

INSULATORS OF HIGH VOLTAGE OVERHEAD
TRANSMISSION LINES UNDER POLLUTED CONDITIONS

*With Special Reference To The Peak Values
Of Leakage Current Criteria*



A THESIS SUBMITTED

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Values Of Leakage Current Criteria"

Thesis Submitted For The M.Sc. Degree
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By

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Abstract:

The present work is devoted mainly towards studying the performance of polluted insulators under different pollution conditions in the normal operating states. The peak values of the leakage current pulses are taken as a criterion to define the performance of polluted insulators.

Various types of insulators had been energized by the operating system voltage and exposed to natural pollution conditions at one of the most severely polluted site in the North-West seacoast of Egypt. The highest peak values of leakage current pulses were recorded during the period of exposure at intervals of two hours. After an exposure period of one complete year, the naturally polluted insulators had been investigated experimentally in the laboratory.

Results obtained from these tests explain the effect of the various parameters on both the highest peak value and the maximum peak value of the leakage current pulses.

A method for the selection of the most suitable insulator for the operation in a certain polluted site is proposed. A certain insulator shape could be selected for the use in El-Amria area which is one of the most polluted areas in Egypt.

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INTRODUCTION

Since the early days of the present century, the need for electrical energy is widely increasing day by day. This necessitates bulk electrical power generation on one hand and high voltage transmission lines on the other hand.

The locations for electric power generating plants are governed by several considerations such as : the existence of water falls for the hydraulic generation, the most nearest areas to water sources sufficient for cooling of thermal or nuclear generation, and in any case, the selected sites must be at locations far from the inhabitant areas by enough distances for safety and health of the people. In other words the electric power generation is almost located far from the consumption centres.

The connection tie between the generation and load centres is performed by transmission lines either underground using insulated cables or overhead transmission lines.

The overhead transmission line is the most extensive mean for transmitting bulk electrical energy due to its simplicity, high efficiency, stability, easier construction,...etc. Also, it is more economical than underground cables.

The most important factor in designing high voltage overhead transmission line is the proper design of its insulators which must ensure the reliable operation of the line and the economical choice of the transmission voltage.

All the outdoor insulators of a power system equipment are exposed to natural pollution conditions; when the insulators become coated with a moist conducting film containing dissolved salts, they may flashover. Rain water is not usually conductive enough by itself to cause trouble, nor are dry salt deposits form any problem. The dissolved salts, contained in the contaminant layer, may build up slowly over many weeks or months. When it is wetted by fog, dew, or any other atmospheric moisture it becomes a conductive layer leading to flashover of insulators.

In designing an overhead transmission line, once the rout of the line is defined, the designer must choose the most suitable

arise due to pollution of insulators during the normal operating conditions of electric power transmission networks.

Some of these studies were devoted to the performance of insulators under natural pollution conditions^{1,2,3,4,5}. Other research workers tried to simulate the natural conditions by artificial methods^{6,7,8,9,10,11,12,13}. Both of them used the physical approach to explain the flashover mechanism of polluted insulators which are briefly mentioned hereinafter:

- a. Measurement of flashover voltage for polluted insulators may be under one of the following conditions:
 - Natural pollution conditions.
 - Artificial pollution conditions.
 - Natural pollution conditions and artificial wetting in the laboratory.
- b. Determination of the pollution severity along the transmission line rout or at each part of it by:
 - Collection of pollution material and measuring its conductivity or making chemical analysis to its componants.
 - Measuring the conductance of the polluted insulator or the test specimen without removing the pollution layer.
 - Measuring the leakage current on the surface of the polluted insulator or the test specimen under the service voltage and normal pollution conditions.

The method of measuring the leakage current on the surface of an energised polluted insulator had been used from about twenty years ago by recording the leakage current pulses exceeding certain values (say 25, 50, 100 m. Amps) flowing on the surface of the polluted insulator under nominal service voltage using electric counters (relays similar to that used in telephone systems)⁴. This method proved to be succesfeul in predicting the flashover of an insulator under service. The limitations of this method are its complexity, poor estimation of the phenomena, difficulty in applying it to normal working networks of thousands of insulator chains.

