ANALYSIS OF NANO COMPOSITE BASED ANTI-CORONA COATING ON ACSR CONDUCTOR

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Abstract-Voltage gradient plays vital role in deciding the corona effect of ACSR (Aluminium core steel reinforce) conductors. In proposed work, simulation has been done using FEM (Finite Element Method) package to reduce the voltage gradient by coating the ACSR conductor with PolyImide/Carbon Nano Tube (PI/CNT) composite material. Simulation was done for different weight percentage of CNT in PI/CNT composite. Two types of coating were applied. In first type outer surface of the conductor was coated and in second type individual strands of the conductor were coated. The simulation result proved that the corona discharge is reduced for nanocoated conductor. The surface coating reduced the voltage gradient by 40% and the strand coating reduced the voltage gradient by 60%. Voltage gradient can be effectively reduced by increasing the weight percentage of CNT content in the PI/CNT composite.

Keywords-*Carbon Nano Tubes, Polyimide/ Carbon Nano Tubes,Voltage gradient, Finite Element Method*

I. INTRODUCTION

Aluminium core steel reinforced (ACSR) conductor is used for transmitting high voltage from generating station to substation. The air around the conductor gets ionized due to HV transmission. Corona discharge occurs when the surface voltage of the conductor exceeds the corona onset voltage.Corona discharge can be minimised by reducing the voltage gradient of the conductor. Transmitted power will be reduced due to this corona discharge which is also termed as corona loss. Voltage gradient of the conductor plays an important role in corona discharge. Corona Inception voltage (CIV), Corona Extinction voltage (CEV), corona loss, Audible Noise (AN) and RIV (Radio Interference Voltage) are variables of corona discharge. Corona loss can be reduced by increasing diameter of a conductor and spacing between the conductors. Corona discharge is more noticeable during fair weather condition. Corona discharge increases under wet and humid conditions increases.

Carbon Nanotubes has long, thin cylinders of carbon. It has unique electrical, thermal and optical properties [1-3]. It is highly conductive to electricity and heat. It haswide range of properties which vary according to the size and structure of the nanotube, and the arrangement of its atoms. The temperature stability of carbon nanotubes is estimated to be up to 2800^{o} C in vacuum and about 750 ^{o} C in air.

Polyimide is a polymer of imide monomers. Polyimide and CNT were PI/CNT nanocomposites can be synthesised by Insitu Polymerization process. Glass transitionand decomposition temperature of polyimide were improved after addition of CNT. Dielectric constant of PI/CNT composite is improved when addition 10wt% of CNT in the composite. Its mechanical properties were also enhanced[4].

I. VOLTAGE GRADIENT

The voltage gradient should be undercontrol to maintain the radio interference (RI),corona loss (CL) and audible noise (AN)within the limit. Maxwell Potential Coefficient Method(MPCM) and Markt and Mengele's method are analytical methods for calculating electric field strength. Successive image method, charge simulation method(CSM), boundary element method and finite element method (FEM) are numerical methods to find electric field strength[5-12].

The electric field distribution on the surface of ACSR conductor was analysed using ANSOFT package. FEM is the most convenient method for a field with many dielectrics, heterogeneous, nonlinear materials, complex fields and a field containing distributed space charges and singular points. It is one of the most successful numerical methods for solving electrostatic field problems because it involves discretization of the domain according to the anticipated value of field distributions.It is also well suited for complicated irregular geometry shapes. Accuracy is improved by iterative process.

III.PROBLEM FORMULATION

The ACSR panther conductor has 7 steel strands and 30 Aluminium strands. The ACSR conductor has one steel strand at centre and 6 steel strands at first layer.It has 12, 18 aluminium strands in the successive two outer layers respectively.

The design procedure for ACSR conductor using ANSOFT package as follows

1. AC conduction solver was used.
2. XY- plane selected for symmetry of drawing.
3. 3mm individual strands diameter dimensions selected for drawing the conductor. Panther conductors has 7 steel strands and 30 aluminium strands with 21mm overall conductor diameter.
4. Balloon boundary was given as background conditions
5. All strands were energized with high voltage- 132 kV.

