Evaluation of Electrical Properties of 11kv Pin and Suspension Insulator

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Abstract - ***High voltage insulators form an essential part of the high voltage electric power transmission systems. Any failure in the satisfactory performance of high voltage insulators will result in considerable loss of capital, as there are numerous industries that depend upon the availability of an uninterrupted power supply. The main aim of this paper concerns the effect of pollution of 11 kV porcelain pin and suspension insulators under healthy and different scenarios. The different scenario conditions are wet condition, sea salt contamination and urea contamination. These scenarios are commonly seen in the field with in-service insulators located near polluting sources like coastal areas and agricultural fields. In the first step, the porcelain pin and suspension insulators are tested under healthy condition, in this the leakage currents of pin and disc insulators are observed with the applied voltage until the flashover occurs. In such a case, the insulator can withstand the voltage stresses much better than under uniform contamination conditions. In the second step the insulator samples are tested under wet condition. In the next cases the insulators are tested under sea salt pollution condition and urea pollution condition. Laboratory tests revealed that the minimum flashover voltage can be attributed to the maximum shortening of the weakly polluted creepage distance of the insulator before its full flashover. By observing the results from the above tests we can predict the schedule maintenance/replacement of the porcelain insulators under different environmental conditions.***

Key Words: *Insulators, Contamination layer, Leakage Current, Flashover Voltage.*

1. INTRODUCTION

There is no piece of electrical equipment that does not depend on electrical insulation in one form or other to maintain the flow of electric current in desired paths or circuits [1]. 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. 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. As the surface becomes moist because of rain, fog or dew, the pollution layer becomes conductive because of the presence of ionic solids [3]. Pollution flashover, observed on insulators used in high voltage transmission, is one of the most important problems for power transmission [4]. On the other hand, the flashover of polluted insulators can cause transmission line outage of long duration and over a large area. The flashover of polluted insulators was the motivation for the installation of a test station in order to perform laboratory tests on artificially polluted insulators [5]. The insulator begins to fail when the pollutants that exist in the air settle in the surface of the insulator and combine with the humidity of the fog, rain, or dew. The mixture of pollutants, plus the humidity form a layer that become conductor and allow passing currents that will facilitate the conditions of short circuit [6]. This is due to a decrease of the resistance of the insulator surface. Unless there is a natural cleaning or an adequate maintenance, the electrical activity will be affected by a possible flashover in the insulator [12].

The probability of appearance of fault situation depends on the type of material of the insulator, the weather of the zone, the type and level of pollution, as well as the working voltage of the insulator [9]. Other problems related to pollution are: corrosion and erosion of the insulator. An increase of pollution produces the increase in the leakage current and then the flashover of the insulator is more probable [7].

In order to compare the performance characteristics of the pin and disc insulators, the tests were carried out under healthy, wet, sea salt and urea pollution conditions. The leakage current characteristics and flashover voltages of the porcelain insulators under these conditions are observed in this paper.

2. EXPERIMENTAL SET UP AND TEST PROCEDURE

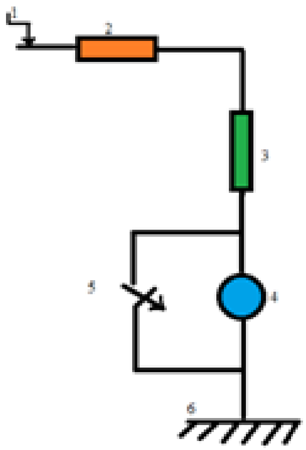
The tested insulators have an insulating part manufactured of porcelain (pin and disc). The tests are conducted on 11kV pin and suspension (disc) insulators. The insulators were tested in High Voltage Engineering Laboratory at our college University College of

Engineering Kakinada, JNTUK Kakinada. The measurement of the Leakage current set up consisted of cascading transformer, HV bus bar, insulators to be tested, control panel with required metering. The specifications of the cascaded transformer are:

Number of stages : 2
KVA rating : 100 KVA
Voltage generated per unit : 250 kV
Total Voltage generated : 500 kV

2.1 Circuit Diagram

The insulators are tested in the High Voltage Laboratory and in the testing process the Leakage current corresponding to the applied voltage are noted down until the breakdown of the insulators occurs. The circuit diagram for the leakage current measurement is as shown in fig.1



1. HV terminal
2. High resistance
3. Test specimen
4. Ammeter
5. Switch
6. Ground

Fig-1: Circuit Diagram for Testing in the HV laboratory showing different equipment used in the testing of Insulator.

