U.S. DEPARTMENT OF
ENERGY

Electricity Delivery
& Energy Reliability

American Recovery and
Reinvestment Act of 2009

New Forecasting Tools Enhance Wind Energy Integration In Idaho and Oregon

Smart Grid Investment Grant
Program Recipient Deliverable

SMARTGRID.GOV
RECOVERY ACT SMART GRID PROGRAMS

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1. Summary

Under the American Recovery and Reinvestment Act of 2009, the U.S. Department of Energy and the electricity industry have jointly invested over $7.9 billion in 99 cost-shared Smart Grid Investment Grant projects to modernize the electric grid, strengthen cybersecurity, improve interoperability, and collect an unprecedented level of data on smart grid and customer

Idaho Power Company (IPC) developed a Renewables Integration Tool (RIT) that enables grid operators to use wind energy more cost-effectively to serve electricity customers in Idaho and Oregon. The tool was developed under a Smart Grid Investment Grant (SGIG) project that invested in new technologies, tools, and techniques for electric transmission, distribution, advanced metering infrastructure, and customer systems. RIT, a series of models and databases for forecasting weather conditions and the availability of wind energy resources, is now fully operational.

At any given time, wind power can provide up to 35% of IPC's system needs. However, variability in the wind can cause grid operators to make rapid adjustments and bring non-wind resources on- and off-line depending on weather conditions. Improvements in wind forecasting tools can enhance the value of wind energy and lower grid integration and operations costs. Table 1 summarizes key results from IPC's application of the RIT wind forecasting tool.

Table 1. Summary of Key Wind Forecasting Tool Results for IPC	
Forecasting Improvements	i. RIT is now a normal part of daily operational practices. An analysis of three months of data from the first quarter of 2014 showed the **RIT was 26%–32% more accurate than the forecasting methods previously used by IPC**. ii. Forecast accuracy is due in part to increased data on wind speed and direction now being collected and analyzed from weather stations located at five of the major wind parks.
Financial Benefits	iii. IPC estimates that **improvements in forecasting accuracy saved about $287,000** over the three-month study period, or about $96,000 a month.
Lessons Learned and Future Plans	iv. **More and better weather data is still needed to support advanced forecasting tools**. IPC plans to expand data collection to more wind parks, and include weather and operational data requirements in new power purchase agreements for wind energy resources. v. Although RIT is a customized software platform, **utilities interested in developing comparable wind forecasting capabilities could use RIT as a template**. However, weather data, wind turbine performance information, and statistical algorithms would have to be created to suit local conditions.

2. Introduction

IPC serves about 512,000 customers in southern Idaho and eastern Oregon. IPC's generation mix relies heavily on coal and hydroelectricity for base load generation and natural gas for meeting peak demands. However, wind power is a valuable contributor and at any given time can provide up to 35% of IPC's electricity generation, depending on weather and system conditions. In 2013 wind provided about 10% of the electricity IPC delivered to its customers. Figure 1 shows a map of the IPC service territory, which includes mountainous terrain and areas with high-quality wind resources.

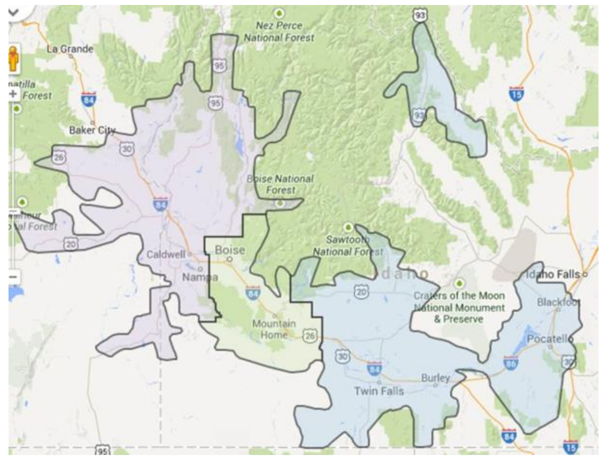

Figure 1. IPC's Service Territory

Because of the high potential for wind integration, the Renewables Integration Tool (RIT) was a key outcome of IPC's larger SGIG project, which also installed transmission line monitors, phasor measurement units, distribution automation equipment, smart meters, communications networks, and web portals and time-based rate programs for customers. The total project budget is about $98.2 million, including $47 million in funding from the U.S. Department of Energy under the American Recovery and Reinvestment Act of 2009.

