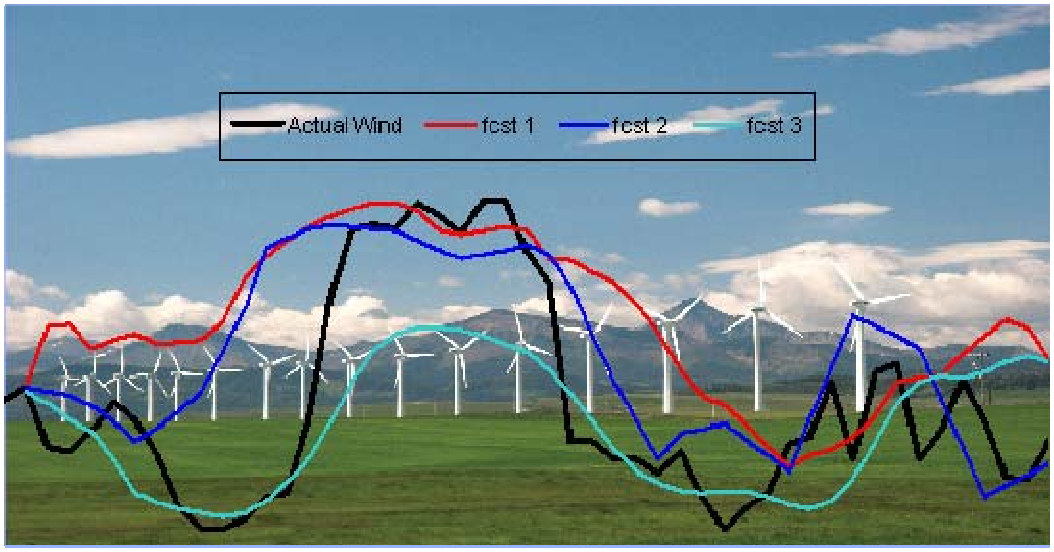
Wind Power Forecasting Pilot Project

Industry Work Group Report



Project Sponsors

Alberta Department of Energy

Alberta Electric System Operator

Alberta Energy Research Institute

Industry Work Group Participants

AltaGas Ltd.

Canadian Wind Energy Association

Environment Canada

NaturEner Energy Canada Inc.

Natural Power Consultants

Shell Canada Energy

TransAlta Wind

TransCanada Energy

Wednesday, August 06, 2008

Executive Summary

I. Introduction

The AESO, in conjunction with the Alberta Energy Research Institute and the Alberta Department of Energy, initiated a wind power forecasting pilot project in the summer of 2006. The purpose of the pilot project was:

- To trial wind power forecasting methods and providers
- To identify the most effective method(s) to forecast wind power in Alberta
- To identify the most effective providers of wind power forecasts
- To educate industry on the capabilities of wind power forecasting in Alberta

The Wind Power Forecasting Work Group was formed to assist the AESO in completing the pilot project. This report summarizes the findings and recommendations of the Industry Work Group to the AESO respecting; forecast accuracy in Alberta, data requirements, centralized versus decentralized forecasting systems, methodologies, Environment Canada's role, and areas for research.

II. Forecast Accuracy in Alberta

Wind power forecasting in Alberta appears more challenging than other locations. In order to achieve the best possible functionality, accuracy and benefits from a forecasting system, the Work Group recommends that the AESO consider factors such as how a wind power forecast will be used (e.g. real time operations) and what aspects of wind power a forecast should focus on (e.g. ramping). The pilot project demonstrated that without this focus, the nature of forecast error may be too broad for one single forecast to be optimal for multiple purposes such as real time operations, transmission scheduling and ancillary service forecasting.

III. Data Requirements

There are various opinions amongst the project forecasters regarding what on-site wind farm meteorological data is necessary to create a forecast. The Work

Group recommends that there should be a basic starting point or minimum set of meteorological data to facilitate preparation of a reasonable forecast. The Work Group recommends that the AESO consult with stakeholders on what the minimum set of meteorological data should be, using the discussions from the project as a starting point.

IV. Centralized versus Decentralized Forecasting

The Work Group recommends a centralized forecasting approach as the most efficient and cost effective approach to create quality and accurate forecasts. Centralized forecasting refers to one forecast supplier providing forecasts for all wind power facilities. A centralized approach by the AESO also permits for further study in the areas recommended by the Work Group with the AESO working directly with a forecaster to develop a customized solution.

V. Methodology

Regardless of the methodology, the Work Group considered that there remains significant room for additional learning and within this pilot there is no clear choice as to the "best" forecast methodology. The forecasters and users of the forecasts learned from each weather event and agreed that there were valuable lessons from the pilot project and there is no substitute for learning by doing. The Work Group recommends that the AESO implement a centralized operational forecast as soon as possible to learn how to better use a forecast for system operations.

VI. Environment Canada

The project demonstrated the important role played by agencies like Environment Canada in the success of wind power forecasting. National weather agencies around the world, like Environment Canada, manage critical meteorological data sources and weather prediction models that form the initial conditions for wind power forecasting. The Work Group recommends that the AESO and Industry should collaborate with Environment Canada to validate its high resolution 2.5 km GEM LAM numerical weather prediction model in Alberta to improve on wind power forecast accuracy.

VII. Areas for Further Research

Southern Alberta is a very challenging environment in which to forecast weather and would be a fascinating area to focus research. The Work Group and forecasters recommended a number of areas for further research in order to improve forecast accuracy in Alberta. The Work Group recommends research is completed in the areas of additional persistence forecast models and wind power ramp rate forecasting as part of any AESO forecast system.

VIII. Conclusion

While forecasting in Alberta is challenging due to its varying weather regimes and complex terrain, there is still valuable information in a wind power forecast and there are many possibilities for continuous improvement. With a better understanding of the capabilities of forecasting and what forecast error looks like, the AESO is now in a better position to decide how to implement a wind power forecasting system in Alberta that will meet the needs of the AESO and market participants.

TABLE OF CONTENTS

1.0 Introduction

The concept of a wind power forecasting pilot project in Alberta originated from the Canadian Wind Energy Association with their commissioned Garrad Hassan forecasting study. The proposal emphasized working with industry stakeholders on the design and implementation of the wind power forecasting pilot.

