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Laboratory Investigation on the Effect of Wind on Corona of HVDC Lines

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- Experimental Setup
- Test Procedure
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- Conclusion

Introduction

With the ever increasing energy demand for electricity, many high voltage transmission lines are being constructed. Recently, the HVDC transmission market is growing at a high annual growth rate, being expected to reach 13.54 billion dollars by 2020.

Introduction

The application of HVDC technologies for electric power transmission has some technical and economic advantages over HVAC transmission.

- HVDC transmission lines have simpler requirements for line tower construction in comparison with HVAC transmission lines, and also lower per-unit costs, including costs per km of line and per MW of transmitted power.
- HVDC transmission lines costs significantly lower for cables of the same transfer capacity as compared to HVAC lines.
- Additional reactive power compensators are not necessary when using long HVDC transmission lines.

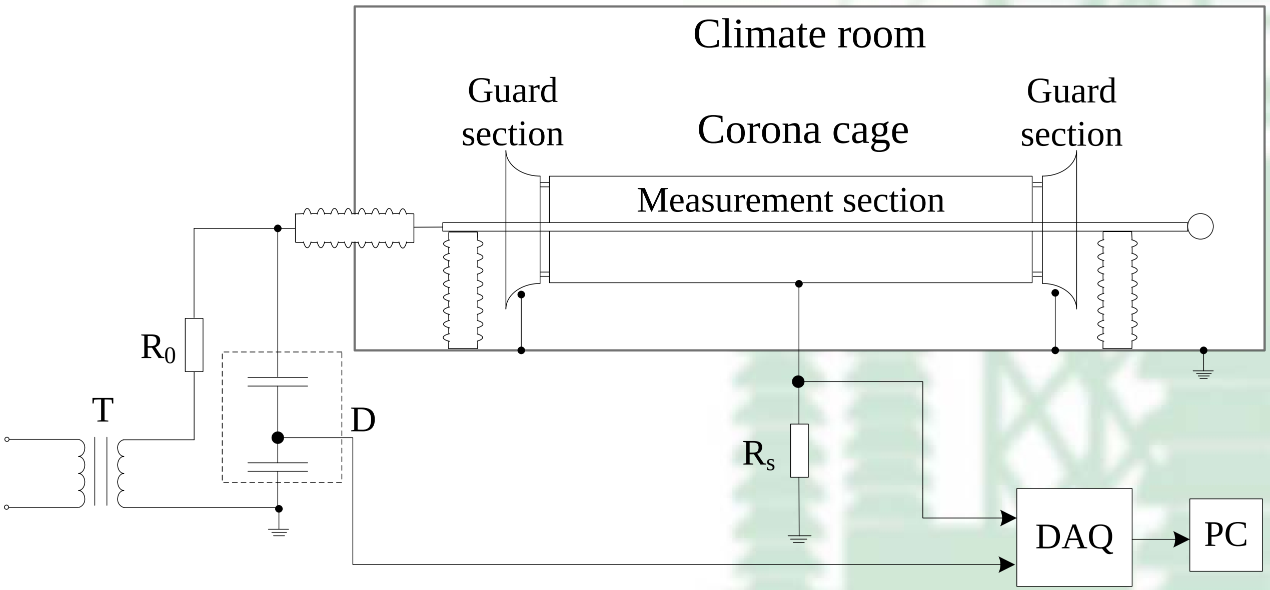
Introduction

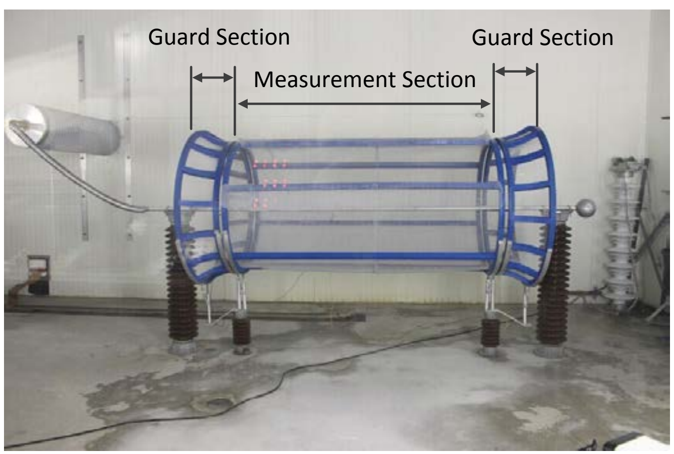
Corona loss is thought to be negligible in fair weather but can be significant under rain and icing conditions.