IPC has recently seen a large growth of available wind power capacity that is expected to continue (see Figure 2). Total wind capacity for IPC is now approximately 700 megawatts (MW). However, a major challenge for grid planners and operators in using wind resources is the inherent variability and uncertainty of wind resources. The newly developed RIT provides a forecasting tool to more accurately predict the hourly level of wind energy generation IPC can procure from energy suppliers.

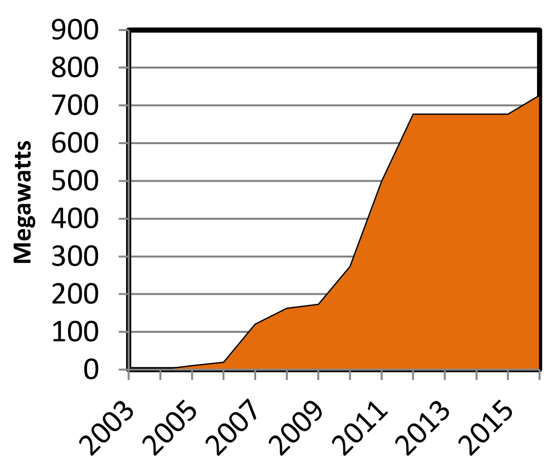

Figure 2. Growth in IPC's Wind Generation Capacity, 2004-2016

IPC's grid operators are now relying on RIT to determine how much wind will be part of the hourly and daily generation mix and what types of other resources—such as quick-start gas-fired units or demand response—will be needed should wind conditions change during the day, as they typically do. RIT forecasting is saving costs and improving operational practices for IPC and helping integrate wind power more efficiently and cost effectively.

Figure 3 shows how the availability of wind energy varies over a two-day period, which requires grid operators to increase or decrease other power supplies to keep overall system generation in line with customer electricity demand (system load). IPC found that available wind power is typically low or moderate in the afternoon and evening, when customer demand is typically peaking. Improved forecasting tools allow IPC to better predict the timing and amount of wind energy resource availability, which reduces the uncertainty associated with wind energy supplies and therefore allows operators to plan for and use other resources more efficiently to lower costs.

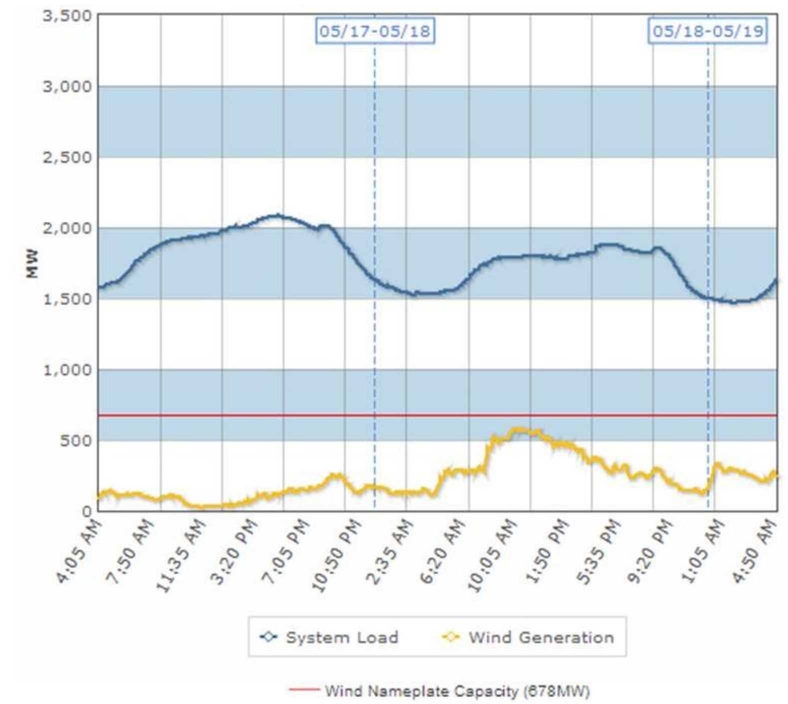

Figure 3. IPC system load and wind generation during a two-day period in May 2014

3. Improvements in Forecasting Wind Energy Resources

IPC determined it would need a customized set of wind forecast models and databases when it found no commercial products that offered the needed level of accuracy. IPC's Power Supply Planning Department had previously developed an in-house wind-generation forecast that relied on rudimentary National Weather Service data and basic rating curves for wind turbine performance. While this system showed potential, further research and development was needed to make it a more useful operational tool.

