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Seasonal Based Pollution Performance of 11kV and 33kV Silicon Composite Insulators

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Abstract**—**This paper presents the experimental results of 11 kV and 33 kV silicon composite insulators under artificial salt and urea polluted conditions. The tests were carried out under different seasons like summer, winter, and monsoon. The artificial pollution is prepared by properly dissolving the salt and urea in the water. The prepared salt and urea pollutions are sprayed on the insulators and dried up for sufficiently large time. The process is continued until a uniform layer is formed on the surface of insulator. For each insulator rating, four samples were tested. The maximum leakage current and breakdown voltage were measured. From experimental data, performance of test specimen is evaluated by comparing breakdown voltage and leakage current during different seasons when exposed to salt and urea polluted conditions. From these results the performance of the insulators can be predicted when they are installed in industrial, agricultural, and coastal areas. The experimental tests were carried out in the High Voltage laboratory using two stage cascade transformer having the rating of 1000 kVA, 500 kV.

Keywords**—**Silicon composite insulators, Urea pollution, Leakage current, Breakdown voltage, salt pollution, artificial pollution.

I. Introduction

IN recent times the demand of electric power is quite enlarged. In order to satisfy this demand, the efficiency of switchgear, transmission, and distribution facilities must be improved. The efficiency of any system is mainly based on the continuity of the service, avoiding faults. To maintain continuity, the performance and characteristics of insulators should be good. In power transmission and distribution systems, ceramic insulators are used from a long time. Now a days, composite insulators are widely used because of low cost, high mechanical strength, light weight, superior insulation performance, and good dielectric strength compared with conventional type of insulators [1]-[4]. One of the main problems that have been found is the effect of pollution on the insulators used in electrical lines. This pollution is the main cause for flashover in the insulator [5]. The insulator starts to fail when pollutants that exist in air deposits on the insulator surface and combines with humidity of fog and dew. This pollution degrades insulator and it severely affects its electrical characteristics. Insulators located near coastal areas and industrial areas are mostly polluted by salt and cement. In agricultural based countries like India usage of urea is customary, this shows there is effect on insulator performance which are mounted near agricultural areas. Flashover occurs as long as pollutants in the contaminant are soluble enough to form a conducting path, due to hydrophilic on the surface of insulator. Repeated occurrence of flashovers will result to puncture. Monitoring of insulators is to be done on estimated performance for different seasons. Some of the researchers have studied the different types of pollution flashover performance on electrical insulators. Jiang et al. [6] have carried out artificial pollution tests to study a.c flashover performances of various types of insulators. The result shows that pollution flashover voltage is affected by equivalent salt deposit density and non-soluble deposit density and that there is a distinct difference among the flashover voltages of various types of polluted insulators. The authors [7] have carried out experimental tests and showed that leakage current of porcelain insulator increases steadily with increase in relative humidity and pollution level due to its hydrophilic surface. Homma et al. [8] introduced dry-salt-layer pollution test method to verify the pollution flashover performance of ceramic and polymeric insulators and stated that the leakage current during the DST test was more than a thousand times higher than during the salt-fog tests.

Many research papers deal with the measurement of leakage current by salt fog test method. In [9], a field exposure test at a heavily polluted coastal site in northern Japan was conducted for a couple of years and examined salt deposit density caused by typhoons in summer and strong seasonal winds blowing from the sea. Aulia et al. [10] studied the insulator performance under different contaminations. Test results show that, salt moisture together with cement dust has significant impact on the suspension insulator performance rather than the moisture alone or the cement dust alone. In [11], a tunnel test was carried out in intermittent high speed aerosol, to study the accumulation of pollution on Rail Insulators and shown that pollution density increases with the aerosol speed at windward side and leeside but decreases at the cross wind side. Barsch et al. [12] presented different methods to evaluate the polymeric materials with simple geometry. The test procedures show that the ranking of materials concerning the tracking and erosion behavior can be improved by the erosion rate. Reference [13] presents measurement of leakage current waveforms on the surface of insulators and materials, the results shows that on completely hydrophobic surface the currents are very low and capacitive in character. However, after a loss of hydrophobic the contamination leads to more resistive and nonlinear. Ramiro et al. [14] give the conclusion that insulators with simple geometry under pollution and wet conditions, the performance of insulation is mainly a function of leakage current, while with complex geometry the pollution performance depends on both their shape and wetting degree.

