A Comparative Study on Leakage Current Harmonics of Porcelain Disc Insulator Contaminated with NaCl and KCl

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***Abstract*—Flashover on disc insulator of over head transmission line is a major problem in power industry. Due to deposition of different contaminants particles, the surface of the disc insulator deteriorates which results in flashover occur on it. Hence, condition of the insulator surface must be monitored on regular basis in order to avoid the failure of power transmission. For this purpose, different approaches are taken to assess the condition of the insulator surface among which measurement of surface leakage current is found to be most efficient. But, existing literature shows that determination of peak value of leakage current is not always a good indicator to investigate the condition of insulator surface. Considering the above-mentioned fact, a different approach has been taken here that can efficiently predict the condition of insulator surface. Instead of determining the peak value, the harmonic contents present in the leakage currents has been evaluated to study the condition of insulator more accurately. For this purpose, an experimental setup has been developed in the laboratory that can measure the surface leakage current at different applied voltage. A disc insulator is contaminated separately with KCl and NaCl mixed with kaolin. The surface leakage current of the contaminated disc insulator is measured at different voltage and salinity level. Harmonic content present in the surface leakage current is evaluated for KCl and NaCl contamination at different voltage and salinity level. It may be observed that the harmonic contents present in leakage current are good indicator of salinity level.**

Keywords—Surface leakage current, Harmonic Components, porcelain disc insulator, NaCl and KCl contamination.

I. INTRODUCTION

Flashover of contaminated insulators in polluted areas is one of the most important factors influencing the operation of transmission and distribution lines and substations. Insulators are subjected to sustained moisture and soluble as well as non-soluble contamination build up i.e., salt, certain chemicals, dust and sand, leading to the formation of an electrolytic solution [1-7].

For monitoring the surface condition of insulators, several parameters have been studied by researchers over the years. These includes leakage current (LC), Equivalent Salt Deposit Density (ESDD), the surface conductance, non soluble deposit density (NSDD), etc. [1-3]. Amongst these parameters, leakage current has been found to be the most efficient in determining the surface condition of an insulator. The deposition of soluble and non-soluble impurities and moisture on the insulator surface affects the surface resistance of the insulator. The resistive part of the leakage current flowing over the surface of the insulator will increase.

With the increase of applied voltage, leakage current increases gradually in contaminated insulators surface. But it has been shown that in case of insulators, peak value of leakage current is not always a good indicator of surface condition [4-6]. Several studies have been carried out to analyze the influence of contamination on the harmonic component of leakage current in insulators. It has been shown that lower order odd harmonic components provide good indication about the level of contamination on insulator surface [7]. Such studies have been conducted at various salinity and voltage levels with either NaCl or KCl as a salt. However, the type of the deposited salt may affect the leakage current harmonics in different ways. It may be possible to determine which parameters are affected more by a particular salt.

In this paper, the authors have experimented with the two different salts, KCl and NaCl, to determine whether there are any marked differences in the harmonic contents. For each salt, the leakage current is measured for three different salinity levels and at three different voltages. The insulators are contaminated artificially by using procedure as given in IEC 60507. According to the procedure in solid layer method salt (NaCl and KCl) is used as a soluble material and kaolin is used as non soluble material. The main objective of this work is to investigate the relation between the leakage current's harmonic components and the different level of salinity and the type of salt deposit.

II. EXPERIMENTAL SETUP AND PROCEDURE

A. Experimental Setup

A porcelain disc insulator having rating of 11 kV has been used for experimental purposes. Fig. 1(a) and 1(b) represents the cross sectional view and photograph of the disc insulator, respectively. The detailed description of the disc insulator has been given in Table 1. An experimental set up has been prepared in the laboratory to measure the surface leakage current of the disc insulator at different voltages as per IEC 60507.The schematic diagram of the experimental setup has

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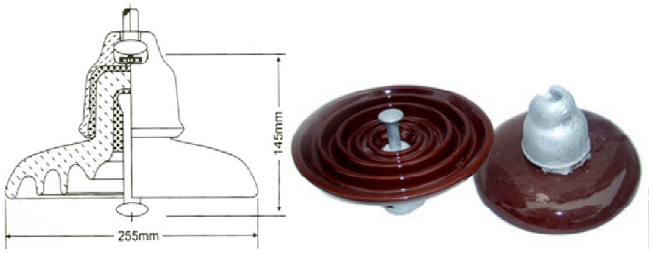
been shown in Fig. 2. A single phase high voltage testing transformer having rating of 150 kVA, 500V/250kV, 50 Hz, is used for supplying the power to the conductor which is hanged from the disc insulator. A water resistance of 180kΩ is connected in series with the conductor for protection purpose as shown in Fig. 2. A 10kΩ shunt resistor is connected to the earth link of the disc insulator in order to measure the surface leakage current. A cathode ray oscilloscope (CRO) is connected across the shunt resistance to acquire the leakage current flowing through the surface of the disc insulator. The CRO used here is completely computer controlled. An overvoltage protection device is used to protect the CRO from transients that may come during measurements due to the flash over on the insulator surface. A voltage divider is connected to the output terminal of the testing transformer to decrease the output voltage level for facilitating the measurements. The input voltage of the testing transformer is controlled from the control unit as shown in Fig. 2.

