Effect of Corona Ring Design and Placement on Distribution of Electric Fields on 500 kV Gantry Substation in Indonesia

Yusrizal Afif , I Made Yulistya and Dimas Anton Asfani
Department of Electrical Engineering
Institut Teknologi Sepuluh Nopember (ITS)
Surabaya, Indonesia
afif.yusrizal@gmail.com

Abstract High electric field intensity in string isolators can trigger corona which results in premature aging of the insulator. One solution to overcome this problem is by installing the corona ring, a corona ring will uniform the electric field distribution of the insulator adjacent to the conductor. However, the dimensions and placement of the corona ring will affect the performance of the corona ring in distributing the electric field. In this study, the effect of dimensions and placement of the corona ring on electric field distribution will be discuss. Parameters observed were length, angle and height of corona rings. Parameter length, angle and height are varied from actual initial values by step of 50 mm, 50 mm and 15° with only changing one parameter while the other parameter are kept constants. Simulation by utilizing finite element method (FEM) is used to model the electric field distribution value for each parameter change and find the minimum electric field. As a comparison, changes in corona ring parameters compared to the corona ring design commonly used in 500 kv gantry substation in Indonesia.

Index Terms - Corona ring, Electric field distribution, Finite element method (FEM), Insulator string, Porcelain Insulator.

1. INTRODUCTION

Increasing the voltage level can be minimized losses in the transmission line. However, the higher the voltage level is used, the higher the electric field intensity on the ceramic insulators string on each transmission tower. High intensity and non uniform electric field cause higher stress on the insulator and cause some disturbances. These disturbances include electromagnetic noises, corona and premature aging in the insulator [1]. Effective solution to minimize the intensity of the electric field in the insulator string by using corona ring. Corona ring can make the distribution of electric field become more uniform, therefore the high local electric field intensity on the insulator nearest the conductor can be minimized [2]. The part of the insulators string that experience the maximum electric field intensity is the insulator that is closest to the conductor. Therefore the corona ring is installed close to the energized end side insulator string section [2].

A lot of research regards to corona ring has been done in order minimize the intensity of the electric field in the insulator string [1-4]. From the researchs, design and placement of the corona ring affect on the value of the electric field distribution on insulator. However, it is becoming a problem if the different countries using different type and placement of corona ring.

The purpose of this study is to analyze changes in the design and placement of the corona ring on the value of the electric field distribution of 500 kV insulators strings. To observe the electric field changes in insulators strings, a simulation with three-dimensional modeling based on Finite Element Method (FEM) is carried out. The modified design parameters focus on the ring length, angle and height of the corona ring. In this study, design of insulator and corona ring commonly used in Indonesia

2. CORONA RING

Corona rings are commonly used in transmission systems to optimize electric field distribution, so that can minimize the occurrence of failures such as breakdown, corona and flash over the insulators string. Corona ring installation has been recommended at a voltage level of 230 kV and higher [5,11].

Table 1 Recommended Corona Ring Instalation by Manufacturer [5,11]

Corona Ring Diameter (mm)	Voltage Rating (kV)			
	230	345	400	500
Line End	203	305	305	381
Tower End	None	None	203	203

However, because of there are no international standards on the design and placement of the corona ring, corona ring installation only follows the recommendations of each manufacturer that has its own design. This is a problem because of there are many designs of corona rings sells in the market, therefore further study for each corona ring design to determine its reability is required consider on its capability to optimize electric field distribution. According some literature, the value of the maximum electric field on the surface of insulator nearest conductor under dry and clean conditions are limited between 350 - 1000 kV / m [6-8]

3. MODEL PARAMETER

The design and dimensions of the insulator string of 500 kV substation on the gantry which is used as the basic design of this simulation is depicted in Figure 1. Dimension of porcelain insulator with ball and pin that used in this simulation based on IEC 120/20 mm standard with electromechanical loads for each insulator is 210 kN [9].

