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Corona Onset Voltage and Corona Power Losses in an Indoor Corona Cage

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Abstract **– The impact of various variables on corona power losses and corona unset voltages are determined for several different conductors in a small indoor corona cage. DC and AC tests are performed at Fuat Kulunk High Voltage laboratory of Istanbul Technical University. The results are compared both from the point of conductor geometries and from the point of excitation voltages.**

Index Terms – DC, AC, corona losses, corona onset voltage, corona cage

I. INTRODUCTION

Corona power loss is one of the most important issues in extra high voltage power transmission systems. That is why corona discharge is taken into consideration in transmission line design.

A corona discharge is an electrical discharge on the surfaces of conductors, electrodes and dielectrics. It is caused by to the ionization of a fluid surrounding a conductor due to exposition of high electrical field stress. Sharp edges and cracks on an electrode are the most appropriate places for corona activity. Corona discharges can be either be transient or self-sustained and they are generally recognized as audible noise, visible light, UV radiation, ozone generation, radio and TV interference [1].

Corona losses (CL) on a conductor depend on the surface geometry of the electrode, on the type of applied voltage and on the atmospheric conditions. CL for stranded conductors are higher when compared to solid conductors and they increase with the conductor diameter for a given surface gradient [2]. For both conductors CL are highest under AC excitations whereas the lowest under positive DC voltages [2, 3]. Atmospheric conditions are very significant for CL on operating transmission lines. Researchers have shown that CL increase substantially in case of precipitation [4, 5] and hoar frost [6]. Humidity is also a factor for increasing CL [7]. In addition, contamination on the conductor surface creates sharp edges which in turn cause high localized electric field stresses and therefore increase CL [8].

In this study corona onset voltage and corona losses are determined for several different conductor sizes in an indoor corona cage under DC and AC voltages. The results are compared both from the point of conductor geometries and from the point of excitation voltages. The aim of the study is to provide relevant information for high voltage power transmission conductors.

II. EXPERIMENTAL STUDIES

A small indoor corona cage with a length of 32 cm and a diameter of 10 cm is used in the experiments. It was built for such corona loss measurements and has a cylindrical shape consisting of two shield segments at both ends and a measurement segment in the middle. The shield segments are directly grounded while the measurement segment is grounded through a micro-ammeter. Shield segments are electrically isolated from the measurement segment in order to measure the corona losses on the conductor surface and to eliminate the losses due to end fittings. The detailed schematic diagram of the corona cage is shown in Fig. 1.

Six solid copper conductors of 0.40, 0.60, 1.00, 1.30, 1.40, 1.70 mm diameters are subjected to the tests. The conductors are carefully checked before the tests for possible cracks and dust to achieve a fairly good surface gradient.

A. DC Measurements

A 100 kV, 20 kVA, 50 Hz test transformer is used for both DC and AC measurements. The DC voltage is obtained by rectifying AC voltage with a 140 kV high voltage diode and a 10 nF regulating capacitor. Test voltages are measured with a 140 MΩ high ohmic resistor. The equivalent test circuit is shown in Fig. 2.

