Incident Review

Future Wind Planning Informed by Current Operating Experience

Primary Takeaway(s)

Power systems with large amounts of wind resources are being faced with operational challenges when high winds force wind generation off-line. This operating incident revealed successful transmission operations and identified resource balancing needs that should be considered in the future planning of high-wind generation systems.

Summary of Incident(s)

A severe storm with high winds impacted the footprint of two regional transmission/independent system operators. The operating organizations experienced transmission outages and high speed wind cut-outs for a portion of the day. Loss of load and generation did not reach a significant reliability risk threshold. However, system operating challenges during the incident demonstrated the potential for future resource shortages, provided a dependency on wind generation.

Two Balancing Authorities (BAs) were significantly affected by this high wind event, collectively losing approximately 13,000 MW of wind resources. Coincidently, a large amount of transmission lines were also lost due to damage from the high winds. This combination of resource loss due to high wind cut-out protection and a constrained transmission system due to loss of transmission lines presented challenges for the BAs.

For BAs dependent on wind resources, a similar incident in the future could result in resource shortages if insufficient amounts of flexible generation are not available to offset the loss of wind generation.

Incident Details (Operating Entity 1)

Wind Generation Reductions

During the incident for Operating Entity 1, the peak reduction of wind generation was approximately 7,000 MW. This reduction in wind generation is attributed to two causes: high speed wind cut-outs and transmission constraints that result from a large number of 69 kV and 161 kV line outages throughout the operating area.

Notable Operational Challenges

During the high wind period, the forecasted wind generation reduction of approximately 4,000 MW did not accurately reflect the actual reduction of 7,000 MW. The increased actual reduction in wind generation was not anticipated by the operators and consequently presented operating challenges in real-time. At one point, these transmission outages consisted of approximately six 345 kV, dozens of 161 kV, and reportedly more than 100 69 kV outages across the system.

During the early stages of the wind generation reduction, gas and coal resources were ramped up to replace the lost wind generation as shown in **Figure 1**.