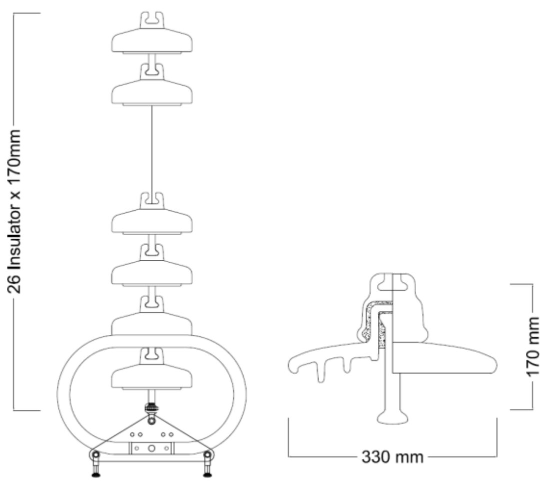


Figure 2 Dimension Insulator string in gantry substation 500 kV and cap-and-pin porcelain insulator unit.

The basic design of the corona ring used in 500 kV gantry substation can be seen on Figure 2. Corona ring using galvanized steel pipe as its material.

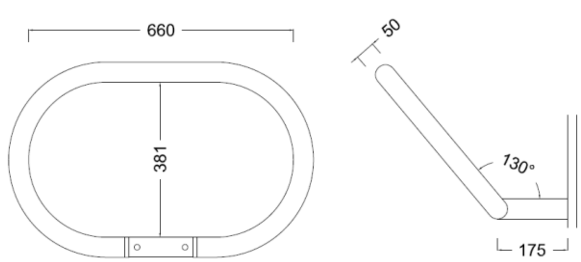
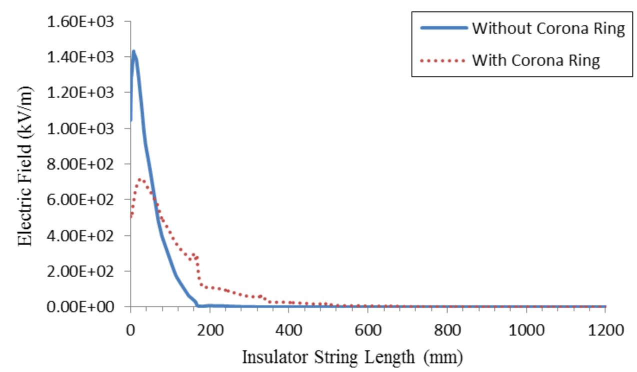


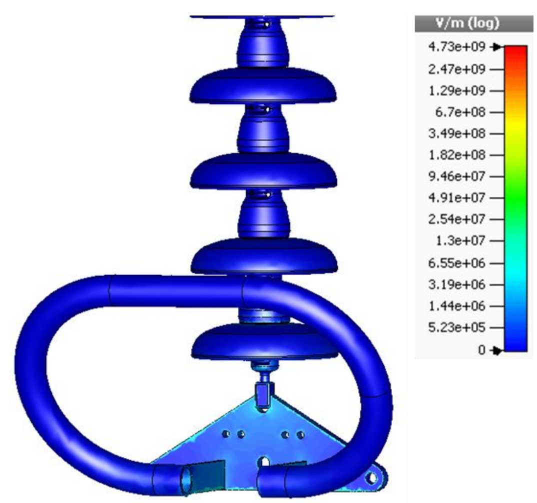
Figure 3 Corona ring and support actual design (mm)

4. CORONA RING EFFECT WITH ACTUAL DESIGN PARAMETER

In order to know how the corona ring optimizing the distribution of the electric field, the simulation has been done by comparing the value of the electric field distribution on the surface of the insulators string with and without corona ring. The results are shown on Figure 3. Its is clearly shown in the figure that the maximum electric field on the insulator string without corona ring is about 1430 kV/m, whereas 719 kV/m on the one with corona ring. Based on actual design by using corona ring the maximum value of electric field can be minimized up to 50%. The intensity of the electric field on insulator strings with a corona ring also became a uniform that can be observed at a distance of 0 – 500 mm. Whereas on insulator strings without corona ring, the electric field intensity stack at a distance of 0 – 200 mm. With the installation corona ring, the distribution of the electric field are becoming more evenly distributed on each insulator.



