August 27-31, 2023
FLORENCE - ITALY
16th International Conference on Wind Engineering
ICWE 16

Transmission line ice accretion and wind loads modelling

D. D. J. Smith [1], R. G. J. Flay [1], R. W. Turner [2], N. J. Locke[3], M. Aghamohammadi[1]

[1]*Department of Mechanical and Mechatronics Engineering, University of Auckland, Auckland, New Zealand, r.flay@auckland.ac.nz*
[2]*National Institute of Water and Atmospheric Research, Wellington, New Zealand*
[3]*WSP Wellington, New Zealand*

SUMMARY
It is imperative to model the ice and wind loads on transmission lines to understand when failures are likely to occur to avoid significant economic losses and electricity supply instabilities. The combination of ice and wind loads can lead to substantial failures, and there is a lack of data and reasonable quantitative estimates of these risks in New Zealand. Numerical modelling of the icing loads supplemented with meteorological data is the preferred approach due to the rarity of large icing events and increase in spatial resolution. The time-dependent Makkonen model is implemented to simulate the ice accretion on New Zealand's transmission lines for a 19 June 2013 storm that resulted in damage in the upper South Island. Ice accumulation predictions are compared to modelling carried out by NIWA, which is based on a combination of the Sakamoto and Makkonen models. The results show good agreement in predicting the loads. However, a direct comparison cannot be made due to the difference in the modelling methodology.

Keywords: transmission line, ice accretion, wind loads modelling

1. INTRODUCTION

Modelling atmospheric ice accretion and wind loads on cables is essential in designing, planning, and constructing transmission line networks, particularly in ice-prone regions. If networks are under-designed, the structural damage due to the combined ice and wind loads may lead to considerable economic losses and electricity supply instability which at best could be inconvenient and worst lead to loss of life. On the other hand, if the structures were designed for unrealistically high ice and wind loads, the construction cost would quickly increase. Therefore, it is vital to accurately estimate ice accretion and the maximum wind loads in different conditions to optimise the design of transmission line networks.

The present paper outlines the implementation of the Makkonen model (Makkonen, 2000), using atmospheric modelling data provided by the National Institute of Water and Atmospheric Research (NIWA) from their numerical weather prediction (NWP) modelling software New Zealand Convective Scale Model (NZCSM). NZCSM is a 1.5 km grid-spaced model which has its own microphysics schemes for forecasting rime and glaze icing. The detailed formulation of the Makkonen ice accretion model is omitted here but can be found in the cited reference. The assumptions used in adopting this model and preliminary results are outlined, pending validation.

2. THEORY

Two different icing regimes, dry and wet, can affect the density and mass of growing ice. The sole driver between the two regimes is the thermodynamic conditions resulting in the system heat transfer. For scenarios where there is a net heat gain in the system, a layer of liquid forms from the droplets on melted ice surfaces. Wet growth is when the liquid layer freezes, resulting in ice development. However, for dry growth, the heat transfer can be neglected as the latent heat released during the freezing of the droplets dissipates without altering the ice state (Makkonen, 2000).

The conditions under which the different accretion types will occur have been defined by Sundin and Makkonen (1998) depending on the wet-bulb temperature. Glaze ice occurs when the wet-bulb temperature is less than $0\,^{\circ}\mathrm{C}$ and it is raining. Rime occurs when the air temperature is less than $0\,^{\circ}\mathrm{C}$ with fog surrounding the transmission lines, or the transmission lines themselves being above the cloud base. Wet snow growth occurs when the wet-bulb temperature is above $0\,^{\circ}\mathrm{C}$ and with heavy snowfall being present.

The rate of ice accretion is computed from the expression $dM/dt = \alpha_1\alpha_2\alpha_3WVA$, where W is the Liquid Water Content (LWC) in the air, V is the average velocity of the impinging droplets, and A is the frontal area of the cable. Furthermore, the three factors α_1, α_2 and α_3 are the collision, collection and accretion efficiencies, respectively, and are functions of the flow properties and surrounding atmospheric conditions. Although it appears that higher impact velocities result in larger accretion, the model demonstrates lower accretion as the wind speed increases due to changes in α_1, α_2 and α_3.