As transverse wind is postulated to be a significant impact factor and has a large influence on the electric field and ion current environment of the transmission lines, the main objective of this study is to obtain detailed information about the wind effect on DC corona under various weather conditions such as fair weather, rain, and icing.

The experiments were carried out in a climate room based on a corona cage at CIGELE laboratories, University of Quebec in Chicoutimi (UQAC).

Experimental Setup





R_s Shunt Resistor

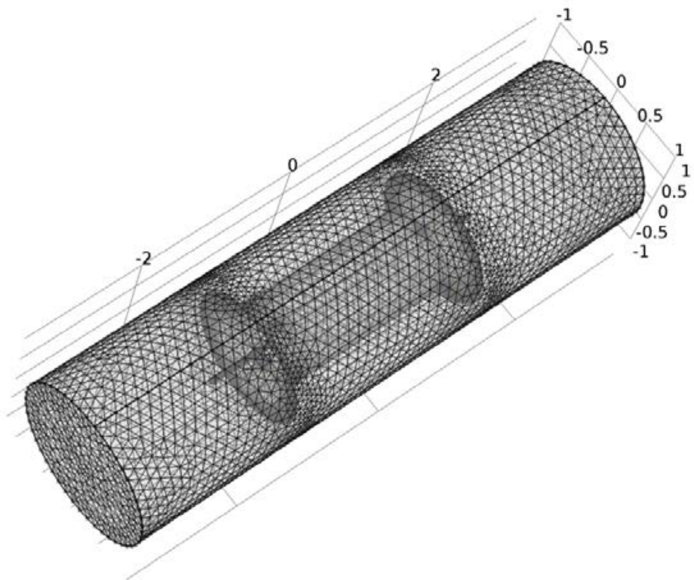
D capacitive voltage divider

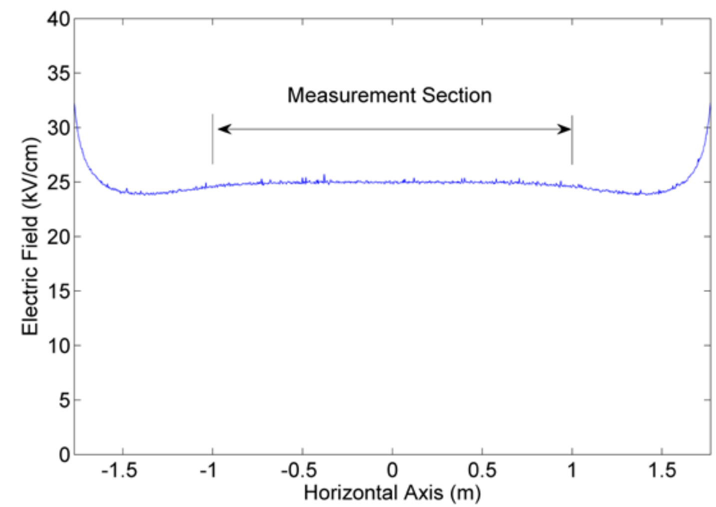
Conductor radius = 0.016 m

Corona cage radius = 0.5 m

$$E_{surface} = \frac{U_{app}}{r_c \ln(R/r_c)}$$

Experimental Setup





Out cylinder:
  Diameter: 2 m
  Length: 6 m

Applied voltage on conductor = 137.7 kV
Theoretical electric strength = 25 kV/cm

Experimental Setup

$P = U \cdot I$

Sampling rate = 100 kSamples/s

Test Procedure

Given the radii of conductor and corona cage, the calculated voltages corresponding to different electric strength levels are as follows

Surface Field Strength and the Corresponding Voltage for the Tested Corona Cage Configuration

	5 kV/cm	10 kV/cm	15 kV/cm	20 kV/cm	25 kV/cm	30 kV/cm	35 kV/cm
Voltage (kV)	27.5	55.1	82.6	110.1	137.7	165.2	192.8