The above procedure was performed and the solution was decided by simulating the given procedure in ANSOFT package. For the post process analysis, respective field tab was chosen to interpret the field distribution.The governing equation which is used by the FEM package for AC conduction solver is given as follows

$$\nabla.\left(J+\frac{\partial D}{\partial t}\right)=0 \quad (1)$$

$$\nabla^2 V(\sigma+j\omega\varepsilon_r\ \varepsilon_0)=0 \quad (2)$$

$$E=-\nabla V \quad (3)$$

Where,

J	:	The current density
D	:	The electric flux density
σ	:	Conductivity of material
ω	:	Angular frequency
$\varepsilon_0$and ε_r	:	Permittivity of free space and relative permittivity of the material respectively.

Geometric simulated diagram of ACSR panther conductor was shown in Figure.3.1. The electric field plot for ACSR Panther conductor was shown in Figure 3.2. It can be understood that E- field obtained at 132kV supply of normal panther conductor is approximately 2.5kV/mm.

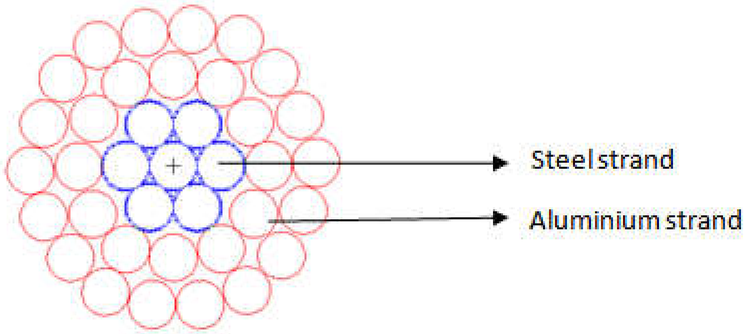

Figure 3.1. ACSR – Panther conductor

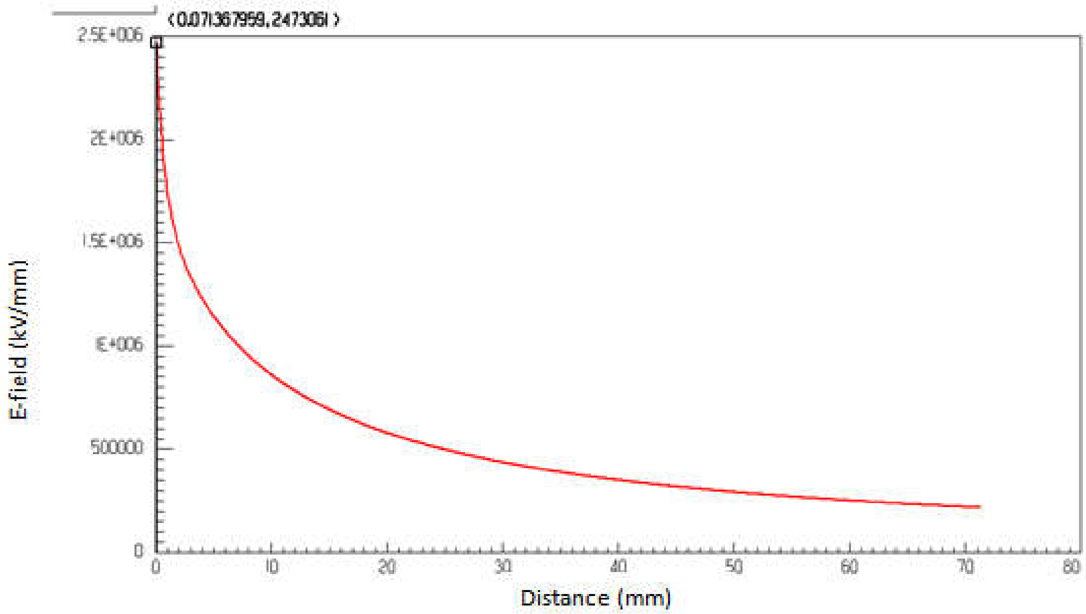

Figure 3.2. E-plot of ACSR conductor

3.1 Lichtenecker's Formula

The permittivity of PI/CNT composite material was found by using Lichtenecker's formula for different weight percentage of CNT.