3. PRELIMINARY RESULTS AND DISCUSSION

An illustrative snowstorm case used for the simulation was on 19 June 2013 and was provided by NIWA. The modelled weather system is shown in Figure 2, with the mean wind speed at 10 m above ground level (agl) and sea level pressure contours (hPa) plotted.

The total ground-level snow accumulation is shown in Figure 1. There is a weak correlation between snowfall and ice accretion due to similar atmospheric properties. The initial results from the ice accretion modelling are shown in Figure 3. The New Zealand transmission line network is overlaid in red, and the location of interest at the top of the South Island is shown with a yellow dot.

A significant portion of the ice accretion forms in the South Island and consists of both wet and dry accretion. The wet accretion contributes to most of the mass as a direct result of the snow accumulation. The amount of ice mass in grid points close to transmission lines is all lower than 0.15 kgm^{-1}, where the larger mass is in the Southern Alps and Central Plateau regions where minimal electrical lines exist.

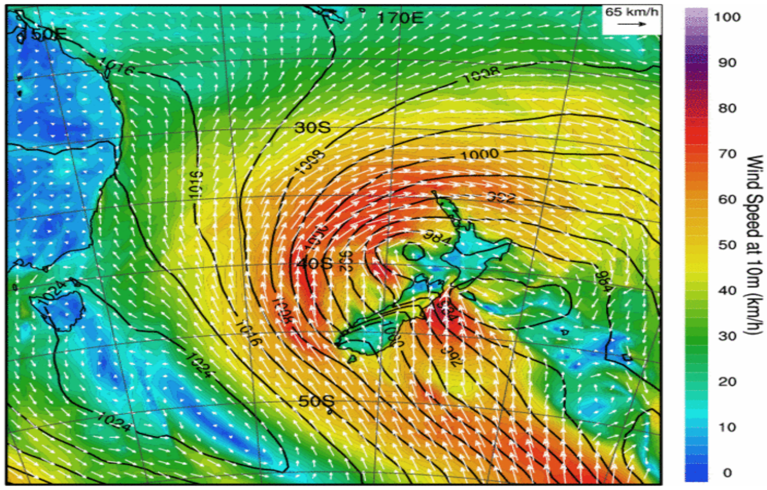

Figure 2. 1.5 km resolution NZCSM output for 19 June 2013 showing mean wind speeds at 10 m agl and sea level pressure contours (hPa)

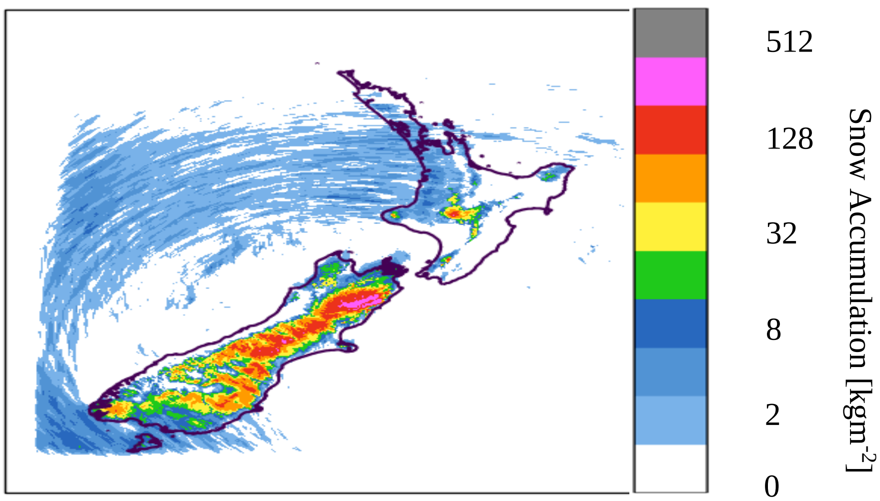

Figure 1. 1.5 km resolution NZCSM output for 19 June 2013 showing total snow accumulation over the 36 hours simulated

NIWA carried out previous modelling for the location of interest in the upper South Island, which showed a combination of wet snow and rime ice accretion on a section of the transmission line. The models used were Sakamoto (2000) for wet snow and Makkonen (2000) for rime icing. Direct comparison between the different methods is not valid due to the uncertainties surrounding the collection efficiency. A sensitivity analysis was conducted by NIWA, while the Makkonen model uses formulations from Finstad et al. (1988). Additionally, the collection efficiency was assumed as unity in NIWA's modelling, which is only valid in the Makkonen model if wind speeds were 1 ms^{-1} or lower.

