

EirGrid's Met Mast and Alternatives Study

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Keywords: GRID CODE, METEOROLOGICAL MEASUREMENTS, ENSEMBLE FORECASTING

Abstract

The current grid code in Ireland requires wind farms to deliver meteorological data to the two transmission system operators, EirGrid and SONI. For wind farms greater than 10 MW in size it is obligatory to submit four meteorological data signals: wind speed, wind direction, air temperature and air pressure. The data is collected within EirGrid and SONI and thereafter used in the wind power forecast process. The wind speed signal is the most important variable as it helps in the detection of high-speed shut down events. The importance of accurate on-site measured wind speed signals increases as a function of the installed wind capacity. Since wind farms have been installed with varying technologies over the past 20 years, the system does not have a single point of failure. The lack of uniformity has been found to be both a handling challenge and reliability strength. In order to investigate the future compatibility of the current quality of met data and to verify, whether and which types of new technology may be an acceptable source of meteorological data to be delivered to the TSOs, a study has been carried out. The study verified whether the quality of meteorological data is sufficient and reliable enough for the 2030 penetration targets set by the Irish government. This paper will describe the methods used to verify the quality of meteorological data signals, along with the various types of meteorological measurements that were found to be acceptable under varying conditions. We will also present a number of recommendations based on the findings of the study, and discuss how these recommendations are being implemented by EirGrid.

1 Introduction

The real-time wind forecasting process applies various quality control checks to ensure that the data being used in the forecast accurately reflects the reality of the on-site wind conditions. In the case that poor data quality is received (which could be due to poorly calibrated/maintained instrumentation), the forecasting process rejects a large portion of this data. The lack of information then reduces the quality of the short-term forecast.

Figure 1 outlines why it is important for EirGrid and SONI to receive high quality meteorological data. The higher the quality of data, the less dispatch down there is for wind farms. Therefore, it is in the best interest of both the System Operator and the wind farm owners' to ensure that accurate meteorological data is provided. During storm events, operational experience from the past few years shows that it often takes less than one hour from when the wind speeds pick up at the west coast of Ireland until a major proportion of the wind farms could be covered by a High Speed Shutdown (HSSD). This poses a risk during storm events and results in the System Operator having to limit the wind generation in advance so that sufficient reserve is available. These short time intervals in critical weather events call for wind farms to provide reliable weather information.

Ireland is geographically the first country in Europe to experience storms propagating from west to east. The information on the storm track and intensity of low pressure systems is sparse to the west. Therefore, weather forecast uncertainty is higher, especially during storm events. For this reason, growing wind power capacity on the island needs to be accompanied by increased reliability of the wind power handling, which is a combination of wind power forecasting and real-time decision making in the control room. Inaccurate wind forecasts could lead to inefficient actions being taken by the System Operator control room engineers.



Fig. 1 Usage flow of the met data in the grid operation

2. Distribution of wind Farms in Ireland

The Wind Energy Forecasting (WEF) system in EirGrid and SONI had, by the end of year 2018, registered 279 wind farms in their Wind Energy Forecasting System (WEF) with a collective capacity of 4.8 GW. These wind farms have differences in age of approximately 20 years and in capacity from kW in size to 100 MW in size. These 279 wind farms are

connected to 109 distinct transmission connections points. Some of the 279 wind farms are registered as multi-phased wind farms, which reduces the number of independent wind farms to 239. Nevertheless, this level of independence is an acceptable risk of large correlated errors and ensures system reliability.

For the past decade the forecasting technique used by WEPROG was based on weather forecasts tuned directly with SCADA MW values from the wind farms. The absolute forecast error however grows with increasing installed capacity.

Figure 2 illustrates the varied concentration of wind farms across Ireland and Northern Ireland. Within each high penetration area, it is observed that the wind farms have very different generation patterns and hence different forecast error levels. One of the main reasons for these patterns is the complex terrain with strong altitude differences.



Fig. 2 Horizontal map of wind farm distribution according to their year of grid connection with colours following the colour scale, blue indicating connection before 1997, dark red in 2017-2018

In order to maintain reliability with increasing wind penetration, several initiatives are required. Among them is the improvement of the usefulness of real-time data from the wind farms to support improved short-term forecasts. The amount of real-time data delivered by wind farms differs somewhat. This is due to various reasons such as: age, size, and jurisdiction. Nevertheless, with increasing penetration and modern information technology, there has been an improvement in the delivery of both real and potential power generation (in the following referred to as *AvailActivePower*) over the past few years. For the system operator, the potential power generation signal is an especially important indication of the available power at a wind farm in cases, where the wind farm has been limited by the system operator. In other words, knowing the potential power generation provides the information about the power coming on to the grid, when the limitation is released.

