wave fronts across the insulators.The string of insulators for an overhead line on the bushing of transformer has frequently a rod gap across it. Fig 8 shows the rod gap across the bushing of a transformer. Under normal operating conditions, the gap remains non-conducting. On the occurrence of a high voltage surge on the line, the gap sparks over and the surge current is conducted to earth. In this way excess charge on the line due to the surge is harmlessly conducted to earth.



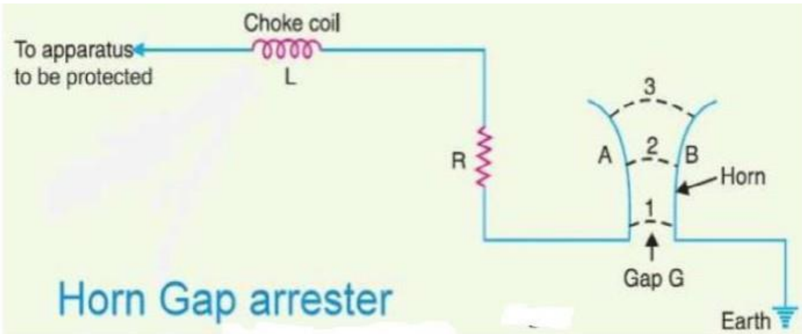
Limitations:

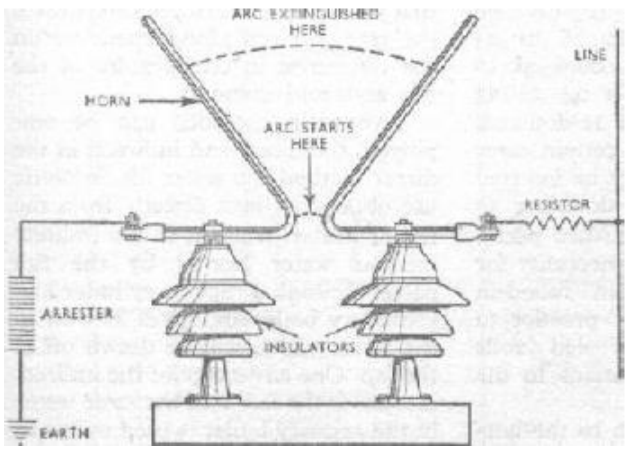
1. After the surge is over, the arc in the gap is maintained by the normal supply voltage, leading to short-circuit on the system.
2. The rods may melt or get damaged due to excessive heat produced by the arc.
3. The climatic conditions (e.g. rain, humidity, temperature etc.) affect the performance of rod gap arrester.
4. The polarity of the f the surge also affects the performance of this arrester.

Due to the above limitations, the rod gap arrester is only used as a back-up protection in case of main arresters.

Horn gap type surge Arrestors

Fig shows the horn gap arrester. It consists of a horn shaped metal rods A and B separated by a small air gap. The horns are so constructed that distance between them gradually increases towards the top as shown. The horns are mounted on porcelain insulators. One end ofhorn is connected to the line through a resistance and choke coil L while the other end is effectively grounded. The resistance R helps in limiting the follow current to a small value. The choke coil is so designed that it offers small reactance at normal power frequency but a very high reactance at transient frequency. Thus the choke does not allow the transients to enter the apparatus to be protected. The gap between the horns is so adjusted that normal supply voltage is not enough to cause an arc across the gap.





Under normal conditions, the gap is non-conducting i.e. normal supply voltage is insufficient to initiate the arc between the gap. On the occurrence of an over voltage, spark-over takes place across the small gap G. The heated air around the arc and the magnetic effect of the arc cause the arc to travel up the gap. The arc moves progressively into positions 1, 2 and 3.At some position of the arc (position 3), the distance may be too great for the voltage to maintain the arc; consequently, the arc is extinguished. The excess charge on the line is thus conducted through the arresterto the ground.

Expulsion type surge Arrestors

This type of arrester is also called 'protector tube' and is commonly used on system operating at voltages up to 33kV. Fig shows the essential parts of an expulsion type lightning arrester. It essentially consists of a rod gap AA' in series with a second gap enclosed within the fiber tube. The gap in the fiber tube is formed by two electrodes. The upper electrode is connected to rod gap and the lower electrode to the earth. One expulsion arrester is placed under each line conductor.Fig shows the installation of expulsion arrester on an overhead line.

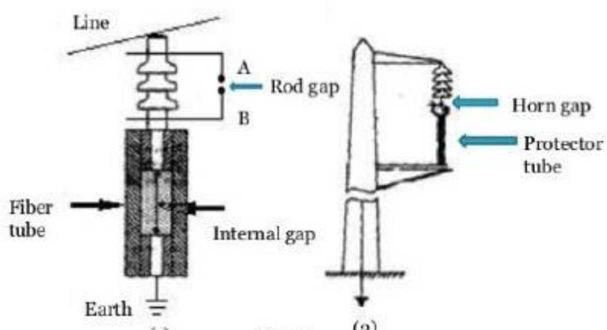


Fig:08

On the occurrence of an over voltage on the line, the series gap AA' spanned and an arc is stuck between the electrodes in the tube. The heat of the arc vaporizes some of the fiber of tube walls resulting in the production of neutral gas. In an extremely short time, the gas builds up high pressure and is expelled through the lower electrode, which is hollow. As the gas leaves the tube violently it carries away ionized air around the arc.This deionizing effect is generally so strong that the arc goes out at a current zero and will not be re-established.

Advantages

1. They are not very expensive.
2. They are improved form of rod gap arresters as they block the flow of power frequency follow currents.
3. They can be easily installed.

Limitations

1. An expulsion type arrester can perform only limited number of operations as during each operation some of the fiber material is used up.
2. This type of arrester cannot be mounted on enclosed equipment due to discharge of gases during operation.
3. Due to the poor volt/am characteristic of the arrester, it is not suitable for protection of expensive equipment

Valve type surge Arrestors :(Non-linear resistor type)

Valve type arresters incorporate non-linear resistors and are extensively used on systems, operating at high voltages. Fig shows the various parts of a valve type arrester. It consists of two assemblies

(i) series spark gaps and (ii) non-linear resistor discs in series. The non-linear elements are connected in series with the spark gaps. Both the assemblies are accommodated in tight porcelain container.

