

DRAFT

There is general consensus that, due to the intermittent nature of wind generation, accurate wind forecasting is essential for efficient and reliable market function. Wind uncertainty can be better captured to a certain extent through accurate forecasting. It is expected to facilitate in reliable and effective integration of wind in province. This paper will not put forth arguments on why there is a need for accurate forecasting, as this has been discussed at length at the wind power standing committee (http://www.ieso.ca/imoweb/consult/consult_windpower-sc.asp).

Stakeholders agree that there is a need for more accurate wind forecasting. With the new “green” outlook, wind generation, along with increased penetration of other renewable, intermittent resources (embedded and non-embedded), will represent an impactful amount of generation. It is essential to have the most accurate forecasts in order to manage these new variable resources efficiently and reliably.

Many issues associated with wind generation have been discussed through IESO stakeholder groups and studies where the following points have been put forward, discussed and agreed to:

- With the growing wind generating fleet, the larger amounts of MW seen from wind generation need to be accurately accounted for in order to reliably and efficiently manage the IESO controlled grid;
- At higher wind penetration levels, heightened attention would be required for the system to be able to handle the variability of wind generation
- In the day-ahead predispach timeframe, the market benefits from accurate forecasting results;
- With accurate wind forecasting, Market Participants will have the necessary information to provide efficient market response; and
- Accurate wind forecasting will better prepare the IESO to make resource decisions to manage security and adequacy.

The following paper is in two parts. The first will discuss the benefits of centralized forecasting while the second part will discuss how other ISO’s are predicting wind contribution as well as companies that provide wind forecasting services. Although this paper discusses wind forecasting specifically, the rationale may be used for all renewable, intermittent resources – embedded and non-embedded.

1. Benefits of Centralized Forecasting

There are many benefits associated with centralized forecasting that will be discussed in more detail below:

- Consistent and accurate forecasts;
- Decrease in overall forecast error;
- Aggregate forecasts of all Ontario;
- Consistent approach to improvement requirements; and
- More cost effective than decentralized.

Centralized forecasting allows for consistent and accurate forecasts. Standardized data would be submitted to a centralized forecaster for each renewable generator. The central forecaster can then compile this data and use it to create a forecast. This could also be accomplished through decentralized forecasting and very specific market rules that would specify form, format and accuracy requirements for each individual forecast. This would require forecasts to be submitted for each generator (embedded and non-embedded).

The IESO currently requires a day-ahead forecast from each directly connected wind generator for the day-ahead commitment process (DACP). After this forecast is provided, additional forecast updates are required as conditions change. Due to wind farm behaviours, some update their forecast hourly while others may not update from the day-ahead forecast. Further to this, one forecast may use persistence forecasting method (using current hour as the next hour predictor) while another may use similar day. Both of these characteristics create a higher aggregate forecast error than if there were consistent forecast methods and update frequency. This error is reflected in a more frequent over-forecast of wind generation, resulting in real-time generation shortages and thus reliability and efficiency concerns in Ontario (data to support this was presented at the wind power standing committee - <http://www.ieso.ca/imoweb/pubs/consult/windpower/wpsc-20080514-Item4.pdf>). While rule changes may address these issues, some generators do not have the facilities for persistence forecasting. Centralized forecasting would allow for control of the frequency of updates as well as the technology used for forecasting.

Each generator may be using different biases with their forecasts, meaning that the forecasts of one generator may have a greater error than another generator. This inconsistency is difficult for the IESO to integrate in its current form. Centralized forecasting would resolve this issue before it got to the IESO through its tools or through new forecasting requirements and standards.

With the number of future renewable generation units, there is likely to be forecast errors in both the positive and negative directions. These errors are visible and impactful with individual forecasts. With centralized forecasting, however, these errors may balance out, resulting in an overall net zero forecast error or minimizing the impact of forecast error seen with individual forecasting.

As the Alberta Electric System Operator (AESO) states (described later in this paper), a forecast of one area can be a determinant for another area. This approach also has the added advantage of providing a forecaster access to all individual facility data where conditions at one facility may be a good predictor of future conditions at another facility. For example, western most facilities may act as sentinels for the more eastern facilities with a westerly flow.

