XVII International Symposium on High Voltage Engineering, Hannover, Germany, August 22-26, 2011

EFFECT OF CORONA RING DESIGN OF POLYMER INSULATORS FOR UHV TRANSMISSION LINE

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Abstract: Recently, the amount of the usage of polymer insulators for transmission line is sharply increased by reason of the economical benefits and excellent contamination performance. However, the number of different kind of polymer insulators manufactured by different vendors is supplied to utilities without enough consideration of corona ring design to reduce local electric field for preventing corona discharges. Electric field distribution along insulator surface has been calculated for different types of corona rings supplied for commercial polymer insulators by use of 3D e-field computational software. With this, it has been verified that each corona ring design can be satisfied with the recommendation of EPRI.

1 INTRODUCTION

Since corona ring (or grading ring) installed for preventing corona discharges play a role to decrease e-field which has exceeded over the critical value, the design and location are important for site application.

One side of end fitting of the insulator is connected directly to a power line which has high potential and the other side is grounded by tower. Although generic recommendations may be made by manufacturer, misapplication of key parameters such as ring size, shape and location can be result in continuing corona activities along the insulator surface. Continuing corona activities at the end fitting can be result in severe degradation of the end fitting seal or internal tracking of polymer insulator which are the reason of sudden failure. Therefore the shape and dimension of corona ring should be well designed to perform the role reducing the potential along the insulator surface.

In addition to that, incorrect installation of corona ring results in occurrence of end fitting corona discharge activity. In general, it is preferable that the corona ring can be selected based on e-field modelling together with test in accordance with electric field measurement [1].

With these regards, in this paper, e-field distribution has been calculated for different types of corona rings supplied for commercial 345kV polymer insulators by use of 3D e-field computational software.

In order to find appropriate design scheme, a few kind of different corona ring size and shape are applied to commercial line configuration. To evaluate the design scheme, it has been verified that the electric fields along the insulator surface are satisfied with the recommended e-field value by EPRI guidance [1].

General outer shape of polymer insulator is shown in Figure 1.

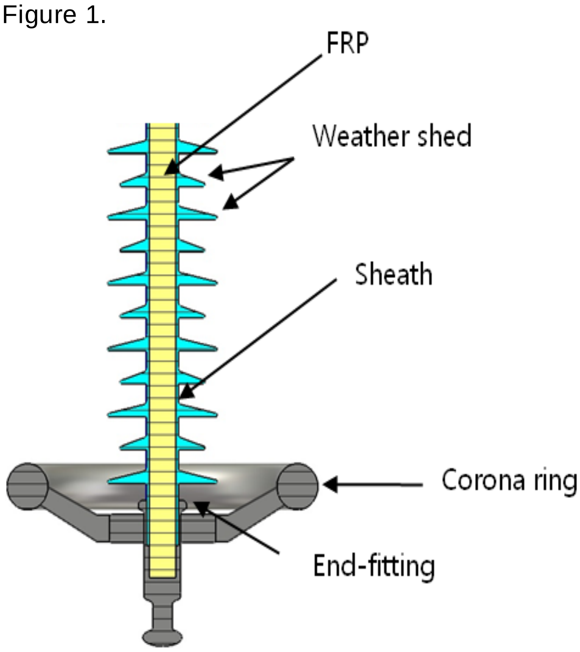


Figure 1: General outer shape of polymer insulator (manufacturer D)

2 EFFECT OF CORONA RING POSITION

Figure 2 and Figure 3 are examples of the wrong installation effect of corona ring.

It can be seen that the corona discharges occurred outside of the ring when the corona ring has been correctly installed.

However, in Figure 3, when the corona ring has been installed 2cm below of correct position, corona discharges continuously occurred at the end fitting. With this result, it can be noticed that the incorrect installation of corona ring can be result in sudden failure of the polymer insulators.