The spark gap is a multiple assembly consisting of a number of identical spark gaps in series. Each gap consists of two electrodes with fixed gap spacing. The voltage distribution across the gap is line raised bymeans of additional resistance elements called grading resistors across the gap. The spacing of the series gaps is such that it will withstand the normal circuit voltage. However an over voltage will cause the gap to break down causing the surge current to ground via the non-linear resistors.

The non-linear resistor discs are made of inorganic compound such as thyrite or metrosil. These discs are connected in series. The non-linear resistors have the property of offering a high resistance to current flow when normal system voltage is applied, but a low resistance to the flow of high surge currents. In other words, the resistance of these non-linear elements decreases with the increase in current through them and vice-versa.

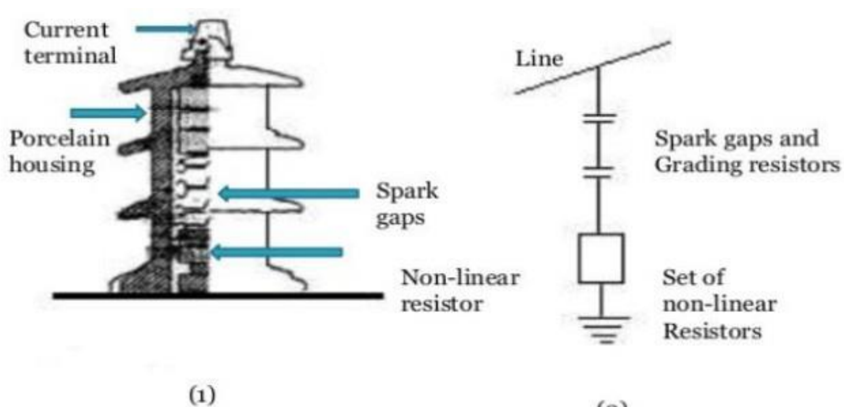


Fig:09

Under normal conditions, the normal system voltage is insufficient to cause the break down of air gap assembly. On the occurrence of an over voltage, the breakdown of the series spark gap takes place and the surge current is conducted to earth via the non-linear resistors.

Since the magnitude of surge current is very large, the non-linear elements will offer a very low resistance to the passage of surge. The result is that the surge will rapidly go to earth instead of being sent back over the line. When the surge is over, the non-linear resistors assume high resistance to stop the flow of current.

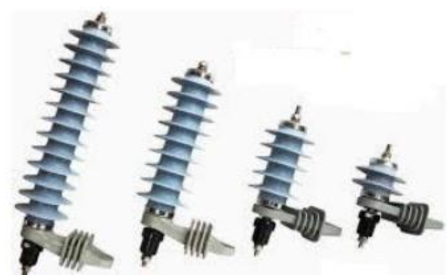
Silicon carbide type surge Arrestors:

A great number of silicon carbide arresters are still in service. The silicon carbide arrester has some unusual electrical characteristics. It has a very high resistance to low voltage, but a very low resistance to high voltage. When lightning strikes or a transient voltage occurs on the system, there is a sudden rise in voltage and current. The silicon carbide resistance breaks down allowing the current to be conducted to ground. After the surge has passed, the resistance of the silicon carbide blocks increases allowing normal operation. The silicon carbide arrester uses nonlinear resistors made of bonded silicon carbide placed in series with gaps. The function of the gaps is to isolate the resistors from the normal steady-state system voltage.

One major drawback is the gaps require elaborate design to ensure consistent spark-over level and positive clearing (resealing) after a surge passes.It should be recognized that over a period of operations that melted particles of copper might form which could lead to a reduction of the breakdown voltage due to the pinpoint effect. Over a period of time, the arrester gap will break down at small over voltages or even at normal operating voltages. Extreme care should be taken on arresters that have failed but the over pressure relief valve did not operate.

Gapless Surge Arrestors

MOV ARRESTER



The MOV arrester is the arrester usually installed today. The metal oxide arresters are without gaps, unlike the silicon Carbide (SIC) arrester. This “gapless” design eliminates the high heat associated with the arcing discharges. The MOV arrester has two-voltage rating: duty cycle and maximum continuous operating voltage, unlike the silicon carbide that just has the duty cycle rating. A metal-oxide surge arrester utilizing zinc-oxide blocks provides the best performance, as surge voltage conduction starts and stops promptly at a precise voltage level, thereby improving system protection. Failure is reduced, as there is no air gap contamination possibility; but there is always a small value of leakage current present at operating frequency. When a metal oxide arrester is disconnected from an energized line, a small amount of static charge can be retained by the arrester. As a safety precaution, technicians install a temporary ground to discharge any stored energy. Duty cycle rating: The silicon carbide and MOV arrester have a duty cycle rating in KV, which is determined by duty cycle testing. Duty cycle testing of an arrester is performed by subjecting an arrester to an AC rms voltage equal to its rating for 24 minutes. During which the arrester must be able to withstand lightning surges at 1-minute intervals. Maximum continuous operating voltage rating: The MCOV rating is usually 80 to 90% of the duty cycle rating.

There are four (4) classifications of surge arrestors. They are:

- Station class
- Intermediate class
- Distribution class (heavy, normal, and light duty)
- Secondary class (for voltages 999V or less)

With respect to the four classes of surge arresters, the station class surge arrester is the best because of its cost and overall protective quality and durability. It has the lowest (best) available protection level and energy discharging capability with successively higher (poorer) protection levels for the other classifications. The gapless metal-oxide surge arrester (MOSA) provides the best performance and reliability. Note that both the gap and gapless type arresters do the same job and the selection and application process of both types are similar. However, the need to select higher voltage levels for the silicone-carbide gap type and the possibility of contamination of the gap means the protection and reliability is slightly less. When gapped type arresters fail, the reader should consider or recommend replacing them with the metal-oxide gapless type

SELECTION AND APPLICATION

The primary objective in arrester application is to select the lowest rated surge arrester that will provide adequate protection of the equipment insulation and be rated such that it will have a satisfactory service life when connected to the power system. An arrester of the minimum practical rating is preferred because it provides the highest margin of protection for the equipment insulation system. There is a fine line between protection and service life of a surge arrester. Higher arrester ratings will increase the capability of the arrester to survive on a specific power system but reduce the margin of protection provided for the insulation level of the equipment it is protecting.