2.2 Test procedure

The procedure for measuring the leakage current and breakdown voltage in the HV Laboratory is as follows:

- The test specimen (11 kV pin insulator) is connected its one end to high voltage conductor and other end to the ground as shown in fig.1.
- Source voltage of power frequency is applied across the bus insulator. By increasing the source voltage at uniform rate gradually in steps of 5 or 10 kV until breakdown voltage is reached.
- The leakage current corresponding to the applied voltage is measured using the ammeter provided in the control panel, by opening the ammeter switch and the switch is closed after measuring the Leakage current.
- The above procedure is repeated for different values of voltage and corresponding leakage currents are noted.
- Increase the voltage till breakdown occurs.
- Observe the breakdown voltage accurately as it suddenly goes off to zero after breakdown.
- Tabulate the reading of voltage and leakage current.
- Repeat the same process for suspension sample insulator.
- The main precaution is that the grounding must be properly given and also the readings should be noted down with care.

2.3 Experimental Setup of Insulators

After washing the insulator samples with tap water, kept dry for 24 hours. Then they are placed in the experimental setup with a ground clearance of approximately one metre. One end of the insulator was connected to high voltage side and the other to ground as shown in fig 2. The occurrence of flashover of 11 kV pin and suspension insulator is as shown in fig 3. They are energised to measure the leakage current and breakdown voltage.

Fig-2(a) Fig-2(b)

Fig.-2: Experimental setup for (a)Pin Insulator (b)Suspension Insulator

Fig-3(a) Fig-3(b)

Fig-3: Flashover of (a)Pin insulator (b) Suspension Insulator

3. TESTS AND RESULTS

3.1. Testing of insulator without pollution

Initially the insulator is tested without any application of pollution to study the variation of leakage current with the breakdown voltage. This is the sample without any contamination on their surface levels. The values of the Leakage current and breakdown voltage i.e., the test results of healthy samples are as follows:

Table-1: Variation of leakage current with applied voltage for 11kv pin and suspension insulator without pollution

S. No	Applied Voltage (kV)	Leakage Current for Pin insulator (μA)	Leakage Current for Suspension insulator (μA)
1.	5	8.1	13.6
2.	10	16.1	28.9
3.	15	24.6	47.9
4.	20	32.1	60.8
5.	25	39.9	82.4
6.	30	49	96.4
7.	40	72.8	124.7
8.	45	82.5	136.0
9.	50	92.4	147.3
10.	60	117.8	Flashover(59kV)
11.	70	146.7	
12.	75	Flashover	

From Table-1 it is observed that flashover occurs at a applied voltage of 75 kV for pin insulator and 59 kV for suspension insulator. A plot is drawn between leakage current and applied voltage and is shown in fig-4.

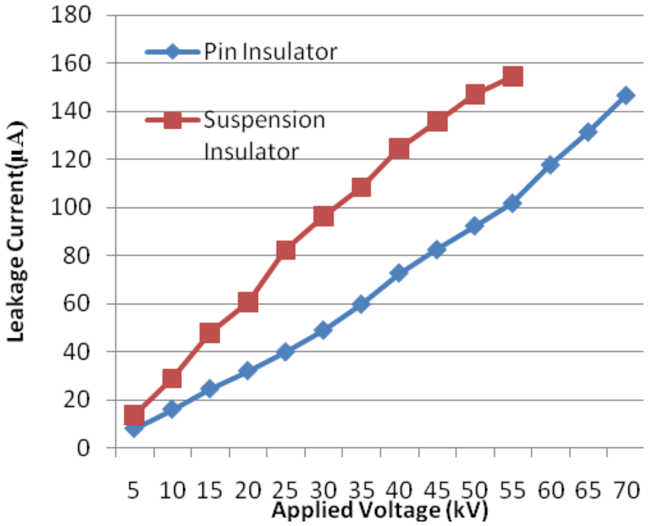


Fig-4: Variation of leakage current with applied voltage for 11 kV pin and suspension insulators without pollution

3.2 Testing under wet condition

The insulators are immersed in water for two to three minutes at a temperature of 28°C and then taken out to perform the leakage current measurement test and results are shown in Table-2

Table-2: Variation of leakage current with applied voltage on 11kv pin and suspension insulator in wet condition

S. No	Applied Voltage (kV)	Leakage Current for Pin insulator (μA)	Leakage Current for Suspension insulator (μA)
1.	5	10.9	20.7
2.	10	21.4	41.3
3.	15	35.7	57.2
4.	20	50.1	78.4
5.	25	67.2	99.2
6.	30	82.6	120.9
7.	35	95.3	148.1
8.	40	112.8	175.8
9.	45	129.5	200.4
10.	50	154.5	Flashover
11.	55	176.2	
12.	57	Flashover	

The leakage current values are also very high even for a lower voltage compared to insulator without pollution. A plot is drawn between leakage current and applied voltage and is shown in fig-5. From the figure 5, it is observed that the leakage current increases and the flashover occurred at 57 kV for pin insulator and 50kV for suspension insulator.

