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CIGRE US National Committee
2015 Grid of the Future Symposium

The Vermont Weather Analytics Center Project: Electricity, Weather and Accelerating the Renewable Grid

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SUMMARY

The Vermont Weather Analytics Center Project (VTWAC) is a two-year, highly collaborative $16.6 million undertaking by VELCO (Vermont Electric Power Company) and IBM Research. It builds on previous smart grid investments by utilizing coupled models and leading-edge analytics to optimize integration of renewable generation resources, increase grid reliability and lower weather event-related operational costs.

KEYWORDS

Predictive weather model, Renewable energy, Probabilistic planning

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WHY IS WEATHER CRITICAL TO THE POWER SYSTEM?
Power system operators have always been concerned with the weather. For years, weather variables have driven electric demand, helping to determine heating load in the winter and cooling demand in the summer. Models that reflected this weather-grid link were developed over time to enable power system operators to anticipate loads and to ensure availability of adequate generation to meet customer demands. These models are less reliable with the rise of distributed generation. These new types of generation are generally not scheduled, but must be accounted for in the total energy picture for efficient and reliable operations.

Utility operations personnel have long been careful weather followers, as distribution system outages can be closely linked to weather impacts on power system equipment and trees. Storms with lightning, rain, wind, snow and flooding all impact the power system and utilities must be prepared to respond to these events in a timely manner. One major enabler of effective response to troubles on the power system is to predict as accurately as possible the locations where troubles will occur. Accurate prediction allows utilities to pre-position resources, thereby reducing restoration times and limiting the duration of service interruptions. Such capability is dependent on accurate weather forecasting.

WHAT IS CHANGING IN FORECASTING?
Traditional forecasting techniques are based on a few national and international weather forecasting computer models, which have proven to be fairly accurate in general, and are modified by local meteorological experts who apply their historical expertise to provide utility-specific forecasts. New computer modeling capabilities are being developed to respond to large sets of data. These new coupled models, such as the one being developed by IBM for the Vermont utilities, take information from international, national and local weather stations and modeling techniques to forecast weather at a much more refined geographic scale and with many more specific attributes.

Traditional forecasts are performed down to a resolution of the 16 km^2. These new techniques provide 48-hour advance forecasts to the 1 km level including wind speed and direction, solar irradiation and precipitation for every 10 minutes.. Power system operators, and wind and solar generators have seen these initial forecasts and are eagerly awaiting their regular availability.

VELCO AND IBM'S RESEARCH PROJECT
The VTWAC project's four components comprises four models: (1) Deep Thunder—a Vermont-specific version of IBM's Deep Thunder predictive weather model to produce high-resolution, accurate forecasts up to 48 hours in advance down to 1 km^2 to lower weather event-related costs and increase grid reliability; (2) Demand Model—an advanced electric demand forecast utilizing smart meters, Deep Thunder and other data sources in order to better plan for future system reliability needs; (3) Renewable Generation Model—generation forecasts for solar, wind and separately correlated hydro to improve power supply planning efficiency; and (4) Renewable Integration Stochastic Engine—coupled model with a probabilistic framework that links and synthesizes the other models' output to produce actionable information for synergistic use of Vermont's renewable generation, efficiency, demand response and transmission resources to achieve optimal system operations and value creation. Our initial application focuses on mitigating transmission constraints to minimize curtailment of renewable energy.

The effort builds upon the on-going work with IBM Deep Thunder, a state-of-the-art high-spatial-resolution and high-temporal-resolution forecasting system, customizable to support specific weather-sensitive business decisions. It is based, in part, on the ARW core of the Weather Research and Forecasting (WRF) model. The Vermont model is run operationally twice daily (initialized at 00 and 12 UTC) nested to 1 km horizontal resolution with high vertical resolution in the lower boundary layer for regional coverage for 48 hours. A number of model and remote sensing data sets are ingested to enable appropriate initial and boundary conditions. Three-dimensional variational data assimilation is performed around each analysis time using MADIS and EarthNetworks WeatherBug observations. Once each execution of the weather model is completed, the results are abstracted to include key variables at the appropriate temporal and spatial resolution. The variables include direct model output as well as diagnostic fields derived from specialized post-processing. These data then permit execution in parallel of data-driven (i.e., via statistical and machine-learning) models to predict wind and solar power, and electricity demand. All of these models operate at a granularity that enables aggregation from the 1 km^2 computational weather grid. Figure 1 shows how the various inputs connect to generate the more accurate forecast.

