International Journal Of Engineering Research And Development
e-ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com
Volume 14, Issue 1 (January 2018), PP.05-11

Role of Multiple Arcs on Flashover of Contaminated Porcelain Disc Insulators

[1]H.C. Mouneswarachar [2]PradipKumarDixit
[1]Research Scholar, Jain University, Bengaluru and working with University B D T College of Engineering, Davangere.
[2]Professor, Department of E & E Engineering. MSRIT, Bengaluru.
Corresponding Author: [1]H.C. Mouneswarachar

ABSTRACT: Mechanism of pollution flashover is complex as it depends on numerous factors. Thus, several simplifying assumptions were introduced in developing a model to formulate an expression for the predetermination of flashover voltage. To simplify the study, both static and dynamic models assume that there is a single dominant arc on insulator surface whereas a large number of investigations carried out in field and laboratory showed that several local discharges would take place on the insulator surface in the same time. The present work deals with the study of role of multiple arcs on flashover voltage of polluted insulators. Experiments were carried out on three porcelain disc insulators with presence of single, two and four arcs in different directions on the polluted surface. Two different arc lengths were considered to show the presence of propagated arcs for the experimentation at four levels of contamination. Electrode rods of different lengths were used to represent the required arc lengths on the polluted surface. The comparison of results of flashover experiments with the presence of two and four arcs with that of single arc condition reveal that effect of multiple arcs on flashover voltage is insignificant.

Keyword: Critical Arc Length,Flashover, Multiple Arc, Pollution, Porcelain

---

Date of Submission: 16 -01-2018 Date of acceptance: 30-01-2018

I. INTRODUCTION

The performance of insulators used to overhead transmission lines and overhead distribution lines is one of the critical factors that govern the reliability of power delivery systems. Pollution induced flashover is the single largest reason of transmission/distribution line outages, next to lightning. A major significance of the problem is that it can repeatedly occur even at working voltages [1] Many studies have been carried out to understand the role of different parameters on the flashover of polluted insulators. For better understanding of the physical phenomena involved in the occurrence of flashover and to predict the flashover voltages over the wide range of field conditions, computer simulation using mathematical models are expected to be effective and economical because of the complexity of practical and realistic experimental simulations. In this context, several models have been developed to predict flashover voltage of polluted insulators [2-5]. Mathematical models developed were both static [6,7] and dynamic [8-10]. The static models are based on Obenaus's model. Based on arc constants and pollution severity, the characteristics of the arc can be obtained that leads to the flashover. While the dynamic model adopts a dynamic approach based on the physical processes constituting the phenomena. To simplify the study, both static and dynamic models assume that there is a single dominant arc on insulator surface whereas a large number of investigations carried out in field and laboratory showed that several local discharges would take place on the insulator surface in the same time [11-13]. The formation and development of these partial arcs lead to the flashover under specific condition. The number of arcs that form will be function of wetting rate, surface conductivity and uniformity of the pollution layer.Many attempts have been made to improve the existing models by introducing the multi-arcs concept [12,14]

A mathematical model [15] which takes into account the presence of multiple arcs has been introduced to study the breakdown of the electrolyte surface. In contrast to a single arc, the power source has to sustain multiple arcs with corresponding electrode drops, resulting in overall higher voltage than a single arc at critical condition. A model to develop electrode fall drop voltage is also introduced. The model is compared with one experimental result. This model [15] (paper) does not indicate any calculation to calculate the critical voltage. It seems impossible to calculate the critical voltage from the given data /information. Depending on the number of arcs the arc current will diner. The number of arcs is not shown in calculations and in the figures. The paper [16] deals with discharge region consisting of multiple arcs and the wet pollution region in series with it. The wet region is characterized by conductance of pollution layer and form factor (depends on insulator profile). A mathematical -formula has been developed to calculate the minimum voltage required to sustain the "m" number of arcs. Maximization of minimum voltage leads to flashover voltage. A parameter, effectiveness of leakage length is introduced and an empirical formula for it is developed. The critical voltage isproportional to effective portion and to total creepage path. There is no comparison of this model with experiments and others. The paper is not very clear as to how to decide the value of "m" and how many arcs are to be considered. The paper [17] developed a multi-arcs dynamic model for predicting the behaviour of polluted insulator under impulse voltage. The model shows better accuracy than single arc one. But, the work was performed on flat plate model rather than real insulator.