$$log\varepsilon = Xlog\varepsilon_1 + Ylog\varepsilon_2 \qquad (4)$$

ε	:	Permittivity of new composite material
X	:	Weight % of CNT
Y	:	Weight % of polyimide
ε_1	:	Permittivity of CNT
ε_2	:	Permittivity of polyimide

Table 3.1 Permittivity of PI/CNT composite

Weight % of CNT	ε
1%	3.55
3%	3.88
5%	4.25

3.1.1 Case studies

The two different type of coating was done for the differentweight percentage of CNT mentioned in table 3.1. They are surface coating and strand coating. The outer surface of the ACSR conductor was coated by PI/CNT composite. The individual strand of the ACSR conductor is coated by PI/CNT composite in strand coating. The E-field of the surface coated and strand coated ACSR conductor was studied.

3.2Surface Coating

In this method, the ACSR conductor was coated on its surface by PI/CNT composite with different CNT weight % [1%, 3% and 5%] shown in Figure 3.3. The thickness of nanocoating is 0.5mm.

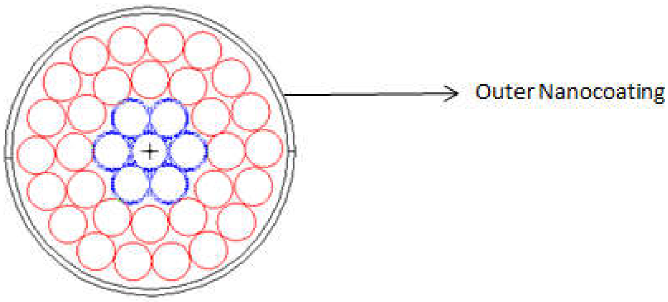

Figure 3.3 Surface Coating of ACSR Conductor

3.2.1CNT 1% - PI 99%

Permittivity of CNT 1%-PI 99% was calculated using eq (4)and found to be 3.55. It was applied in the outer coated surface.The maximum E-field 1.5kV/mm obtained for ACSR conductor with CNT 1% surface coated shown in the Figure 3.4. The E-field shows zero potential when it crosses the boundary.

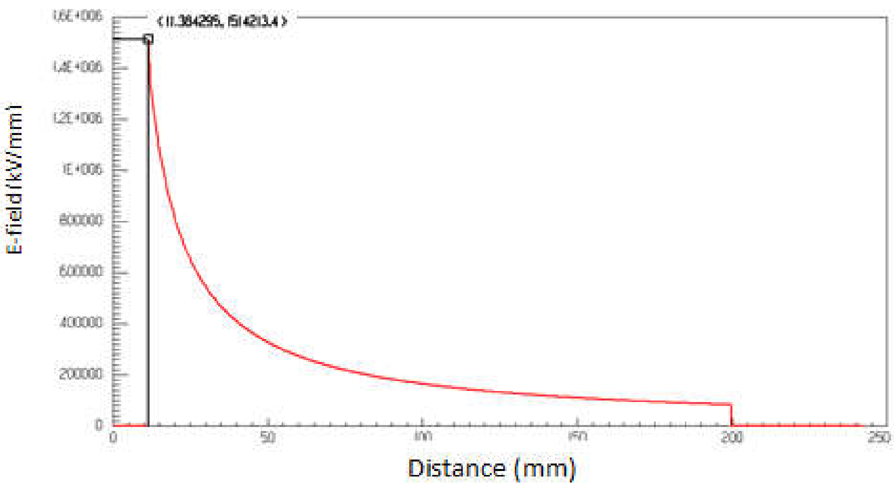

Figure 3.4 E-plot for CNT 1% - PI 99% - surface coating

3.2.2CNT 3% - PI 97%

Permittivity of CNT 3%-PI 97% was calculated using eq (4)and found to be 3.88. It was applied in the outer coated surface.The maximum E-field 1.49kV/mm obtained for ACSR conductor with CNT 3% surface coated was shown in the Figure 3.5.

