

The Performance Characteristics of Low Voltage Insulators in a Polluted Environment

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Abstract: Low voltage insulators form an essential part of the electric power transmission system. Any failure in the satisfactory performance of low voltage insulators will result in considerable loss of capital, as there are numerous industries that depend upon the availability of an uninterrupted power supply. In this work, an 11KV porcelain insulator contaminated by different pollutants such as Salt, Cement, Ash, Acid rain and carbon II oxide was tested using a PGK 250KV transformer to ascertain the breakdown voltage of the insulator due to the different pollutants. Test results were recorded as follows: Dry insulator 90KV, dry insulator with water 78.3KV, dry insulator with cement 90KV, wet insulator with cement 20KV, dry insulator with ash 70KV, wet insulator with ash 25KV, dry insulator with Salt 70KV, wet insulator with Salt 20KV and dry insulator with carbon II oxide 78.3KV.

Keywords: pollutant, low voltage, insulator, environment, dielectric.

I. Introduction

Insulators are materials in which electricity cannot flow [1]. A true insulator is a material that does not respond to an electric field and completely resists the flow of electric charge. In practice, however, perfect insulators do not exist [1,2]. Therefore, *dielectric* materials with high dielectric constants are considered insulators. In insulating materials valence electrons are tightly bonded to their atoms. These materials are used in electrical equipment as *insulators* or *insulation*. Their function is to support or separate electrical conductors without allowing current through [3].

Insulators are meant to work effectively in a clean environment. Our environment is polluted by different types of pollution from industries, cars etc. This paper analyses the effect of an insulator in a polluted environment.

II. The Mechanism For Insulation Breakdown

Outdoor insulators are being subjected to various operating conditions and environments. The surface of the insulators is covered by airborne pollutants due to natural or industrial or even mixed pollution [4]. Contamination on the surface of the insulators enhances the chances of flashover [2]. Under dry conditions the contaminated surfaces do not conduct, and thus contamination is of little importance in dry periods [5]. As the surface becomes moist because of rain, fog or dew, the pollution layer becomes conductive because of the presence of ionic solids. The leakage current flows through the conducting surface film, generating heat which tends to increase the film temperature most rapidly at those points where the current density is greatest, i.e. at narrow sections of the insulator, such as the area around the pin. Eventually, the temperature in these areas approaches boiling point, and rapid evaporation of the moisture occurs producing dry areas [6,7]. The development of the dry areas is independent of the insulator type, something that has also been verified experimentally, since the insulator's body diameter differs very little from one type to another. Pollution flashover, observed on insulators used in high voltage transmission is one of the most important problems for power transmission. Pollution flashover is a very complex problem due to several reasons such as modelling difficulties of the insulator complex shape, different pollution density at different regions, non-homogenous pollution distribution on the surface of insulator and unknown effect of humidity on the pollution [8]. The performance of insulators under polluted environment is one of the guiding factors in the insulation coordination of high voltage transmission lines. On the other hand, the flashover of polluted insulators can cause transmission line outage of long duration and over a large area. Flashover of polluted insulators is still a serious threat to the safe operation of a power transmission system. It is generally considered that pollution flashover is becoming ever more important in the design of high voltage transmission lines. Research on insulator pollution is directed primarily to understanding the physics of the growth of discharge and to develop a mathematical model, which can predict accurately the critical flashover voltage and critical current [9,10].

III. Types Of Contaminant And Sources Of Pollution

The level and the type of pollution of a region area associated with the sources of pollution, as well as the weather factors of the place, are shown in table 1.