In the summer of 2006, the AESO, in conjunction with the Alberta Energy Research Institute and the Alberta Department of Energy, funded a wind power forecasting pilot project.

The purpose of the pilot project was:

- To trial wind power forecasting methods and providers
- To identify the most effective method(s) to forecast wind power in Alberta
- To identify the most effective providers of wind power forecasts
- To educate industry on the capabilities of wind power forecasting in Alberta

The Wind Power Forecasting Work Group was formed to assist the AESO in completing the pilot project on wind power forecasting in Alberta based on the recommendations from the AESO's Wind Integration Impact Studies and the AESO's stakeholder consultation to these studies. This document outlines the Work Group's findings and recommendations to the AESO based on the pilot project study. A recommendation is defined as a proposed next step for Industry and/or the AESO agreed to by most or all of the Work Group based on the pilot project study and discussions.

2.0 Pilot Project Design

In the project, three different forecasting methodologies and vendors from an assortment of backgrounds and jurisdictional experiences were trialed. The forecasters selected via a RFP process were AWS Truewind from the US, WEPROG from Denmark, and Energy & Meteo Systems from Germany.

The forecasters provided forecasts for 12 different wind power facilities (7 existing facilities and 5 future facilities) spread out across southern Alberta in four regions defined by similar wind patterns (SW, SC, SE, and CE). From May 1, 2007 to May 1, 2008, forecasts were delivered each hour, predicting the next 48 hours. The forecasts included the hourly average, minimum and maximum of wind speed, wind power and wind power ramp rate at each facility.

Genivar (formally Phoenix Engineering) collected the meteorological data and observed power data and sent the data to the forecasters. ORTECH Power provided an independent quantitative analysis of the forecast results. All of the collected meteorological data and forecast information was kept confidential between Genivar, the forecaster and ORTECH. The AESO was only provided with the aggregate wind power forecast from the existing facilities for its own analysis. The graphics shown in this report represent the aggregate forecast of the existing facilities (350 MW).

At the end of the project, each forecaster submitted a report outlining their lessons learned and their recommendations for how to best implement a forecast system in Alberta. ORTECH submitted quarterly reports and a final report with all the quantitative analysis of the submitted forecast information throughout the year. The Work Group used these reports along with individual event analysis to form the content in this document.

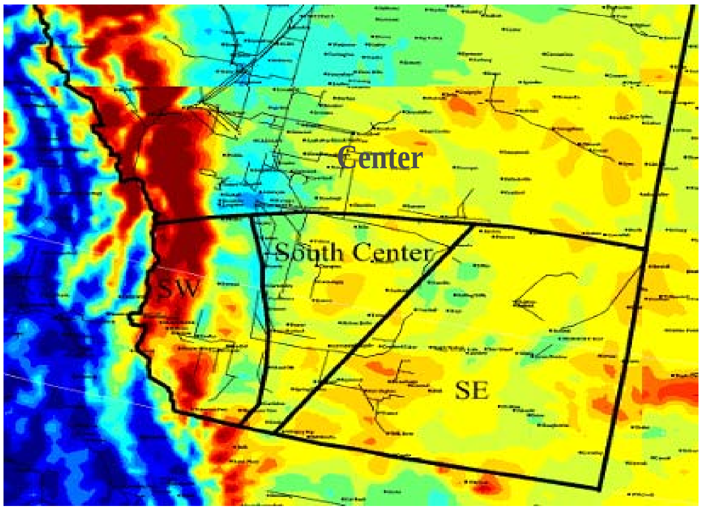


Figure 1 – Alberta Regions

3.0 Forecast Accuracy

One of the primary purposes of the pilot project was to understand what may be achievable in terms of creating accurate wind forecasts in Alberta. The strategy was to first understand what can be achieved and what forecast error looks like before setting up requirements for forecasting and operational procedures to manage any errors.

At the outset, the Work Group agreed to not select any particular accuracy metric to focus on, so as to not limit any future considerations. In other words, simply ask for a best forecast each hour. Many accuracy metrics were investigated and assessed to characterize forecast error, with each one presenting different information about the errors. Wind event analysis was also used as a means to break down individual forecasts; examining what caused the forecast to be successful or not and what that particular error would have meant to system operations. It is also important to note that the first three to six months should be reviewed with caution as there was some instability in processes still being resolved.

3.1 General Accuracy versus Persistence, Time Horizon, Season

The project demonstrated that forecasting in Alberta appears more difficult than in other locations. This is primarily due to the extreme or variable weather patterns experienced in Alberta, such as chinooks and complex terrain, being close to the Rocky Mountains.

In the very short term (i.e. up to 6 hours out), the forecasting models were comparable to persistence forecasts, where persistence assumes that conditions at the time of the forecast will not change. This was assessed by using Mean Absolute Error (MAE) and Root Mean Square Error (RMSE) as a metric. Beyond 6 hours, the forecast models outperformed persistence forecasts. It should be noted that a persistence forecast by definition will never capture extreme ramps.

As the time horizon increased, the accuracy of the forecasts decreased. Each forecaster experienced a decrease in forecast accuracy over time horizon using both MAE and RMSE as a metric. This pattern was true for all regions studied where the South West region showed the greatest forecast error, and central region showed the lowest.

The results showed that forecast error was highest in the afternoon between 13:00-18:00 hours compared to other times during a day. The Work Group considered that this error may be due to more unstable weather patterns in the afternoon, and because the wind speeds are normally highest during these times, thus at non-linear slopes on the turbine power curves. The results also showed that forecast error was high during the winter months compared to other seasons. A comparison to other seasons was not definitive due to instability in the process of data capture during the first three to six months of the project and given the project was only one year in duration.

3.2 Ramp Rate Forecast Accuracy

Certain wind events led to a focused evaluation on how well wind power ramps could be forecasted, given that ramps can pose significant system operational challenges. The project highlighted that ramp rate forecasting is difficult in Alberta. However, the forecasters all indicated that this may have been because their models were not trained to focus on ramp rates. Given that they were not told at the outset what exactly to focus on, the forecasts were trained for low average errors which can suppress ramp signals, similar to hedging. This was an important learning for the Work Group. A forecast trained to provide a low long term average error may not be suitable for short term system operations if the forecast methodology hedges against ramps or extremes. As such, it is critical to define the exact use and needs for forecast information. The project demonstrated that without these definitions, the nature of forecast error is too broad for one single forecast to be useful for all purposes.