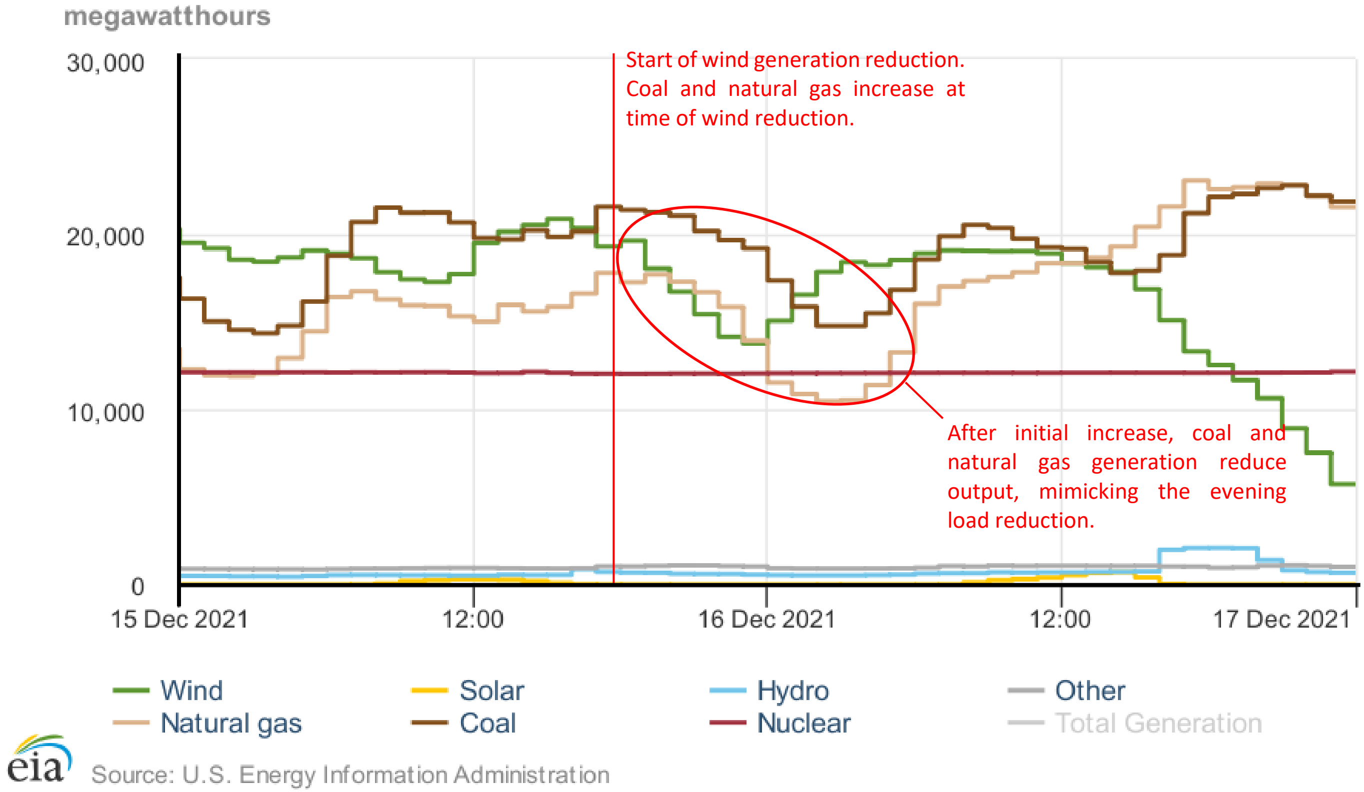

Figure 1: Entity 1 Generation Actual Output [Energy Information Administration]

As the incident continued for Operating Entity 1 into the evening hours, the typical daily downslope of load commenced as shown in **Figure 2**. This decrease in load offset some of the reduction of wind generation during that period.

