CEATI INTERNATIONAL
Centre for Energy Advancement through Technological Innovation

Report No. T153733-33/101

State of the Art Report on Designing Transmission Lines for Wet Snow Accumulation

Contractor:

Kjeller Vindteknikk AS
Kjeller, Norway



Background

- Wet snow occurs in any region of the world where snow falls at ambient temperatures of around $0^{\circ}C$.
- Conductors and ground wires are especially prone to wet snow accumulation.
- Severe wet snow events are reported for all continents in the Northern Hemisphere.
- Wet snow needs to be taken properly into account in the design phase.

Scope

– The objective is to provide a description of state of the art methods for designing transmission lines for wet snow accumulation, and to make recommendations that improve current industry standards.
  - Task 1: Literature review of the physics of wet snow accumulation.
  - Task 2: Description of wet snow accretion models.
  - Task 3: Review of historical wet snow storms from various countries.
  - Task 4: Review of the treatment of wet snow loads in international design standards. Identification of knowledge gaps.
  - Task 5: Discussion of mitigation measures, including actual examples.
  - Task 6: Conduction of a utility survey.

Findings

Wet Snow Physics

- Wet snow icing is primarily a problem on single phase conductors and overhead earth wires. It may also occur on bundled conductors, but to a lesser extent.
- Results:
  - 5-6 additional bullet points for each section (i.e. ‘Results,’ ‘Shortcomings’) summarizing the findings.
- Identifying:
  - The meaning of these results.
  - Shortcomings.
  - Areas for improvement.

Findings

Wet Snow Physics

- Primarily a problem on single phase conductors and overhead earth wires. It may also occur on bundled conductors, but to a lesser extent.
- Wet snow icing on transmission lines only occurs in a very narrow range of atmospheric conditions, and requires positive air temperature.
- Wet snow may occur infrequently, but still poses a significant risk over the lifetime of a transmission line.
- The density may vary from 200 to 800 kg/m^3.
- The impact process of wet snowflakes is still poorly understood.
- Practical models require a combination of theory and empirical relations.

Findings

Modelling Wet Snow Accumulation

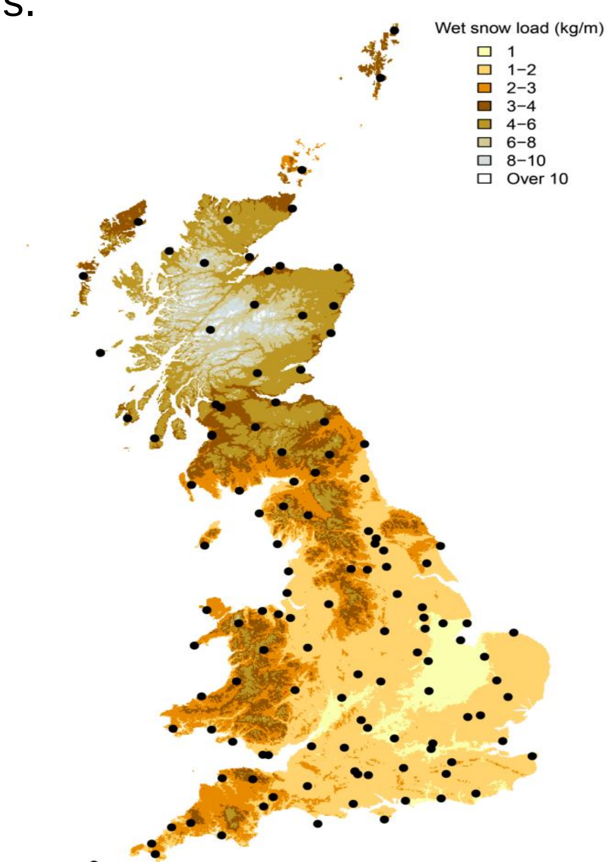
- A variety of models and parameter settings have been proposed in the literature. Issues have been identified with widely used models, and the most recently published papers on the respective subject are recommended.
- Modeling based on weather station data:
  - Care should be taken regarding the quality of meteorological measurements during wet snow storms.
- Modeling based on Numerical Weather Prediction (NWP) models:
  - Methods are at a very early stage of development, and the use of such models should be carried out in collaboration with NWP experts.

CEATI INTERNATIONAL
Innovation Through Collaboration

Findings

Modelling Wet Snow Accumulation

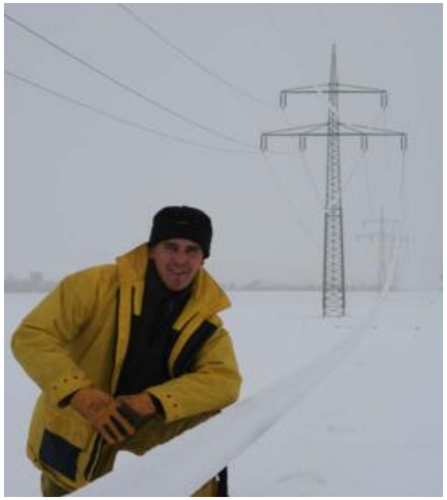
– Regional or national maps of wet snow occurrence and its extreme value distribution can be made based on a dense network of weather stations and/or hindcast archives from NWP model simulations.