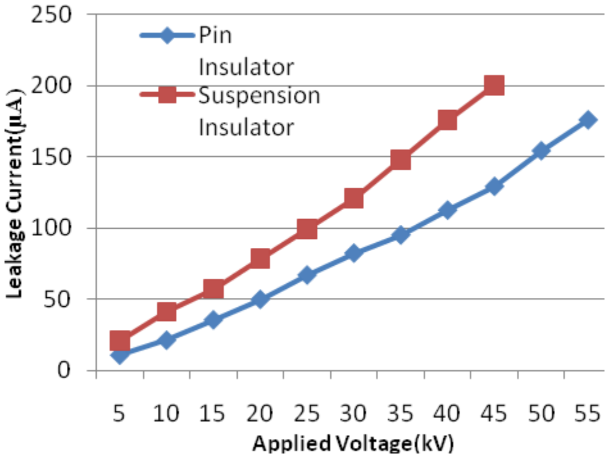


Fig -5: Variation of leakage current with applied voltage for 11 kV pin and suspension insulators under wet condition

3.3 Testing of insulator with sea salt water pollutant

Sea water from the coastal regions is taken and crystal salt is mixed with in proportions of 200gms of salt in 1 litre of sea water. Then the mixture is sprayed on the insulators three times a day for 7 days continuously. The insulator is kept dried until pollution layer formed on the surface of the insulators. Then the samples were tested for leakage current measurement. The leakage current of this insulator with sea water pollution is measured. The leakage current and applied voltage is given in Table-3.

Table-3: Variation of leakage current with applied voltage on 11kv pin and suspension insulator under sea salt pollution.

S. No	Applied Voltage (kV)	Leakage Current for Pin insulator (µA)	Leakage Current for Suspension insulator (µA)
1.	5	13.1	26.6
2.	10	25.4	44.6
3.	15	36.9	61.6
4.	20	49.5	82.9
5.	25	67.9	103.2
6.	30	78.3	125.7
7.	35	96.1	152.3
8.	40	117.3	181.6
9.	50	147.4	Flashover(47kV)
10.	55	Flashover	

From the table it is observed that the flashover is occurred at 55 kV for pin insulator and at 47kV for suspension insulator. The leakage current values are also very high even for a lower voltage compared to insulator without pollution. A plot is drawn between leakage current and applied voltage and is shown in fig 6.

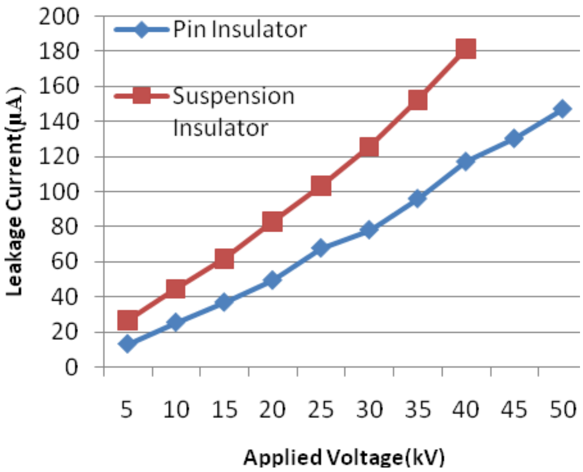


Fig -6: Variation of leakage current with applied voltage for 11 kV pin and suspension insulators under sea salt pollution condition.

3.4 Testing of insulator with urea pollution

Sea water from the coastal regions is taken and urea is mixed with in proportions of 200gms of salt in 1 litre of sea water. Then the mixture is sprayed on the insulator three times a day for 7 days continuously. The insulator is kept dried until pollution layer formed on the surface of the insulator. The leakage current of this insulator with urea pollution is measured. The leakage current and applied voltage is given in Table-4.

Table-4: Variation of leakage current with applied voltage on 11kv pin and suspension insulator under sea salt pollution.

S. No	Applied Voltage (kV)	Leakage Current for Pin insulator (µA)	Leakage Current for Suspension insulator (µA)
1.	5	65	188
2.	10	86	209
3.	15	185	227
4.	20	231	303
5.	25	322	384
6.	30	381	456
7.	35	400	Flashover
8.	40	Flashover	

From the table it is observed that the flashover is occurred at 40 kV for pin insulator and at 36 kV for suspension insulator under urea pollution. The leakage current values are also very high even for a lower voltage compared to insulator without pollution, wet condition and sea salt pollution. A plot is drawn between leakage current and applied voltage and is shown in fig-7.