2.1 Quality of met data and value for short-term forecasting

In 2018, 113 wind farms (2.75 GW or 57% of installed capacity) provided meteorological data and *AvailActivePower* data signals. The wind speed signals are particularly important at the flat ranges of the power curve, where the power generation is not started yet or does not increase any more. The latter being a critical signal, when the wind speeds move towards a level, where high-speed shutdown occurs.

The quality of the data has however been found to vary and we identified that only 1.4 GW of approximately 60 wind farms is of reasonably good quality over longer time periods. This corresponds to only 29% of the overall installed capacity (4.8 GW). This is not unusual and has been found in other studies as well (e.g. [1,2]). Nevertheless, the low fraction of reporting wind farms on the total installed capacity combined with an increasing need for short-term forecasting with a higher level of accuracy was one of the main reasons to conduct this study and a workshop with wind farm owners and operators in order to explain the need and reason for the requirements to met data.

One of the major issues is that the Irish coast line is poorly covered with reporting wind farms, which is not optimal from a short-term forecasting and hence, from a system security perspective. The coastal wind farms often experience full load conditions and some of the coastal wind farms are the first to give a sign that wind speeds have changed.

An improvement in the submission of wind speed data signals from coastal wind farms would allow for earlier weather changes to be detected and predicted in the short term, because the coastal wind farms provide the best opportunities to improve the forecast for two reasons:

1. They provide the most uncorrelated information, due to being furthest away from each other.
2. The wind speed signal is less disturbed due to the coastal conditions, where the surface temperature changes are modest and the surface roughness is most homogeneous.

Further away from the coast, the diurnal cycle plays a stronger role, which may cause difficulties in or delayed detection of weather changes, because the wind speed changes are first visible in higher altitudes.

Wind farms located in coastal regions may be limited to the provision of nacelle data due to a lack of planning permission for met masts. The grid code should take such situations into account in order to avoid scenarios where little or no signals are being provided.

2.1.1 Distance based computation of effective wind speed coverage

In order to verify the effect of the coverage of wind speed measurements for the forecast quality, we

carried out a distance based computation of effective wind speed coverage. It was found that there was a band of wind farms in the middle of the country, where no signals were provided and which separated the northern sites from the southern sites. Without this data, the ST forecast consists of two large clusters with limited benefit for each other due to the distance in between, where measurement influence is interrupted. The conclusion that can be drawn from this investigation is that a sufficient coverage of met data (assuming good quality) is best achieved by setting the installed capacity limit of wind farms for the provision of met data to around 10-20MW, which was also in line with the grid code requirement [3].

3 Data Requirements

The current grid code [3] requires wind farms that are greater than 10 MW in size to provide EirGrid and SONI with the following meteorological signals:

- (1) Wind speed, (2) Wind direction, (3) Air pressure, (4) Air temperature.

This data is collected within EirGrid and SONI and, as described briefly above, is used in the wind power forecast process. The wind speed signal is the most important variable as it helps in the detection of high-speed shut down events.

A real-time forecast process must apply quality control to only use data that reflects the reality of the current weather conditions at the wind farms. In the case of poorly maintained data recording and delivery, the forecast process will at best reject a large fraction of data and sometimes process erroneous measurements leading to higher errors in the wind power forecast. Inaccurate wind forecasts can lead to inefficient actions taken by the System Operator control room engineers. The study therefore focused mainly on wind measurements and the various types of alternative instrumentation that can be used without compromising quality. Allowing diversity in the meteorological data that wind farms provide has the advantage that different technologies have different qualities that may add value to the forecasting system.

3.1 Time Resolution of Met Measurements

Traditional forecast data and measurement collection in the power sector has been on a 15 minute basis. However, as IT infrastructure improvements and penetration levels increase, a system wide 1-minute resolution can be regarded as a standard for data feeds, both with respect to maintenance and the exploitation of the data.

The study also reviewed the benefits of the high-resolution 1-min averages with respect to forecasting processes and in comparison to other jurisdictions. In comparison to 8 other system operators, there are only 3 that have a lower resolution than 1-minute. As an example, the allowance of averaged nacelle driven wind speed feeds from each turbine will provide a

better tracing of the HSSD signals to the turbines and wind farms as a whole, while nacelle measured signals provide little or no information about the vertical wind profile. Met masts and Lidars will on the other hand provide important information on gusts and the vertical wind profile in stable and unstable conditions.