It is important to note that the Makkonen model predicts small amounts of glaze ice which was not observed during the storm. This is due to the atmospheric conditions being suitable for the growth of glaze, but realistically the small amount modelled would have been dispersed by the wind. Although the snow accumulation at ground level is quite high, the amount which sticks to the cables is still very low due to the wet bulb temperature being below 0 °C for a large portion of the storm. The wet-bulb temperature must exceed 0 °C for the LWC in the snow to be high enough to stick to the cables instead of bouncing off.

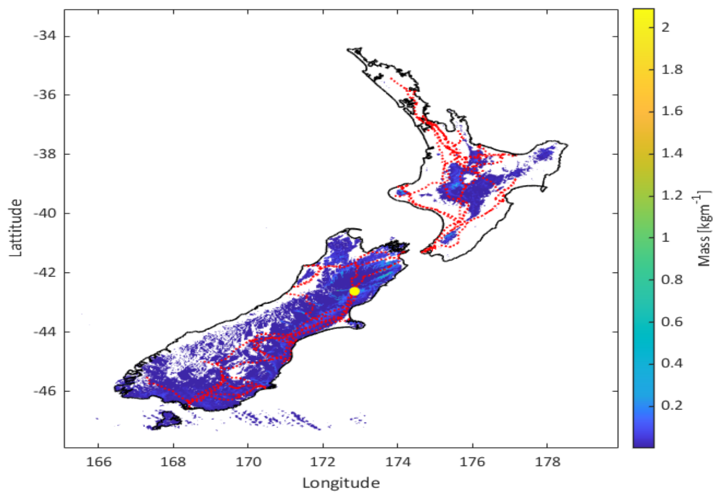

Figure 3. Preliminary ice accretion on the New Zealand transmission line network for the storm of 19 June 2013. The location of interest is shown with a yellow dot

4. CONCLUSIONS

The modelling of ice accretion and wind loads on transmission lines was investigated in this paper. The Makkonen model was shown to be a comprehensive model for calculating the expected ice accretion on transmission lines and was exploited to model ice accretion in New Zealand. The results were compared with the meteorological data from NZCSM provided by NIWA for a snowstorm that occurred on 19 June 2013. Due to the uncertainty surrounding the collision efficiency, the exact measurements could not be compared directly. However, the ice load in the location of interest from the Makkonen model was approximately 0.06 – 0.11 kgm^{-1}, whereas the previously calculated values (from NIWA) were between 0.133 – 0.296 kgm^{-1}. The results can help to ensure that the structural components are strong enough to withstand the additional loading from the added mass of ice and increased wind loads. Future work will involve validating the assumptions and modelling inputs used.

ACKNOWLEDGEMENTS

Funding for this research has been provided by the New Zealand Government through the Weather and Wildfire Theme of Resilience National Science Challenge (Kia Manawaroa - Ngā Ākine o Te Au Tūroa) under the Programme Subcontract: GNS-RNC048.

REFERENCES

Finstad K., Lozowski E., Makkonen L., 1988. On the median volume diameter approximation for droplet collision efficiency. *J Atmo Sci.* 45: 4008-4012

Goodwin III E., Mozer J., Di Gioia Jr A., Power, B. (1983). Predicting ice and snow loads for transmission lines. *Proceedings of the First IWAIS*, Hanover, USA. 1983

Makkonen L., 2000. Models for the growth of rime, glaze, icicles and wet snow on structures. *Phil trans R Soc Lond A.* 358:2913-2939

Sakamoto Y., 2000. Snow accretion on overhead wires. *Phil trans R Soc Lond A.* 358:2941-2970

Sundin E., Makkonen L., 1998. Ice loads on a lattice tower estimated by weather station data. *J App Met.* 37:523-529