POLLUTION FLASHOVER PERFORMANCE OF HIGH VOLTAGE INSULATORS AROUND JEDDAH REGION

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SUMMARY: As a result of rapid development and growth of populated areas in the Kingdom of Saudi Arabia, several high voltage power transmission systems operating at various voltages up to 380 kV have been put into service and flashover difficulties with insulators of these systems caused by pollution of different types have been experienced. In order asses the pollution behaviour of line insulators in the Western Region of the Kingdom, two insulator types (longrod and cap-and-pin) have been subjected to natural pollution at four selected localities for 100 days and 2 years periods, without voltage being applied. The naturally polluted insulators have been tested in the High Voltage Laboratory of King Abdulaziz University. The investigation has shown that heavy pollution can accumulate on the insulators operating in Jeddah areas for over two years and the tested longrod insulator which is used in some part of the system can safely be used for years without any preventive measure. The cap-and-pin type appeared to be more appropriate for the region and leakage current recorder has been recommended for a better estimation of the insulator cleaning period.

Key Words: Pollution, high voltage, insulators.

INTRODUCTION

The flashover of polluted high voltage insulators constitues one of the most important high voltage energy transmission problem. Due to rapid rise of transmission voltages and growth of pollution, this problem has drawn more attention in recent years (1).

Pollution is the most essential element in a flashover phenomenon. Three types of pollution can be distinguished:

a. Saline or marine pollution which is common at coastal regions. In Saudi Arabia, many parts of long coast where population concentration exists are characterized by high humidity and the possibility of spray of salty mist from the Arabian Gulf and the Red Sea.

b. Industrial pollution existing in industrial sites in dry and gas forms may give rise to dangerous situations under wet conditions.

c. Desert pollution is mainly dust which accumulates gradually on the insulators. However, during sand storms the insulators are covered with sand and dust particles very rapidly. Such particles may be carried over long distances to non-desert areas by strong winds. In the large part of the Middle East countries (Bahrain, parts of United Arab Emirates, North Africa, Egypt, Syria, etc.) and in some regions of Australia desert type of pollution composed of dust and sand are experienced. In the Karachi area (Pakistan) a combination of desert and marine pollution has presented severe flashover problem. The Jordan Dead Sea area experiences relatively severe salt and desert dust pollution (2-6).

The pollution flashover has gained special importance in Saudi Arabia in recent years as several high voltage

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energy transmission systems have been put into operation in polluted areas such as desert areas and coastal regions (3,6). This problem in Saudi Arabia will maintain its importance and even may become more severe because of:

a. The construction of more open substations, transmission lines and power stations at coastal areas due to the demand for cooling water.

b. The increase in transmission voltage. The present highest transmission voltage in Saudi Arabia is 380 kV. It is probable that a higher transmission voltage (500kV) may be considered for a contemplated transmission system linking East and West coastal regions.

c. The quick spread of industrial areas and associated pollution in addition to desert pollution.

On account of importance of the problem for Saudi Arabia, a large scale research project has been initiated by the University of Petroleum and Mineral (UPM) in colaboration with the Elecricity Corporation (6). Several test stations have been set up at representative areas where various types of dead and energized insulators under constant voltage were exposed to environmental conditions and several measurements such as recording number of flashovers, counting of leakage current surges exceeding certain values and measurement of meteorological data (humidity, rain intensity, temperature, speed and direction of wind etc.) are made. In accordance with a time table, the insulators are removed from the testing stations to the High Voltage Laboratory of UPM for flashover tests and measurement of pollution degree and types. Thus, representative design information required for the insulator coordination of high voltage systems will be obtained (7,8).

A project of the same nature confined only to the Western Region of the Kingdom has already been completed by the Authors. This paper reports some results of this investigation.

