Australian Journal of Basic and Applied Sciences, 9(36) December 2015, Pages: 459-464

ISSN:1991-8178

Australian Journal of Basic and Applied Sciences

Journal home page: www.ajbasweb.com

Flashovervoltage Modeling of An Outdoor Porcelain Insulators

[1]Santhosha B.M, [2]Shridhar S.M, [3]Kamal Kishore

[1]*Assistant professor, EEE Dept. Ballari Institute of Technology and Management, Bellary, Karnataka.*
[2]*Assistant professor,EEE Dept. Ballari Institute of Technology and Management, Bellary, Karnataka.*
[3]*Assistant professor, EEE Dept. Ballari Institute of Technology and Management, Bellary, Karnataka.*

ARTICLE INFO

Article history:
Received 1 December 2015
Accepted 31 December 2015
Available online 10 January 2016

Keywords:
ESDD, Flashover, Porcelain, pollution severity factor

ABSTRACT

The aim of this paper is to develop a new mathematical model, which can predict accurately the critical AC flashover voltage and current of the polluted porcelain disc insulators. Three types of porcelain insulators are examined. They are standard porcelain Type A, Type B and Type C insulators. The salient feature of this model is that it takes into account the effect of ESDD, Equivalent Salt Deposit Density, as pollution severity to predict V_{ec}, the rms value critical AC flashover voltage. This model also considers the form factor of the insulators profile while predicting the critical flashover voltage.

To Cite This Article: Santhosha B.M, Shridhar S.M, Kamal Kishore., Flashovervoltage Modeling of An Outdoor Porcelain Insulators. ***Aust. J. Basic & Appl. Sci.****, 9(36): 459-464, 2015*

INTRODUCTION

Outdoor insulators play an important role in maintaining the reliability of the power system. Insulators used for high-voltage power transmission which are made from glass, porcelain or composite polymer materials. The primary function of insulators in the overhead lines is to mechanically support the conductors and electrically isolated them from the towers, which have grounded potential. When these insulators are installed near industrial, agricultural or coastal areas, airborne particles are deposited on these insulators and the pollution builds up gradually, which results in the flow of leakage current (LC) during wet weather conditions such as dew, fog or drizzle. The LC density is non uniform and in some areas sufficient heat is developed leading to the formation of dry bands. Voltage redistribution along the insulator causes high electric field intensity across dry bands leading to the formation of partial arcs. When the surface resistance is sufficiently low, these partial discharges will elongate along the insulator profile which may eventually cause the insulator flashover. Various researches are carried out to understand the physics of the growth phenomenon of the discharge and also to develop new mathematical model, which can accurately predict the critical flashover voltage and current.

The pollution flashover phenomenon is very complex due to the effect of the chemical pollutant. Few research works has been reported the study of pollutants on critical flashover phenomenon, but they failed to develop any new mathematical model based on chemical pollutant factors. Ghosh *et al* had proposed a new mathematical model, which takes into account the effect of chemical change of the pollutant on the critical flashover (Ghosh, P.S. and N. Chatterjee, 1996).

The present paper proposed a new mathematical model for the prediction of critical flashover voltage for practical insulators by introducing a new factor called, 'pollution severity factor', K1,taking into account ESDD, Equivalent Salt Deposit Density, instead of the parameter Rp, Resistance per Unit Length. In the present study, it has been observed that the new pollution severity factor varies with the chemical nature of the pollutant.The results of the developed model will be analyzed using the experimental results. These results are taken from an experiment carried out on two standard cap and pin insulators and one anti-fog insulator. The validity of the this new mathematical model was verified by comparing the modeled results against the experimental results and good agreement has been obtained.

II. Proposed Modeling Techniques:

A. Critical Flashover Voltage,V_{ec} Modeling:

The mathematical model used to represent the AC flashover process of polluted insulators is given by (Ghosh, P.S. and N. Chatterjee, 1995);

$$Vm = xNI_m^{-n} + Rp(L - x) \quad (1)$$

Corresponding Author: Santhosha B.M, Assistant professor, EEE Dept. Ballari Institute of Technology and Management, Bellary, Karnataka

Where Vm is the maximum (peak) value of the AC voltage applied to the insulator, I_m is the maximum (peak) value of the current passing through the surface of the insulator, Rp the surface resistance of the pollution layer, x the length of the arc, N & n are the constants of the arc characteristics.