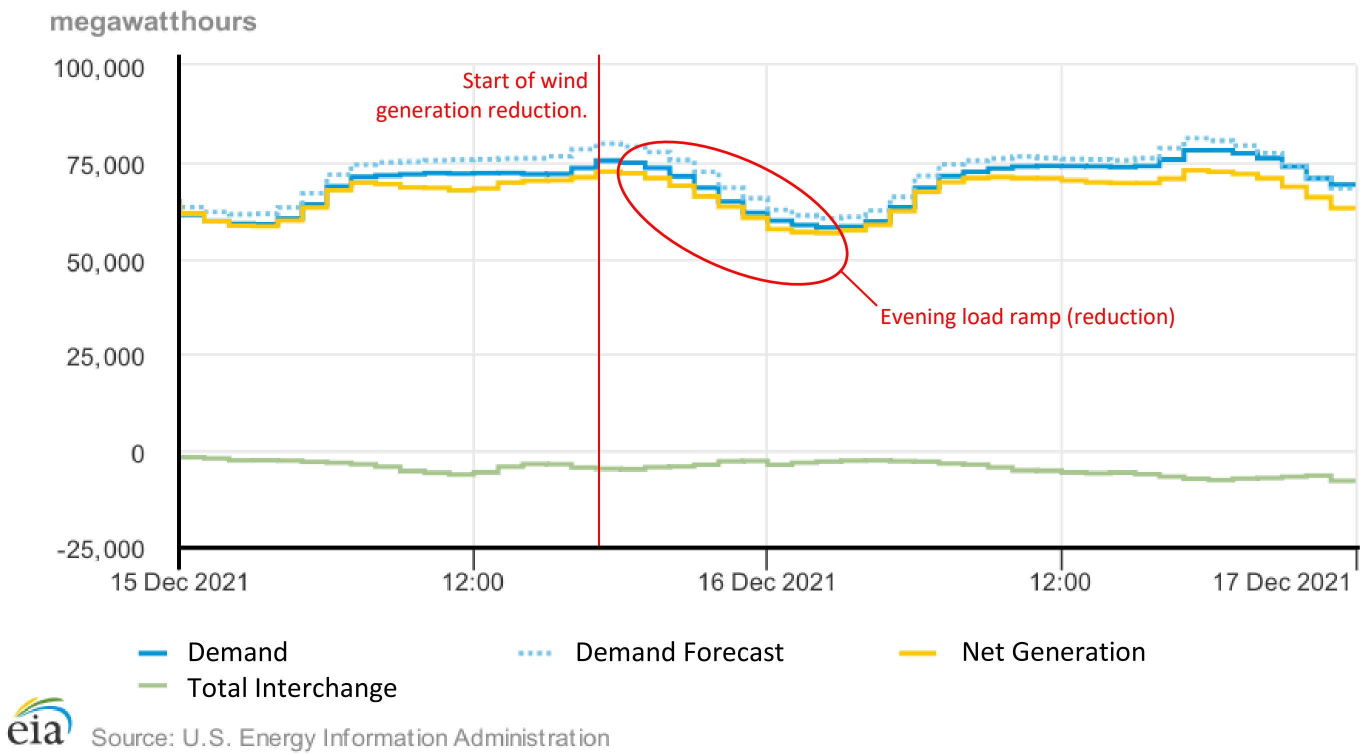

Figure 2: Entity 1 Demand Data [Energy Information Administration]

Forecasted vs. Actual Wind Generation Information

Figure 3 illustrates the day ahead forecast (orange line), the intra-day forecast (gray line) and real-time/actual (blue line) wind over a two day period. The dip in the forecast curves, starting at hour fifteen on the first day, includes high wind cut-out predictions. As is often the case, potential reasons for generation reduction varies:

- Prior to hour fifteen, most of the generation reduction is associated with dispatch reduction signals to manage congestion on the system.
- During the high wind period, reductions in generation were a combination of cut-outs and dispatch reductions.
- Into the following morning, the updated forecasts likely adjusted for some generation outages from transmission outages, impacts of icing that occurred on the backside of the storm, and dispatch reduction orders to facilitate congestion management in a very fragmented system.