The present work was carried out to study the effect of presence of multiple arcs on the flashover voltage of insulators initiated in the different directions on the polluted surface. The experiments were conducted on the three porcelain disc insulators with the presence of single, two and four arcs formed on the surface. The two arc lengths; (i)Larc = 1% of L and (ii) Larc = distance equal to pin-to last rib were considered for the experimentation at four levels of contamination. The presence of multiple arcs in different directions were represented by using electrode rods of appropriate length and size. Experimental results reveal that the flashover strength/ voltages obtained with the presence of two and four arcs were almost same as compared to the flashover results of single arc condition (which was taken as the reference). Thus, the effect of multiple arcs on the flashover voltage of polluted porcelain disc insulators is not significant.

II. EXPERIMENTAL WORK

A. Test Specimens

In this study, three porcelain disc insulators have been used. They are designated as Insulator-A, B, and C respectively. First two insulators (A and B) are of standard and the rest (insulator-C) is Antifog. The geometrical dimensions of insulators are given in Table 1.

B. Experimental Setup

The AC flashover performance tests have been carried out on insulators using the experimental setup shown in Fig.1. High voltage setup consists of a Transformer, an auto transformer and a pollution chamber. Transformer rated as 415/

Table.1: Geometrical Parameters of tested insulators

Designation of Insulators used	Diameter D (cm)	Height H (cm)	Creepage Length L (cm)	form factor	No. of ribs
Type-A (Standard)	25.5	14.6	31.8	0.57	4
Type-B (Standard)	25.5	14.5	33.0	0.81	5
Type-C (Antifog)	30.5	17.0	50.1	0.90	4

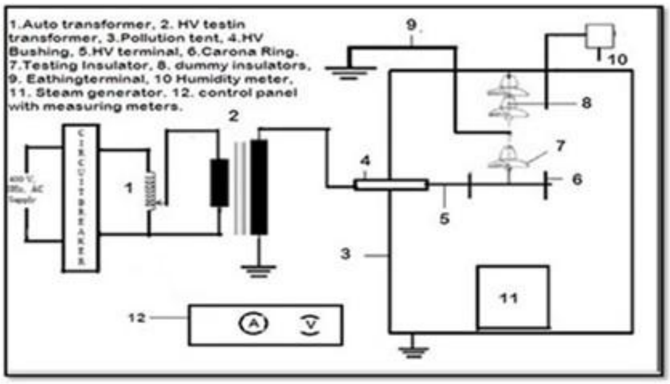


Fig.1: Schematic diagram of experimental setup

60 kV, 60kVA with 1 A secondary current (Continuous). The test power supply satisfies the requirements recommended by IEC60507[18].

C. Test Procedure

The solid layer method recommended by IEC60507[18] has been adopted to pollute insulators artificially. Four ESDD levels 0.05, 0.1, 0.2 and 0.3 mg/cm^2 have been selected for this study which represent low, medium, high and very high levels of pollution respectively. The artificial contamination slurry is a mixture of commercial salt (NaCl), Kaolin and de-ionized water.

Before the test, the insulators are cleaned to ensure removing of all traces of dirt and grease and then dried. The cleaned insulator is dipped in the prepared slurry. The top and bottom surfaces have polluted uniformly and has dried artificially. The insulator with the known ESDD has mounted vertically in the pollution chamber of dimension 3.0 m X 3.0 m X 3.0 m shown in Fig.1. The steam is allowed in the chamber for 15 minutes to wet the insulator. Then, the AC voltage has been applied gradually with a uniform rate of rise across the insulator till the flashover. The flashover voltage is recorded. Immediately after the flashover, the insulator has taken out and ESDD has been measured using IEC-60507[18] recommended calculation.