TABLE I. DETAIL DIMENTION OF THE DISK INSULATOR

Parameter	Value
Total creepage Distance	255mm
Height	145mm
Pin diameter	20mm



(a) (b)

Fig. 1. (a) Cross-sectional view and (b) actual photograph of disc insulator

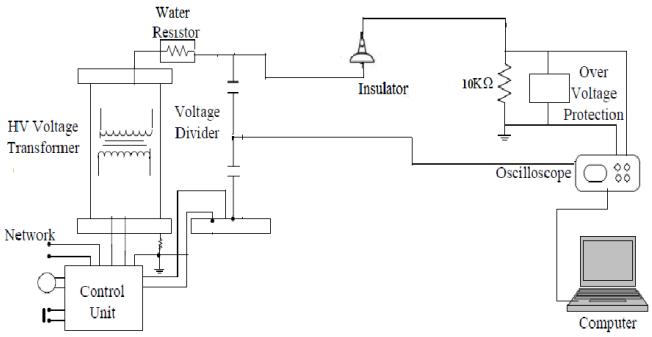


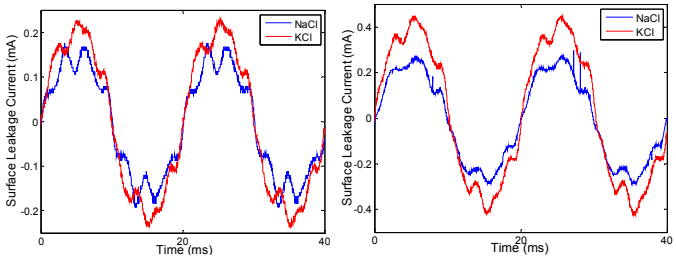
Fig. 2. The schematic diagram of experimental setup

B. Experimental procedure

The disc insulator is separately contaminated by NaCl and KCl with kaolin, the surface leakage current is measured at different supply voltages using the experimental setup as discussed section IIA. For this purpose, the disc insulator is washed by distilled water and cleaned by a cloth in order to remove any contaminant particles that may reside on its surface. The insulator is then dried using an air-blower. A fixed quantity of NaCl mixed with known amount of kaolin, is coated on the surface of the disc insulator in order to achieve a certain level of salinity. The coated insulator is kept 24 hours for drying purpose. The contaminated insulator is then hanged with the help of a hook. The height of the insulator on the ground is kept according to instruction as given in IEC 60507. The flash over test is performed in order to obtain the flash over voltage of the insulator. The conductor which is hanged from the insulator (as shown in Fig. 2) is supplied with different voltages (below flash over voltage) and corresponding surface leakage current are measured. The salinity level of NaCl on the disc insulator is varied using the same procedure as discussed above and corresponding surface leakage current are measured at same supplied voltage. The same process is followed in case of KCl (with kaolin) contamination to measure the corresponding surface leakage current. In order to facilitate a better comparison, the salinity level and supplied voltage for both cases are kept same. In the present work, the salinity level is kept at 0.5, 1.0 and 2.0. The surface leakage current of the insulator is measured for the voltage level of 5 kV, 15 kV and 30 kV at each salinity level for the both cases.

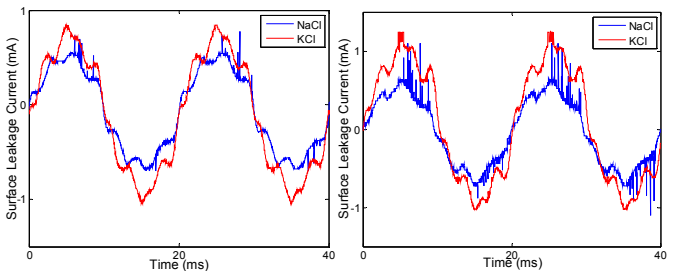
III. EXPERIMENTAL RESULTS AND DISCUSSIONS

In the present work, surface leakage current of the disk insulator contaminated separately with NaCl and KCl, is measured at different applied voltages using the procedure as discussed in section II. The salinity level of the insulator has been kept at 0.5, 1.0 and 2.0. The surface leakage current of the insulator is measured at each salinity level for different applied voltages (5 kV, 15 kV and 30 kV). The measured surface leakage current for NaCl and KCl at salinity level of 0.5 and 2.0, has been shown in Fig. 3 and 4, respectively for the applied voltage of 5 kV and 30 kV.