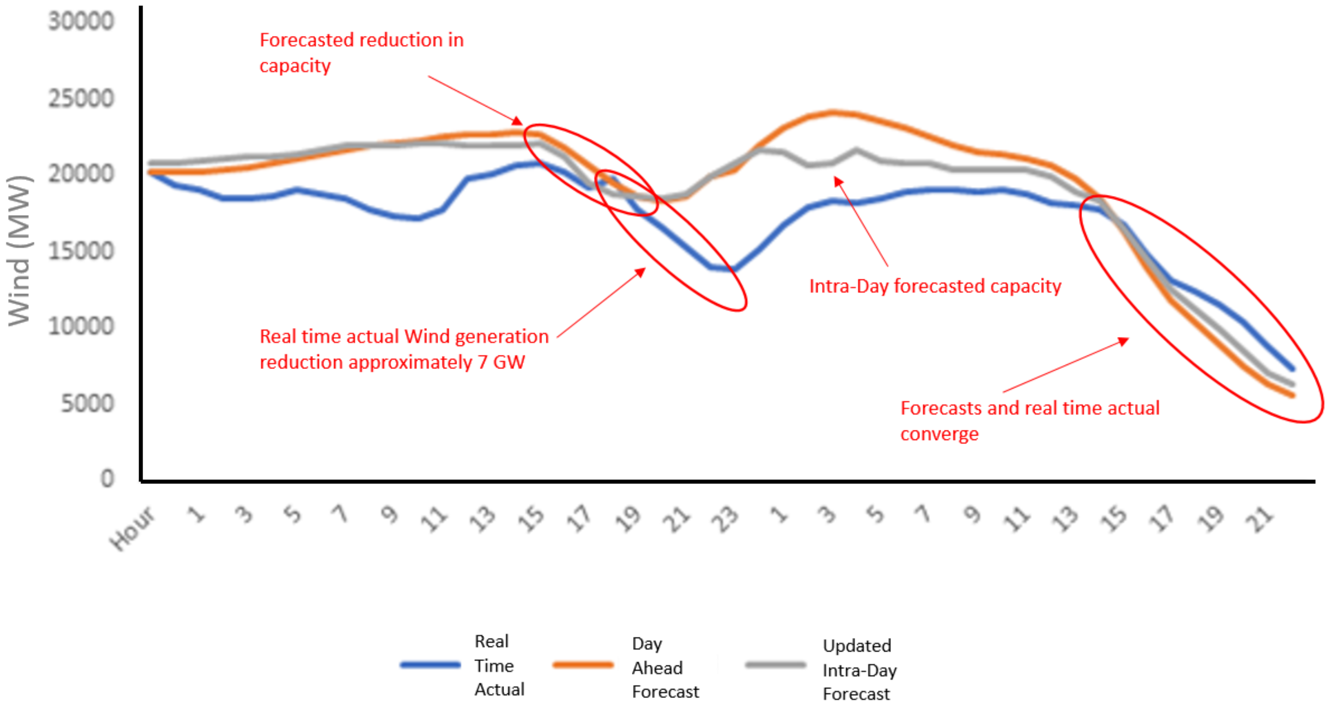

Figure 3: Entity 1 Actual and Forecasted Wind Generation [Operating Entity 1]

Incident Details (Operating Entity 2)

Wind Generation Reductions

During the incident for Operating Entity 2, the peak reduction of wind generation was approximately 6,000 MW. This reduction was a combination of high speed cut-outs and curtailments due to market redispatch and transmission congestion outages.

Notable Operational Challenges

Operators responded to transmission constraints due to a large number of forced outages, including some 345 kV facilities.

As shown in **Figure 4**, natural gas and coal resources ramped up to replace a portion of the lost wind generation. The entity filled the remainder of the generation void by increasing interchange imports as shown in **Figure 5**.

