

1. Abstract

Some effects of ice on wind turbine blades are:

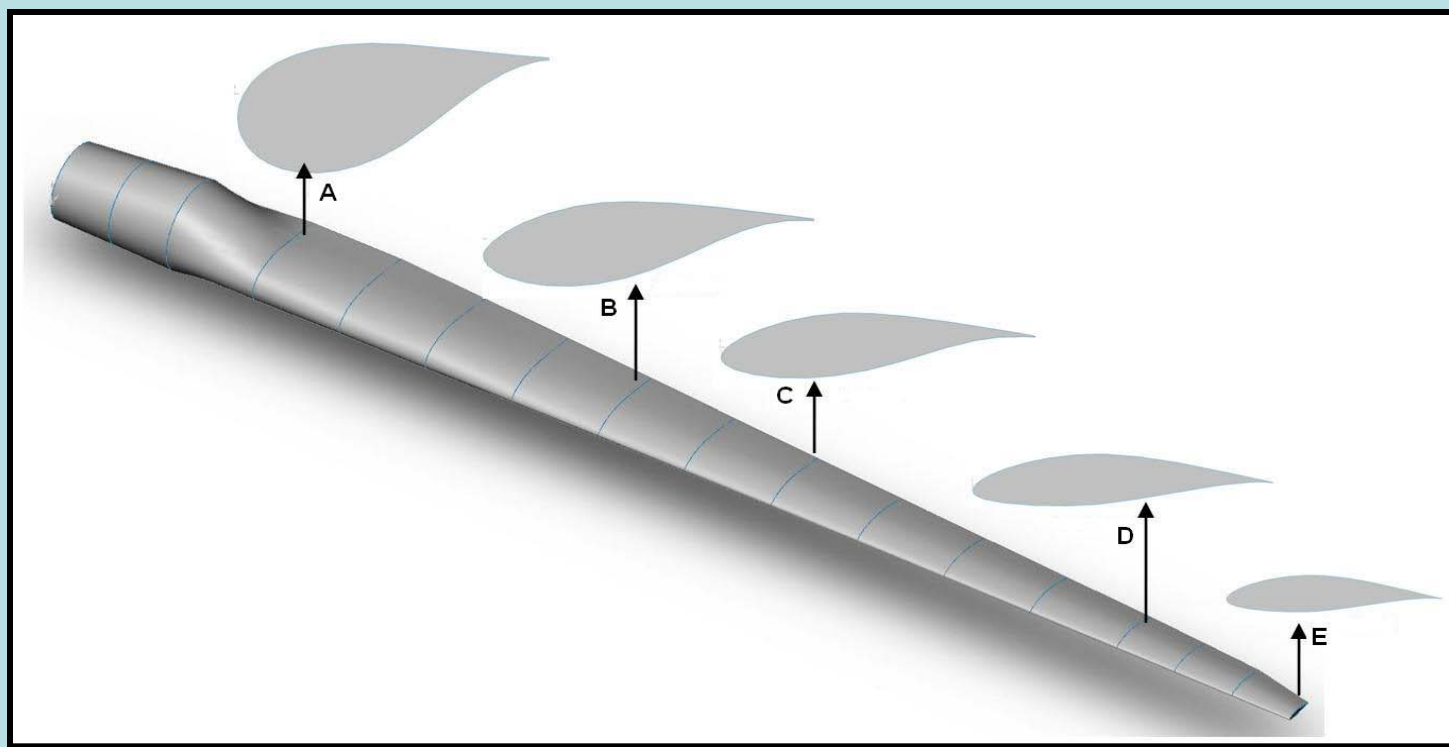
1. **Reduced energy production.** (Studied in this work.)
2. Overloading.
3. Increased fatigue
4. Dangers from ice shedding.

To better understand the effect of icing on energy production;

1. Ice accretion was modelled for a large pitch controlled wind turbine.
2. The effect on the power curve was calculated.
3. The changes in power production were compared with measurements from icing events at Nygårdstjell windpark.

