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A STUDY ON PERFORMANCE OF 11 kV OVERHEAD POLYMERIC AND PORCELAIN INSULATORS UNDER CONTAMINATED CONDITIONS

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ABSTRACT

In recent decades, overhead insulators play a major role in electrical distribution system for transmitting power through transmission line over long distances owing to its high insulation strength. Nonetheless under contaminated conditions, insulation strength decreases due to rise in pollution levels of environment. Hence, it is required to check the ability of the insulator by artificial test approaches in polluted situations. This paper deals with the performance on high voltage 11 kV rated overhead insulators of polymer and porcelain type under contaminated conditions based on IEC 60805. Insulators are contaminated with suitable proportions of NaCl and applied uniformly on the surface. In this study, tests are carried out on insulators under power frequency to check for the withstand voltage test, lightning and switching impulse withstand voltage tests with negative impulses. It is clear from the experiments done on the insulators that flashover occurs at lesser voltages when the pollution level is high which in turn increases conductivity. The relation between leakage current and applied voltage, under different fixed levels of pollution is observed.

Keywords: ceramic insulator, polymer insulator, flashover, contamination, leakage current.

1. INTRODUCTION

Insulators play a major role in electrical transmission systems. Transmission voltage level is greater than before owing to the increase in electrical power demand. For uninterrupted operation of the power system, the withstand capability of the insulation along with the design of the insulator play an important role. Non polymeric insulators are used in bulk power transmission over long distances. When these insulators are installed in polluted areas, foreign particles get accumulated on the surface of insulator which increases conductivity during wet environment, leads to flow of non-uniform leakage current. Pollution is the cause of degradation of dielectric performance over a period of time in service. Voltage redistribution along the insulator surface leads to scintillations followed by flashover at less than the normal rated voltage. Increasing the creepage distance in the insulator design prevents the outage of the power system. However for continuous operation of the power system it is important to consider the withstand insulation levels of insulator and also the withstand pollution level of the insulator. Anti-pollution methods are implemented to avoid the flashover using aerodynamic profile such that by natural rain the foreign particles are splashed away and by periodic maintenance pollutants are detached but it is prone to irregular weather conditions and time consuming. Polymeric insulators are used nowadays to overcome the drawbacks owing to its good hydrophobicity [1].

Many research papers deal with the measurement to understand the surface degradation and aging of polymer insulators under contaminated conditions. Author R.S. Gorur proposed that surface resistance of insulators can provide valuable information about the degradation of insulator under contaminated conditions [2]. A. Cavallini proposed that partial discharge test is used to identify the severity of contamination of outdoor insulators [3]. Author S. Chandrasekar has shown that statistical parameters of the PD patterns, time and frequency domain characteristics of PD pulses identify severity of pollution level on outdoor polymeric insulators [4].

In this work, a 11 kV ceramic and polymer insulators are subjected to various pollution levels and its performances are studied. Power frequency withstand voltage test, lightning and switching impulse withstand voltage tests with negative impulses are carried out on insulators.

2. EXPERIMENTAL PROCEDURE

A 11 kV polymer and porcelain insulator is used as specimen for the experiment under different levels of contamination. Test object before pollution test is prepared such that the surface is not contaminated and other parts are coated with water repellent material. After drying, insulator is subjected to pollution test by coating with different proportion of pollution. Voltage is increased and maintained for several minutes upto the withstand capability according to IEC standard. If no flashover takes place then the insulator is assumed to be in good condition. To determine the maximum degree of pollution upto which the insulator is capable of withstanding or to determine the voltage that can be handled for a particular pollution level, pollution test is performed.

Pollution test is carried out artificially in the high voltage laboratory for outdoor insulator with contamination for detecting the severity level since natural pollution test is time dependent even though it provides better result. Different types of pollutants are used for contamination over the insulator. Pollutants levels are classified into very low, low, medium, high, very high according to the salinity contained in the pollutant. Sodium chloride with different proportions in addition with Kaolin is used as contaminant in this study. As per IEC 60805 [5, 6] solid layer method is used as test method. Insulator is erected as in the real case using a stand and is rinsed with water before testing to remove the

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contaminants available on the surface of insulator. Rated voltage for the test is 11 kV, 50 Hz, single phase AC supply [7]. Block diagram for the power frequency test and impulse test are shown in figure 1 and Figure-2.

