

Overcoming Icing Effects on Wind Turbines



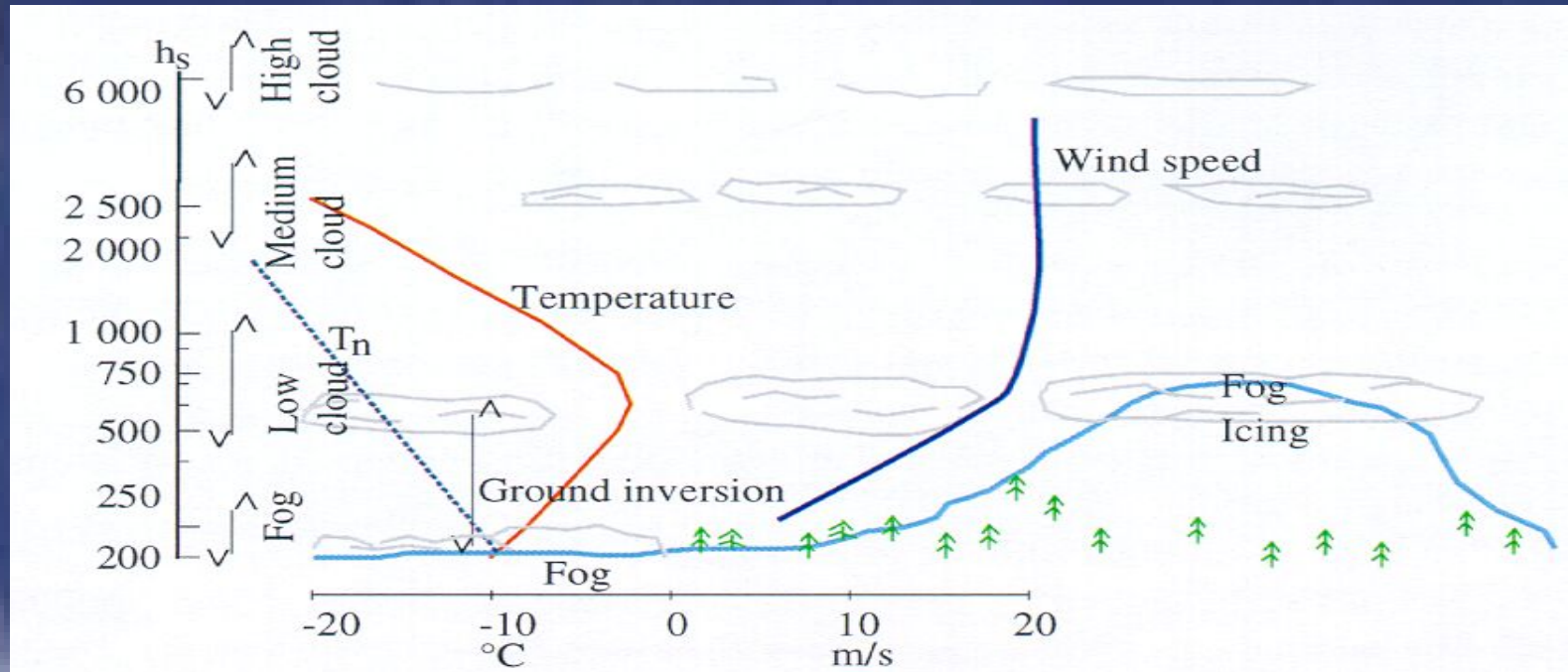
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Rime and Glaze Icing

- In the Whitehorse area, rime icing typically occurs at higher altitudes
- Rime icing can also be present in lower lying areas further north than Whitehorse, particularly near sources of humidity
- Glaze icing can occur throughout most of North America, but is most prevalent along Canada's east and west coastal regions

