EXPERIMENTAL INVESTIGATIONS TO STUDY THE IONIC CURRENT ENVIRONMENT OF HVDC TRANSMISSION LINES

[1]M.RajaNayak, [2]SK.Saleem, [3]E.Chandra Shekar, [4]M.Naresh, [5]N.Ravi Nayak
[1] Assistant Professor, [2,3,4,5] UG Students
[1,2,3,4,5] EEE Department,
[1,2,3,4,5] Holy Mary Institute of Technology & Science, Hyderabad, India.

***Abstract:** Corona on power conductors causes the power loss in high voltage transmission system. Not only the power loss, but it is also responsible for generation of space charge Ions, audible noise, television interface etc . Drifting of these space charge ions towards the ground plane in the direction of electric field causes "Ionic current" flow to any living organism which moving under these line conductors Hence it is very important to study the corona generated ionic current environment of high voltage transmission system. In this project, in order to analyses this corona generated ionic current environment completely, an attempt is made to generate and study the corona generated ionic current flow for different line conductor diameters. The proposed project work gives the laboratory model experimental setups to generate the corona phenomenon by using "IGNITION coil" for different electrode configurations. Also the variations of ionic current flow for different line conductor diameter are presented.*

I. INTRODUCTION

HVDC offer greatly for bulk power transmission over longer distances. Because of the key advantage in long power delivery, UHVDC projects are developing in India. Presently in India ±500kV HVDC overhead lines are in operation and lines of ±800kV voltages are under construction. Designing of the HVDC transmission lines at Ultra High Voltage levels, various problems associated with it has been not fully analyzed in India. One of the critical criteria in the design of HVDC lines is their corona phenomenon which leads to corona discharge [1]. The primary effect of corona discharge on HVDC transmission line causes power loss and the secondary effects of formation of ionized fields, ionic current flow between the line to ground plane, Audible noise (AN), Television interference (TVI), Radio Interference (RI) etc. The major effects influencing corona discharge of the HVDC transmission lines are its conductor surface gradients at given operating voltage levels, corona onset gradients, and ambient weather conditions such as temperature, pressure, wind, humidity, presence of aerosols, ambient electric fields produced by atmospheric electricity etc. With the presence of any human body or any living organisms at UHVDC levels under DC transmission lines, the ionic current density and ionized fields are perturbed with an enhancement.[3] [4] [5]. Therefore, the ionic current through a human body that stands on ground plane under the transmission lines and also the people who lives in the vicinity of the UHVDC lines are always attended by the government.

Although the proposed safe limits of electric field and ionic current densities at ground level under the HVDC transmission lines using analytical methods such as Charge simulation method (CSM) [6], Finite Element Method (FEM) [7], Flux tracking Method (FTM) [8] etc. was not fully analyzed and also by line designers due to the limitations of analytical methods up to now. Since these parameters are a disturbance and can be sensed by personnel, acceptable levels have to be established to guide the transmission line designers. However, it is observed from literature [1] [2] [3] [4], to analyze the ionic current environment of HVDC transmission lines by conducting long term full scale experiments solely is tedious process and time consuming. On account of this fact, scale down models of experimental findings in laboratory conditions can provide significant help to evaluate the performance of ionic current densities at ground levels. The authors have made an attempt to investigate the ionic current environment at ground levels under HVDC line conductors in laboratory conditions using the scale down models. The measured experiment results of scale down models and their performances at different line conductor diameters are presented in this paper.