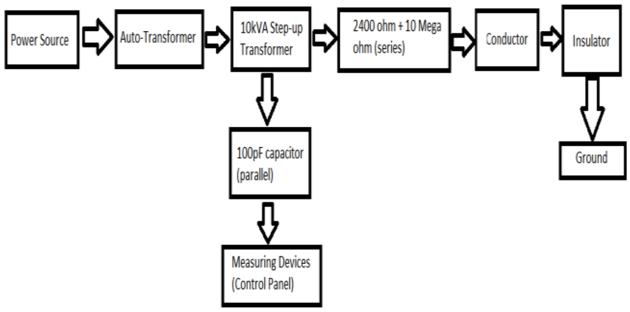

Figure-1. Power frequency voltage withstand test block diagram.

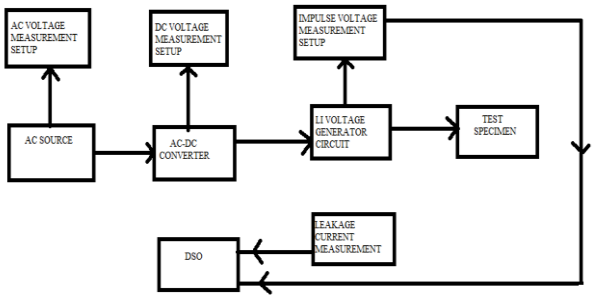

Figure-2. Block diagram for impulse test.

For power frequency voltage withstand test, insulator is subjected to a specific voltage. Voltage is initially raised to 75 percent of the rated voltage quickly and raised slowly in the rate of 5 percent in the interval of three minutes until flashover takes place. Again the insulator is subjected to 90 percent of the flashover voltage quickly and raised slowly until flashover takes place. This is repeated upto to a voltage that can be withstood for a particular pollution level and voltage is noted. Circuit diagram for the lightning impulse voltage and switching impulse voltage test are shown in the Figures 3 and 4. The standard for lightning impulse voltage wave shape is an aperiodic voltage impulse that does not cross the zero line which reaches its peak in 1.2μsec and then decreases slowly (in 50μsec) to half the peak value. The rapid increase and slow decay can be generated by two discharging circuits with two energy storages.

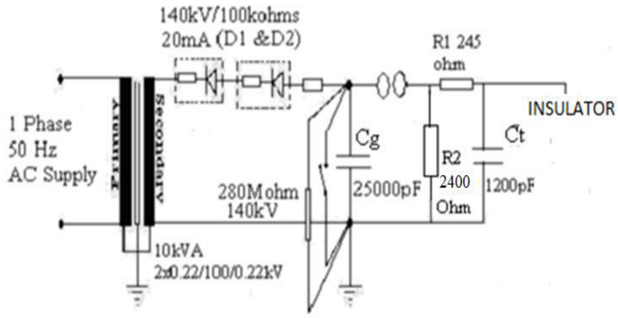

Figure-3. Lightning impulse voltage withstand test circuit diagram.

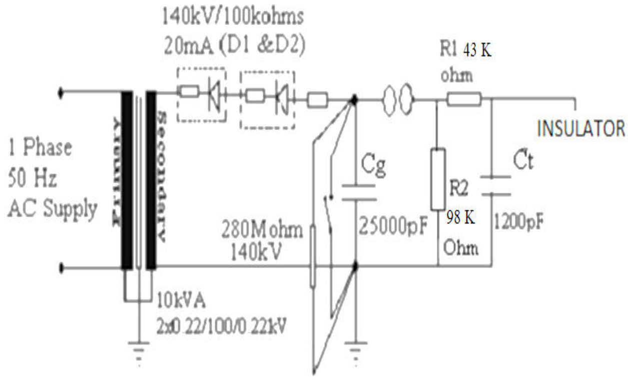

Figure-4. Circuit diagram for switching impulse voltage withstand test.