One of the options available with a centralized approach is that a forecaster generating an aggregate forecast of all facilities can perform an area forecast instead of summing individual facility forecasts. This option is not available in a decentralized approach where individual facilities have to be forecast and then summed. The AESO study stated that aggregate regional forecasts were more accurate than aggregate forecasts for individual regions.

Another benefit of centralized forecasting is that there is one central group determining whether improvements, methodology or technological, need to be made and what those improvements should be. This common methodology will allow for targeted evolution of forecast modelling to provide continuous improvement. These improvements will be across the board as opposed to one area making improvements to their forecast while other areas may not choose to do the same improvements, thus creating more differences between the already individual forecasts. Furthermore, when improvements are required, it is more cost effective and efficient to make changes once to one tool as opposed to each renewable generator having to implement the changes.

The wind power standing committee stated that the inefficiencies caused by forecasting error was trivial and that the cost of centralized wind forecasting was too much to incur at that time. With the changing supply mix and the increase of renewable generation, it is expected that a centralized forecaster could be more cost effective than individual forecasts for each generator. Without receiving quotes, it may be reasonable to suggest that the cost of an individual forecast is greater than paying for a portion of a single centralized forecaster. An example of cost savings is through upgrade requirements. If the IESO deems that more accurate and/or specific data is required from each generator, one change to a centralized forecaster is more cost effective than many individual changes to each generator forecast. A centralized forecaster using individual data appears to be more efficient for all involved parties.

2. What Other's Are Doing

2.1 Other ISOs

The increasing amount of renewable energy that the IESO is seeing and will be seeing in the next few years is a global trend. ISO's all over the world are looking for the most efficient methods of integration and forecasting for these variable generation sources.

Many of these ISOs have created working groups or task forces to address the forecasted increase of renewable resources. The following is a synopsis of wind forecasting for jurisdictions who have published their findings. Wind seems to be the focus although the methodology can be carried over to other renewables.

NYISO

As of September 1, 2008, there were over 700 megawatts of wind generating capacity in commercial operation in New York State. Wind capacity in New York is projected to grow to more than 1,200 MW by the summer of 2009. Proposed projects adding another 6,500 MW of wind capacity to be developed by 2011 are proceeding through the grid interconnection study process administered by the NYISO.

In 2005, NYISO co-funded a study entitled, *The Effects of Integrating Wind Power on Transmission System Planning, Reliability, and Operations* (2005 Wind Study) with New York State Energy Research and Development Authority (NYSERDA). The 2005 Wind Study was conducted by GE Energy in two phases. Phase 1 of the study provided a preliminary assessment of the impact of large-scale wind generation on the reliability of the New York State bulk transmission system. Phase 2 of the study expanded upon Phase 1 to provide a detailed technical evaluation of the impact of 3,300 MW of large-scale wind penetration state-wide (10% of the NYISO peak load in 2004). The study identified centralized forecasting of wind power production across the state as an essential tool for system operators to minimize the impacts of the variable, intermittent wind generation.

In June 2008, NYISO implemented a centralized wind forecasting system to forecast the amount of energy expected to be produced by each wind plant for use in the NYISO's day-ahead and real-time SCED systems. The NYISO contracted with AWS Truewind, of Colonie, N.Y., to provide the NYISO with wind power forecasts for each wind power project, based on meteorological data and historical operating characteristics of the wind power projects. The data is fed directly into the NYISO operational systems that determine the balance of load and generation. Further to this, wind plants are required to collect data on wind speed and direction and transmit this information to AWS. Wind forecasts are updated every 15 minutes and fed into the NYISO real-time commitment dispatch process.

NYISO produced a white paper in October 2008 explaining the integration of wind generation into their system dispatch. The proposed wind plant dispatch rules will require all applicable wind plants to submit economic offers into the NYISO's real-time market. Real-time offers are due 75 minutes before each operating hour. The offers can be for up to 11 price-quantity pairs, and may change hourly. Since wind resources cannot offer to increase output, the offers would indicate prices below which the resource would no longer want to generate. The supply offers and load forecast are run through the NYISO real-time SCED to determine schedules for generators every five minutes.

