

METEOROLOGY & MARKET DESIGN FOR GRID SERVICES WORKSHOP REVIEW

DENVER, CO JUNE 4 - 6, 2019

Tutorial:

Electricity Markets and Forecast Utilization: How They Work and How They Interact

Co-Chairs: **Erik Ela and Aidan Tuohy, EPRI**

Erik Ela and Aidan Tuohy of EPRI led a tutorial session that looked to bridge the gaps between the two main topics of this workshop - renewable forecasting and its use, and the design of wholesale electricity markets. Starting with an interactive poll-based discussion on attendee's interest in the area and experience level, the presenters provided a Forecasting Use 101 and Electricity Markets 101. These introductory presentations focused on how forecasts are developed and used, and then on the evolution of wholesale markets and how energy markets are designed. Strong audience interaction resulted in a lengthy and interesting discussion on issues, like how large penetration of storage and hybrid renewable-storage plants will impact the use of forecasts and market design, how distributed resources can be considered and how planning tools should consider market operations and forecast uncertainty. After a break, advanced topics were covered, including ancillary service designs, financial transmission rights and capacity markets, and how emerging technologies may impact wholesale market design. The session finished with a discussion on advanced use of forecasting in power system operations, covering topics like probabilistic renewable forecasting, forecasting of reserve requirements and forecasting of frequency response. Audience discussion focused on issues like how market designs can reflect forecasting approaches and vice versa, and the value of improved forecasting in the context of the market designs.

Opening Plenary Session:

Common Ground – Forecasting & Market Design for Clean Energy Futures

Chair: **Bethany Frew, NREL**

Panelists: **Mark Ahlstrom**, NextEra Energy Resources; **Rob Gramlich**, Grid Strategies; **Ben Hobbs**, Johns Hopkins University; **Mark O'Malley**, NREL; **Emma Nicholson**, Concentric Energy Advisors; **Sue Haupt**, NCAR; **Aaron Bloom**, NextEra Analytics

This session covered a wide range of topics relating to market design, meteorological forecasts, and more broadly, the unifying theme of uncertainty. The four session speakers presented on current market design considerations in the United States, options for how to incorporate (or not) probabilistic forecasts in existing U.S.-based markets, and thought-provoking ideas on how to think about the structure and value of future grid resources, including potentially game-changing ideal resources. The panel discussion during the second half of the session touched on many topics, including a debate between the merits of a centralized vs. decentralized approach to system operation (and a more hierarchical option that



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is somewhere in the middle), early indicators of the impact of climate change on the operational and investment risk of renewable resources, the potential need for an ideal load resource, the need for forecasters to provide the scenarios (and not just statistics) from ensemble forecasts, and a high-level soccer team analogy where the key needs of the grid are good resources (players) that can respond to good signals (coaches).

Forecasting Session 1: Solar Forecasting 2 Program

Chair: **Tassos Golnas**, DOE

Panelists: **Justin Sharp**, Sharply Focused; **Yangang Liu**, Brookhaven National Lab; **Hugo Pedro**, UCSD; **Larry Berg**, PNNL; **Manajit Sengupta**, NREL; **Paul Kalb**, Brookhaven National Lab; **Bri-Mathias Hodge**, NREL + UC Boulder; **Aidan Tuohy**, EPRI; **Venkat Krishnan**, NREL

The DOE-supported solar forecasting projects have been seeing progress on a number of fronts, from alpha versions of the forecast evaluation portal, to encouraging results from alternative cloud microphysics, to innovative uses of Bayesian statistics in probabilistic forecasts, to successful cloud identification and irradiance forecasts from low-cost sky imagers. The research community feels that there is healthy cross-pollination with the broader meteorological and climate science field and eagerly awaits the impact of assimilating data from the new GOES satellites into forecasts. Still there is plenty of debate about the value of the solar power forecast in an environment of rapidly changing conditions regarding the generation mix and the operation of the grid.

Markets Session 1: Hybrid Resources and Virtual Power Plants – Are They for Real?

Chair: **Erik Ela**, EPRI

Panelists: **Ulrich Focken**, energy & meteo systems, Germany; **Ben Carron**, Sunrun; **Jim Baak**, Consultant; **Nikita Singhal**, EPRI; **Gary Dorris**, Ascend Analytics

In this session, five speakers discussed evolving approaches to the ways in which multiple technologies combine to participate in electric power systems to provide energy, capacity or a variety of reliability services. Many different definitions were given from each speaker including those for hybrid co-located technologies, distributed energy resource aggregations, and virtual power plants. The speakers discussed ways in which these technologies can provide offers in electricity markets, including some where they are already doing so. Other speakers discussed how this may be evolving in the future and some of the key challenges that may be viewed. The audience keyed up some great questions for the panel on whether special treatment is necessary for these resources, and whether fundamental changes to the power system and its electricity markets were essential for being able to extract the most value out of these combined set of technologies.