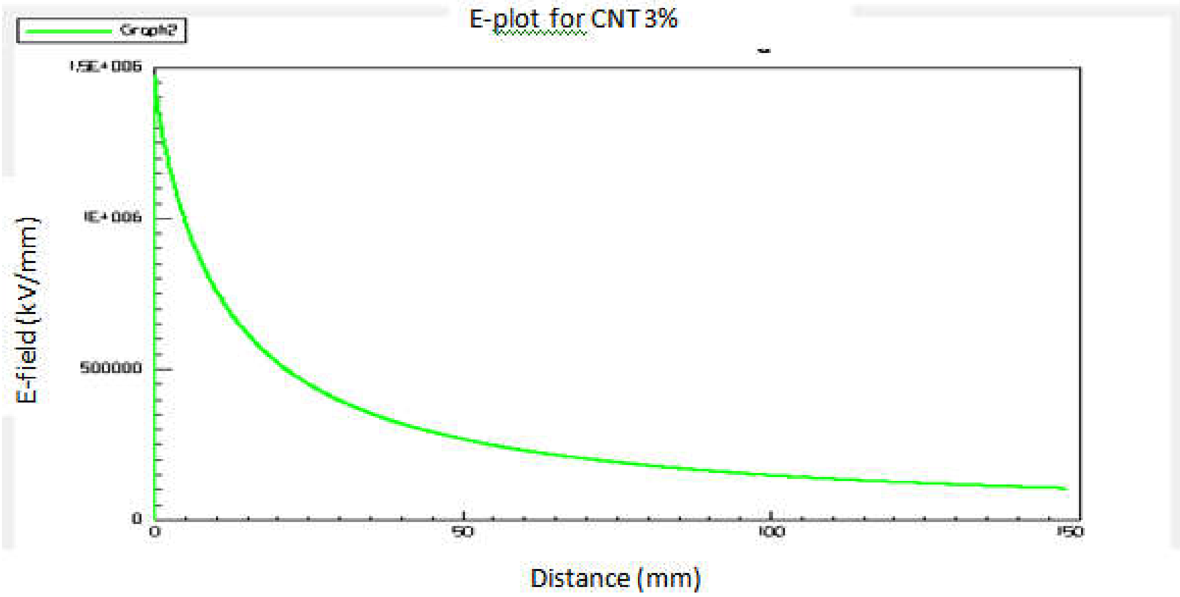

Figure3.5. E plot for CNT 3% and PI 97%-Surface Coating

3.2.3CNT 5%- PI 95%

Permittivity of CNT 5%-PI 95% was calculated using eq (4)and found to be 4.25. It was applied in the outer coated surface.The maximum E-field 1.48kV/mm obtained for ACSR conductor with CNT 5% surface coated was shown in the Figure 3.6.

