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Pollution Severity Diagnose on Solid Insulators using the Partial Discharge and Flashover Characteristics

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Abstract: ***In this paper deals with the investigation of partial discharge and flashover characteristics of the ceramic and non-ceramic insulators in order to succeed a best diagnostic tool to determine the pollution severity of exterior insulators. In this experiment, laboratory based tests are achieve on the ceramic and non-ceramic insulators under AC voltage at various pollution levels manipulate the sodium chloride (NaCl) a as contaminant. Initially the test are conducted by the pure and contaminated at sample of insulators. In supplement, Partial discharge (PD) occurs on the contaminated surface of the sample insulator is to be measured and to investigate the PD wave form. The PD detection is sufficient to analyze maintenance of insulators of the transmission line. To evaluate the statistical analysis of PD patterns in order to accomplish a numerical judgment of pollution severity of the ceramic and non-ceramic insulators. In consequence, ceramic and non-ceramic insulator exhibit the pollution severity of the exterior insulators should be recognized from the partial discharge patterns investigation.***

Keywords : Insulators, statistical analysis, flashover, partial discharge, contamination, pollution severity, ESDD.

I. INTRODUCTION

An exterior insulators are plays an important role for preservation of the secure a power system. A long time the ceramic insulators are generally used in power system transmission and distribution. Now a days the non-ceramic insulators are used because of their better insulation performance when its compared to the ceramic insulators [1, 2]. The flashover occurrence on the high voltage exterior insulators are a serious warning to secure the transmission and distribution system. The insulators are located near by the industries, agricultural and coastal area; soaring particles are deposited on the surface of the insulators. Under dry condition, there is no problem for soaring particles and do not decrease the properties of the insulator at service voltage.

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While wet condition the conductive layer is formed on the surface of the insulator and further large leakage current (LC) under the service voltage. It should be affect the properties of the insulators [3]. The path of the LC density is occasional and in few areas some amount of heat is established leading to the dry band formation which can be pass over by the one or more incomplete arcs, i.e. partial discharge mostly predecessor of flashover the line insulators [4, 5].

In the case of ceramic and non-ceramic insulators, the well known incomplete arcs will leading to weakening and chemical breakdown of the insulating materials. While the outside resistance is fairly low, those PD will spread over the insulator shapes and may shortly produced by the flashover of insulators surface.

By providing the obstructive maintenance, the insulator surface cleaning is basis to minimize the flashover danger, but it too expensive. As a result, some researchers have been executed to optimize preservation times. The standard Equivalent Salt Deposit Density (ESDD) method has been recommend, but it focus both difficult to self- operation and time absorbing [6]. A proposed approach based on the measurement of surface resistance to recognize the surface corruption of the non-ceramic insulators. LC surge count is used to recognize the amount of conductive pollution present in the outdoor insulator. The earlier paper shows that the PD characteristics of glass and ceramic insulators. PD identification and investigation as a tool will allocate the huge awareness about the appliance regulating the activity of PD in the appearance of conductive layer pollution and consequently, further a powerful evaluation of surface affection.

The effect of conductive layer pollution on the PD occupation is detected through the experiment carry out on the polymeric insulator at various pollution ratio and different relative humidity conditions. In order to, evaluate the statistical analysis of PD patterns [7]. PD detection and analysis to collect the pollution severity of the ceramic insulator. The RTV coated glass insulator is used. Detection and analysis of PD to says that the pollution and flashover performance of composite insulators [8]. The behavior of insulator under desert pollution and the wave let transform technique was used to calculate the standard deviation at various harmonic components of LC [9]. The glass insulator surface can be identified by using the LC flow and space charge distribution. The depletion in amplitude of charge appears that few of charge were trapped in the polluted layer and field distribution can be modified [10].

Chandrasekar et al [11], proposed to phase angle value of silicon rubber and porcelain insulator at various pollution level and humidity condition. Fast Fourier Transform technique is used to calculate the phase angle values of leakage current signal and applied voltage. Although, the behavior of PD is very low in polymeric insulators.