RESEARCH PROGRAM

Aim of the Research

In order to meet the growing electric power demend in the Western Region of Saudi Arabia, several high voltage power networks operating at 110kV and 380 kV and connecting Jeddah to Taif, Makkah and Yanbu have been installed. The insulators of Jeddah-Makkah transmission lines are subjected to desert pollution which is formed of fine dust, sand storm and humidity. The insulators of power network near Taif may frequently be exposed to drizzling rain. The insulators of those parts of the transmission lines near the Red Sea are subjected to marine and desert type pollutions.

Pollution flashover difficulties with the line insulators in the Western Region have been experienced and coating of the insulators with silicone grease and washing of polluted insulators have been tried in order to provide trouble-free operation of the transmission lines (10). Furthermore, a rapid industrialization and extension of polluted areas in the Western Region are taking place. This will result in more pollution and increased operational difficulties caused by the insulator flashover. The research program partly reported in this paper has been designed to asses the pollution flashover performance of high voltage insulators used in the transmission lines operating around Jeddah.

Scope of the Research

In order to carry out the investigation, four typical locations representing marine, industrial and desert types of pollution along the 110kV-380kV lines connecting Jeddah to Makkah have been selected. The description of the locations and the related pollution characteristics are given in Table 1.

Table 1: Description of the selected locations.

Location	Description of the location
1	Jeddah industrial region and environment of a gas turbine power plant (industrial and partly marine pollution)
2	110/380 kV Prince Fawaz substation (desert pollution)
3	Tower No: 9 of the Fawaz-Hadda 110 kV transmission line (agricultural and desert pollutions)
4	Tower No: 42 of the Fawaz-Hadda transmission line (sand storm and desert pollution).

Two basic insulator types, cap-and-pin and longrod, have been chosen for the tests. The profiles of these insulators are shown in Figure 1. The seleected porcelain insulators have been exposed to various types and intensities of pollution at the selected localities for two durations.

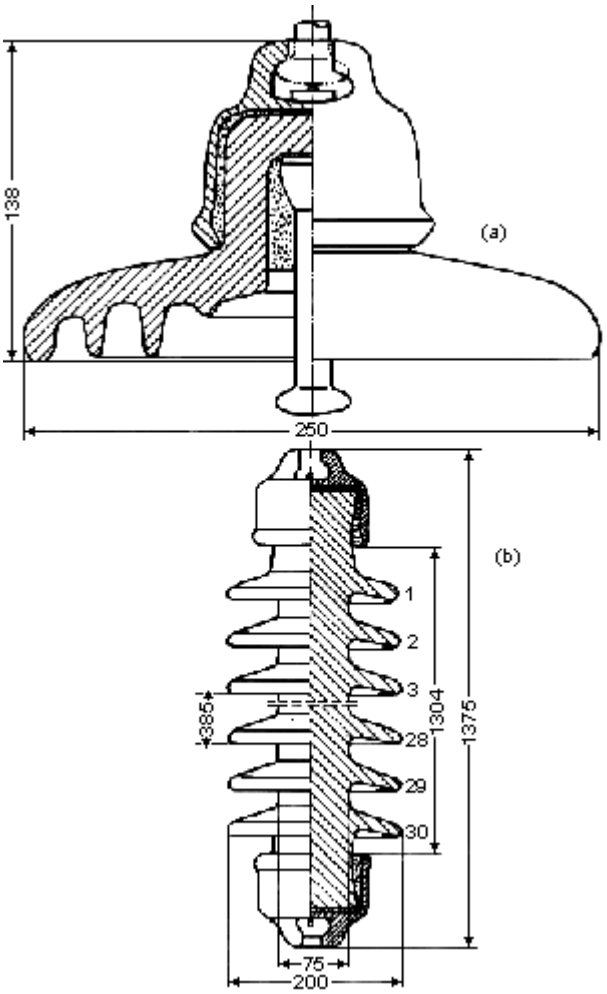

Figure 1: Profiles of the insulators tested. (a) Cap-and-pin type, leakage path 292 mm. (b) Longrod type, leakage path 4650 mm and number of sheds 30.