Wind Plants will receive dispatch signals from the NYISO and the following will be required:

- During normal (unconstrained) operating periods, wind plants will continue to operate as today and be paid for all output pursuant to the NYISO's special market rules and penalty exemptions.
- During periods of reliability constraints, wind plants will be provided a redispatch signal if they are economically identified to relieve a constraint.

- Wind plants will be required to follow this dispatch instruction until the reliability issue is resolved.
- Wind plants will be paid for all output at or below the re-dispatch signal.

Wind plants are expected to pay for maintaining the centralized forecasting system. There are additional penalties to those who fail to continually deliver meteorological data to the forecaster.

CAISO

The California Independent System Operator (CAISO) expanded a forecasting program that already covered about a quarter of the state's wind-power capacity. This expansion was to include a day ahead forecast to their already existing hour-ahead wind forecast.

With the hour-ahead forecast in CAISO, generators are geared up for possible shortages expected due to the intermittent nature of wind. These generators require time to gear up for each hour, which falls outside of the hour-ahead forecast. As a result, many of the generators are geared up unnecessarily. The day-ahead forecast will shed more accuracy on if these backup generators are required, which is expected to improve costs substantially for CAISO as the backup generators will not be armed unnecessarily as often.

As stated in the Market Surveillance Panel report published on January 30, 2009, CAISO obtained a 3 – 5% error reduction in their day-ahead wind forecast from centralized forecasting. Centralized forecasting also reduces the need for gearing up generators to backup possible wind shortages, thus resulting in overall cost savings.

ERCOT

Texas is looking to add a wind forecasting system and is also planning on integrating wind into their dispatch system. With this system, wind generators would be able to indicate their willingness to redispatch rather than ERCOT having to rely on out-of-market actions.

In order to improve forecasting accuracy, ERCOT is looking to make protocol changes that require all wind farms to use an ISO provided forecast. This would require each wind site to provide meteorological data to improve the overall forecast. ERCOT is working with AWS Truewind to identify additional forecasting tools and techniques to have an accurate wind forecast.

On February 26, 2008, ERCOT declared an electric emergency due to an unexpected 1000 MW drop in wind. The wind-forecasting pilot project between ERCOT and AWS was running during this time and had predicted the wind drop more than a day earlier. This solidified ERCOT's need to have accurate centralized forecasting.

MISO

MISO started centralized wind forecasting in June 2008. They use Energy and METEO (E&M) based out of Germany to forecast wind. The wind farms do not provide any information to E&M nor do they pay for the forecasting service. MISO pays for the centralized forecasting service through their fees.

MISO provides the latitude and longitude values of each wind farm to E&M along with real-time output for each wind farm. E&M then uses their own wind forecasts along with the real-time information from MISO to create wind forecasts.

E&M uses Numerical Weather Prediction (NWP) to predict weather conditions. NWP uses current weather conditions as input into mathematical models of the atmosphere to predict the weather. This method produces 3 individual forecasts for any given area. E&M provides these 3 forecasts at 4 levels: Commercial Pricing (CP) Nodes, zones, regions and all of MISO. Most of the time, the CP nodes represent an individual wind farm. E&M forecasts a power output (MW value) that is submitted to MISO at each of the 4 levels for each of the 3 different forecasts as well as an aggregate estimate of all three forecasts.

AESO

The Alberta ISO (AESO) has completed a wind forecasting pilot project. The purpose of this project was to see the most effective means of wind forecasting for Alberta's unique weather patterns and complex terrain. The project trialed different methods and vendors of wind power forecasting to determine the best approach to forecasting wind power in Alberta in the future.

Three vendors were chosen with global forecasting experience; AWS Truewind (New York), Energy & Meteo Systems (Germany), and WEPROG (Denmark). Each vendor forecasted for 12 geographically dispersed wind power facilities for a year (May 07 to May 08) providing a forecast covering the next 48 hours refreshed hourly. The quantitative analysis of the results analyzing methods, timeframes and geographical locations was contracted out separately in order to get unbiased results. These results are summarized, in part, below.

As AESO did a large scale study, more information around data requirements was able to be obtained for the purposes of this paper. It can be assumed that much of this information, or similar, is being required for forecasting for the NYISO as well as ERCOT and CAISO as AWS has been contracted in all areas.