(a)



(b)

Figure 3 Maximum electric field value for insulator string with and without ring (a), Electric field distribution for corona ring with corona ring along surface of insulator string (b).

5. Simulation of Different Parameter of Corona Ring

In this simulation, the parameters of the corona ring changed i.e. length (L), angle (A) and installation height (H) of the corona ring based on actual corona ring can be seen on Figure 4. Parameter L, H and A are varied from actual initial values by step of 50 mm, 50 mm and 15° with only changing one parameter while the other parameter are kept constants. To avoid corona ring design that exceeds the support or contact with insulation, constraint has been given the for each parameter.

Corona ring Height : 0 mm $\leq H \leq$ 200 mm
Corona ring length : 600 mm $\leq$ L $\leq$ 800 mm
Corona ring Angle : 90° $\leq$ R $\leq$ 150°

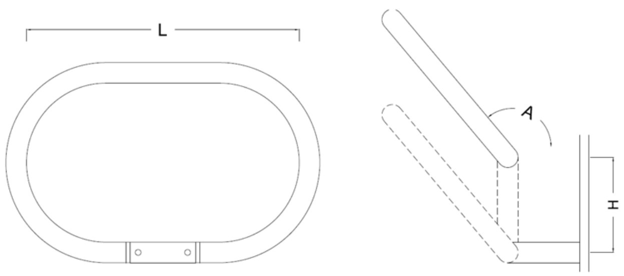


Figure 4 Concept of parameters change used in this simulation

The simulation result show that by increasing the length of the corona ring from 600 mm to 750 mm, the electric field strength decreases to reach minimum value. After that, the value of electric field increasing again at L = 800mm as shown in Figure 5. Compare with maximum electric field value of the actual ring design about 719 kV/m, the value of maximum electric field can be reduced to 652 kV/m by using parameter L = 750 mm and A = 105° for H = 0.

Table 2 Electric field value for the constant height of corona ring with difference corona ring length and angle parameter.

Ring Angle (deg)	Ring Length (mm)				
	600	650	700	750	800
90	895179	757915	714404	659553	706081
105	885462	749688	706650	652394	698417
120	959765	812599	765948	707140	757025
135	924588	782815	737875	681222	729278
150	967816	819414	772373	713071	763375

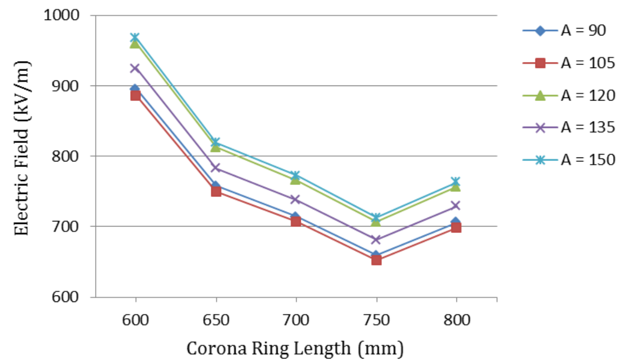


Figure 5 Maximum electric field value vs corona ring length with different corona ring angle and H = 0mm (not changing height support).

When the corona ring angle constant at A = 130°, firstly by increasing the height of corona ring from 0 – 150 mm slightly affact to the maximum electric field value. After corona ring mounting height increased to 200 mm, the maximum electric field reduced to the minimum value about 520 kV/m for L = 700 mm as shown in Figure 6. By using parameter H = 200, L = 700 and A = 130° the maximum electric field can be reduced to 27.6 % of the actual design value.

Table 3 Electric field value for the constant angle of corona ring with difference corona ring length and height parameter.