Higher Altitude Operation



Source: Finnish Meteorological Institute, Wind Energy Production in Cold Climate

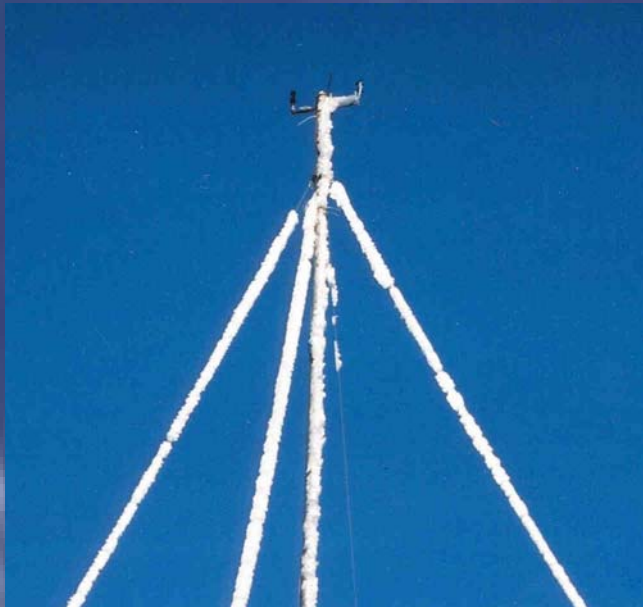
- Higher energy winds tend to be found on ridges, hilltops and mountains
- These locations lead to cloud and rime ice formation



Measuring Duration and Severity of Icing

- Reliable detectors for rime and glaze icing needed
- Limited supply on market at present
- Models on market do not seem to cope well with severe rime icing
- Two heated anemometer approach is reasonably reliable