The goal was to address three wind forecast intervals: within one hour, hourly, and day ahead. IPC investigated a number of approaches, including a forecasting tool used by the Bonneville Power Administration. IPC eventually identified a set of weather forecasting models and datasets developed by the University of Arizona that was used and tailored to develop RIT for IPC's specific needs. RIT uses several weather models. The primary forecasting model for short-term forecasts runs four times a day and makes wind predictions 72 hours into the future. A second model—run once every day, Monday through Friday—makes predictions 180 hours into the future and is the primary forecast model for time frames beyond 72 hours.

RIT uses models that forecast power requirements based on weather data from meteorological towers located in multiple sites in five major wind parks, and from various public meteorological sites. The wind parks are geographically dispersed across about 300 miles of hilly terrain. RIT includes analysis and mapping tools that can graphically show wind speeds at 10 meters and 80 meters above the ground, abrupt changes in wind directions, and other important weather parameters.

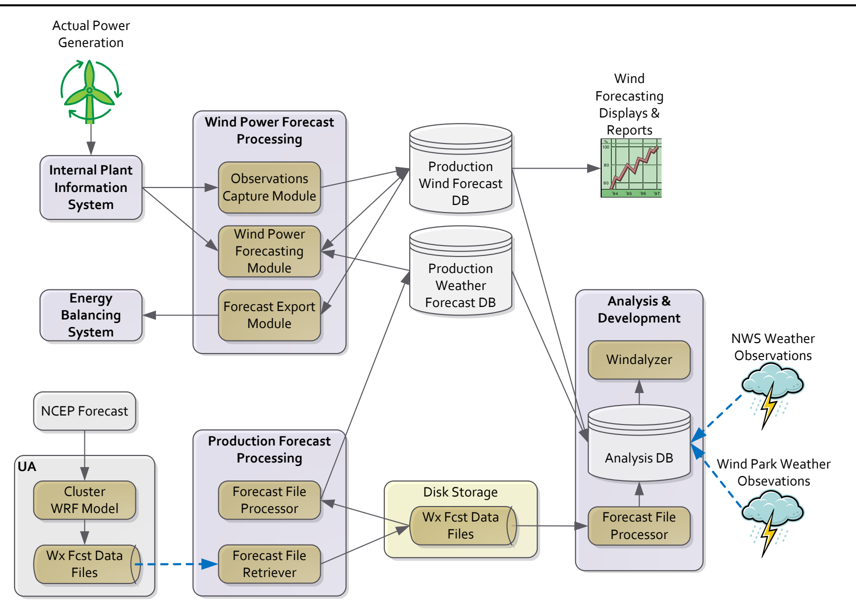

Figure 4. IPC's Renewables Integration Tool for Wind Energy Forecasting

Figure 4 is a diagram of the RIT system and shows the various modules and components.
IPC has measured RIT's improvement in forecast accuracy. One of the metrics for measuring forecast accuracy is the mean-absolute-hourly-error (MAE), which is the sum of absolute value of the observed amount of hourly wind generation, minus the forecasted amount, and divided by the total number of hours in the forecasting period. Using RIT, grid operators have seen an approximate 40% reduction in MAE for the short-term wind forecasts.

IPC conducted a detailed analysis covering a three-month period from February to April 2014 to compare forecasting accuracy using three different methods, shown in Table 2.

Table 2. Forecasting Accuracy from February – April 2014

Method	Average Hourly Error Rate
The assumption from IPC's previous forecasting method that 33% of total installed wind capacity would be available	MAE of 136 MWH
A rolling 3-day average of actual historical wind generation	MAE of 149 MWH
RIT model forecasting	MAE of 100 MWH

The actual average hourly amount of energy from wind during this time period was 233 MWH. **The analysis demonstrates a 26% to 33% improvement in forecasting accuracy over three months using the RIT compared with the other two methods**. However, IPC still sees a wide variability of energy received in any given hour due to the difficulty of predicting hourly wind characteristics. As a result, grid operators still confront significant levels of uncertainty due to unexpected variations in wind generation. While RIT creates higher confidence in wind generation forecasts, this confidence can vary from day-to-day as well as from hour-to hour.