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Forecasting Session 2: Forecasting for Distributed Energy Applications

Chair: **Bri-Mathias Hodge**, NREL & UC Boulder

Panelists: **Frank Monforte**, Itron; **Ulrich Focken**, energy & meteo systems, Germany; **Brady Stoll**, NREL; **Amir Javanbakht**, CAISO

This session was primarily focused on the role of behind-the-meter solar PV power in load forecasting. Frank Monforte of Itron started the session with an update on how they are treating BTM PV in existing load models with 10-20% penetrations. Ulrich Focken continued by providing some insights into how this is handled in Germany, where both PV and wind are primarily interconnected on the low voltage network, and the methods they utilize for forecasting each component individually, and then integrating the forecasts. Amir Javanbakht provided information about the experience in CAISO where they had been noticing increasing load forecasting error metrics, and the process to attribute them to BTM PV. While the other presentations were focused on operational forecasting, Brady Stoll from NREL showed the impacts of planning-level forecasts of distributed PV on power system capital and operational costs.

Markets Session 2: Forecasting and Market Design for Grid Services

Chair: **Eric Gimon**, Energy Innovation

Panelists: **Nitika Mago**, ERCOT; **Nick Engerer**, Solcast and Australian National University; **Gunnar Shaffer**, SPP; **Allison Weis**, Ascend Analytics

Nitika Mago from ERCOT started the session with a presentation on system inertia in ERCOT. She gave an introduction to why the grid needs inertia and a concept of "critical inertia," which is the amount of inertia (in GW-sec) needed to make sure frequency drops slowly enough after a system trip for primary frequency response resources to kick in to address the problem. She talked about ways to lower the critical inertia threshold, including new fast frequency response resources. Nick Engerer, Solcast in Australia, showed how his company uses a global satellite network to give a timely distribution forecast of rooftop PV performance to poles & wires network operators. Solcast is going beyond forecasting, though, and helping integrate their information into APIs and distribution infrastructure decision analysis. Decision analysis was a key theme of the session. Gunnar Shaffer, SPP, discussed challenges they are having with current -- soon to be even greater -- levels of wind power with occasional large multi GW up and down ramps in wind power supply. He is part of a special unit which looks at forecast data and committed units in the day ahead window and makes manual calls several times a year to prepare the system for an unusually strong wind power change the next day. Allison Weis, Ascend Analytics, discussed decision analysis in the context of one-hour batteries operating in the CAISO real-time energy market or day-ahead ancillary market. These batteries use market and weather forecast data to profitably position themselves to either supply power during price spikes or otherwise provide ancillary services. She anticipates a fairly large market in CAISO for such batteries (saturating at ~10GW) and in any market with significant variable renewable energy penetration.



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Forecasting Session 3:

Solar and Wind R&D Forecasting Advances - Part 1

Chair: **Craig Collier**, DNV-GL

Panelists: **Marc Perez**, Clean Power Research; **Andrea Staid**, Sandia National Labs; **Anamaria Sabau**, ConWX; **Julie Lundquist**, University of Colorado Boulder; **Sue Haupt**, NCAR

In Forecasting Session 3, Marc Perez provided us demonstrable financial value of PV forecast improvements and described how battery technology can be used to effectively recover forecast error in plant operation. Andrea Staid provided a data-centric view of BPA wind forecast errors, where within certain events, phase errors theoretically could be reduced by simple shifts of the forecast. While her presentation did not cite particular phenomena giving way to such phase errors, Anamaria Sabau discussed a feature well known to wind forecasts: cold fronts. She highlighted the potential for forecast error reduction due to the correlation of upstream forecasts. Finally, Julie Lundquist and Sue Haupt closed the session. Julie merged the meteorological, financial, and legal dimensions of wind plant siting as relevant to inter-plant waking, while Sue demonstrated from first principles of the energy cascade how mesoscale and microscale meteorological modeling are being fused together to effect a better wind forecast, raising the spectre of an operational form using GPU processors.

Markets Session 3:

Current and Future Market Revenue Streams

Chair: **Mark O'Malley**, NREL

Panelists: **Paul Denholm**, NREL; **Robin Hytowitz**, EPRI; **Onur Aydin**, Brattle Group; **Ryan Wisser**, LBNL

Current and future market trends are pointing towards electricity generation portfolios consisting of large quantities of solar, wind, and gas generation with declining nuclear and coal and newer technologies including storage. This transition is driven largely by economics and by decarbonization policies. Although markets, in theory, should have no technology biases and should be able to handle these changes, there is a consensus that these changes will require markets to adapt to properly reflect the true value of individual technologies. These values are reflected in the services of energy, capacity and ancillary services. There is potential for markets that are not adaptive to not deliver the "best" portfolio. With the evolving portfolio, the value of some of these services will increase, and others may decrease, with the technologies having varying degrees of capability to provide these services.