Wind Speed & Icing Event Monitoring – Haeckel Hill

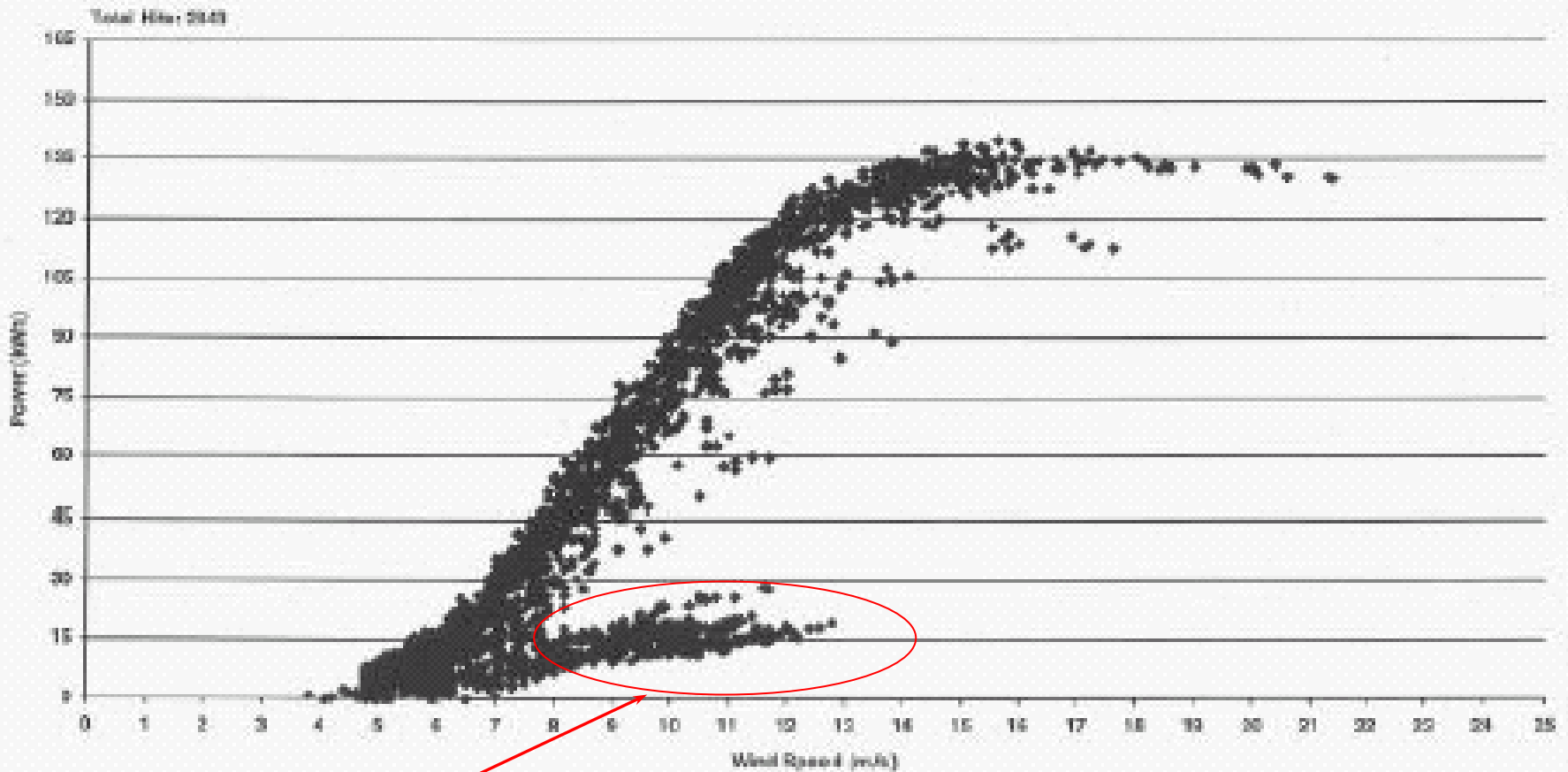


NRG Heated Anemometer &
Wind Vane (30 m).
Ice detector at ground level.



Bonus Heated Bearing
Anemometer (30 m)
(replaced in first year)