Forecasting Data Requirements

The forecasters indicated that both historical and real time power output is important for accurate forecasting. Historical power output is important for statistical training of the forecast models, and real time power output is important to describe current conditions, reset forecast initial conditions, and to further train the models. The forecasters also indicated that turbine availability is important both historically and in real time. Historical availability is used for model training and real time and planned

availability for future forecasts. In addition to receiving availability data, periods of time where availability data was absent or in error have to be clearly identified to the forecaster to avoid misleading the continuous statistical training of the models.

Centralized versus Decentralized

The forecasters in the AESO pilot project all recommended a centralized approach to forecasting. They indicated that this would likely result in the most efficient and economical approach and would provide uniform, quality and accurate forecasts. This approach also has the added advantage of providing a forecaster access to all individual facility data where conditions at one facility may be a good predictor of future conditions at another facility. For example, western most facilities may act as sentinels for the more eastern facilities with a westerly flow.

A centralized approach also provides the most feasible method for the AESO to work with a forecast provider to identify what the ISO needs from a wind power forecast and how to use it for their specific system operations. Having the ability to discuss these needs with a forecaster and try different things is better done under a centralized approach.

One of the forecasters pointed out that it may be possible that under a decentralized approach, due to competition amongst the many forecasters involved, the decentralized cost per facility may approach that of a centralized approach. Additionally, having a forecaster focus on an individual facility rather than all facilities could have the impact of improving the forecast accuracy for that facility.

The AESO pilot project showed that when the forecasts were evaluated as an aggregate of regional forecasts, the error was lower than for individual regions. This implies that, where possible, it is better to use an aggregate forecast taking advantage of geographic diversity and smoothing of error where the facility forecasts are uncorrelated. This was shown with a centralized approach with uniform forecasts and data from all facilities available so one facility could act as a sentinel for another. One of the options available with a centralized approach is that a forecaster generating an aggregate forecast of all facilities can perform an area forecast instead of summing individual facility forecasts. This option is not available in a decentralized approach where individual facilities have to be forecast and then summed. However, the project did not demonstrate that area forecasts had higher accuracy than the summation of individual facility forecasts. This was commented on by the forecasters during the project.

Integration of Variable Generation Task Force (IVGTF)

The IVGTF is a NERC task force that is composed of nearly 50 industry volunteers (with 20 full time members and the rest as observers) representing all facets of variable resource component production through to their use. The goals of this task force are to raise awareness of and to investigate changes to traditional approaches to integration of variable generation.

NERC's IVGTF has published a Special Report, titled "Accommodating High Levels of Variable Generation," which describes the characteristics of variable generation and identifies changes to planning and operations practices, techniques and tools required to reliably integrate large amounts of variable generation into the bulk power system. The IESO, as a full member, has remained involved in

the development of this report over the past year, in line with its goals of supporting a robust continent-wide reliability framework and reliable integration of clean environmental energy. The IVGTF's report contains a section on forecasting of variable generation with a focus on wind. This report states that in most cases, operators have been able to manage the uncertainty around the intermittent nature of wind because the amounts of wind seen in operating systems are small. However, moving forward, there is going to be much more wind and the need for more accurate forecasting is paramount.

The report states that the difference between demand forecasting and variable generation forecasting is that variable generation forecasting is sensitive to the time horizon. For example, the error in wind forecasting grows as the forecast gets further away from real-time.

AESO's pilot project is also quoted in this paper. The IVGTF states that there is a need for improvements to short term forecasting techniques that are used for real-time forecasting. This would decrease the variations between actual wind and the aggregate wind forecast, thus providing the system operator with a valuable tool that should be integrated into the existing tools.

The IVGTF recognizes that there has been significant effort made in developing wind plant output forecasts for real-time, hour ahead and day-ahead operations for planning purposes however there is a need to integrate the forecasting products into the actual operations planning procedures and software systems. They state that there are significant efficiencies to be realized through the incorporating of wind plant output forecasts into market planning and unit commitment procedures. Further, there are significant operations concerns and reliability impacts which can be mitigated through the incorporation of hour-ahead forecasts that are incorporated in the system operating procedures.