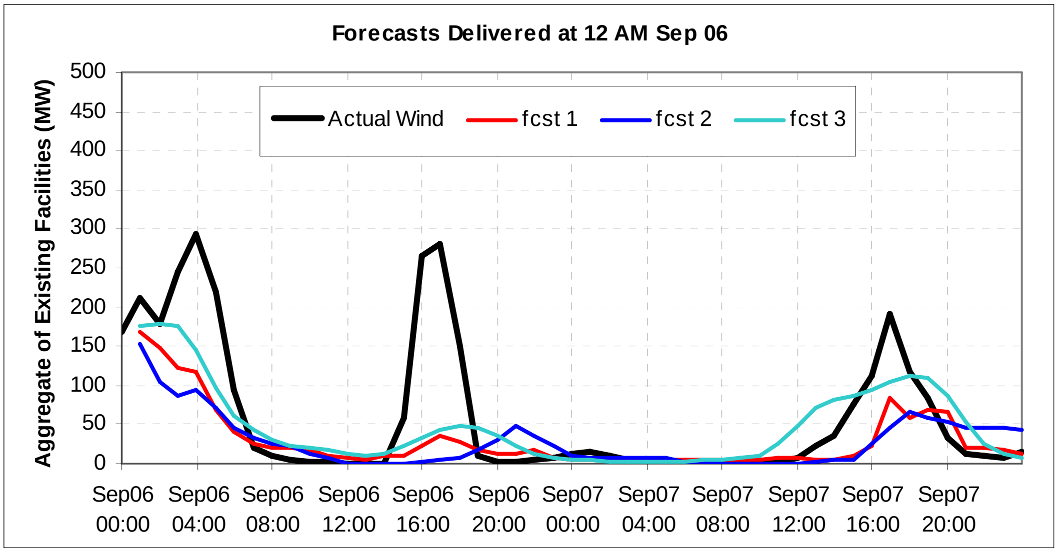


Figure 2 – The event on the afternoon of September 6, 2007 shows how wind ramps can be missed where forecasts are trained to have low average errors.

3.3 Understanding Forecast Error

It was found that forecasts can have error both in amplitude and phase (timing). Therefore, a forecast should be viewed as more of an indicator, not necessarily an absolute value at any point in time, and should be treated as advanced warning of a sequence or pattern over a future period of time. The uncertainty in a forecast is important when using a forecast as an indicator. Some weather patterns (examples: large scale westerly or easterly flows) are more certain than others which can translate to better certainty in a wind power forecast.

The project showed that the maximum error in any particular forecast does not exceed 3.5 times the mean absolute error of a forecast 95% of the time. This is the 95% confidence level or certainty band around a particular forecast. The magnitude of this 95% confidence level was higher in the short term than in the longer term. The Work Group considers that levels of uncertainty associated with forecasts are valuable to system operations.

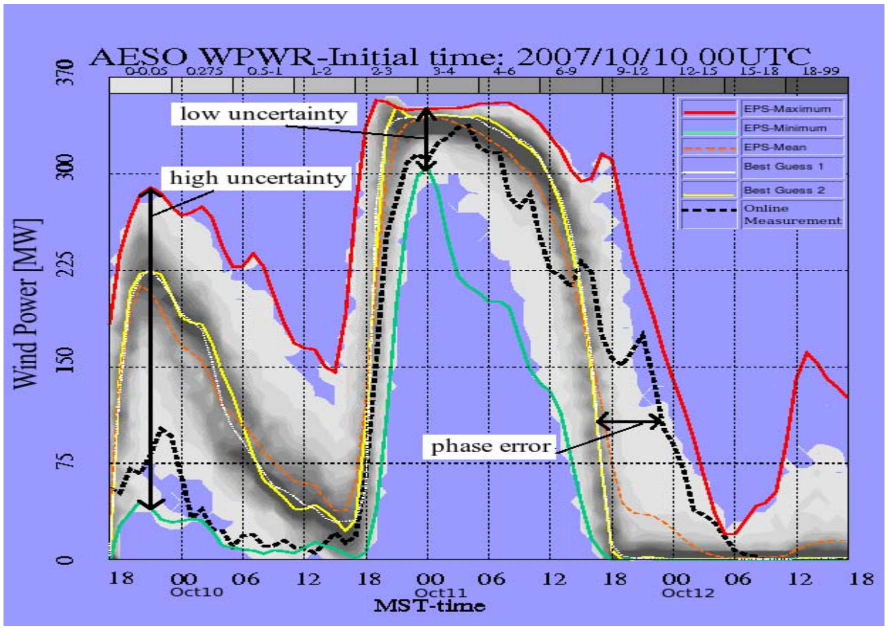


Figure 3 – This graphic was provided by WEPROG showing their ensemble probabilistic forecast delivered at 18:00 MST on October 9 (00:00 UTC). Dark shading translates to areas where many ensemble forecast members agreed. A wide band translates to a wide spectrum of possibilities. Both of these visuals are indicators of levels of uncertainty. This forecast also demonstrates phase error where the forecast was about 6 hours earlier from the actual wind power between 18:00 and 00:00 on October 12.

3.4 Potential Methods to Improve Forecast Accuracy

Each of the forecasters was asked to recommend how they could improve forecast accuracy. Each forecaster made several worthwhile recommendations outlining plans for improvements thus demonstrating there are opportunities for innovation. These opportunities include both improvements to their own internal forecasting methods and for external inputs to their processes (discussed further in section 7.0). The forecasters also summarized areas they researched throughout the project that improved accuracy such as increased resolution, weather regime characterization and Numerical Weather Prediction (NWP) selection. The Work Group considered that if the proper incentives or targets are put in place, further improvements could be achieved.