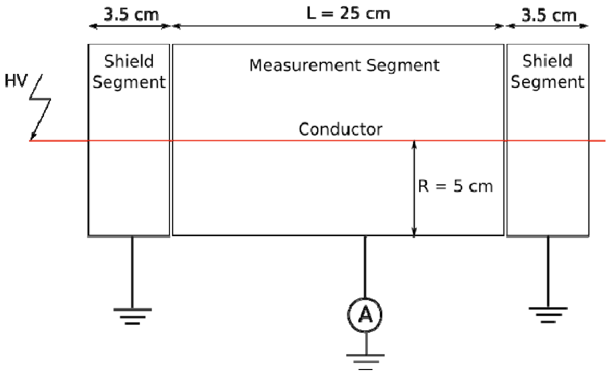

Fig. 1 Schematic diagram of the corona cage

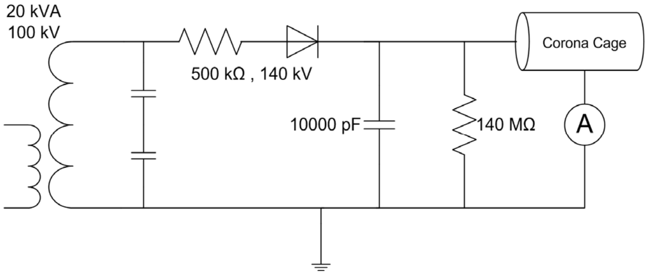

Fig. 2 Equivalent circuit for DC measurements

DC corona current is measured with a micro-ammeter connected to the measurement terminal of the corona cage and corresponding power losses per unit length are calculated by using (1).

$$P_{dc} = \frac{U.I_{dc}}{L} \qquad (1)$$

where,

P_{dc} = corona power loss per unit length (W/m)

U = applied voltage to the conductor (V)

I_{dc} = measured corona current (A)

L = length of the measurement segment (m)

The voltage at which the current starts to flow through the ammeter is taken as the corona onset voltage of the corresponding conductor..

Considering the conductor and the corona cage as a coaxial cylindrical system the conductor surface gradient is theoretically calculated by using (2).

$$E_{max} = \frac{U}{r.\ln(\frac{R}{r})} \qquad (2)$$

Where,

E_{max} = conductor surface gradient (kV/cm)

U = applied voltage to the conductor (kV)

r = conductor radius (cm)

R = radius of the corona cage (cm)

B. *AC Measurements*

The conductor, corona cage and the insulation (air) together can be considered as an electrode system and therefore modeled as a capacitor. The capacitance, loss angle, tangent of the loss angle and corona power losses of the electrode system is measured using a Schering Bridge. Actually tangent of the loss angle and the capacitance are directly measured by the bridge Corona power loss per unit length is then calculated by using (3).

$$P_{ac} = \omega.C_x.U^2.\tan\delta_x \qquad (3)$$

Where,

P_{ac} = corona power loss per unit length (W/m)

U = applied voltage to the conductor (V)

C_x = measured capacitance of corona cage (F)

$\tan\delta_x$ = measured loss tangent

The reference capacitor used with the Schering Bridge is a loss-free one having a capacitance of 100.47 pF. The equivalent test circuit is shown in Fig. 3.

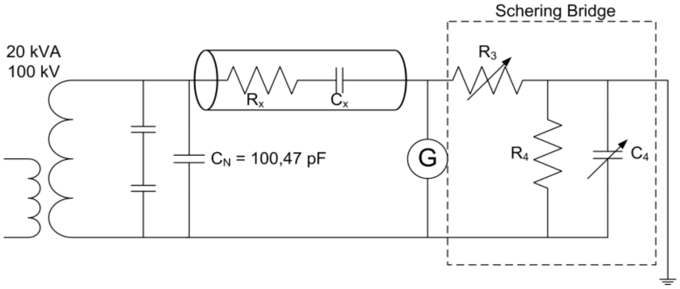

Fig. 3 Equivalent circuit for AC measurements

III. RESULTS AND DISCUSSION

A. *Corona Onset Voltage*

Fig. 4 and Fig. 5 show corona onset voltages and corona onset gradients (electric field strengths) versus conductor diameter, respectively. It can be seen from Fig. 4 that the corona onset voltage increases with increasing conductor diameter. The reason is clearly the higher surface gradients on the surface of conductors having small diameters.