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Wang et al. [15] studied an exposure test of insulator natural contamination in six typical areas shows that, the contamination degree in industrial and highroad areas is higher than coastland, agricultural area, residential area and mountainous area. While in residential area it is not serious; contamination degree of insulators in mountainous and agricultural areas is the lowest. Ye et al. [16] give the contamination accumulation performance along with withstand voltage characteristics of various types of insulators. Research conducted that, the contamination degree of the overall surface of outer-rid type insulators was thirty percent of the conventional fog type insulators; compared with the porcelain long rod insulator, contamination degree of polymer was higher. Indeed, researches had already evaluated the pollution performance on different types of insulators [17]-[19] and proposed valuable conclusions.

India is an agricultural country, especially East Godavari is meant for agriculture, the insulators connected in line nearer to agricultural areas are affected severely by urea pollution. When this urea pollution mixed with other pollutants, the severity of pollution will be higher. Therefore, the breakdown of the insulator takes place in a short period. On this basis, the aim of this work is to conduct experimental tests to observe the urea and salt pollution severity in different seasons on the polymeric insulators in agricultural and coastal conditions like East Godavari. Under these conditions, the maximum LC and BDV were measured in each season and seasonal based pollution performances of polymer insulators are compared.

The rest of the paper is organized as follows: Section II describes experimental procedure; Section III presents results and discussions; Section IV gives the conclusions.

II. Details of Experimentation

A. An Experimental Setup

The tests were carried out in the High Voltage laboratory of Jawaharlal Nehru Technological University. The experimental test facility includes Cascade transformer, HV bus bar, control panel. The major technical parameters of cascade transformer are as follows: rated capacity is 1000 kVA, voltage generated per unit is 250kV, maximum current of 200 mA. Schematic arrangement of experimental setup and specimen during test were shown in Figs. 1 and 2. The test specimens were connected in vertical position with one end to high voltage side and the other end to ground side. AC test voltage was applied to the insulator gradually during different polluted conditions and then maximum leakage current and breakdown voltages were measured by measuring meters connected in the system.

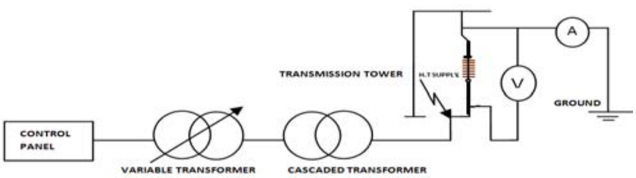

Fig. 1 Schematic diagram of experimental setup

Fig. 2 Experimental arrangement of Insulator in the test

B. Test Specimens

In this paper for each rating four virgin samples were tested. The dimensions for the test specimen were measured as per IEC 61109 [20]. In this work, urea pollution tests are conducted on 11kV silicone composite insulators coded as A11, B11, C11 and D11 whereas salt pollution tests are conducted on 33kV silicone composite insulators coded A33, B33, C33 and D33. Test specimen and dimensions are shown in Figs. 3 (a), (b) and Table I.

(a) (b)

Fig. 3 Test Specimens: (a) 11kV Insulator (b) 33kvIinsulator

TABLE I
SPECIMENS' DIMENSIONS

S.No	Particulars	Rating	
		11kV	33kV
1	Length of the insulator (mm)	280	510
2	Dry Arcing Distance (mm)	108	380
3	Creepage Distance(mm)	310	910
4	Specific Creepage Distance (mm/kV)	25	25
5	Shed Diameter (mm)	90	90
6	Number of Sheds	3	8
7	Core diameter (mm)	20.5	20.5
8	Shed Thickness(mm)	3	3
9	Shed Spacing (mm)	52	45

C. Test Procedure

1. Pre Conditioning

Before testing, all the insulator surfaces were cleaned by DM water to remove dust particles and grease [21]. After cleaning, the insulators then are dried naturally for several hours. Now for the healthy samples the maximum leakage current and breakdown voltage were measured. The quantitative spraying method was used to contaminate the surfaces of insulator. Salinity is the most commonly reported as parts per thousand (ppt) which is equivalent to adding 35 grams of salt per 1 liter of water. In this work a salt water containing salinity 88 ppt was sprayed on the surface of insulators under salt pollution test. For urea pollution test 100 grams of urea was dissolved in 1 liter of water and sprayed on the samples. These pollutions were sprayed on the samples for a number of days to form a thin layer, the wind from the land and with sunshine promote drying. This process was repeated to even distribution of droplets that will cover the entire insulator surface with evenly distributed pollution layer.