Bonus 150 kW Performance



Icing Periods

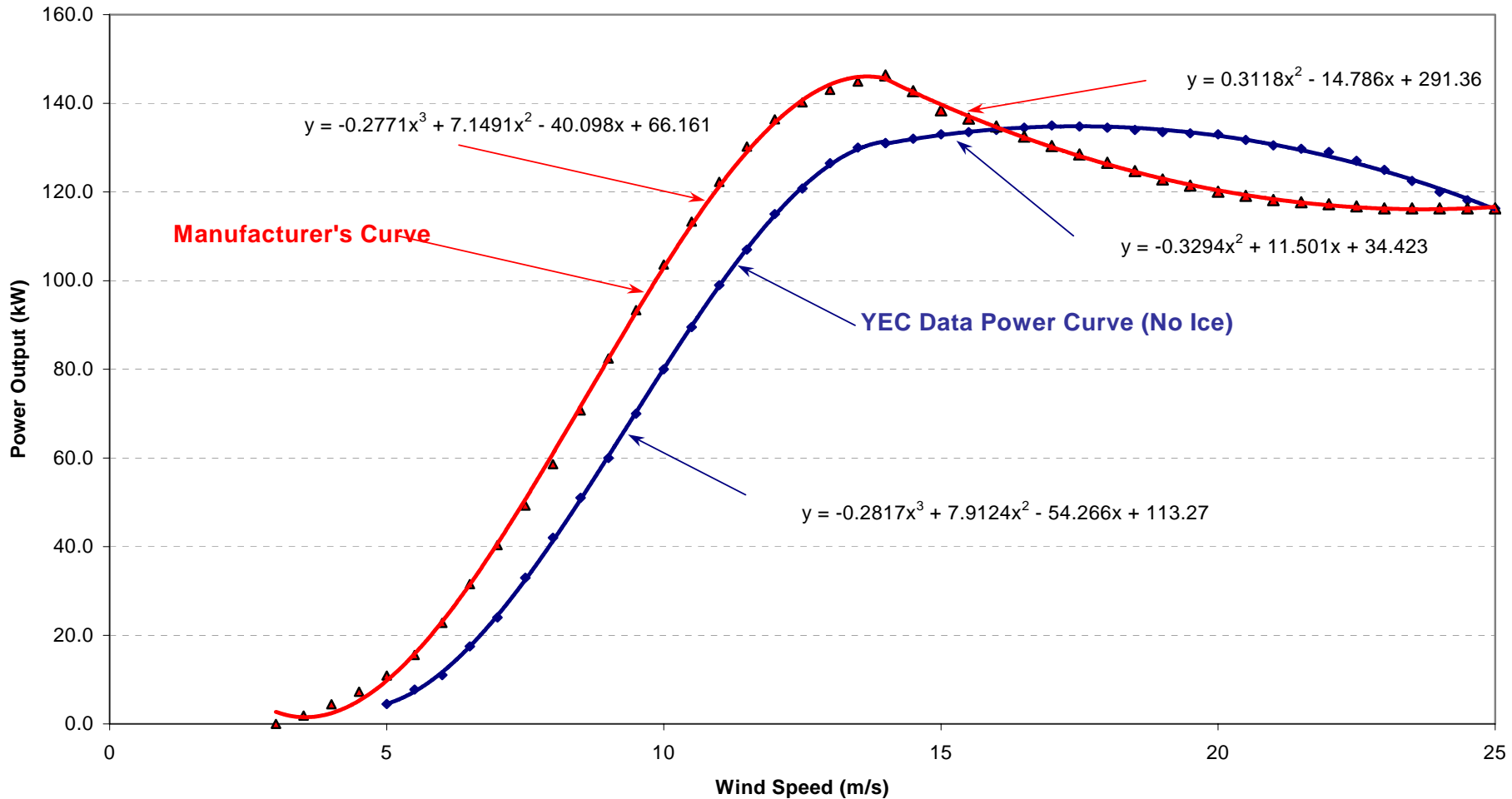


Bonus Performance Under Icing

- Wind data multiplied by actual ice-free power curve to determine maximum possible energy yield per month
- This ice-free maximum is compared with actual performance data
- The performance data are then compared to icing data from the monitoring station
- All three are independent data sets

