THE FEASIBILITY OF USING A CORONA CAGE TO PREDICT AUDIBLE NOISE LEVELS UNDER HVDC LINES

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Abstract: In the 1980's Eskom commissioned a corona cage at high altitude (1500 m above sea level) to engineer a suitable conductor bundle for its high voltage alternating current (HVAC) 765 kV lines. This was successfully done, and the cage was later also utilised for conductor selection in compact and double circuit 400 kV line designs. The cage diameter is 7 m and 40 m in length. The key question to be answered is whether the corona cage can be used successfully in the engineering of conductor bundles for DC applications. The focus of this paper is the comparison of field measurements under a DC line to audible noise predictions using data from the corona cage. A secondary objective was to test the hypothesis that an equivalent AC voltage can be used to test DC applications. Preliminary results indicate that the DC corona cage results can be used for audible noise predictions as long as the conductor bundle tested is fully aged. Audio and radio interference measurements have indicated that an AC voltage cannot be used to evaluate DC applications. DC applications have to be tested with DC voltages.

1 INTRODUCTION

Corona and field effects are significant in the design of transmission lines above 132 kV. In the case of Eskom's 765 kV lines [1,2], such effects were responsible for the selection of critical parameters; including the size of the phase conductors, number of conductors in each bundle and conductor clearances to ground. It can thus be appreciated that corona and field effects can have a substantial influence on the cost of line. An important local factor which distinguishes the design of South African lines from most of those elsewhere is reduced air density or altitude. Reduced air density causes, in general, higher levels of corona activity. In the design of a line, therefore, it is necessary that the above factors be rigorously taken into account [3].

The corona cage is used extensively to predict audible noise levels under proposed HVAC transmission lines. Measurements under different lines have been compared to different predictions, and the corona cage method was found to be the most accurate prediction for dry conditions [4].

The main objective of this work is to determine whether the Eskom corona cage can be used to predict audible noise (AN) under HVDC transmission lines.

The second objective is to validate the concept of using an AC voltage to evaluate DC conductor bundles and hardware.

Eskom currently has only two DC lines operating in South Africa, these being the Cahora-Bassa 533 kV HVDC lines. Currently one is operating at -375 kV and the other at +500 kV. The voltage on the negative pole is too low to produce corona. Field measurements were taken under the positive pole and compared to cage measurements.

A quad Zambezi conductor bundle, similar to the bundle currently used on the Cahora-Bassa lines was installed in the corona cage (Figure 1). Measurements for both AC and DC were taken over a range of voltage gradients. The cage predictions were then compared to the field measurements.

Figure 1: Quad Zambezi in the Eskom Corona Cage, 1500 m above sea level, Johannesburg, South Africa.

2 CORONA CAGE MEASUREMENTS

The corona cage is 40 m long, with a 7 m diameter (Figure 2). Radio interference voltages (RIV) at 0.5 MHz and audible noise are measured in the cage at an altitude of 1500 m above sea level. Radio interference voltages are measured using a band pass and a band stop filter according to CISPR [5]. The audible noise is measured with a Rion NA28 precision sound level meter.

The conductors are sprayed with water during a test to evaluate it for wet conditions. A rain rate of 2 mm/min is applied. This represent a heavy rain or L5 (Wet) condition (95 % probability of occurrence in actual rain conditions) [6]. The wet conductor or L50 (Wet) result is measured one minute after the artificial rain is stopped (50% probability of occurrence in actual rain conditions) [6].

Figure 2: Lateral view of the Eskom Corona Cage.

3 CONDUCTOR AGING USING AN AC VOLTAGE

The DC source that was available for this project is not an outdoor unit, and could therefore not be kept energised over night and without an operator.

The conductor bundle was therefore aged using an AC voltage. The bundle was kept energised with an AC voltage of 220 kV between tests (peak voltage of 310 kV to produce a gradient of 20.18 kV/cm). AN and RIV were measured regularly to monitor the ageing of the conductor.

As expected, the wet and heavy rain results did not show any improvement with time (Figures 3 and 4). The reason being that, under wet conditions, the water droplets are the main corona source and not the condition of the conductor.

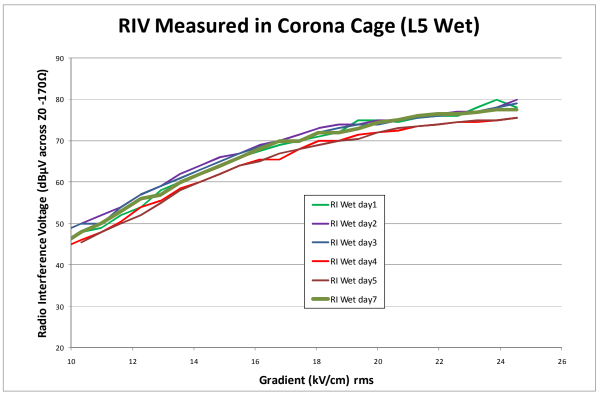

Figure 3: Radio interference voltage measured in corona cage: Heavy rain (L5 Wet)