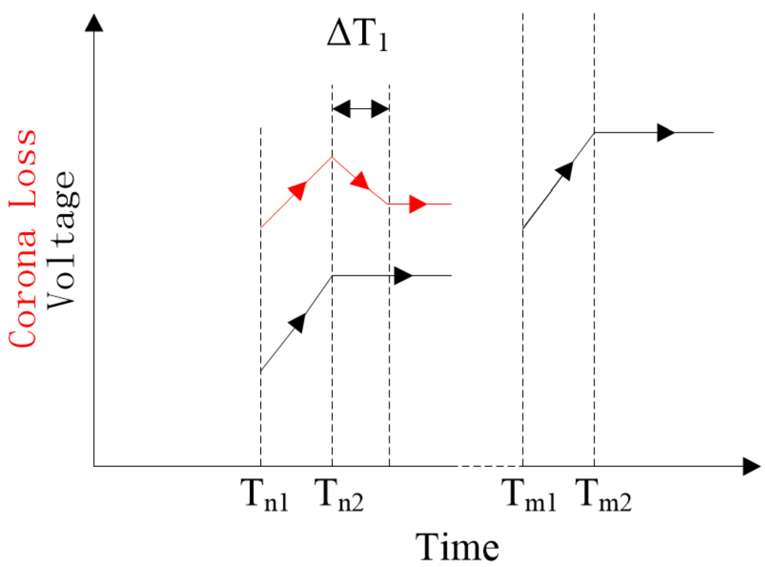
The environmental parameters for fair weather, rain, and rime are as follows

Environmental Parameters.

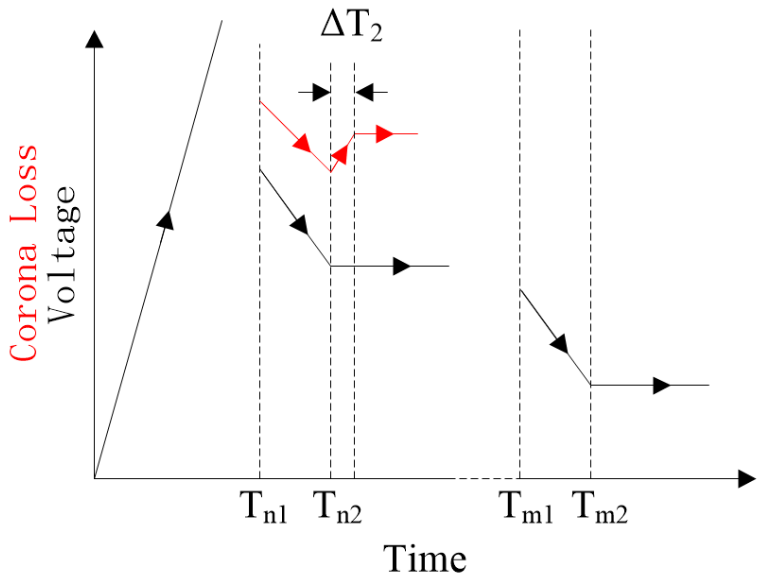
	Dry	Rain	Rime
Ambient air temperature (°C)	12	5	-15
Water droplet size (µm)		38	38
Freezing water conductivity (µS/cm) at 20 °C		50	50
Wind velocity (m/s)	0, 2	0, 2	0, 2
Precipitation rate (mm/h)		15	15

Test Procedure

Corona loss stabilization problem



With increasing voltage



With decreasing voltage ✓

$\Delta T_1 > \Delta T_2$

Test Procedure

Fair weather

The climate room was firstly regulated to a preset temperature set by a proportional integral and differential system (PID). Then, the fans were turned on to generate the desired wind velocity. After that, the corona losses were measured at different voltages. During the corona loss measurement, after corona loss was measured at a certain voltage, ten minutes were spared for stabilization after the voltage was changed for another corona loss measurement.