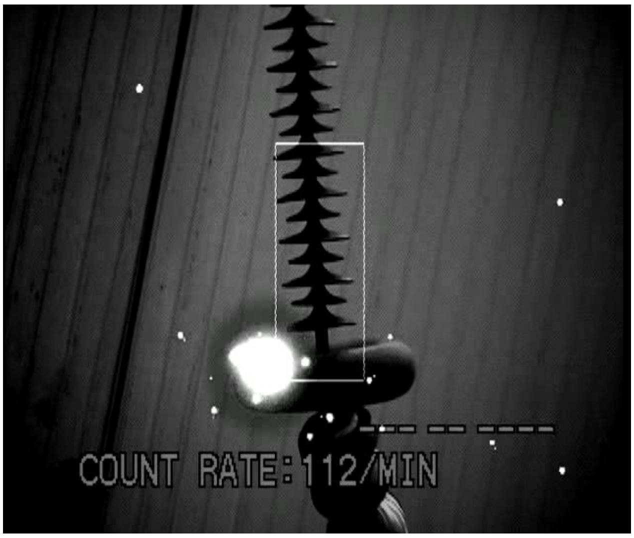


Figure 2: Correct position of corona ring

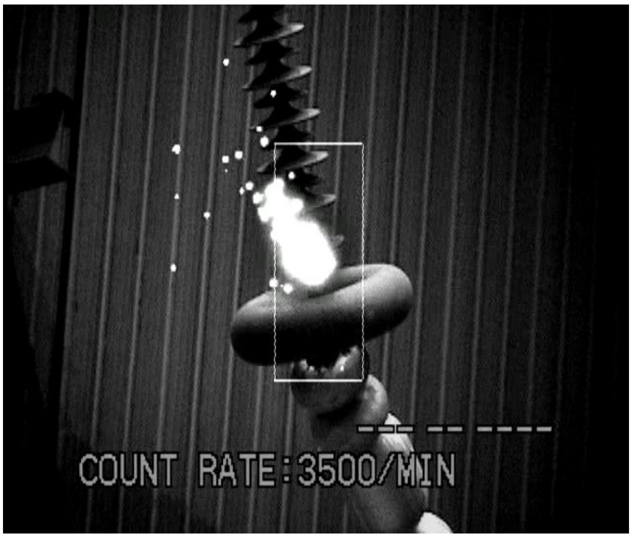


Figure 3: Incorrect corona ring position (2cm below of correct position)

3 E-FIELD CALCULATION SETUP

Among the commercially available software packages, in this paper, a mathematical method was used for determining e-field distribution: the FDTD algorithm. Normally, in many cases, Finite Element Method (FEM) is used to read electronic data in this research area.

However, in this paper, Finite Difference Time Domain (FDTD, commercialized by CST Ltd.) method was used. In order to obtain accurate results, the following needs to be accounted for the model [1][2]:

1. Three-dimensional matter of the problem
2. Dimension and material properties of the polymer insulator
3. Dimensions and position of the corona ring
4. Dimensions and material properties of the structure
5. Conductor bundle
6. Hardware that attaches the polymer insulator to the conductor and structure
7. Nearby phases
8. The presence of the earth (i.e., ground plane) and the height above
9. Voltages (potential) of the components being modeled

Permittivity of the silicon rubber and FRP rod in accordance with manufacturers is listed in Table 1.

Table 1: Permittivity of the part of the subjected insulators

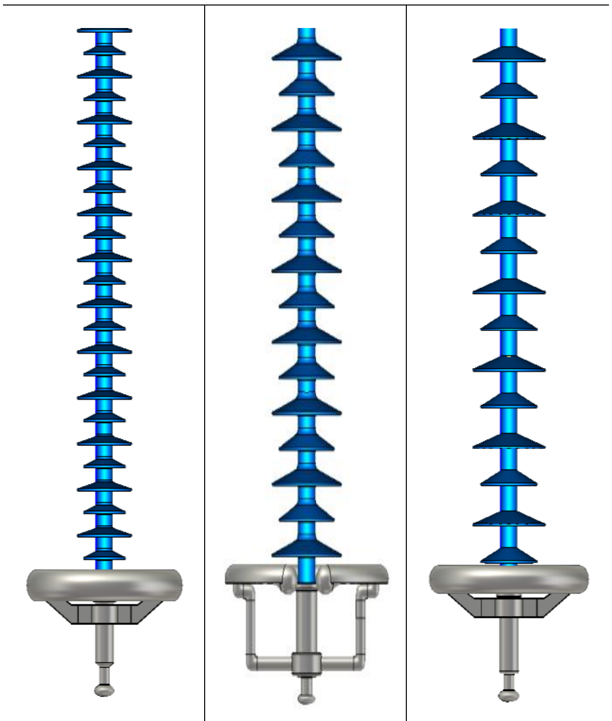
	Permittivity		
Manufacturer	D	X	Z
silicone	3.2	4.2~4.3	3
FRP	4.4	3~6	3

All of the physical length of the polymer insulators is 3,315mm but the shape of the shades differs to manufacturers as can be seen in Table 2 and Figure 4. End-fitting, for example, is designed with 22mm socket according to IEC60120 with ball shape in accordance with the weight increase of the insulator. Detail dimensions on the shape and the components part of the housing are noted in Table 2.

