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On The Effect of Insulator Angle With Respect to the Cross Arm on the Distribution of Lightning Electric Fields

Mahdi Izadi[1*], Mohd Zainal Abidin Ab Kadir[2], Mohamad Syahmi Ab Rahman[3], Mohammad Rezazadeh Mehrjou[4], Maryam Hajikhani[5]
[1,2,3,4,5]Centre for Electromagnetic and Lightning Protection Research (CELP), University Putra Malaysia, Malaysia
[1]Electrical Department, Islamic Azad University, Firoozkooh Branch, Iran
Email: [1*]aryaphase@yahoo.com

***Abstract*—In this paper, the effect of insulator angle with respect to the cross arm on the electrical performance of a polymer insulator under lightning impulse voltage condition was studied and the results discussed accordingly. An insulator angle with the cross arm of other than 90° is usually due to defects in the connections or being under pressure from the line angles and it can be an important issue for the stability of the line against lightning. The results show that the insulator angle can play an important role in increasing the electric fields around insulator and thus increase the chance of electrical breakdown of the insulator.**

Keywords-Polymer insulator, Lightning, Electric fields

I. INTRODUCTION

Consideration of the electrical performance of polymer insulators under lightning conditions is one of the important issues necessary to take into account in order to increase the insulation level of the line and also the stability of power lines overall [1, 2]. Several studies have been undertaken to evaluate the effects of humidity and pollution on the electrical performance of insulators [3-7]. The angle of the insulator with respect to the cross arm can also have an effect on the field distribution along the insulator. It should be mentioned that an incorrect insulator angle to the cross arm is usually caused by defects in the connections, a lack of periodic control of fillings and also the pressure caused by the line angle. In this paper, the electrical performance of a 10 kV polymer insulator under different angles with respect to the cross arm was considered and two samples of impulse voltage were set as voltage sources. Moreover, the electric fields at different observation points along the insulator were evaluated and the results were discussed accordingly. The basic assumptions in this study are listed as follows:

1- The weather conditions are dry.
2- The pollution effect is ignored.
3- The potential of the cross arm is zero.

II. POLYMER INSULATOR

Figure 1 shows pictures of two distribution lines in which the polymer insulators have an angle with respect to the cross arm of other than 90°. In this paper, the performance of an insulator with different angles under lightning impulse voltage conditions will be studied.

Figure 1. Two real medium voltage lines

A 10 kV polymer insulator was considered as illustrated in Figure 2 and the insulator parameters were as listed in Table I.

Figure 2. A real 10 kV polymer insulator

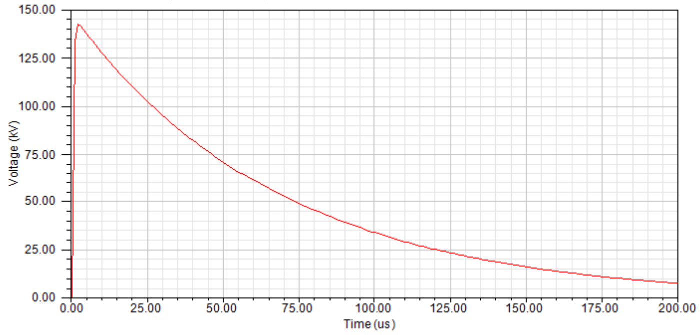
TABLE I. Polymer insulator specifications

Part of Insulator	Dimensions
Shed diameter (mm)	148/118
Shed-to-shed spacing (mm)	50
Structure Height (mm)	250
Min Nominal Creepage distance (mm)	420

III. Results and Discussion

Two different impulse voltage wave shapes were applied on the insulator under different angles with respect to cross arm as shown in figure.3. It should be mentioned that the case a is a standard wave shape (1.2/50us) with the voltage peak that was obtained from experimental work in the high voltage lab on the breakdown voltage and case b is evaluated lightning induced voltage on a typical line with 10m height and 50m distance with respect to lightning channel where the applied current was illustrated in figure.4. [8].