II. HVDC LINE IONIC CURRENT ENVIRONMENTAL EFFECTS

From the point of view of assessing the HVDC ionic current environmental effects, it is necessary to characterize ionic current environment of HVDC lines as completely as possible. Designing a transmission line with minimum environmental impact requires a study of three factors, namely, the impact of electrical fields, the visual impact of the design and impact of physical location [8] [9]. The electrical environment under a DC line is significantly different from that existing under AC lines. At voltages above corona inception, the breakdown of air results in generation of space charge around the conductors. On an unipolar DC transmission line, ions having the same polarity as the conductor voltage that fill the entire inter-electrode space between the conductors and ground. On a bipolar HVDC transmission line, corona occurs almost simultaneously on conductors of both positive and negative polarities. The ions generated on the conductors of each polarity are subject to electric field driven drift motion either towards the conductor of opposite polarity or towards the ground plane, as shown in Figure 1. As a result, the gradient at the conductor surface is decreased, whereas the gradient at the ground plane is increased. The drifting of space charge towards the ground plane or towards the conductor of opposite polarity gives rise to a current flow in the entire inter electrode space between the conductors and the ground plane. Therefore, the electric field environment under a DC line may be characterized by

- Electrical field distribution
- Space charge density, and
- Ionic current density.

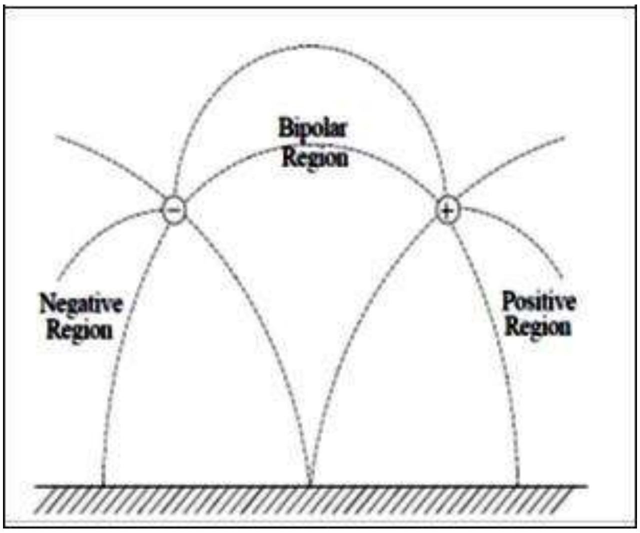

Figure 1: Ionic Current flow of a unipolar and Bipolar HVDC transmission lines

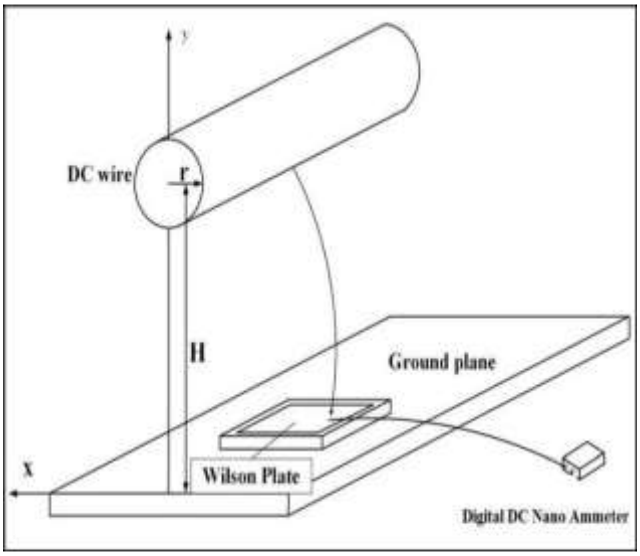

Figure2 Schematic Diagram of Ionic Current Measuring System.

The field intensity and ionic current density at ground level, are the important design parameter characterizing the electrical environment under a DC line, as the effects of these parameter are felt by persons and objects located under the line. Knowledge of the space charge ion-flow characteristics is essential for the performance evaluation of existing and planned lines.

III. MEASUREMENT SYSTEM OF IONIC CURRENT DENSITY

Since HVDC transmission lines generally allow operation with slight corona discharge above onset voltage, considerable positive and negative ions are generated around the lines, which flow between the conductors and toward the ground [10]. To estimate the ion-current density on the ground, a collecting plate usually called a Wilson plate is used to intercept the ions which migrate from the lines to the ground. The schematic diagram of measurement system of ionic current flow at ground plane is shown in Figure 2. The value of the ion-current or its density can be measured by using the digital DC NANO ammeter. This digital DC NANO ammeter can read current from sensing electrode under the line conductor directly.

