Games and other news from IEA Wind Task 36 Forecasting for Wind Energy

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***Abstract*— The International Energy Agency (IEA) Wind Task 36 on Forecasting for Wind Energy organises international collaboration, among national weather centres with an interest and/or large projects on wind forecast improvements (NOAA, DWD, ...), forecast vendors and forecast users to facilitate scientific exchange to be prepared for future challenges.**

The talk discusses the general setup of the Task, and the latest developments. Among those are decision making under uncertainty. To this aim, actual forecasting situations were gamified and was tested by a wide audience. During the game, the participants could experience the benefit of probabilistic information on their decisions to trade.

A major effort of the Task is the IEA Recommended Practice for Forecast Solution Selection which is divided into 3 parts: (1) "Forecast Solution Selection Process", (2) "Designing and Executing Forecasting Benchmarks and Trials", and (3) "Evaluation of Forecasts and Forecast Solutions". The group initially identified three key contributing factors for failing to get the optimal value from the forecasts: (1) the specification of the wrong forecast performance objectives in the forecast solution selection process, (2) the use of poorly designed benchmarks or trials to select a forecast solution for a user's application and (3) the use of non-optimal evaluation metrics to assess the performance of candidates or existing forecast solutions. For this year, we intend to update the guideline in the light of the experiences throughout the industry in its initial application, and after collecting this experience at 3 Open Space workshops. A fourth part will be added, extending the guideline to Measurements for Real-time Forecasting Applications.

Another current activity of the task is the Numerical Weather Prediction (NWP) benchmark. NWP model providers have been asked to run two well-measured sites. One is from the Wind Forecast Improvement Project 2 and represents a difficult case of mountain waves in the US, the other one is based on a week of data from an offshore wind farm in the Baltic. A common validation framework was developed for that case and is available from Github.

Finally, we submitted a paper on the uncertainty propagation throughout the entire modelling chain, where we investigated the part of the uncertainty that is coming from the model, that of the model inputs, and the part that is weather related. The analysis is done separately for the planning phase, operational phase and market phase of the plant and forecast system.

Keywords—wind power forecast, wind power prediction, IEA, forecast selection, probabilistic forecast

I. Introduction

In general, short-term prediction of wind power on a time scale of minutes to weeks is done using online data from the wind farms to be predicted, and meteorological forecasts.

The International Energy Agency's Technological Collaboration Programme Wind (IEA TCP Wind) Task 36 Forecasting for Wind Energy brings together academia, meteorological institutes, forecast vendors and end users to improve both the quality of the forecasts and the use of the forecast information.

The flow of data in a typical wind power forecasting context is shown in figure 1. For forecasts in the minute to a few hours range, the timely online input is paramount. For forecasts further than that, Numerical Weather Prediction (NWP) is needed. For some uses, additional measured weather data can improve the forecasts. See e.g. the new Technical Report from the IEC [2], which was also created using strong input from IEA Wind Task 36.

The three work packages (WP) of Task 36 were aligned to the forecasting steps outlined above and in Figure 1. WP1 deals with global coordination in the improvement of the attributes of NWP models that are most important for wind power prediction and therefore the meteorological aspects of the forecasts. WP2 focuses on the conversion of meteorological variables to power output, the benchmarking of forecast performance as well as the interaction between forecast vendors and users in the selection of the best forecast solution for a specific application. WP3 addresses the use of probabilistic forecasts and optimal end use of forecasts, including research into decision making under uncertainty using forecasting games.

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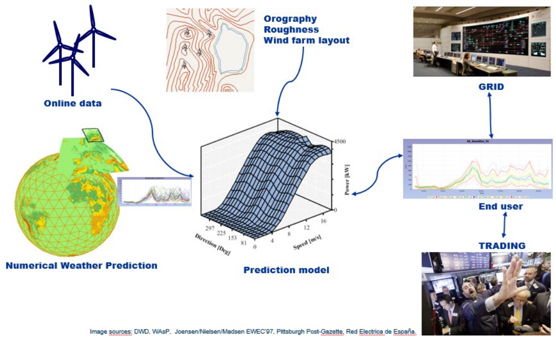

Figure 1: The general data flow in a short-term forecasting model. [1]

II. WP1: Global Coordination in Forecast Model Improvement – Meteorological Aspects of Wind Energy Forecasts

There are two distinct needs for validation of the NWP models used for wind power forecasting. The first is applicable primarily to operational models, for which ongoing validation requires real-time data. The second is applicable to the developmental environment for updated versions of these models prior to the updates becoming operational.

