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Wind Ramp Events at Turbine Height – Spatial Consistency and Causes at Two Iowa Wind Farms

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Introduction

Ramp events, defined by a 3 ms^{-1} change in wind speed between 6 and 12 ms^{-1} in 4 hours or less, cause a significant change in power output at a wind farm. Few studies have been done on the behavior of these events and they are caused by multiple meteorological phenomena, so forecasting is difficult. If these events are found to be spatially significant forecasting could be improved.

Data and Methodology

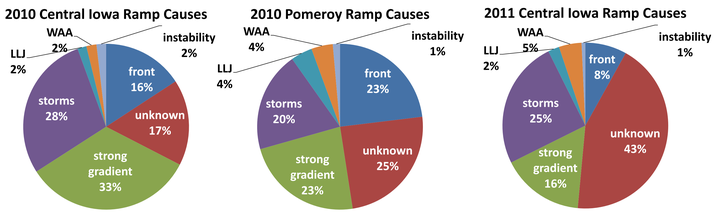
Wind speed and direction data was taken from a n 80 m northwest Iowa meteorological tower, six 80 m nacelles and a 10 m ASOS station in a central Iowa wind farm approximately 160 km apart from June-September 2010 and June-August 2011. Archived radar, wind profilers, mean sea level pressure maps, and station plots were used to attribute a meteorological cause to each ramp event. Ramps at 10 m were scaled according to the power law

$$\frac{u_{10}}{u_{80}} = \left(\frac{z_{10}}{z_{80}}\right)^{\propto}$$

with α set to 1/7 during the day and 1/4 at night to capture the low level jet.

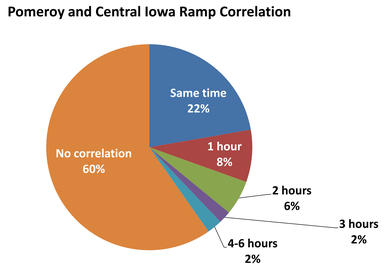
Results

The most prevalent causes of ramp events were found to be the presence of a strong gradient, storms, and frontal passage.

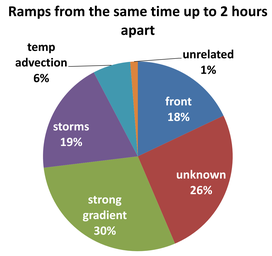


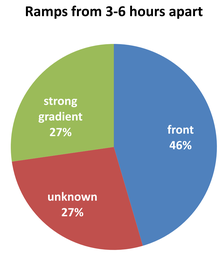
Unknown ramp causes can be due to small scale events and occasions where profiler data was unavailable.

Ramp-ups and ramp-downs in central Iowa with same meteorological cause as a ramp in northwest Iowa occurring within 6 hours of each other were considered to be the same ramp.



Thirty-six percent of ramps in central Iowa occur within 2 hours of a ramp in northwest Iowa suggesting spatial consistency.



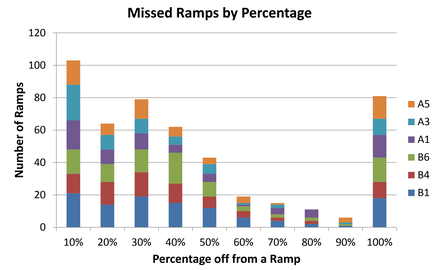


Correlation of 10 m and 80 m Ramps

	Ramp at 10 m	**Ramp at 80 m**
Ramp at 10 m		47% 2010 56% 2011
Ramp at 80 m	72% 2010 59% 2011	

In 2010, 10 m ramps not correlated with a ramp at 80 m were either due to unknown causes or out of the limits of this study.

Ramps behavior within a wind farm



B1, B4, B6, A1, A3, A5 are the names of the turbines in the central Iowa wind farm. When one or more turbines did not experience a ramp while others did, most were only 10% away from a ramp followed by 100% off of a ramp. This was defined as a ramp in the opposite direction, a ramp-up when the others experienced a ramp-down or a ramp outside the bounds of the study.

Conclusions

Ramp events were found to be spatially consistent within 160 km. Most ramps were due to the presence of a strong pressure gradient, storms, or frontal passage. There were many ramps classified with an unknown cause suggesting further work should be done. Finally 10 m ramps could be used as an estimate for 80 m wind behavior.

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