On this research, the objective of the present work is to execute the laboratory based experiments in order to recognize the pollution severity of ceramic and non-ceramic insulator at a various pollution level. To attain a complete detail about PD occurrence and flashover characteristics. PD is obtained through a PD diagnosis system which is able to gather the wave form as well as the predictable PD patterns. In order to fulfill numerical judgments of pollution severity of ceramic and non-ceramic insulators and to evaluate the statistical analysis of PD patterns.

II. EXPERIMENTAL SETUP

A. Test Object

An 11kV ceramic and non-ceramic insulator was used for these experiments. Figure 1 shows that the experimental setup. Test insulator was prorogate vertically inside the chamber. In the case, the top of the test insulator connected to high voltage pin and bottom of the insulator is connected with ground. Before the test, to remove any dust and grease by using the isopropyl alcohol and rinsing with distilled water. IEC 60507 clean fog test procedures were conducted by the sample of test insulator. To replicate saline pollution classic of coastal area, prepare the contamination layer by blending the sodium chloride, kaolin and distilled water. Kaolin is act as the pollutant agent. The insulator was polluted at different ratio by using brushing method. The absorption of the NaCl saline was varied to provide with ESDD in mg/cm^2.

B. Flash Over Voltage And Partial Discharge Measurement System

The artificial pollution tests have been accomplished in an artificial chamber. The experimental setup consists of coupling capacitance, high voltage test transformer, and the specimen is hold to artificial chamber. The test transformer rated output voltage is 100kV. The testing transformer is used to create both AC and DC voltages. In this research the pollution test have been convey using AC supply. Control panel is used to control the experimental setup. PD pulses were investigated to determine anyway some details about severity of pollution could be able to sample the complete PD waveforms at a sampling rate of up to 100 MSa/s and bandwidth of 0-50 MHz. The sensitivity ranges from 2 mV/div to 5 V/div. There no coupling capacitor was inserted into the test specimen. The PC is used to gather a PD pulses.

Fig.1. Experimental setup and control panel

The ESDD (Equivalent Salt Deposit Density) values are calculated by as per standards IEC 60815.

$$ESDD=\frac{Sa\times V}{A} \quad (1)$$

$$S_a = (5.07\times \sigma_{20})^{1.03} \quad (2)$$

Where, S_a= Salinity of the solution,(kg/m^3), V= Volume of the solution in cm^3, A=Area of the cleaned surface in cm^2, σ_{20} = The layer conductivity at a temperature of 20°C (S/m)

$$\sigma_{20} = \sigma_\theta [1-b(\theta-20)] \quad (3)$$

Where, σ_{20} = The layer conductivity at a temperature of 20°C (S/m) , σ_θ =The volume conductivity at a temperature of 0°C (S/m) , θ =The temperature of the insulator surface (0°C), b is a factor which depends on the temperature.

$$b = -3.200\times10^{-8} (\theta)^3 + 1.032\times10^{-5} (\theta)^2 + -8.272\times10^{-4} (\theta) + 3.544\times10^{-2} (5.2) \quad (4)$$

III. TEST PROCEDURE

Laboratory based tests were executed in the following test conditions.

i. Ceramic and non-ceramic insulator at clean condition.
ii. Ceramic and non-ceramic insulator at various pollution levels varied with respect to the ESDD.

IV. EXPERIMENTAL RESULTS

A. Flashover voltage

Flashover values are also depends upon the leakage distance for various types ceramic and non-ceramic insulators clean and salt fog respectively. The flashover voltage decreases and increases in the pollution levels.

Table.1. Flash over test in unpolluted condition

Samples	Breakdown voltage in kV	Leakage current in mA
Pin type	94.1	42.03
Post type	101.84	42.63
Disc (Porcelain)	110.95	57.33
Disc (Glass)	85.34	40.66
Polymeric	97.33	41.43

Table.2. Flash over test in 1:1 ratio condition

Samples	Breakdown voltage in kV	Leakage current in mA	ESDD in mg/cm^2
Pin type	88.81	34	0.0109
Post type	87.42	31	0.0106
Disc (Porcelain)	77.02	25.5	0.011
Disc (Glass)	72.16	28.5	0.0106
Polymeric	97.14	45.5	0.0156