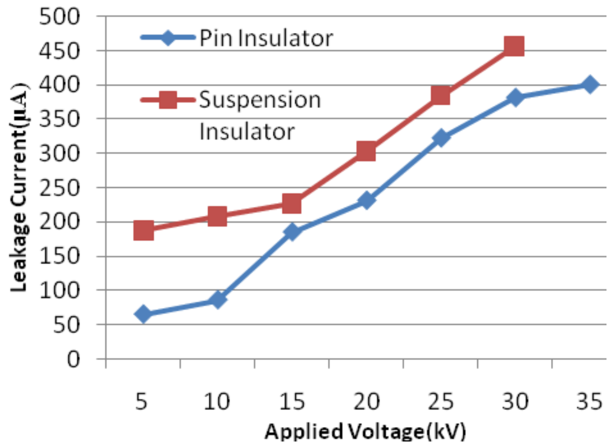


Fig-7: Variation of leakage current with applied voltage for 11 kV pin and suspension insulators under urea pollution condition

3.5 Analysis of the test results

3.5.1 Variation of leakage currents for 11 kV Pin and Suspension insulators under different conditions

The break down voltage of an insulator is the minimum voltage that causes a portion of an insulator to become electrically conductive. Break down voltage is the characteristic of an insulator that defines the maximum voltage difference that can be applied across the material before the bushing fails. In solid insulating materials, this usually creates a weakened path within the material by creating permanent molecular or physical changes by the sudden current. A plot is drawn to compare the breakdown voltages of the pin and suspension samples under pollution conditions.

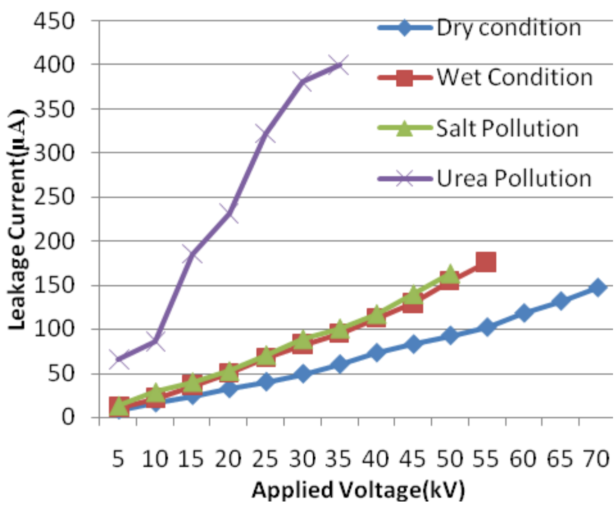


Fig-8: Variation of leakage current of 11kV pin insulator under healthy and different pollution conditions

A comparison is made between the breakdown voltages of the insulator samples under different conditions. A graph is shown below for variation of breakdown voltages for without pollution and with polluted samples in fig-8. for pin insulator. In this figure variation of breakdown voltages for both dry and wet conditions are also shown and fig 5.9 shows the variation of breakdown voltages for all polluted conditions of a suspension insulator.

From the fig.8, we can observe that the leakage current characteristics of pin insulator under wet and salt pollution conditions are almost similar and under urea pollution the leakage currents are too high when compared with remaining pollution conditions. From this, we can say that the urea coating has more impact on leakage current than the cement coating. The flashover voltage is less for Urea coated insulator than the other polluted insulators.

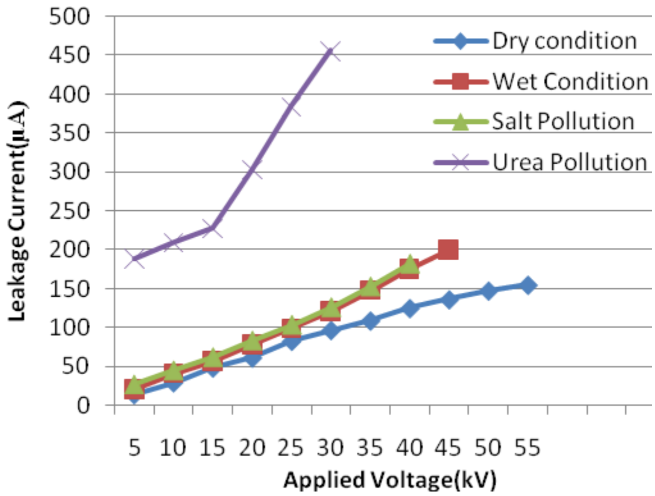


Fig-9: Variation of leakage current of 11kV suspension insulator under healthy and different pollution conditions.