Findings

Historical Events

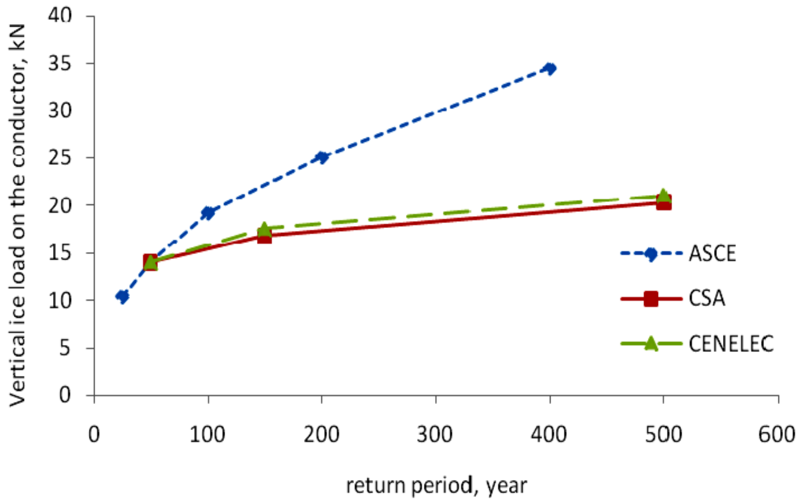
- Severe events of wet snow are reported for all continents in the Northern Hemisphere.
- Several cases have also been registered in New Zealand and South Africa.
- A wet snow storm in Germany (2005) was the most severe wet snow storm in terms of total damage and economic consequence.
  - This case clearly illustrates that wet snow icing can suddenly strike a region where past experiences have been limited.



Findings

Industry Standards

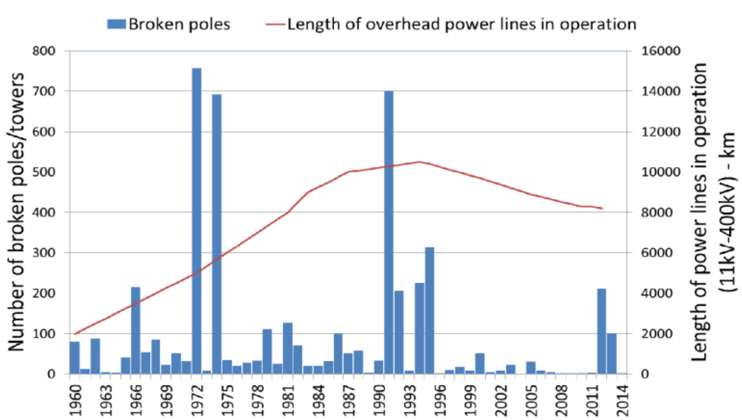
- The utility survey shows that wet snow loads are considered differently amongst utilities, varying from country to country.
- In some wet snow prone regions, a map or tabulated reference values of characteristic wet snow loads are provided according to area and altitude.
- A fixed ice density of 900 used in many standards is not applicable to wet snow icing.
- From the author's point of view, it is necessary to treat the load case of wet snow according to the climatic conditions of the specific region or country.
- Different factors are used for conversion to return periods other than 50 years:

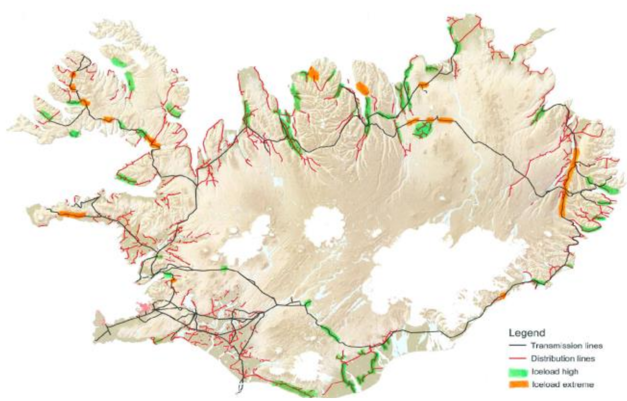


Findings

Mitigation

- No fully reliable method for preventing icing on overhead line conductors or for removing formed ice was found.
- In critical situations, de-icing measures such as joule heating or mechanical ice removal are actively used by various utilities.
- In case of failure or collapse due to wet snow, it is important to review designs for wet snow loadings in the restoration process.
- The most effective mitigation method seems to be designing the line according to the expected loading for the area. This includes configuration according to the local topography, prevailing exposure, and wind direction.
- Crossing a valley at a different angle has been used as an efficient mitigation method in Iceland.
- Systematic collection and documentation of wet snow events has improved the mitigation strategy in Iceland, and consequently reduced the number of failures.





Conclusions and Recommendations

- Since wet snow, freezing rain, and rime ice result from different physical processes, their statistical properties accordingly differ as well. Extreme values must therefore be calculated individually for each process.
- A fixed ice density of 900 kg/m3, which is used in many standards for calculating wind pressure on iced conductors, is not applicable for wet snow icing. Wet snow icing normally has a considerably lower density. A site specific value can be calculated using meteorological data.
- Measurements of wet snow icing can be performed where icing is frequent, preferably through the use of test spans instrumented on line load cells or data loggers. The greatest potential for improving the data collection of local wet snow icing conditions is through combining a measurement campaign with a model study, such that a wet snow accretion model is coupled to an NWP model.

Conclusions and Recommendations (cont’d)

- In case of failure or collapse due to wet snow, it is important to review designs for wet snow loadings in the restoration process.
- Analyses of design loads should take local conditions into account, including prevailing wind direction during icing, and its normal component to the transmission line. If there is a lack of reliable and representative weather station data, studies using NWP models must be considered.
- To further improve the reliability of wet snow models, case studies should be carried out for the main historical events identified in the report.
- Factors for converting wet snow loads to different return periods should also be studied further, by simulating wet snow loads over multiple decades.