Table.3. Flash over test in 2:1 Ratio Condition

Samples	Breakdown voltage in kV	Leakage current in mA	ESDD in mg/cm^2
Pin type	74.45	32.5	0.024
Post type	82.03	29.25	0.019
Disc (Porcelain)	66.89	26.75	0.016
Disc (Glass)	68.02	26.8	0.018
Polymeric	95.56	36.5	0.017

Table.4. Flash over test in 3:1 Ratio Condition

Samples	Breakdown voltage in kV	Leakage current in mA	ESDD in mg/cm^2
Pin type	48.30	17.5	0.0174
Post type	58.51	23.6	0.0204
Disc (Porcelain)	59.19	25	0.0309
Disc (Glass)	59.19	25	0.0286
Polymeric	50.35	18.5	0.0405

Histogram of flashover voltage of ceramic and non-ceramic insulators with various ESDD levels should be obtained from the data accumulated through the experiments indicated by the following Fig. 2-5.

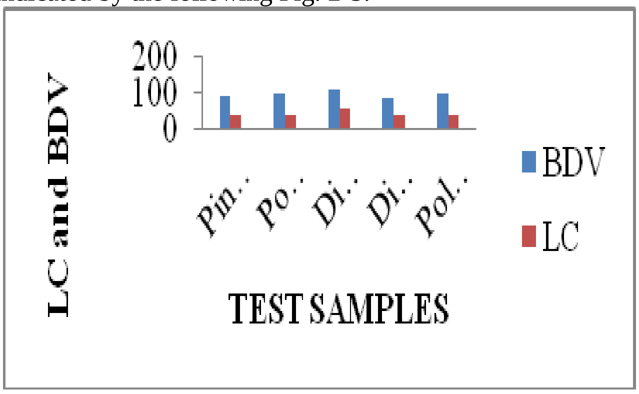

Fig.2. Breakdown voltage and leakage current of 11kV insulator with unpolluted conditions

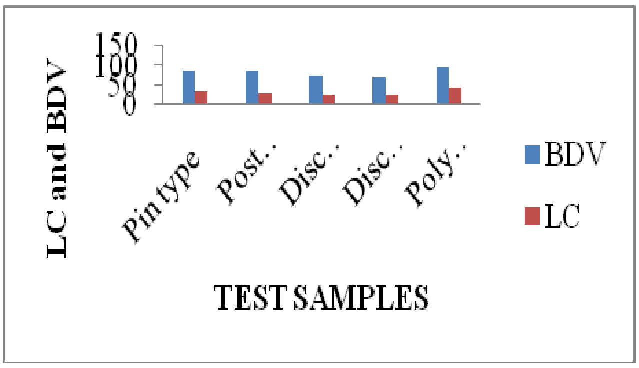

Fig.3. Breakdown voltage and leakage current of 11kV insulator with 1:1 ratio conditions

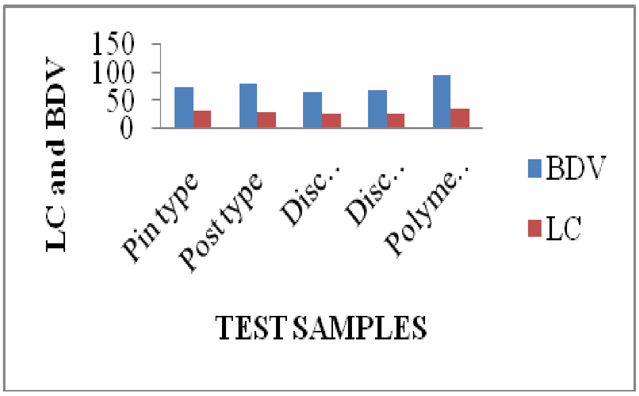

Fig.4. Breakdown voltage and leakage current of 11kV insulator with 2:1 ratio condition

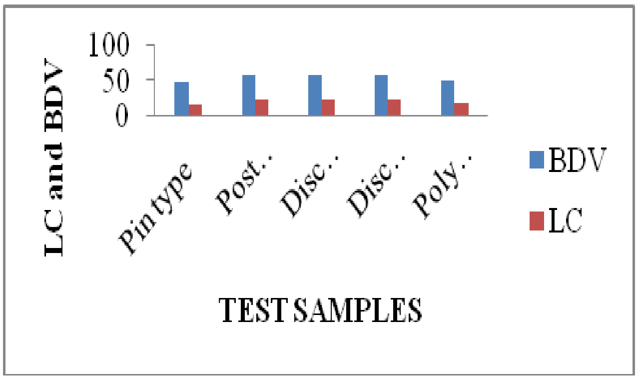

Fig.5. Breakdown voltage and leakage current of 11kV insulator with 3:1 ratio conditions