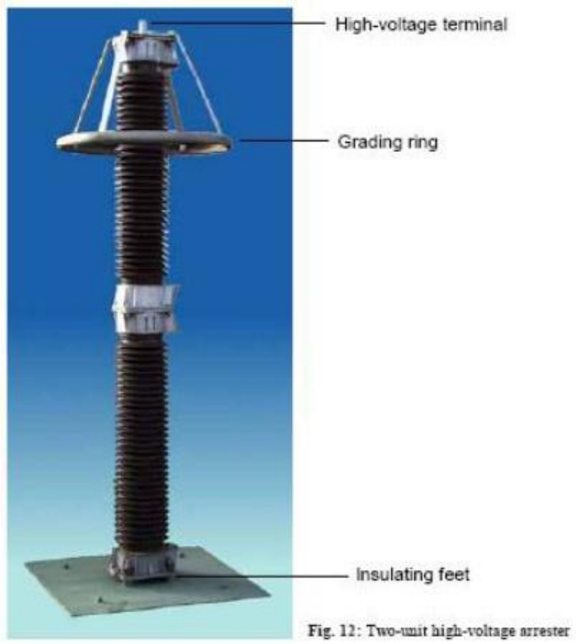


Fig. 12: Two-unit high-voltage arrester

There are some basic considerations when selecting the appropriate surge arrester for a particular application:

- Continuous system voltage o
- Temporary over voltages
- Switching surges (more often considered for transmission voltages of 345KV and higher, capacitor banks, and cable applications)
- Lightning surges

CONTINUOUS SYSTEM VOLTAGE

When arresters are connected to an electrical system, they are continually exposed to the system operating voltage. For each arrester rating, there is a recommended limit to the magnitude of voltage that may be applied continuously. This is termed the Maximum Continuous Operating Voltage (MCOV) of the arrester. The arrester rating must be selected such that the maximum continuous power system voltage applied to the arrester is less than, or equal to, the arrester's MCOV rating.

TEMPORARY OVER VOLTAGES

(TOV) Temporary over voltages (TOV) can be caused by a number of system events, such as switching surges, line-to-ground faults, load rejection and ferro-resonance. The primary effect of TOV on metal-oxide arresters is the increased current and power dissipation, and a rising arrester temperature. These conditions affect the protection and survivability characteristics of the arrester.

SWITCHING SURGES

The arrester's ability to dissipate switching surges can be quantified to a large degree in terms of energy. The unit used in quantifying the energy capability of metal-oxide arresters is kilojoules/kilovolt (kj/kv).

SYSTEM CONFIGURATION

Knowing the system configuration, wye/delta, grounded or ungrounded, is a key factor in selecting an arrester rating. the arrester nominal ratings for various utilization system voltages (line-to-line) are based on the system's grounding configuration. If the system is solidly grounded, then a lower rated arrester can be chosen. If the system is ungrounded, impedance grounded or temporarily ungrounded, and then a higher arrester rating must be chosen. If the system configuration is unknown, then the reader should assume the system is ungrounded.

INSTALLATION

The best location for installation of a surge arrester is as close as possible to the equipment it is protecting, preferably at the terminals where the service is connected to the equipment. Lead length for the connection of the surge arrester to the equipment terminals and to ground should be minimized and installed as straight, minimizing bends in the leads, as possible. This will ensure that the surge energies are shunted to ground by the most direct path. Increases in the lead length will reduce the protection capabilities of the surge arrester, due to the additional increase of impedance in the lead.

ARRESTER FAILURE

If the capability of an arrester is exceeded, the metal-oxide disk(s) may crack or puncture. Such damage will reduce the arrester internal electrical resistance. This condition will limit the arrester's ability to survive future system conditions; it does not jeopardize the insulation protection provided by the arrester.

REVIEW QUESTIONS:

Q.1 Why surge arresters are important in electrical protection system?

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Q.2 What are the causes of over voltages/surge?

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Q.3What is the best location for installation of a surge arrester?

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Q.4 Define duty cycle testing of an arrester?

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OBSERVATION/OPINION:

EXPERIMENT NO 13

TO ANALYZE THE CONNECTION OF TRANSMISSION LINE WITH 3Ø FEEDER

Name of Student: …………………………………………………

Roll No.: ………………………………Section: …………………

Date of Experiment: ……………………………………………….

Report submitted on: …………………………………………………

Marks obtained: ……………………………………

Instructor's Signature: ……………………………...

COLLEGE OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL ENGINEERING

EXPERIMENT NO. 13

TO ANALYZE THE CONNECTION OF TRANSMISSION LINE WITH 3Ø FEEDER

OBJECTIVE:

Objective of this experiment is to study and analyze the connection of transmission line with 3Ø feeder using energy analyzer.

TOOLS REQUIRED:

Transmission board.
Connecting wires.
Power supply.
3Ø feeder.

THEORY:

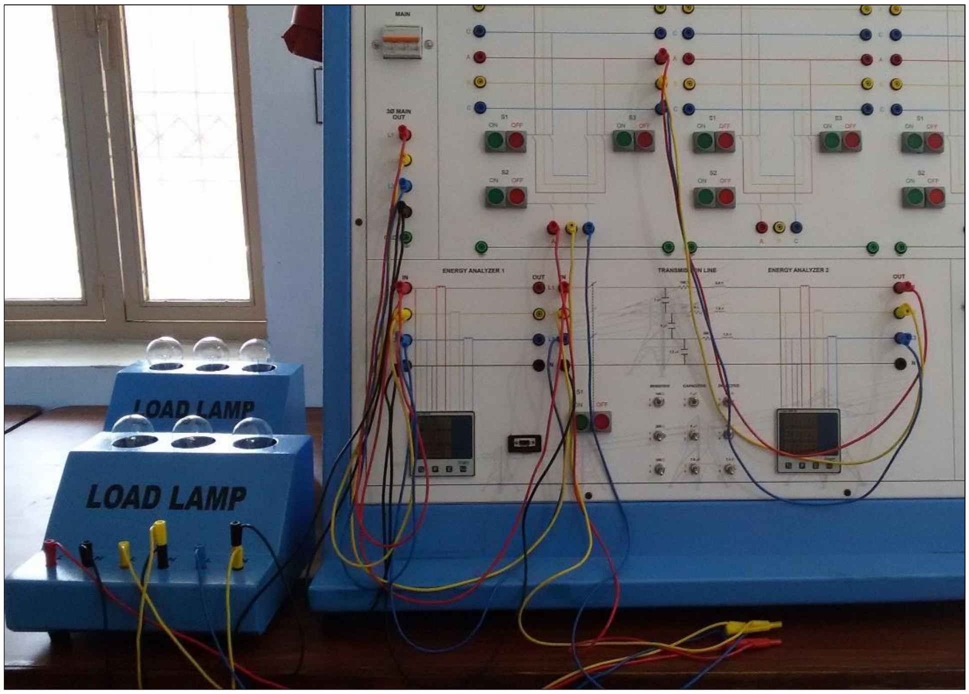
Electric power transmission or "high voltage electric transmission" is the bulk transfer of electrical energy, from generating power plants to substations located near to population centers. This is distinct from the local wiring between high voltage substations and customers, which is typically referred to as electricity distribution. Transmission lines, when interconnected with each other, become high voltage transmission networks.