2. Modelling of icing

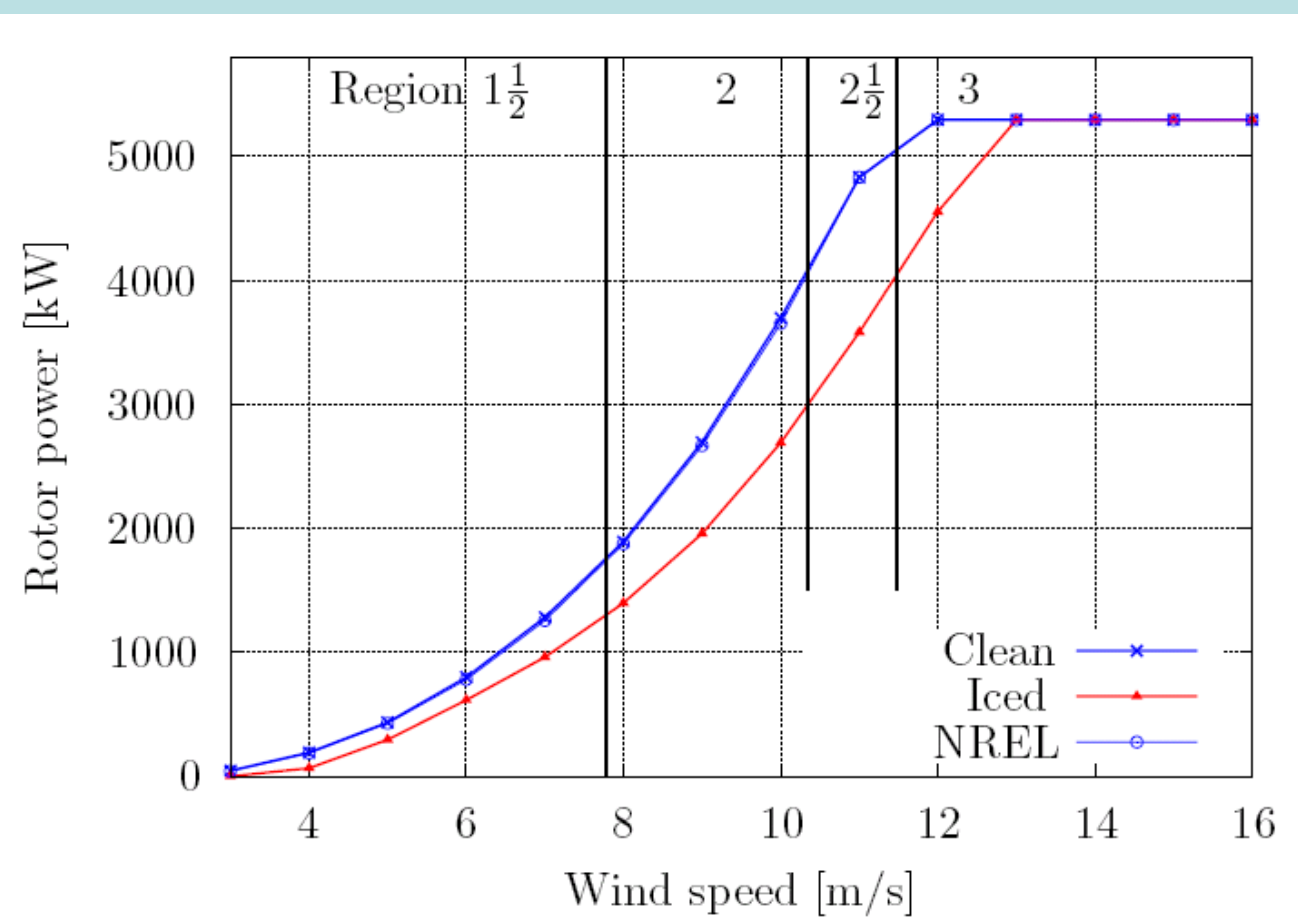
Ice accretion during a 1 hour icing event was modelled at five stations along the blade using the CFD solver FENSAP-ICE and the aerodynamic coefficients of the clean and iced profiles were determined using FENSAP.



Sections where ice accretion was modelled.