The ESDD level increase and flashover voltage will be decreases. The flashover voltage is also depends upon the atmospheric condition and the pollution levels. The flashover voltage will affect the properties of the insulator like mechanical strength, dielectric strength, resistivity, and conductivity.

B. Partial discharge test

Partial discharge test with unpolluted condition

Initially, ceramic and non-ceramic insulator specimen was tested by absent of applying any pollution, with an applied voltage under the dry condition. Then, a ceramic and non-ceramic insulator was tested inside the chamber without applying any pollution. During both dry surface tests, there is no exceptional discharge. Figure 6 shows that the partial discharge at unpolluted condition.

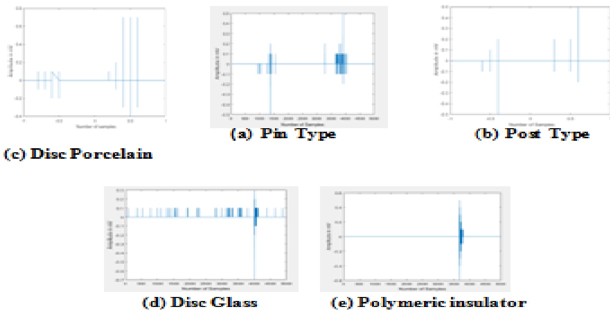

Fig.6. Partial discharge at unpolluted condition

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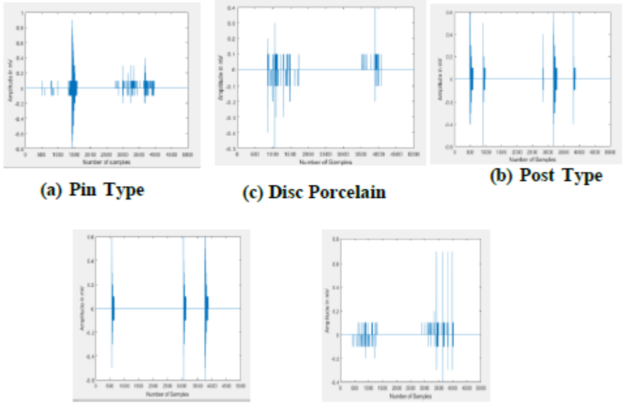
Partial discharge test with 1:1 ratio condition

Initially, ceramic and non-ceramic insulator specimen was tested by applying the pollution, with an applied voltage under the dry condition. Then, a ceramic and non-ceramic insulator was tested inside the chamber with applying the pollution under 1:1 ratio condition. During both dry surface tests, there is corona discharge will be occurred. Figure 7 shows that the partial discharge at 1:1 ratio polluted condition.



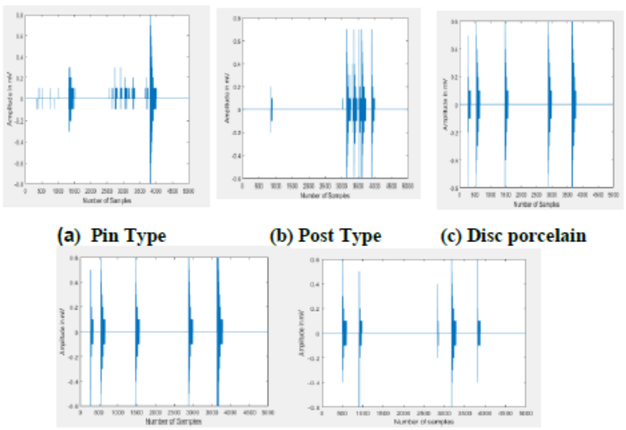
(a) Pin Type (c) Disc Porcelain (b) Post Type

(d) Disc Glass (e)Polymeric insulator

Fig.7. Partial discharge at 1:1 ratio condition

Partial discharge test with 2:1 ratio condition

Initially, ceramic and non-ceramic insulator specimen was tested by applying pollution 2:1 ratio condition, with an applied voltage under the dry condition. Then, a ceramic and non-ceramic insulator was tested inside the chamber with applying the pollution under 2:1 ratio condition. During both dry surface tests, there is surface discharge will be occurred. Figure 8 shows that the partial discharge at 2:1 ratio polluted condition.