But Ghosh *et al* had used Ve and I_e as the rms values of voltage and current respectively in his research work.

$$Ve = kxNI_e^{-n} + Rp(L-x)I_e + Ue \quad (2)$$

Where

$$k = \left[\frac{\sqrt{2}}{1.3}\right]^{-(n+1)} \quad (3)$$

By differentiating equation (2) partially with respect to I_e and then equating it to zero will give the V_{ec}(critical voltage).

$$V_{ec} = Lk^{\frac{1}{n+1}}N^{\frac{1}{n+1}}R_p^{\frac{n}{n+1}} \quad (4)$$

In this paper, the modeling of V_{ec} has been developed based on ESDD, the surface area, A, and form factor, F instead of commonly used R_p.

$$R_p = ESDD^{\frac{1}{n}} \cdot F^{-1} \cdot A^{\frac{1-n}{n}} \quad (5)$$

It has been observed that the expression for V_{ec} which is obtained by substituting (5) in (4) violates the dimensional analysis rules. Therefore to satisfy the above rule a more appropriate expression has been proposed for R_p as shown in equation (6) (Ricardo, W.S. Garcia, *et al*., 1991; Guan Zhicheng and Zhang Renyu, 1990).

$$R_p = K_1^{\frac{1}{n}} \cdot F^{-1} \cdot A^{\frac{1-n}{n}} \quad (6)$$

Thus the proposed equation V_{ec} for is given by the following equation (7).

$$V_{ec} = L.K^{\frac{1}{n+1}}.N^{\frac{1}{n+1}}.K_1^{\frac{1}{n+1}}.A^{\frac{1-n}{1+n}}.F^{\frac{-n}{n+1}} \quad (7)$$

The new proposed factor, K1 has been defined as pollution severity factor for practical insulator.

B.Dimensional Analysis of Pollution Severity Factor:

According to Rizk (Farouk, A.M. Rizk, 1970), the dimension for V_{ec}(critical flashover voltage) is given by $ML^2T^{-3}A^{-1}$. Based on this, an attempt has been made to equate the dimensions of the right hand side of equation (7) to the left hand side of the equation. In order to utilize the algebraic approach to dimensional analysis, it is convenient to display the dimensions of the respective variables by a tabular arrangement. The variables under consideration are surface area, A ,static arc constant, N, form factor, F, leakage distance of the insulator, L, and the new pollution severity factor K1 in the critical flashover equation (7).

The dimension of pollution severity factor K1 is obtained using the dimensional analysis method as shown in the following 4 X 4 matrix.

	L	K_1	A	N
L	1	-2	2	1
M	0	0	0	1
T	0	0	0	-3
A	0	0	0	n-1

From the above matrix, it is evident that n=0 gives an overall dimension of $ML^2T^{-3}A^{-1}$ for the right hand side of equation (7) and it is equal to the dimension of critical flashover voltage V_{ec}. Thus, from the above analysis, we conclude that the pollution severity factor for the practical insulator may be defined as;

$$K1 = \frac{Salinity}{ESDD * L}(cm^{-2}) \quad (8)$$

III. Discussion Of Modeled Output:

A. Experimental Data:

The data used in the present study has been taken from the experiment performed in the small fog chamber at CEPEL's laboratory (Md Abdus Salam, Hussein Ahmad, *et al*, 2000).

Table 3.1: Insulator dimensions

Type	H (cm)	D (cm)	L (cm)	Lp	Surface area (sq. cm)	Form factor	No of sheds/ribs
Type A(70kN) Standard Porcelain Disc	13.2	25.5	18.9	21.6	1456.0	0.7701	4
Type B(90kN) Standard Porcelain Disc	13.5	25.4	20.2	25.	1221.0	0.8203	4
Type C (120kN) Standard Porcelain disc	14.8	25.4	22.7	33.0	1736.0	0.7306	5