From the fig-9, we can observe that the leakage current characteristics of suspension insulator under wet and salt pollution conditions are almost similar and under urea pollution the leakage currents are too high when compared with remaining pollution conditions. From this, we can say that the urea coating has more impact on leakage current than the cement coating. The flashover voltage is less for Urea coated insulator than the other polluted insulators.

- The maximum value of leakage current for healthy sample dry condition was 146.7µA for pin insulator and 154.8 µA for suspension insulator.
- The maximum value of leakage current for wet sample 176.2 µA for pin insulator and

200.4 µA for suspension insulator. The leakage current increased in wet condition.

- The maximum value of leakage current for salt contaminated insulator 162.8µA for pin insulator and 181.6 µA for suspension insulator.

- The maximum value of leakage current for urea contaminated insulator 400µA for pin insulator and 456 µA for suspension insulator.

3.5.2 Variation of Breakdown Voltages of 11kV pin and suspension Insulators under different conditions

From the experimental results, the flashover voltages of 11 kV pin and suspension insulators are compared under healthy and different pollution conditions as shown in the fig-10.

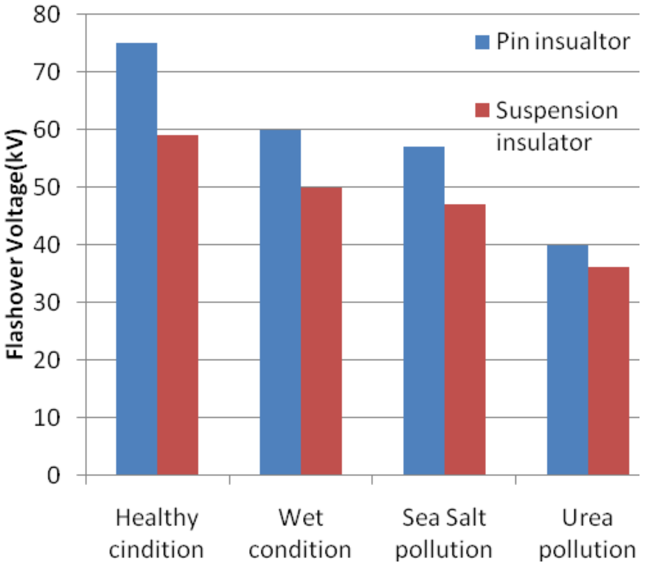


Fig-10: Graphical representation of flashover voltages of 11kV pin and suspension insulators under healthy and different pollution conditions.

Table-5 gives the Comparison of flashover voltages of 11kV Pin and Suspension insulators under different pollution conditions.

Table-5: Variation of flashover voltages of 11 kv pin and suspension insulator under healthy and different contamination conditions

	Flashover Voltages			
Type of Insulator	Healthy Condition	Wet Condition	Sea-Salt Condition	Urea Condition
Pin Insulator	75	60	57	40
Suspension Insulator	59	50	47	36

1. There is a 21% decrease in flashover voltage of suspension insulator when compared to pin insulator under healthy condition.

2. There is a 16.67% decrease in flashover voltage of suspension insulator when compared to pin insulator under wet condition.

3. There is a 17.54% decrease in flashover voltage of suspension insulator when compared to pin insulator under salt pollution condition.

4. There is a 10% decrease in flashover voltage of suspension insulator when compared to pin insulator under Urea pollution condition.

5. CONCLUSION

The leakage current measurement and flashover studies are done on 11 kV pin and suspension overhead insulators without and with pollution coatings. The contaminations of pollutions are

(a) Wet Condition
(b) Sea Salt pollution
(c) Urea pollution.

The pollution coatings done are similar to pollutions that exists on overhead insulator in industrial areas.

The leakage current values with pollution coating is higher than without coating in case of all insulators. Similarly flashover voltage is less for polluted insulator than unpolluted insulator.

The effect of pollution on leakage and flashover voltage also studied. It is observed that the leakage current in urea coated insulator is higher than that of the other coatings. Similarly, the flashover voltage is less for Urea coated insulator than the other polluted coated insulators. This is because of the fact urea have high conductivity value than the other conditions, i.e., wet condition and salt contamination condition.

The salt coating has high impact on leakage current than the wet coating. The flashover voltage is less for salt coated insulator than the wet insulator.

From the above facts it is observed that design of insulator is based on the type environment present around the insulator. From these results observed we can predict the schedule of the maintenance/replacement of the insulator under different pollution conditions.

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