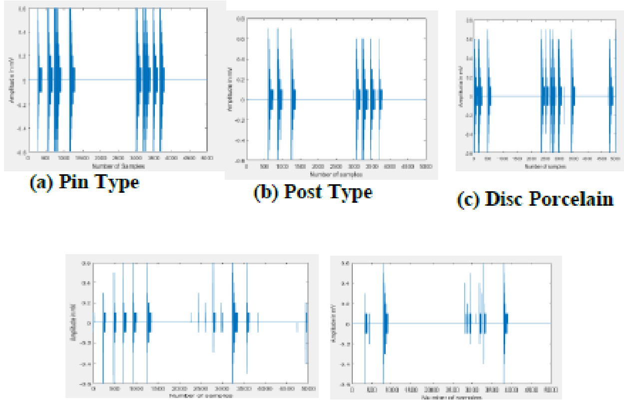
(a) Pin Type (b) Post Type (c) Disc porcelain

(d) Disc Glass (e) Polymeric insulator

Fig.8. Partial discharge at 2:1 ratio condition

Partial discharge test with 3:1 ratio condition

Initially, ceramic and non-ceramic insulator specimen was tested by applying pollution 3:1 ratio condition, with an applied voltage under the dry condition. Then, a ceramic and non-ceramic insulator was tested inside the chamber with applying the pollution under 3:1 ratio condition. During both dry surface tests, there is internal discharge will be occurred. Figure 9 shows that the partial discharge at 3:1 ratio polluted condition.



(a) Pin Type (b) Post Type (c) Disc Porcelain

(d) Disc Glass (e) Polymeric insulator

Fig.9. Partial discharge at 3:1 ratio condition

V. STATISTICAL PARAMETERS

Statistical parameters are used to determine the severity of the insulation degradationn and the position of PD. Kurtosis and skewness are used to evaluated with respect to the reference normal distribution. Skewness is a measure of assymmetry with respect to the normal distribution. Sk=0; If the distribution is symmetry. Sk>0; if it is assymmetry to left side. Sk<0 if it is assymmetry to right side. Kurtosis is an indicator of sharpness of the distribution. Ku=0; if the distribution is normal distribution. Ku>0 if it is compliment. The statistical operator can be computed as follows:

$$\text{Skewness} = \frac{\sum (Xi-\mu)^3 \times Pi}{\sigma^3} \tag{5}$$

$$\text{Kurtosis} = \frac{\sum (Xi-\mu)^4 \times Pi}{\sigma^4} \tag{6}$$

Where, X_i – Data, μ - Mean, σ - Standard deviation, P_i – Probability.

The skewness value is three and kurtosis value is zero; if it is lies on the normal distribution. The statistical parameter for clean insulator are tabulated in Table 5.

Table.5. Evaluation of statistical parameter for clean insulator

Insulator type	Applied voltage(kV)	Skewness	Kurtosis
Pin type	37	-1.1318	16.6664
	38	-1	16.1103
	39	-1.0450	14.6794
Post type	36	-0.09562	32.0181
	37	-1.3106	7.5878
	38	-2.3633	132.8229
Disc type (Porcelain)	40	0.4993	12.4289
	41	0.1804	9.3436
	42	0.3722	8.7685
Disc type (Glass)	30	-1.1544	19.2734
	31	1.4445	26.0149
	32	0.0766	3.3692
Suspension type (Polymer)	35	-6.0507	73.9620
	36	1.1102	5.7119
	37	-0.4303	28.0081

The statistical parameter for polluted insulator under the 1:1 ratio condition are tabulated in Table 6.