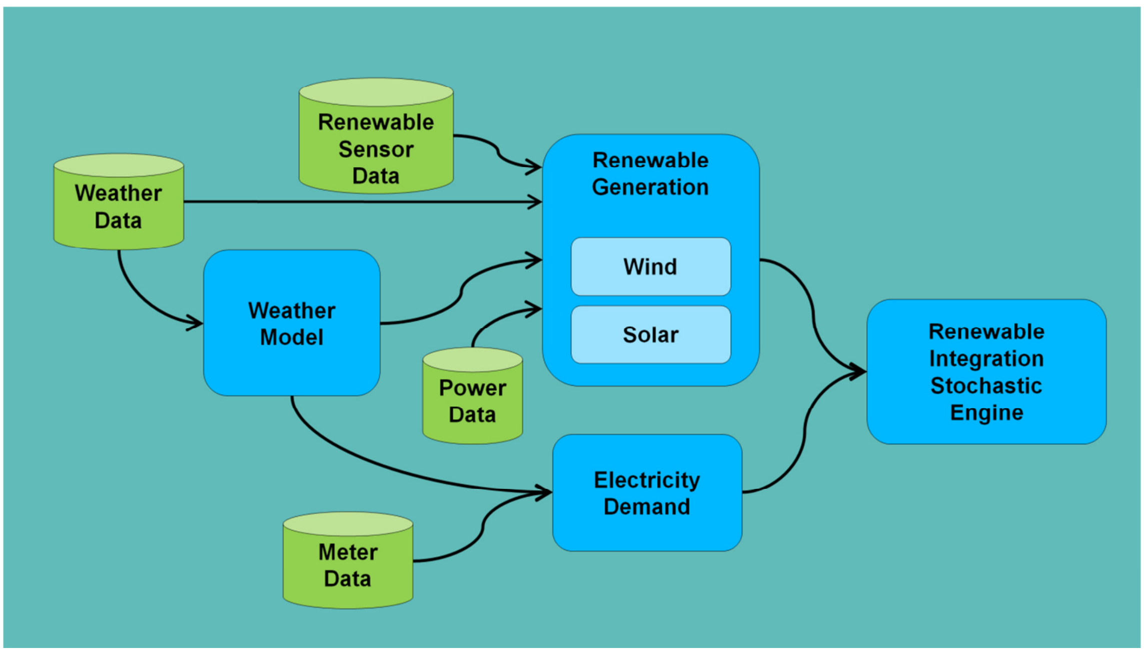

FIGURE 1: Various inputs to the weather model

RENEWABLES ARE DRIVERS FOR BETTER WEATHER FORECASTS

As renewables have proliferated in the US, wind and photovoltaic solar generators have been connected at both distribution and transmission levels. These generators are considered variable sources as their power derives from the wind or the sun. Both of these sources can and do change. Wind is not constant and clouds affect solar irradiation and generation output. One challenge of these new types of generation is to be able to forecast their output. Being able to predict the generation output is important for operational purposes as well as financial perspectives. Figure 2 shows the difference on the Vermont total load between a sunny day and a cloudy day. This different is significant and illustrates some of problems with scheduling generation in a day-ahead market.

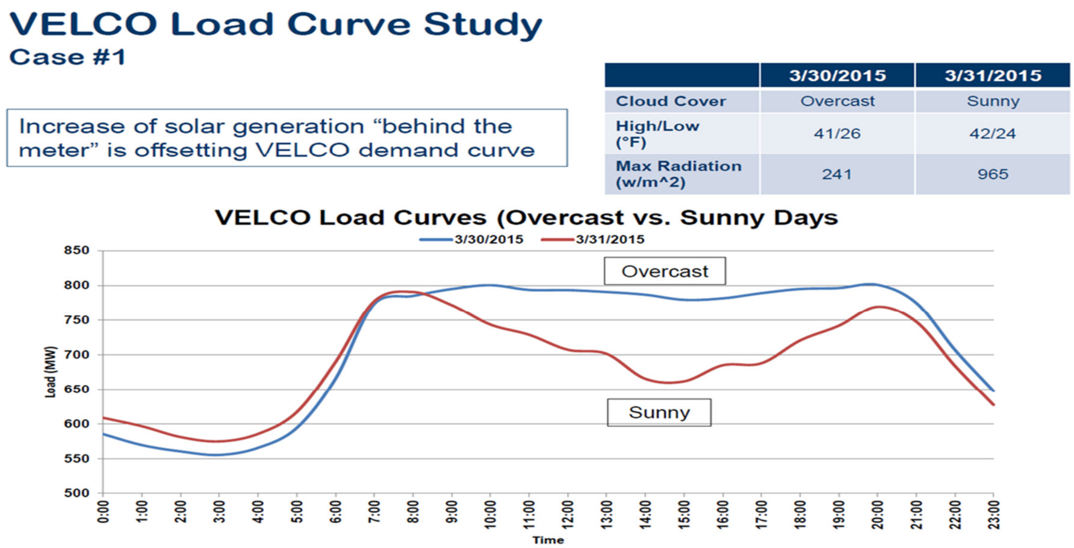

FIGURE 2: The impact of solar generation on state loads

At the finest scale, wind power forecasting is done at the turbine level, solar at each utility-scale facility and demand at the distribution sub-station level. In addition, the demand model predicts solar power generation for distributed systems behind the meter. These models use training sets, which consist of both forecasts and hindcasts of the weather model, and historical power and other data from the utilities. This joint project’s results will improve grid resiliency, unlock additional renewable energy value, better ensure necessity of additional transmission investments and, by proving out renewable energy performance, substantially bolster our regional policy advocacy to advance renewable energy integration.