2. Pollution Distribution

In this investigation, it was observed that in early morning hours, the thin layers of salt and urea deposited on the surface of insulator gets dissolved in to water droplets and flows to the ground. As a result of this, the previously deposited pollution layers become very thin. It took place due to temperature variations in the atmosphere and the cold wind flows on the surface of insulator. Fig. 4 represents water droplets formed on the test specimen.

Fig. 4 Appearance of water droplets on the surface of insulator in the early morning hours

3. Flash Over Mechanism

Surface current flows when polluted insulator is wet. This causes dry band on the surface of insulator. Most of the voltage-drop will be across the dry band [21]. Spark-over (scintillation) across the dry band takes place. Surface current increases during scintillation. This causes formation of more dry bands on the surface of insulator. Much scintillation may occur simultaneously. If scintillation current crosses a rated value then flash-over will take place.

4. Voltage Application

A low voltage was applied on the test samples individually for both 11kVand 33kV insulators and the voltage was increased till the breakdown takes place. At the time of breakdown, the maximum leakage current and break down voltage were recorded from the meters used in the experiment. This process was repeated for every fifteen days to know the effect of pollution on the insulator under different seasons; winter, summer and monsoon.

III. Experimental Results and Discussions

The experimental tests on the virgin samples and polluted samples of silicon composite insulators have been carried out in the laboratory. The maximum leakage current and break down voltage were measured in the following cases.

a) Healthy specimens in clean position (both 11kV and 33kV insulators)
b) Four specimens of 11kV insulators under urea pollution for every 15 days.
c) Four specimens of 33kV insulators under salt pollution for every 15 days.

A. Measurement of LC and BDV for Healthy Samples

From the control panel, the virgin samples were energized. Then the maximum leakage current in μA and breakdown voltage in kV were recorded by meters connected in the system. The correction factor is applied as per IEC 60060-1 and 2 [22], [23] and the results are given in Table II.

TABLE II
LC & BDV Value for 11kV Healthy Insulators

Applied voltage	A11 LC	B11 LC	C11 LC	D11 LC	Average
0	0	0	0	0	0
10	9	10	8	5	8
20	16	16	17	18	16.7
30	23	22	23	26	23.5
40	31	31	31	35	32
50	36	34	35	40	36.25
60	46	45	45	50	46.5
70	60	61	63	64	62
BDV	76	76	75	79	76

It is observed from Tables II and III that the leakage current increases with increase of voltage for both 11kv and 33kV insulators. In healthy conditions, for 11kV insulator the flashover occurs at 76 kV with a leakage current of 62μA which is almost double the rated withstand voltage as per IS 731. For 33kV insulator also it is almost double of rated withstand voltage.

TABLE III
LC&BDV Value for 33kV Healthy Insulators

Applied voltage	A33 LC	B33 LC	C33 LC	D33 LC	Average
0	0	0	0	0	0
20	5	11	5	5	6.5
40	10	20	20	15	16.25
60	28	35	28	29	30
80	45	55	46	46	48
100	66	70	67	66	67.25
120	100	95	97	100	98
140	151	130	146	150	119.25
BDV	157	162	156	154	157.25

B. Measurement of LC and BDV for 11kV Insulators under Urea Polluted Conditions

11kV specimens were exhibited to urea pollution. After spraying urea pollution for several days, a thin layer is formed on the insulator surface. The photographs of polluted specimens are given in Fig. 5.

