An Analysis of Sub-Hourly Ramping Impacts of Wind Energy and Balancing Area Size

National Renewable Energy Laboratory

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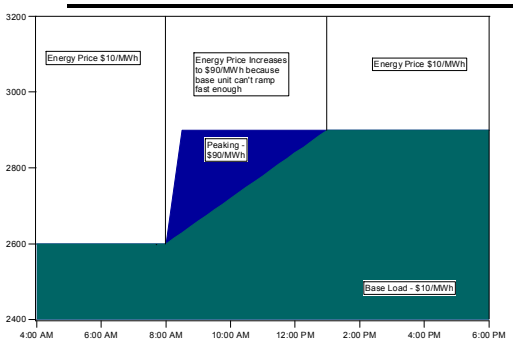
Objective

- Explain why ramping can be costly when marginal generators cannot ramp fast enough
- Examine the impact of within-hour (5-minute) ramping impacts of a high wind penetration
- Quantify the benefits of Balancing Area combined operations on mitigating these ramp impacts.

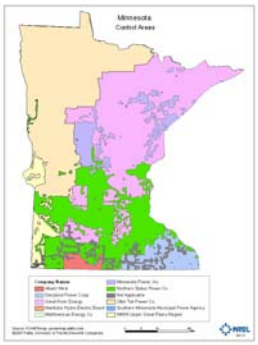
Approach

- Obtain 5-minute load and wind power data from the Minnesota 20% Wind Integration Study
- Utilize the 25% (by energy) wind penetration
- Calculate ramp requirements:
  - Separate Balancing Area Operations vs. Combined Balancing Area Operations.

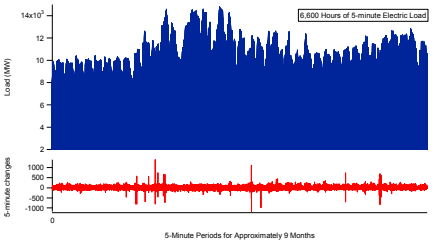


Why can ramping be costly?

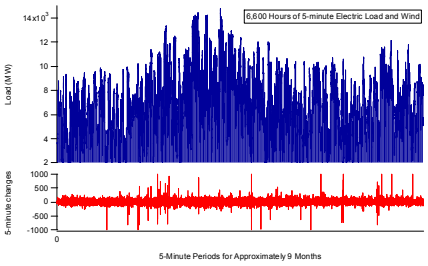
Ramping capability may be limited in some circumstances, even though there is sufficient overall capacity. This can cause higher dispatch costs, as illustrated in this figure. The base load generation cannot ramp fast enough, so a peaking unit is necessary to provide the ramp. This increases costs. Ramping can be part of energy if it is abundant or it may need to be a separate service if it is scarce.



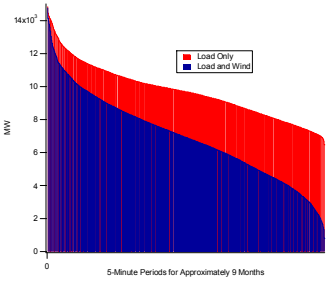
We used data from the MN 20% Wind Study, divided by Balancing Area: Great River, Minnesota Power, Northern States Power, and Minnesota Power.



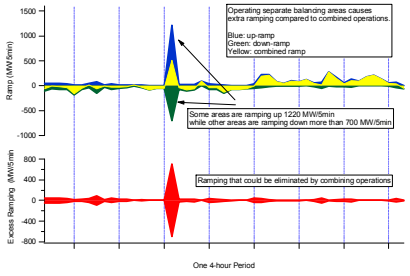
Combined load (no wind) has considerable variability in the 5-minute time scale. The top panel shows the load itself, the bottom panel shows that some 5-minute load ramp requirements can be as high as 500 MW to 1000 MW within 5 minutes.



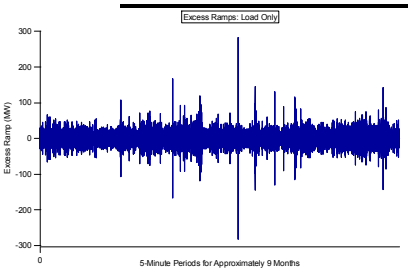
Ramp requirements increase with 25% wind energy penetration. The upper panel also shows the importance of being able to achieve lower minimum loads by the conventional generation fleet.



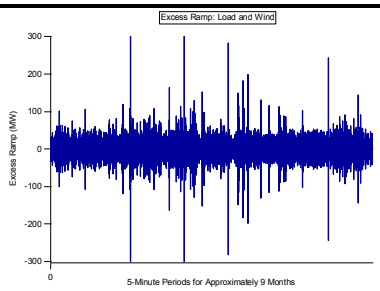
The need for additional turn-down capability is also shown by this load duration curve, based on 5-minute data. Lower minimum loads require greater flexibility but additional capacity is not needed.



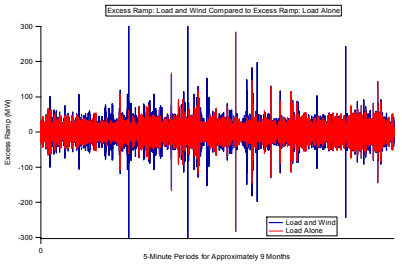
Combining Balancing Area operations can result in the 'cancelling' out of some ramp requirements when one BA needs upward ramps at the same time another BA needs lower ramps. This graph shows an illustration from the MN data for load and wind together.



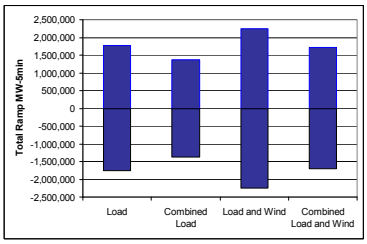
Even without wind there is excess ramping when Balancing Areas operate separately. This graph shows the ramps that could be eliminated with combined operations.



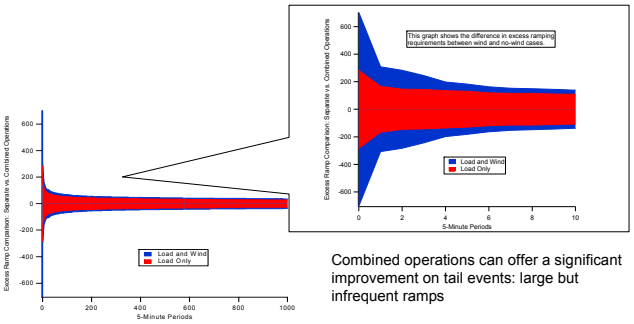
With a large wind penetration, there is an increase in excess ramping when Balancing Areas operate separately.



This graph combines the previous two graphs. The red trace shows the excess ramping from load alone, and the blue shows excess ramping from load and wind together. It is clear that the excess ramping is larger with wind and load together, compared to load alone.



For load alone, there is a 22.4% reduction in ramping requirements when operations are combined. For load and wind together, this reduction is 23.8%.This graph shows the total ramping, measured in MW-5min (one MW ramp for 5 minutes)



Combined operations can offer a significant improvement on tail events: large but infrequent ramps

Conclusions

- Combined operations of separate Balancing Areas can reduce 5-minute ramping needs, both without wind, and with wind
- Additional turn-down is needed at high penetrations, but not extra capacity
- Combined operations can significantly reduce large but infrequent ramps.

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