Some other investigators used another method of recording ~~the surface leakage current of an insulator for a certain period~~ of time which may reach several hours under a certain voltage. Comparing the r.m.s. value of the base current with the maximum peak value of the leakage current, it was possible to determine the performance of insulators^{12,14}.

Studying the performance of insulators referring to the leakage current values as a monitor of the pollution particles precipitated on the insulator was developed by the High Voltage Laboratories of West Germany using a digital electronic instrument for measuring the peak value of the leakage current pulses of a polluted insulator under normal service conditions. Many laboratory tests were performed to study the performance of this instrument in measuring the leakage current pulses of artificial polluted insulators. The research workers of this laboratory declared that such an instrument can be used as a pollution monitor^{13,18}.

The present work includes the following three main purposes:

- The first is to study the possibility of using the above mentioned instrument as a pollution monitor under normal service conditions which include all the various parameters which influence the efficiency of the insulator such as: the insulator shape and its dimensions, the pollution severity, the atmospheric conditions, the variation of service voltages, ... etc. Also, it is interesting to realise that this instrument and its accessories can withstand the continuous and normal operating conditions without interrupting the working network.
- The second is to study the possibility of using this type of instruments for making a field comparison between insulators under normal operating conditions and thus selecting the most suitable insulator to be efficiently used in a certain site.
- The third is to compare between field and laboratory tests in order to reach some conclusions to be followed for correcting the laboratory results and thus to realise the best

situation of reliable operation of electrical networks in different sites referring to the results given by these instruments.

The test insulators used in the present work are of different materials: porcelain, glass and silicone rubber sheds fixed on fibre glass rods. They are energized and naturally polluted for a long period of time to study the effect of pollution on the insulator material under normal service conditions.

The present thesis consists of the following chapters:

- Chapter 1; includes the previous work in the field of the performance of polluted insulators, the flashover mechanism and leakage current criteria.
- Chapter 2; includes the test circuits in both the laboratory and field. The different arrangements for the testing procedures are also included.
- Chapter 3; includes the analysis of the test results which had been obtained from laboratory tests concerning the peak values of the leakage current pulses. The effect of the different parameters on the highest and maximum peak values of the leakage current pulses are discussed.
- Chapter 4; includes the comparison between various insulator shapes using both field and laboratory tests. The proposed method to select the most suitable insulator shape for a certain polluted site is mentioned. An example of applying this method had been performed and the optimum insulator shape and dimensions to be used in the North-West seacoast had been performed.
- Chapter 5; includes a discussion to the results obtained during performing the present work.
- The last part is a list of conclusions obtained from this work.

CHAPTER- I

FLASHOVER MECHANISM AND LEAKAGE

CURRENT CRITERIA

A clean insulator can be represented by an equivalent circuit including a capacitance in the order of several tens of picofarads shunted by a very high ohmic resistance in the order of several tens of megaohms. When the insulator is put in normal service conditions, the pollution particles is precipitated on its surface. The dry pollution layer is not conducting by itself although it contains salt components. Once it is wetted by any mean, the salt components are dissolved and an electrolyte contaminant layer is established. Thus the contaminant layer becomes conductive and the surface resistance of the polluted insulator decreases to values in the order of several kilo ohms allowing a leakage current to flow on the polluted surface of the insulator. The leakage current has a thermal effect proportional to the square of its r.m.s. value times the thermal resistivity of the contaminant layer. A quantity of heat will be generated causing dryness of certain zones on the pollution layer. These dry zones will be of relatively higher resistance than the wetted ones. The dry zones will thus suffer from large voltage stresses. This in some cases causes a breakdown to the air film adjacent to them. The phenomena is called the scintillation effect in which small arcs will set up causing more dryness to the neighbouring wet areas starting some other arcs. This accumulates more and more until many separate arcs are formed covering the whole surface between the two electrodes of the insulator. Once those separate arcs are connected together, a powerful arc will be established bridging the whole surface of the insulator causing a flashover on that insulator.