Ring Height (mm)	Ring Length (mm)				
	600	650	700	750	800
0	729922	731544	712765	725333	562990
50	741784	743432	724347	737120	572139
150	674201	675699	658353	669962	520012
200	724044	725652	707024	719491	558456
250	829239	831081	809746	824025	639593

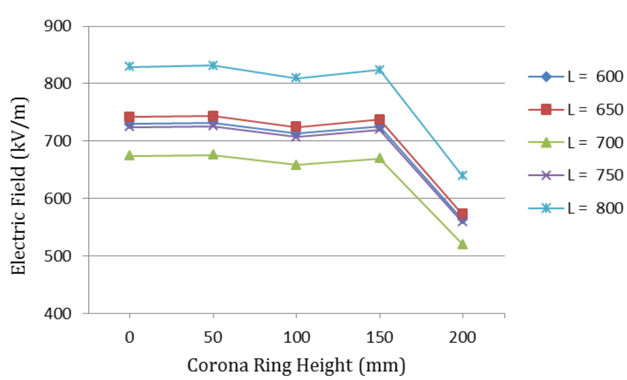


Figure 6 Maximum electric field value vs corona ring Height with different corona ring length and A = 130°.

By increasing height of corona ring with constant ring length parameter doesn't significantly influence to reduce the maximum electric field value. However, when the angle of corona ring increased from 90° - 135°. The maximum value of electric field are drastically decrease to the minimum value about 549 kV/m, afterwards increasing again at A = 150° as shown in Figure 7.

Table 4 Electric field value for the constant length of corona ring with difference corona ring angle and height parameter.

Ring Angle (deg)	Ring Height (mm)				
	0	50	100	150	200
90	873688	920540	930509	959745	934899
105	768690	809911	818682	844404	822545
120	694363	731599	739522	762757	743011
135	549961	579453	585728	604131	588492
150	724294	763135	771400	795636	775039

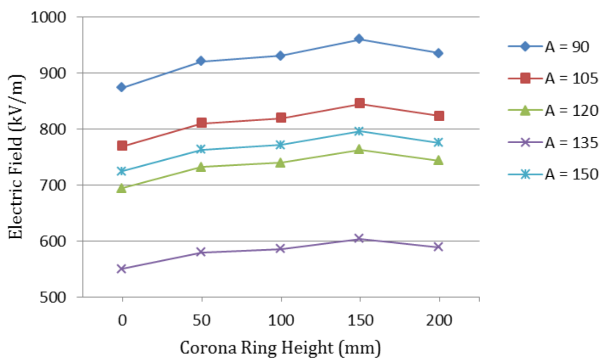


Figure 7 Maximum electric field value vs corona ring height with different corona ring angle and L = 660mm.

Minimum value of the electric field for each simulated corona ring parameter are shown in Table 5. The best corona ring parameter to minimize the value of electric field distribution in insulator string that is by using L = 700 mm, A = 130° and H = 200 mm. That parameters can be minimize the value of electric field distribution until 27.6 % of the actual corona ring design.

Table 5 Minimum value of the electric field value for each parameter

Constant Parameter	Changing Parameter	Electric Field
H = 0 mm	L = 750 mm & A = 105°	652 kV/m
L = 660 mm	A = 135° & H = 0 mm	549 kV/m
A = 130°	L = 700 mm & H = 200 mm	520 kV/m

6. CONCLUSION

This study presents the influence of the design and placement of the corona ring on the electric field distribution. It is known that changes in the design and placement of the corona ring have a large influence on the value of the electric field distribution on the surface of the insulators string. Based on the simulation results for each corona ring parameter can be concluded the maximum value of the electric field on the surface of the insulators string without using a corona ring is about 1430 kV/m. By installing the corona ring with the actual design. The electric field value can be reduce until 40%, which is 719 kV/m.

For each corona ring parameter that is changed, the ring width, ring angle and height of corona ring placement can be concluded. For a constant height H = 0, the minimum electric field value obtained is 652 kV/m using the parameter L = 750 mm with A = 105°. Whereas for a constant angle parameter A = 130°, the minimum electric field value obtained is 520 kV/m with the parameters L = 700 mm with H = 200 mm. And for a constant length parameter L = 660 mm, the minimum electric field of 549 kV/m is obtained for the parameters A = 125° with H = 0 mm.