RESULTS

Power frequency withstand voltage test is performed on both polymer and porcelain insulators with different levels of pollution. Voltage is increased and its corresponding leakage current is noted down. It is clear from Figure-5 that leakage current Vs voltage curve is not linear. This is due to the presence of pollution layer over the surface of the insulator. As the voltage is increased beyond 44.7 kV flashover occurs with high leakage current and the circuit is tripped for the first proportion of the solution. It is evident that the current suddenly rises to a very high value when flashover occurs and this may pose a serious threat to power system.

The power frequency voltage withstand test shows that at higher pollution levels the leakage current Vs voltage curve is extremely non-linear and heavy scintillations occur . Scintillations started occurring at lesser voltage when compared to first normal solution. If the voltage is increased beyond a certain level then the flashover of the insulator occur. The circuit is tripped due to the heavy current drawn by the insulator.

Figure-5 shows the variation of leakage current Vs voltage for all the three levels of pollution [8, 9, 10]. It can clearly be seen from the graph that as the pollution increases audio corona inception, scintillation inception and flashover occurs at lesser voltage. The graph shows that for the same voltage, the leakage current is more for the more polluted insulator. The circuit gets tripped due to

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flashover in all the three cases but the current drawn by the more polluted insulator is more.

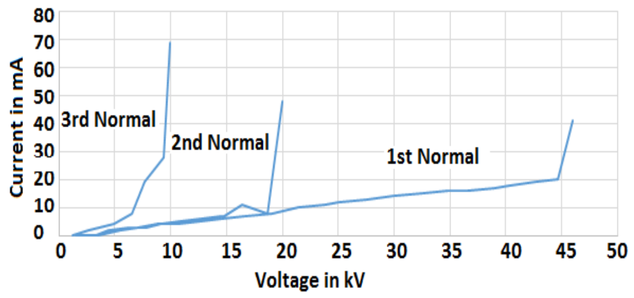

Figure-5. Voltage vs leakage current for 3 levels of pollution.

Figure-6 is the standard lightning impulse which is represented as 1.2/50 which represents that the lightning impulse reaches its peak value in 1.2 µs and half of its peak value in 50 µs. The lightning impulse decays to zero in short time. Figure-7 shows the chopping of voltage due to flashover.

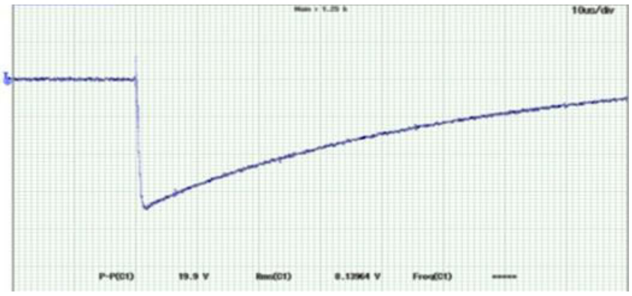

Figure-6. Standard lightning impulse.

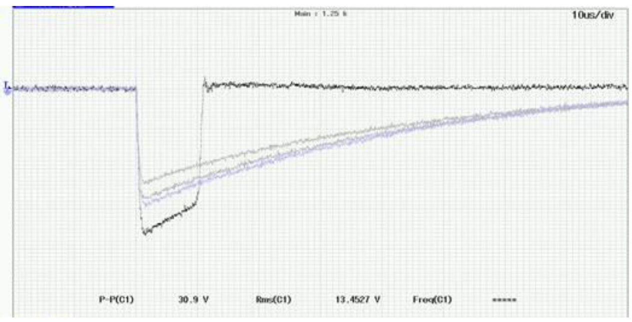

Figure-7. Chopping of voltage due to flashover.

Figure-8 shows the variation of voltage with conductivity levels [11]. It can be clearly seen that the withstand voltage of the insulator gets decreased as the conductivity of the pollution layer is increased.

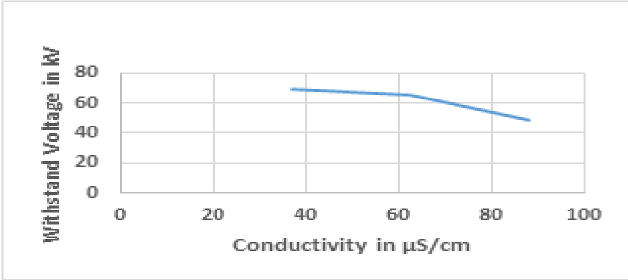

Figure-8. Withstand voltage vs conductivity.