Grid services were summarized by Paul Denholm of NREL and included a summary of how wind power as a technology can provide many of the services. Robin Hytowitz of EPRI presented a detailed analysis of ancillary services revenues that gave good insights into current markets and possible evolutions in the future; it was noteworthy that the revenues are small relative to total revenues. Capacity markets, which exist in some regions and not in others, was the subject of Onur Aydin's (Brattle) presentation and as is typical when capacity markets are discussed, some strong opinions were expressed by several commentators. Ryan Wisser of LBNL did a nice job bringing it all together, highlighting the dynamic nature of markets, their evolution and their importance in underpinning future generation portfolios.



Forecasting Session 4:

Solar and Wind R&D Forecasting Advances - Part 2

Chair: **Jeff Lerner, Vaisala**

Panelists: **Mikkel Westenholz, ENFOR**; **Tyler McCandless, NCAR**; **Ryan Kilpatrick, NRCan**; **Stan Benjamin, NOAA**

This session covered the application of NWP guidance and machine learning statistical models to the advancement of forecast methodologies for various extreme, harder to forecast wind power events. We also saw the application of a new method from NCAR on using a multi-step regime-dependent neural network method to solar power forecasting and its potential to battery storage. The HRRR model is now being used by system operators and forecast providers in the past couple of years. NOAA has been very responsive to incorporating energy industry requests (e.g., forecast horizon changing from 18-36 hours ahead in July 2018). We discussed during the panel how we might look at worst forecast errors as a trackable standard metric since it's often (but not necessarily) these errors that can inflict hurt on the end user. One of the takeaways from the panel discussion was that all boats will float with improvements to the foundational NWP models. One conspicuous void of the NWP input data is boundary layer wind data that is currently privately held by wind farm owner/operators. The industry has a trusted partner with NOAA and many ISOs have a data store of historical and realtime hub height wind speed data from each wind farm. Is there a data working group (at ESIG or other organization) that could take up the issue of wind energy industry data integration in NWP modeling?

Markets Session 4:

Innovation of Services and Markets – Learning from Distribution and Vertically Integrated Utility Experiences

Chair: **Elaine Hale, NREL**

Panelists: **Beth Hartman, Rocky Mountain Institute**; **Jeff Dennis, AEE**; **Pete Bronski, Energy Web Foundation**; **Forrest Small, Concentric Energy Advisors**

This panel covered a wide range of topics on the subject of distributed energy resource (DER) integration:

- DER adoption continues to accelerate due to customer preferences, cost declines, and expanding use cases.
- The Federal Power Act created jurisdictional silos—wholesale markets, transmission and FERC on one side; retail markets, distribution and states on the other—that were workable at the time of its passing, but are increasingly strained and challenged by DERs and related needs to coordinate distribution and transmission systems.
- Recent FERC actions and independent system operator (ISO) responses are opening wholesale markets to storage and DER participation, but many issues remained unresolved—participation models are underdeveloped, and there are no clear rules for harmoniously operating DERs across the retail, distribution and transmission/wholesale levels.



- Blockchain technology is not appropriate for all energy transactions, however, it may be able to improve data quality (over, e.g., current REC trading practices); facilitate multi-scale dispatch and settlement (e.g., aggregated DERs in wholesale markets, hierarchical transactive energy markets); or enable high-quality, small-scale investments (e.g., tradable investments in community-scale solar).

Audience members asked whether DSOs could enable smoother DER participation in ISOs, about DSO short- and long-term planning needs, whether well-designed retail tariffs might be a simpler solution to the DER problem, to what extent customers will actually want their DERs used to help the grid, how conflicts between multiple DER uses will be resolved, and how NERC might fit into the jurisdictional puzzle.

Forecasting Session 5: IEA WIND Task 36 – Forecasting for Wind Energy

Chair: **Caroline Draxl**, NREL

Panelists: **Will Shaw**, PNNL; **Jeff Lerner**, Vaisala; **John Zack**, UL-AWS; **Mikkel Westenholz**, ENFOR; **Aidan Tuohy**, EPRI

This session presented the latest activities in the IEA Wind Task 36 – Forecasting for Wind Energy, Phase II. Will Shaw presented on work package 1 of the task and gave an update on global coordination in forecast model improvement and energy forecast metrics in NWP models. Jeff Lerner and John Zack presented on recommended guidelines for forecast solution selection, which is a major component of work package 2. Three documents have been published: one on (i) Forecast Solution Selection Process, one on (ii) Design and Execution of Benchmarks and Trials, and one on (iii) Evaluation of Forecast and Forecast Solutions. These best practices guidelines are based on many years of industry experience and are intended to achieve maximum benefit for all parties involved in the forecasting area. They are available on www.ieawindforecasting.dk. Mikkel Westenholz then talked about data communication standards for wind and solar forecasting and asked for help and contributions to this task.