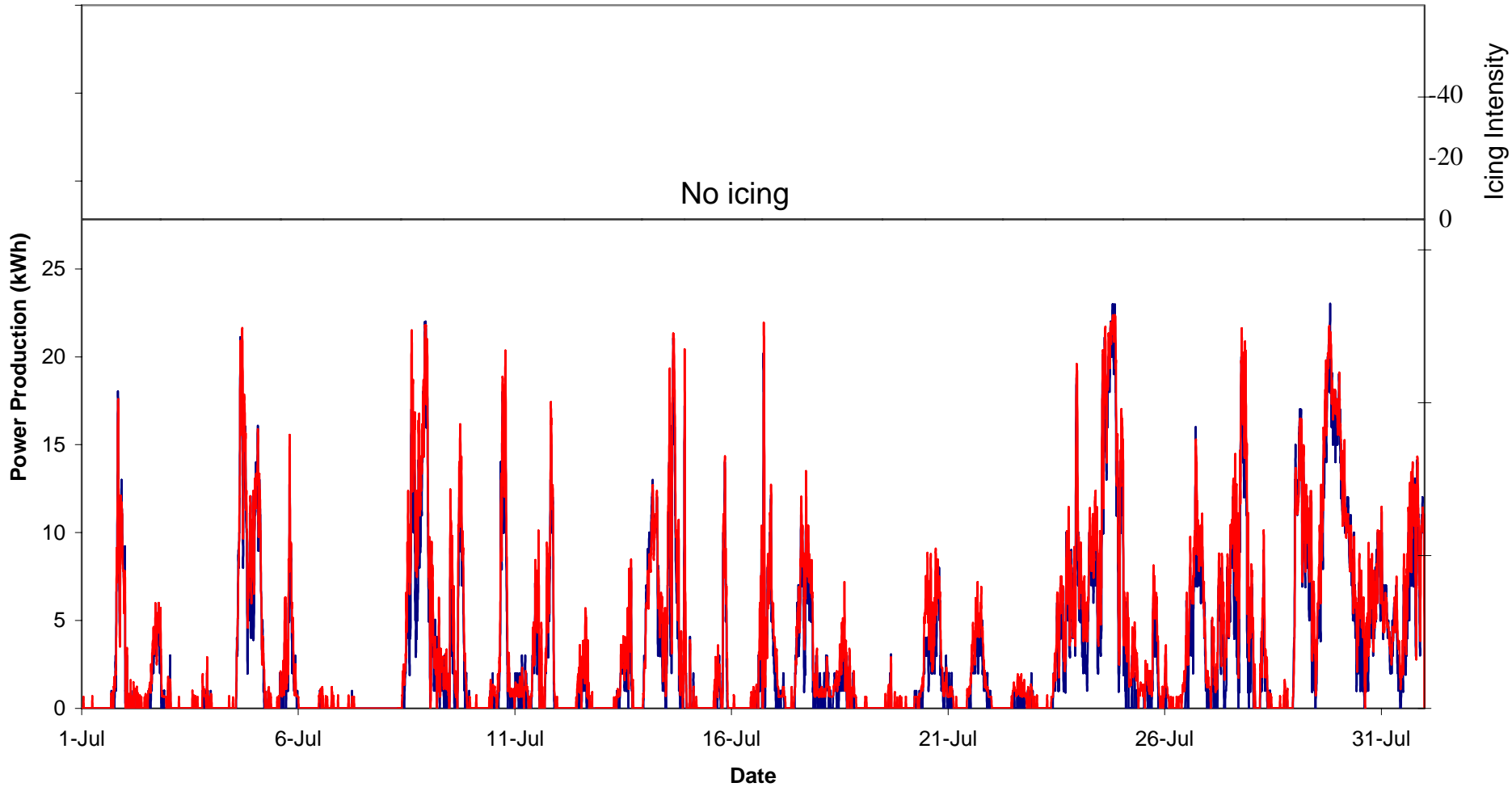
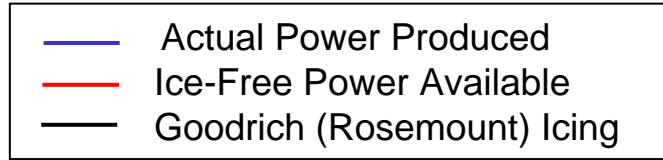
Manufacturer's vs. Actual Power Curves

