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Electric field computation on polymeric insulators

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Abstract: In power sector industry insulators play amajor role especially in high voltage applications. In earlyday's porcelain insulators have been widely used in transmission and distribution lines, but now as there is a development in the technology, porcelain insulators are being slowly being replaced by polymeric insulators. Thepolymeric insulators have many advantages than the ceramic insulators in terms of cost, weight and maintenance but it also has some drawbacks when it is used on high voltage applications. At higher voltages thatis beyond 220 kV electric field is non-uniformly distributed along the insulators and the intensity is very high near to the triple junctions, for the insulators at higher voltage electric field is the major area of concern. There are several methodologies are proposed to analyzethe electric field along the insulator, to make it more uniform and to reduce the intensity of the field at some points on the insulator both experimentally and numerically of which former method might requiring thenumber of experimental trials. The advent of super computers makes numerical analyses feasible on anycomplex geometry model and the overall optimization techniques to control the electrical field become quite easier. However, the main drawbacks in second method of analyses are more computation time and memory, making it desirable to simplify the structure. Hence a methodology based on 2-D (axi-symmetry model of insulator with and without corona ring) for a dimension and location of corona rings is proposed using the trial and error method. Based on the electric field along shed surface and FRP rod of the insulator for different voltageratings of 200 kV,400 kV and 765 kV the dimension and location of corona rings using are calculated. A suspension type I string assembly is used for this study. The design and simulation is done in 2D- axisymmetric model in COMSOL multiphysics software. The future scope is for II suspension, V string and Y string insulators.

Key words - *Silicone rubber, suspension, corona rings, Electric field computation, FEM, COMSOL.*

I. Introduction

II. Power system is the combination of electric power generation, transmission and distribution. The electrical power requirement is increasing day by day in all over the world, there are many generation methods adopted to meet the load requirement on the power system that is from renewable and non-renewable power generation sources. Thegeneration voltage is 3.3 kV,6.6 kV and 11 kV. The generating stations are located in the remote locations whichis far away from the load centers may be residential, agricultural and industrial loads. The generated power istransmitted by overhead transmission lines over the long distance at very high voltage up to 66 kV,110 kV and 220 kVin order to reduce the line losses. Transmitting the power at higher voltages require the higher level of insulating material,the insulator is a very high resistance material which is used to separate the conducting part and non-conducting body in transmission lines. There are mainly three types of insulatorsare used for transmitting the power in the power system namely ceramic and non-ceramic insulators. The ceramic insulators are again classified into porcelain and glass insulators and the non-ceramic insulator is polymer insulators. In earlier days' porcelain and glass insulators weremost commonly used in transmission lines but polymeric insulators are replacing the ceramic insulators because of themany benefits of the polymeric insulators as compared to theceramic insulators. The advantages of the polymeric insulators are very less heaviness that is 10 percent of the ceramic insulators, low price and maintenance is very less. Due to these benefits the ceramic insulators are replacing bypolymer insulators in the distribution as well as in the transmission lines. Apart from these advantages the polymeric insulators have some drawbacks also, one of the main drawback is the electric field. Electric field distributionis non-uniform along the FRP and sheds of the polymer insulator due to this non-uniform distribution the electric stress will be more this will reduce the life span of the insulators and also results in the corona discharge if the electric field values exceeds the critical value. In order to reduce intensity of the electric field grading or corona rings are used. Corona ring is a hollow metallic tube of copper or aluminum which is circular in shape and is places near to theline end side for voltages up to 220 kV and for more than thisvoltage level the corona rings can be used at both line end andground end side of the insulators. The approach is based on the establishing the relation between electric field profiles along the FRP and weather sheds and the corona rings for 2Dmodels for 220 kV, 400 kV and 765 kV polymeric insulators.In this project the COMSOL multiphysics tool used to designand computation the electric field along the FRP and weathersheds in 2D axi-symmetry for I suspension. The future scope in this project is the field computation can be carried out for doubles suspension, V string and Y string

II. METHEDOLOGY

A. Critical field values

The electrical field values, above which the discharge activity takes place, form the critical value for theoptimization procedure. The values indicated below are fordry unpolluted polymeric insulator in kV/mm (peak) [4]

- Inside the fiberglass rod (FRP-Fibre Reinforced Plastic) and weather-shed material (SiR-Silicone Rubber)-4.25 kV/mm.
- On the surface of weather-shed material and surrounding the end fitting seal (measured 0.5 mm above the surface of the sheath)-0.64 kV/mm.
- Surrounding the metallic end fittings and corona/grading rings-2.4-2.97 kV/mm.