The transmission and Distribution system is based on the Pakistani standard voltage which is 11 K v for the transmission, 0.4 kV for the 3 - phase and 230 V for the 1 phase distribution system. Power frequency is 50 Hz.

PROCEDURE:

1. First connect main supply to the input of energy analyzer.
2. And also make both neural same.
3. Than connect input of energy analyzer 1 to the input of transmission line.
4. Connect output of transmission line with 3Ø feeder.
5. Connect load on the output of feeder.
6. Then note all the readings and effects on transmission line carefully using energy analyzer.

CONNECTION DIAGRAM:



ANALYSIS AND RESULTS:

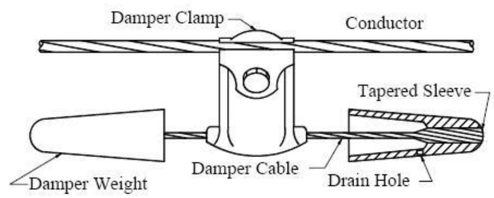
Sr.No	Readings (Before load)	Readings (After load)

OBSERVATION/OPINION:

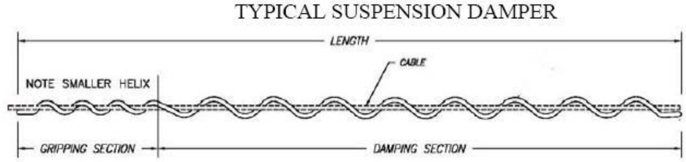
EXPERIMENT NO. 14
INVESTIGATE VIBRATION DAMPER AND ITS TYPES USED IN TRANSMISSION LINE

OBJECTIVE:
Objective of this experiment is to investigate vibration damper and its types used in transmission line.

THEORY:
Vibration Dampers are used to absorb Aolian Vibrations of conductor of Transmission Lines, as well as ground wire, OPGW, and ADSS. It is mostly composed of the following; Weights – made up of cast iron, Clamp – made up of Aluminum Alloy, Nuts and Bolts made up of galvanized or stainless steel and Messenger cable made up of Galvanized Steel.



TYPICAL SUSPENSION DAMPER

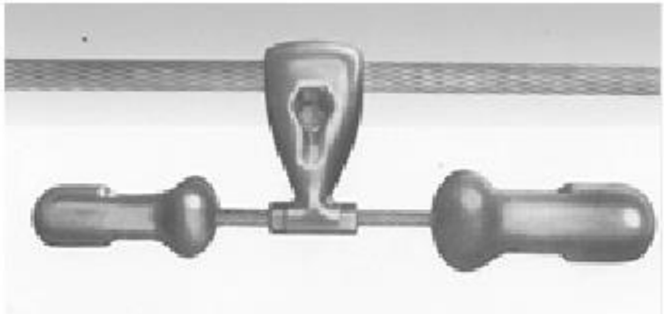


Vibration Dampers are used in areas of severe vibration. Dampers act to decrease aolian vibration amplitudes thereby reduce the dynamic bending stress at hardware location and extend conductor life. These fatigues stresses have maxima at suspension and dead end attachments. They can also occur at mass discontinuities and may lead to failures of individual strands. In composite conductors (ACSR, ACCR, etc.) it may eventually lead to failure of all aluminum layers.

WORKING:
When a vibration wave passes the damper location, the clamp of a suspension type damper oscillates up and down, causing flexure of the damper cable and creating relative motion between the damper clamp and damper weights.
Stored energy from the vibration wave is dissipated to the damper in the form of heat. For a damper to be effective, its response characteristics should be consistent with the frequencies of the conductor on which it is installed.

TYPES OF VIBRATION DAMPER:
1. VORTX/ Stock bridge Type:

Some dampers, such as the VORTX Damper utilize two different weights and an asymmetric placement on the strand to provide the broadest effective frequency range possible.



The “Stockbridge” type vibration damper is commonly used to control vibration of overhead conductors and OPGW. The vibration damper has a length of steel messenger cable. Two metallic weights are attached to the ends of the messenger cable. The centre clamp, which is attached to the messenger cable, is used to install the vibration damper onto the overhead conductor.

Placement programs, such as those developed by PLP for the VORTX Damper, take into account span and terrain conditions, suspension types, conductor self-damping, and other factors to provide a specific location in the span where the damper or dampers will be most effective.

The asymmetrical vibration damper is multi resonance system with inherent damping. The vibration energy is dissipated through inter-strand friction of the messenger cable around the resonance frequencies of the vibration damper. By increasing the number of resonances of the damper using asymmetrical design and increasing the damping capacity of the messenger cable the vibration damper is effective in reducing vibration over a wide frequency or wind velocity range.

2. Spiral Vibration Damper:

For smaller diameter conductors (< 0.75”), overhead shield wires, and optical ground wires (OPGW), a different type of damper is available that is generally more effective than a Stockbridge type damper.

The Spiral Vibration Damper has been used successfully for over 35 years to control Aeolian vibration on these smaller sizes of conductors and wires.