Rain Condition

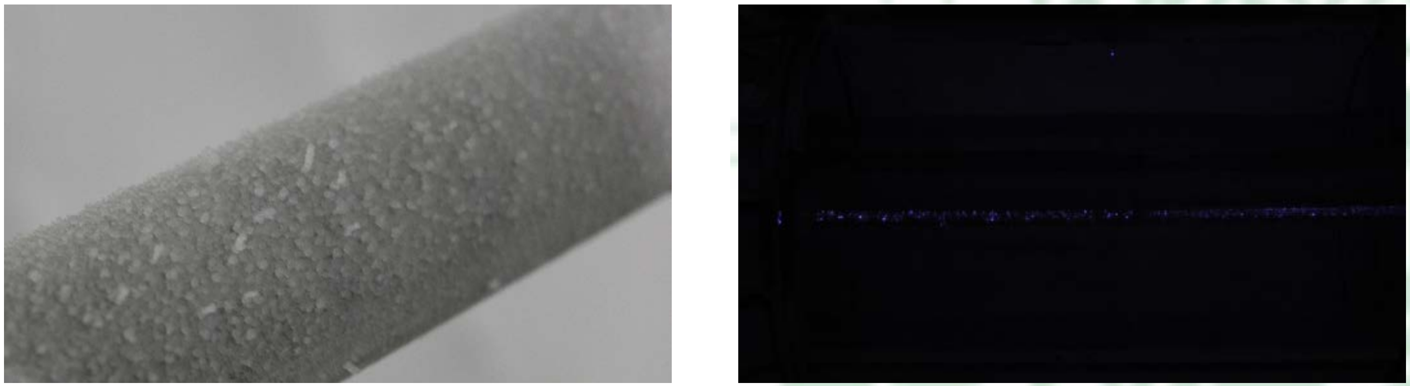
The climate room was firstly adjusted to the preset temperature set by PID. Fans were then turned on to generated desired wind velocity and nozzle system was opened. After that, the corona losses were measured at different voltages. Under the rain condition, one minute was spared for stabilization before each corona loss measurement.

Test Procedure

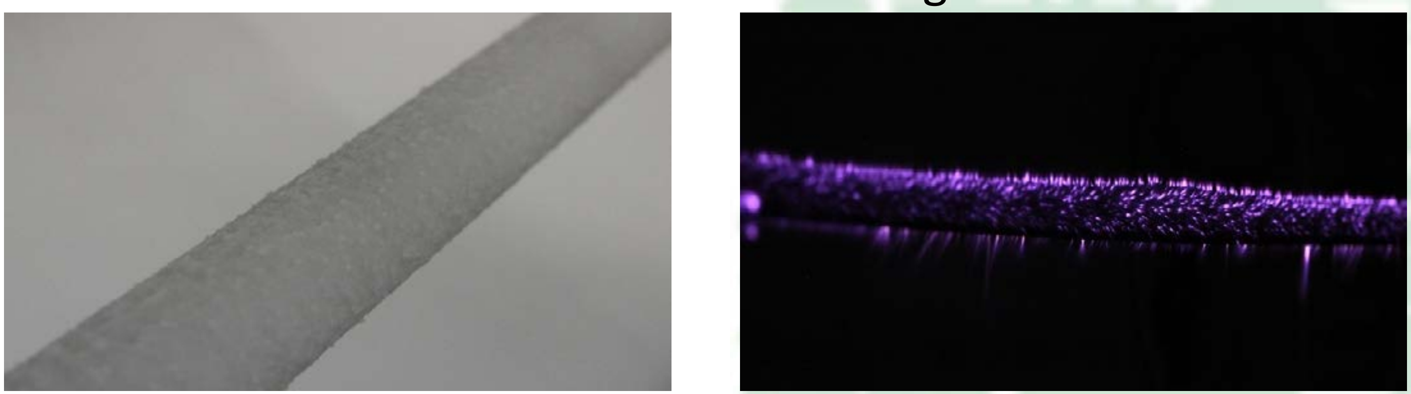
Icing Condition

The climate room was first cooled down to a preset temperature set by PID. After the preset temperature was reached, it was followed by one hour for stabilization. After the preset temperature was reached, fans were turned on to generate the desired wind velocity and it was followed by one hour for stabilization. Then, the voltage was applied to the conductor to yield the desired surface field strength level. After that, the nozzle system was opened and the fans were turned on simultaneously to generate the anticipated wind velocity. The ice accretion process lasted 40 minutes. After ice accretion, the nozzle system was closed for corona loss measurement.

