UNDERSTANDING ICE ACCUMULATION TO WIND TURBINES WHITE PAPER

Marty McKewon, Chief Meteorologist, Indji Systems

BACKGROUND

The accumulation of ice on wind turbines, in particular the blades, poses several significant problems to the industry. These problems can be both financial and safety related. The cost due to turbine downtime can be substantial on a large farm with many turbines. Better understanding of the problem of ice accumulation can be extremely helpful for wind farm owners and operators. First, let's examine the impact created by ice accumulation to wind turbines.

Problems due to ice accumulation on blades:

- Up to 20% annual energy production loss
- Increased component fatigue from load
- Safety risk due to ice shedding
- Increased noise levels

OBJECTIVE

The intent of this white paper is to help wind industry professionals have a better understanding of the types of ice accumulation to wind turbines and to clearly understand the weather patterns and conditions that lead to icing. Understanding the different types of ice accumulation will allow for more informed business decisions. Increased awareness of forecast methods and resources will help you with preparedness and mitigation of ice accumulation before and after the event.

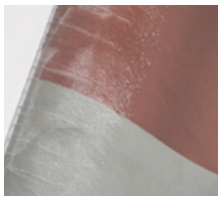
FORECAST METHODS

There are multiple forecasting methods. Publicly available forecasts such as local television and the National Weather Service can bring awareness to precipitation based icing and freezing fog. However, they are targeted to predict ice accumulation below 30 meters. Forecasts from private, commercial sources, continue to improve and new ensemble model forecasts are more accurate and can target ice accumulation forecasts to wind farms. Additionally, alerts can be issued to provide advance notice of impactful events. Larger OEMs and Owner/Operators may have meteorologists on staff who can perform a deeper analysis of weather patterns and conditions to deliver a more wind farm specific forecast. This can be especially valuable for in-cloud icing events.

TYPES OF ICE ACCUMULATION, RELATED WEATHER CONDITIONS, PROPERTIES

PRECIPITATION BASED ICING[1]

Freezing drizzle



Freezing rain

Wet snow

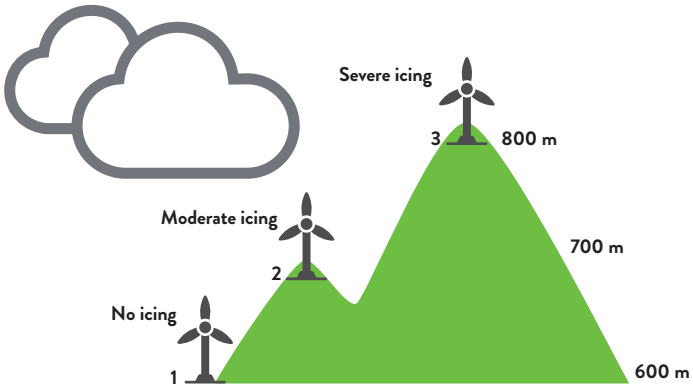
Freezing drizzle and freezing rain occur when supercooled water droplets fall onto the surface (wind turbine blade) of an object with a temperature below freezing. Wet snow can cause ice accumulation to turbine blades because it is made up of partially melted snow crystals which can stick to the blades and freeze upon contact. A wet snow icing event followed by a cold snap with very low temperatures can cause strong accretion of ice to blades that can persist for an extended period of time (days).

Precipitation based icing is the best understood type of icing by the lay person and it is also the most frequently forecast type by local TV and National Weather Service sources. Precipitation based icing results in a glaze type of icing. The ice accumulation that occurs from precipitation events is generally clear in color and has the highest density of the icing types. The rate of accumulation is dependent on the following:

- Wet bulb temperature
- Wind speed / stronger winds = more ice
- Rate of precipitation

Fortunately, precipitation-based icing is usually a short-lived event, lasting only hours.

UNDERSTANDING ICE ACCUMULATION TO WIND TURBINES WHITE PAPER



IN-CLOUD ICING[2]

- Turbines are shrouded in the clouds
- Most common type of icing
- Most severe in elevated locations

In-cloud icing occurs when super-cooled water droplets in the cloud come in contact with a surface (wind turbine blade) and freeze on impact. Not only is in-cloud icing the most common type of icing, it also has the most significant impact with pro-longed events lasting over 24 hours, and significant ice accumulation is possible. In-cloud icing is dependent on the height of the cloud base. As shown in the drawing above, it is possible to have some turbines impacted and others not impacted during the same event. In-cloud icing is the most complex type of icing because it can result in three types of ice accumulation.

- Glaze
- Hard rime
- Soft rime

In the first category, in-cloud and precipitation-based icing can occur at the same time resulting in a heavy glaze ice accumulation. The most impactful and most likely to lead to a turbine shut-down. In the case of hard or soft rime icing, accumulation is dependent on the water droplet size, wind speed and atmospheric moisture content. Forecasts for in-cloud icing are challenging and typically come from private sources.

FREEZING FOG/MIST[3]

- Usually results in light ice accumulation
- Often not well forecasted
- Prolonged events can occur

As with in-cloud icing, accumulation of ice occurs in freezing fog or mist when super-cooled, tiny water droplets come in contact with a turbine blade that has a surface temperature below freezing. This form of icing can occur with air temperatures well below freezing. It can also occur when air temperatures are above freezing but the blade surface is below freezing.

Icing from freezing fog and mist results in a soft rime accumulation which has the lowest density of the ice types and often has a frosty appearance. This type of icing is more common in the central and northeast United States in the mid to late winter. One common scenario when freezing fog occurs is when an arctic cold front with shallow, dense air undercuts a warmer, moist airmass in place causing lift, clouds and in some cases, even freezing mist/fog. Another example would be when a warmer, moist airmass is transported into a region with snow cover. In this case, cooling occurs and the airmass becomes saturated and fog develops. At that point the tiny water droplets of fog can freeze onto the cold, surrounding surfaces.

UNDERSTANDING ICE ACCUMULATION TO WIND TURBINES WHITE PAPER

CONCLUSIONS

Icing to wind turbines, and in particular, the blades, is a serious problem in cold weather climates. Advanced notification and awareness of these events will increase preparedness and aid in mitigation efforts to reduce the impact the event has on operations. Consider the following actions that could take place:

- Fine-tuning of power forecast to account for reduction in output and avoid being caught short in your power production forecast to the market
- Increased awareness to owners and off-takers, days ahead of the event, that power production could be significantly impacted
- Smarter maintenance planning and scheduling through awareness of the event duration and total impact
- Improved safety awareness through review of the post event forecast to determine the ice shedding threat
- Awareness of expected significant events could lead to a pro-active shutdown of turbines to avoid excess load and component fatigue

Forecasts from commercial providers continue to improve in this area. Industry stakeholders can expect and should require continued improvements in the area of ice forecasting accuracy and advanced alerting of events to help mitigate the impact to operations.

REFERENCES

[1] Wind Power Engineering and Development; Wind power technicians face the freeze - image. 2016

[2] TechnoCentre Eolien; Develop a business case that optimizes cold climate generation - image. 2014

[3] M. Marten; “My” wind farm - image. May 2013