3.5 Recommendations

3.5.1 The Work Group recommends that the AESO should consider factors such as how a wind power forecast will be used (e.g. - system operations), and the aspects of wind power forecasting to focus on (e.g. - ramp rates) to achieve the overall desired functionality and accuracy from a forecast system.

3.5.2 The Work Group recommends that the AESO work to understand how to best use uncertainty information as part of forecasts.

3.5.3 The Work Group recommends that in any forecasting system, there needs to be mechanisms in place to encourage ongoing improvements to forecast accuracy and innovation.

4.0 Data Requirements

At the outset of the project, each forecaster was asked what data was required from the AESO and from the wind power facilities to facilitate an optimal forecast. The forecasters requested they be provided with whatever data was available. They would make use of what they could and discard what they couldn't. As a result, it was decided to provide a basic dataset from what was available at each site and determine if more was needed as the project progressed. The following site data was provided from each facility at the goodwill of many wind developers.

- 10 minute facility power (MW) output: historical and real time (1 year of historical data where available)
- 10 minute wind speed, wind direction, temperature and pressure: historical and real time (differing sensor heights, differing tower locations, and 1 year of historical where available)
- 10 minute real time turbine availability (only at 2 sites)

At the end of the project, the forecasters were asked to recommend what wind facility data was needed based on their experience during the project. In other words, from the dataset that was provided, what was useful, what was not useful, and what additional data would have been useful.

4.1 Forecaster Data Needs

The forecasters indicated that both historical and real time power output is important. 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 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.

The forecasters differed on the requirements for on site meteorological data. The use and importance of this data depended on the methodology used or vendor. However, where a forecaster did not use on site meteorological data during the project, they did indicate that there could be a possible use of real-time on-site meteorological data in the future.

4.2 Data Quality

During the Pilot Project, the data was provided at the goodwill of the developers, therefore there were no defined requirements on the data quality or availability. The Work Group considered that when defining the data requirements, the required quality needs to be defined as well as what happens if and when data is not available. It has been found in other jurisdictions to be useful to design a clear diagnostic path in the data gathering system to help trace data flow problems should they arise.

4.3 Recommendations

4.3.1 The Work Group recommends that the AESO consult with stakeholders on what the minimum set of meteorological data per wind facility should be based on the following as a starting point. Wind Power Facilities should provide the following information to the AESO:

- ***Turbine availability real time and planned (for forecast horizon) once an hour,***
- ***Met tower data from hub height and one other height including wind speed, wind direction, temperature and pressure based on 10 minute averages delivered every 10 minutes.***

5.0 Centralized versus Decentralized forecasting

Centralized forecasting refers to one forecast supplier providing forecasts for all wind power facilities. Decentralized forecasting refers to one or more forecast suppliers providing individual and independent forecasts on a wind power facility basis.

The pilot project was structured as a centralized approach to allow comparison between methods and vendors. As such, a direct comparison between a centralized and decentralized approach was not done. However, the forecasters were asked to provide their recommendation to the work group as to what would be best in Alberta based on their experiences throughout the project and in other jurisdictions.

5.1 Forecaster Recommendations

The forecasters all recommended a centralized approach to forecasting. They indicate 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 continue to work with a forecast provider to identify what the AESO needs from a wind power forecast and how to use it for system operations. Having the ability to discuss these needs with a forecaster and try different things is better done under a centralized approach.

On the other hand, 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 might 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.

5.2 Aggregate Forecasts

The 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. This was not studied in this project, but the forecasts may be even less correlated under a decentralized system.

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.

5.3 Recommendations

5.3.1 The Work Group recommends that the AESO implement a centralized approach at this time, to foster an optimal learning environment.

5.3.2 The Work Group recommends that forecasts to the AESO in the future should be by wind power facility, whether centralized or decentralized, instead of an area forecast. This allows for aggregation by the AESO into whatever zones they see fit for operational purposes and analysis.

5.3.3 The Work Group recommends that where possible, aggregate forecasts should be utilized, taking advantage of geographic diversity, as this should result in lower overall forecast error.

6.0 Methodology

The pilot project aimed at identifying the best methodology to forecast wind power in Alberta. However, the most effective forecast of the three forecast methods and vendors trialed varied with the time horizon and weather pattern combination. While one forecaster performed well in one condition, they would perform less well in another, making it difficult to determine the better methodology. As such, it became more a matter for the Work Group to identify the important components that influence the performance of a forecast and to highlight those areas as methods or approaches that should be encouraged.

Regardless of the methodology, there remains significant room for training and learning. The forecasters, models and forecast users learned from each weather event that was experienced. Forecasters learned about the weather patterns in Alberta and what forecast information is of importance to the users, while the users learned about the information within a wind power forecast and about its possible application. It seems there is no substitute for learning by doing.

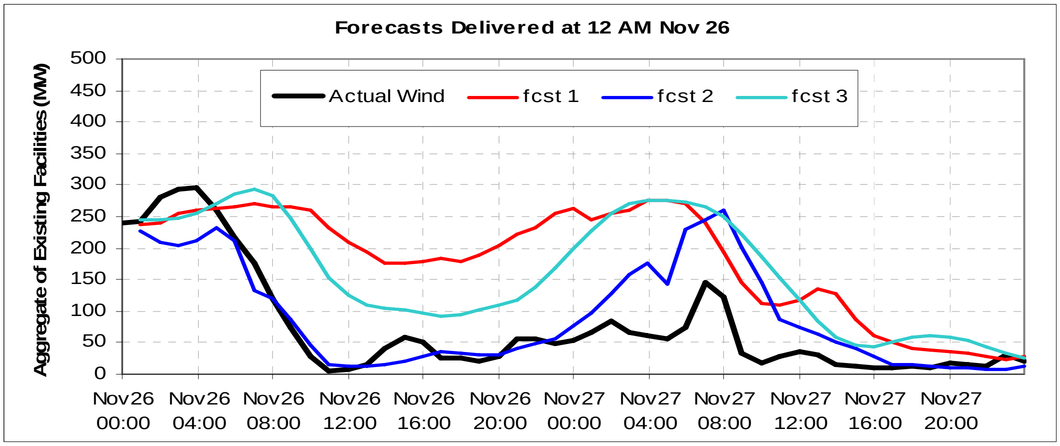


Figure 4 – The ramp down event on November 26, 2007 shows how there can be three different forecasts for a wind event.

