VARIOUS TYPES OF INSULATORS USED IN POWER SYSTEM FOR SAFE OPERATIONS OF THE TRANSMISSION LINES.

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ABSTRACT
Overhead bare conductors on steel towers or concrete poles are utilized in transmission and distribution of bulky electric power. These conductors are bare and do not have any insulated coating over them. To ensure safe operation of the lines, a necessary clearance between metal structure in case of tower and bare conductors, insulators are mounted. Insulators provide support to the bare conductors and also provide insulation of high voltage conductors with metal structures. In this paper, the importance of insulators in power system transmission is discussed along with the structure, operational principle, types, failure, choice of insulators and recommendations proffered.

Keywords: Insulator, Transmission, Distribution, Conductor and Flashover voltage.

1.0 INTRODUCTION

Insulator is an essential part of transmission line that has a dual function of mechanically supporting the transmission lines and providing electrical insulation to the transmission line. An insulator in performing its function in transmission line safe operations maintains an air gap [1] by separating the line from the ground and equally resists mechanical stresses, electrical stresses and environmental stresses on the transmission line. Hence the design of an insulator is such that the stress developed owing to contraction and expansion in any part of insulator does not lead to any defect. Due to increase in industrial development coupled with the growth in population especially in Nigeria, there is increased demand for supply of reliable, efficient and stable electric power, hence serious need for optimum performance of insulators to ensure safe operations of transmission lines. It has been noticed that forced outages due to insulation fault form high percentage of network outages [2]. This situation can be as a result of network design deficiency, insulator manufacturing process problems, inappropriate insulation choice considering regional climatic conditions, insulator damage by human or natural accidents and unscheduled maintenance application [3]. To detect and replace the faulty insulators on power transmission lines are of great importance for safe operation of the power system [4]. Different types of insulators are shown in fig. 1.