Table 2 – Dimensions of the subjected polymer insulators in accordance with manufacturers

	Dimensions		
Manufacturer	D	X	Z
Length	3315mm	3315mm	3315mm
Housing thickness	39mm	39mm	38mm
Core rod diameter	32mm	30mm	30mm
Weather shed Diameter(mm) (major/minor)	134/104	150/120	170/133
Shed number	85	59	48
Shed spacing (Between Major Sheds)	71mm	98mm	122mm
Corona ring Diameter(mm) (outer/inner)	380/280	350/250	370/270

In Figure 4, typical schematic appearances are shown of the simulated polymer insulators in accordance with manufacturer. As can be seen in the figure, all of corona rings has different shapes and dimensions. Line voltage was 345kV with ACSR 480SQ (R-type) conductor and the number of meshes is fixed for simulation with 15,000,000.



D	X	Z

Figure 4: Polymer insulators design

4 SIMULATION RESULTS

4.1 Comparison of FEM 2D and FDTD 3D

Figure 5 and Figure 6 are the comparative result by use of FEM (MAXWELL 2D) and FDTD 3D (CST Ltd.) simulation method for the polymer insulator supplied by company D. As can be seen in the result of the FEM and FDTD result, for the both cases, the maximum e-field is around 1.4kV/mm with corona ring attachment.
However, the e-field distribution along the surface is different. It is considered that the differences are owing to the different simulation environment. In other words, in this study, 2-dimensional (2D) FEM software and 3-dimensional (3D) FDTD software are used respectively.

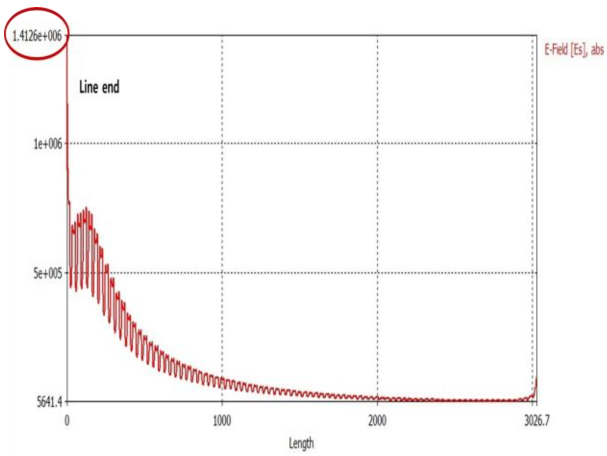


Figure 5: E-field distribution along the insulator surface (FDTD 3D)

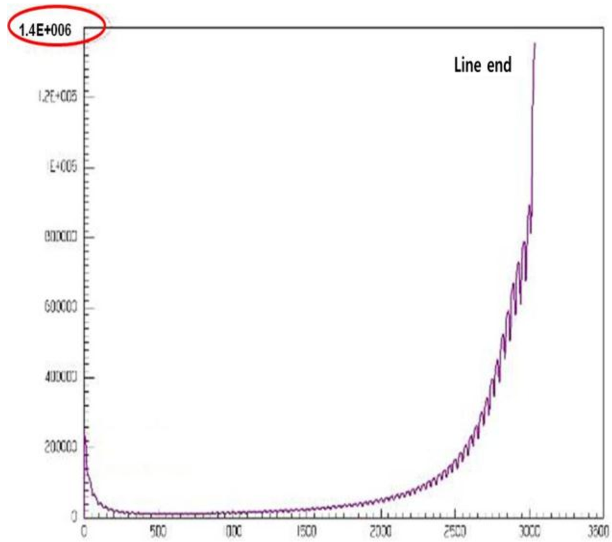


Figure 6: E-field distribution along the insulator surface (FEM 2D)

4.2 E-field distribution along the surface of each insulators

E-field distribution along the insulator surface has been compared for each insulators supplied by manufacturers D, X and Z.

Those results are plotted in Figure7 through Figure 12 respectively.

From the results, for the all cases of with and without corona ring, it can be noted that the e-field along the insulator surface exceeded EPRI guidance level 0.42kV/mm.[3] Maximum e-field at the triple point is noted in Table 3 in accordance with manufacturers.
In addition to that, e-field usually concentrated at the triple junction point which different materials of metal end fitting, silicon rubber housing and FRP rod come across.