The panel discussion focused on two topics: 1) Did we miss anything in the Recommended Practices Phase II plans? and 2) Would a Recommended Practice on probabilistic forecasts be useful?

The main take-aways are:

- Users are often not aware if they have the best solution, many are satisfied with “a” solution. The experience of many long-time members of the renewable forecasting community suggests that users need more education on how to select an optimal forecast solution.
- The development of decision support tools that provide probabilistic information to the user, such that it is easily understandable or automates the decision process, could also help.
- If we understand the risk profile, more value can be extracted from probabilistic information. Therefore, we need to encourage users to better define and understand their risk profiles. The consensus of the discussion was that a recommended practice on probabilistic forecasting would have considerable value. Although probabilistic forecasts are not widely used at present, such a document would be an important contribution to the education of potential users and facilitate expanded use of probabilistic forecasts in the future.



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Markets Session 5: System Operation Under Extreme Weather Events

Chair: **Josh Novacheck**, NREL

Panelists: **Justin Sharp**, Sharply Focused LLC; **Hannah Bloomfield**, U of Reading, UK;
Kevin Howard, Western Area Power Administration; **Stephen Rose**, MISO

Markets Session 5 brought together a diverse set of speakers to discuss extreme weather events and their impact on power system operations.

Justin Sharp, Sharply Focused LLC, shared progress from an ongoing project where he is mining the NREL's wind and solar resource datasets to identify potentially stressful weather events. He stepped through two particular events, providing analysis of the weather and the impact to wind and solar generation potential. The first event was a well known set of winter storms. The second was more benign from a weather perspective, but the impact on wind generation potential highlighted the importance of understanding these events as we plan for systems with more weather dependent generation.

Hannah Bloomfield, University of Reading (UK), gave a forecaster's perspective of understanding extreme weather on the power system. She provided examples of weather forecasting for power system operations at multiple time-scales, including short range forecasts (hours to days), extended range (weeks to months), and long term (years to decades). Hannah concluded by highlighting the challenges of climate-uncertainty and how integrating climate models to power system models requires more research, but is vital as we make infrastructure investment decisions.

Kevin Howard, WAPA, presented an overview of the hydropower and some of its key flexibility capabilities and constraints when responding to weather's impact on wind and solar generation. He gave some specific examples of hydro units operated by WAPA and some of their changing and less flexible generation profiles due to recent changes to environmental regulations. However, he also highlighted the use of after bays to increase operational flexibility while maintaining mandated river flows.

Finally, Stephen Rose, MISO, highlighted events within MISO's footprint that impact system operations. The main event Stephen presented came in January 2019 during an extreme cold wave. This event caused outages of all types of generation on the system, including gas and coal, but wind's deviation from the forecast was particularly challenging. Many turbines shutdown due to cold temperature thresholds which were not including in the forecast, but this particular problem has already been addressed by the forecast vendor. Stephen closed by providing a "wish list" for forecasts, which included better forecasts of extreme load and wind events, distributed solar forecasts, and forecasts for novel events.



Closing Plenary Session:

Global Perspectives on Forecasting and Market Design for the Future Energy System

Chair: **Aidan Tuohy**, EPRI

Panelists: **Laurent Dubus**, EDF, France, **Magnus Korpås**, NTNU, Norway,
Anna Evans, MIT Energy Initiative; **Aaron Townsend**, ERCOT

The closing plenary session covered a range of topics related to the market design and meteorology theme for the workshop. Each of the four presenters covered a different angle. Laurent Dubus, a meteorology researcher at EDF described the energy transition happening in France, and more broadly in Europe, and how meteorology is informing these issues, particularly around improved renewable forecasting methods. Magnus Korpås from NTNU in Norway, and a visiting scholar at MIT, described the benefits of increased coordination between European electricity markets, and how market coupling can provide benefits from day ahead through real time, particularly with regard to forecasting. Aaron Townsend from ERCOT discussed some of the recent experiences there in integrating large amounts of wind power into their market, describing how their market has adopted to be faster and more flexible and how it is continuing to evolve. Finally, Anna Evans from MIT discussed planning related issues in her native Australia, with a focus on why there hasn't yet been much take-up of the distribution non wires alternative option by utilities there. After the presentations, there was a group discussion. This included discussion on differences between Europe, Australia and the US in terms of market design and integration of renewables, as well as ideas on how market design may need to change. The value of forecasting to system operations was also discussed, as was the need for greater cooperation between neighboring regions.



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