From the analysis for each corona ring parameter, the most minimal electric field values are using the parameter of 700 mm corona ring length 130° ring corona angle and 200 mm corona ring installation height. When compared with the actual corona ring design used in gantry substatation, this parameter configuration can reduce 27.67% from the maximum actual electric field value design.

Because the differences in the parameters of length, angle and height of the rings cause differences in the minimum value of the electric field. And there is a possibility of obtaining more optimal electric field value from different step parameters. Then there needs to be optimization for a combination of three parameters to get the optimal electric field value.

REFERENCE

[1] B. M'hamdi, M. Teguar, A. Mekhaldi, "Optimal design of corona ring on HV composite insulator using PSO approach with dynamic population size", IEEE Trans. Dielectr. Electr. Insul., vol. 23, no. 2, pp. 1048-1057, Apr. 2016.

[2] E. Akbari, M. Mirzaie, M. B. Asadpoor and A. Rahimnejad "Effects of Disc Insulator Type and Corona Ring on Electric Field and Voltage Distribution over 230-kV Insulator String by Numerical Method", Iranian J. Electr. Electron. Eng., Vol. 9, pp. 58–66, 2013.

[3] S. Ilhan, A. Ozdemir "Effects of Corona Ring Design upon Impulse Voltage Withstand Level of 380 kV V-Strings", IEEE Trans. Dielectr.Electr. Insul., Vol. 18, No. 5, pp. 1638-1646, 2011.

[4] J. Du, Z. Peng, J. Li, S. Zhang, N. Li and C. Fan "Electric Field Calculation and Grading Ring Optimization for 1000 kV AC Post Porcelain Insulator", IEEE Conf. Solid Dielectr., Bologna, Italy, pp. 198-201, 2013.

[5] Ohio Brass Catalog 24 ,http://www.hubbellpowersystems.com

[6] A. Phillips, A. Maxwell, C. Engelbrecht and I. Gutman, "ElectricField Limits for the Design of Grading Rings for Composite Line Insulators", IEEE Trans. Power Delivery Vol. 30, No. 3, pp. 1110-1118, 2015.

[7] S. Zhang, Z. Peng, L. Peng and H. Wang, "Optimization of CoronaRing Structure for UHV Composite Insulator Using Finite Element Method and PSO Algorithm", IEEE Conf. Solid Dielectr., Bologna, Italy, pp. 210-213, 2013.

[8] T. Doshi, R. S. Gorur and J. Hunt, "Electric Field Computation of Composite Line Insulators up to 1200 kV AC", IEEE Trans. Dielectr. Electr. Insul., Vol. 18, No. 3, pp. 861- 867, 2011.

[9] SPLN 10 - 1A : 1996.

[10] R. Anbarasan and S. Usa Electrical Field Computation of Polymeric Insulator using Reduced Dimension Modeling", IEEE Trans. Dielectr Electr. Insul., Vol. 22, No. 2, pp. 739-746, 2012.

[11] MacLean Power System, http://www. macLeanpower.com

[12] Ashouri, M., Mirzaie, M. and Gholami, A., "Calculation of Voltage Distribution along Porcelain Suspension Insulators Based on Finite Element Method" Journal of Electric Power Components and Systems, Vol. 38, pp. 820-831, May 2010.

[13] Zhang Ziyang, Zhao Yanzhen, Li Hualiang, Ma Xikui, "Voltage distribution along glass insulator strings for 1000 kV ultra high voltage transmission lines", *East China Electric Power*, vol. 35, pp. 29-31, June 2007.

[14] L. Jintao, P. Zongren, Z. Shiling, "Electric-field calculation and grading ring design for 750 kV AC composite insulator", *Solid Dielectrics (ICSD) 2013 IEEE International Conference on Bologna*, pp. 206-209, July 2013.