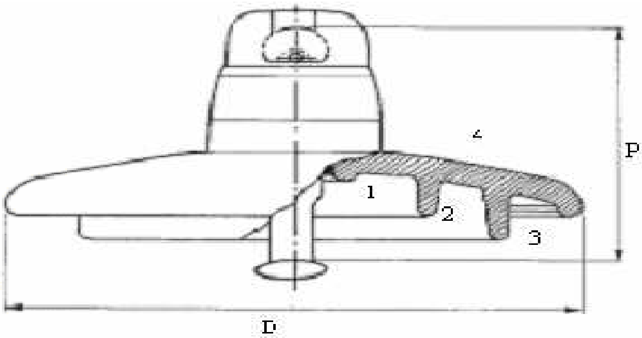

Fig 3.1: Insulator profile

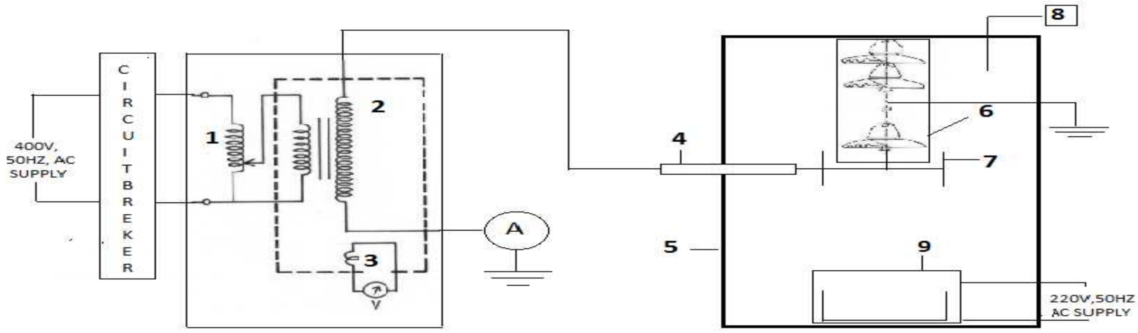

Fig. 3.2: Experimental setup to determine the flashover voltage under different polluted conditions

1. Auto transformer, 2. High voltage winding, 3.Measuringwinding, 4. High voltage bushing

5.Pollution tent (2.75m×2.75m×2.75m), 6. Test insulator, 7. Corona rings 8. Humidity sensor, 9. Steam generator

According to the IEC507 standard specification the experiment was conducted. The experiment has been conducted on three insulators Type A, Type B & Type C. Insulator profile is shown in the Figure 3.11. The insulator strings were tested in the vertical position. Dimensions of the insulators are shown in table 3.1. A schematic of the experimental test set-up used in the present work is shown in Figure 2. The test arrangement consists of a plastic (synthetic) tent of dimension 2.75m×2.75m×2.75m, which is supported by a metallic frame. From the center of the tent provision was made for the arrangement of the suspension string consists of three disc insulators of which top two insulators are dummy. The bottom of the insulators was connected to conductor clamp. The high voltage lead consisting of rubber cable was taken through FRP tube. The steam was generated by boiling the water in a boiler. The power was supplied from a 60kV, 60kVA transformer with a primary voltage of 230/415V and a rated continuous current of 1A.

Using these experimental set-ups, the voltage is applied to the insulator string followed by the wetting process. This wetting process of the insulator is using the chemical kaolin as a stitching agent in the concentration of 40g/l, steam input rate at 0.35g/h/m3 and salinity of 3.5g/l of salt fog. The up and down method with ten voltage applications is used to determine the flashover voltage of insulators (Jaafar, S., *et al*., 2002).

The experimental results are tabulated in Table 3.2.

Table 3.2: Experimental data

ESDD in mg/cm^2	Type A FOV in kV	Type B FOV in kV	Type C FOV in kV
0.04	15.50	20.20	23.50
0.09	12.50	16.04	17.80
0.15	10.50	14.30	12.50
0.21	9.80	12.02	11.01
0.25	8.70	10.50	9.50
0.32	7.50	9.01	9.03
0.4	6.50	8.03	8.00

B. Computed Data:

While applying the proposed modeling technique, there are several issues, which could be addressed. Previous research works have used constant values of N &*n* to model critical flashover voltage. In fact, for the first time in the research of pollution flashover modeling of insulators, Ghosh *et al* (1995) proposed that the optimal combination of N &*n* is dependent on the chemical nature of the pollutants. In this case, the values for arc constant, N=360 &*n*=0.59 have been used for the modeling. Using equations (7&8) the values of modeled Vec, are computed using insulators dimensions, arc constant and ESDD from Table 3.3. The experimental results are then compared against the modeled(computed) results. Flashover voltages are simulated using the program developed in the MATLAB for different pollution severities and for selected insulator samples Type A, Type B and Type C. The results are tabulated in Table 3.3.