5 Data Analysis and Results

The analysis and validation methodology was computed for a three year period from January 2015 to November 2018 on the signal quality of meteorological data submitted by wind farms to the system operator. The methodology was designed for future monthly or 3 monthly examination of observational data signals, where two targets were set for the validation:

1. To identify the amount of valid and qualified data submitted
2. To identify the root errors of signals and generate information to wind farm owners to allow for fast signal recovery

Simple approaches such as a cross correlation analysis will not meet these targets as such verification is challenged by the irregular distances among wind farms and the need for long verification periods. It is not feasible, if for example the time from when an issue with data signals starts until it is diagnosed and solved may take 6-12 months.

Another issue would be to determine the correctness of data signals of two neighbouring wind farms if they are not consistent. This would quickly develop into a complex process in order to find out or decide which of the measurements are correct. Since all wind farms differ and are distant enough to not experience identical weather, a new methodology to evaluate the correctness of measurement signals was required.

5.1 Methodology to validate the correctness of measurement signals

Apart from outages in the submission, the validation process of wind speeds need to be based on statistics over long time periods. There should also be an averaging process of the data to e.g. 10-15min averages in order to eliminate the impact of the turbulent motion, which is generated as a result of frictional forces from the terrain on the air as well as the imbalance in the diurnal cycle and the temperature difference between the air and the surface. Therefore, the methodology that was used for the validation was a combination of consistency checks between:

- forecasted wind speed versus measured wind speed
- forecasted temperature, wind direction, pressure against measured values
- forecasted power versus active power checked with SCADA MW
- computed active power from measured wind speed versus actual active power

- comparison against previous years per wind farm
- cross-comparison to the average error level of all wind farms in the same period

In an operational setup, monthly or 3-monthly verification statistics along with the methodology described above will be able to clarify, whether the accuracy of the submitted data signals is acceptable or not. The statistical test and metric used in the following analysis is similar to the verification of the forecast error, except that we use the forecast with a known accuracy level as the reference, because it is the measurement that we want to validate against. By validating in different sub periods of the year, it can be shown whether the error pattern has been temporary or on a long-term basis. We used different statistical tests in order to have the best possible data basis for the interpretation of the data accuracy (see details on metrics in the report [4])

5.2 Analysis of Met Data at individual Wind Farms

In order to evaluate the met data signals an initial evaluation took place to define the acceptance limits for the 4 met variables: wind speed and direction, air temperature and pressure. To do this, the quality of the data in terms of BIAS, MAE and CORRELATION was tested against the mean of the MSEPS ensemble forecasting system, containing 75 numerical weather prediction (NWP) models, over a period of 2 years.

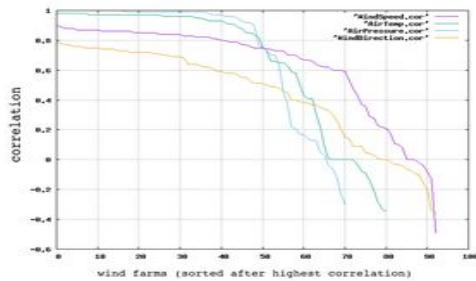


Fig. 2 Results from a 2 year statistical verification of met data signals on CORRELATION for 4 variables. The x-axis shows wind farms ordered with the highest correlation first.

In a graphical evaluation the degradation of quality was displayed for each wind farm. In all cases a continuous degradation was followed by a steeper slope for the last fraction of the wind farms. The change from a continuous to a steep degradation of the quality was then used to draw an acceptance limit for further testing.

Figure 2 shows the correlation test to illustrate the procedure. The other tests can be found in the study report [4].

5.2.1 Acceptance limits for Met Data Quality

When analysing the met data in the initial test, it was found that wind farm data quality followed a sliding scale. When we define limits based on the accuracy against an ensemble mean forecast, a widespread limit is required in order to avoid situations where correct measurements are disqualified or rejected. The limit will therefore also accept some incorrect data.

The results of the initial test to define the limits for acceptable quality are shown in Table 1. Using these definitions for nacelle and mast data over a period of 47 months we were able to compute an average acceptance fraction.

Table 1: Proposed error thresholds for statistical tests of wind farm meteorological data signals. The accuracy limits stem from a two year evaluation of meteorological signals from 93 wind farms.