3.1 Experimental Set Up

In order to measure the corona generated ionic current of the line conductor, an ignition coil is used as high voltage DC source rated with maximum voltage of 30 kV. Measurements of the vertical component of the ion-current density in the vicinity of dc power lines are performed with a flat collecting aluminum plate with DC NANO ammeter combination. The flat plate, historically referred to as a Wilson plate [11], on the ground plane is shown in Figure 3. The 10x10-cm Wilson plates have commonly been employed for ion-current density measurements under dc power lines. In case of indoor measurements miniature Wilson plates may be more convenient, since the sensing surface is minimized, the accuracy of the measurement system should be guaranteed. However, in case of outdoor measurement maximum size of Wilson plate will be employed due to interruption of ionic current measurement happens by the influence of wind in field.

IV. EXPERIMENTAL RESULTS

4.1 Case A

A unipolar dc wire comprising of copper material with 0.27 mm in diameter at different height is built as shown in Figure 4. Wilson plate is put on the ground under the centre of the test wire. The line conductor was energized with the 30 kV of positive polarity voltage. The experimental set up is shown in Figure 4. The measured values of ionic current densities under laboratory atmospheric conditions at varying different heights of the conductor for applied voltage source of 30 kV are listed in Table 1. The ionic current was measured directly under the line at different heights using the digital DC NANO ammeter.

It can be observed from Table 1 that the recorded values of ionic currents are lower in magnitudes as height of the conductor increases. This shows the ionic current of the line conductor is in inversely in relation with conductor height. It is also observed that, higher magnitude of ionic current during voltage rise of the DC line due to rate of change voltage with respect to time i.e. dv/dt. It is observed that the magnitude of ionic current is higher during the dv/dt as compared to the maximum value.

The variation of ionic current at different conductor heights under the line is shown in Figure 5. It is clearly observed that the variation of ionic current for a given DC voltage is in non linear in nature. All these measured values are recorded at two different atmospheric temperatures conditions of 32ºC and 28ºC for short time duration.

Figure 3: Schematic view of unipolar DC line experimental line setup

It is also observed that, the ionic current magnitude variation is higher at higher atmospheric temperature and is lower at lower atmospheric temperature. This can be attributed to the movement of ions at higher temperatures is faster as compared to the movement of ions at lower temperatures. Faster movement of ions may result in generation of ions due to more collisions in their expedition.

Table 1: Ionic current magnitudes of DC line conductor

Applied voltage in kV	Height of the conductor in cm	Ionic current In µA
30	5	1832
30	10	1523
30	15	1349
30	20	1069
30	25	726

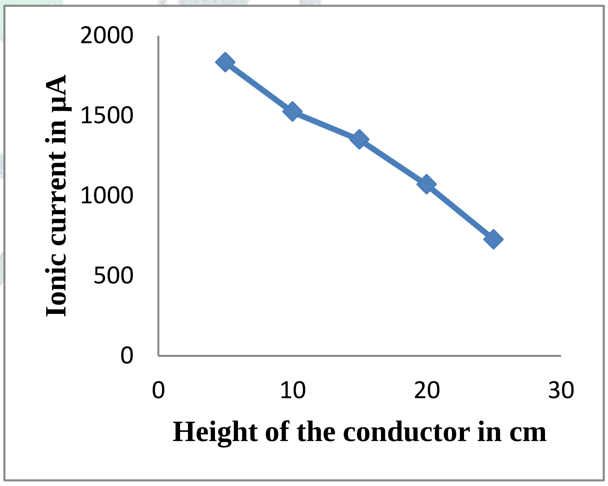

Figure 4: Variation of ionic current

4.2 Case B

The ionic current measurements are carried for another conductor diameter of 0.51mm with different conductor heights as followed incase A. The variations of ionic current magnitudes observed are tabulated in Table 2.