At this stage, the Work Group considered that it would be best to continue the learning process through an operational forecast system removing the limitations inherent in the pilot project. The pilot project had limitations such as confidentiality for individual site data and forecasts, lack of uniformity on data sets provided by each facility, and lack of ability to experiment with different approaches given the comparative nature of evaluation. The Work Group considered that the AESO needs the ability to work directly with a forecaster to develop a customized solution.

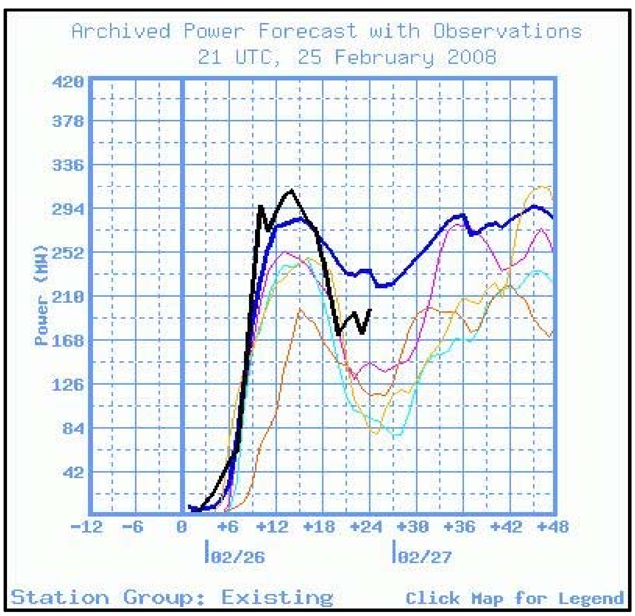


Figure 5 – This graphic was provided by AWS Truewind. The black line is the actual wind power on February 25, 2008. The four thin lines (pink, orange, yellow, light blue) are the individual NWP model outputs. However, the thick blue is the delivered forecast which after statistical correction, performed better than all four individual NWP model outputs. This demonstrates the value of statistical training which will get better over time with more data and weather events.

6.1 Modeling Methods

The use of multiple Numerical Weather Prediction (NWP) models provides a good sense of the uncertainty associated with a forecast. NWP model outputs from agencies like Environment Canada's Canadian Meteorological Center (CMC) provide the basis for weather forecasts by predicting the atmospheric conditions forward in time using physical equations. Using multiple NWP model outputs is like getting a second opinion on the weather forecast. Making use of various NWP models having different update cycles and update times should provide a more robust approach. This can also be beneficial as one NWP model might be better with certain weather regimes or in different timeframes than another NWP model.

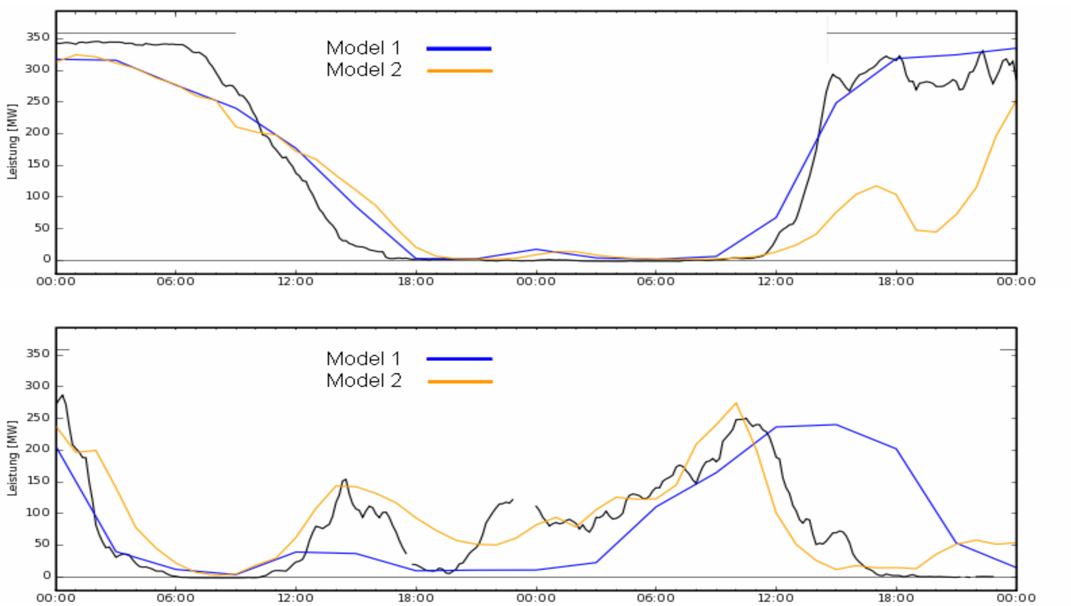


Figure 6 – These graphics were provided by Energy and Meteo Systems. These show their individual forecasts based on different NWP models for two different weather situations. Top: Ramp event that was very well captured by Model 1 which is in general the better performing model. Bottom: However, in certain weather situations such as small low pressure systems with fronts, Model 2 captures the sequence of events better than the Model 1.

Higher resolution modeling can be beneficial for complex topography, such as the foothills of Alberta, detailing the complex terrain which strongly contributes to the local effects of the wind. However, there is also potential for false alarms due to the increased sensitivity around initialization uncertainty. With higher resolution modeling, better and more weather data is needed to resolve the variability in the weather over the shorter distances. As well, the higher the resolution, the more computational power required to run the models. Each forecaster seems to have differing capabilities in utilizing higher resolution modeling.

6.2 Wind Speed Conversion to Wind Power

The importance of wind speed conversion to power was emphasized in the forecaster reports. One forecaster, who used on-site meteorological data in their methodology, showed that a meteorological tower that doesn't represent the wind conditions observed by the turbines will lead to increased forecast error even if the wind speeds are forecast well. The Work Group considered that the proper siting of meteorological towers and/or a validated facility wind power curves could be beneficial to forecast accuracy.