(a) (b)

Fig. 3. Surface Leakage Current for 5 kV at salinity level (a) 0.5 (b) 2.0



(a) (b)

Fig. 4. Surface Leakage Current for 30 kV at salinity level (a) 0.5 (b) 2.0

It may be observed from Fig. 3 and 4 that surface leakage current for NaCl is higher than the KCl at each salinity and voltage level. Hence, it can be said that KCl has more

detrimental effect on the surface leakage resistance of disk insulator than NaCl. It may also be observed from Fig. 3 and 4 that the magnitude of surface leakage current increases as the salinity level on the insulator surface increases. The increase of salinity level on the insulator surface reduces the surface leakage resistance which results in increase of surface leakage current [2-3].

It may also be observed from Fig. 3 and 4 that the waveshape of the measured surface leakage current deviates significantly from sinusoid. So, it can be said that the presence of harmonic content in the surface leakage current have an adverse affect on the deterioration of the insulator surface. In order to investigate the effect of harmonics on insulator surface, the harmonic contents present in each leakage current waveform, have been extracted using Fast Fourier Transform (FFT). It has been observed that only odd harmonic contents (fundamental, 3^{rd}, 5^{th}, 7^{th} etc.) are present in the surface leakage currents. The percentage values of odd harmonic contents present in the surface leakage currents with respect to corresponding fundamental components has been shown in Table II-IV.

TABLE II. % HARMONIC COMPONENTS PRESENT IN LEAKAGE CURRENT WITH RESPECT TO FUNDAMENTAL COMPONENT AT SALINITY LEVEL OF 0.5

Harmonic Components	5 kV		15 kV		30 kV	
	KCl	*NaCl*	*KCl*	*NaCl*	*KCl*	*NaCl*
Third	08.44	07.81	06.45	06.11	05.67	05.18
Fifth	09.96	02.36	10.07	02.56	10.62	03.85
Seventh	00.59	16.57	07.94	15.45	02.61	11.81
Nineth	05.64	05.43	07.05	03.72	08.14	05.00

TABLE III. % HARMONIC COMPONENTS PRESENT IN LEAKAGE CURRENT WITH RESPECT TO FUNDAMENTAL COMPONENT AT SALINITY LEVEL OF 1.0

Harmonic Components	5 kV		15 kV		30 kV	
	KCl	*NaCl*	*KCl*	*NaCl*	*KCl*	*NaCl*
Third	07.99	07.50	04.69	04.32	06.04	04.41
Fifth	08.88	02.35	09.94	02.42	12.27	05.09
Seventh	03.59	16.48	03.37	16.06	04.19	13.83
Nineth	05.76	05.39	06.16	04.05	09.77	06.56

TABLE IV. % HARMONIC COMPONENTS PRESENT IN LEAKAGE CURRENT WITH RESPECT TO FUNDAMENTAL COMPONENT AT SALINITY LEVEL OF 2.0

Harmonic Components	5 kV		15 kV		30 kV	
	KCl	*NaCl*	*KCl*	*NaCl*	*KCl*	*NaCl*
Third	06.99	05.95	03.95	03.75	05.03	03.99
Fifth	08.86	08.29	10.17	08.64	12.79	08.87
Seventh	03.24	03.48	05.73	06.91	04.01	06.93
Nineth	06.06	03.29	06.31	03.42	09.95	03.52

It may be observed from Table II-IV that percentage value of fifth harmonic content present in surface leakage current due to KCl contamination is higher than the corresponding other harmonic components at each salinity level. Hence, it may be said that presence of fifth harmonics in surface leakage current can be the prime detrimental factor for the degradation of insulator surface when KCl deposits on it.

It may also be observed from Table II-IV that presence of seventh harmonic content in surface leakage current due to NaCl deposition is significantly higher among all other harmonic content at salinity level of 0.5 and 1.0. But it reduces notably when the salinity level of the deposited NaCl becomes 2.0. Hence, it can be stated that seventh harmonic content in surface leakage current is significantly affected by the salinity level of NaCl. So, magnitude of seventh harmonic can be a good indicating parameter of salinity level when NaCl deposits on the surface of an insulator.

It may also be observed from Table II-IV that % value of 3^{rd}, 5^{th} and 9^{th} harmonic content with respect to fundamental component, present in leakage current for KCl contamination is higher than NaCl contamination at each voltage and salinity level. But, on the other hand, % value of 7^{th} harmonic content with respect to corresponding fundamental component, present in surface leakage current for KCl contamination is lower than NaCl contamination. The variation of % value of different harmonic content present in surface leakage current with respect to fundamental component for KCl and NaCl contamination at 15 kV has been shown in Fig. 5, 6 and 7, respectively for each salinity level.