Table 2: Ionic current magnitudes of DC line conductor

Applied voltage in kV	Height of the conductor in cm	Ionic current In µA
30	5	1562
30	10	1312
30	15	1079
30	20	816
30	25	591

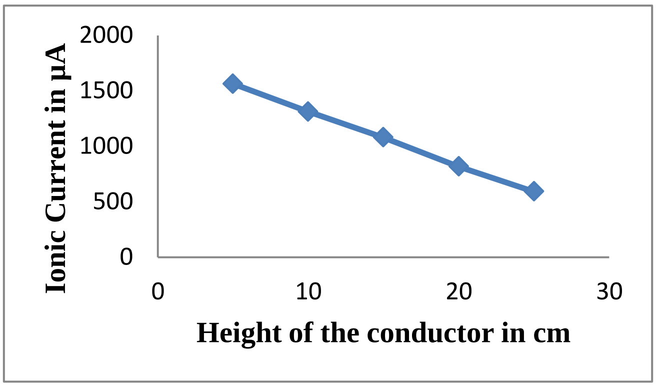

Figure 5: Variation of ionic current

It can be observed from Table 2 that the recorded values of ionic currents are lower in magnitudes as height of the conductor increases. The variation of ionic current for different applied DC voltages to the above conductor configuration under the line is shown in Figure 6. It can be observed clearly from Figure 6 that the variation of ionic current at reduced conductor diameter as compared to the case A, higher the ionic current magnitudes for reduced conductor diameter. Also, the variation of ionic current is non linear in nature.

4.3 Case C

The ionic current was also measured for another line conductor configuration comprising of copper conductor material with 1.22 mm in diameter at different conductor heights. The line conductor was energized with the 30 kV of positive polarity voltage. The ionic current was measured directly under the line. It is observed from table 3 that, the higher in the ionic current measurements for given conductor diameter and as compared to the above case B. Also, it is observed that, lower magnitudes of ionic currents for a given conductor diameter as compared to the case A.

Table 3: Ionic current magnitudes of DC line conductor

Applied voltage in kV	Height of the conductor in cm	Ionic current In µA
30	1.0	1236
30	1.5	995
30	2.0	765
30	2.5	516
30	3.0	311

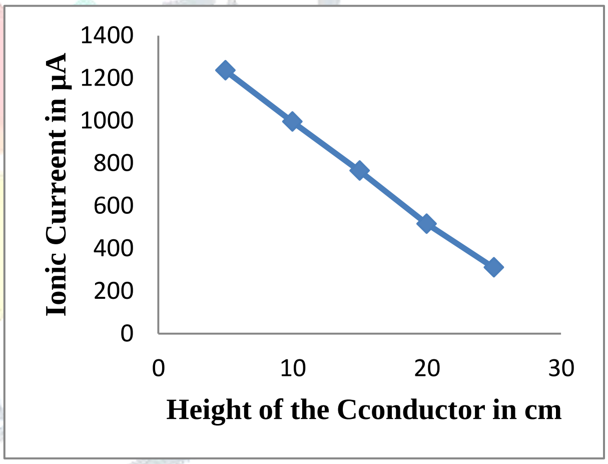

Figure 6: Variation of ionic current

V. DISCUSSION

From the experimental results of ionic current for copper conductor, it is observed that, the magnitude of ionic currents are higher for smaller conductor diameter. It is observed from the experimental conducted at different atmospheric temperatures conditions of laboratory, that the ionic current reduces as height of the conductor is increased and vice versa. This indicates that the atmospheric parameters such as temperature, pressure, wind velocity, aerosols, humidity etc., have the significant influence in generation of ions in the vicinity of the HVDC transmission lines.

It is also observed from the experimental results presented that, the ionic current densities are higher in magnitude initially and lower magnitudes are measured. This may be due to the life span of the generated ions in the corona discharge which has significant influence in magnitude of the ionic current flow at ground levels. This phenomenon is also observed by [12].

