Development the Relationship between ESDD and the Distance from the Source of Contaminants for the Insulator

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Abstract: The contamination severity on the insulator surface can be expressed by Equivalent Salt Deposit Density (ESDD). The value of ESDD varies with the distance of the insulator from the source of contaminants. Normally, the main sources of contaminants affecting insulators are coming from the coastal regions, industrial areas and also deserts. The values of ESDD tend to decrease with increasing distance from the seacoast. In this paper, a relationship between the ESDD and the distance of the insulator from the source of contaminants has been derived based on Dimensional Analysis technique. The results obtained from the proposed relationship are compared to the other researcher's results and good agreement is observed. With this finding, effective implementation of line and station insulation coordination in contaminated conditions will be obtained.

I. INTRODUCTION

With rising trend in transmission line voltage, importance of the research on the insulator contamination has increased considerably in its importance. The performance of the insulator under contaminated condition will be the guiding factor in the future coordination of insulation in the transmission and distribution network systems.

The contaminants on the insulator surface can be classified into two types. One soluble conductive component and other is insoluble non-conductive components. The most common conductive components consist of ionic salts are sodium chloride, sodium sulfate and also magnesium chloride etc. The severity of contamination on the insulator surface due to these salts are generally presented and expressed by the term Equivalent Salt Deposit Density (ESDD). In the seaside, NaCl is the main component of the insulator contamination. This contaminant is coming out from the sea and deposited on the insulator surface. The contaminated insulator is shown in Fig. 1. The deposited contaminants decrease the insulation resistance of the insulator when moisten by dews or light rain. During monsoon season, when strong seasonal winds are blowing, the ESDD tends to increase tremendously with decreasing the distance from the seacoast [1]. The same pattern of ESDD exhibits in the case of industrial pollution to the insulator [1]. Empirically few results have been published about the variation of ESDD of the insulator with the distance from the source of contaminants. Here, the mathematical relationship between the ESDD and the distance of the insulator from the source of contaminants has been proposed using Dimensional Analysis technique [2]. The values of ESDD calculated from the proposed expression are compared to the other researcher results.

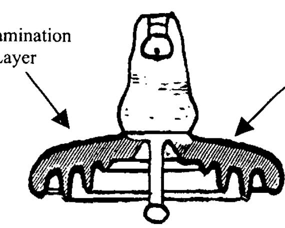

Fig. 1. Contaminated cap-and-pin glass insulator

II. THEORETICAL DEVELOPMENT

In practices, the values of ESDD are dependent on the distance of the insulator from the source of contaminants, exposure time, and static arc constant and also supply voltage system. Basically, small supply voltage system is required for determination the values of ESDD. The relationship among the variables can be written as follows,

$$ESDD = ESDD\,(x, et, N, V) \tag{1}$$

where:

x - Distance of the insulator from the source of contaminants;
et - Exposure time of the insulator;
N - Static arc constant;
V - Supply voltage for determines ESDD.

The dimensional matrix of the above variables can be written as:

	$ESDD$	x	N	et	V
L	-2	1	1	0	2
M	1	0	1	0	1
T	0	0	-3	1	-3
A	0	0	$n-1$	0	-1

where:

L - Length in SI units;
M - Mass in SI units;
T - Time in SI units;
A - Current in SI units;
n - Arc constant.

The rank of the matrix is 4 and the dimensionless product of the whole set is 1. The homogeneous linear algebraic equations from the above matrix can be written in the following ways [3].

$$-2k_1 + k_2 + k_3 + 2k_5 = 0 \quad (2)$$

$$k_1 + k_3 + k_5 = 0 \quad (3)$$

$$-3k_3 + k_4 - 3k_5 = 0 \quad (4)$$

$$-k_5 + (n-1)\,k_3 = 0 \quad (5)$$

Where k_1, k_2, k_3, k_4 and k_5 are the exponents of the respective variables. The expression of k_2, k_3, k_4 and k_5 in terms of k_1 can be derived from equation (2) to (5). These expressions are

$$k_2 = \frac{4n-1}{n}k_1, k_3 = -\frac{1}{n}k_1, k_4 = -3k_1, \quad k_5 = \frac{1-n}{n}k_1 \quad (6)$$