Station	A	B	C	D	E
Radius (m)	13.25	33.75	41.95	54.25	63
Chord (m)	4.557	3.748	3.256	2.518	1.419

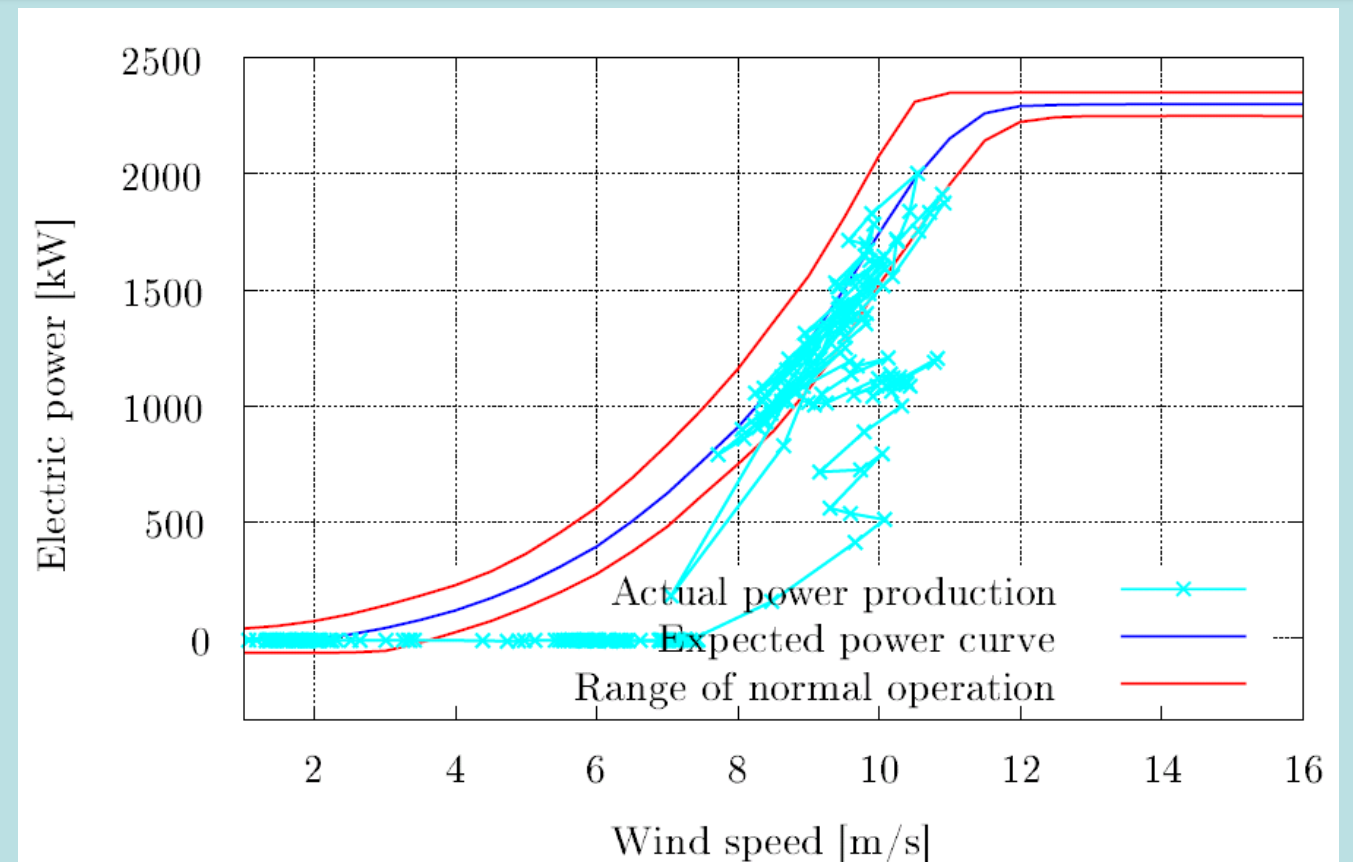
Blade element momentum (strip) theory was then used to calculate the power curves for the clean and iced cases (shown below).