Fig. 5 11kV Specimen under urea pollution

TABLE IV
LC&BDV VALUE FOR 11KV INSULATORS UNDER UREA POLLUTION

Days	A11		B11		C11		D11		Average	
	BDV	LC	BDV	LC	BDV	LC	BDV	LC	BDV	LC
15	74	57	75	59	75	56	80	40		
30	64	82	66	87	64	79	69	84		
45	62	87	61	95	64	107	60	130	61	108
60	55	105	53	118	54	127	53	140		
75	49	173	47	182	49	157	52	191		
90	43	270	42	295	49	310	53	350		
105	45	230	38	310	41	245	49	378		
120	35	340	40	383	41	398	37	489	40	476
135	37	475	38	463	36	492	39	573		
150	36	819	38	922	38	906	37	894		
165	38	361	37	442	36	410	38	668		
180	45	619	33	769	45	361	38	628		
195	38	789	37	835	38	923	37	939		
210	43	872	42	832	44	934	46	823	40	825
225	39	787	40	901	37	920	41	936		
240	35	875	36	898	39	930	40	940		

In Table IV, the days between 15 and 75 are in winter season, the days between 90 and 165 are in summer, and from the days between 180 and 240 are in monsoon season. From the data, it is observed that the leakage current increases with number of days. In healthy condition before urea pollution the maximum leakage current of four samples was 62μA. During pollution state it is 108 μA (winter), 476 μA (summer) and 825(monsoon). This may be due to increase of contamination on the surface of insulator. However, the breakdown voltage is same in summer and monsoon seasons. Fig. 6 represents the relationship between the leakage current and seasons.

Fig. 7 shows the relation between breakdown voltages among different seasons. And from this, it is observed that the breakdown voltage was gradually decreasing with the number of days in urea pollution. In healthy condition, the BDV measured was 76kV and after applying pollution as the days increased, it is reduced to 61kV in winter season. And it remains almost constant in summer and monsoon season (40 kV). This shows that the effect of urea contamination is less in winter season when compared to summer and monsoon.

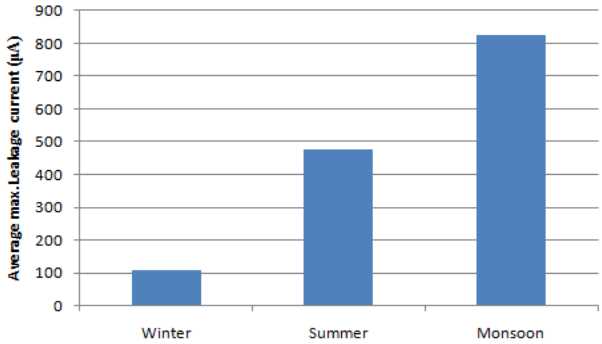

Fig. 6 Leakage current at various seasons for 11 kV insulators

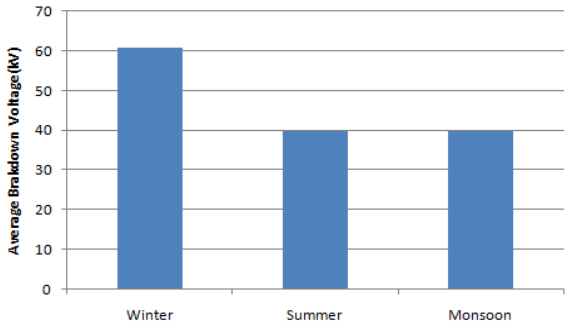

Fig. 7 Average breakdown voltage at various seasons for 11 kV insulators

C. Measurement of LC and BDV for 33kV Insulators under Urea Salt Conditions

33kV specimens were exhibited to salt pollution. After spraying salt pollution for several days, a thin layer is formed on the insulator surface. Polluted specimens are shown in Fig. 8.

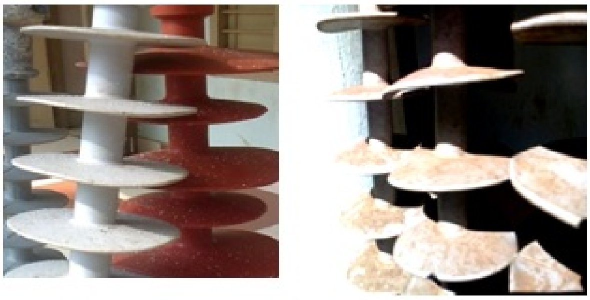

Fig. 8 33 kV Specimens under salt pollution

The leakage current (μA) and breakdown voltage (kV) are measured for every fifteen days during summer, winter and monsoon seasons are recorded and the results are tabulated in Table V. It shows a relation between the maximum leakage current and seasons. It is obtained and shown in Fig. 9. And a relation between breakdown voltage and seasons is shown in Fig 10.