Case a: 142kV (1.2/50us)



Case b: 160kV

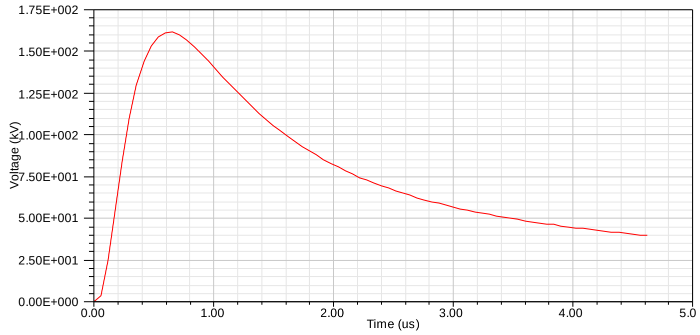


Figure 3. Applied impulse voltage wave shapes (case a: standard wave shape, case b: lightning induced voltage wave shape)

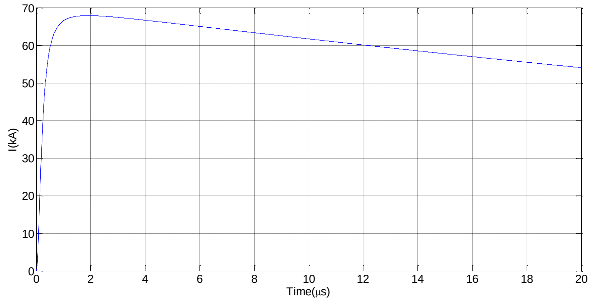


Figure 4. The applied return stroke current wave shape for evaluation of lightning induced voltage on typical distribution line

Figure 5 illustrates the observation points along the polymer insulator. Moreover, the material parameters of the insulator are tabulated in Table II [9, 10]. Moreover, the model was simulated in the Maxwell software where the geometry of model was demonstrated in figure.6.

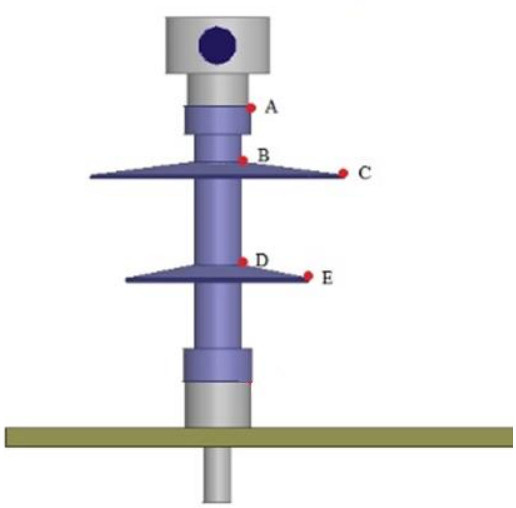


Figure 5. The geometry of the observation points

TABLE II. Electrical parameters of the polymer insulator

Parts / Material	Relative permittivity (ε_r)	Relative Permeability (μ_r)	Volume Conductivity (σ) S/m
Fitting Aluminum	1	1.000021	3.8×10^{7}
Sheds Silicone	3	1	1×10^{-17}
Core Fiberglass	5	1	1×10^{-12}

Figure 7 shows the electric field profiles for case 'a' under different angles with respect to cross arm. As illustrated in figure 7, by decreasing of angle the values of electric field in the air between the insulator and cross arm will be increased and the chance of electrical breakdown will be significantly increased.

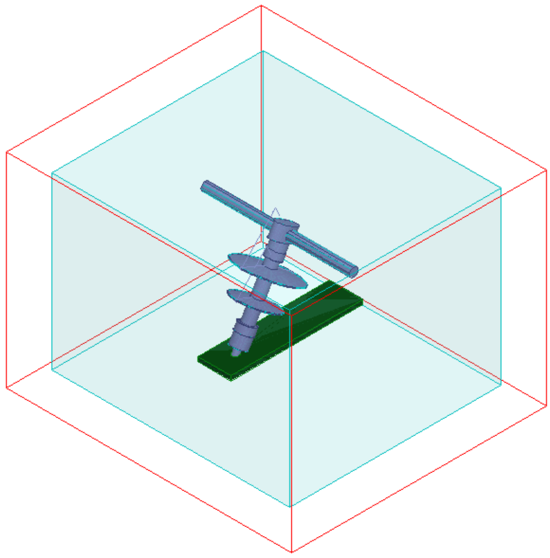


Figure.6. Geometry of model

Likewise, the values of electric field and current density at different parts of insulator (based on figure.5) were listed in Table.III. The results illustrate that the angle value has an inverse relationship with the values of electric filed on the insulator surface and it is significantly effective on the values of charge density at different observation points on the insulator surface.