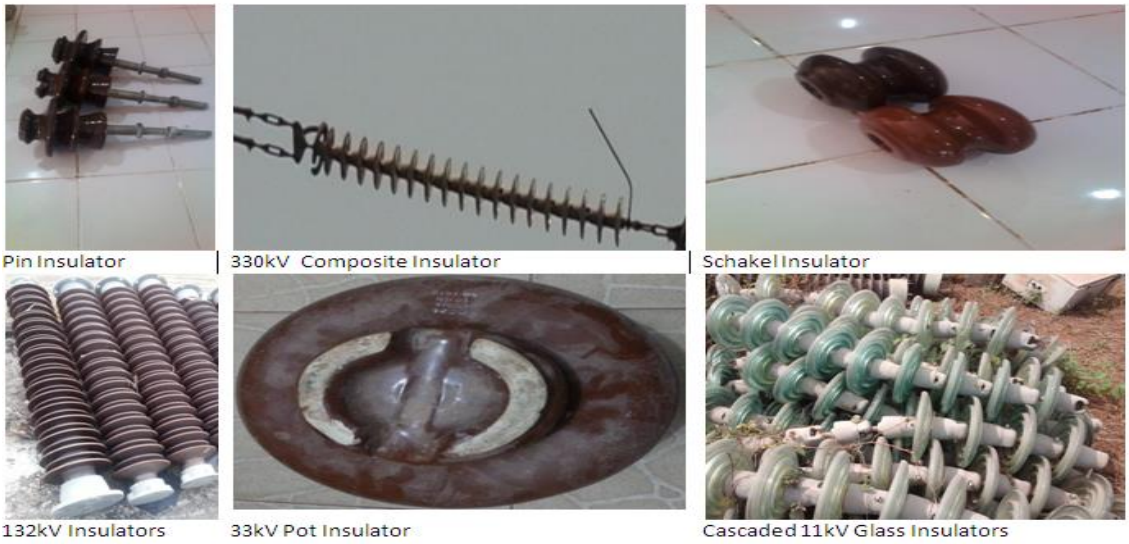

Fig.1: Different types of Insulator

2.0 Operation of an Insulator

When an electrical insulator or breaker is in operation at the high voltage transmission line systems, for example: 132 kV, 330 kV and 660 kV or higher voltages, those devices are subjected to a strong electrical stress and also damage by the environmental conditions [5].An insulator is therefore normally distinguished by its resistivity though practically no perfect insulator exists, because it has been established that insulators contain small numbers of mobile charges [6]. It is well known that the presence of voids and inclusions introduced in the manufacturing processes, or generation and propagation of cracks inside the electrical insulators, when those devices are in operation under high voltage stress, that a partial discharge begins as localized dielectric breakdown. Furthermore, partial discharge can also occur along the boundary between different insulating materials. Once begun, partial discharge causes progressive deterioration of insulating materials, ultimately leading to electrical breakdown and, eventually, explosion with stop of energy transportation [7]. In addition, all insulators become electrically conductive when a sufficiently large voltage is applied such that the electric field tears electrons away from the atoms. Therefore, the insulator due to its critical role in the safe operation of the transmission line has the following properties:

1. High mechanical strength in order to withstand conductor load, wind load and any other load that may arise.
2. High electrical resistance in order to avoid leakage currents to earth.
3. High relative permittivity in order that dielectric strength will be high.
4. Non-porous, Crack and Impurity free to lower the permittivity.
5. High ratio of puncture strength to flashover voltage.

These insulators are widely made of mainly Porcelain, glass and synthetic resins. Most commonly used in the manufacture of overhead insulators is porcelain but glass, steatite and special composition materials are also used to a limited extent [8].

3.0 Classification of Insulators

Insulators can be classified using the different criteria such as, different operating voltage, location of installation, and their external design characteristics. There are three distinct classes of insulators viz:

(a). Pin Type Insulator: This is used for transmission and distribution of electric power at operating voltage up to 50kV and beyond 50kV, pin insulator becomes too bulky and uneconomical.

Fig. 2: Pin Insulators

(b). Suspension Type Insulator: Though practically pin insulator can be used for voltages up to 50kV, suspension insulators are used for operating voltages above 50kV. A set consist of a number of porcelain disc connected in series by metal links in the form of a string. Each disc is designed for low voltage of about 11kV, hence for a 33kV working voltage, three discs in series will be needed for the string. In practice, there are three types of suspension insulators (i) Hewlett or inter linking type, (ii) Cemented-Cap type, this is commonly used (iii) Core and link type. Suspension insulators have the following advantages over the pin type insulators:

- They are usually cheaper than pin insulators
- Easy to maintain
- More flexible to the transmission line and mechanical stresses are reduced in this arrangement.
- Helps in reducing treat of lightning strikes when used in conjunction with steel supporting structures
- Easily cascaded in operation since each disc in the cascade is manufactured for comparatively low voltage of about 11kV
- Adaptability or Interchangeability is assured. In case of increase in load on transmission line which involves increase in operating voltage, more discs can easily be added to meet the new capacity without much problems.

330kV suspension composite insulator

33kV suspension insulator

11kV suspension insulator

Fig. 3 Different types of Suspension Insulator depending on Voltage capacity

(c). Strain Type Insulator: This is a special function insulator. When there exists a corner, sharp curve, Tee-off of or a dead end of a line, such that the transmission line is subjected to greater tension, strain insulator is employed to relieve the line of excessive tension. Shackle insulators are used for lines with operating voltages below 11kV while for high voltage transmission lines, an assemblage of suspension insulators are used, the number discs and form depend on the intensity of tension.

11kV application of Strain insulator

33 kV application of Strain insulator

330 kV application of Strain insulator

Fig. 4 Different applications of Strain Insulator

(d). Shackle Type Insulator: Shackle insulators are normally used in low voltage distribution lines either in a horizontal or vertical position. These are mainly made of porcelain material.

