OUTDOOR INSULATION FOR HVDC OVERHEAD LINES:
A RESEARCH PROJECT

INNOVATIVE TOOLS FOR OFFSHORE WIND AND DC GRIDS

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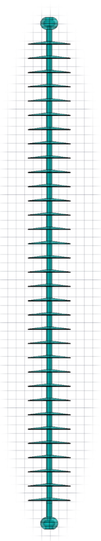
Motivation

In a world of growing power demand, it is critical to increase the power transfer capability of the power system. This can be ensured through a grid physical expansion, voltage uprating of existing AC lines, or their conversion from AC to DC operation. The latter option is the focus of this project, which investigates the Performance of Outdoor Insulation under HVDC Stress.

The research is now developing solutions for the conversion of transmission overhead lines from AC to DC operation, which allows to increase the power transfer capability by a factor of 3. In this regard, climate and environment as well as specific tower configurations were considered. This is a growing engineering challenge, as conversion cases are starting to become more needed around the world to address growing bulk electrical energy transfer. A systematic approach for assessing the best engineering choice for the most suitable HVDC scheme must be considered to optimise energy delivery under fault conditions.

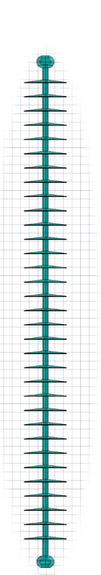


Background

- During the course of the past century, all over the industrially developed countries, electric power transmission has been ensured through the development of an HVAC infrastructure. Mostly 50 and 60 Hz frequencies have been used for the operation of power systems. High voltage is necessary for transmission, to minimise power losses over long distances. Therefore, research on insulating high voltages has been crucial. This process led to the development of different types of insulators.
- Up to now, porcelain and glass have been the most used materials for outdoor insulation. Only from the 70s, polymeric insulators and then composite insulators started to be competitive on the market and represent nowadays a reliable solution.
- Recent technological development has allowed HVDC transmission to be a viable candidate. It enables the connection of non-synchronous AC systems and its losses are inferior over long distances. Moreover, the conversion of existing HVAC overhead lines to HVDC has started to be implemented all over the world, to avoid building new right of ways. To do so, the insulation needs to be changed, otherwise the operating voltage would have to be lowered, because of the pollution problem.
- In fact, given the nature of the DC electric field is monopolar, a continuous force is exerted on the pollution particles in the vicinity of the insulator, which may lead to an increase of the amount of electrolyte deposited on its surface in case of light rain or fog. Such an undesirable accelerated pollution on the insulator surface can result in more frequent discharge activity and lead to flashover.
- Composite insulators represent an interesting solution. Hydrophobicity transfer from the bulk of the silicone rubber material to the polluted surface reduces the effect of pollution on surface conduction and discharge activity.

Objectives

- To select and dimension composite insulator solutions for HVDC overhead lines, for suspension long-rod and insulated cross arms.
- To study voltage distribution along the insulator, adopting a parametric geometrical approach.
- To develop solutions for several case studies. Possibly, the most relevant cases on the market will be analysed.
- To investigate both bipolar and tripolar configurations, to understand the pros and cons of each one and when to deploy them in real cases.
- To collaborate with manufacturers such as FCI, and Transmission System Operators (TSOs), such as National Grid, to stick to real or realistic case studies.
- To collaborate with Universidade do Porto in the period Dec 2018 – Feb 2019 for HVDC testing of composite insulators.



Methodology

Early Stage Researcher 4 project, entitled "Performance of Outdoor Insulation under HVDC Stress", is carried out with the use of several types of models, including:

- **Finite Element Method (FEM) based models**

Different software allows FEM computation for electro-magnetics e.g. Flux Cedrat, Maxwell. However, Comsol Multiphysics is used for this purpose.

It is worth considering that particle tracing may be very difficult to model, due to the complexity of turbulence depending on wind speed and insulator geometry. Moreover, results cannot be validated by field experiments.

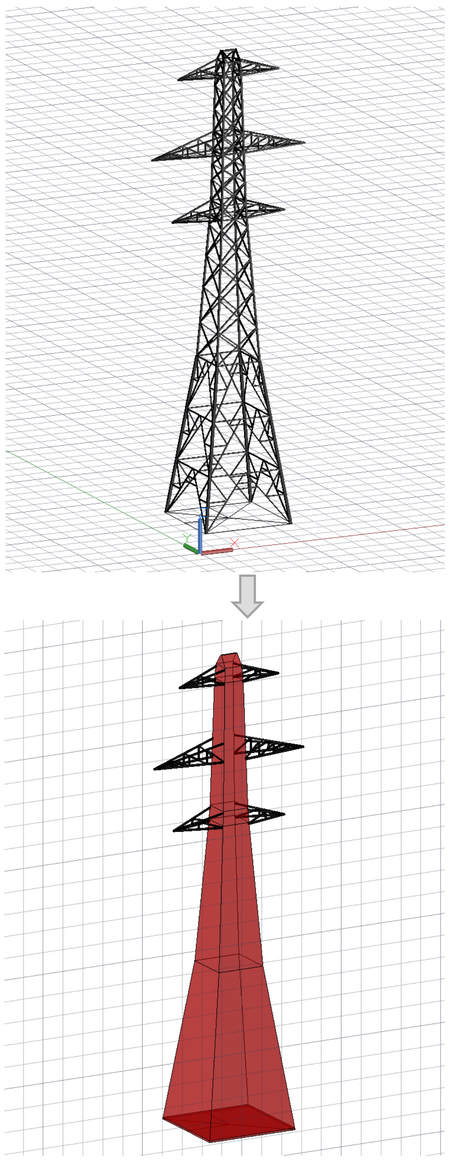
Computational modelling is necessary but not sufficient. That is when testing comes into play.