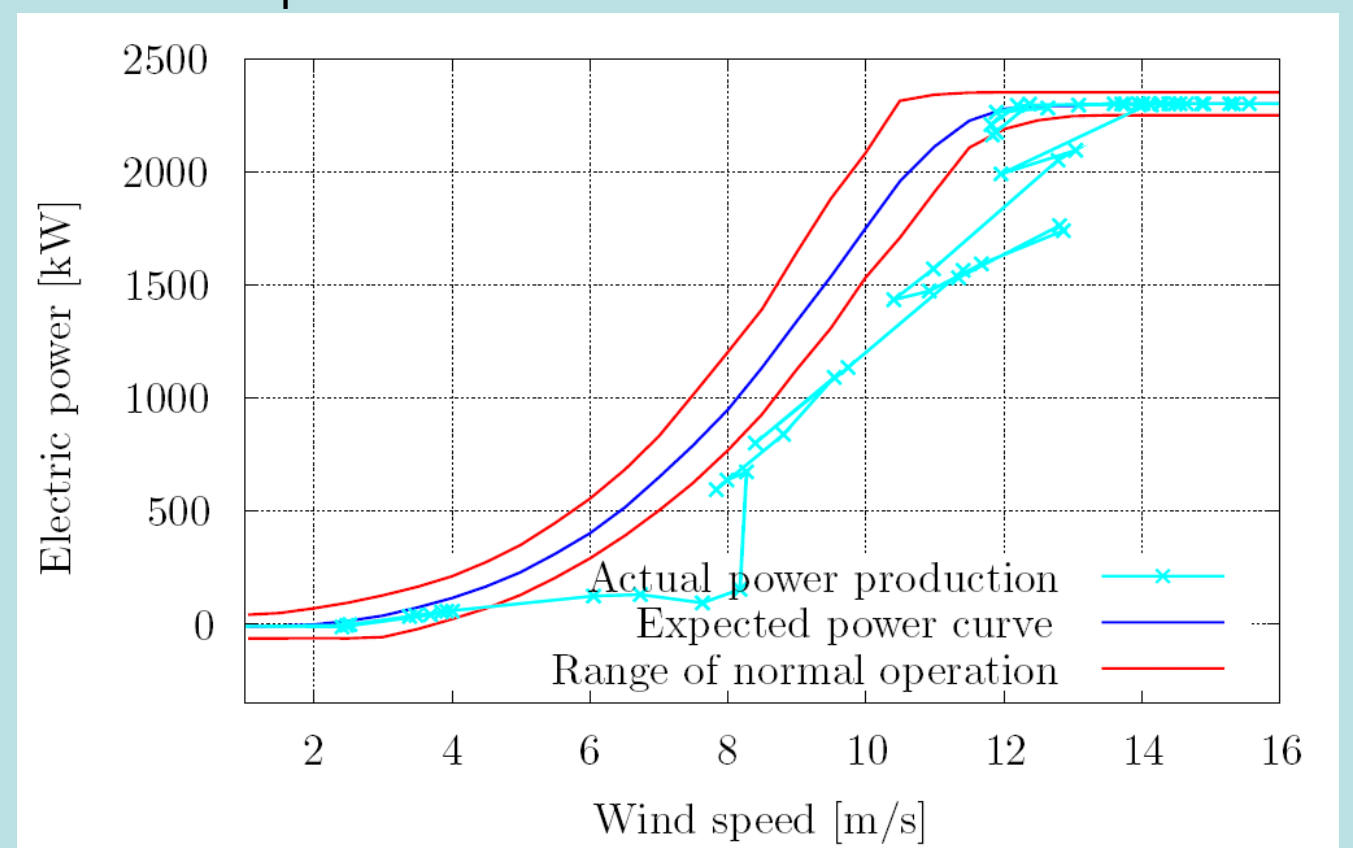
4. Conclusions

- Modelled icing losses were found to be about 27% in control region 2.
- Modelled reduction in icing corresponded reasonably well with the measured results.
- The observed events lasted much longer than the 1 hour modelled event.