III. EXPERIMENTS TO FIND THE ROLE OF MULTIPLE ARCS ON FLASHOVER VOLTAGE

In the proposed work flashover experiments were conducted to study the effect of multiple arcs on flashover voltages with the presence of single, two and four arcson the surface of insulators initiated in different directions. The change in the arc length has been represented artificially by using a round rod electrodes of different lengths. In this process, it has been assumed that arc has been moved to the desired point on the surface of the insulator by satisfying any one criteria of propagation proposed by earlier authors. Further, it is clarified that here the rod represents only the length of the propagated arc not the arc. It is known that, the arc is a plasma channel with a certain voltage drop and this voltage drop across the rod (known as arc voltage drop, (V_{arc}) was very small as compared to the un bridged pollution resistance drop (V_R) and the flashover voltage, therefore, it is neglected [19]. Based on the results of our earlier paper [20], an electrode rod of radius 2.1 mm has been selected for further experimentation.

In the beginning, flashover experiments were conducted on insulator-A with the presence of single arc on the surface of the insulator. To show the presence of arcs on the surface, two arc lengths were selected for the experimentation. The single arc was artificially represented by pacing an electrode rod of length equal to 1% of its creepage in any one direction from the pin. The ESDD level was maintained at 0.05 mg/cm^2. The polluted insulator was kept in pollution chamber. Steam was allowed for 15 min for wetting of the insulator. Then, AC voltage was gradually applied till flashover occur. Immediately after the flashover, the insulator has taken out and ESDD has been measured using IEC-60507[18] recommended calculation. At least three trails were under taken to confirm the repeatability of the results. During the experiments, a visual observation of initiation of arcs and direction of arc path leading to the flashover was done. The same procedure was repeated with the presence two and four arcs in two and four directions for the given arc length and ESDD. These conditions were represented artificially by placing two and four electrodes of length equal to 1% of its L in diagonally opposite directions from the pin. Further, the above tests were repeated with arc length equal to the distance between the pin and the last rib. The above set of experiments were repeated for other ESDD levels. The above tests were conducted for other two insulators B and C.

IV. RESULTS AND DISCUSSIONS

The flashover experimental results of obtained in the previous section with the presence of single, tow and four arcs in one, two and four directions at two arc lengths for three insulator types A, B and C were tabulated in tables 2, 3 and 4 respectively. Further, the comparison of flashover voltages at given arc length for the presence of one, two and four arcs at four ESDD levels for the same insulators were also plotted in the figures 2, 3 and 4 respectively. It is observed from theTable 2 of insulator-A and its corresponding plot in Figure 2 that, the mean flashover voltages obtained for the presence of two and four arcs in different directions were almost equal to the flashover voltages obtained with the presence of single arc condition for the given arc length and ESDD level.

The same trend was also observed from the table 3 and its plot in Fig. 3 for the insulator type-B. An interesting point observed in Type-B insulator is that the number of under ribs are equal to 5 which is different from other insulators A and C considered in this work. Even then, for the arc lengths, equal to the distance between the pin and the last rib (here, the last rib is the 5th rib), flashover voltages obtained with the presence of two and four arcs is almost same with that of single arc condition for the given ESDD level. It is also observed from the Table 4 and the Fig. 4 for Type-E insulator that the mean flashover voltages obtained for the presence of two and four arcs in different directions are almost same when compared to the flashover results of single arc condition for the given arc length and ESDD level. Again, an interesting point is that this insulator is of Antifog which is different from other two insulators A and B.

From the above discussions, it can be concluded that a single dominant arc leads to the flashover even multiple arcs were initiated in different directions on the surface.