The Spiral Vibration Damper is an “impact” type damper made of a rugged non-metallic material that has a tight helix on one end that grips the conductor or wire. The remaining helixes have an inner diameter that is larger than the conductor or wire, such that they impact during Aeolian vibration activity. The impact pulses from the damper disrupt and negate the motion produced by the wind.

SPACER DAMPERS

Spacers serve to establish a distance between the partial conductors of a bundle line in order to prevent the conductors from knocking together and thus avoid damage done to conductors. Spacer dampers will be used if vibrations excited by wind need to be expected. the vibration amplitudes of the conductor can be reduced to an uncritical dimension. In this context, many different models of the spacers are available for different bundle arrangements.

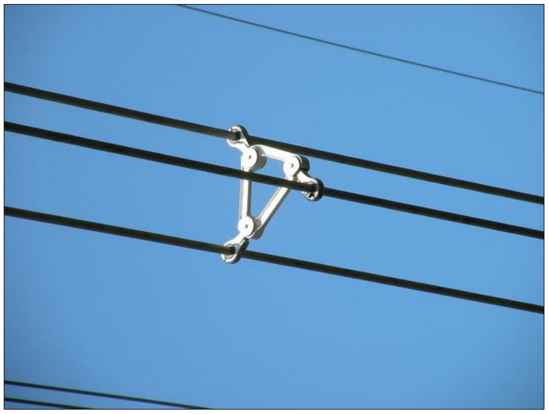
3. TWIN SPACER

Twin Spacer - Dampers are used to control vibration and conductor oscillation, maintain conductor spacing and restore conductor spacing after a short circuit occurs. Material: Frame, arm and keeper Aluminum alloy Nut and bolt.

4. TRIPLE SPACER DAMPER:

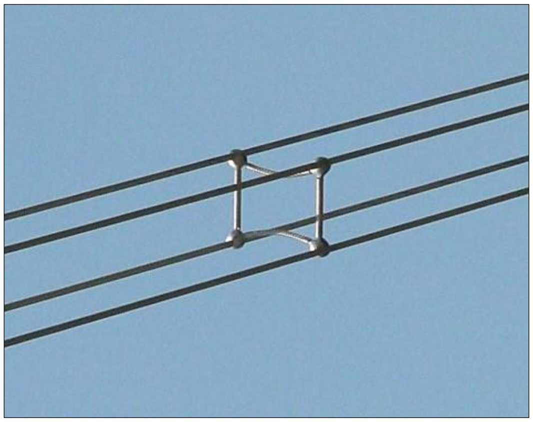
Spacer dampers were originally developed to suppress bundle conductor sub span oscillations that could cause damage to multi-conductor bundle systems.

Spacer Dampers are designed to provide corona free performance on operating voltages up and including 500 kV. Special designs are available for 765 kV applications.



5. QUADRUPLE SPACER DAMPER:

Spacer-damper installed on a square four conductor bundle to control both vibration and wake induced oscillation.



USE OF VIBRATION DAMPERS:

The use of such vibration dampers should be on a case-by-case basis. A certain item should not be used merely because it has given satisfactory performance in another location.

Vibration Dampers should be selected on the basis of the frequencies one expects to encounter in the terrain that must be traversed. The engineer should not specify a certain type of damper or armor rod simply because everyone else is using them.

An improperly located damper can affect the amount of protection and ability of the damper to suppress the damaging effects of aeolian vibration.

OBSERVATION/OPINION:

EXPERIMENT NO 15
Investigate the types of underground cables

Underground cables

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

Although several types of cables are available, the type of cable to be used will depend upon the working voltage and service requirements. In general, a cable must fulfill the following necessary requirements:

1. The conductor used in cables should be tinned stranded copper or aluminum of high ductivity.Stranding is done so that conductor may become flexible and carry more current.
2. The conductor size should be such that the cable carries the desired load current without overheating and causes voltage drop with permissible limits.
3. The cable must have proper thickness of insulation in order to give high degree of safety and reliability at the voltage for which it is designed.
4. The cable must be provided with suitable mechanical protection so that it may withstand the rough use in laying it.
5. The materials used in the manufacturing of cables should be such that there is complete chemical and physical stability throughout .

Construction of cables

Fig 11.1 shows the general construction of a 3-conductor cable. The various parts are:

1. **Cores or Conductors:**

A cable may have one or more than one core (conductor) depending upon the type of service for which it is intended. For instantance ,the 3-conductor cable shown in Fig 1.1 is used for 3-phase service. The conductor are made of tinned copper or aluminum and are usually stranded in order to provide flexibility to the cable.

2. **Insulation:**

Each core or conductor is provided with a suitable thickness of insulation,the thickness of layer depending upon the voltage to be withstood by the cable . the commonly used materials for insulation are impregnated paper,varnished cambric or rubber mineral compound.

3. **Material Sheath:**

In order to protect the cable from moisture ,gases or other damaging liquids (acids or alkalies) in the soil and atmosphere ,a metallic sheath of lead or aluminium is provided over the insulation as shown in Fig 1.1

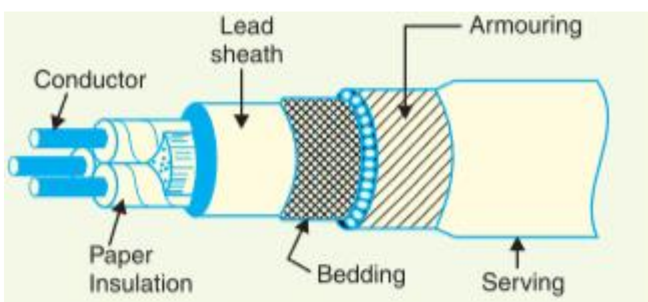


Fig. 11.1 Construction of a Cable

4. **Bedding:**

Over the metallic sheath is applied a layer of bedding which consist of a fibrous material like jute or hessian sheath is applied a layer of bedding is to protect the metallic sheath against corrosion and from mechanical injury due to armoring.

5. **Armouring:**

Over the bedding , armouring is provided which consists of one or two layers of galvanized steel wire or steel tape. Its purpose is to protect the cable from mechanical injury while laying it and during the course of handling. Armouring may not be done in case of some cables.