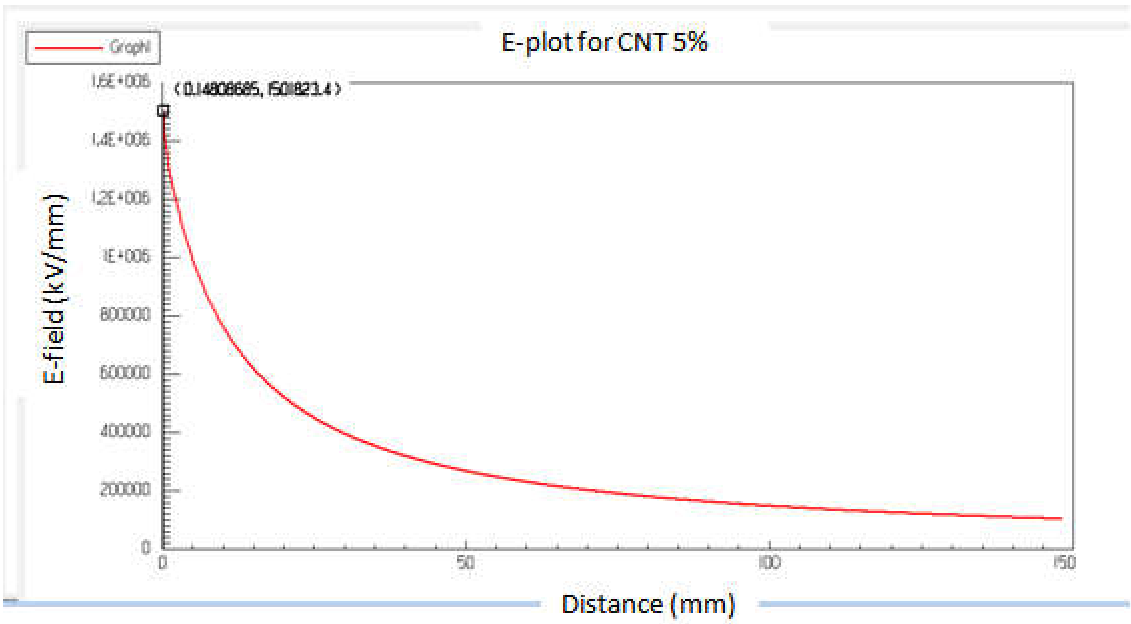

Figure3.6.E-plot for CNT 5%and PI 95%- Surface Coating

3.3 Individual Strand Coating

Out of curiosity, individual strand coating was performed to analyse the E-field performance of ACSR conductor. The ACSR conductor strands are individually coated with different CNT weight % [1%,3% and 5%]. The strand coating increases the thickness of strand surface by 1mm. Hence the conductor diameter also increased, thereby reduce in voltage gradient was attempted.

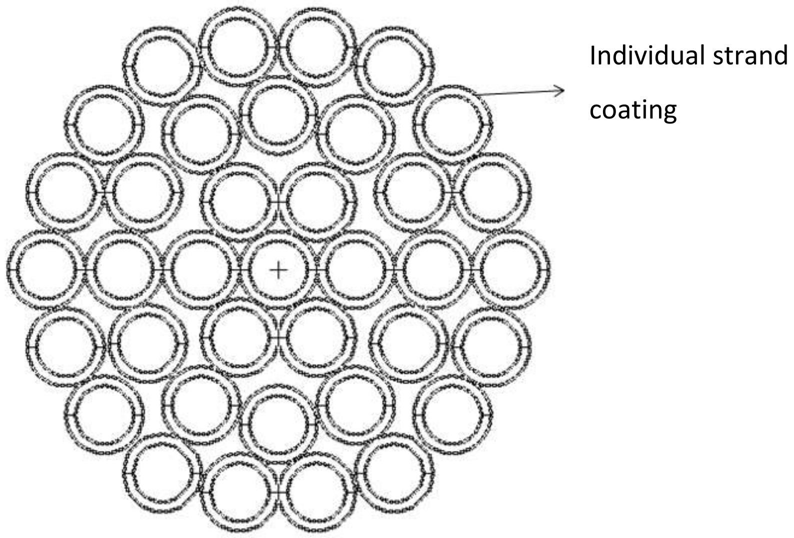

Figure3.7. Individual Strand Coating

3.3.1 CNT 1%- PI 99%

The calculated permittivity 3.55for this composite material was assigned to individual strands and its E-field performance was shown in Figure 3.8.The maximum E-field of ACSR conductor with CNT 1% was found to be 0.905kV/mm.