FORECASTS LEAD TO NEW PREDICTIONS

These new predictive statistical models will predict electric demand at a detailed geographical level with the corect modelling of the negative load from distributed PV generation as well as wind generation output.

This prediction is at the level of the individual wind generator for the next day by hour. This ability to predict accurately generation a day ahead has benefits to both power system operators who can lower the amount of additional generation being run for grid reliablity purposes as well as for commercial wind operators. For instance, wind generation operators will be more confident in their ability to make day-ahead commitments for energy deliveries into the wholesale competitive power markets with greater confidence that they will be able to meet these commitments.

Solar power forecasting is based on predictive statistical models built from historical weather forecasts, observations and measured power outputs. Since the model can predict solar irradiance at a specific small geographic area, it is possible to understand the impact of solar PV on distribution circuits during the day and impact of clouds on generation levels at different times of the day. A key innovation is that shading effects are considered to improve accuracy.

This research has generated some excellent results. The models are continuously being refined as more weather stations are being added to train the model. The results are very encouraging.

INITIAL PERFORMANCE METRICS

The VTWAC project has achieved unprecedented accuracy in forecasting. For example, wind direction is predicted with an error of only 0.09 degrees, and wind speed error is less than 1.65 m/s. Energy demand forecasting achieves an accuracy of 97.6% at the statewide level and 97.3% at the Distribution Utility level. In addition to accuracy, these forecasts quantify uncertainty for use in the stochastic engine.

HOW IT ALL COMES TOGETHER

Uncertainty reduction is a goal of all this work. Integrating the uncertainty of these new variable generating sources into the power system in order to keep the system in equilibrium is a challenge. The project's culminating component is to develop a Renewable Integration Stochastic Engine (RISE), which will seamlessley integrate renewable generation probability forecasts to produce more accurate power flow analyses.

Traditional analysis of normal power system operations accounts for: dispatch levels of conventional (scheduled) generation, predicted mean consumption of loads, and deterministic renewable generation. New techniques of analysis recognize the levels of uncertainty and account for: variability in net-metering output, large swings in renewable generation output due of changing weather conditions, a larger set of scenarios for realized renewables availability, an identification of potential system problems such as congestion and overloads at various times or during contingencies.

More accurate weather forecasts down to the 1 km^2 will enable utilities to better predict where and when problems may occur. This will lower crew and material storm response costs, reduce response times and increase customer satisfaction.

WHAT IS NEXT?

Work continues on refining our forecasting methods. As confidence in these models grows and the level of renewables continues to grow, the economic value of the tool will be obvious to both power system operators and generation owners. Keeping load and generation realiably balanced is a requirement, not an option, for our modern society. These new tools will be important to accomplishing this balance in a manner that reduces the total costs to customers by reducing the conservatism in the reserve margins of generation needed to deal with uncertainty of variable renewable energy.

This project's potential impact is staggering in terms of benefits. VELCO in 2013 successfully secured deferral by our regional grid operator, ISO-NE, of $400 million in transmission investment through quantification of non-transmission resources, including distributed renewables, using early analytical models. VELCO also worked to secure an ISO-NE policy change to include more customer-owned solar generation to save New England customers up to an estimated $100 million annually in capacity costs. With over $4.8 billion in New England transmission reliability projects currently planned, VTWAC's ability to unlock additional value from renewables through documented performance results could trigger project and policy changes that will save customers millions. Applied nationally, the avoided costs would be in the billions. Improved forecasting of intermittent wind and solar renewable resources could potentially be worth at least $1 million to $4 million annually to New England and several hundred thousand dollars to Vermont to start—and could add billions of value worldwide. This doesn't account for the savings in greenhouse gas and particulate emissions from fossil fuel-fired generators that run due to renewable generator uncertainties. While more difficult to quantify, increased effectiveness of weather event assessment leads to lower-cost preparation, response and customer service restoration from increasingly severe and frequent weather events. Most of this project's elements are easily replicated: smart meters, fiber optic cable and utility collaboration with a services provider. In the end, through this project we seek to keep people safer, save customers money, and improve our ecosystem impacts.