By assigning the value of k_1 is 1 and the expression of equation (6) can be written in the matrix form in the following way,

	k_1	k_2	k_3	k_4	k_5
	$ESDD$	x	N	et	V
π	1	$\frac{4n-1}{n}$	$\frac{-1}{n}$	-3	$\frac{1-n}{n}$

The general expression of the matrix can be written as,

$$\pi = ESDD\, x^{\frac{4n-1}{n}}\, N^{\frac{-1}{n}}\, (et)^{-3}\, V^{\frac{1-n}{n}} \quad (7)$$

By applying the Buckingham's π theorem, the equation (7) can be re-written as:

$$ESDD = d_c x^{-\frac{4n-1}{n}}\, N^{\frac{1}{n}}\, (et)^3\, V^{-\frac{1-n}{n}} \quad (8)$$

Where d_c is the dimensional constant. It should be noted that in a work [4] on application of Dimensional Analysis technique for relating insulator flashover voltage with pollution resistance, other variables were considered as constant. Therefore, in the present paper equation (8) has been modified by denoting the value of n is 0.28 [5] and treating N, V considered as constants so as to highlight the relationship between Salt Deposit Density (ESDD) and the distance of the insulator from the source of contaminants.

$$ESDD = d_c\, x^{-0.46}\, (et)^3 \quad (9)$$

III. RESULTS

The values of ESDD are calculated from the equation (9). During the calculation of ESDD, the value of exposure time is considered 1 hour. Both results are plotted together for comparison. It is shown in Fig. 2. The Fig. 2 represented the relationship between the amount the contaminants in terms of ESDD on the insulator surface and the distance of the insulator from the source of smoke of the industries. Here the values of ESDD calculated from the proposed model are decreased exponentially with increasing the distance of the insulator from the source of industry.

The values of ESDD on the insulator surface at different values of exposure time are also calculated from equation (9). These calculated values of ESDD are plotted together, which are shown in Fig 3. In Fig. 3, it has been observed that the values of ESDD increased with the increase of exposure time of the insulator. Because the values of ESDD is directly proportion to the third power of exposure time.

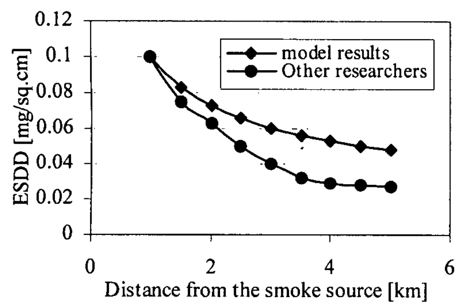

Fig. 2. Variation of ESDD with the distance from the smoke source

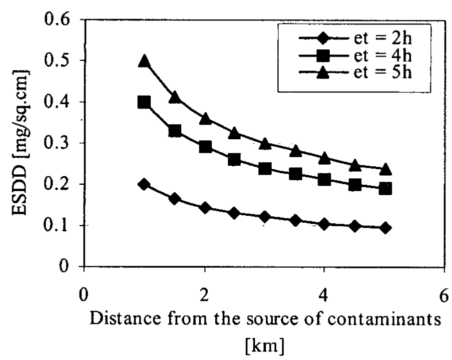

Fig. 3. Variation of ESDD with the distance at different exposure time

IV. CONCLUSIONS

The values of ESDD are varied with the distance of the insulator from the source of contaminants. In this paper, the relationship between the ESDD and the distance of the insulator from the source of contaminants with considering the exposure time has been proposed based on the Dimensional Analysis technique. The results obtained in this paper are summarized as follows:

1. The calculated values of ESDD with exposure time 1 hour are compared with the measured values of ESDD of other researchers and to be found in close agreement.

2. From the proposed expression, the values of ESDD can be determined directly by putting the values of exposure time and also the distance from the source of contaminants of the insulator.

V. REFERENCES

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