Execution of the Program

The investigation was initiated by hanging two groups of the selected insulators in each of the selected four regions on June 14, 1981. The porcelain insulators in one locality consisted of three cap-and-pin strings (each string having three units) and three longrod insulators. The test insulators have been hanged at the same height of the line insulators, without voltage being applied, and have been left to natural pollution.

The first group of insulators consisting of one cap-and-pin string and one, longrod from each locality has been brought to the High Voltage Laboratory of King Abdulaziz University after about 100 days of exposure duration (first period). After about 2 years of exposure duration (second period) the remaining insulators have been transferred to the Laboratory for testing.

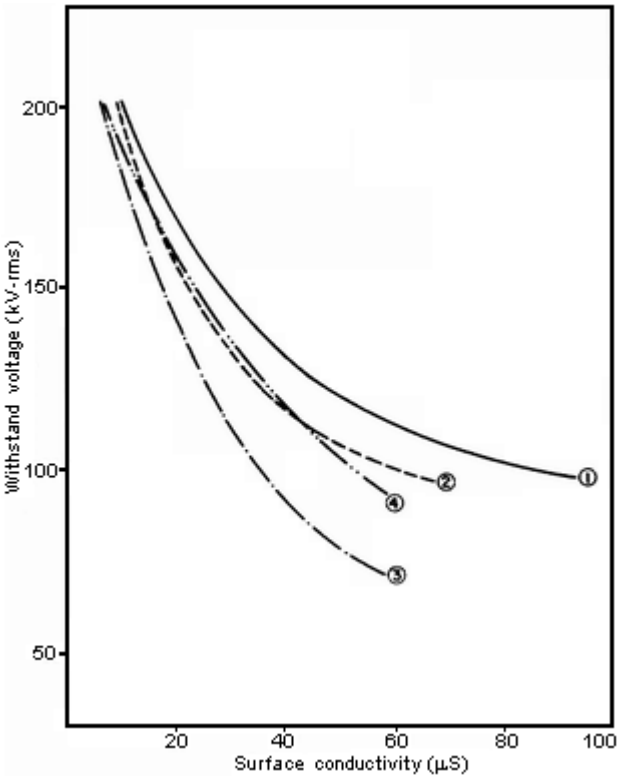

Figure 2: Withstand characteristics of the longrod insulator exposed to pollution over the second period at the selected localities.

Withstand Characteristics

Different types of measurements such as surface resistance, capacitance and loss angle etc., have been performed on the test insulators. However, attention has been paid to the measurement of withstand characteristics which indicates the flashover behaviour of polluted insulators.

The withstand characteristics have been measured in accordance with the IEC-507-1975; "solid layer method - procedure a" (11). The naturally polluted insulators vertically hanged in a chamber have first been wetted under clean fog. A pre-estimated ac test voltage has then been applied, in a time not exceeding 5 seconds, to the insulator with its pollution layer having maximum conductance and maintained for 15 minutes if no flashover occurred. For a selected test voltage, up to five successive tests have been performed on the same insulators. Further detail about testing procedure can be found in Ref. (9, 11).

The withstand characteristics of the test insulators exposed to natural pollution at four different locations are given in Figures 2 and 3. These characteristics are given