Bonus 150 Mark III Power Curve



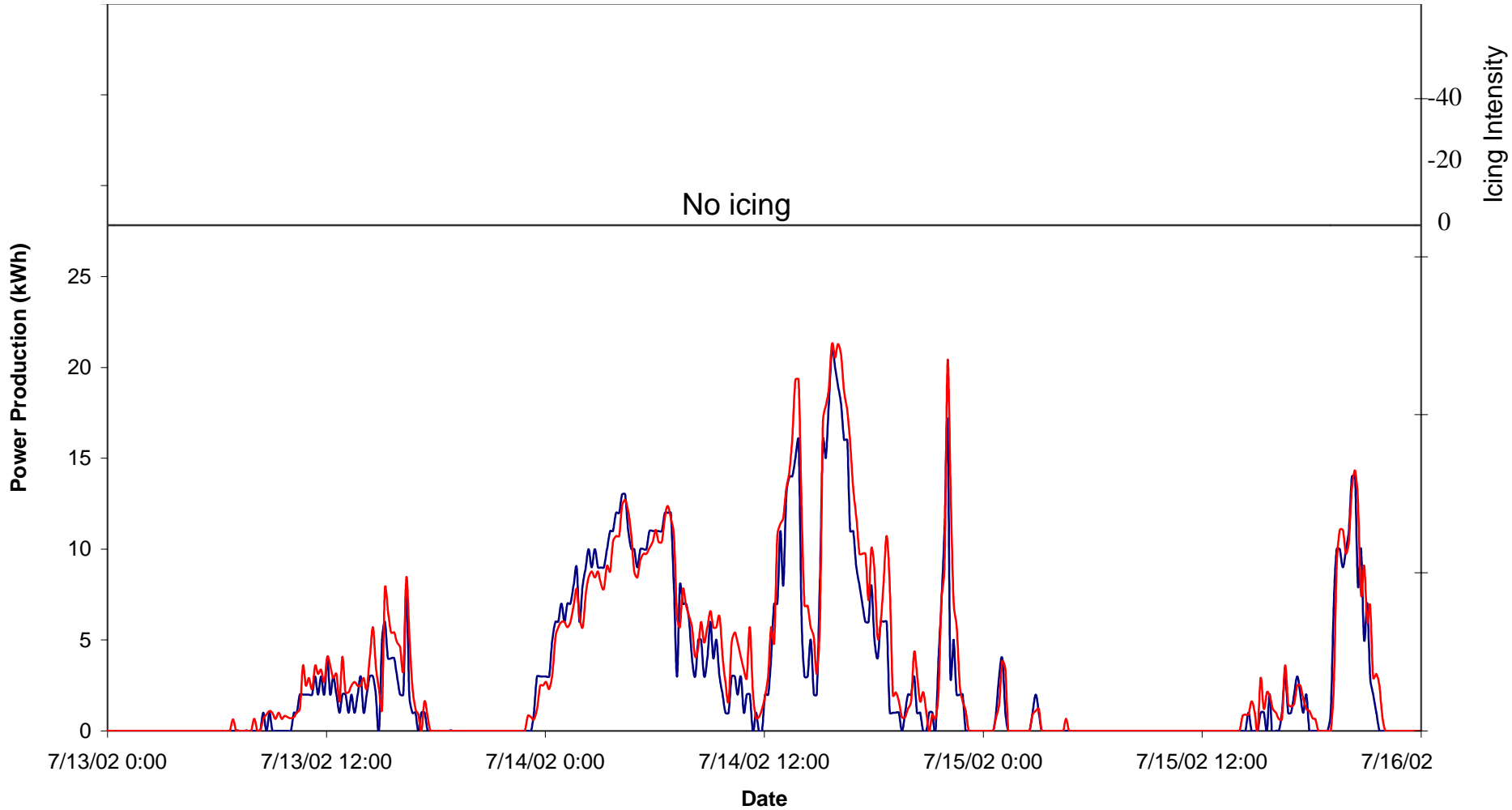
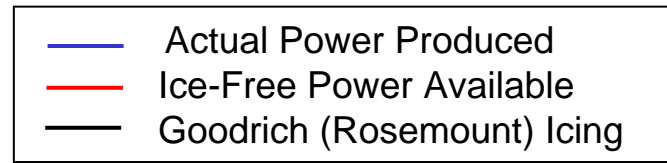
Bonus 150 kW Actual v. Ice-free Performance