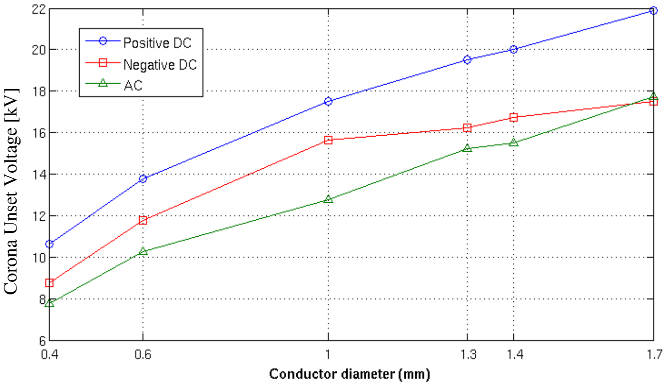

Fig. 4 Effect of conductor diameter on corona onset voltage

The corona onset gradient however shows opposite behavior. On conductors with large diameter corona starts at lower surface gradients. This is due to the well-known fact that the dielectric strength increase for the electrodes having smaller curvature radiuses.

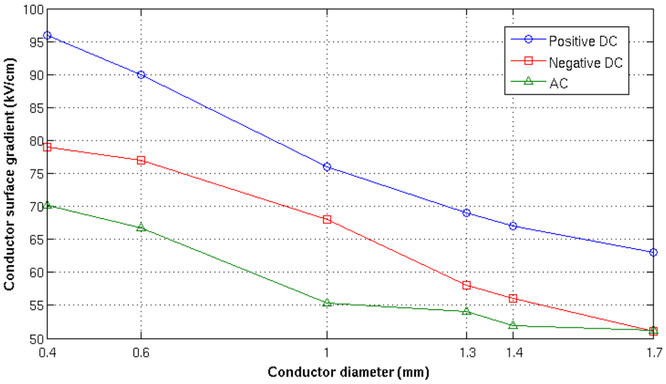

Fig. 5 Effect of conductor diameter on corona onset gradient

For all conductor samples, corona onset voltages and corona unset gradients are the highest for positive DC test voltages and the lowest for AC voltages. Similar results are obtained in [3]. Low corona onset voltages for AC test voltages could be connected with the absence of space charges, whereas low corona onset voltages for negative DC compared to positive DC could be due to free electrons which move rapidly to the ground [3].

B. *Corona Losses*

The effect of conductor surface gradients on corona power losses for positive DC, negative DC and AC conditions are shown in Fig. 6, Fig. 7 and Fig. 8 respectively.

As expected CL increase with the conductor surface gradient. It can also be seen from the figures that for a given conductor surface gradient, CL increases with conductor diameter. This is related with the low corona onset gradients on conductors having large diameters. These observations are similar to those reported in [3].