Variable	Unit	Bias	MAE	Correlation
Wind speed	[m/s]	3	1	0.65
Wind direction	[°]	13	20	0.55
Temperature	[°C]	2	2.5	0.75
Pressure	[hPa]	50	85	0.85

The results of this second acceptance test are displayed in Table 2. It can be seen that the nacelle computed or mounted wind data signals have a higher acceptance level of approximately 19% for wind speed. Moreover, the nacelle wind speed data signals win every partial measure with about the same margin. This is most likely due to the fact that measurements from met masts are more independent and may reflect the complexity in local conditions. And the nacelle wind speeds of newer turbines are well calibrated relative to the produced power. A more in-depth analysis on this follows in the next sections.

Table 2: Summary of the percentages of average accepted met data signals for met masts and nacelle wind farms for three metrics, BIAS, MAE and Correlation. The counting implied that wind farms succeeded on all three metrics.

Variable	Metric	Met Mast	Nacelle Data
Wind speed	ALL	47	66
Wind direction	ALL	11	24
Air Temperature	ALL	37	50
Air Pressure	ALL	50	69

5.3 Long-term analysis of met data signals

The long-term analysis of met data signals was to investigate the accuracy of the on-site wind speed data in more detail and over a longer time period, covering 4 years instead of 2 years. For this, we have developed a data validation technique which provides an

overview and gives details without disclosing confidential information on individual wind farms. With this technique it was possible to highlight the number of wind farms providing data of different quality levels over the 47 month time period. The technique in fact allowed for the examination of subgroups of wind farms and to highlight their characteristics with respect to quality.

We computed the available active power generation (*AvailActivePower*) in MW with the same method from two different wind speed signals. Both were calibrated individually but otherwise the forecast methodology is the exact same. From experience, we know that the normalised MAE forecast error range is between 6-16% of installed capacity, depending on the wind farm and the weather conditions and with monthly variations that go beyond the band.

For this reason, we have defined a target range for the MAE improvement of measured against forecasted wind speed between 3-10% of installed capacity.

It is possible that the improvement can exceed 10% if the forecast has had abnormally higher errors at a particular wind farm. An example of a high error could be a full HSSD error, which for a shorter while could imply 100% error. It could however also be zero wind speed in case of outages at the wind farm, i.e. indicating that there was an issue that the forecasting system did not know of. An improvement below 3% is a sign that the measured data should improve.

5.4 Analysis of Meteorological Mast Data Signals

The corresponding graphical analysis contained 47 months of data for up to 93 wind farms, which was used to generate figures with 9 percentile bands of the MAE improvement. For every month the available wind farm's data signals have been used to compute the monthly percentile distribution of the MAE (forecasted wind speed) - MAE (measured wind speed). Towards the end of the 4 years there were approximately 9 wind farms in each colour band in the figures including all the wind farms (see Fig. 3)

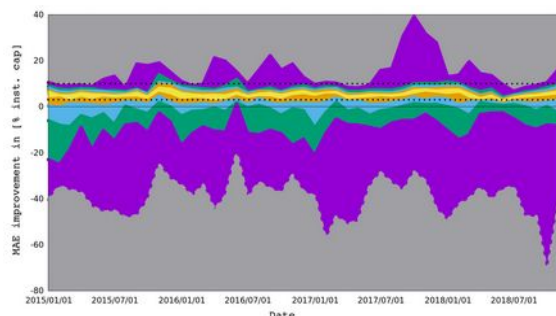


Fig. 3 MAE improvement for met data signals shown with 9 percentiles P10-P90 for forecasts using measured wind speed to compute power generation. The black dotted lines indicate the target range.

Overall we found 6 colour bands within the target range for improvement (black dotted lines in Fig. 3) starting with P30 ending with P90 expressing that 60% of the 93 wind farms hit the target range. The nacelle wind speed signals had the highest percentage of data within the target range. Their high improvement rate of 27% was found to be due to non-recognised outages in the forecast system. This is a disadvantage that needs consideration, as it provides an incorrect representation of the weather conditions, which is one of the main objectives of met data signals, i.e. an independent measure of the potential production of wind farms.

5.5 Summary of the long-term analysis

In summary 15% of all wind farms passed the quality requirements, where 60% would be required for the real-time forecasting system to function well. From all submitted data signals, 20% of wind farms did not reach the expected and required accuracy. This corresponded to approximately 32 MW of the examined and 50MW of all wind farms > 10MW not reaching the 3-10% accuracy target range.

In summary, we can conclude that the validation procedure allowed for a thorough examination of the wind farm met signal data. The graphs contain detailed information about how much capacity is not performing well and temporary outages can easily be seen as spikes in the graphs.