These needs were addressed in WP1 by:

- Compiling a list of available sources of real-time data, especially from tall towers;
- Reporting annually on field measurement programs that could support NWP validation; and
- Organizing meetings and a special session at international conferences on wind energy.

Validation of operational models requires real-time data because resources generally do not permit preserving full output for extended periods or re-running the models when data from field campaigns eventually becomes available. Ideally, real-time observations of the wind at turbine heights would be reported to weather services to allow continuous monitoring and validation of NWP forecasts. In practice, very little data is provided. Thus, to more broadly facilitate the validation of NWP model forecasts of wind at typical turbine heights (~ 100 m) a catalog of tall masts with wind measurements was created. The catalog was not limited exclusively to masts providing real-time data, but most masts in the catalog are producing data available in real time. An additional benefit of identifying sources of real-time hub-height data is their application for improving initial conditions. While this requires careful monitoring of data quality, recent research [3] has shown the benefit of improved initial conditions for wind forecast accuracy.

Organizations running NWP models operationally are generally also engaged in the development of updated versions of these models, in which the representation of physical processes, the application of numerical methods and data assimilation techniques are improved. Prior to becoming operational, these new versions also need to be validated. In many cases field campaigns are designed to provide validation data to researchers to illuminate specific physical processes, and for these purposes the effective measurement of key processes is more important than real-time availability. Because of the cost of field campaigns, it is important for the NWP model development community to be aware of and thus able to take advantage of existing data sets. An additional component of WP1, therefore, was to annually update a list of significant field campaigns that could support development and validation of improved NWP models. During Phase I of Task 36, there were two such campaigns: the Second Wind Forecast Improvement Project (WFIP2) in the U.S. and the New European Wind Atlas (NEWA) sequence of several field studies in Europe.

We designed a benchmark exercise to provide an opportunity for stakeholders to evaluate the performance of different configurations of numerical models at both intra- and inter-organizational levels. This exercise also serves as a platform for stakeholders to share and compare wind forecast evaluation metrics between organizations. The primary goal of this benchmark exercise is to demonstrate the importance of reproducible, metrics-based model assessments, which should be part of every organization's validation strategy. Setting up a rigorous validation framework also aligns with the verification and validation framework proposed in the Second Wind Forecast Improvement Project (WFIP2) as well as the IEA Wind task 36 Recommended Practice for Forecasting Solution Selection [18]. After the collection of data from the participants, we anonymously evaluate the submitted data using an open-source, Python-based validation tool, which is also publicly available at https://github.com/joejoeyjoseph/i-validate. In the data analysis, we will use statistics such as root-mean-square error and mean absolute error, as well as more sophisticated skill scores for wind ramp events. We hope that the validation tool will become a consistent reference forecast evaluation framework for the wind energy community.

A third objective of this task was to facilitate communication regarding NWP model improvement for wind power forecasting among the various international groups engaged in this area. Several informal meetings and discussions occurred around international conferences such as ICEM (International Conference on Energy Meteorology) and WESC (Wind Energy Science Conference). To this aim, we had a special session at ICEM 2019, and a mini-symposium at WESC in 2021, where we used the opportunity to introduce our work to the community and get the community's input and feedback.

III. WP2: Benchmarking, Predictability, and Model Uncertainty – Power Conversion and Forecast Vendor Aspects

The main outcome of WP2 in the first phase of the Task (running from 2016-2018) was the publication of an IEA Recommended Practices for Selecting Renewable Power Forecasting Solutions subsequently referred to as "RP". The document is split into three parts. The first part "Forecast Solution Selection Process" deals with the selection and background information necessary to collect and evaluate when developing or renewing a renewable energy forecasting solution. The second part "Benchmarks and Trials" addresses the set up and execution of benchmarks and trials that optimally assess alternative forecasting solutions for relative performance and the fit-for-purpose. The third part "Forecast Evaluation" provides information and guidelines regarding effective evaluation of forecasts and forecast solutions. Another paper at WIW21 provides an overview of the first version of the RP, and the feedback that has been received and resulting plans for an update at the end of 2021. Additionally, a part 4 is added on the real-time use of meteorological measurements as opposed to the more traditional use for resource assessment, their potential benefits, and the requirements to the measurement quality and transmission speed [4].