Sometimes IPC is highly confident of the accuracy of its wind forecast due to previous experiences with comparable weather conditions; however, in other instances more unpredictable weather cause confidence levels to be much lower. **Further refinements and more experience are needed for IPC to fully understand the contributions and limits of RIT in improving the grid integration of wind**.

4. Financial Benefits from Improved Wind Forecasting Accuracy

IPC conservatively estimates that RIT enables a 25% improvement in forecast accuracy when making operational decisions on a daily basis—representing the low end of accuracy improvements demonstrated in IPC's three-month analysis of forecast improvements. To estimate the financial benefits from this improved forecasting accuracy, IPC used a conservative estimate of $15 per megawatt (MW)-based on analysis of many economic and energy variables including hourly loads, day-ahead market prices, real-time market prices, coal plant dispatch prices, gas plant dispatch prices, hydro generation prices, minimum loading on generators, regulating margins, and required reserves. Better forecast accuracy produces operational savings due to reductions in the amount of regulating reserves that IPC grid operators need to have available to meet variations in wind generation.

As a result, **IPC estimates that using the RIT saved about $287,000 for the three-month period analyzed**. This translates into cost savings of about $96,000 per month from using the RIT as compared to the two other forecasting methods that were used before RIT was developed. Over time, these savings outweigh the costs of developing, maintaining, and upgrading the RIT.

More accurate forecasts can also help grid operators to anticipate high wind conditions that can damage equipment. To prevent damage, wind turbines are taken offline (referred to as "cutouts") during these conditions. Predicting cutouts in advance helps operators manage turbine maintenance and downtimes by more efficiently bringing other resources online to meet demand.

5. Lessons Learned and Future Plans

IPC addressed several challenges in developing wind energy forecasting capabilities and with their integration into electric power system planning and operations.

Getting timely and accurate data on wind speeds and wind generation were early problems that are still being addressed. For example, IPC's power purchase agreements with wind power developers were written before the needs for more accurate wind forecasts were known to be needed. Some of the agreements lacked provisions for expanded data collection. Going forward, IPC wind power purchase agreements will need to take data collection requirements into account.

There is also a lack of meteorological towers in or near all of the wind parks serving IPC, raising difficulties with correlating wind speeds to power generation. For example, because of intermittent updrafts and downdrafts in hilly areas, acquiring accurate wind measurements and processing the data in real time to produce accurate wind generation forecasts is a continuing challenge for meteorologists and wind modelers. Managing large volumes of weather, wind turbine performance, and other system-related data on electricity demand and power supplies requires continuing efforts to develop algorithms that can process and analyze the data to extract the most relevant data sets for operations and decision making. As a result, improvements in data analytics remain an important priority for the future. Figure 5 provides an example of RIT's current data analytical capabilities.