Figure-9 is the standard switching impulse which is represented as 2500/250 which represents that the lightning impulse reaches its peak value in 2500 µs and half of its peak value in 250 µs.

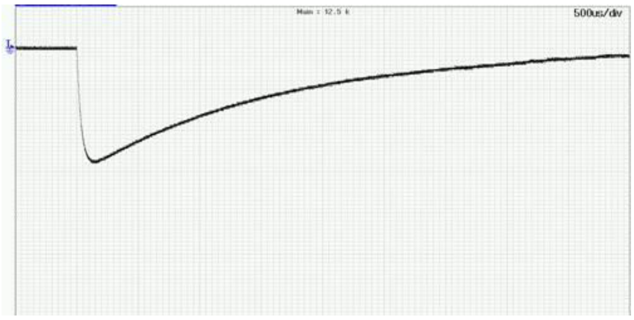

Figure-9. Standard switching impulse.

Figure-10 shows how the switching impulse voltage varies with time. More the pollution, more are the distortions and lesser is the withstand voltage.

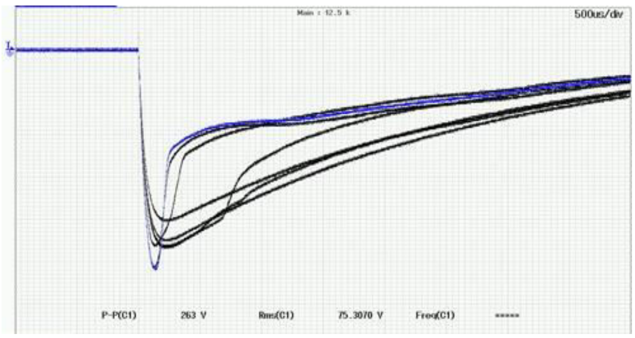

Figure-10. Chopping of voltage due to flashover.

Figure-11 shows the variation of withstand voltage of polymer and porcelain insulators with the conductivity of the pollution layer. It is seen from the graph that as the conductivity of the pollution layer gets increased, the withstand voltage of the insulator is decreased. The graph also shows that the pollution performance of the polymer insulator is better when compared to the porcelain insulator.

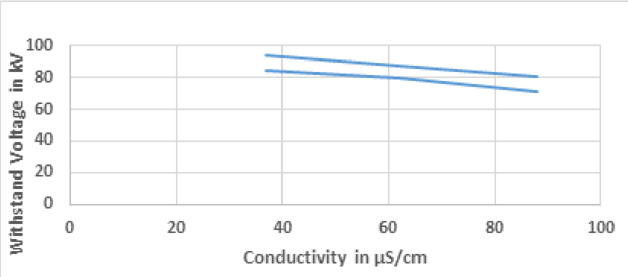

Figure-11. Withstand Voltage VS conductivity.

CONCLUSIONS

In this work pollution performance tests are performed on polymer and porcelain insulators. When the pollution level of the conducting layer is increased leakage current gets promoted. The incremental leakage current is very dangerous for the stability of the power system as it assists in flashover of the insulator.

When the light rain occurs then the contamination collected on the sheds of the insulators gets washed away after some time but still scintillations may occur due to the moisture trapped inside the inner surfaces of the insulator. This though may not seem big problem but can actually pose a very serious threat for power systems especially for the equipments connected to the insulators.

Porcelain insulator is hydrophilic in nature and hence water is retained on the surface of the insulator for longer time whereas in case of polymer insulator water is not retained on the surface of the insulator as they are hydrophobic in nature. Performance of polymer insulator is better when compared to the porcelain insulator. But, the pollution layer if present in case of porcelain insulator gets washed down along with water whereas in polymer insulator rain water do not washes away the pollution layer easily due to which chances of flashover may increase.

When polymer and porcelain insulators are subjected to the lighting and switching impulses, flashover occurs at lesser voltage in case of porcelain insulators. The impulse gets chopped due to flashover i.e. the voltage gets collapsed and reaches to zero value. This may cause failure of the insulation system and leads to long outages.

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