Table 3.3: Computed data

ESDD (mg/cm^2)	Type A (FOV in kV)	Type B (FOV in kV)	Type C (FOV in kV)
0.04	19.30	17.84	21.97
0.09	14.19	13.11	16.15
0.15	11.46	10.59	13.04
0.21	9.98	9.22	11.36
0.25	9.46	8.74	10.77
0.32	8.74	8.08	9.95
0.4	8.31	7.68	9.46

C. Comparison of Experimental and Computed Results:

The flashover voltages determined analytically for different pollution severities are compared with the experimental results obtained in our laboratory for the same pollution severity. The calculated results at different pollution severities are plotted together with the experimental results for comparison. Figures 4.1(a), 4.1(b) and 4.1(c) shows the comparison of plots for the selected insulators Type A, Type B and Type C respectively.

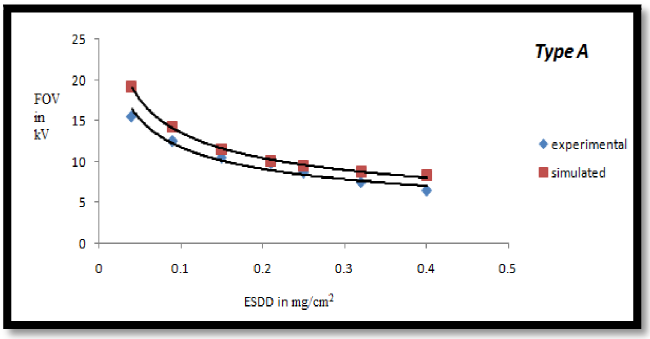

Fig. 3.3: Comparison of experimental and Computed FOV for Insulator Type A

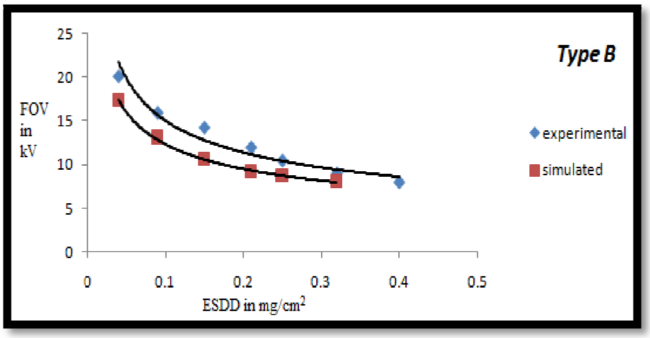

Fig. 3.4: Comparison of experimental and Computed FOV for Insulator Type B

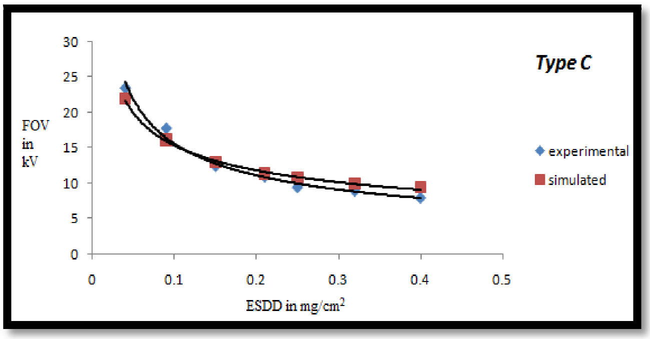

Fig. 3.5: Comparison of experimental and Computed FOV for Insulator Type C

It is observed from the figure 3.3 for the Type A insulator that the simulated results are higher than the experimental results for lower and higher ESDD ranges. For ESDD level 0.01 to 0.3 range the percentage error is within the permissible limits i.e. varying from +7.4% to -6.67%. In the lower range of ESDD's i.e. 0.04 and at very high ESDD level i.e. 0.4, the error is 14% and 18.5% respectively.

It is observed from the figure 3.4 for the Type B insulator that the simulated results are lesser than the experimentally obtained results for all ESDD levels. The percentage error varies from -7.8% to -32.3%. The percentage error somewhat decreases at 0.4 ESDD level.

It is observed from the figure 3.5 for the Type C insulator that the simulated results are almost in agreement with experimentally obtained results with permissible error limits.