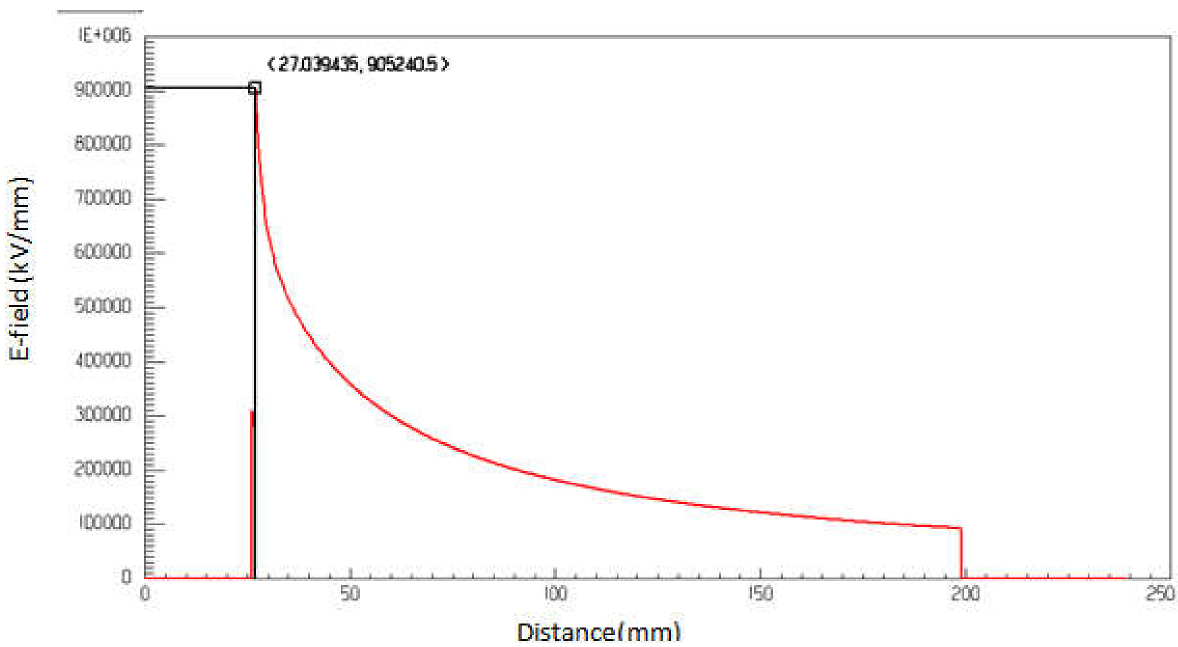

Figure 3.8.E-plot for CNT 1% and PI 99%

3.3.2CNT 3% - PI 97%

The calculated permittivity 3.88 for this composite material was assigned to individual strands and its E-field performance was shown in Figure 3.9.The maximum E-field of ACSR conductor with CNT 3% was found to be 0.915kV/mm.

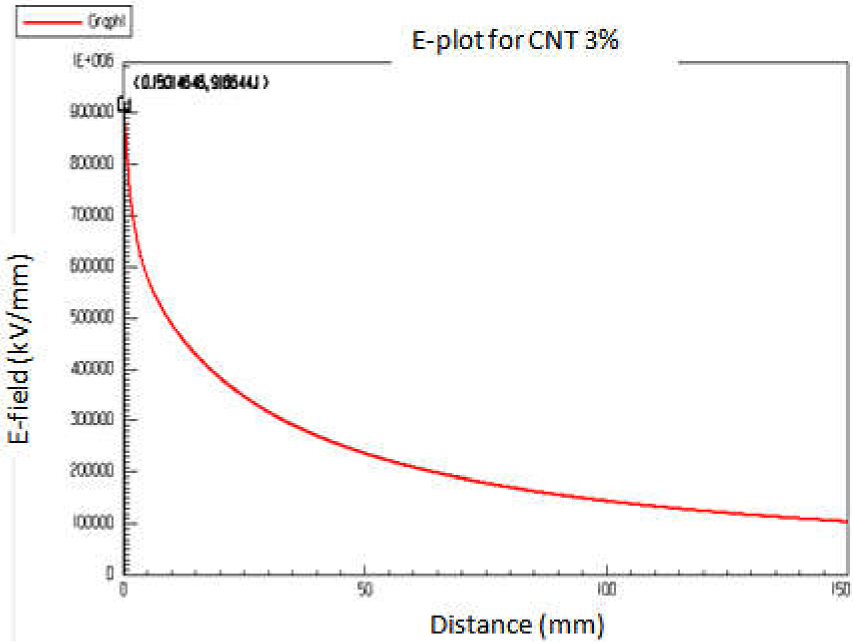

Figure3.9.E-plot for CNT 3% and PI 97% - Strand Coating

5.4.3CNT 5% - PI 95%.