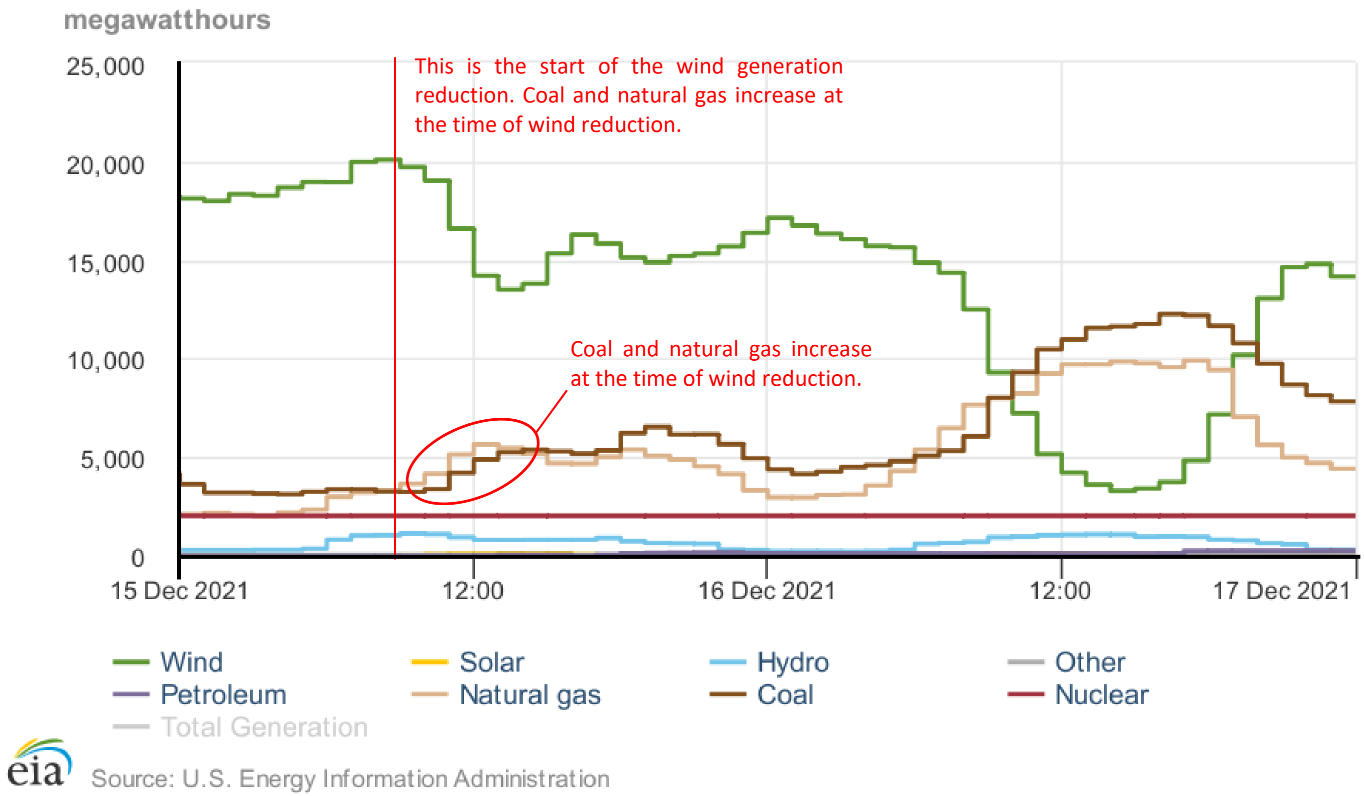

Figure 4: Entity 2 Generation Actual Output [Energy Information Administration]