V. CONCLUSIONS

In this study, artificial pollution flashover experimentshave been carried out to study the effect of multiple arcs on the flashover voltages. Two arc lengths equal to; (i) Larc = 1 % of L and (ii) Larc = distance between pinand the last rib were considered to represent the presence of multiple arcs. Flashover experiments were conducted with the presence of single, two and four arcs on the polluted surfaceof three practical porcelain disc insulators A, B and C at four ESDD levels mentioned.The results were tabulated and discussed.Based on the analysis and discussions made in the paper. The mean flashover voltages obtained for the presence of two and four arcs in different directions on the polluted surface were almost equal to the flashover voltages obtained with the presence of single arc condition for the given arc length and ESDD level. Thus, it can be concluded that a single dominant arc leads to the flashover even multiple arcs were initiated in different directions on the polluted surface.

ACKNOWLEDGEMENT

The first authour would like to thank the Principal and authorities of University B D T College of Engineering, Davangere for their help in carrying out this research work. The authors would like to thank vice-chancellor and authorities of Jain University, Bengaluru for their support and encouragement. The authors would like to thank Principal and authorities of MSRIT, Bengaluru, for their help and support.

REFERENCES

[1]. Burnham J.T., “Bird streamer flashovers on FPL transmission lines”, Proc. of IEEE, Power delivery, vol.10, No.2, April 1995.

[2]. Dixit, Pradipkumar, Studies on Pollution Performance of Ceramic Insulators, A Thesis Submitted to Visvesvaraya Technological University, 2009.

[3]. Dust, fog pushed northern grid close to collapse on Wednesday night [Online]. Available: http://archive.indianexpress.com/news/dust-fog-pushed-northern-grid-close-to-collapse -on-Wednesday-night/1209677/0.

[4]. Enquiry Committee Report on Grid Disturbance of 7th & 9th March, 2008 [Online]. Available from: http://nrpc.gov.in/reports/enq/07-09Mar2008.pdf.

Table. 2: flashover voltages with the initiation of single, two and four arcs on polluted surface of type-a insulator

At Two Arc Lengths For Four Esdd Levels

Arc Length	No. of Arcs initiated on the surface	ESDD in mg/cm^2	FOV in kV	Mean FOV in kV	ESDD in mg/cm^2	FOV in kV	Mean FOV in kV	ESDD in mg/cm^2	FOV in kV	Mean FOV in kV	ESDD in mg/cm^2	FOV in kV	Mean FOV in kV
Arc length = 1% L	Single Arc	0.047	15.5	14.0	0.098	14.0	12.5	0.213	9.0	9.5	0.276	7.0	7.0
		0.049	13.0		0.098	12.0		0.198	10.0		0.291	8.0	
		0.051	13.5		0.109	11.5		0.214	9.5		0.321	6.0	
	Two Arcs	0.051	14.0	14.2	0.098	12.0	12.3	0.232	10.0	9.7	0.312	7.0	6.8
		0.05	13.5		0.098	13.0		0.212	10.0		0.270	7.0	
		0.05	15.0		0.113	12.0		0.209	9.0		0.286	6.5	
	Four Arcs	0.047	14.5	14.5	0.114	12.5	12.8	0.221	9.0	9.2	0.298	7.0	7.2
		0.049	14.0		0.107	13.0		0.210	9.0		0.291	7.5	
		0.048	15.0		0.099	13.0		0.200	9.5		0.321	7.0	
Arc length = Pin-to-last rib	Single Arc	0.052	6.0	5.0	0.114	4.0	4.2	0.212	3.5	3.5	0.286	3.0	3.0
		0.049	4.0		0.107	4.5		0.209	3.0		0.291	3.0	
		0.05	5.0		0.099	4.0		0.221	4.0		0.330	3.0	
	Two Arcs	0.049	5.0	4.8	0.098	4.0	4.0	0.196	4.0	3.7	0.320	3.0	3.2
		0.049	5.5		0.109	4.0		0.223	3.5		0.310	3.5	
		0.051	4.0		0.100	4.0		0.214	3.5		0.300	3.0	
	Four Arcs	0.05	5.0	4.8	0.098	5.0	4.5	0.202	3.0	3.3	0.269	3.0	3.3
		0.048	5.0		0.097	4.5		0.231	3.0		0.298	3.5	
		0.051	4.5		0.096	4.0		0.208	4.0		0.301	3.5	