3. Observations

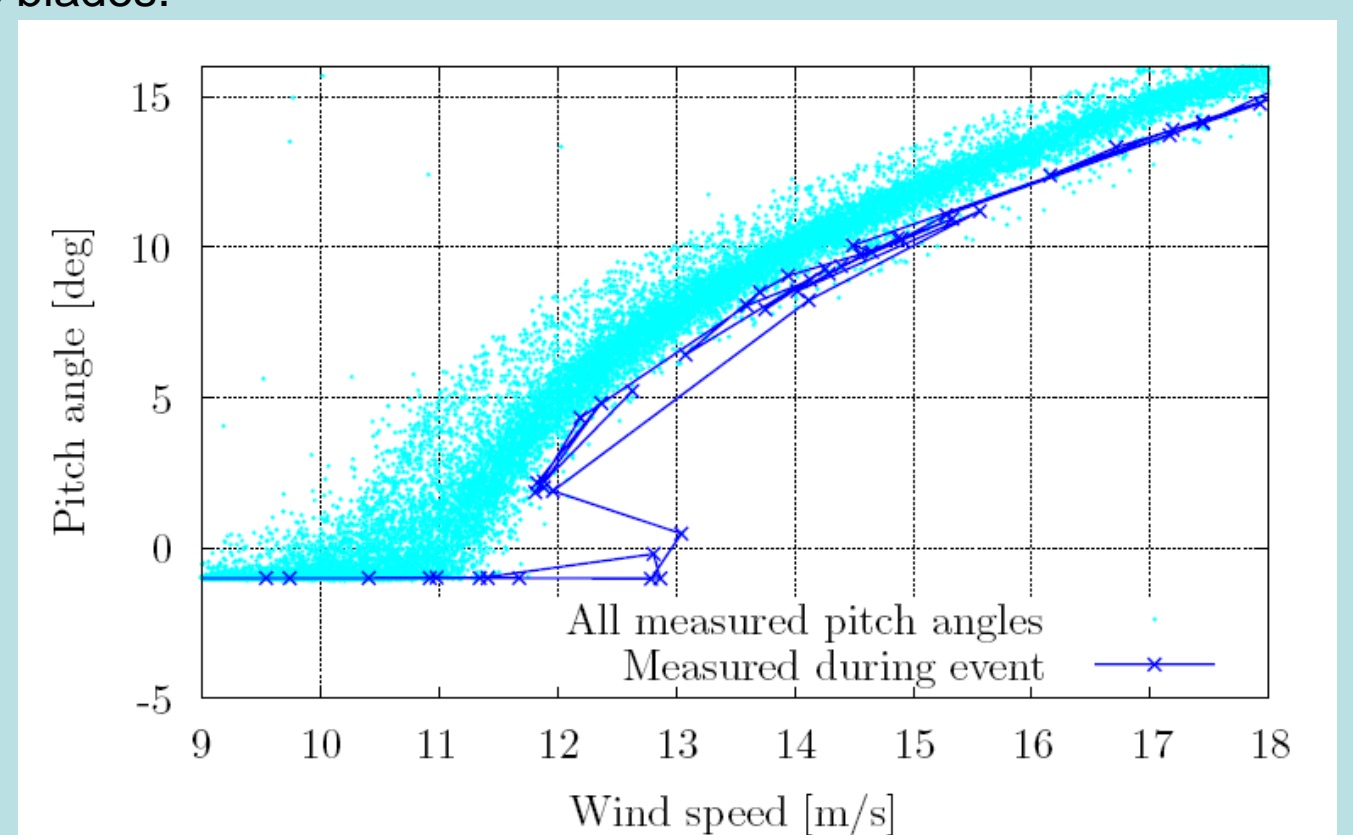


Ice event 1 – Ice accumulates with wind of about 8-10 m/s. Increasing ice leads to gradually lower production while wind speed is stable. Duration of over 12 hours. Production finally ceases with the iced turbine when the wind speed falls below about 8 m/s.



Ice event 2 – Wind speed increases during the event. Ice shedding is assumed to cause the vertical jump in production at around 8 m/s. Above rated wind speed the turbine is able to maintain rated power. Duration about 6 hours.

Lower than normal pitch angles were observed above rated wind speed as the turbine compensated for the lower aerodynamic performance of the blades.



- Observed power losses exceeded modelled power losses during parts of the events (likely due to the longer duration).
- Above rated wind speed the operating turbine was observed to compensate for the ice accretion by decreasing the pitch angle (this may have unintended consequences).