6.3 Methods of Forecast Application

The wind event analysis also provided a means to evaluate ways to make use of forecasts in system operations. The event analysis demonstrated the possible value to system operators of getting extreme weather warnings, uncertainty levels associated with a forecast, and human oversight of forecast information.

Extreme weather warnings or uncertainty levels in a forecast provide system operators a heads-up to potential conditions. This lead time may allow system operators to ensure they are both watching the wind conditions along with other system conditions and to be prepared in real time as conditions change. A simple time series forecast average output may not capture this uncertainty or possible extremes. Section 3.0 already contemplates the value of uncertainty information.

Although not verified by the project, it was hypothesized that human oversight of forecasts could add value by being able to describe the expected pattern or manually account for model limitations and poor model initializations. However, in order to reduce the amount of human involvement, which may come at a significant cost, it would seem more feasible to identify clock times of importance to receive a best forecast that may imply human oversight before delivery. For example, the forecast information at 7am each morning would be used to forecast the next day's ancillary service requirements.

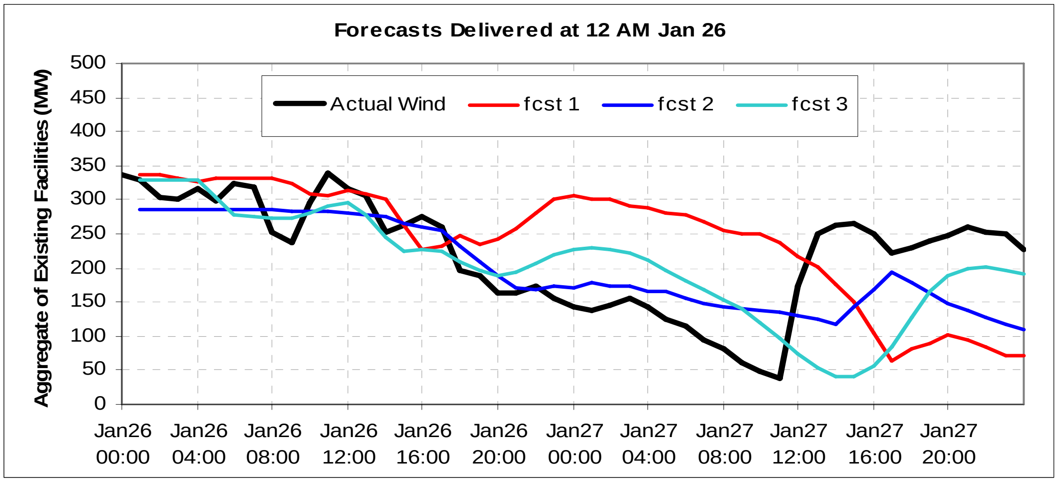


Figure 7 – On the afternoon of January 25, 2008 one of the forecasters sent an email indicating that the weather forecasted for January 27, 2008 has a lot of uncertainty associated with it and that there is potential for an extreme ramp. This is not clear when looking at the hourly forecast information above. It turns out that this assessment was correct. The use of this human assessment and uncertainty information could have been useful.

It may also be useful if the users of a wind power forecast understand the strengths and weaknesses of the forecasting process. This would permit the best possible use of the information including uncertainty, extreme weather warnings, and dialogue with forecast service providers.

6.4 Recommendations

6.4.1 ***The Work Group recommends that the AESO should move to implementing an operational forecast as soon as possible to learn how to better use forecasting for system operations.***

6.4.2 ***The Work Group recommends that any forecaster used in the future should ensure accurate wind power facility power curves where wind speed, wind direction, and air density are used prior to forecasting a facility.***

7.0 Environment Canada

As the project progressed, it became clear that agencies like Environment Canada play a large role in the success of wind power forecasting. Environment Canada houses both local forecasting expertise and an in-depth knowledge of their NWP models. NWP model outputs from agencies like the Canadian Metrological Centre (part of Environment Canada) or the National Center for Environmental Prediction (US) form the basis for wind power forecasts by providing the general weather forecast. If the NWP models or the initial conditions inputted into these models are in error, the downstream wind power forecasts will likely contain errors. The initial conditions come from many data sources like meteorological towers, airports, airplanes, etc. Environment Canada is one of the collectors of this weather data.

Given the important role Environment Canada plays, it was beneficial to have, as a member of the Work Group, a representative from Environment Canada to receive some of the requests and lessons from the project. The Work Group considered that Environment Canada should play a role in any future initiatives with improving wind power forecasting. This was supported by all three forecasters.

7.1 Numerical Weather Prediction

One of the forecasters made a request to Environment Canada for a more frequent issue of NWP forecasts. Currently the Canadian Metrological Centre's NWP model output is issued every 12 hours versus the National Center for Environmental Prediction (US), who issues their NWP model output every 6 hours. The forecasters expressed that a more frequent issue would be useful and would increase their use of the CMC NWP outputs.

Environment Canada is currently working on a project to develop a high resolution 2.5 km Global Environment Multi-scale (GEM) Limited Area Model (LAM) NWP for wind power forecasting in Quebec. Environment Canada expressed an interest in validating this model in Alberta during the project; however, it was not possible to add this to the project scope at the time identified.

This should be pursued given the possible benefits from high resolution modeling identified in section 6.0. This would involve a collaborative effort where on site facility data is made available to Environment Canada for validation purposes.