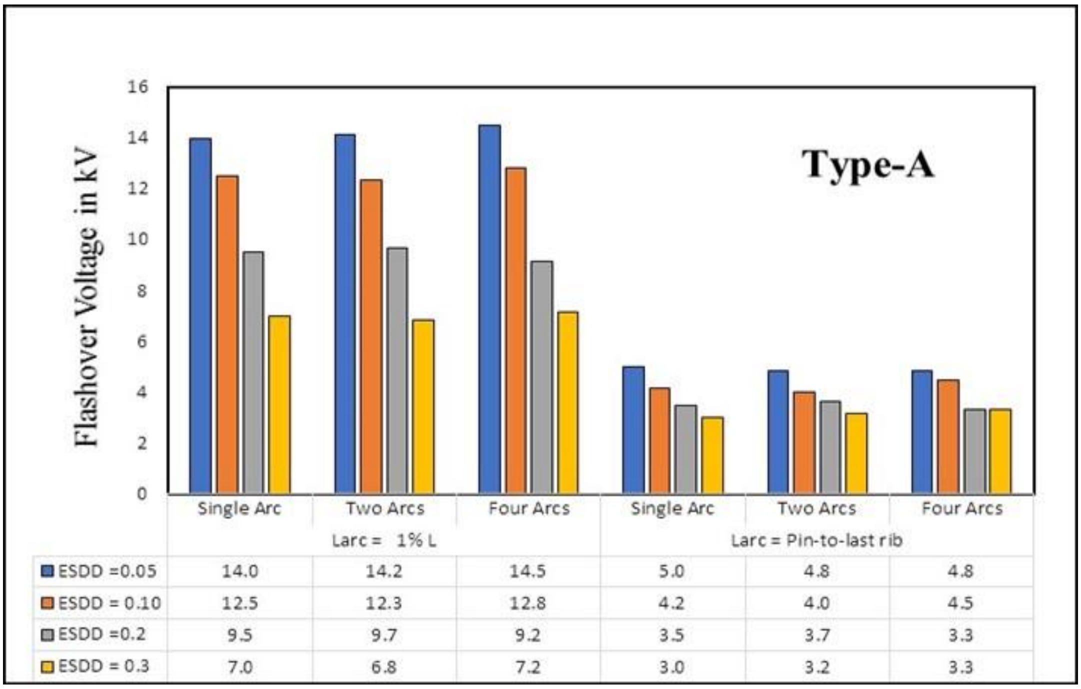


Fig. 2: Comparison of Flashover voltages obtained with the presence of single, two and four arcs at two different arc lengths of Type-A insulator for four ESDD levels.

Table. 3: Flashover voltages with the initiation of Single, Two and Four Arcs on polluted surface of Type-B insulator at two arc lengths for four ESDD levels