An important new addition to the RP is a section on data definitions and an exchange standard between forecast providers and consumers using the most commonly used formats in renewable energy forecasting. One of the goals here is to have an independently generated online source of definitions and examples that can be accessed by the ever growing forecast consumer base (both large and small). The end result is that more widespread adoption of these recommendations (along with the existing RP for Forecast Solution Selection) will benefit consumers by being able to more quickly onboard or test different forecast providers. For the forecast provider, the main benefit is less time spent on custom software development, thus shifting focus to improving forecast accuracy. An overview of this effort was also presented on the previous workshop [5].

Finally, a list of freely available data sets was published in the task's homepage that are well suited for research and development of wind power forecasting models.

IV. WP3: Use of Probabilistic Forecasts - Optimal End Use of Forecasts

WP 3 targets the use of probabilistic forecasting, which provide a forecast user with an estimate of the uncertainty of a forecast as well as predictions of the future value of the target variable of interest (e.g. wind power production). Uncertainty forecasts fill a gap of information in deterministic approaches and are gradually moving into the control rooms and trading floors. Nevertheless, there are a number of barriers in the industrial adaptation of uncertainty forecasts that have their root in a lack of understanding of the methodologies and their respective applicability. There is a barrier associated with the greater complexity of information in probabilistic forecasts that needs to be overcome in order for industry to move forward.

In the first phase of this task, we addressed the gap between available products on the market and the lack of knowledge and documentation in how to apply, derive decisions and make efficient use of probabilistic forecast information by end-users. The effectiveness of forecasts in reducing the cost of managing the variability of power generation from wind and solar plants is largely dependent upon the ability to effectively choose and use the most relevant forecast information in the grid management decision-making process. This process is becoming more complex with higher penetration levels and the possibilities to engage large amounts of information to generate forecasts.

Understanding the benefits and the pitfalls of employing probabilistic forecasts requires objective documentation that is scientifically sound, practical and understandable for the industry. For this reason, WP3 is dedicated to translating academic knowledge into industry applications to increase this acceptance and provide objective information about existing methods to deal with uncertainty. This includes the three W's ("what, when and which") regarding methods to be applied to typical or specific challenges and to publish freely accessible objective information for the industry and interested individuals through the Task 36 website (ieawindforecasting.dk) and open access publications.

A schema of high-level methodologies that are available today as industry standards was presented in a review article [6].

A. Review on Uncertainty Quantification

A group of Task 36 experts wrote a review detailing out a qualitative overview of sources of uncertainty in forecasts and their propagation through the modelling chain [7]. In the review, forecast errors and associated uncertainties which propagate through the forecast modelling chain have been described and analysed. The review's objective was shed light into the forecasting uncertainties that need to be dealt with on a daily basis and that may even increase as climate change effects are getting more extreme and penetration levels increase. It was found that some of these uncertainties cannot be eliminated, but forecasted and hence mitigation strategies applied and developed. The uncertainty quantification in the review spans from the planning phase through the operation phase of wind projects, where also non-weather related uncertainties in the park control and maintenance schedules are reviewed. Uncertainties specific to the market phase of projects, when the generated electricity is traded on a power exchange, are also reviewed. The quantified uncertainties are not limited to weather related uncertainties, but also technical and computational aspects that add to the uncertainty of the forecasted output are discussed and mitigation strategies suggested. The review provides the basis for further work and developments to close the gap from knowledge and recognition of uncertainties in the modelling chain to the use of uncertainty forecasts in the end-users' applications.

In the summary and analysis of recent trends the review suggests to look upon forecast uncertainties in a more holistic way and to further encourage interdisciplinary work groups that together can pave the way to "integrated forecasting" methodologies and strategies in the future.

B. Enhanced understanding of probabilistic forecasts through gamification

Another effort to close the gap between knowledge of uncertainties in forecasting and end-user applications is the IEA Wind Task 36 "Probabilistic Forecasting Games and Experiments" initiative in collaboration with the Max-Planck Institute (MPI) of Human Resources in Berlin. Here a group of task experts together with the MPI psychologist investigate the existing industry barriers that inhibit adoption of forecast uncertainty information into decision-making processes.