From the results it is observed that, the value of maximum leakage current under healthy condition is 119.25μA, whereas under polluted condition it is 181μA (winter), 202μA (summer) and 244μA (winter). Hence, leakage current is gradually increasing with the increase of voltage. From this data we can say that the leakage current is almost doubled after completion of 150 days in salt pollution.

TABLE V
LC&BDV VALUE FOR 11KV INSULATORS UNDER UREA POLLUTION

Days	A33		B33		C33		D33		Average	
	BDV	LC	BDV	LC	BDV	LC	BDV	LC	BDV	LC
15	148	151	157	140	145	160	150	170	147	181
30	140	185	140	190	142	190	140	185		
45	143	192	141	197	145	193	192	190		
60	147	205	149	210	145	200	146	201		
75	138	165	152	171	137	163	148	169		
90	151	161	148	162	155	170	152	175	153	202
105	145	195	167	232	162	195	155	212		
120	152	179	165	141	156	137	146	183		
135	141	239	157	207	154	241	156	285		
150	143	205	150	212	147	246	139	253		
165	145	183	167	212	152	194	155	232		
180	141	209	149	214	146	206	135	239	149	244
195	143	212	151	221	148	219	139	230		
210	140	290	158	255	152	265	140	278		
225	149	216	145	285	156	260	160	268		
240	151	242	157	255	165	252	156	265		

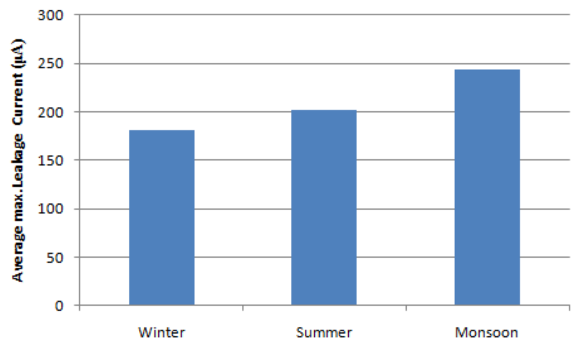

Fig. 9 Leakage current at various seasons for 33 kV insulators

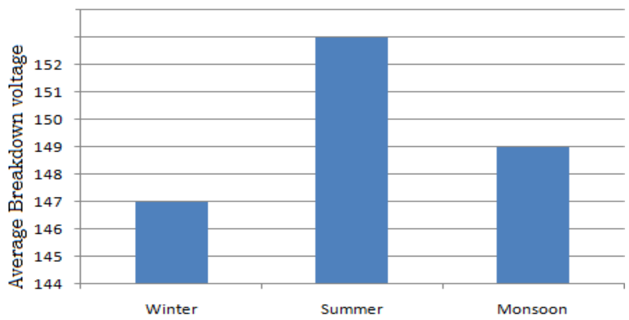

Fig. 10 Breakdown voltage at various seasons for 33 kV insulators

From Fig. 10 it is observed that, there is large change in breakdown voltage among seasons. In healthy condition, the average breakdown voltage of four samples is 157.25 kV but in winter season, it is reduced to 147 kV, in summer season, it raised to 153 kV and in monsoon season, it once again reduced to 149 kV. This shows that the breakdown strength will be higher in summer season, compared to winter and monsoon seasons. And the effect of salt pollution is less in summer season compared to winter and monsoon.

IV. CONCLUSION

The experimental test results show that the breakdown voltage and leakage currents are affected by the urea and salt contamination deposits. And under urea and salt contamination Leakage current was increased gradually when compared to healthy samples. It is also noticed that the Leakage current was increased as the number of days increased. Under salt contamination, the leakage current values are increasing from winter to monsoon seasons. However, the breakdown voltage is high in summer compared to winter and monsoon seasons. For insulators under urea contamination, the leakage current was increasing from winter to monsoon. In addition, it is observed that the breakdown voltage was the same in summer and monsoon but higher in winter season.

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