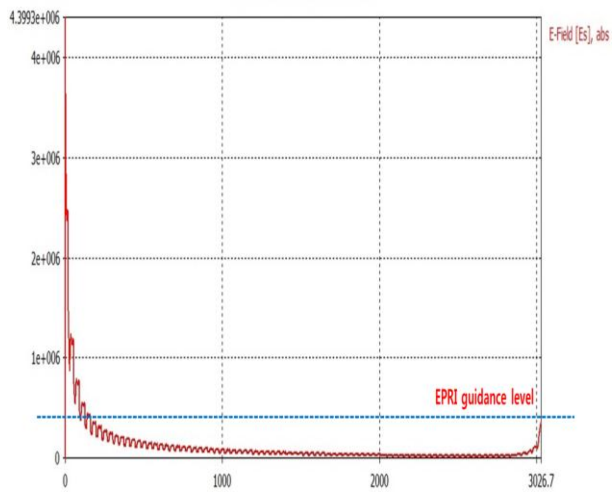


Figure 7: Without corona ring (manufacturer D)

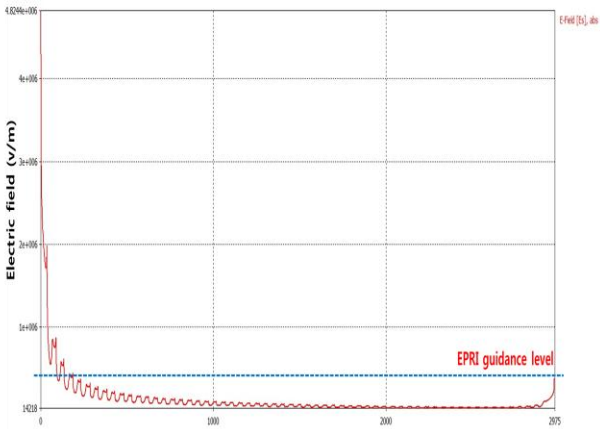


Figure 8: Without corona ring (manufacturer X)

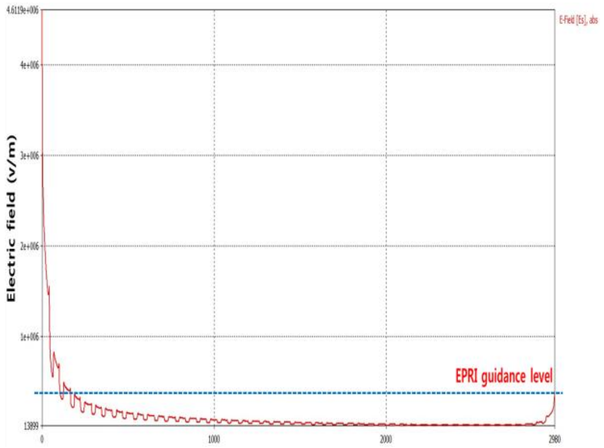


Figure 9: Without corona ring (manufacturer Z)

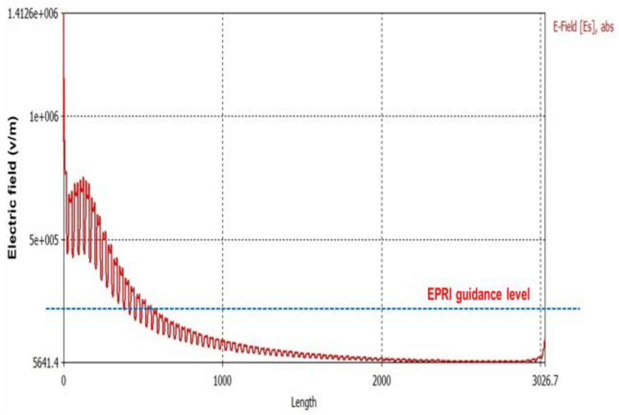


Figure 10: With corona ring (manufacturer D)

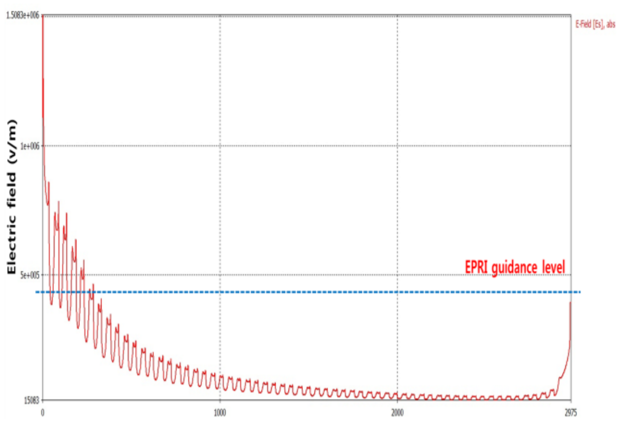


Figure 11: With corona ring (manufacturer X)