Arc Length	No. of Arcs initiated on the surface	ESDD in mg/cm^2	FOV in kV	Mean FOV in kV	ESDD in mg/cm^2	FOV in kV	Mean FOV in kV	ESDD in mg/cm^2	FOV in kV	Mean FOV in kV	ESDD in mg/cm^2	FOV in kV	Mean FOV in kV
= Arc length = 1% Creepage Length	Single Arc	0.051	21.0	21.0	0.107	18.0	17.3	0.212	14.0	14.5	0.291	11.0	11.7
		0.051	22.0		0.099	17.0		0.209	14.5		0.321	12.0	
		0.05	20.0		0.114	17.0		0.221	15.0		0.286	12.0	
	Two Arcs	0.05	20.0	20.7	0.107	17.0	17.2	0.210	15.0	14.2	0.291	11.0	11.0
		0.047	22.0		0.099	18.0		0.200	13.0		0.330	10.0	
		0.049	20.0		0.098	16.5		0.212	14.5		0.320	12.0	
	Four Arcs	0.048	20.0	20.3	0.109	17.0	16.8	0.209	13.5	14.5	0.310	12.0	11.5
		0.052	19.0		0.100	16.5		0.221	14.5		0.300	12.0	
		0.049	22.0		0.098	17.0		0.196	15.5		0.269	10.5	
Arc length = Pin-to-last rib	Single Arc	0.051	6.0	5.7	0.097	5.0	4.5	0.223	3.0	4.0	0.298	3.5	3.2
		0.051	6.0		0.096	4.5		0.214	4.5		0.301	3.0	
		0.049	5.0		0.097	4.0		0.202	4.5		0.330	3.0	
	Two Arcs	0.048	5.0	5.5	0.102	4.0	4.2	0.231	4.0	4.2	0.320	3.5	3.3
		0.051	5.5		0.106	3.5		0.223	4.0		0.310	3.5	
		0.05	6.0		0.097	5.0		0.214	4.5		0.300	3.0	
	Four Arcs	0.051	5.0	5.2	0.109	5.0	4.3	0.202	3.5	3.8	0.269	3.5	3.5
		0.05	4.5		0.096	4.5		0.231	4.0		0.298	3.5	
		0.05	6.0		0.109	3.5		0.214	4.0		0.300	3.5	

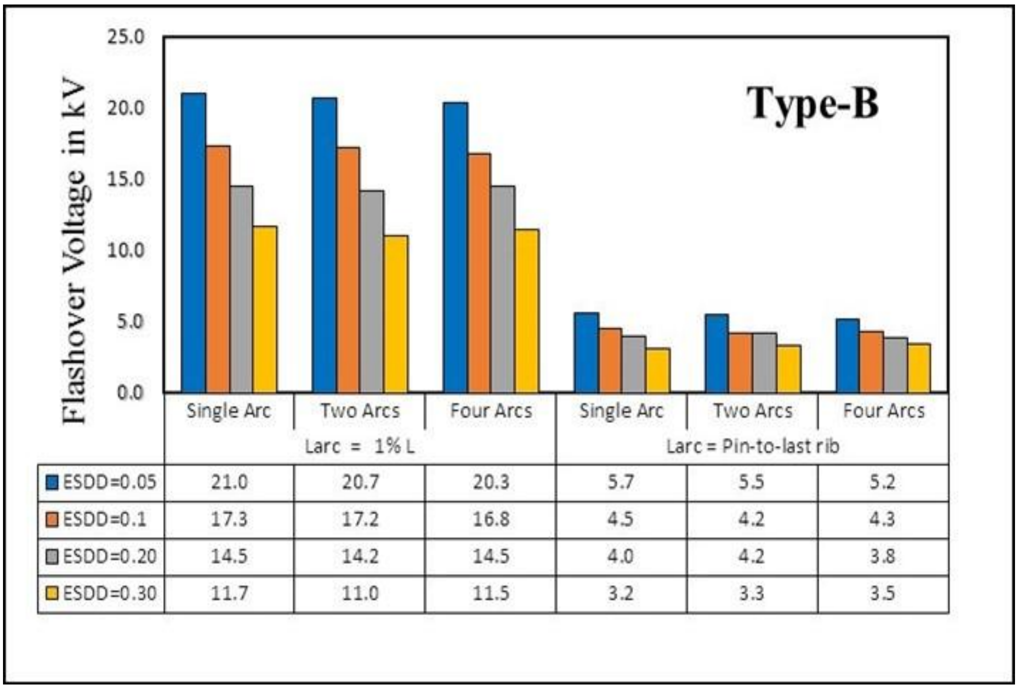
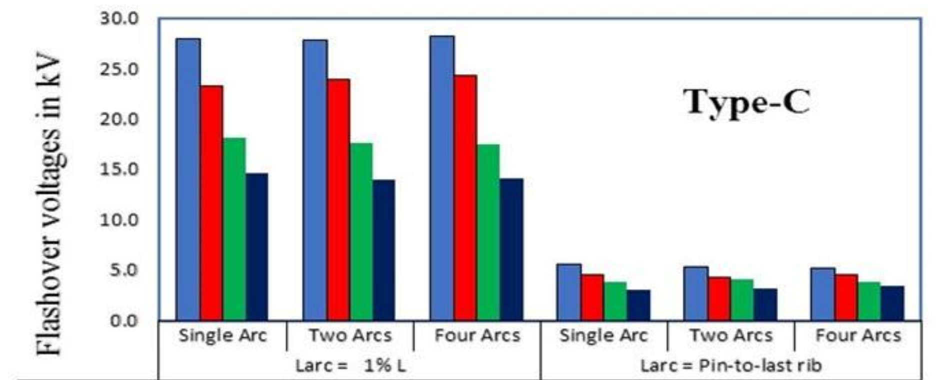