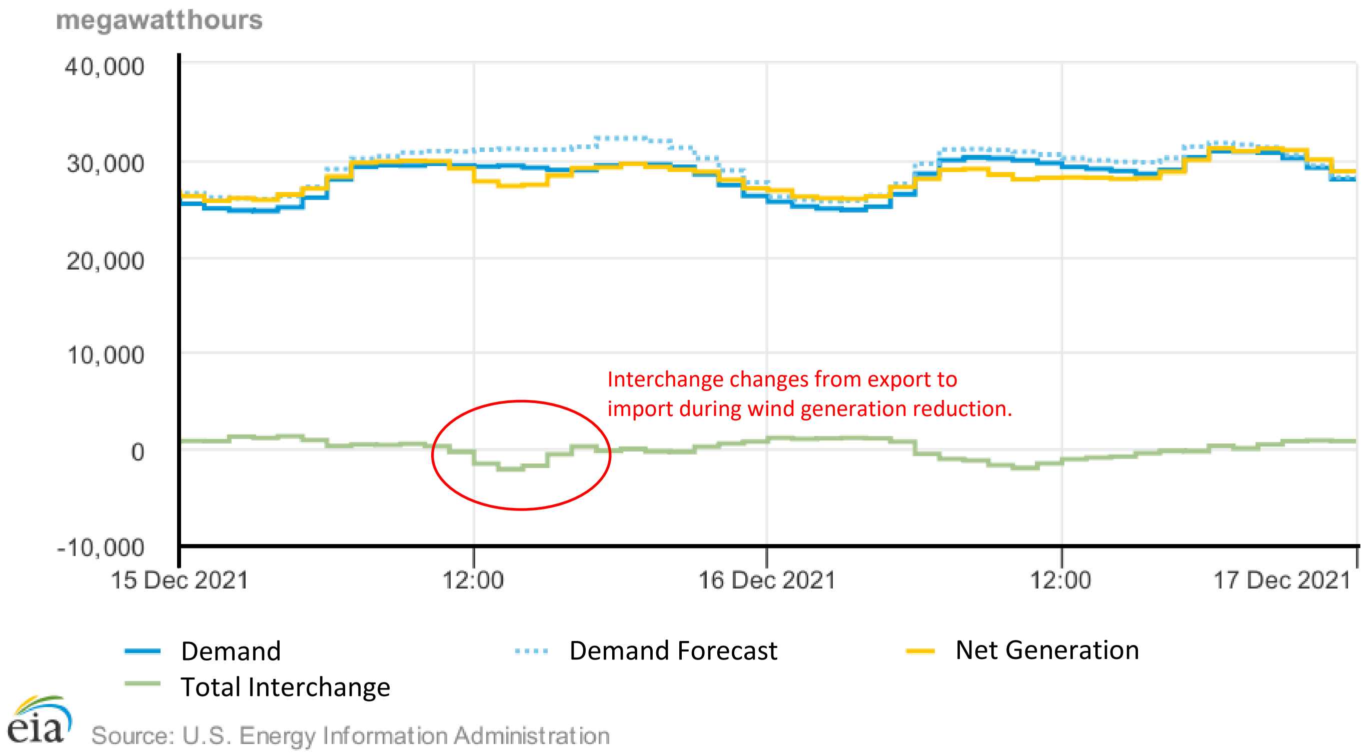

Figure 5: Entity 2 Demand Data [Energy Information Administration]

Forecasted vs. Actual Wind Generation

A study was run during the afternoon on the day prior to the incident when the forecast was updated with the latest weather models, analysis, and information from the forecast vendor on the risk of cut-out. The updated forecast predicted a significantly lower wind generation, consequently accurately identifying the potential wind generation availability during the incident. The vendor's forecast accounted for the cut-out speeds to within the capabilities of the weather models.

Figure 6 illustrates the actual wind generation and predicted operating responses during the incident time frame. The dotted black line is the forecasted wind capacity based on day ahead studies. The solid black line shows the actual generation (MW) output from wind. The blue area is wind generation not dispatched by the market based on locational marginal pricing (LMP) analysis; the green area is wind generation that was curtailed manually by dispatchers based on real time conditions. This results in the top of the green area being the final real-time wind capacity. A study run on the afternoon prior to the incident accounted for additional cut-out risk, shown with the yellow line reflecting the updated forecast. As can be seen in Figure 6, the "first run" day ahead forecast (dotted black line) was approximately 5,000 MW higher than actual available wind generation during the high wind time period. The updated forecast (yellow line) predicted a capacity approximately 3,000 MW less than actual during the high wind period.

During rapidly changing weather situations, the models are often incapable of accurately predicting wind speed and duration values, particularly if the duration is less than one hour in time. In those cases, the wind forecast typically will not expose the full extent of the cut-out risk. Unfortunately, a lack of resolution in capacity loss data from the actual wind farms impeded differentiation between whether their loss in capacity was for cut-out or just lower wind values. This makes it difficult to quantify the accuracy of wind generation loss without extensive manual tracking. However, the reduction in wind generation matched operator expectations for the most part.