Results and Discussion

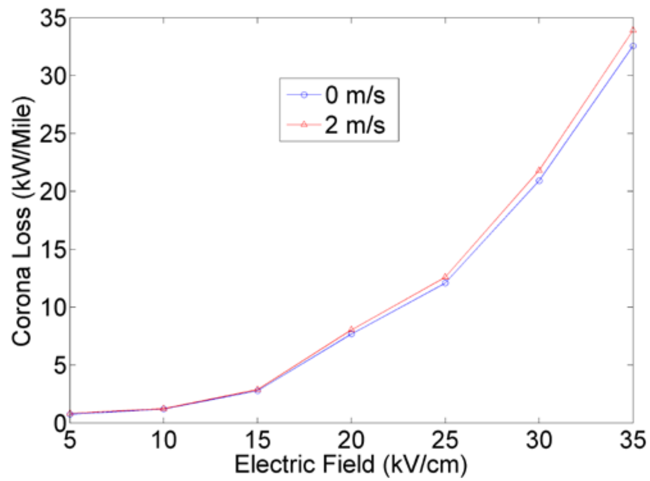


DC+ corona discharge

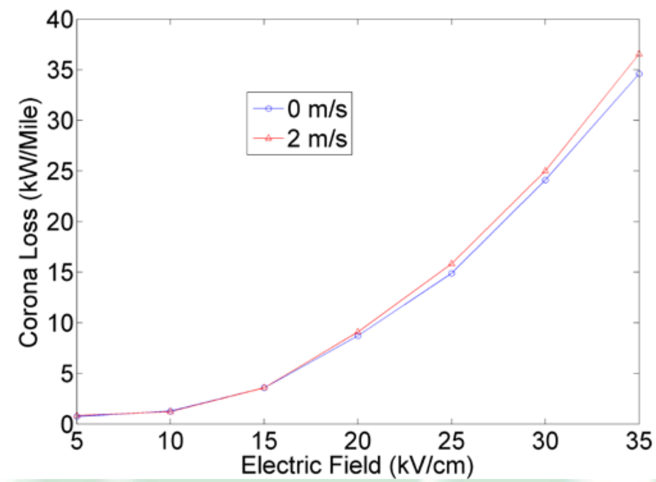


DC- corona discharge

Results and Discussion



DC positive under fair weather

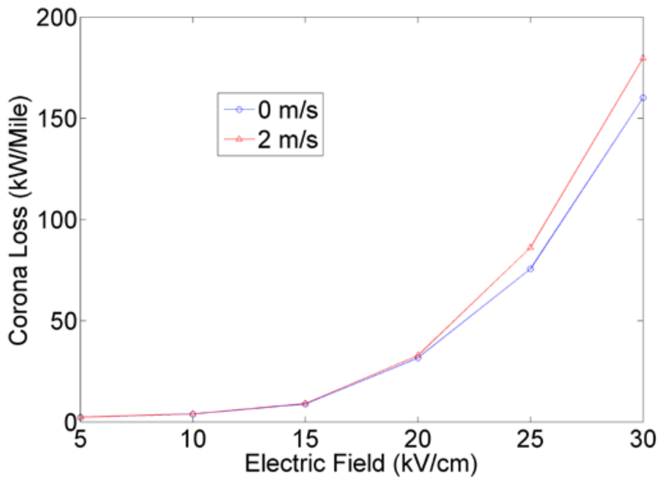


DC negative under fair weather

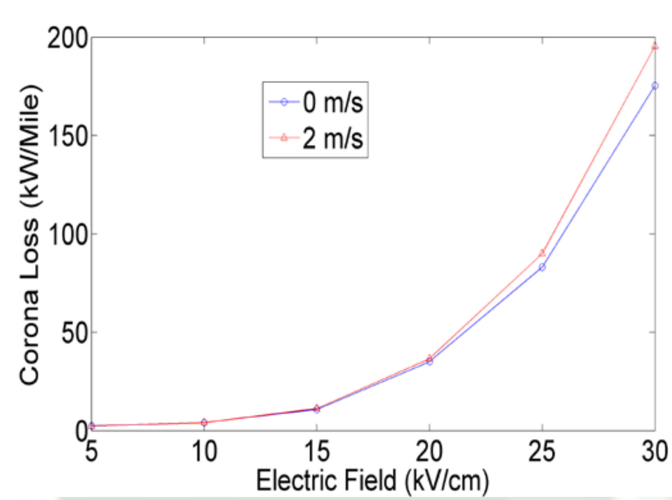
$$\frac{CL_{E=35kV/cm,v=2m/s}}{CL_{E=35kV/cm,v=0m/s})} = 104.2\%$$