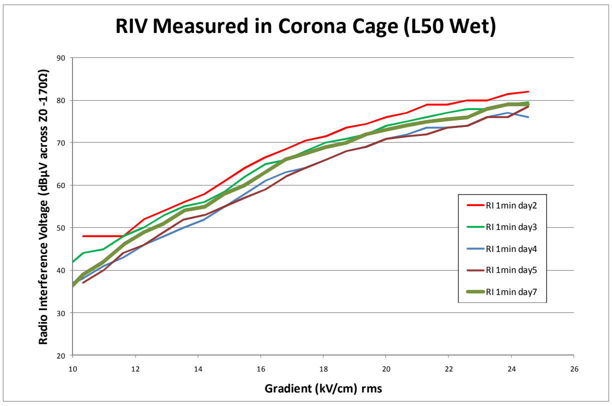

Figure 4: Radio interference voltage measured in corona cage: Wet conductor (L50 wet)

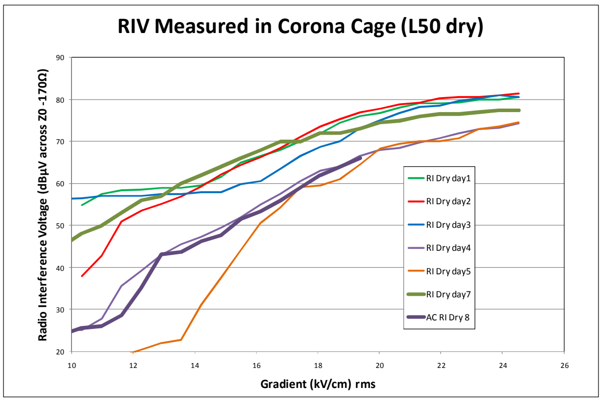

Figure 5: Radio interference voltage measured in corona cage: Dry conductor (L50 dry)

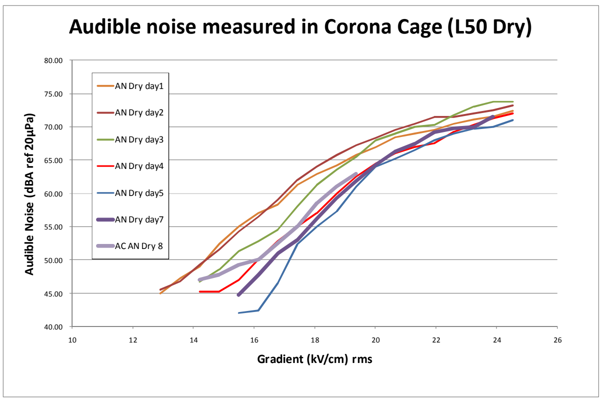

Figure 6: Audible noise under dry conditions

The RIV and AN curves for dry conditions, Figure 5 and Figure 6, show that the conductors were not fully aged as the eighth day readings fall within the range of the previous measurements. It is expected that the readings from a fully aged conductor will be lower than that made on a new conductor. It should be noted that the conductor bundle were not energised between days 5 and 7. The RIV and AN results lost some of their aging in this period, i.e. it returned to previous values.

4 DC RESULTS

Although the conductor bundle was not fully aged, some DC measurements were done to compare with levels obtained in the field under the Cahora-Bassa line and with similar AC results. From the DC results in Figure 7 and Figure 8 it can be seen, as in the AC case, that complete aging has not yet been achieved, as the measurement in the latter days are not consistently lower than earlier readings.

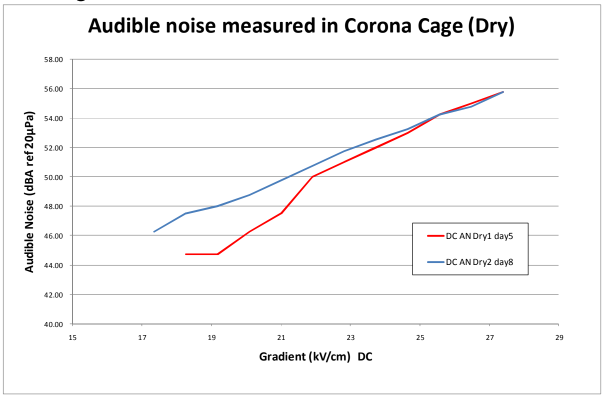

Figure 7: Audible noise measurements in Corona cage (DC): Dry conditions

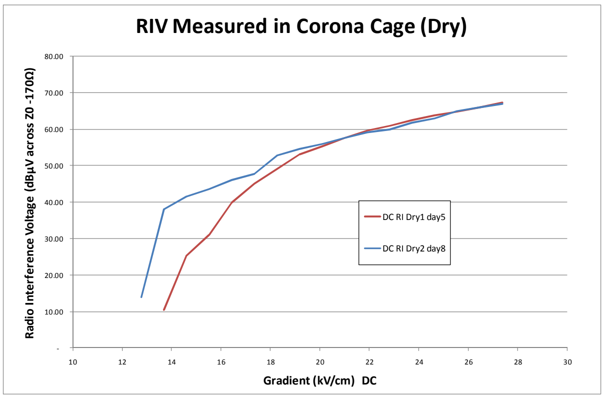

Figure 8: RIV measurements in Corona cage (DC): Dry conditions

5 FIELD VS CAGE MEASUREMENTS

Field measurements were performed on 3 different days under the Cahora-Bassa line (Figure 9). The geometry of the line, at the measurement site, and the voltage on the line at the time of measurements were used to calculate the conductor surface gradient of the quad Zambezi conductor bundle. The noise levels under the line are considered low. Fortunately, the background levels in the area were very low, thus making it possible to obtain some usable measurements.