B. Design of the insulator

The polymeric insulator made with three parts namely core rod, end fittings such as socket and ball and weather sheds. The design of the insulators is done in the COMSOL by using the standard data.

- The core rod made up of FRP that provides the required mechanical strength to withstand the mechanical load
- Socket and ball are made up of steel that conveys the mechanical load to the central core

SIR sheath and weather sheds enclosed around the FRP core that protects the rod and provides the required creepage distance.

Fig 1. 2D Insulator Model

C. Electric field computation in 2D

A ball electrode is located at the line end of the insulator,while a socket electrode is located at the ground end. The inside core is constructed of fiber reinforced plastic (FRP), which has a relative permittivity of 5.0, and the housing is built of silicone rubber (SiR), which has a relative permittivity of 4.3. Ball and socket requirements are in line with IEC 120, and housing dimensions are in line with IEC 60815-3. A 2-D FEM software is used to compute the electrical field's distribution, taking use of rotational symmetry along the central axis while neglecting the supportfor the corona ring [5]. The ball end has a voltage and the socket has 0V. The simulation was run using the COMSOL program, and the electric field was detected. In order to reduce the field values, the insulator modelled with corona ring at the line side and simulated the same and the results shows that the electric field decrease at the line end and increase at the ground end. If the corona rings are uses at theboth the ends the electric field values can be reduced below.

III. OPTIMIZATION

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Table 1. Maximum electric field values with and withoutcorona rings

Voltage rating in kV	Electric field without corona ring in kV/cm		Electric field with corona ring in kV/cm	
	FRP	Sheds	FRP	Sheds
220	16	36	28.5	28
400	22	75	24.8	76
765	41	142	25	18

Corona ring installation is used to improve electric field and potential distributions as well as to reduce theelectric field and, in turn, the failure rate in transmission linesrunning at 220 kV and higher as well as to increase the lifespan of the insulators. The electric field on the insulator surface is not currently subject to any rules that establish restrictions on it. The range of 350–1000 kV/m is the recommended electric field limit to prevent corona discharges on dry, clean polymer insulator surfaces, according to the literature that is currently accessible. The highest electric field limit for the sheath portions was 450 kV/m, according to the Electric Power Research Institute (EPRI). There is still a chance for the corona ring installationto fail.

50 mm ≤ z <500 mm 150 mm ≤ r < 500 mm10 mm ≤ R < 40 mm

Where H= mounting height of the ring,

R= radius of the corona ring and r= ring radius

Case1: In the above mentioned dimensions one is varied andother two are kept constant till the completion of the range and the field computation is done.

Case 2: In this case the second parameter is varied and the other two are kept constant and field computation is done along FRP and weather sheds.

Case 3: The third parameter is varied and other two parameters are kept constant.

Like this the electric field computation is calculated in the insulator and those values are checked whether the electric field values are exceeding the critical values, if it exceeding again the dimension is varied and calculated the value till it becomes less than the critical values.