Fig.5: Application of shackle Insulators

There is another class of insulator though modern known as composite insulator designed and manufactured originally for only high voltage applications by PFISTERER in 1975 [9]. This is however currently designed and produced using Silicone Rubber technology based on feedback reports and research for complete range of applications ranging from 1.5kV – 1000kV for alternating current (AC) and direct current (DC) applications [9]. Composite insulators are mainly used as suspension insulators, as lower head line post insulator and station post insulators, see figs 6 and 7.

Fig. 6 Different types of Composite Insulator in Power Station used for various purposes

Fig. 8 Composite Insulators used as Post Insulators at 132/33kV Ohia Transmission Staion in Umuahia

More than 1,000,000 sets of composite insulators are in service, without any failure [10] and this record is showing very well the reliability and the quality of Zonri composite insulators, which is connected to the high quality raw materials used and the one-step molding technology normally employed in the production process.

4.0 Insulator Failure

When an insulator is subjected to a voltage higher than its designed voltage it suffers electrical breakdown, that is when the electric field applied across an insulating substance exceeds in any location the threshold breakdown field for that substance, it conducts causing an electric arc. Electrical breakdown of an insulator manifests as either as a puncture arc or as a flashover arc. Insulators like other engineering devices fail sometimes under operation leading to accidents, electrocution and sometimes eventual death. Because the electrical characteristics of insulators are normally the best [11], insulator puncture rarely occurs because in practice sufficient thickness of porcelain is provided in the insulator to avoid puncture by the line voltage [6]. The ratio of puncture strength to flashover voltage is therefore known as Safety Factor of Insulator, hence,

$$\text{Safety Factor of Insulator} = \frac{Puncture\ Strength}{Flashover\ Voltage} \qquad (1)$$

Failure in insulators is normally attributed to abnormal stress, cracks, flashover and ageing. It has been practically proven that the commonest cause of insulator failure is due to flashover [11]. Flashover is associated with a voltage known as Flashover/breakdown voltage. This a voltage at which the air around the insulator breaks down and flashover takes place shorting the insulator [6]. At this point, an arc occurs between the line conductor and insulator pin (i.e. earth) and discharge jumps across the air-gaps following shortest distance. Failure degenerates more with deposits caused on the

insulator by rain drops, pollution, dirt, and mist since the deposits help in reducing the dielectric and in turn increases surface leakage current.

Choice of Insulators

Insulators are not just chosen arbitrarily. Certain statutory tests are carried out to select an insulator for a desired or particular function. These tests are conducted in accordance with the standards and they are:

i. Mechanical tests to confirm suitability of an insulator to withstand the corresponding mechanical stresses.
ii. Electrical insulation test, this includes power frequency voltage, power frequency over voltage and impulse voltage tests to ascertain the insulator's electrical characteristics suitability.
iii. Environmental and Temporal Cycle tests which includes alternate temperature cycles, sudden temperature changes, pollution and other environmental stress tests.
iv. Corona and Radio interference tests which includes, power frequency, porosity and Galvanizing tests.

CONCLUSION

As the demand for efficient, reliable and stable supply of electric power increases, there is serious need to operate the power system optimally devoid of faults. Once the power system is completely designed and operative, it is necessary to protect it from faults. If power system is not secured and stable, then economic cost for power delivery also increases [12]. Therefore, there is serious need to employ some protecting and sensing devices which enhance safe operation of the power system. Insulator is one of the important protecting devices which protect the transmission line from abnormal conditions by firmly supporting the conductors and providing effective electrical insulation between the bare conductors and metal structures. The function of an insulator is to provide support to the bare conductors and also provide insulation of high voltage conductors with metal structures. One cannot imagine what transmission line operation and transmission stations would have been like without the different types of insulators. From illustrations in fig. 7 and others, it is very evident that without the right insulators, the high-voltage lines that supply electricity might not have existed or extremely dangerous. Therefore we can say that insulator is considered as one of the major components of the power system,

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