Fig. 3: Comparison of Flashover voltages obtained with the presence of single, two and four arcs at two different arc lengths of Type-B insulator for four ESDD levels.

Table. 4: Flashover voltages with the initiation of Single, Two and Four Arcs on polluted surface of Type-C insulator
At Two Arc Lengths For Four Esdd Levels

Arc lengths	No. of Arcs initiated on the surface	ESDD in mg/cm^2	FOV in kV	Mean FOV in kV	ESDD in mg/cm2	FOV in kV	Mean FOV in kV	ESDD in mg/cm^2	FOV in kV	Mean FOV in kV	ESDD in mg/cm^2	FOV in kV	Mean FOV in kV
Arc length = 1% Creepage Length	Single Arc	0.047	19.0	18.7	0.098	17.0	16.3	0.213	13.0	12.8	0.276	11.0	10.0
		0.049	18.0		0.098	15.0		0.198	12.5		0.291	10.0	
		0.051	19.0		0.109	17.0		0.214	13.0		0.321	9.0	
	Two Arcs	0.051	20.0	19.0	0.098	16.0	16.7	0.232	13.0	13.2	0.312	9.5	10.2
		0.05	18.0		0.098	17.0		0.212	14.0		0.270	10.0	
		0.05	19.0		0.113	17.0		0.209	12.5		0.286	11.0	
	Four Arcs	0.047	18.0	18.7	0.114	18.0	17.0	0.221	12.0	13.0	0.298	10.0	10.3
		0.049	19.0		0.107	16.0		0.210	13.0		0.291	10.0	
		0.048	19.0		0.099	17.0		0.200	14.0		0.321	11.0	
Arc length = Pin-to-last rib	Single Arc	0.052	6.0	5.3	0.114	5.0	4.7	0.212	4.0	4.0	0.286	4.0	3.3
		0.049	5.0		0.107	5.0		0.209	4.5		0.291	3.0	
		0.05	5.0		0.099	4.0		0.221	3.5		0.330	3.0	
	Two Arcs	0.049	6.0	5.5	0.098	4.0	4.8	0.196	4.0	3.8	0.320	3.0	3.2
		0.049	5.5		0.109	5.5		0.223	4.0		0.310	3.5	
		0.051	5.0		0.100	5.0		0.214	3.5		0.300	3.0	
	Four Arcs	0.05	6.0	5.3	0.098	5.0	5.2	0.202	4.5	4.0	0.269	3.0	3.3
		0.048	5.0		0.097	4.5		0.231	3.5		0.298	3.5	
		0.051	5.0		0.096	6.0		0.208	4.0		0.301	3.5	



	Single Arc	Two Arcs	Four Arcs	Single Arc	Two Arcs	Four Arcs
	Larc = 1% L			Larc = Pin-to-last rib		
ESDD = 0.05	28.0	27.8	28.3	5.7	5.3	5.2
ESDD = 0.10	23.3	24.0	24.3	4.5	4.3	4.5
ESDD = 0.20	18.2	17.7	17.5	3.8	4.2	3.8
ESDD = 0.30	14.7	14.0	14.2	3.0	3.2	3.5

Fig. 4: Comparison of Flashover voltages obtained with the presence of single, two and four arcs at two different arc lengths of Type-C insulator for four ESDD levels.