The calculated permittivity 4.25 for this composite material was assigned to individual strands and its E-field performance was shown in Figure 3.10.The maximum E-field of ACSR conductor with CNT 5% was found to be 0.905kV/mm.

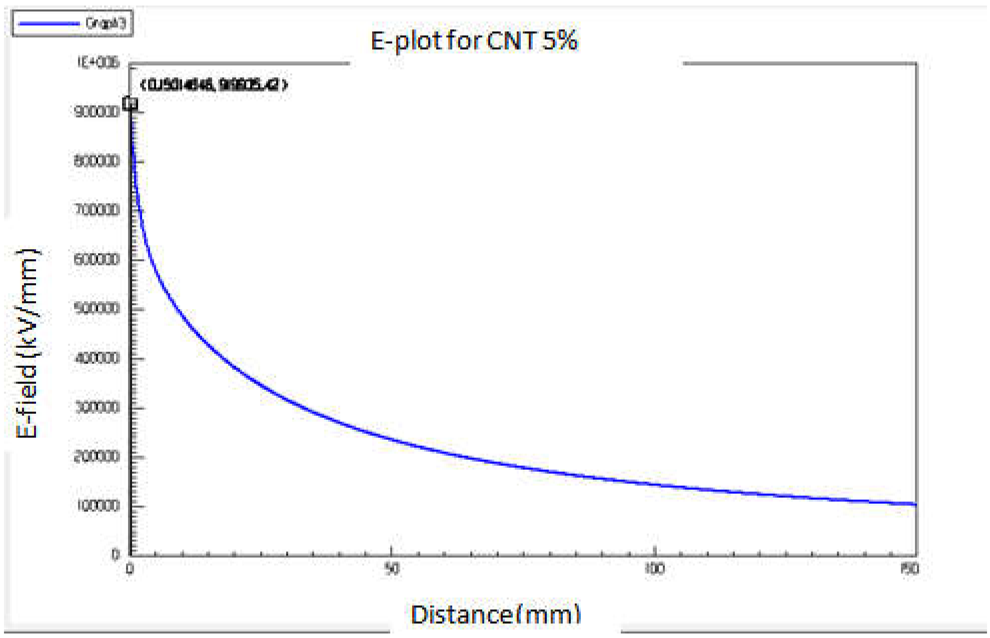

Figure3.10E-plot for CNT 5% and PI 95% - Strand Coating

IV. RESULT

The E-field obtained for ACSR conductor with different case studies was compared in table 4.1. It seems that the maximum reduction of E-field by surface coating was achieved with 5% of CNT in the PI/CNT composite. The table 4.1 also shows that the maximum reduction of E-field by strand coating was achieved by 1% of CNT in the composite. Surface coating is cheaper than strand coating. Maximum reduction was obtained in the strand coating than surface coating. Corona discharge will be expected to occur at low chances in nanocoated ACSR conductor.

Table 4.1 Comparison of E – field

CNT %	surface coating E-field(kV/mm)	%E-field reduction	strand coating E-field(kV/mm)	%E-field reduction
1%	1.50	40	0.9003	64
3%	1.49	40.4	0.915	63
5%	1.48	40.8	0.905	63.8

V.CONCLUSION

The ACSR conductor was coated by a PI/CNT composite material. The CNT proportion was varied by its weight percentage in the composite material. Simulation was done for two different types of coating. The E-field obtained for the ACSR panther conductor by giving nominal voltage of 132kV is around 2.5 kV/mm. The surface coating reduces the field by approximately 40% and the strand coating reduces the field by approximately 60%. Compare with the surface coating, strand coating reduces more E-field. By increasing the CNT content in the PI/CNT composite, it will reduces the E-field effectively. The corona discharge can be reduced by the addition of nanocomposite with the ACSR conductor.

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