IV. RESULTS AND DISCUSSION

4.1 Electric potential distribution

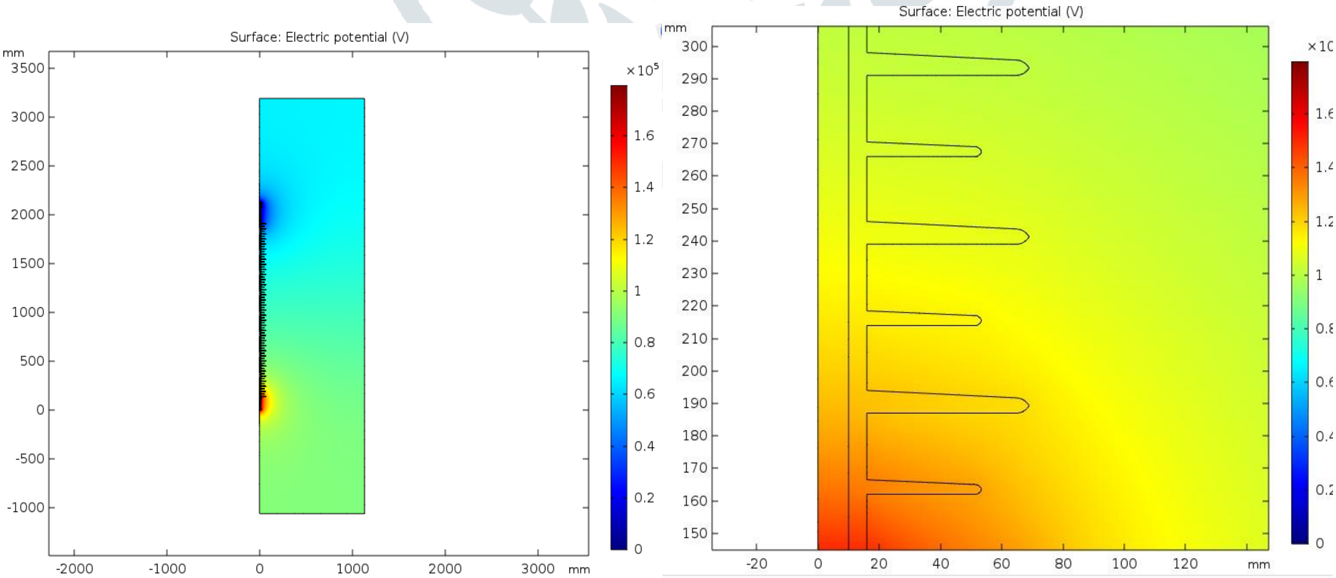

Fig 2. Potential distribution nephograph

Corona rings of the right design may be used to not only decrease the electric field's strength but also to make it moreuniform and to transfer the location of the maximum electricfield away from the triple point [8]. These characteristics arechosen as the objective function's choice variables because they have an impact on the electric field on the insulator's surface and end fittings. The variables are R, r, and z, where R is the radius of the corona ring tube, r is the radius of the corona ring, and z is the height at which the corona ring is mounted. By changing one parameter while holding the other two constant, the corona ring size and placement are optimized. The findings that were achieved for FRP and weather sheltersare displayed below.