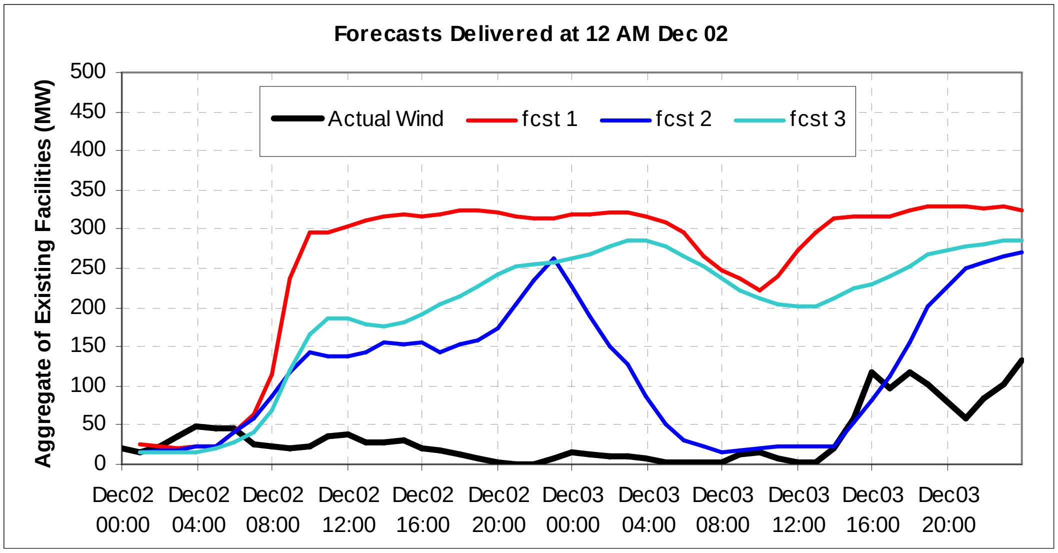


Figure 8 – All three forecasters predicted a ramp up of wind power during the morning of December 2, 2007 that did not happen. Each forecaster continued to predict that the winds would ramp up over the next two days with each hourly forecast after 0600 on December 2. The forecasters identified that this was because the NWP models all predicted this would happen emphasizing the importance of the role of NWP modelers at agencies like Environment Canada. Incorrect turbine availability data at facilities was also identified as reason for the error.

7.2 Environment Canada Data

There also appears to be a need for more weather data for Southern Alberta (including BC and the Pacific Ocean) to help predict the boundary atmospheric conditions to input into forecast models. One possible way to increase the coverage, for example, is to install temperature sensors on transmission and communication towers at pre-determined elevations to give added boundary layer thermal conditions. There are numerous towers across southern Alberta and BC at peak elevations. Sampling these temperatures on a regular basis would give a better idea on the boundary layer temperature profile from which one can deduce useful information from certain critical weather patterns.

Another way to increase the data over southern Alberta is by making better use of current weather data sites. Kelowna Upper air station launches weather balloons every 12 hours. The Work Group considered that collaboration between Environment Canada and the private sector should be considered where extra balloon launches could be beneficial to all parties. It may be possible to influence changes to the programming of Environment Canada weather stations. Specific modifications/additions to the data would benefit the forecasting for winds in southern Alberta. Accessing the data more frequently should also be explored.

7.3 Recommendations

7.3.1 The Work Group recommends that Environment Canada issue their NWP model outputs more frequently than every 12 hours.

7.3.2 The Work Group recommends that AESO and Industry should collaborate with Environment Canada to validate its high resolution 2.5 km GEM LAM NWP model in Alberta when developing the operational forecast system.

8.0 Areas for Further Research

One of the most important outcomes of the pilot project was to identify areas for improvement in wind power forecasting accuracy in Alberta. This is of value to Alberta stakeholders and also to other jurisdictions as many of the lessons learned and areas for improvement apply universally. Alberta appears to be a very challenging environment in which to forecast weather and would be a fascinating area to focus research.

Areas of further research to be considered by the AESO when developing the operational forecast system are listed in the following section. It was also considered that a standing Work Group of the AESO and the Industry should be set up to oversee the development of the operational system including these research areas.

8.1 Persistence Modeling

The simplest form of persistence was used in the forecasting comparison during the pilot project. However, there are additional persistence formulas that should be evaluated to determine if they improve the accuracy. Since there is little cost associated with this work, exploration of persistence methodologies may provide the greatest value for improving accuracy levels for hours one through six recognizing that persistence by nature does not capture extremes.

8.2 Sources of Error

While the magnitude of the errors associated with forecasting is now well understood, the source of these errors is mostly unknown. This was outside the scope of the comparative quantitative analysis and although discussed, was not provided explicitly by any forecaster. There are many possible sources including NWP model output, meteorological tower location, anemometer sensors, wind power conversion models, turbine availability data, etc. If the source of the errors can be determined, this information can focus effort to improve accuracy.

8.3 Ramp Forecasting

The pilot project identified that a forecast trained for a low average error may suppress ramping signals and possibly miss extreme wind power ramps. The forecasters indicated that if they were to focus on ramp rates, they could improve on ramping forecast accuracy. The AESO should work with a forecaster to prove this assertion, and determine how to ask for and evaluate ramp rate forecasting. The AESO needs to define the aspects of ramping that have the highest priority such as ramp time start, ramp rate or magnitude. This work would include studying how to better forecast the causes of ramp events such as chinooks and northerly fronts.

8.4 Recommendations

8.4.1 The Work Group recommends that additional persistence formulas be evaluated by the AESO to determine if they improve accuracy.

8.4.2 The Work Group recommends that the AESO focus on forecasting ramping events when developing the operational forecast system.

8.4.3 The Work Group recommends there be a standing Work Group of the AESO and the Industry to provide oversight, expertise and guidance with respect to wind power forecasting implementation in Alberta.

9.0 Conclusion

Reflecting on the original project purposes, as defined in the background section, the project achieved much of its intended aims. Different forecast methodologies and providers were trialed, valuable lessons were learned, recommendations were made for improvement, and the Industry was educated on the capabilities of wind power forecasting in Alberta.

While forecasting in Alberta is challenging due to its varying weather regimes and complex terrain, there is still valuable information in a wind power forecast and there are many paths for continuous improvement. With a better understanding of the capabilities of forecasting and what forecast errors look like, the AESO is now in a better position to decide how to implement wind power forecasting in Alberta that will meet the needs of the AESO and market participants.

Appendix A - Summary of Recommendations

3.5.1 The Work Group recommends that the AESO should consider factors such as how a wind power forecast will be used (e.g. - system operations), and the aspects of wind power forecasting to focus on (e.g. - ramp rates) to achieve the overall desired functionality and accuracy from a forecast system.

3.5.2 The Work Group recommends that the AESO work to understand how to best use uncertainty information as part of forecasts.

3.5.3 The Work Group recommends that in any forecasting system, there needs to be mechanisms in place to encourage ongoing improvements to forecast accuracy and innovation.