Table.6. Evaluation of statistical parameter for 1:1 ratio polluted insulator

Insulator type	Applied voltage(kV)	Skewness	Kurtosis
Pin type	33	7.1798	692.2331
	34	1.1684	39.9095
	35	-0.8887	12.7072
Post type	30	-2.0766	202.0698
	31	-1.3393	40.8723
	32	1.1250	68.4704
Disc type (Porcelain)	20	0.5453	34.5185
	21	0.6082	41.2206
	22	0.8193	85.5514
Disc type (Glass)	25	8.2467	199.4362
	26	-0.7854	159.3835
	27	1.3648	68.1586
Suspension type (Polymer)	29	3.9537	683.5446
	30	-3.3186	59.8234
	31	-1.3246	91.4412

The statistical parameter for polluted insulator under the 2:1 ratio condition are tabulated in Table 7.

Table.7. Evaluation of statistical parameter for 2:1 ratio polluted insulator

Insulator type	Applied voltage(kV)	Skewness	Kurtosis
Pin type	20	-3.5396	41.8435
	22	-0.9646	9.8775
	23	0.3846	31.5476
Post type	20	-0.5631	70.0792
	21	-2.6325	59.1908
	22	-2.2973	49.4597
Disc type (Porcelain)	14	-5.3833	296.9193
	15	5.9575	286.5279
	16	1.4466	113.0377
Disc type (Glass)	17	-3.7080	160.8559
	18	3.2667	158.9818
	19	-33.1023	1.9025 e^3
Suspension type (Polymer)	20	0.0611	9.9758
	21	0.3716	28.9335
	22	0.4647	13.7377

The statistical parameter for polluted insulator under the 3:1 ratio condition are tabulated in Table 8.

Table 8 Evaluation of statistical parameter for 3:1 ratio polluted insulator

Insulator type	Applied voltage(kV)	Skewness	Kurtosis
Pin type	20	2.0756	40.1105
	22	-0.9646	9.8775
	23	-1.1026	8.8045
Post type	20	0.0799	58.0437
	21	0.2137	36.4862
	22	0.2068	25.8015
Disc type (Porcelain)	13	0.2146	18.8015
	14	0.2455	10.2537
	15	-0.1780	7.0772
Disc type (Glass)	17	-1.2104	70.6107
	18	-3.0627	53.9926
	19	-1.5091	41.8520
Suspension type (Polymer)	20	0.0920	5.6975
	21	-0.2854	59.3694
	22	0.9065	68.1028

For both unpolluted and polluted condition the evaluation of the statistical parameters i.e. Skewness and Kurtosis does not lies on the normal distribution. But it should lies on the both positive and negative side. The kurtosis value isn't zero, so the sharpness of the distribution is not a normal distribution.

If the is asymmetry so we can use another distribution like Weibull distribution, Gaussian distribution, generalized extreme value distribution etc.

VI. DISCUSSION

Break down Voltage of investigated clean insulator is higher than the polluted insulators. Increase in the ESDD levels on the surface will affect the breakdown voltage of the insulators. Partail discharge detection is used to maintain the equipment because the equipment too costly. If the clean condition there is no discharge occurred from the surafce of the insulator.

The lightly polluted condition the corona discharge occurred from the surface of the insulator. The mordered polluted condition the surface discharge occurred from the surface of the insulator.

The heavy polluted condition the internal discharge occurred from the surface of the insulator. Finally the equipment will be damaged.

The statistical parameters evaluated were useful in describing the behaviour of a distribution, to judge the severity of the insulation degradation and the position of PD.

VII. CONCLUSION

In this paper, AC artificial pollution test for ceramic and non-ceramic insulators under various pollution severity levels with different ratio for soluble materials and partial discharge measurement were conducted. The following are the inference from the obtained results.

- ❖ Flashover voltage gets reduces with increase in pollution severity level.
- ❖ The insulator breakdown voltage performance varies with respect to various quantity of pollution severity.
- ❖ The breakdown voltage gets decreases with the increase in contamination on the surface of the insulator
- ❖ Comparing to ceramic insulators, non-ceramic insulators, the non-ceramic insulator provides better flashover performance in important polluted regions.
- ❖ Formation of PD plays a major role in determining the life time of the solid dielectrics was observed from the statistical analysis of PD pattern.
- ❖ The statistical parameters evaluated from PD waveforms provides the information about pollution severity of the ceramic and non-ceramic insulators.

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