In the following there are a brief illustration to the build up of the contaminant layer, the flashover mechanism and the highest leakage current criterion.

1.1. The Contaminant layer build up:

As mentioned above when an insulator is put into service it will be exposed to pollution precipitation from the natural atmosphere. The pollution layer differs from place to place due to several factors. The pollution severity depends upon the type of contaminant, its chemical components, and the atmospheric conditions.

1.1.1. Types of Natural Pollution:

Most of the overhead transmission lines and substations are located in different locations; in desert areas such as the 500 KV Asswan - Cairo lines or in agricultural areas, such as in the 220, 66 KV Lines in the Delta area, nearer to industrial areas, or nearer to the sea shores such as the 220 KV lines in El- Amria area. The surrounding atmosphere of these areas is almost carrying pollution particles which are transported to the insulator surface by wind. The main types of pollution contaminated on the insulators are:-

1. Desert pollution:

In desert areas, there are often dust particles coming from the sand found in the ground or the dust of any other raw materials in the area. There are also frequent - dust carrying winds occasionally developing into a sand storm.

The contamination layer on the surface of an insulator in desert builds up slowly and gradually because the sandstorms may help in the self cleaning of the insulator surface. It was found that the light sand grains of sizes below 74 μm constitute the main source of desert contamination¹, and the scarcity of rain in desert on the other hand leads to increase the contamination.

2. Marine pollution:-

This type of pollution arises from the wind coming from the sea carrying salt particles. These particles are precipitated on the insulator surfaces. The build up of the contaminant layer by this way depends upon the distance between the sea shore and the insulator location, the speed of the wind, and rainfall intervals¹⁵.

3. Agricultural pollution (dust pollution):-

For insulators located in agricultural areas, the contaminant layer is composed of dust particles having a great ability for sticking on the insulator surface due to the high humidity of the surrounding atmosphere. The chemical contents of the dust pollution depends on the geological conditions of the area which in most cases contains salt compounds¹⁶.

4. Industrial pollution:-

When insulators are used in industrial areas, it was found that the chemical compounds of the smokes and fumes of the surrounding factories and power stations are representing most of the contents of the contaminant layer. The depositing rate of this layer on the surface of the insulators depends on: the meteorological conditions such as the wind speed and direction, the rainfall frequency and severity¹⁶.

5. Combined Pollution:-

Practically, more than one type of those pollution types mentioned above, combine altogether, form the pollution layer. In Egypt the important wellknown severest polluted area is at Alexandria zone, in El- Amria area, on the

north sea coast, very near to the sandy western desert and to the agricultural area of the Nile valley and in the same time many industrial factories such as the Alexandria cement factory, oil refineries, and other factories, are located there. For this reason a part of the experimental studies of the present work is performed in that area, as it will be later discussed.

1.1.2. Contamination Collection:

Contamination particles for any type of pollution are transported to the surface of the insulators from the surroundings by the wind. The sticking of these particles on the insulator surfaces depends on several factors such as: the wind speed and its direction, the size of particles, the insulator shape and its surface roughness, the frequency of rain intervals, ...etc.

Although the dynamics of contamination collection on the insulator surface have been widely studied,^{17,18,19,20} there are still many factors which are not yet exactly understood. This do not allow the collection rate to be predicted accurately for any given shape of insulator.

In a recent report prepared by IEEE Working group on insulator contamination¹⁶, the following points were concluded:

1. The significance of wind direction on the contamination pattern is easily seen in most locations observing the underside of the insulator. Accumulation of contaminant is usually greater between skirts or other irregularities on the insulator surface where air turbulence exists. This effect is particularly noticeable in locations where wind is fairly constant in direction.
2. The electrostatic field has a significant effect on the collection of wind - borne particles in