From this paper, the NERC Operating Committee should ensure that state-of-the-art forecasting requirements are addressed in its review of FAC-001. Furthermore, the task force recommends that the industry's research and development should be encouraged to improve forecasting methods, in particular niche applications such as severe weather and ramp forecasting.

2.2 Forecast Providers

AWS Truewind

AWS has provided some form of wind forecasting services (full time services, consultation, as part of a study, etc.) to many ISOs including NYISO, CAISO, ERCOT and AESO. AWS eWind has become a North American wind forecasting market leader with thousands of megawatts of installed capacity in its portfolio.

AWS is also responsive to the needs of the solar industry, providing irradiance and solar power forecasts using the same proven methods found in the eWind forecasting system.

Energy and Meteo Systems

MISO is currently using Energy and Meteo Systems (EMS) for their wind forecasting. Previento is the forecasting tool used by EMS. This tool not only predicts wind but calculates a margin of error in reference to the actual prediction value dependent upon the current uncertainty in weather conditions. The prediction data is centrally calculated on EMS servers and then relayed to their customers over the internet.

This system has the following specifications:

- Prediction of the wind power for
 - the entire country
 - selected control areas
 - particular counties
 - selected wind farms
- time interval: 0 to 96 hours
- time resolution: 15 Min. to 1 hour
- prediction updated several times per day
- available from at 7:00 AM (GMT) in the morning
- per E-Mail or sftp
- ASCII (csv, txt) or Excel (xls)
- optional: integration of online measurement data to optimize the prediction

Weather and wind Energy PROGnoses (WEPROG)

WEPROG provides real-time wind predictions. WEPROG has developed a unique short-range ensemble prediction system which runs a large number of different model configurations and then evaluates the uncertainty of the final product. This means that each wind farm could have multiple equations that are all used to determine a final wind prediction. This technology can also be used for hydro predictions.

3Tier Environmental Forecast Group

3Tier provides forecasts hour-ahead, day-ahead and week-ahead to their clients with their PowerSight forecasting system. This forecast system is a combination of publicly available weather forecasts, advanced statistical algorithms, highly customized mesoscale numerical weather prediction (NWP) models and self-learning artificial intelligence models. These models are combined with on- and off-site observations to generate both short- and long-term forecasts.

3Tier has many forecasting products for wind as well as for hydro and one system for solar forecasting.

Garrad Hassan

Garrad Hassan provides pure wind forecasting. GH Forecaster uses operational data from individual wind farms along with weather model inputs to provide short term power forecasts. The refinement of the weather model input and conversion to wind farm power is achieved through the application of high resolution models accounting for the topography and turbine wake effects, and through statistical routines that “learn” using feedback from their site.

GH currently provides service in 10 countries across 4 continents around the world.

WindLogics

WindLogics Visionpoint Wind Energy Forecasting blends real-time data from wind plants with multiple forecasts from national and global weather sources, and even custom local forecasts, the system optimizes the forecast for specific uses. Wind Logics focuses on continuous improvement in forecast accuracy through our patented Computational Learning System. By first reviewing all available historical plant data, and then by examining multiple forecasts as well as actual performance, the WindLogics system produces results that are continually tuned to conditions specific to that wind plant environment.

3. Next Steps

When determining the appropriate steps going forward, the following points need to be considered and discussed:

- Appropriate Forecast Requirements
 - What level of detail is required for reliable operation of the IESO controlled grid?
 - Is there an existing forecast methodology that the IESO can use when determining the most effective method for Ontario (i.e. similar to that of the NYISO or the MISO)?
- Cost: the forecasting the IESO receives today from the wind farms through submitted schedules needs to be more accurate for reliability and market purposes. The IESO requires a more accurate forecast to effectively administer the IESO controlled grid.
 - Is paying for centralized forecasting more cost effective than improving the accuracy of the forecasts of each individual wind farm?
 - Centralized forecasting will result in more accurate determination of wind quantities across the province (resulting in less forecast error for the province as a whole). Does the market efficiency gain and the resulting cost savings of the accurate forecasting offset the cost of centralized forecasting?
 - Who will pay for the service?
- Should the IESO look at test projects for different types of forecasting services?