6. **Serving:**

In order to protect armouring from atmospheric conditions, a layer of fibrous material (like Jute) similar to bedding is provided over armouring .this is known as Serving.
It may not be out of place to mention here that bedding ,armouring and serving are only applied to cables for the protection of conductor insulation and to protect the metallic sheath from mechanical injury .

Insulating materials for cables:

The satisfactory operation of a cable depends to a great extent upon the characteristics of insulation used.therefore ,the proper choice of insukating material for cable is of considerable importance .In general ,the insulating materials used in cables should have the following properties:

1. High insulation resistance to avoid leakage current .
2. High dielectric strength to avoid electrical breakdown of the cable
3. High mechanical strength to withstand the mechanical handling of cable.
4. Non -inflammable .
5. Low cost so as to make the underground system a visible proposition
6. Unaffected by acids and alkalies to avoid any chemical action .
7. Non-hygroscopic i.e. ,it should not absorb moisture from air or soil.the moisture tends to decrease the insulation resistance and hastens the breakdown of the cable. In case the insulating material is hygroscopic ,it must be enclosed in a waterproof covering like lead sheath.

The principal insulating materials used in cables are rubber,vulcanused India rubber ,impregnated paper,Varnished cambric and polyvinyl chloride.

1. **Rubber :**

Rubber may be obtained from milky sap of tropical trees or it may be produced from oil products .It has relative permittivity varying between 2 and 3, dielectric strength is about 30 kV/mm and resistivity of insulation is 1017Ω cm. Although pure rubber has reasonably high insulating properties, it suffers form some major drawbacks viz., readily absorbs moisture, maximum safe temperature is low (about 38ºC), soft and liable to damage due to rough handling and ages when exposed to light. Therefore, pure rubber cannot be used as an insulating material.

2. **Vulcanised India Rubber (V.I.R.).**

It is prepared by mixing pure rubber with mineral matter such as zine oxide, red lead etc., and 3 to 5% of sulphur. The compound so formed is rolled into thin sheets and cut into strips. The rubber compound is then applied to the conductor and is heated to a temperature of about 150ºC. The whole process is called vulcanisation and the product obtained is known as vulcanised India rubber. Vulcanised India rubber has greater mechanical strength, durability and wear resistant property than pure rubber. Its main drawback is that sulphur reacts very quickly with copper and for this reason, cables using VIR insulation have tinned copper conductor. The VIR insulation is generally used for low and moderate voltage cables.

3. **Impregnated paper.**

It consists of chemically pulped paper made from wood chippings and impregnated with some compound such as paraffinic or napthenic material. This type of insulation has almost superseded the rubber insulation. It is because it has the advantages of low cost, low capacitance, high dielectric strength and high insulation resistance. The only disadvantage is that paper is hygroscopic and even if it is impregnated with suitable compound, it absorbs moisture and thus lowers the insulation resistance of the cable. For this reason, paper insulated cables are always provided with some protective covering and are never left unsealed. If it is required to be left unused on the site during laying, its ends are temporarily covered with wax or tar. Since the paper insulated cables have the tendency to absorb moisture, they are used where the cable route has a *few joints. For instance, they can be profitably used for distribution at low voltages in congested areas where the joints are generally provided only at the terminal apparatus. However, for smaller installations, where the lenghts are small and joints are required at a number of places, VIR cables will be cheaper and durable than paper insulated cables.

4. **Varnished cambric**.

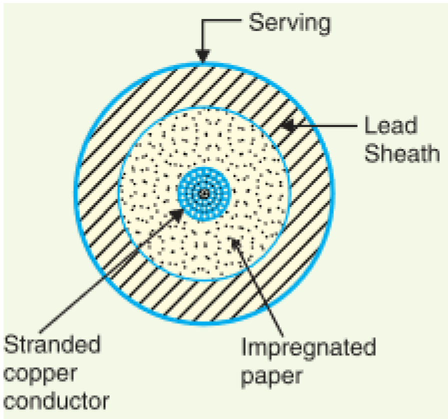
It is a cotton cloth impregnated and coated with varnish. This type of insulation is also known as empire tape. The cambric is lapped on to the conductor in the form of a tape and its surfaces are coated with petroleum jelly compound to allow for the sliding of one turn over another as the cable is bent. As the varnished cambric is hygroscopic, therefore, such cables are always provided with metallic sheath. Its dielectric strength is about 4 kV/mm and permittivity is 2.5 to 3.8.

5. Polyvinyl chloride (PVC).

This insulating material is a synthetic compound. It is obtained from the polymerisation of acetylene and is in the form of white powder. For obtaining this material as a cable insulation, it is compounded with certain materials known as plasticizers which are liquids with high boiling point. The plasticizer forms a gell and renders the material plastic over the desired range of temperature. Polyvinyl chloride has high insulation resistance, good dielectric strength and mechanical toughness over a wide range of temperatures. It is inert to oxygen and almost inert to many alkalis and acids. Therefore, this type of insulation is preferred over VIR in extreme environmental conditions such as in cement factory or chemical factory. As the mechanical properties (i.e., elasticity etc.) of PVC are not so good as those of rubber, therefore, PVC insulated cables are generally used for low and medium domestic lights and power installations.

Classification of cables:

Cables for underground service may be classified in two ways according to (i) the type of insulating material used in their manufacture (ii) the voltage for which they are manufactured. However, the latter method of classification is generally preferred, according to which cables can be divided into the following groups:



1. Low-tension (L.T.) cables — upto 1000 V
2. High-tension (H.T.) cables — upto 11,000 V
3. Super-tension (S.T.) cables — from 22 kV to 33 kV
4. Extra high-tension (E.H.T.) cables — from 33 kV to 66 kV

5. Extra super voltage cables — beyond 132 kV

A cable may have one or more than one core depending upon the type of service for which it is intended. It may be (i) single-core (ii) two-core (iii) three-core (iv) four-core etc. For a 3-phase service, either 3-single-core cables or three-core cable can be used depending upon the operating voltage and load demand.

