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Development of a reliable modeling system for the calculation of rime ice loads on overhead transmission lines

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The development and validation of a model-based system for calculation and prediction of rime ice loads on overhead transmission lines is presented in this paper. The work is carried out within the frame of the FRonT-LINES research project, and is motivated by recent mechanical failures of transmission lines in Norway caused by extensive ice loads, particularly in the areas exposed to in-cloud icing. The comprehensive modeling is developed in order to improve the calculation of design ice loads as well as for monitoring of lines under operation, including forecasting of potentially critical weather events.

The project comprises mesoscale numerical weather predictions (NWP), field measurements, laboratory tests, and ice accretion modeling including CFD simulations. The NWP model with an optimized setup is used to simulate the local atmospheric conditions and time development of the relevant atmospheric variables, i.e. wind field, temperature, supercooled atmospheric water content, air humidity, etc. The predicted variables are validated using measurements from three different project test sites specially selected within the project and located in exposed mountainous regions of Norway.

To verify the results of calculations, in addition to measurements of standard weather parameters, the following instrumentation has been installed at the test sites:

- A recently developed ice load sensor (Ice-Troll)
- A heated web camera system for reliable ice monitoring
- Real-time ice load measurements in overhead line test spans and in operational high voltage transmission lines

Modeling the time dependent accumulation of rime ice is based on the theory of collision between droplets and cylinders (ISO12494 / Finstad et al. 1988). Initial results of the FRonTLINES project indicated that the readily available formulae for calculation of collision efficiency were inadequate for the large icing diameters often observed at the test sites.

In order to collect empirical data on the collision efficiency for large cylindrical objects, laboratory experiments were designed and carried out at the icing wind tunnel at VTT Technical Research Centre of Finland. Similar experiments were also carried out utilizing a CFD model including droplet trajectory calculations. These calculations were conducted by The Arctic University of Norway (UiT), using the CFD simulation tool ANSYS FENSAP-ICE.

The results show that the icing predictions based on the improved modeling system correspond very well to the measurements in terms of ice accumulation on test spans and operational transmission lines. Maximum ice loads obtained over long time periods are however sensitive to ice shedding events which are somewhat less predictable. Measurements also show that the relative difference between the maximum ice loads on single conductors and maximum ice loads on bundled conductors increase with increased ice load, and that the difference is mainly explained by more frequent ice shedding from bundled conductors.

The paper finally demonstrates how the modeling system can be used for improved calculation of design ice loads in future projects.