The noise levels measured in the corona cage (46 and 49 dBA) at the required gradient (20.18 kV/cm), were used to predict the noise levels under the line. The results are depicted in Figure 10. The low cage prediction is only 3 dB higher than the measured levels under the line. Since full conductor aging has not yet being achieved, this is considered a very good prediction.

Figure 9: Measurement site under Cahora-Bassa 533 kV line (Positive monopole)

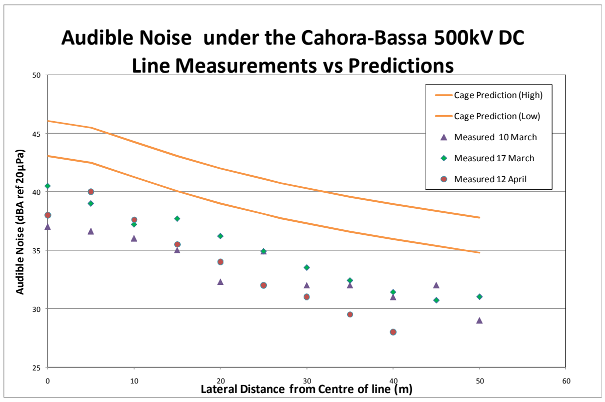

Figure 10: Cahora-Bassa 533 kV DC line (Positive monopole): Audible noise measurements vs Predictions

6 AC VS DC MEASUREMENTS

Hardware or conductors to be used in DC applications are often evaluated with AC voltages applied, because of the unavailability of DC facilities. The AC voltage is then chosen for the peak voltage to be the same as the required DC voltage. To evaluate this theory AC and DC measurements were performed directly after one another.

The results are depicted in Figures 11 and 12 below. From the results it is clear that equipment to be used in DC applications cannot be evaluated using AC voltages.

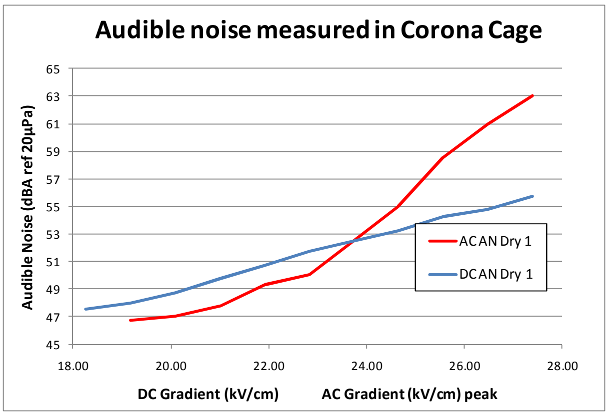

Figure 11: Audible Noise measured in corona cage: AC vs DC

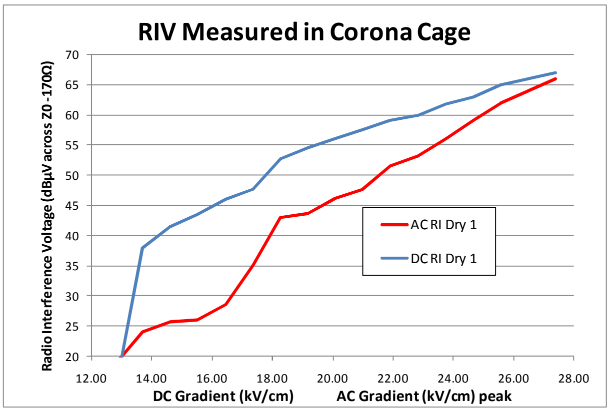

Figure 12: RIV measured in Corona cage: AC vs DC

7 CONCLUSION AND RECOMMENDATIONS

The corona cage appears to provide valid data to be able to predict audible noise levels under monopolar DC lines. The RIV measurements do not show a correlation for the tests conducted in the cage. This is possibly due to the influence of space charge within the corona cage on radiated RI generation [7].

The work indicates, in general, that AC results cannot be applied to DC applications and the evaluation of DC hardware and conductors needs to be conducted with a DC test voltage.

Further work is focused on conducting negative polarity measurements under the Cahora Bassa line and performing aging of conductors under DC. Methods available for the evaluation of Bi-polar configurations is also being investigated.

8 ACKNOWLEDGMENTS

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