4.2 Results

A. 220 kV polymeric insulator

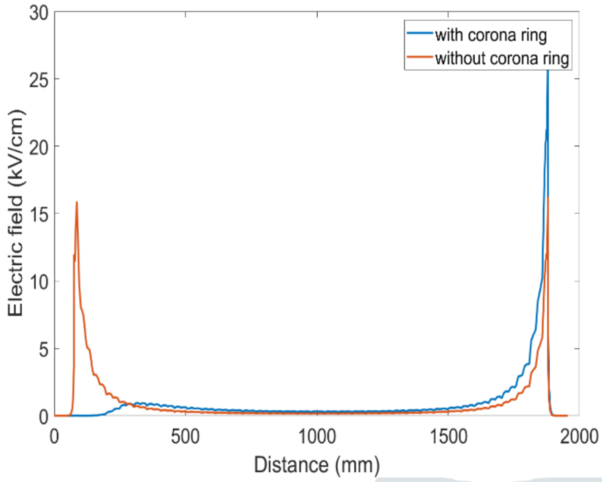

Fig. 3 Electric field along the FRP

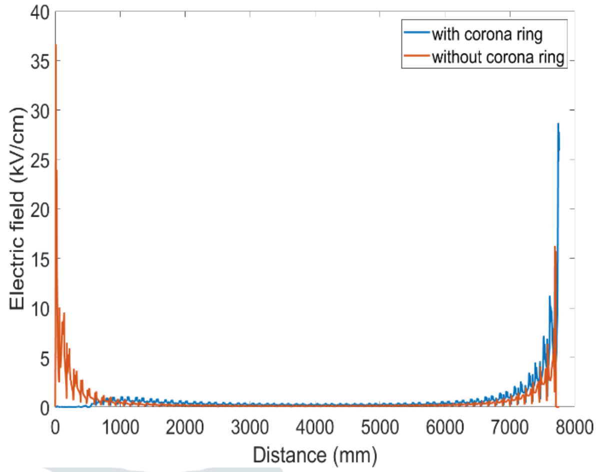

Fig. 4 Electric field along the sheds

The above results show the potential and electric field along the FRP and the surface sheds for 220 kV polymeric insulator with corona ring for R= 40 mm, r= 300 mm and z= 400 mm and also without corona ring. The corona ring with above dimensions gives the lesser field values as listed in the table in chapter 3. The applied voltage to the ring is √2*220 kV / √3= 180 kV (phase voltage). From the graph 4.2 and 4.4 it can be seen that the red line indicates field along the FRP and weather sheds without ring. The field is very high at line end and ground end that is at the triple junctions because at the triple junction more than two materials of different permittivity are joined which is more prone to the high electric field [3]. The blue line indicates the field with corona ring it can be seen that the field values are reduced after using the corona ring at the line end but increase at the ground end but it is within the critical value.

B. 400 kV polymeric insulator

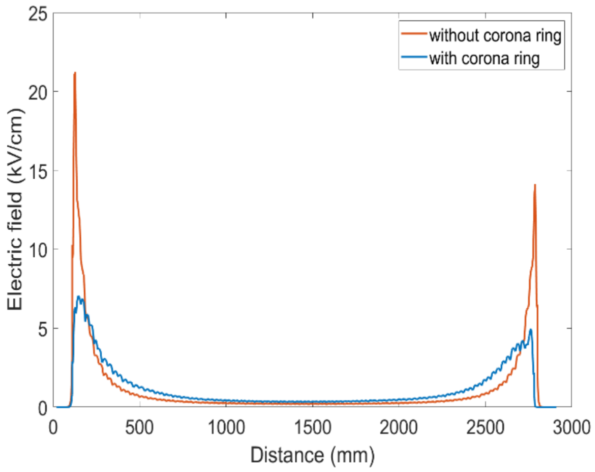

Fig. 5 Electric field along the FRP rod

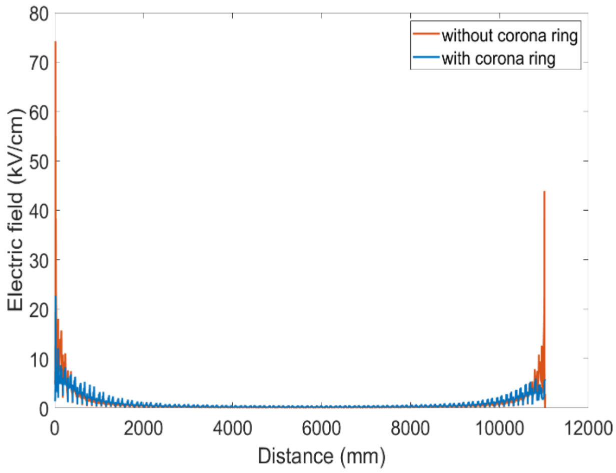

Fig 6. Electric field along the sheds

Above results show the potential and electric field along the FRP and the surface sheds for 400 kV polymeric insulator with corona ring for R= 50 mm, r= 300 mm and z= 100 mm and without corona ring. Copper is used as the material for corona ring, its permittivity is used as 10000 F/m and the applied voltage to the ring is √2*400 kV / √3= 326.9 kV (phase voltage). In the graphs 4.6 and 4.8 the red line indicates field along the FRP and weather sheds without ring. The field is very high at line end and ground end that is at the triple junctions because at the triple junction more than two materials of different permittivity are joined which part is subjected to the high intensity electric field. The blue line indicates the field with corona ring it can be seen that the field values are reduced after using the corona ring at the line end but increase at the ground end but it is within the critical value. Since the voltage is very high the field values are also high and exceeds the critical values to reduce value the corona rings are placed both the ends then it can be observed that reduction in the field values at both the ends