Table III. Evaluated electrical parameters for case a

Parameters	Points of Measurement	Angle		
		90°	60°	45°
Max Electric Field (kV/m)	A	1933.50	1910.90	2222.10
	B	1740.20	1767.00	2013.70
	C	393.42	559.65	694.21
	D	847.61	976.12	988.29
	E	611.04	654.30	701.48
Current Density (Am^{-2})	A	81.87	80.12	84.96
	B	156.65	157.47	167.25
	C	23.13	7.59	7.88
	D	34.01	35.52	34.11
	E	4.52	4.77	5.04

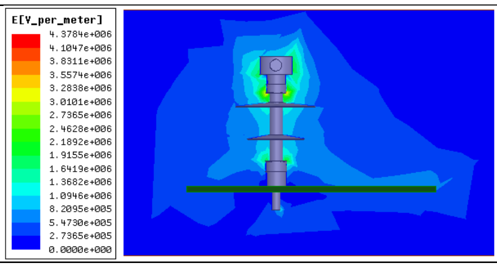
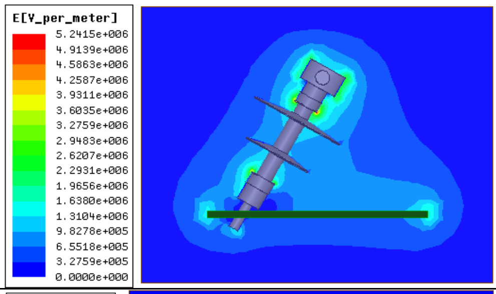
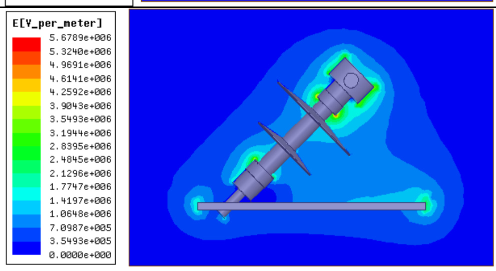
Inclination Angle	Electric Field Distribution
90°	
60°	
45°	

Figure.7. Electric field profiles under different angles for case a

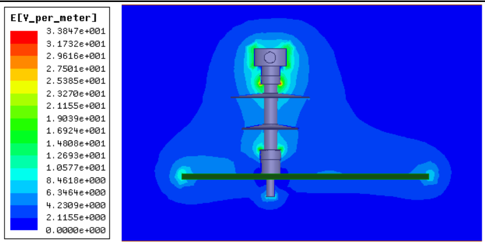
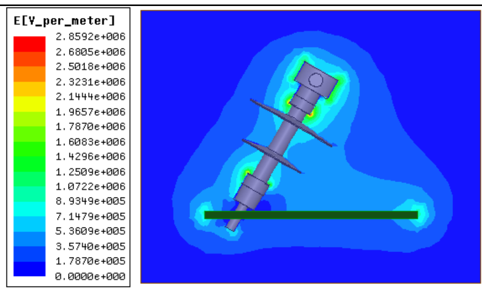
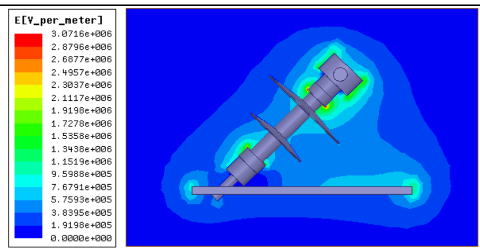
Inclination Angle	Electric Field Distribution
90°	
60°	
45°	

Figure.8 Electrical field profiles under different angles for case b

Figure.8 illustrates the electric field profiles of insulator for case b where it shows that by reducing of the value insulator angle, the electric field values at the air gap between insulator and cross arm were increased and it can be directly effective on increasing the chance of breakdown in that area.