REFERENCE

[1]. Badachi, Chandrasekhar A., and Pradipkumar Dixit. "Analytical model to predict the pollution flashover voltages of porcelain disc insulators." Acta Electrotechnik et Informatic a 15.1 (2015): 42-49.

[2]. F.A.M. Rizk, "Mathematical Models for Pollution Flashover", Electra, Vol. 78, pp. 71-103, 1981.

[3]. Slam, M. El-A., Abderrahmane Beroual, and H. Hadi. "Analytical computation of discharge characteristic constants and critical parameters of flashover of polluted insulators." IEEE Transactions on Dielectrics and Electrical insulation 17.6 (2010).

[4]. Anjana, S., and C. S. Lakshminarasimha. "Computation of flashover voltages of polluted insulators using dynamic arc model." Sixth International Symposium on High Voltage Engineering. No. 30.09. 1989.

[5]. Sundarajan R. and Gorur R.S., "Dynamic arc Modelling of Pollution flashover of insulators under dc voltage", IEEE EI, vol.28, No.2, April 1993, pp.209-218.

[6]. N. Dhahbi-Megriche and A. B´eroual, ''Flashover Dynamic Model of Polluted Insulators under ac Voltage'', IEEE Trans. Dielectric. Electr. Insul. Vol.7, pp. 283_289, 2000.

[7]. Rizk, Farouk AM, and D. H. Nguyen. "Digital simulation of source-insulator interaction in HVDC pollution tests." IEEE transactions on power delivery 3.1 (1988): 405-410.

[8]. Cheng, T. C., and H. I. M. Nour. "A Study on the Profile of HVDC Insulators." IEEE Trans. on Elect. Insul 24.1 (1989): 113-117.

[9]. Zmajkovič, Peter. Modélisation du contournementélectrique et validation expérimentale du mécanismeproposé pour l'extension de la décharge. Diss. Toulouse 3, 1996.

[10]. Taheri, S., M. Farzaneh, and I. Fofana. "Improved dynamic model of DC arc discharge on ice-covered post insulator surfaces." IEEE Transactions on Dielectrics and Electrical Insulation 21.2 (2014): 729-739.

[11]. Cheng, T. C., C. Y. Wu, and H. Nour. "DC interfacial breakdown on contaminated electrolytic surfaces." IEEE Transactions on Electrical Insulation 6 (1984): 536-542.

[12]. Cheng, T. C., and H. I. M. Nour. "A study on the profile of HVDC insulators-mathematical Modeling and design considerations." IEEE Transactions on Electrical Insulation24.1 (1989): 113-117.

[13]. Dhahbi-Megriche, Nabila, and Abderrahmane Beroual. "Self-consistent multi-arcs dynamic model for high voltage polluted insulators." IEEE Transactions on Dielectrics and Electrical Insulation 23.5 (2016): 2899-2907.

[14]. Standard, I. E. C. "60507." Artificial pollution tests on high voltage insulators to be used on AC systems (1991).

[15]. H C Mouneswarachar and PradipDixit, Experimental Investigation on Role of Arc Foot Radius on pollution Flashover Voltage of Porcelain Disc Insulators",Journal of Electrical Engineering: Volume 17 / 2017 - Edition: 2, pp 240-246

1H.C. Mouneswarachar . "Role of Multiple Arcs on Flashover of Contaminated Porcelain Disc Insulators." International Journal Of Engineering Research And Development , vol. 14, no. 01, 2018, pp. 05–11.