TABLE 1: CONTAMINANTS AND THEIR SOURCES OF POLLUTION

CONTAMINANT	SOURCES OF POLLUTION
Salt	Coastal areas Salt Industries High ways with deposits of snow where salt is used to melt the snow
Cement	Cement Plant Construction sites Rock quarries
Earth	Pillowed fields Earth moving on construction projects
Fertilizers	Fertilizer plants Frequent use of fertilizers in cultivated fields
Metallic	Coal mining Coal handling plants/thermal plants Coal burning/brick kilns areas
Volcanic ash	Volcanic activity areas
Defecation	Roosts of birds areas
Chemical	Wide variety of Chemical/process industries, oil refineries...
Smog	Automobile emissions at highways crossing Diesel engine emissions at railway crossing /yards
Smoke	Wide fire Industrial burning Agricultural burning

[12,13]

IV. Laboratory Test Methods For Insulation Breakdown:

- (1) **Wet Insulation Test:** The insulator was contaminated with Salt and water, ash and water, dust and water, cement and water and then subjected to high voltage of up to 250KV.
- (2) **Dry Insulation Test:** The insulator was contaminated with dry salt, dry ash, dry dust, carbon mono oxide, and cement and then subjected to a high voltage of 50KV.

V. Experimental Procedure

A PGK machine was used. The PGK transformer with rating 250KV was connected to the PGK control desk and then the HT indicator was connected to the control desk of the PGK. The secondary side of the transformer was connected to one end of the insulator through a protective resistor whose work is to limit the flow of the current from the transformer to avoid surge while the other end of the insulator was earthed. The block diagrams test equipment are shown while the test results are shown in Table 2.

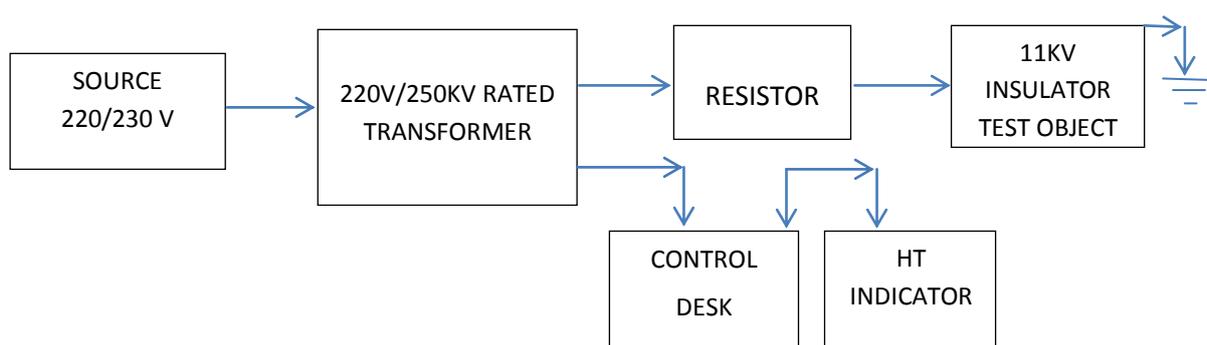


FIG 1: BLOCK DIAGRAM OF AN INSULATION TEST

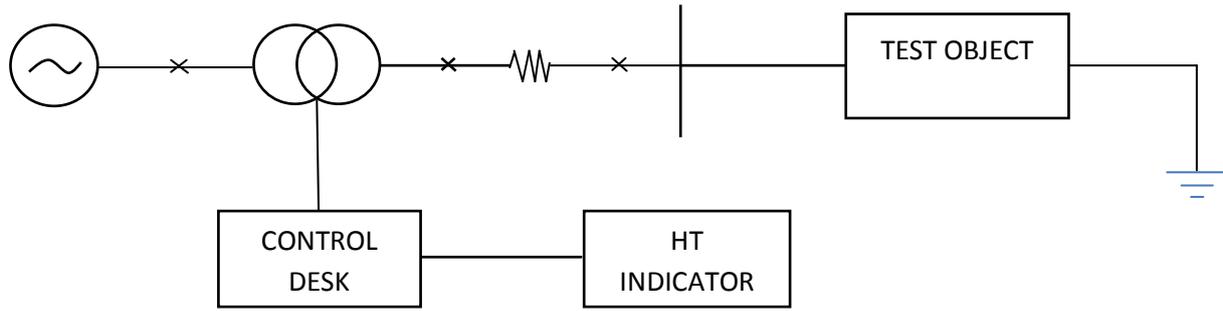


FIG 2: CIRCUIT DIAGRAM OF AN INSULATION TEST

4 LABORATORY TEST RESULT

TABLE 2: Breakdown & Inception Voltage, Leakage Current of Contaminated Insulators.