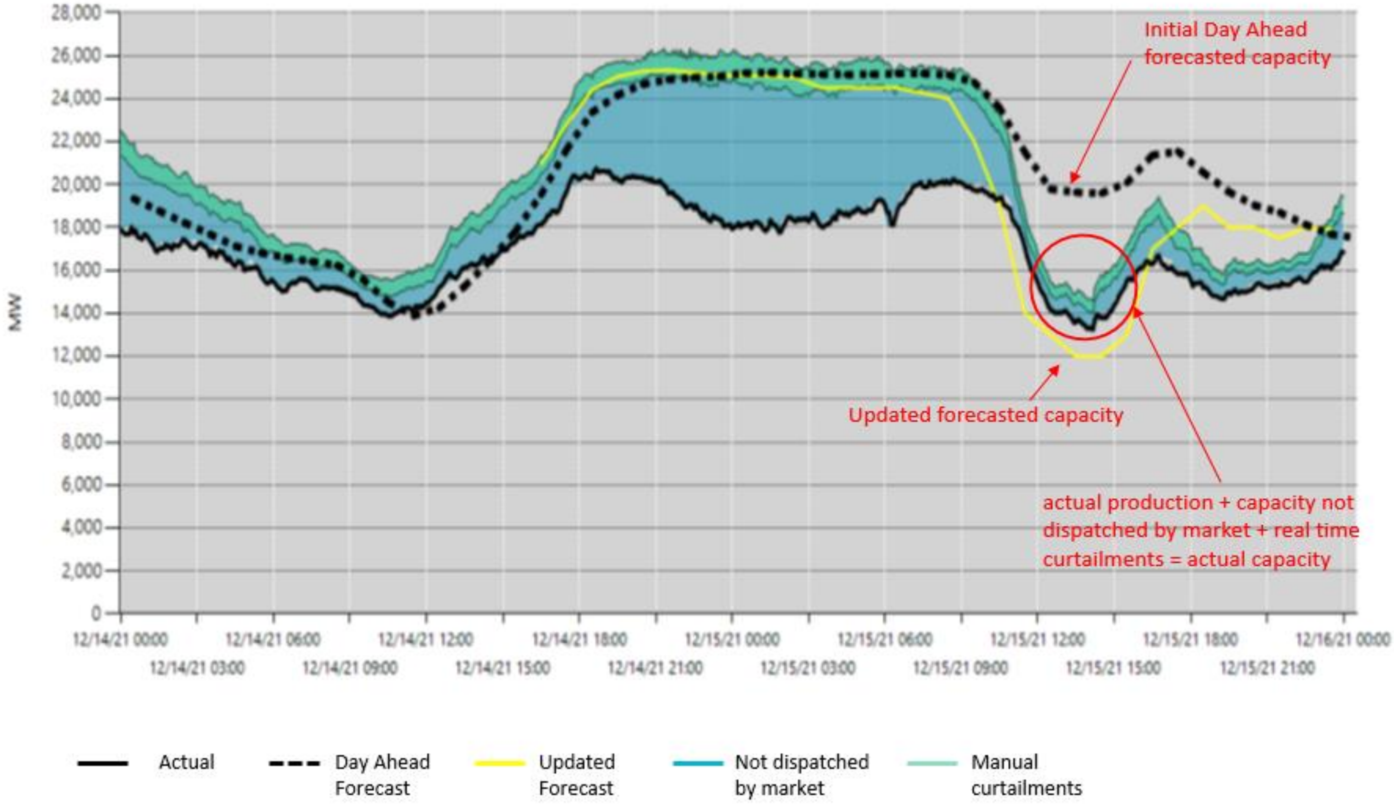

Figure 6: Entity 2 Wind Generation Actual, Forecasts, and Curtailments [Operating Entity 2]

Future Resource Planning Considerations

As the BPS progresses to a carbon free/reduced carbon generation model, wind generation will likely produce a greater percentage of the total energy output at any given time. High-wind scenarios like what is described in this document could result in higher generation losses. Consequently, more extensive/comprehensive planning and operating prowess to manage the increased amount of generation loss is required. Additionally, there will be less dispatchable/flexible generation available in this type of scenario. These conditions elicit the following thoughts/considerations:

- Adequate transmission and dispatchable/flexible generation resources are needed to support operator flexibility as the amount of variable resources increase.
- Natural-gas-fired generation is the current and near-future primary balancing resource, and ensuring a reliable and flexible natural gas delivery and transportation system is imperative.

- Batteries are expected to become the new dispatchable resource of the future. Adequate amounts of battery energy storage systems will assist operators in managing the system during these types of incidents.
- An alternative option to batteries for managing these scenarios could be geographically dispersed generation reserves with appropriate transmission facilities. This would enable generation not impacted by a high wind event to be dispatched to the area experiencing losses.
- Probabilistic composite planning methods for generation and transmission loss will need to be incorporated to properly plan for generation reserve amounts and locations to accommodate these types of losses on the future grid. However, it must be recognized that “capacity-equivalent” forecast values of variable generation are only a forecast, and the impact of forecast error is magnified as variable generation increases.
- Generation forecasting will also be critical in future operating scenarios because accurately predicting the amount and the area of generation loss will be a necessity for operators to manage the system during these events.
- As this incident demonstrates, maintaining continuous forecasting updates provides more precise information improving operator preparation time prior to a potential storm/high wind incident.

As the grid transforms, the use of wind generation will certainly multiply. Current operating experiences, such as the one summarized in this vignette, can serve as thought opportunities revealing faint signals of more serious issues. These vignettes present valuable insights for operating reliably in the future, provided lessons are identified, considered, and incorporated appropriately into planning/operating activities.

For more information please contact:
NERC – Event Analysis

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