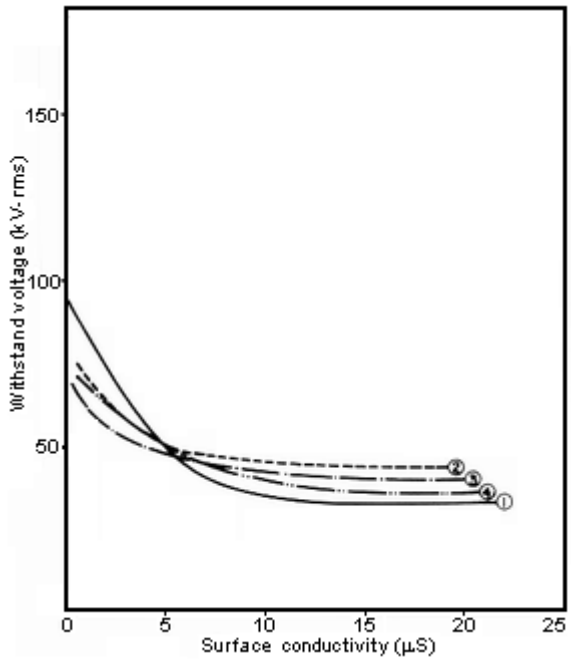

Figure 3: Withstand Characteristics of the cap-and-pin insulator exposed to pollution over the second period at the selected localities.

for the second period only as the withstand voltages measured for the insulators exposed to pollution over the first period were significantly lower than the second period values.

DISCUSSION AND CONCLUSION

In the estimation of pollution level of a region, the surface conductivity which is obtained by aid of form factor of the insulator and the measured pollution saturated conductance is considered to be a representative parameter. In the present investigation, maximum surface representative parameter. In the present investigation, maximum surface representative parameter. In the present investigation maximum surface conductivities measured under hundred percent humidity for the first period remained less than 20 μS for locations 2,3 and 4 (light pollution) and was higher up to about 70 μS for location 1 (heavy pollution). However, this figure for the second period varied between 45-100 μS which indicated that the insulators exposed to pollution at the selected four locations during the second period have become heavily polluted.

The measured withstand characteristics can be used in the estimation of flashover performances of the selected insulator types under prevailing conditions of the region. Although, a direct comparison of the cap-and-pin type with the longrod type is not possible as neither their leakage path and nor overall height are comparable, a comparison based on the average withstand gradients can give a general idea about their performances. The lowest average gradients measured for the cap-and-pin and longrod types have been found as 30 kV/(3*29.2) cm = 0.342 kV/cm and 85 kV/465 cm= 0.183 kV/cm, respectively (the cap-and-pin type having about 87% higher value). Considering equal height as basis for comparison, a cap-and-pin string having about 1275/138=10 units has to be taken into consideration. Assuming a linear relation between the leakage path and the withstand voltage (11), the cap-and-pin string provides about 100 kV withstand voltage, 15% higher than the withstand voltage of the longrod type. However, tests on both types having the same height are needed in order to reach a sound conclusion for which type provides a better flashover performance.

The longrod insulators indicated in Figure 1 and tested in this investigation is used in some parts of the 110 kV transmission lines in the Region. This insulator has so for presented no significant operational difficulty. It can be seen from the withstand characteristics that the measured minimum withstand voltage (85kV) of this insulator always remained above $110/(3)^{0.5}$=63.5kV which is the continuous operating voltage across the insulator. The main reason for the good performance might be its very high (leakage path/voltage) ratio= 465/63.5=7.32 cm/kV.

It has been concluded that the longrod insulators tested in this investigation will present no operational difficulty due to pollution when used in the 110kV system over two years period. This also implies that for two years duration the insulators needs no cleaning. In order to stop pollution flashovers, washing and greasing are the measured adopted in Saudi Arabia. The live washing is gaining preference over greasing because of cleaning difficulty with the second method. In this respect, leakage current counters can be recommended for a better estimation of the cleaning period.

The investigation has also indicated that the cap-and-pin string having 10 standard units can provide a better pollution flashover performance than the longrod type having the same height. It should be noted that a much better flashover performance can be obtained if the cap-and-pin with anti-fog desing is used. However, the cap-and-pin insulator type is not adopted in Saudi Arabia.

The present investigation has initiated a research on this important practical subject and specified the dimensions of the problem at regional level. The research project initiated by the UPM on a larger scale will certainly produce more information on the subject and will provide desing values that can safely be used in the desing and coordination of high voltage energy transmission systems in Saudi Arabia.

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