S/N	Sample	I _c V(KV)			V _D (KV)			I _L A (mA)			A _v V _D	A _v I _C	A _v I _L
1	Dry insulator	50	50	50	90	90	90	5	5	4	90	50	4.67
2	Dry insulator with water	35	40	42	75	80	80	3	3	2	78.3	39	2.67
3	Dry insulator with cement	52	52	52	90	90	90	3.5	3.5	3.5	90	52	3.5
4	Wet insulator with cement	20	20	20	20	20	20	9	9	9	20	20	9
5	Dry insulators with ash	28	30	30	70	70	70	3.2	3.0	3.1	70	29.3	3.1
6	Wet insulators with ash	20	20	20	25	25	25	0.9	0.9	0.9	25	20	0.9
7	Dry insulators with salt	30	30	30	70	70	70	1.2	2	2.5	70	30	1.9
8	Wet insulators with salt	20	20	20	20	20	20	9	9	9	20	20	9
9	Dry insulators with CO	50	50	50	80	80	75	3.2	3.2	3.2	78.3	50	3.2

* The temperature during the experiment is in the range of 28 to 29°C

Average temperature $T = \frac{t_1 + t_2}{2} = \frac{28 + 29}{2} = 28.5^\circ\text{C}$

The pressure during the experiment is $b = 1010\text{mb}$ and it remained constant throughout the experiment.

The Air density factor was obtained as:

$$D = \frac{b}{1030} \times \frac{273 + 20}{273 + T}$$

Where; b = atmospheric pressure

T = Average temperature

D = Air density factor

$$D = \frac{1010}{1030} \times \frac{273 + 20}{273 + 28.5}$$

$D = 0.9525$.

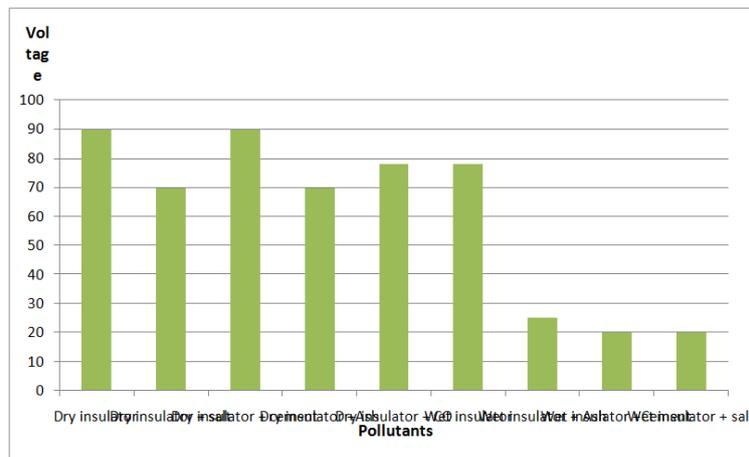


Fig 3: Breakdown Voltage against different level of contaminants

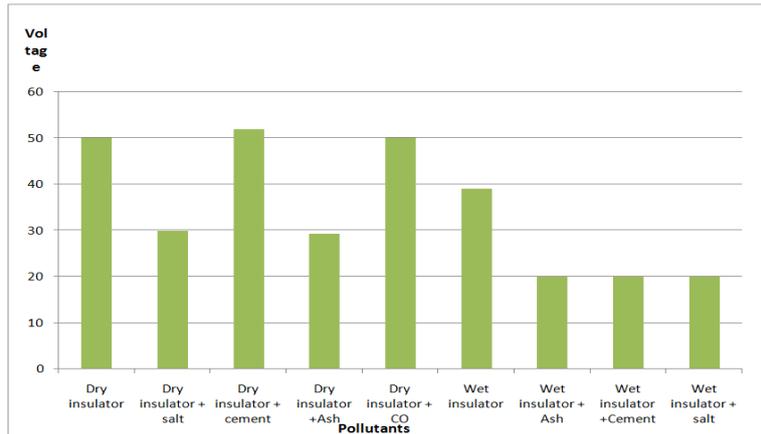


Fig 4: Inception Voltage against different level of contaminants

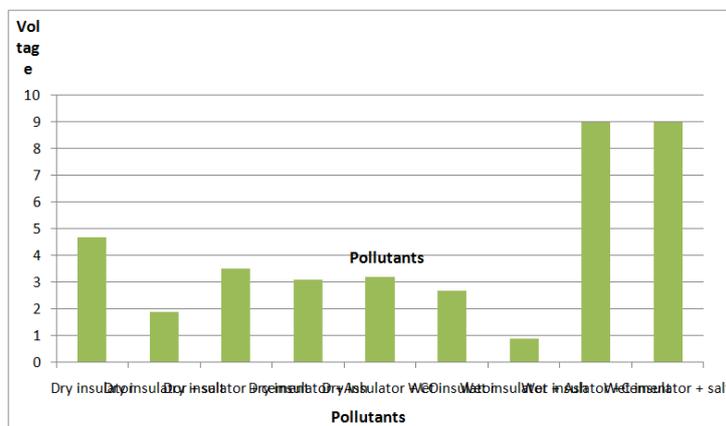


Fig 5: Leakage current against different level of contaminants

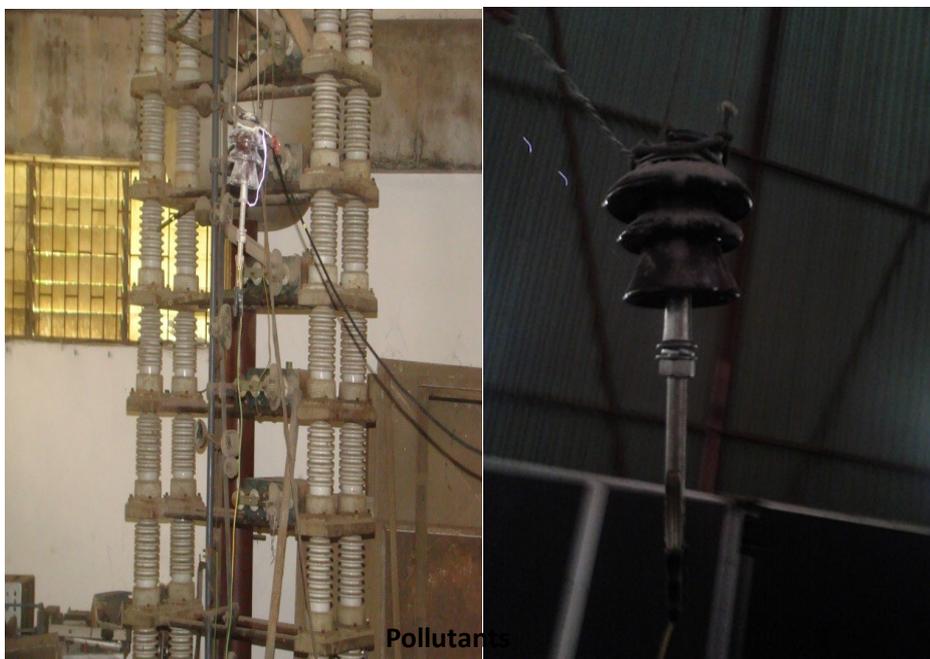


Fig6: Ash flashover Spark and the Insulated Contaminated with Ash.



Fig 7: Contamination of Insulator with Cement

The breakdown voltage of CO produced a spark and the contaminationof the insulator by CO is shown in fig 8 below,



FIG 8: Contamination of Insulator with Co and the Flash over voltage Spark.

VI. Conclusion

The effect of insulators in an environment polluted with different pollutants such as salt, cement, Ash, Acid water and carbon II oxide was investigated and there breakdown voltages were recorded. Results from test showed that optimal breakdown voltage is realized when the insulator is dry. The result also revealed that the dielectric strength of the insulator decreases depending on the level of contamination/combination of contaminants. Thus the mixture of wet insulator and any contaminant produces very low breakdown voltage and insignificant spark because the dielectric strength of the insulator is reduced.

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