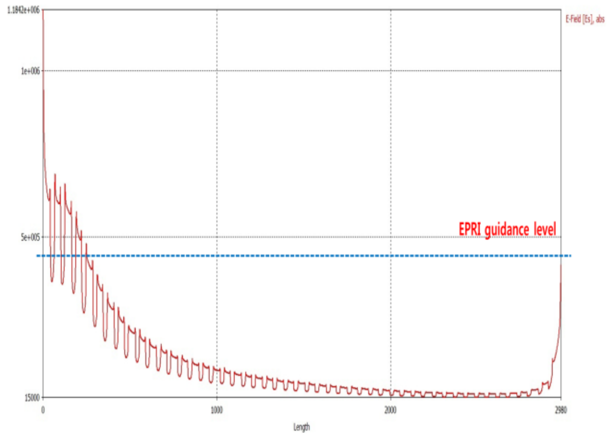


Figure 12: With corona ring (manufacturer Z)

Table 3: Maximum e-field at the triple point

	Maximum e-field (kV/mm)		
Manufacturer	D	X	Z
Corona ring	1.412	1.508	1.184
Without Corona ring	4.399	4.824	4.611

4.3 Equipotential distribution of each polymer insulator assemblies

Equipotential distribution is shown with assembly hardware in Figure 13 through 15. As can be noticed in the figures, a high potential emerges at the corner of the assembly hardware and the edge of end fittings.

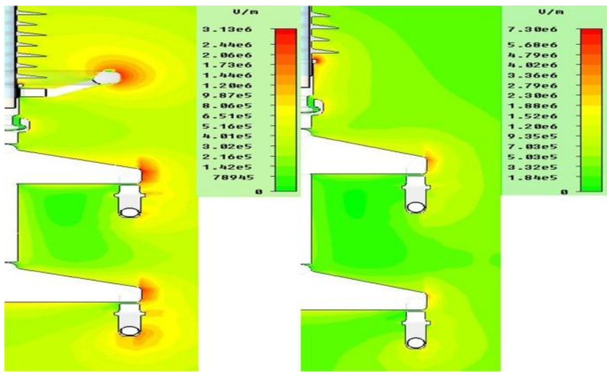


Figure 13: Geometry and contours for insulator end fitting (manufacturer D)

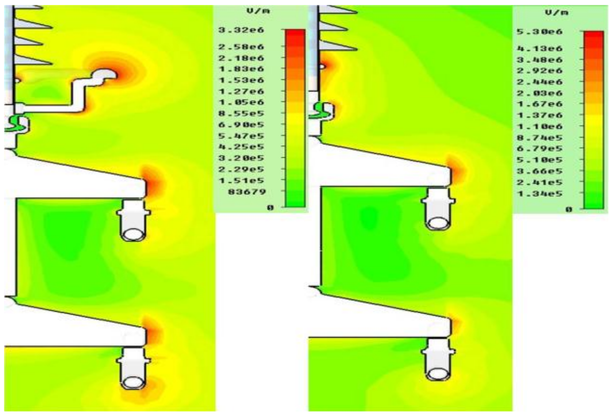


Figure 14: Geometry and contours for insulator end fitting (manufacturer X)

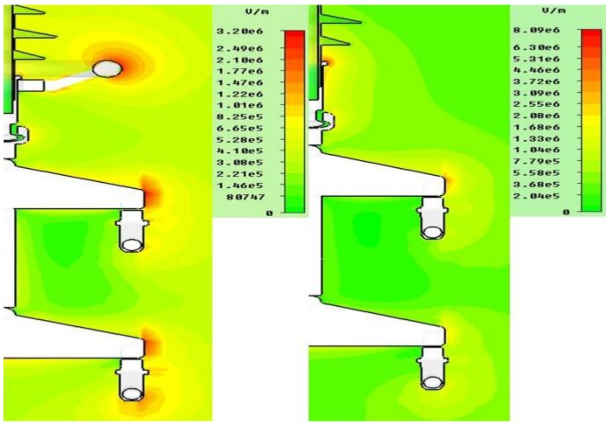


Figure 15: Geometry and contours for insulator end fitting (manufacturer Z)

5 CONCLUSION

In this paper, e-field distribution along the polymer insulator surface with and without corona ring installation has been evaluated with the EPRI guidance level.

All of the e-field level of the insulators surface exceeds the EPRI guidance 0.42kV/mm. Therefore it is needed that the manufacturers should modify the design of corona ring and end fitting to prevent sudden failure and to assure insulator's long term reliability.

In addition to that, it should be noted that the utilities using polymer insulators for UHV transmission line should consider selection and installation of corona ring correctly.

6 ACKNOWLEDGMENTS

7 REFERENCES

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[3] "Application of Corona Rings on 115/138 kV Polymer Transmission Line Insulators," TR 1015917 EPRI. A. Phillips, Oct. 2008.