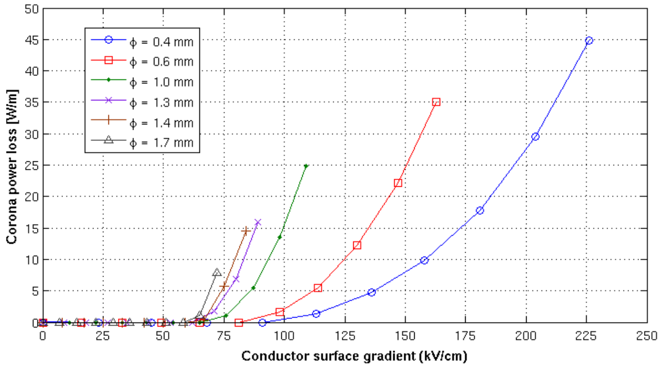

Fig. 6 Effect of conductor gradient on corona losses: positive DC

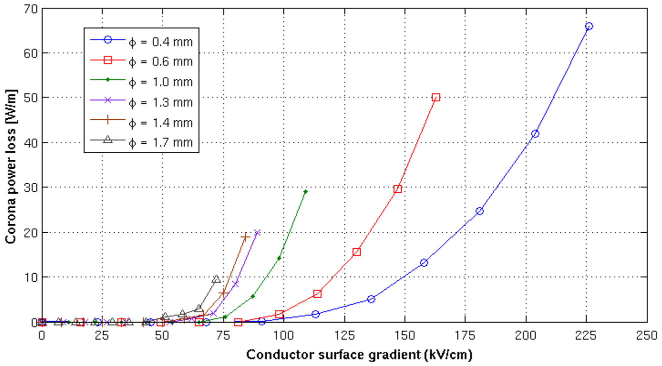

Fig. 7 Effect of conductor gradient on corona losses: negative DC

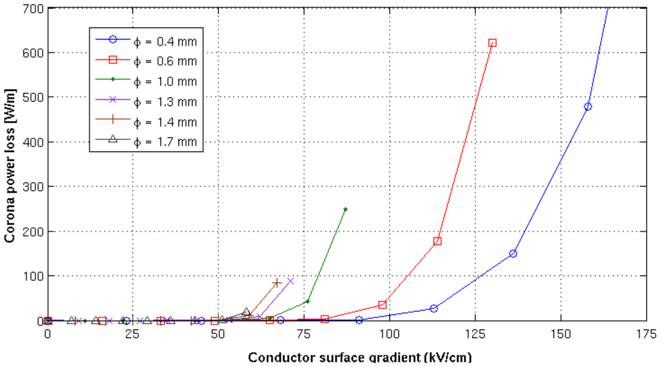

Fig. 8 Effect of conductor gradient on corona losses: AC

The comparison of corona losses for different voltage types are shown in Fig. 9 – 14. AC corona losses are the highest while the positive corona losses are lowest for all conductors. High losses for AC voltages are related with the absence of space charges and higher losses on negative DC compared to positive DC can be explained with the electrons moving to the ground [2, 3].

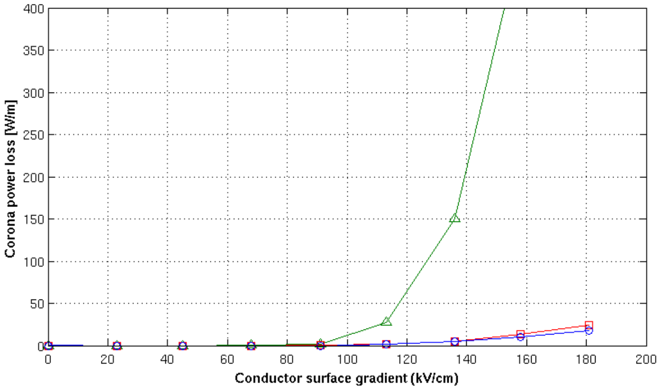

Fig. 9 Comparison of corona losses under different voltage types (0.40 mm)

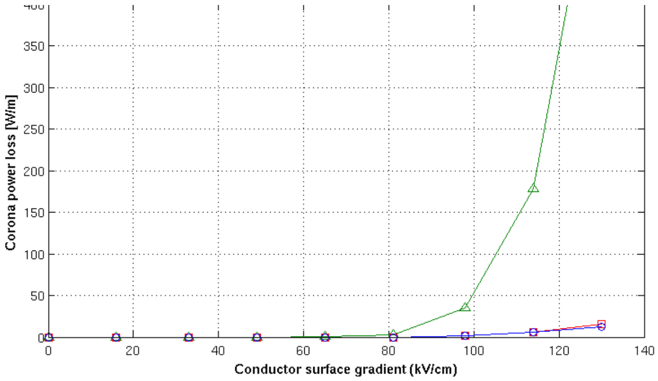

Fig. 10 Comparison of corona losses under different voltage types (0.60 mm)