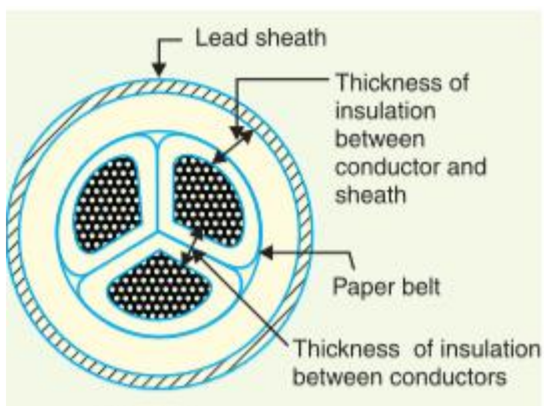
Cables for 3-Phase Service

In practice, underground cables are generally required to deliver 3-phase power. For the purpose, either three-core cable or *three single core cables may be used. For voltages upto 66 kV, 3-core cable (i.e., multi-core construction) is preferred due to economic reasons. However, for voltages beyond 66 kV, 3-core-cables become too large and unwieldy and, therefore, single-core cables are used. The following types of cables are generally used for 3-phase service:

1. Belted Cables — up to 11 kV
2. Screened Cables — from 22 kV to 66 kV
3. Pressure Cables — beyond 66 kV.

1. **Belted Cables:**

These cables are used for voltages up to 11kV but in extraordinary cases, their use may be extended up to 22kV. Fig. 11.3 shows the constructional details of a 3-core belted cable. The cores are insulated from each other by layers of impregnated paper. Another layer of impregnated paper tape, called paper belt is wound round the grouped insulated cores. The gap between the insulated cores is filled with fibrous insulating material (jute etc.) so as to give circular cross-section to the cable. The cores are generally stranded and may be of noncircular shape to make better use of available space. The belt is covered with lead sheath to protect the cable against ingress of moisture and mechanical injury. The lead sheath is covered with one or more layers of armoring with an outer serving (not shown in the figure).



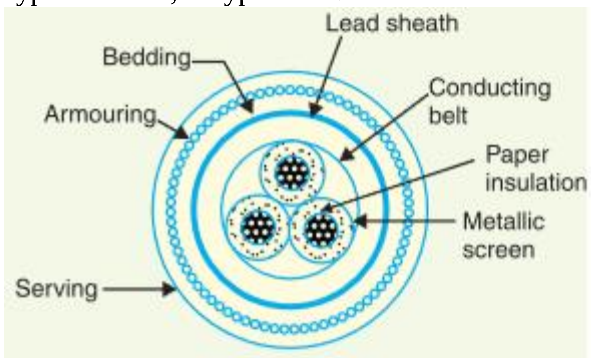
The belted type construction is suitable only for low and medium voltages as the electrostatic stresses developed in the cables for these voltages are more or less radial i.e., across the insulation. However, for high voltages (beyond 22 kV), the tangential stresses also become important. These stresses act along the layers of paper insulation. As the insulation resistance of paper is quite small along the layers, therefore, tangential stresses set up **leakage current along the layers of paper insulation. The leakage current causes local heating, resulting in the risk of breakdown of insulation at any moment. In order to overcome this difficulty, screened cables are used where leakage currents are conducted to earth through metallic screens.

2. **Screened Cables:**

These cables are meant for use up to 33 kV, but in particular cases their use may be extended to operating voltages up to 66 kV. Two principal types of screened cables are Hype cables and S.L. type cables.

(i) H-Type Cables:

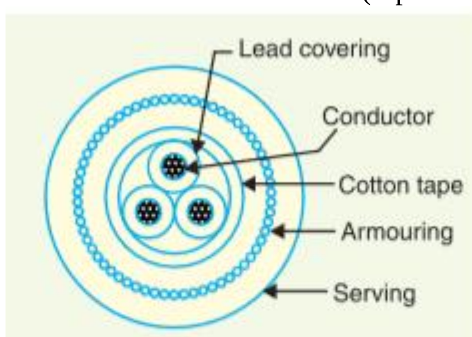
This type of cable was first designed by H. Hochstadter and hence the name. Fig. 11.4 shows the constructional details of a typical 3-core, H-type cable.



Each core is insulated by layers of impregnated paper. The insulation on each core is covered with a metallic screen which usually consists of a perforated aluminum foil. The cores are laid in such a way that metallic screens make contact with one another. An additional conducting belt (copper woven fabric tape) is wrapped round the three cores. The cable has no insulating belt but lead sheath, bedding, armouring and serving follow as usual. It is easy to see that each core screen is in electrical contact with the conducting belt and the lead sheath. As all the four screens (3 core screens and one conducting belt) and the lead sheath are at †earth potential, therefore, the electrical stresses are purely radial and consequently dielectric losses are reduced. Two principal advantages are claimed for H-type cables. Firstly, the perforations in the metallic screens assist in the complete impregnation of the cable with the compound and thus the possibility of air pockets or voids (vacuous spaces) in the dielectric is eliminated. The voids if present tend to reduce the breakdown strength of the cable and may cause considerable damage to the paper insulation. Secondly, the metallic screens increase the heat dissipating power of the cable.

(ii) S.L. Type Cables:

Fig. 11.5 shows the constructional details of a 3-core *S.L. (separate lead) type cable.



It is basically H-type cable but the screen round each core insulation is covered by its own lead sheath. There is no overall lead sheath but only armoring and serving are provided. The S.L. type cables have two main advantages over H-type cables. Firstly, the separate sheaths minimize the possibility of core-to-core breakdown. Secondly, bending of cables becomes easy due to the elimination of overall lead sheath. However, the disadvantage is that the three lead sheaths of S.L. cable are much thinner than the single sheath of H-cable and, therefore, call for greater care in manufacture.

Limitations of Solid Type Cables.

All the cables of above construction are referred to as solid type cables because solid insulation is used and no gas or oil circulates in the cable sheath. The voltage limit for solid type cables is 66 kV due to the following reasons:

(a) As a solid cable carries the load, its conductor temperature increases and the cable compound (i.e., insulating compound over paper) expands. This action stretches the lead sheath which may be damaged.

(b) When the load on the cable decreases, the conductor cools and a partial vacuum is formed within the cable sheath. If the pinholes are present in the lead sheath, moist air may be drawn into the cable. The moisture reduces the dielectric strength of insulation and may eventually cause the breakdown of the cable.