C. 765 kV polymeric insulator

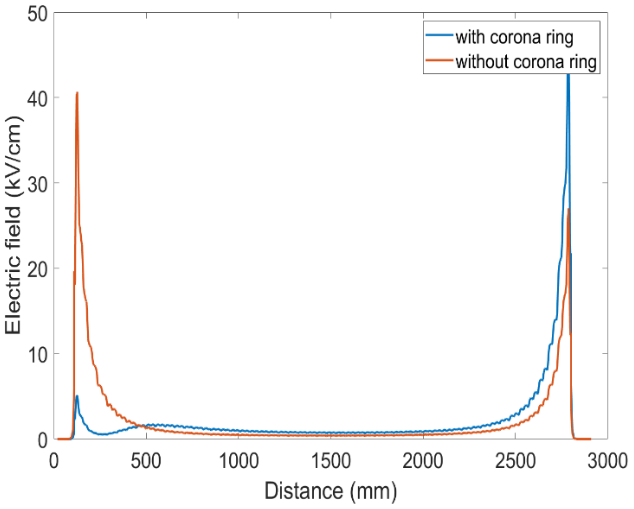

Fig 7. Electric field along the FRP rod

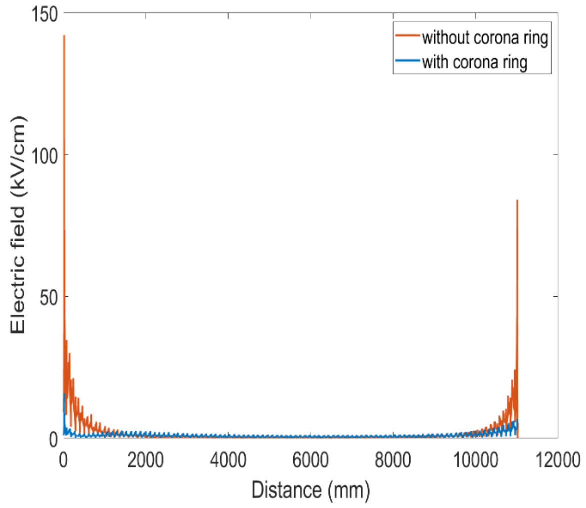

Fig 8. Electric field along the sheds

For 765 kV insulator the above results show the potential and electric field along the FRP and the surface sheds with corona ring for R= 40 mm, r= 300 mm and z= 300 mm and without corona ring. For this insulator also copper is used as the material for corona ring, its permittivity is used as 10000 F/m and the applied voltage √2*765 kV / √3= 625.265 kV (phase voltage). In fig. 5 and 5.2 the red line indicates field along the FRP and weather sheds without ring respectively.

V. CONCLUSIONS

Electric field computation plays a critical role in the design, selection and application of polymeric insulators to ensure corona-free operation and long service life. Electrical field distribution in the crucial regions must be calculated using hardware fittings for the best design of. As there are no standards for corona rings, the use of software tools providesan efficient way to analyze the field distribution along the insulator. The field along the FRP and weather sheds are computed for 220 kV, 400 kV and 765 kV polymeric insulators for I suspension. The field increases with increasein voltage and it is very high near to the triple junction at bothline end and ground end side of the insulator and also it non-uniformly distributed. The field reduces at line end when it is simulated with corona ring at line end side but field values increase at the ground end. When the corona rings are used atthe both the field can be reduced below the critical values. In future the corona ring optimization is done for double string, V string and Y string using the different techniques.

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