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Types of Insulators Used in Transmission (Overhead) Lines

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Abstract: *Overhead transmission lines play a critical role in the efficient and reliable transfer of electrical power across vast distances. The choice of insulator type is a crucial aspect of their design and performance. This research paper presents a comprehensive comparative analysis of the various types of insulators used in overhead transmission lines, focusing on their electrical, mechanical, and environmental attributes. The paper begins by discussing the fundamental requirements of insulators in transmission systems, including their role in preventing current leakage, flashovers, and maintaining system reliability. It then delves into the different categories of insulators, namely pin, suspension, and strain insulators, examining their structural compositions, materials (such as porcelain, glass, composite, and polymer), and manufacturing processes.*

The main body of the paper outlines the key factors influencing insulator selection, which include voltage levels, environmental conditions, pollution levels, mechanical loads, and cost considerations. The electrical characteristics of insulators, such as their voltage distribution along the surface, corona inception voltage, and tracking resistance, are analyzed in relation to their impact on transmission line performance. The mechanical behavior of insulators is investigated, including their load-bearing capacity, tensile strength, and resistance to vibrations and extreme weather conditions. Special attention is given to insulator string design and the mitigation of mechanical stresses to prevent insulator failure Furthermore, the paper evaluates the environmental sustainability of insulator materials and their resistance to environmental pollution, highlighting the advantages of composite and polymer insulators in minimizing resource depletion and offering long-term stability. To provide a practical perspective, case studies of transmission line projects employing different types of insulators are presented, showcasing the real-world implications of insulator selection on system reliability, maintenance, and overall performance. In conclusion, this research paper offers a comprehensive overview of the various insulator types used in overhead transmission lines, providing valuable insights for engineers, researchers, and industry professionals involved in the design, operation, and maintenance of power transmission systems. The comparative analysis serves as a foundation for making informed decisions regarding insulator selection based on technical, economic, and environmental considerations.

Keywords: Overhead Transmission Lines, Insulators.

I. INTRODUCTION

Insulators are the elements of transmission system which provide necessary insulation between line conductors and supports and hence, prevent any leakage current from the conductors to the earth.

The line conductors in the overhead transmission lines should be supported on the poles or towers in such a way that the current from the conductors do not flow to the earth through the supports which means the line conductors must be properly insulated from the supports. This is achieved by using the insulators between the line support and conductors.

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Type of Insulators Used in Transmission lines

There are 5 types of insulators used in transmission lines as overhead insulation:

- Pin Insulator
- Suspension Insulator
- Strain Insulator
- Stay Insulator
- Shackle Insulator

Pin, Suspension, and Strain insulators are used in medium to high voltage systems. While Stay and Shackle Insulators are mainly used in low voltage applications.

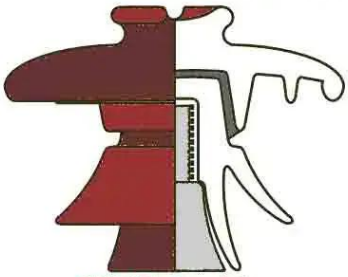
Pin Insulator

Pin insulators are the earliest developed overhead insulator, but are still commonly used in power networks up to 33 kV system. Pin type insulator can be one part, two parts or three parts type, depending upon application voltage.

In a 11 kV system we generally use one part type insulator where whole pin insulator is one piece of properly shaped porcelain or glass.

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. We provide one, two or more rain sheds or petticoats on the insulator body to obtain long leakage path.

In addition to that rain shed or petticoats on an insulator serve another purpose. We design these rain sheds or petticoats in such a way that while 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 damp pin insulator surface.



33KV Pin Insulator

In higher voltage systems – like 33KV and 66KV – manufacturing of one part porcelain pin insulator becomes more difficult. The higher the voltage, the thicker the insulator must be to provide sufficient insulation. A very thick single piece porcelain insulator is not practical to manufacture.

In this case, we use multiple part pin insulator, where some properly designed porcelain shells are fixed together by Portland cement to form one complete insulator unit. We generally use two parts pin insulators for 33KV, and three parts pin insulator for 66KV systems.

Designing Consideration of Electrical Insulator

The live conductor attached to the top of the pin insulator which is at the live potential. We fix the bottom of the insulator to supporting structure of earth potential. The insulator has to withstand the potential stresses between conductor and earth. The shortest distance between conductor and earth, surrounding the insulator body, along which electrical discharge may take place through the air, is known as flashover distance.

When the insulator is wet, its outer surface becomes almost conducting. Hence the flashover distance of insulator is decreased. The design of an electrical insulator should be such that the decrease of flashover distance is minimum when the insulator is wet. That is why the uppermost petticoat of a pin insulator has umbrella type designed so that it can protect, the rest lower part of the insulator from the rain. The upper surface of the topmost petticoat is inclined as less as possible to maintain maximum flashover voltage during raining.