July 2002



Bonus 150 kW Actual v. Ice-free Performance

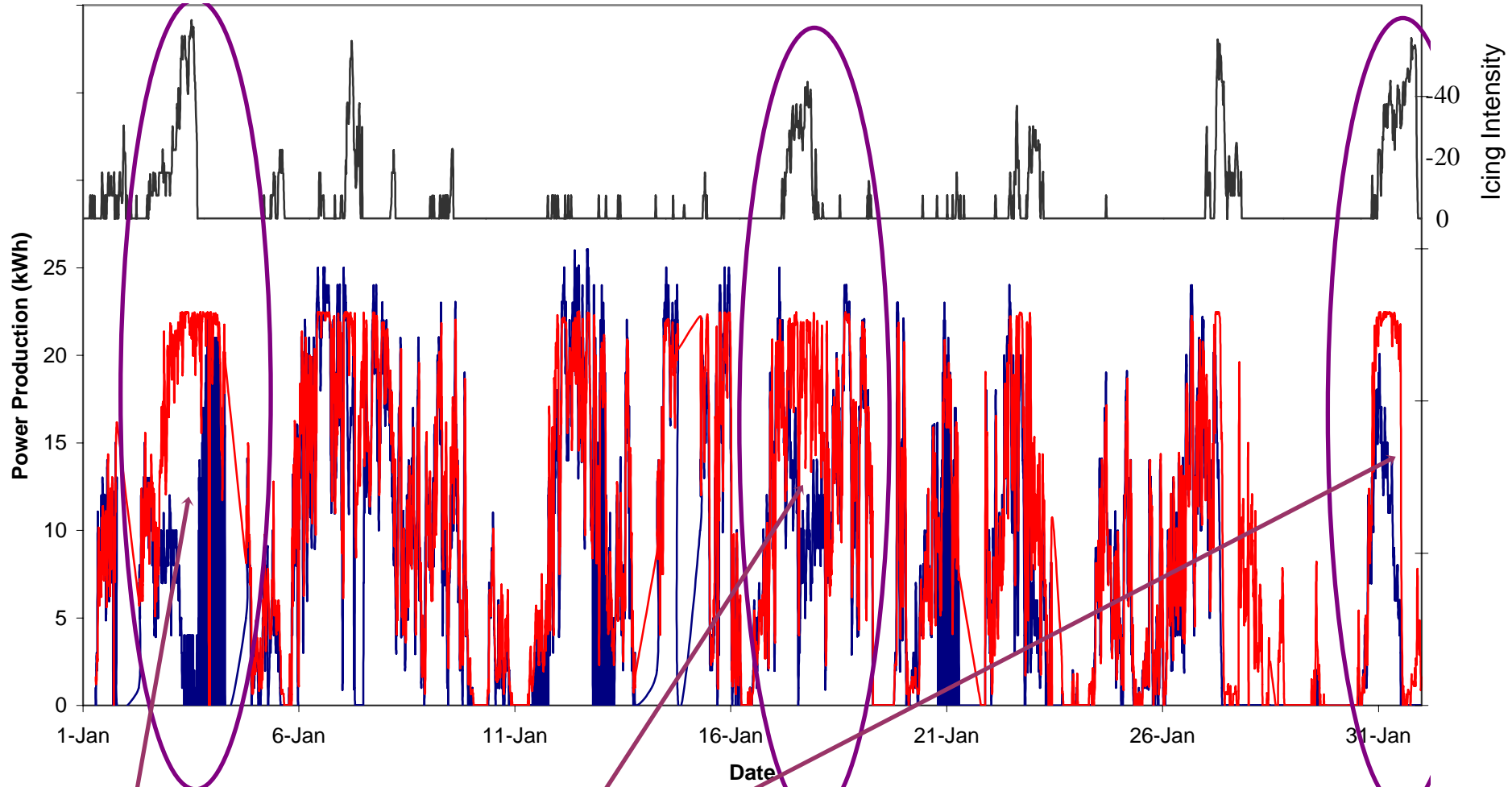
July 2002



Bonus 150 kW Actual v. Ice-free Performance

January 2001

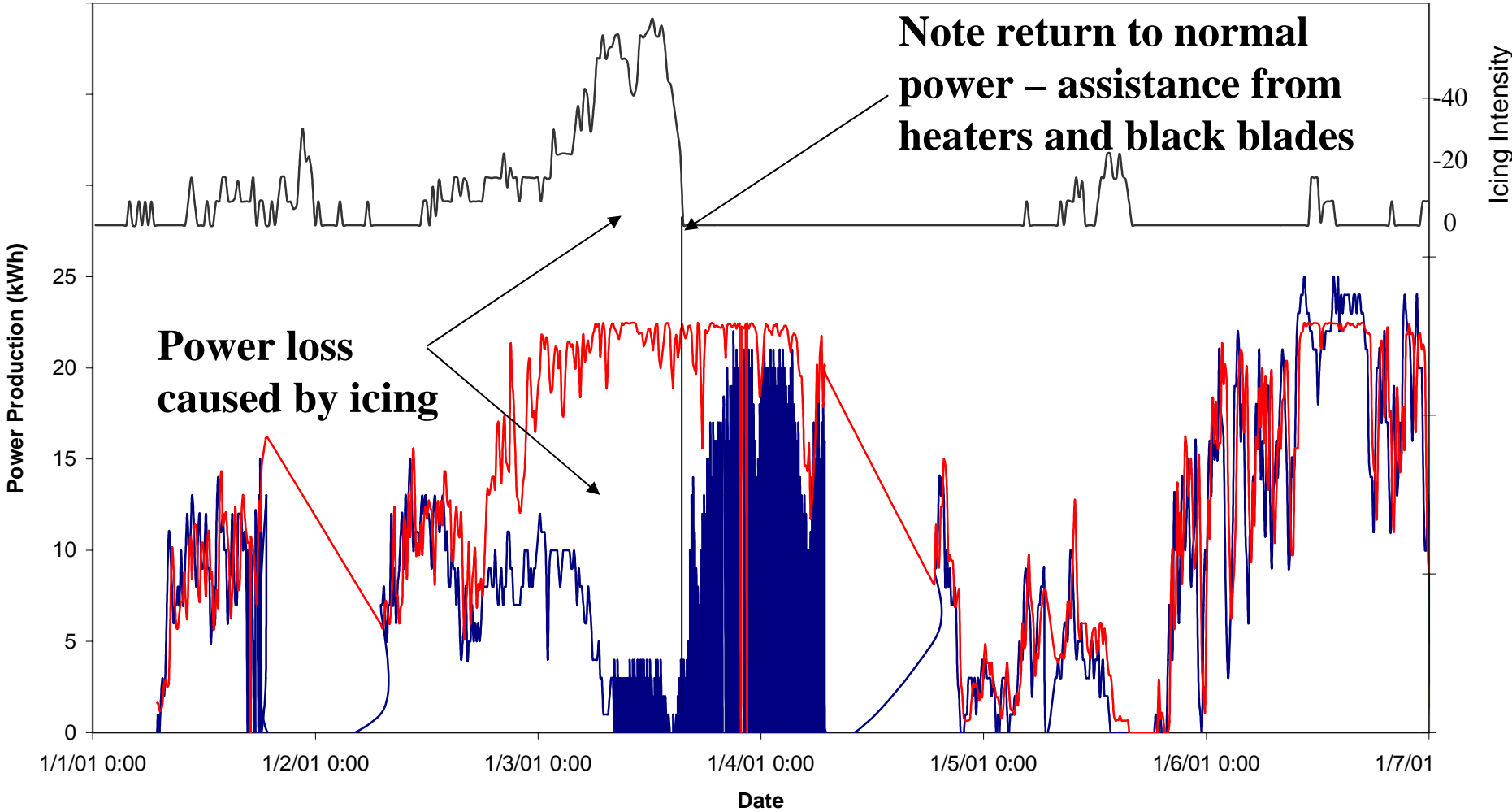
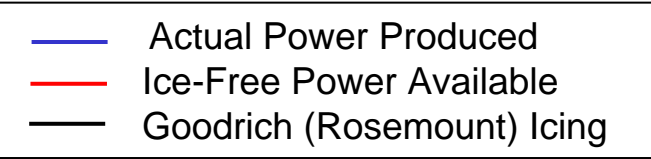
- Actual Power Produced
- Ice-Free Power Available
- Goodrich (Rosemount) Icing



Underproduction due to Ice

Bonus 150 kW Actual v. Ice-free Performance

January 2001





Achievements

- Heated wind instruments and ultrasonics now quite good
- Low temperature synthetic lubricants and fluids
- After-market blade heating systems and blade coatings
- Reductions in energy losses



Challenges Remaining

- Ice detectors for severe conditions
- Off-the-shelf blade heating systems
- Further reductions in energy losses
- Adaptations of turbine control algorithms



Manufacturers Working on Cold/ Icing Environment Equipment

Large Machines

- Vestas
- Bonus
- NEG Micon
- Enercon
- Lagerwey

Small Machines

- Atlantic Orient Corp
- Vergnet
- Northern Power Systems
- Bergey

(no blade heating yet
available)

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