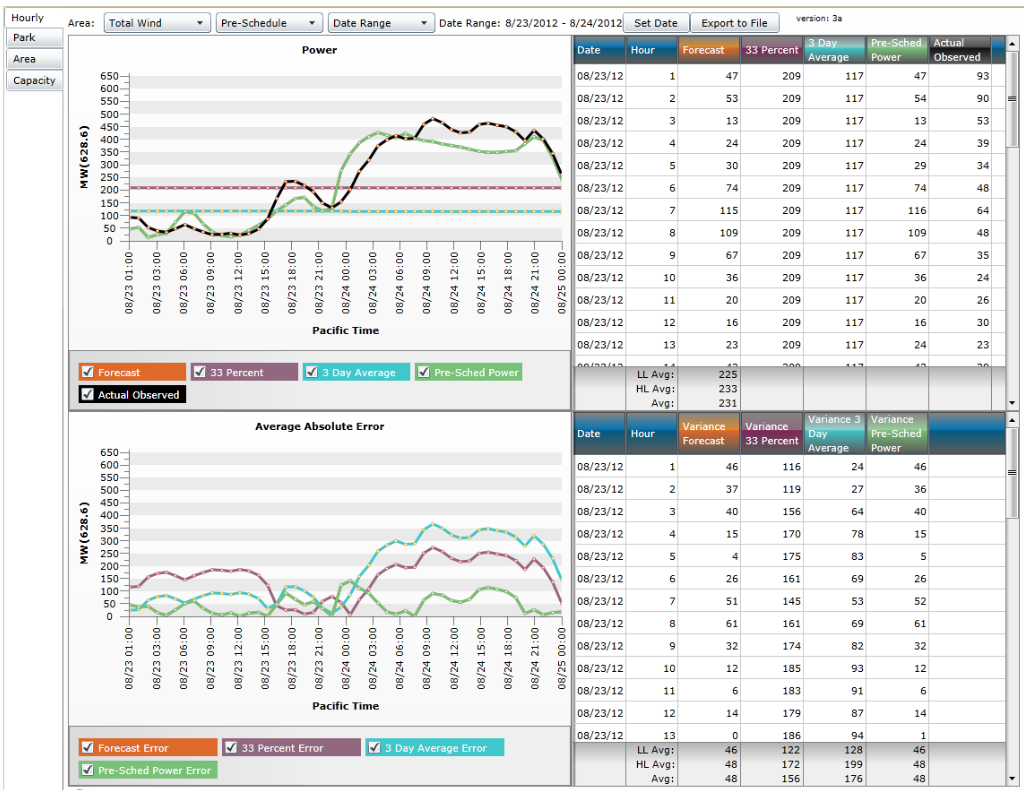

Figure 5. RIT Screen-shot of the Pre-schedule Forecast Comparing New and Previous Forecasts in the Top Portion of the Display and Hourly Error Values in the Bottom Portion.

In developing RIT, IPC assembled technical teams of analysts and data specialists with expertise in programming, electric system planning and operations, and meteorology. A key factor of project success was getting the electric system planners and operators involved in the development efforts from the earliest stages. This enabled the development teams to focus on user friendliness and visually appealing data displays.

The RIT is a customized software platform that is specific for IPC's service territory. Other utilities interested in developing comparable wind forecasting capabilities could use the RIT platform as a template but weather data, turbine performance statistics, data on system supply and demand conditions, and statistical models would have to be created for the specific locations where they will be applied.

Going forward, IPC plans to expand RIT by incorporating more weather data from additional wind parks. One of the priorities involves refinements to the models that forecast high-wind speed conditions and cut-outs. IPC also plans to detect approaching changes in wind speeds from weather observations "upstream" of the wind parks and create early-warning forecasts, particularly for thunderstorms which can disrupt the availability of wind resources for power generation. In addition, IPC plans to refine its databases and data flows on wind turbine performance to improve understanding of wind power capacities.

6. Where to Find More Information

To learn more about national efforts to modernize the electric grid, visit the Office of Electricity Delivery and Energy Reliability's website and www.smartgrid.gov. DOE has published several reports that contain findings on topics similar to those addressed in IPC's SGIG project and this case study. Web links to these reports are listed in Table 3.

Table 3. Web Links to Related DOE Recovery Act Reports and Case Studies

SGIG Program and Progress Reports	**i.**	Progress Report II, October 2013
	ii.	Progress Report I, October 2012
	iii.	SGIG Case Studies
Smart Grid Demonstration Program Reports	**iv.**	Technology Solutions for Wind Integration in ERCOT, September 2013
	v.	Dynamic Line rating Project, August 2013
Other Recent Publications	**i.**	Smart Meter Investments Yield Positive Results in Maine, January 2014
	ii.	Smart Meter Investments Benefit Rural Customers in Three Southern States, March 2014
	iii.	Control Center and Data Management Improvements Modernize Bulk Power Operations in Georgia, August 2014
	iv.	Using Smart grid Technologies to Modernize Distribution Infrastructure in New York, August 2014
Transmission and Synchrophasor Technologies	**v.**	Synchrophasor Technologies and their Deployment in Recovery Act Smart Grid Projects, August 2013
	vi.	Model Validation Using Synchrophasors NASPI Technical Workshop, October 2013
	vii.	Phasor Tools Visualization NASPI Technical Workshop, June 2012
	viii.	Synchrophasor Technology and Renewables Integration NASPI Workshop, June 2012