- **Test Methods**

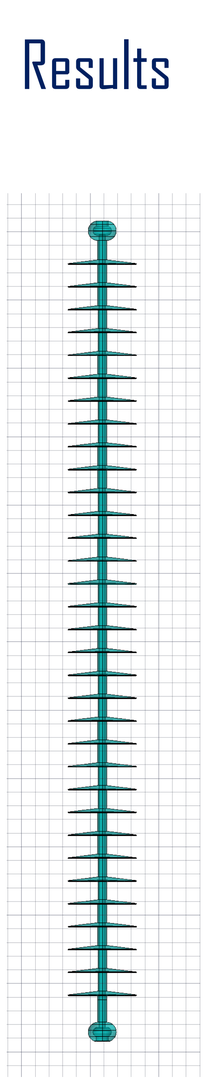
The most common test methods are the Salt Fog, the Solid Layer methods. However, there is a need for the development of new standards for composite insulators tested with HVDC.

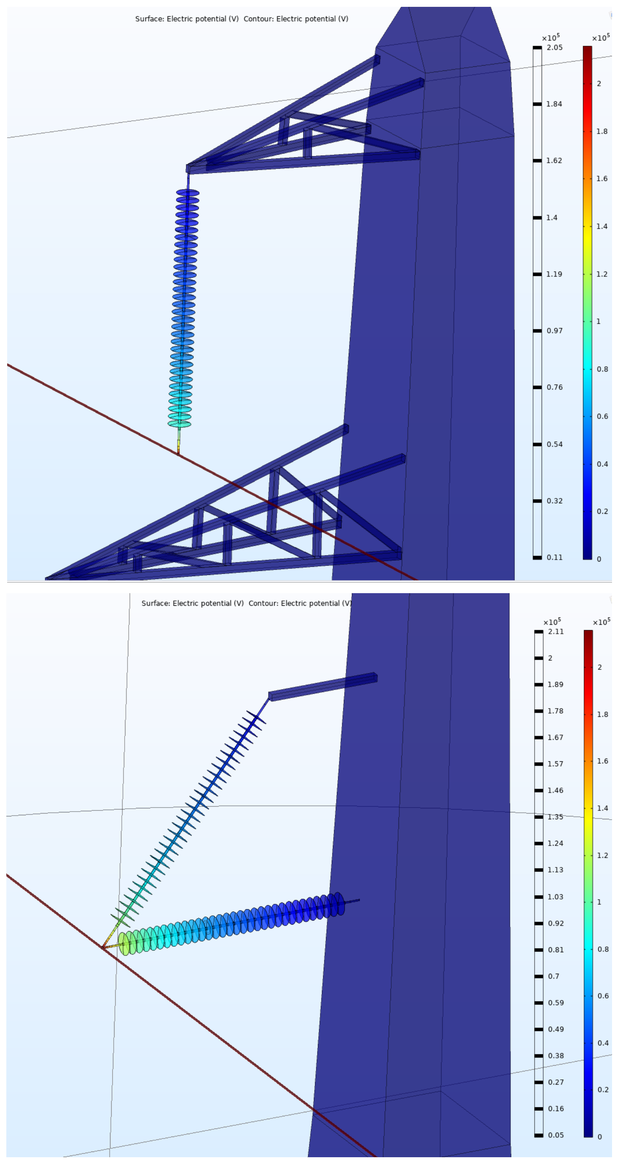
- **Empirical based models**

Models based on empirical collection of data may be used in absence of testing opportunities and as a starting point. One of these empirical-based models is described in CIGRE 518. Its purpose is to serve researchers and engineers to assess the optimal selection of profile and optimal dimensioning, based on expected climatic and environmental conditions. This model has been applied to develop the insulator shown in the results section. Also, switching surge overvoltage recommendations by EPRI have been used to define the suspension insulator length.



Results





Conclusions

- This research project investigates Outdoor Insulation under HVDC Stress.
- First assessments have shown that a power transfer increase of two to three times may be possible in the event of HVAC to HVDC conversion of existing overhead lines.
- The case study of this 132 kV line to line AC tower confirms such evaluations.
- Considered the pollution flashover phenomenon of a highly polluted environment and the typical switching surge factor of 1.5, the conversion leads to a pole to ground voltage of 216 kV.
- The suspension insulator solution is limited by the space constraint set by the live parts of the tower, namely the metallic cross arms.
- The insulated cross arm solution is limited by the compression insulator capacity to withstand compression mechanical stress. It is not yet clear what this length limit would be. However, the proposed voltage is possible to withstand.
- This first assessment suggests that power transfer maximisation could be achieved thanks to the latter solution, according to the mechanically constrained length limit of the compression insulator.
- Further investigation is necessary to assess critical conditions such as movement of conductors due to high wind, operation condition during and after fault.

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