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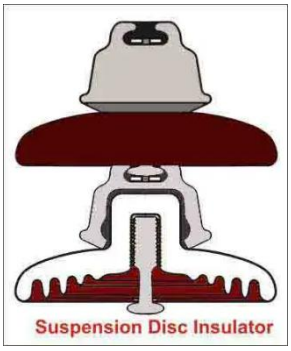
The rain sheds are made in such a way that they should not disturb the voltage distribution. They are so designed that their subsurface at a right angle to the electromagnetic lines of force.

Suspension Insulator

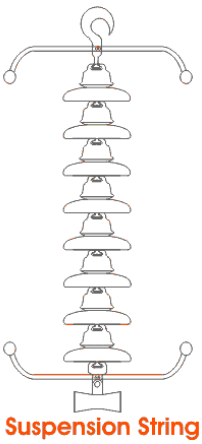
In higher voltage, beyond 33KV, it becomes uneconomical to use pin insulator because size, weight of the insulator become more. Handling and replacing bigger size single unit insulator are quite difficult task. For overcoming these difficulties, suspension insulator was developed.

In suspension insulator numbers of insulators are connected in series to form a string and the line conductor is carried by the bottom most insulator. Each insulator of a suspension string is called disc insulator because of their disc like shape.



Advantages of Suspension Insulator

- Each suspension disc is designed for normal voltage rating 11KV (Higher voltage rating 15KV), so by using different numbers of discs, a suspension string can be made suitable for any voltage level.
- If any one of the disc insulators in a suspension string is damaged, it can be replaced much easily.
- Mechanical stresses on the suspension insulator is less since the line hanged on a flexible suspension string.
- As the current carrying conductors are suspended from supporting structure by suspension string, the height of the conductor position is always less than the total height of the supporting structure. Therefore, the conductors may be safe from lightening.



Disadvantages of Suspension Insulator

- Suspension insulator string costlier than pin and post type insulator.
- Suspension string requires more height of supporting structure than that for pin or post insulator to maintain same ground clearance of current conductor.
- The amplitude of free swing of conductors is larger in suspension insulator system, hence, more spacing between conductors should be provided.

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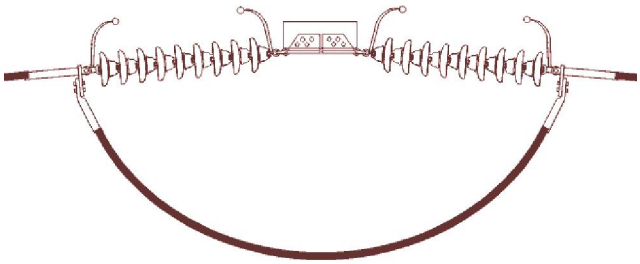
Strain Insulator

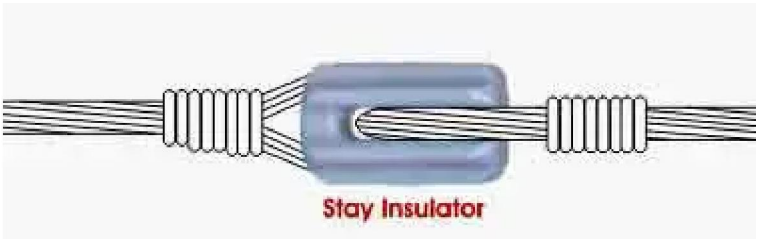


STRAIN INSULATOR

When suspension string is used to sustain extraordinary tensile load of conductor it is referred as string insulator. When there is a dead end or there is a sharp corner in transmission line, the line has to sustain a great tensile load of conductor or strain. A strain insulator must have considerable mechanical strength as well as the necessary electrical insulating properties.

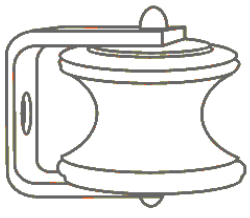
Rated System Voltage	Number of disc insulator used in strain type tension insulator string	Number of disc insulator used in suspension insulator string
33KV	3	3
66KV	5	4
132KV	9	8
220KV	15	14

Stay Insulator



Stay Insulator

For low voltage lines, the stays are to be insulated from ground at a height. The insulator used in the stay wire is called as the stay insulator and is usually of porcelain and is so designed that in case of breakage of the insulator the guy-wire will not fall to the ground.



Shackle or Spool Insulator

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Shackle Insulator

The shackle insulator (also known as a spool insulator) is usually used in low voltage distribution network. It can be used in both the horizontal or vertical positions. The use of such insulator has decreased recently after increasing the using of underground cable for distribution purpose.

The tapered hole of the spool insulator distributes the load more evenly and minimizes the possibility of breakage when heavily loaded. The conductor in the groove of shackle insulator is fixed with the help of soft binding wire.

II. CONCLUSION

The selection of insulators for overhead transmission lines is a critical aspect of ensuring the reliable and efficient operation of power delivery systems. This research paper has provided a comprehensive exploration of the various types of insulators used in these systems, highlighting their distinct characteristics, advantages, and limitations.

The study underscores that insulators are not merely passive components but essential elements that directly impact the safety, stability, and performance of transmission lines. The analysis of pin, suspension, and strain insulators, along with their materials and manufacturing processes, demonstrates the diversity of options available to engineers and system designers.

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