5.6 Reference to Applicable Standards

Standards regarding measurements and design of measurement collection in the wind energy and power industry regarding meteorological measurements have so far only been developed for the planning and commissioning phase of wind farms. Here, the meteorological measurements serve as an indicator of the wind resource and expected power output at the site of interest for the financing of a wind project. We have therefore analysed a number of standards published by the European Wind Energy Association (EWEA) and the meteorological society for their usefulness in real-time operation applications of power system operators (see [5,6]). These standards and recommendations were mainly analysed with respect to applications using power forecasting technologies.

6 Implementation of Recommendations

The importance of accurate on-site measured wind speed signals increases as the overall wind power capacity increases; however, the study found that only approximately 15% of wind farms were providing good quality wind speed data, which lead to the recommendation to introduce a delivery requirement on wind speed data submitted by the wind farms to the transmission system operator (TSO). Such a requirement should be fair to all accepted types of

measured wind speeds, but ensure that the wind speeds comply to a minimum accuracy and reliability.

The overall conclusion regarding instrumentation types is that a path towards a uniform wind speed source type is not feasible nor required. Objectively, those nacelle data signals that have been passing the requirements set out in the evaluation procedure can and should be allowed as an alternative source of met data in Ireland and Northern Ireland. Allowance for remote sensing instruments such as LiDARs or SODARs should only be given after an evaluation period of a minimum of 3 months for approval in the real-time environment. In other words, the instruments have to be capable of providing data with the required accuracy and reliability under real-time conditions, due to their sensitivity to weather conditions, which are common in Ireland and Northern Ireland.

In general, all wind speed signals need to comply to accuracy thresholds. The study showed that cases can occur, where such thresholds are met, but the data may still be unreasonable. To avoid long-lasting discussions, it is recommended that the TSOs can request a formal calibration with an independent measurement source after the IEC61400-12-1:2017 Annex I standard. The requirement should be permanent for new wind farms, whereas it should be for old wind farms after e.g. a sliding reduction of the requirements to prevent wind farms from getting excessive maintenance costs towards the end of their operational phase. This could also include the reduction of height for met masts from hub height to 30-35m agl (above ground level). In summary, the following recommendations were given:

1. Met Mast Alternatives

- a) Correctly calibrated and computed nacelle sourced wind speed is an accepted source of met data
- b) Lowering the met mast height requirement to a height of 30m agl. or greater. (a) Subfigure 1
- c) LiDARs will need to be able to comply to a delivery percentage of 98.5% in Ireland in order to be acceptable as alternatives to met masts
- d) LiDARs can be used as a calibration method according to IEC61400-12-1:2017 to proof correctness of met masts or nacelle sourced data signals
- e) New technologies (e.g. remote sensing LiDARs, SODARs, RADARs) should be allowed to apply as alternative measurement type or in combination with other instruments, but need to go through a real-time acceptance test of a minimum of 3 months in a windy period

2. Met data quality

- a) met mast sourced wind speed signals are required to be provided from multiple cup anemometers at 3 different heights above ground level
- b) Accurate met data should be provided by wind farms 98.5% of the time (see section 4.4 in [4])

- c) Continuous quality assessment of met data should be part of the forecasting system
- d) Accurate high-speed shutdown (HSSD) signal provision should be a requirement with validation by forecasters
- e) Incorporation of announcements by wind farms on full and partial scheduled and non-scheduled outages should be entered into the IT system
- f) Provision of accurate available active power capability should be provided by all wind farms subject to dispatch instructions

6.1 Implementation of Recommendations

EirGrid has begun the process of implementing the recommendations from this study. We are engaging with the Irish Wind Energy Association (IWEA) regarding the relevant updates to the WFPS Meteorological Signals Provision Document [7] and the grid code [3].

The meteorological signals are also being assessed on an ongoing basis (every three months). Any wind farms that are providing signals that are found to be of poor quality during this period will be notified by the TSO and asked to investigate and fix any underlying issues. As previously discussed, it is in both the TSO and wind farm owners' best interest to ensure that these signals are of high quality as it will ultimately result in a more efficient dispatching schedule, hence, less dispatch down for the wind farms.

The first pilot programme for the real-time operation of a LiDAR is also in the process of being tested with results expected in early 2021. The meteorological signals from the LiDAR will be monitored over a three-month period, and if the quality and reliability of the signals meet our criteria, then the LiDAR being tested will be an acceptable source of meteorological data. This pilot programme will allow the TSO to put in place a framework for assessing the use of alternative technologies in the future, if requested by a wind farm.

7 References

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