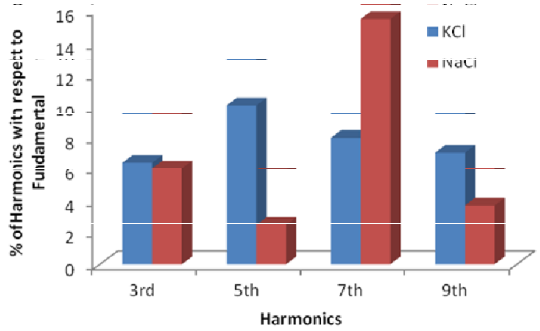


Fig. 5. Comparison of harmonic components present in surface leakage current for the applied voltage of 15 kV at salinity level 0.5.

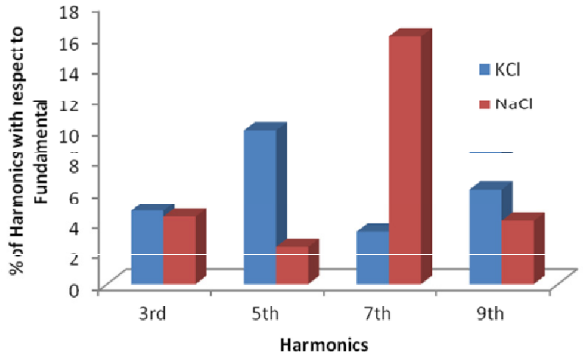


Fig. 6. Comparison of harmonic components present in surface leakage current for the applied voltage of 15 kV at salinity level 1.0.

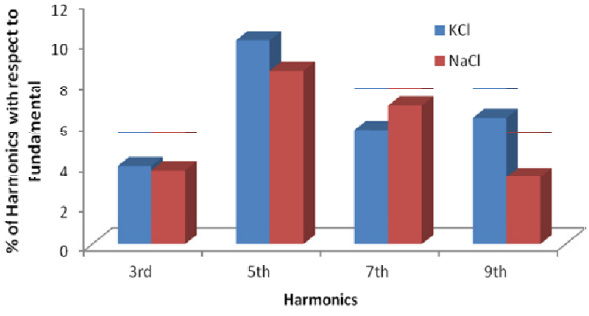


Fig. 7. Comparison of harmonic components present in surface leakage current for the applied voltage of 15 kV at salinity level 2.0.

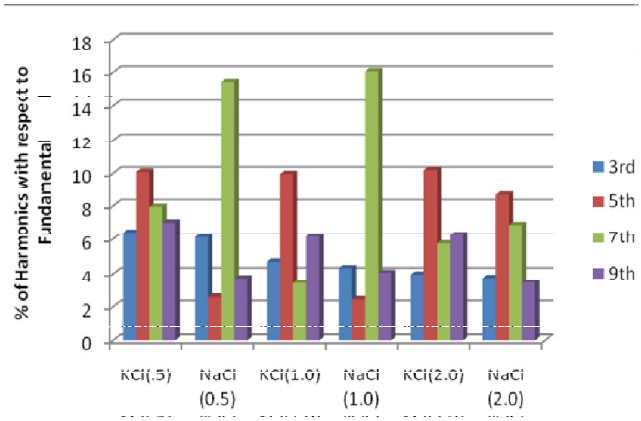


Fig. 8. Comparison of harmonic content with salinity level for the two salts

IV. CONCLUSIONS

In the present work, an experimental setup has been made in the laboratory that can measure the surface leakage current at different supply voltage. Using this setup, the leakage current of a porcelain disc insulator has been measured separately for KCl and NaCl contamination at 5 kV, 15 kV and 30 kV. The salinity level for both cases has been kept same (0.5, 1.0 and 2.0) in order to facilitate a better comparison. It is observed that the magnitudes of leakage current for KCl contamination are higher than NaCl contamination at each voltage and salinity level. Hence, it is inferred that KCl has comparatively more detrimental effect on the surface leakage resistance than NaCl. Besides this, in order to obtain more accurate information regarding degradation of insulator surface, the harmonic contents present in the surface leakage current is extracted using FFT. It is observed that fifth harmonic content has more detrimental effect on surface leakage resistance than other harmonics when KCl deposits on insulator surface. On the other hand, magnitude of 7th harmonic is comparatively higher when salinity level of NaCl is low (0.5 and 1.0). But its value reduces significantly when salinity level increases (2.0). Hence, it may be said that magnitude of 7th harmonic is a good indicator of salinity level for NaCl contamination. Besides this, % value of 3rd, 5th and 9th harmonic content with respect to fundamental component in leakage current is higher for KCl contamination than NaCl whereas corresponding 7th harmonics has lower value. Hence, it may be concluded that harmonic content present in surface leakage current can be used as a good indicator of salinity level for different contamination.

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