Background and objectives

Wind energy’s contributions as a reliable source of clean energy continue to grow, both in North America and globally. In Canada, wind energy installed capacity increased by 20% annually from 2008 to 2018 and is one of the lowest cost sources of new generating capacity in the country. Cold climate operation however continues to be challenging. Ice that accumulates on the wind turbine rotor from freezing precipitation (glaze) or supercooled water droplets formed in clouds (rime) changes the shape and surface roughness of the airflow profiles, affecting the aerodynamic efficiency of the turbine and reducing power production [1, 2]. Production is further impacted if site safety is affected by the risk of ice throw or if turbine shutdowns are triggered. Ice accumulation can also increase vibrations and fatigue of wind turbine components [3].

Estimation of cold climate - induced losses

NRCan conducted a study 89 Canadian wind farms over 2009-2016 to examine the effect of cold climate on Canadian wind farm performance in terms of energy losses, financial losses, and avoidable greenhouse gas (GHG) emissions. The study used monthly wind farm production data obtained through the Wind Power Production Incentive (WPPPI) and EcoEnergy for Renewable Power (EcoERP) federal incentive programs.

Survey of cold climate operations

The Cold Climate Challenges for Wind Power Projects in Canada Survey was conducted in 2017 by the University of Calgary to gain insights on cold climate challenges for project developers and operators, including regional differences in wind turbine icing, site safety accessibility impacts, and observed cold climate induced losses at commercial wind project sites. 43 wind power projects from across Canada participated in the survey, representing 13 unique operating companies and 3,540 MW of installed capacity, roughly 30% of Canada’s total wind power capacity at the end of 2017. AEP losses were generally in line with the results of the wind energy production.

Developing an operational icing forecast

Modeling ice thickness on rotating blades is complicated by the number of parameters involved and the non-linear rates of ice accumulation and shedding. Nergica has developed a transfer function to produce energy loss forecasts from observation data. This model is known as GPEO, for “Modèle de Givre et de Pertes Énergétiques Opérationnelles” (Icing and Production Loss Model [5]).

Icing forecast model validation

GPEO’s modeled ice accumulation estimates were compared to other ice detection methods including a Goodrich meteorological ice detector, nacelle-mounted ice monitoring camera, double anemometry (heated and unheated) and Combitech instrumental ice detector. GPEO successfully identified most meteorological icing periods, but appeared to be less accurate at modelling instrumental icing periods. Each of the sensors measures different parameters related to icing, in different locations (e.g. met. mast vs. wind turbine) underscoring the difficulty in establishing a single reference signal for icing to measure GPEO performance against. The accuracy of the GPEO icing forecast is also highly dependent on the accuracy of the ECCC input forecasts. Several icing events that were not well captured by GPEO could be attributed to an absence of icing conditions (e.g. precipitations or clouds) in the meteorological forecasts.

Discussion and conclusions

Two independent studies were conducted and contrasted to better understand the scale and magnitude of cold climate impacts and challenges at Canadian wind farms, in terms of lost revenue for wind farm owners, and lost energy to the grid representing avoidable GHG emissions.

Utilities and system operators face uncertainty around the timing and magnitude of icing events, and the resulting wind farm power loss, and may need to hold additional reserves in their system to account for such events. As the penetration of wind and other renewables increases, an accurate method for forecasting icing events is critical, allowing system operators to avoid unnecessarily holding additional reserves or curtailing entire wind farms in advance of a potential icing event. Nergica is working to further develop the transfer functions between icing accumulation estimates and utility grid impacts, and will conduct additional on-site validation with wind farm operational and observation data. NRCan aims to provide operational icing forecasts to Canadian utilities, and will support validation and testing of the model within actual utility settings.