4.3.1 The Work Group recommends that the AESO consult with stakeholders on what the minimum set of meteorological data per wind facility should be based on the following as a starting point. Wind Power Facilities should provide the following information to the AESO:

- Turbine availability real time and planned (for forecast horizon) once an hour,
- Met tower data from hub height and one other height including wind speed, wind direction, temperature and pressure based on 10 minute averages delivered every 10 minutes.

5.3.1 The Work Group recommends that the AESO implement a centralized approach at this time, to foster an optimal learning environment.

5.3.2 The Work Group recommends that forecasts to the AESO in the future should be by wind power facility, whether centralized or decentralized, instead of an area forecast. This allows for aggregation by the AESO into whatever zones they see fit for operational purposes and analysis.

5.3.3 The Work Group recommends that where possible, aggregate forecasts should be utilized, taking advantage of geographic diversity, as this should result in lower overall forecast error.

6.4.1 The Work Group recommends that the AESO should move to implementing an operational forecast as soon as possible to learn how to better use forecasting for system operations.

6.4.2 The Work Group recommends that any forecaster used in the future should ensure accurate wind power facility power curves where wind speed, wind direction, and air density are used prior to forecasting a facility.

7.3.1 The Work Group recommends that Environment Canada issue their NWP model outputs more frequently than every 12 hours.

7.3.2 The Work Group recommends that AESO and Industry should collaborate with Environment Canada to validate its high resolution 2.5 km GEM LAM NWP model in Alberta when developing the operational forecast system.

8.4.1 The Work Group recommends that additional persistence formulas be evaluated by the AESO to determine if they improve accuracy.

8.4.2 The Work Group recommends that the AESO focus on forecasting ramping events when developing the operational forecast system.

8.4.3 The Work Group recommends there be a standing Work Group of the AESO and the Industry to provide oversight, expertise and guidance with respect to wind power forecasting implementation in Alberta.

Appendix B - Work Group Assessment and Process Review

The wind power forecasting pilot project has been a valuable and challenging learning experience in many aspects. It has involved the dynamics of an industry work group, the development and issuance of Request for Proposals, the negotiation of five separate yet dependent service contracts, the delivery and analysis of hourly real-time wind power forecasts, and finally the reporting and communication of the progress and results to the stakeholder community. Each aspect has had its unique challenges, and the following sections provide a brief discussion of how the process worked.

I. The Industry Work Group

The Industry Work Group was set up to assist the AESO in carrying out this project. The intent was to establish a volunteer work group that had a representation from those in industry affected by wind power forecasting and those in industry who could provide advice and guidance to the AESO. Naturally, this resulted in a large representation from the wind industry, but there were members from other market participants and both Provincial and Federal Government Departments.

The role of the Industry Work Group was to help guide the AESO in development and completion of the project, and to develop recommendations to go to the AESO pertaining to wind power forecasting in Alberta. This model has proven to be successful. Certainly there were times where work group members differed on how they saw the results or progress, but in the end this type of discussion served to generate a soundly based project, better recommendations and a broad understanding of the issues.

The work group members who participated in the project included:

- Darren McCrank (AESO)
- John Kehler (AESO)
- Valerie Carson (AESO)
- Ming Hu (AESO)
- Serge Besner (Environment Canada)

- Brad Shannon (Environment Canada, retired)
- Claude Mindorff (NaturEner until June 08, CanWEA)
- Kevin Van Koughnett (TransAlta Wind)
- Chris Best (TransCanada Energy)
- Mary-Ellen Jones (Natural Power Consultants)
- Matthew Good (ADOE)
- Ian McKay (ADOE)
- Wally Brown (ADOE)
- Paula McGarrigle (Shell Canada Energy)
- Chris Zeisler (Shell Wind Energy)
- Richard Nelson (AERI)
- Brian Norgaard (AltaGas, until February 2008)

II. Request for Proposals

The RFP was the first deliverable to come from the work group. The development process was successful, and will assist in the development of the next RFP for an operational forecast.

The evaluation of the RFP submissions was the second deliverable of the work group. To accomplish this, a common template for evaluation was used, and several meetings were held to decide which vendors to recommend that the AESO contract with. Again, the work group model proved to be very valuable during this stage, as everyone brought to the table a different perspective allowing for the optimal selection of participants.

III. Contracting

The contracting phase of the project involved primarily the AESO and the service providers for commercial sensitivity reasons. This is the phase where project design and intent interacts with reality. Both sides must ensure that the scope is clear and executable before signing the agreements. One of the biggest obstacles overcome was achieved by Genivar in negotiating Non-Disclosure

Agreements with the wind developers to enable the flow of wind facility data for the purpose of forecasting.

IV. Project Execution and Evaluation

The delivery of forecasts began in mid-April. However, during the first few weeks there were still some data transfer and format issues being resolved, so the actual evaluation of forecasts did not begin until May 1, 2007. For the next 12 months, the work group met to discuss quarterly evaluation reports from ORTECH and event analysis performed by the AESO. These quarterly evaluations proved to be very necessary to assist the work group in ensuring the project was on track and to develop the knowledge required to assess the forecast performance.

One of the main discussion items during the design of the project was around defining accuracy metrics to be used to evaluate the forecasts. Wind Forecast error was not well understood and defined, making it difficult to define what a forecaster should focus on. The Work Group decided not to prioritize accuracy metrics for this purpose in order to keep the scope broad and set an unbiased baseline to work from. It was decided to learn about forecasting capabilities before defining the needs, leaving open the opportunity to define the needs based on capabilities.

The special event analysis proved to be very useful to help define forecast error. This analysis involved breaking down individual events from the perspective of forecasting or how the forecast would have impacted system operations. It was through this analysis that a common level of knowledge was achieved regarding forecast methods. It visually described the error which allowed for a better understanding of the many statistics used to describe forecast error.

V. Reporting

The reporting stage involved the submission and analysis of all the participant reports including the forecasters, ORTECH and Genivar. The process used to review the reports was to pull out findings from the content to be factored into the work group discussions and recommendations. This involved capturing findings and evaluating their implications.

Finally the project closed with the submission of the work group report to the AESO on how to move forward with wind power forecasting in Alberta.