Table IV.Evaluated electrical paramaters for case b

Parameters	Points of Measurement	Angle		
		90°	60°	45°
Max Electric Field (kV/m)	A	2183.90	2147.10	2351.00
	B	1980.01	2392.40	2667.70
	C	433.09	544.18	822.72
	D	1120.60	1188.90	1275.8
	E	662.19	732.22	787.03
Current Density (Am^{-2})	A	167.57	163.14	168.87
	B	368.98	147.41	158.19
	C	63.45	73.33	32.24
	D	46.23	48.45	51.44
	E	23.12	25.85	27.77

Likewise, the values of electric field and current density at different parts on the insulatro were tabulated in table IV. Table IV demonstrates that the insulator angle can be effective on the values of electric field and charge density on the surface of insulator. It should be mentioned that the values of charge density on the insulator surface can be effective on the surface breakdown.The results show that the values of the electric fields were affected by the insulator angle with respect to the cross arm. Therefore, in order to increase the insulation level of the line against this effect, the difference percentage of electrical parameters (between 90 degrees and possible angles) can be evaluated and taken into account for designing new lines or improving existing lines.

IV. CONCLUSION

In this paper, the effect of the insulator angle with respect to the cross arm was considered and the values of the electric fields under two samples of impulse voltage were evaluated and the results discussed accordingly. The results show that the values of the electric fields and charge density are affected by the insulator angle, such that by reducing the insulator angle the chance of electrical breakdown in the air gap between insulator and cross arm will be increased. Moreover, by evaluating and taking into account the percentage difference in the results for different angles, the overall insulation level of the line will be increased, which should be considered in the design of new lines and when improving existing lines.

REFERENCES

[1] W. A. Chisholm, "New challenges in lightning impulse flashover modeling of air gaps and insulators," IEEE Electrical Insulation Magazine, vol. 26, pp. 14-25, 2010.

[2] C.-j. WANG, L.-y. ZHU, S.-c. JI, and Q.-g. ZHANG, "Present and Development of Lightning Protection for HV Transmission Lines and Substations [J]," Insulators and Surge Arresters, vol. 3, p. 017, 2010.

[3] B. Du and Y. Liu, "Pattern analysis of discharge characteristics for hydrophobicity evaluation of polymer insulator," Dielectrics and Electrical Insulation, IEEE Transactions on, vol. 18, pp. 114-121, 2011.

[4] M. Abd Rahman, M. Izadi, and M. Ab Kadir, "The Electrical Behaviour of Polymer Insulator under Different Weather Conditions," in Applied Mechanics and Materials, 2015, pp. 60-64.

[5] M. Abd Rahman, M. Izadi, and M. Ab Kadir, "Influence of air humidity and contamination on electrical field of polymer insulator," in Power and Energy (PECon), 2014 IEEE International Conference on, 2014, pp. 113-118.

[6] S. Chandrasekar, C. Kalaivanan, G. C. Montanari, and A. Cavallini, "Partial discharge detection as a tool to infer pollution severity of polymeric insulators," Dielectrics and Electrical Insulation, IEEE Transactions on, vol. 17, pp. 181-188, 2010.

[7] H.-f. GAO, L.-M. FAN, Q.-f. LI, Z.-y. SU, Y. LI, X.-L. LI, et al., "Comparative Analysis on Pollution Deposited Performances of Insulators on the±500 kV Gao-Zhao DC Transmission Line [J]," High Voltage Engineering, vol. 3, p. 022, 2010.

[8] M. Izadi, A. Kadir, M. Z. Abidin, C. Gomes, and W. F. W. Ahmad, "An analytical second-FDTD method for evaluation of electric and magnetic fields at intermediate distances from lightning channel," Progress In Electromagnetics Research, vol. 110, pp. 329-352, 2010.

[9] T. Doshi, "Performance Analysis of Composite Insulators up to 1200 kV ac using," Arizona State University, 2010.

[10] M. Santo Zarnik and D. Belavic, "An experimental and numerical study of the humidity effect on the stability of a capacitive ceramic pressure sensor," Radioengineering, 2012.