The flashover voltages using the mathematical model V=f (L, N, A, K1) are higher than the experimentally obtained results for almost lower and higher ESDD levels. The reason could be the error in the measurement of form factor, ESDD and the assumed values of arc constants N and n. the arc constants N and n varying from 24 to 523 and 0.24 to 1.1 respectively. Hence there may be error in the values N=360 & n=0.59 using in this model. In spite of the above limitations, the analytical model is more effective since it uses Equivalent Salt Deposit Density (ESDD) instead of resistance per unit length (Rp) in the equation which is relatively difficult to measure.

Conclusions:

A new mathematical model of insulators for flashover voltage modeling, $V_{ec} = f(L, N, A, K1)$, has been proposed using the new factor i.e. 'pollution severity factor', K1. The proposed new factor K1 utilizes the normal parameters given in the manufacturer's data and maintenance conditions values to calculate the critical flashover voltage, V_{ec}. Hence, the new model has to be more effective compared to the earlier models in findings the critical flashover voltage.

In the present model, a new mathematical model $V_{ec} = f(L, N, A, K1)$, for AC flashover voltage prediction for practical insulator has been derived using the 'pollution severity factor', K1. The factor K1 is determined using Dimensional Analysis. The important feature of the present model is, to use Equivalent Salt Deposit Density (ESDD) as pollution severity, instead of Pollution Resistance per unit length (R_P) to predict critical flashover voltage. Experiments are conducted according to IEC 60507 standard specifications in two phases . The computed results obtained in Phase-I and experimental results obtained in Phase-II were tabulated, discussed and compared with each other and the following conclusions are drawn.

- The Mathematical model has been proposed a new factor called pollution severity factor

$$K1= \frac{Salinity}{ESDD*L}(cm^{-2})$$

- The measurement of ESDD is easier rather than the measurement of pollution resistance Rp.
- The predicted values using this model higher than the experimental results for all pollution levels. The reason could be the creeping in error in the measurement of form factor and the arc constants N and n.
- This mathematical model is Pessimistic.

Future Scope:

The flashover voltages using the mathematical model V=f (L, N, A, K1) are higher than the experimentally obtained results for almost lower and higher ESDD levels. The reason could be the error in the measurement of form factor, ESDD and the assumed values of arc constants N and n. the arc constants N and n varying from 24 to 523 and 0.24 to 1.1 respectively. Hence there may be error in the values N=360 and n=0.59 using in this model.

But the error can be reduced by correctly measuring the dimensions of insulator, thereby actual form factor can be obtained. The environmental conditions also affect on ESDD level. Hence error can also be reduced by maintaining constant environmental conditions and by choosing exact values of arc constants for the corresponding ESDD levels.

REFERENCES

Ghosh, P.S. and N. Chatterjee, 1996. "*Arc Propagation Over Electrolytic Surface Under Power Frequency Voltage*", IEEE Trans. On Dielectrics and Electrical Insulation, 3(4): 529-536.

Ghosh, P.S. and N. Chatterjee, 1995. "*Polluted Insulator Flashover Model for AC voltage*", IEEE Trans. on Dielectrics and Electrical Insulation, 2: 128-136.

Ricardo, W.S. Garcia, Ronaldo Bosignoli and Edegard Gomes Jr, 1991. "*Influence Of The Non-Uniformity Of Pollution Distribution On The Electrical Behavior Of Insulator*", Proceeding ICPADM, pp: 342-345.

Guan Zhicheng and Zhang Renyu, 1990. "*Calculation of DC and AC Flashover Voltage of Polluted Insulators*", IEEE Trans. on Electrical Insulation, 25: 723-729.

Md Abdus Salam, Hussein Ahmad, *et al*, 2000. "*Effect Of Equivalent Salt Deposit Density On Flashover Voltage Of Contaminated Insulator Energized By HVDC*", Proceeding ICPADM, pp: 821-824.

Farouk, A.M. Rizk, 1970."*Application Of Dimensional Analysis To Flashover Characteristics Of Polluted Insulators*", IEE Proceeding, 117(12): 2257- 2260.

Australian Journal of Basic and Applied Sciences, 9(36) December 2015, Pages: 459-464

Jaafar, S., A.S. Ahmad, P.S. Ghosh and S.A.K Aljunid, 2002. " *A New Approach In Modeling AC Flashover Voltage For Polluted Insulator"*, CEIDP, pp: 558-561.