$$\frac{CL_{E=35kV/cm,v=2m/s}}{CL_{E=35kV/cm,v=0m/s})} = 105.7\%$$

Results and Discussion



DC positive under rain

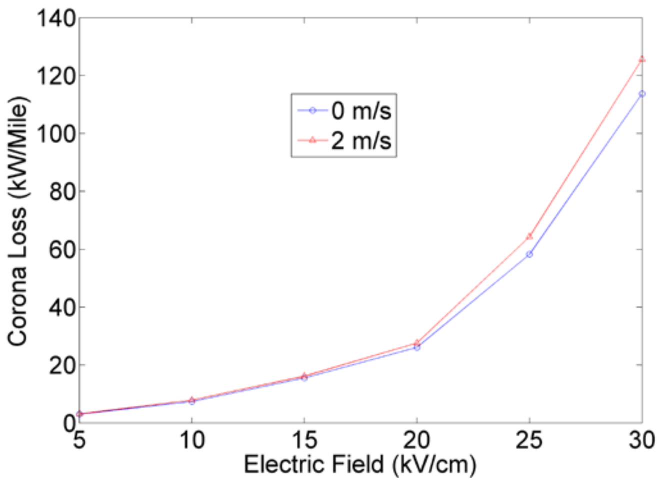


DC negative under rain

$$\frac{CL_{E=35kV/cm,v=2m/s}}{CL_{E=35kV/cm,v=0m/s})} = 112.3\%$$

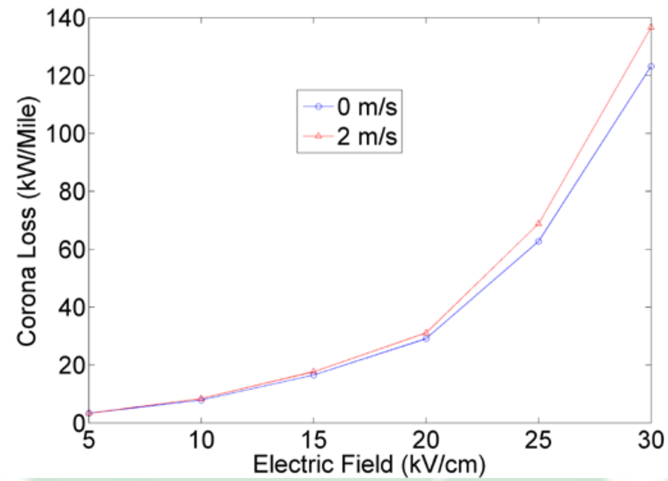
$$\frac{CL_{E=35kV/cm,v=2m/s}}{CL_{E=35kV/cm,v=0m/s})} = 111.4\%$$

Results and Discussion



DC positive under icing

$$\frac{CL_{E=35kV/cm,v=2m/s}}{CL_{E=35kV/cm,v=0m/s})} = 110.5\%$$



DC negative under icing

$$\frac{CL_{E=35kV/cm,v=2m/s}}{CL_{E=35kV/cm,v=0m/s})} = 110.9\%$$

$$I = \int J ds$$

$$\boldsymbol{J} = \mu_E \boldsymbol{E} \rho_e + \boldsymbol{u} \rho_e - D_{IA} \nabla \rho_e$$

Conclusion

- Corona discharges under positive and negative DC voltage are different. When the DC positive voltage applied on the conductor is beyond the corona onset voltage, a smooth bluish-white glow can be observed. However, when the applied voltage is negative, reddish tufts are formed.
- Measured corona losses increases with applied voltage for both positive and negative conditions.
- Since negative ions have a higher mobility than positive ions, corona loss is higher for negative than positive ions for the same applied voltage.
- Under fair weather, the effect of wind on corona loss is minor. However, in the presence of wind, corona loss can be increased by 6-12% after corona onset under rain and icing conditions.

Thank you for your attention!