In the first part of the initiative, a forecast game was designed as a demonstration of a typical decision-making task in the power industry. The game was introduced in an IEA Wind Task 36 workshop in Glasgow in January 2020 and thereafter released to the public. The initial version of the game was based on 12 cases in which the participants were presented with a wind power forecast and a wind speed forecast and had to make a dichotomous trading decision on whether to trade 100% or 50% of the expected power generation according to a cost-loss function and taking into consideration a possible high-speed shutdown of the wind farm. Two decisions had to be made: (1) a trading decision with information from deterministic forecasts of power production and wind speed and (2) a decision whether or not to change the decision when being presented probabilistic forecasts from an ensemble forecasting system.

The game was open for the public to play for 6 months and had been played by 106 participants when it was closed to perform the final analysis of the results. The overall outcome of the game experiment indicated that the additional information from the probabilistic forecasts resulted in a slightly higher income for most participants, more correct decisions and less risky decisions. The results also indicated that participants changed their mind after they were presented with the probabilistic forecasts in 18% of all decisions and that 91% of participants changed their mind at least once. The higher income in this case cannot be considered significant, however, it suggests that a positive effect on the income is a reasonable expectation. The fact that more correct decisions were made needs to be investigated in more detail, as this is an important factor for the application of uncertainty forecasts and the adoption in the industry. The increase in less risky decisions indicates that the additional information generates more risk-averse behaviour on the one hand, but also suggests that not having uncertainty information may lead to risky decisions that may be unwanted – in psychology called "over-confidence". The first experiment has revealed a number of interesting aspects for the decision making in the context of extreme events, but also the use of probabilistic forecasts in the power industry in general. More details of the first experiment can be found in [11] and following open access publication which is in the submission stage.

The second experiment, which will be introduced at the European Meteorological Society's annual meeting 2021 [13] and made available in September 2021 for the public is an enhanced experiment that builds upon the first setup, but with a different decision structure, a larger sample of cases, a different environment and the possibility to play multiple times linked to a unique ID. Here, the decisions are to be made for a wind farm in complex terrain. The decision type will be similar to the first experiment, i.e. trading of 50% or 100% depending on, whether there is an expectation of a partial high-speed shutdown at the wind farm or not. This time the participants are provided with deterministic forecast for all cases first and thereafter with the same, but randomly shuffled set of probabilistic cases. Additionally, the confidence level of each decision is requested from the participants. The idea here is to also learn about the strategies participants have or develop under way, prior or after an introduction/lecture on the forecasting methods used in the experiment and it can be analysed whether the type of forecast (deterministic versus probabilistic) provides more or less confidence to the participants when taking their decision. The cases are selected from a real-time environment, where the participants may also be surprised by the outcome of some cases due to forecasts that fail to warn or over-predict. Psychologically, these type of cases are interesting for the study on human reaction to failure and whether certain information can help reduce the negative effect of emotions after failures and enhance confidence in the decision making progress.

V. Other Results

We communicated the major results in the form of webinars on the IEA Wind Forecasting YouTube channel, where all public workshops conducted and sponsored by Task 36 can be seen in their entirety [8]. For a quick overview, the Task itself, the RP and the probabilistic end use, there are handouts available at our website.

To disseminate the main findings of phase 2 of the Task there will be carried out a series of 4 webinars throughout November. The detailed announcements will be on the Task's website and will circulate through the Task's mailing list and social media (e.g. LinkedIn).

VI. The Next Phase

The framework conditions have changed significantly since 2016, when IEA Wind Task 36 Forecasting for Wind Energy started. Already then, most of the vendors used their knowledge to provide both wind and solar power forecasts, as many of their clients had both technologies in their portfolio. The just released IPCC report on the physical science basis makes it very clear that humans are the main contributor to the rapid climate change we experience in recent years [16]. One of the solutions to prevent if not climate change itself, but at least the more drastic variants, is to steer society to a carbon free course, which with current technology means a many-fold increase in renewable generation. Since the generation is variable with the "fuel", i.e. wind and solar radiation, the entire system has to be flexible to adapt to these changes. Therefore, the next phase of the Task will be under the heading of Forecasting for the Weather Driven Energy System. This will entail stronger collaboration with especially IEA PV Task 16 on the solar resource, which also is responsible for forecasting, but possibly also with tasks in other IEA TCPs like hydropower, biomass or Smart Grids.

VII. Conclusions

IEA Wind Task 36 is the largest collaboration for wind power forecasting, connecting more than 300 people from weather prediction, forecast vendors, end users and academia. The Task helps to discuss common interests, improve the methods, and aids the value creation at end users. For collaboration, please contact the Operating Agent (grgi@dtu.dk).

Acknowledgment

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