(c) In practice, †voids are always present in the insulation of a cable. Modern techniques of manufacturing have resulted in void free cables. However, under operating conditions, the voids are formed as a result of the differential expansion and contraction of the sheath and impregnated compound. The breakdown strength of voids is considerably less than that of the insulation. If the void is small enough, the electrostatic stress across it may cause its breakdown. The voids nearest to the conductor are the first to break down, the chemical and thermal effects of ionization causing permanent damage to the paper insulation.

3. **Pressure cables**:

For voltages beyond 66 kV, solid type cables are unreliable because there is a danger of breakdown of insulation due to the presence of voids. When the operating voltages are greater than 66 kV, pressure cables are used. In such cables, voids are eliminated by increasing the pressure of compound and for this reason they are called pressure cables. Two types of pressure cables visa oil-filled cables and gas pressure cables are commonly used.

(i) Oil-Filled Cables:

In such types of cables, channels or ducts are provided in the cable for oil circulation. The oil under pressure (it is the same oil used for impregnation) is kept constantly supplied to the channel by means of external reservoirs placed at suitable distances (say 500 m) along the route of the cable. Oil under pressure compresses the layers of paper insulation and is forced into any voids that may have formed between the layers. Due to the elimination of voids, oil-filled cables can be used for higher voltages, the range being from 66 kV up to 230 kV. Oil-filled cables are of three types viz.,

1. Single-Core Conductor Channel,
2. Single-Core Sheath Channel
3. Three-Core Filler-Space Channels.

Fig. 11.6 shows the constructional details of a single-core conductor channel, oil filled cable. The oil channel is formed at the center by stranding the conductor wire around a hollow cylindrical steel spiral tape.

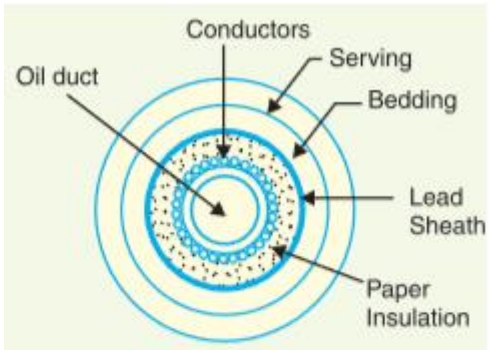


Fig. 11.6 Single-core conductor channel, oil-filled cable

The oil under pressure is supplied to the channel by means of external reservoir. As the channel is made of spiral steel tape, it allows the oil to percolate between copper strands to the wrapped insulation. The oil pressure compresses the layers of paper insulation and prevents the possibility of void formation. The system is so designed that when the oil gets expanded due to increase in cable temperature, the extra oil collects in the reservoir. However, when the cable temperature falls during light load conditions, the oil from the reservoir flows to the channel. The disadvantage of this type of cable is that the channel is at the middle of the cable and is at full voltage w.r.t. earth, so that a very complicated system of joints is necessary. Fig. 11.7 shows the constructional details of a single core sheath channel oil-filled cable. In this type of cable, the conductor is solid similar to that of solid cable and is paper insulated. However, oil ducts are provided in the metallic sheath as shown. In the 3-core oil-filler cable shown in Fig. 11.8, the oil ducts are located in the filler spaces. These channels are composed of perforated metal-ribbon tubing and are at earth potential.

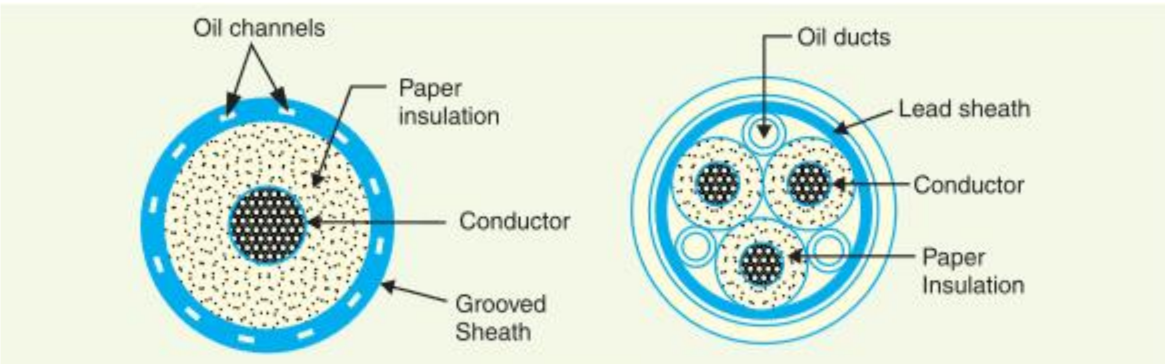


Fig. 11.7 *Oil-filled cables* **Fig. 11.8**

The oil-filled cables have three principal advantages.
Firstly, formation of voids and ionization are avoided.
Secondly, allowable temperature range and dielectric strength are increased.
Thirdly, if there is leakage, the defect in the lead sheath is at once indicated and the possibility of earth faults is decreased. However, their major disadvantages are the high initial cost and complicated system of laying.

(ii) Gas Pressure Cables:

The voltage required to set up ionization inside a void increase as the pressure is increased. Therefore, if ordinary cable is subjected to a sufficiently high pressure, the ionization can be altogether eliminated. At the same time, the increased pressure produces radial compression which tends to close any voids. This is the underlying principle of gas pressure cables. Fig. 11.9 shows the section of external pressure cable designed by Hochstetler, Vogel and Bowden. The construction of the cable is similar to that of an ordinary solid type except that it is of triangular shape and thickness of lead sheath is 75% that of solid cable. The triangular section reduces the weight and gives low thermal resistance but the main reason for triangular shape is that the lead sheath acts as a pressure membrane. The sheath is protected by a thin metal tape.

Fig. 11.9

The cable is laid in a gas-tight steel pipe. The pipe is filled with dry nitrogen gas at 12 to 15 atmospheres. The gas pressure produces radial compression and closes the voids that may have formed between the layers of paper insulation. Such cables can carry more load current and operate at higher voltages than a normal cable. Moreover, maintenance cost is small and the nitrogen gas helps in quenching any flame. However, it has the disadvantage that the overall cost is very high.

Laying of Underground Cables:

1. Direct laying.
2. Draw-in system
3. Solid system

OBSERVATION/OPINION: