Porcelain Insulator Performance under Different Condition of Installation around Aligarh

Asfar Ali Khan and Ekram Husain

***Abstract*—**Modern Society is strongly dependent on a reliable power supply. The availability of cheap and reliable supply of electrical energy is an indicator of societal welfare. Uninterrupted reliable operation of a modern power system depends to a great extent on reliable and satisfactory performance of insulators under different environmental conditions. This paper reports result of natural pollution tests that have been done at sites around city of Aligarh (India). Flashover voltage per insulation distance (FOVUID) of porcelain disc insulator for different pH values, ESDD has been recorded for proper correlation between electrical and chemical parameters. The pH of the contaminants has been suggested to be an effective pollution severity indicator and may be used as a diagnostic parameter for proper maintenance of porcelain insulators.

***Keywords*—**Porcelain insulators, Flashover Voltage, pH value, Conductivity, ESDD.

I. Introduction

PORCELAIN as an insulating material has more than one century of service history. The chemical stability of porcelain resists ageing thus making it suitable for long term use. The stable chemical bonds of ceramic material imply high surface free energy, a property that describes the strength of the surface adhesion of contaminants. With high surface free energy, porcelain is easily wetted and the water on the surface tends to form filaments thus making porcelain hydrophilic. Hydrophilic surfaces tend not to perform well under polluted conditions, as the water filament dissolves the conductive pollution, lowering the overall surface resistance of the insulation with a conductive electrolyte along a continuous path, which can initiate the flashover process [1], [2].

The successful, reliable and uninterrupted operation of electrical power system depends on reliable and satisfactory performance of insulators under different environmental conditions. Contamination induced flashover is the most serious problem with high voltage insulators. The major contributors to environmental pollution are dust, dirt, industrial emissions, vehicular pollution, saline deposits, desert salts etc. These contaminants, under damp conditions interact with water, which then behaves as an important pollutant vis-à-vis insulation capability [3].

Judicious selection of outdoor insulation for a new environment is a difficult task. Also economical frequency of maintenance procedure for an area with existing transmission line is important. Both these objective necessitates assessment and measurement of pollution severity of an area. The known methods employed for pollution severity measurement as given [4] includes ESDD measurement, conductivity measurement without removing contaminant, chemical analysis, leakage current measurement, use of directional deposit gauges. The performance of insulators can be assessed by natural pollution tests, which are imprecise but realistic, and by artificial tests, which are much more precise but less realistic [5].

This paper describes results of experiments conducted under condition of natural fog on naturally exposed insulators polluted around the city of Aligarh. As reported earlier [6]-[9], pH of the contaminant affects the flashover characteristics. To understand effect of pH on naturally contaminated insulators, this study was undertaken near the identified site. The results were indicative of the fact that pH, in addition to conductivity (ESDD) can also be used as a pollution severity indicator and can be developed into a diagnostic testing and monitoring (DTCM) technique.

II. Area of Study

The area of study chosen is Aligarh district of Uttar Pradesh state in India. Aligarh lies in the northern region of India and lies in a subtropical climatic zone with location at 27.88°N latitude and 78.08°E longitude at height of 178m above mean sea level. The area has hot and dry summer with mean temperature between 32.2-33.8°C; the mean winter temperature ranges between 12.2- 15.0°C. Aligarh has intermittent rainy season with an annual average rainfall of around 850mm. The study was conducted in an area separated by about 10-15km in and around city of Aligarh. The three typical locations identified having different level of pollution is given in Table I.

TABLE I
Different Level of Pollution

	Area	Area characteristic
Location A	A residential area near Aligarh Muslim University, Aligarh	No industry nearby and a very low volume of traffic
Location B	Area outside city of Aligarh at an electrical substation on national highway 91 (connecting New Delhi-Kanpur)	High vehicular pollution, agricultural and industrial pollution
Location C	Area adjoining a coal fired thermal power plant that runs on about 3200 metric ton of coal daily	Area has fly ash, dust, agricultural and vehicular pollution.

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III. Experimental Procedure

The natural pollution tests were carried out using the cap and pin type insulators that are extensively used in overhead networks in India. The unit diameter is 254mm, spacing 146 mm and leakage distance 305mm. The surfaces of the specimen insulator were cleaned and washed with detergent to remove repellency. The pretreated insulators were installed at the identified location as given in Table I.

The investigation was initiated by installing the cap and pin type insulator at the selected location, under unenergized state, in first week of July 2007. The test insulators were positioned at almost the same height as of the line insulators and were left to natural pollution. The samples were periodically removed in March 2008, December 2009, December 2010 and December 2012. The naturally polluted insulators were brought to the high voltage laboratory for measurement of desired parameter under natural wet condition.

IV. Measurement

The flashover voltage of the sample was measured in morning hour (Temperature around 5 - 20°C & pressure 740 mm Hg) using high voltage testing transformer. The contaminants were removed from the sample and the pH and conductivity of the pollutant measured.

A. Voltage Measurement

The high voltages were obtained from a 1-phase testing transformer of 0.391/150kV, 50 Hz, 30kVA rating, 15A short circuit current at maximum excitation. The voltages were measured using a voltmeter (accuracy ± 3%) connected to the primary side of the transformer, that reads the low side voltage. The corresponding high voltages are obtained from a calibration curve [10] drawn by using the sphere – sphere electrode system having diameter of 25cm (IS: 1876-1963) [11].

B. Conductivity Measurement

The conductivity of the contaminant deposited on the surface of the insulators was measured using CM 180 conductivity meter having cell constant 0.1 to 1 and conductance range 20μS to 200mS.

C. pH Measurement

The pH value of the contaminant was measured after removing deposited salt on the sample using LI 120 pH meter with range from 0-14.

D. ESDD Calculation

Since electrical condition along contaminated surface is because of ionic conduction in aqueous solution of salts, the quantity of potentially conducting soluble material is conventionally described by an equivalent amount of NaCl or equivalent salt deposit density (ESDD) [12]. ESDD value is obtained from measurements of volume conductivity, solution temperature and volume of wash water solution using (5) [13].

V. Results and Analysis

The contaminated insulators after being exposed to natural wet conditions were subjected to high voltage for recording wet flashover voltage. For normalization, the observed value of flashover voltage was divided by the leakage distance to get the flashover voltage per unit insulation distance. The flashover voltages per insulation distance (FOVUID), pH and calculated value of ESDD have been used to draw the graphs shown in Figs. 1-6.

Figs. 1-3 show the general trend that as ESDD increases FOVUID values drop. This drop can be attributed to the presence of electrolytic/ionic solution under wet conditions. The common content of dust in and around Aligarh consists of cautions such as Na^+ , K^+ , Ca^{2+} , Mg^{2+} and anions such as HCO_3^- , CO_3^{2-} , Cl^- , NO_3^{2-}, SO_4^{2-} . This may be due to the reason that surface and ground water in Aligarh has presence of above ions [6], [14], [15]. The presence of such cautions and anions contribute to the conduct of electricity. For location A, which is a residential area away from main highway, has a very low vehicular traffic with dust deposit of less than 20 gm/m^2 per month [8]. There is a railway line about 200metres from the site of installation, the train frequency is very low and is run on diesel locomotives. The area does not have any agricultural fields and as such pollutants arising of fertilizers are not found. Thus the deposits to which the insulators at this site are subjected are the common contents that are listed above. For location B, in addition to above contents of dust, the insulators are also subjected to tiny particles of carbon, ash, oil formed by incomplete combustion of fuel. It is to also mention that location B has few industries that produce cooking oil and wheat flour. The area also has large agricultural area using variety of fertilizers. For the case of site near thermal power plant, that runs on 3192 metric tonne of coal/day produces oxides of sulphur, nitrogen and carbon particulates. In addition to the above contents, the insulators are also subjected to fly ash deposits that consist mainly of SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, P_2O_5, carbon and carbonate ions**.** Apart from these components the area also has number of brick kilns using coal as fuel and large agricultural area using variety of fertilizers. It is to be noted that increase in fly ash concentration increases the water hold capacity of deposits, pH, conductivity and also increase in sulphate, carbonate, bicarbonate and other metal ions**.** Moreover, the characteristics of the inert ash deposited on the samples that forms an inert matrix also influences the FOV characteristics [9].

It is worth mentioning after careful examination of Figs. 1-3, that the maximum drop in FOVUID values are for the samples tested in March 2008. This may be due to the reason that during the period December 2007 and March 2008 normal winter rains did not occur; thereby self cleaning of insulator surface did not happen leading to substantial deposits on the insulator. Apart from this, the relative humidity was very high during the first week of March 2008 and unusual fog conditions prevailed on 6th, 7th and 8th March 2008, the days when testing of samples was done [16]. Thus in addition to high ESDD, higher values of relative humidity played a vital role in lowering the voltage at which the insulators flashed over leading to large scale outage in the northern grid of India.

The samples during the period March 2008 and December 2009 undergo two monsoon season natural washing and hence FOVUID values are higher as the ESDD value is smaller compared to March 2008 samples. For samples tested in December 2010 and December 2012, the FOVUID values are slightly less as the ESDD has increased owing to extra deposition of local pollutants. It is also clear that for same ESDD we get different FOVUID values. This is due to the reason that prevailing weather conditions and location affects insulating capability of insulators.

The variation of FOVUID with pH value of the contaminant is given in Figs. 4-6. The curves have been drawn from the data collected over an exposure period of about four years. Figs. 4-6 show that as pH of the contaminant increases (towards 7); there is increase in FOVUID values. This is due to the reason that as pH increases there is decrease in the hydrogen ion concentration implying less acidic nature of the electrolytic solution. Since pH is based on logarithmic scale, a change of 0.4 pH implies about 2.5 fold changes in hydrogen ion concentration. It can be observed from Figs. 4-6 that the pH ranges from 6.52 – 6.92 for samples installed at location B (NH-91) and location C (thermal plant). The deposits are more acidic than deposits of location A (Fig. 4) due to the difference in the contents of deposits. The contents listed for location B & C are responsible for forming acidic nature of deposits. Although the ground water in Aligarh is alkali bicarbonate (pH > 7), it is observed that pH of ground water around location B is 7.12, that near location C around 6.98 and that around location A it is 7.22. This difference in pH of groundwater will naturally affect the pH of the aqueous dust solution in these areas. Apart from this SO_x and NO_x produced from combustion of coal and hydrocarbons combine with atmospheric moisture and form acidic deposits on the samples. Near the thermal power plant fly ash adsorbs these gases and with interaction under natural wetting condition produces corrosive acids and thus results in lower pH of these deposits. Thus near thermal plant the insulators in addition to dust are also subjected to fly ash deposits that consist mainly of SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO,P_2O_5 ,carbon and carbonate ions. The presence of these soluble/non-soluble components decides the FOVUID characteristics [17].

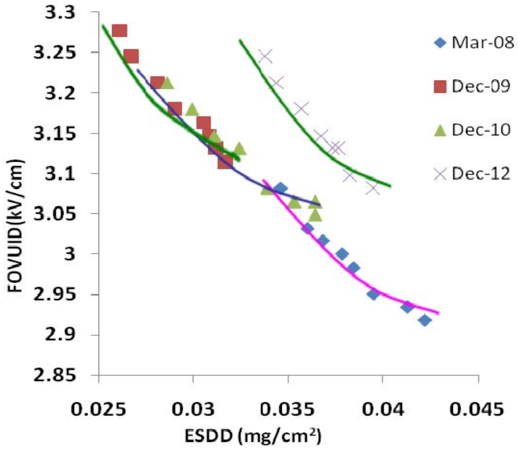

Fig. 1 FOVUID vs ESDD for Location A (Residential)

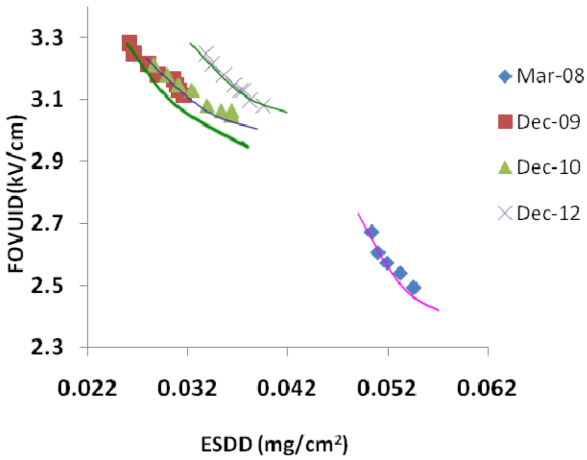

Fig. 2 FOVUID vs ESDD for Location B (Highway)

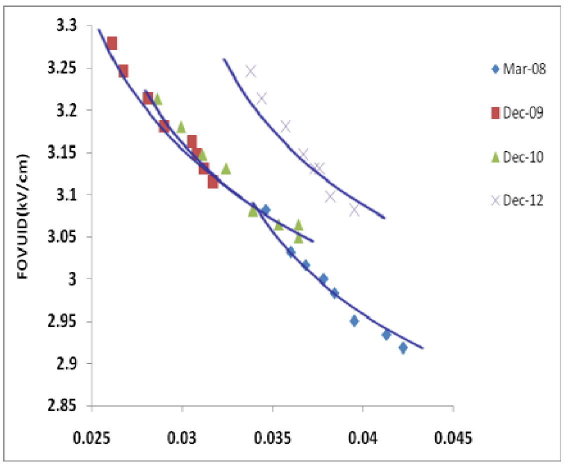

Fig. 3 FOVUID vs ESDD for Location C (Thermal plant)

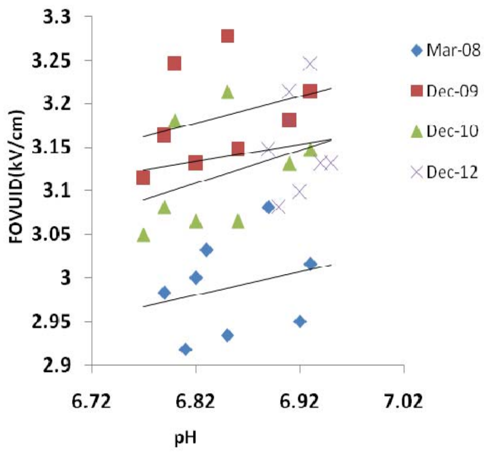

Fig. 4 FOVUID vs pH for Location A (Residential)

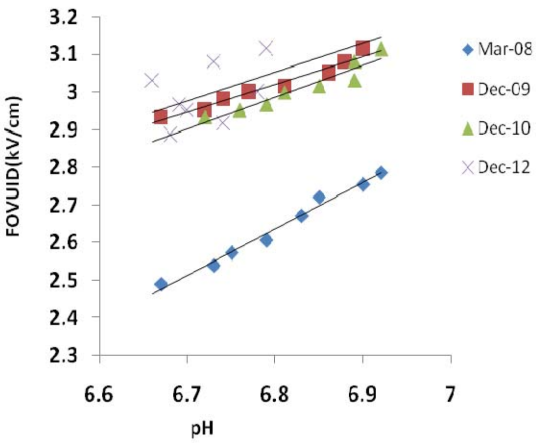

Fig. 5 FOVUID vs pH for Location B (Highway)

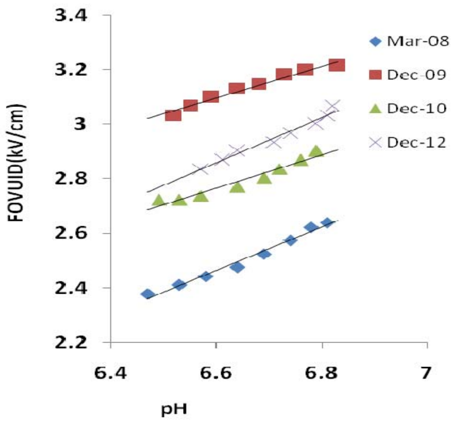

Fig. 6 FOVUID vs pH for Location C (Thermal plant)

VI. Conclusions

From the analysis of results, it can be concluded that pH, ESDD of contaminant plays an important role vis-à-vis the flashover characteristics of the insulator. The factors influencing Flashover performance of porcelain insulators can be summarized as:

a. Increase in ESDD results in considerable decrease in flashover voltage.
b. Increase in pH (towards 7) value of contaminant results in substantial increase in FOV values.
c. The flashover voltage of an insulator depends on the environment in which it is installed.
d. Relative humidity plays a major role in deciding flashover characteristics as at higher RH, the availability of dissociated water ions increases leading to easy conduction.
e. Nature of deposit decides pH of surface pollutant.
f. Even for same ESDD, flashover voltage may be different owing to occurrence of major non soluble components in the dispersed pollutants.

The continuous monitoring of pH and conductivity (ESDD), which is an indication of pollution severity of deposits on insulators, can be used for preparation of preventive maintenance schedule. Further pH monitoring can be used as a Diagnostic test for condition monitoring (DTCM) for devising a maintenance schedule as soon as pH of prevalent contaminant exceeds a predetermined value. It is also suggested that smart pH sensors be developed for effective condition monitoring of insulators to make the grid smarter for better and improved reliability [18].

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