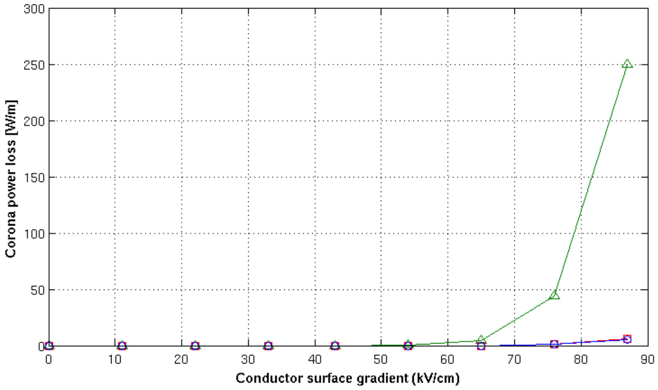

Fig. 11 Comparison of corona losses under different voltage types (1.00 mm)

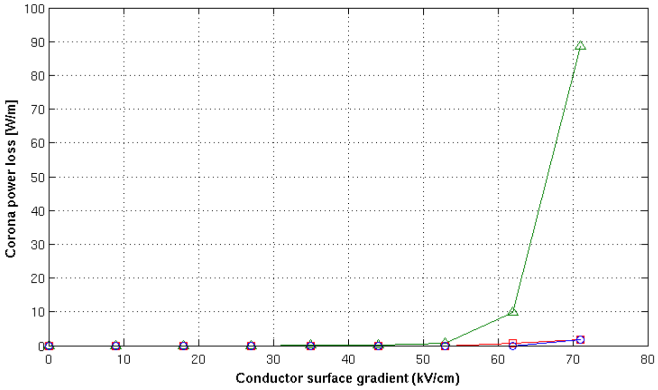

Fig. 12 Comparison of corona losses under different voltage types (1.30 mm)

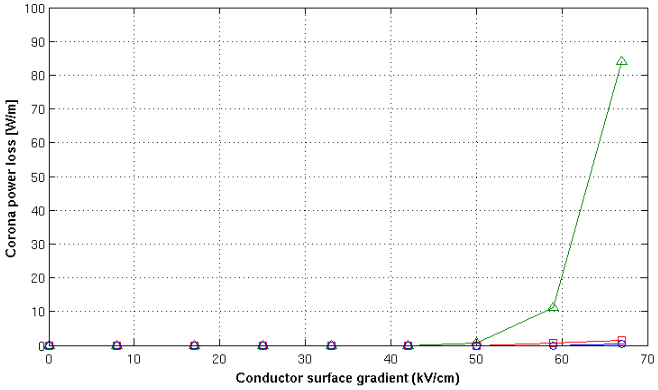

Fig. 13 Comparison of corona losses under different voltage types (1.40 mm)

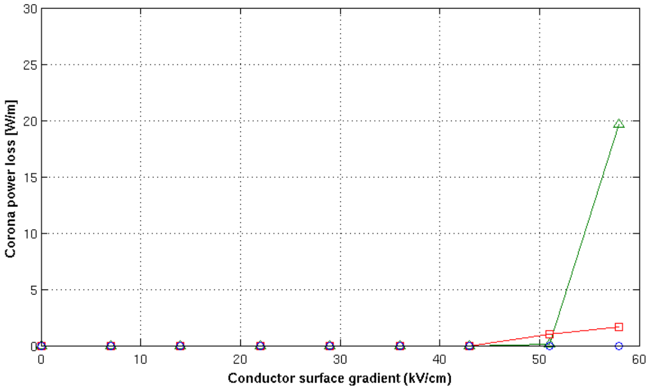

Fig. 14 Comparison of corona losses under different voltage types (1.70 mm)

IV. CONCLUSION

This study has presented corona onset voltages and corona losses for several different conductor sizes in an indoor corona cage under DC and AC voltages. The results obtained from the experiments have shown that:

- Corona onset voltage increases with an increasing conductor diameter,
- Corona onset gradient decreases with an increasing conductor diameter.
- Corona onset voltages for positive DC excitation are the highest while they are the lowest for AC excitations.
- Corona losses increase with an increasing conductor surface gradients for all types of voltages. AC corona losses are significantly higher when compared with DC losses and losses for negative DC are higher than those for positive DC.

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