VI. CONCLUSION

The scale down models of experimental study on different HVDC line conductors by various experimental setups at laboratory conditions was conducted. From the experimental results of the study, it is concluded that:

1. The ionic current flow at ground level is nonlinear in nature due to life span of the generated ions in ionization layer.
2. The ionic current varies inversely with height of the conductor.
3. The ionic current varies inversely with the conductor diameter
4. Atmospheric parameters like temperature, humidity, pressure, aerosols, wind velocity etc., have the profound influence on the ionic current flow at ground levels.
5. Considerable amount of space charge was observed during the voltage raise, this attributes during voltage fluctuations at UHV levels of the line results in deposition of the space charge ions in form of surface charges on the tower end insulators causes short term flashes.

VII. ACKNOWLEDGMENT

The authors wish to thank EEE department staff for help in conducting the experimental work and Holy Mary Institute of Technology & Science management for permitting to publish this paper.

VIII. REFERENCES

[1] P. S. Maruvada, "Influence of Ambient Electric Field on the Corona Performance of HVDC transmission lines," IEEE transactions on Power Delivery, Vol. 29, No.2, April 2014, pp.691-698.

[2] Feng Tain, Zhanqing Yu, Rong Zeng, Han Yin, Bo Zhang, Lei Liu, Min Li, Ruihai, Li and Jinliang He "Resultant Electric Field Reduction with Shielding Wires under Bipolar HVDC trasmission lines," IEEE transactions on magnetics,Vol. 50,No. 2, February 2014.

[3] P.S.Maruvada, "corona-generated space-charge environment in the vicinity of HVDC transmission lines," IEEE transactions on electrical insulation,Vol. EI-17, April 1982, pp.125-130.

[4] Maruvada. P. Sharma, W.Janischewskyj, "Corona loss characteristic of practical HVDC transmission lines, Part I- Unipolar Lines ," IEEE transactions on power apparatus and systems, Vol. PAS-89, No. 5 pp. 860-867, May/June 1970.

[5] Maruvada. P. Sharma, W.Janischewskyj, "Corona loss characteristic of practical HVDC transmission lines, Part II- Bipolar lines ," IEEE transactions on power apparatus and systems, Vol. PAS-90, No. 3 pp. 1055-1062, May/June 1971

[6] M. Abdel Salam and S. Abdel Sattar, " Calculation of Corona V-I Characterisics of Monopolar Bundels using the Charge simulation Method ," IEEE transactions on Electrical Insulation , Vol. 24 No. 4 August 1989.

[7] Yongzan Zhen, Xiang Cui, Tiebing Lu, Xuebao Li, Chao Fang, Xiangxian Zhou, "3-D Finite Element Method for Calculating The Ionized Electric Field and the Ion Current of the Human Model Under the UHVDC Lines," IEEE transactions on power Delivery, Vol. 28, No. 2 pp. 965-971, April 2013.

[8] Maruvada. P. Sharma, "Electric Field and Ion Current Environment of HVDC transmission lines: Comparison of calculations and Measurements," IEEE transactions on power delivery, Vol. 27, NO. 1January 2012, pp. 401-410.

[9] "Electric field and Ionic current Environment of HVDC Overhead Transmission Lines," CIGRI Report-473, August 2011.

[10] Chao Fang, , Xiang Cui, Xiangxian Zhou, Tiebing Lu, Yongzan Zhen, Xuebao Li, "Impact Factors in Measurements of Ion Current Density produced by High Voltage DC Wire's Corona" IEEE transactions on power Delivery, Vol. 28, No. 3 pp. 1414-1422, July 2013.

[11] A.J, Otto and H.C Reader, "HVDC Corona Space Charge Modelling and Measurement" IEEE transactions on power Delivery, Vol. 26, No. 4, pp. 2630-2637, October 2011.

[12] Kanako Sekimoto and MitsuoTakayama, "Fundamental Process of Corona Discharge- Surface Analusis of Traces Stained with Discharge on Brass Plate in Negative Corona", J. Inst. Electrostat Jpn. Volume 33, 1 (2009) 38-42