IEA Wind Task 36 – An Overview

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***Abstract*— Wind power forecasts have been operationally used for over 25 years. Despite this fact, there are still many possibilities to improve and enhance forecasts, both from the weather prediction side and in the use of the forecasts. Until now, most applications have focused on deterministic forecast methods. This is likely to change in the future as penetration levels increase and weather conditions become more unstable due to climate change. Probabilistic methods are therefore receiving more attention from users. The International Energy Agency (IEA) Wind Task 36 on Wind Power Forecasting organises international collaboration, among national weather centres with an interest and/or large projects on wind forecast improvements (NOAA, DWD, UK MetOffice, ...), forecast vendors and forecast users to facilitate scientific exchange to be prepared for future challenges.**

Collaboration is open to IEA Wind member states; 12 countries are already actively collaborating. The Task is divided in three work packages: Work Package (WP) 1 is a collaboration on the improvement of the scientific basis for the wind predictions themselves. This includes numerical weather prediction (NWP) model physics, but also widely distributed information on accessible datasets. This WP will also organise benchmarks for NWP models. The efforts of WP2 resulted in the publication of an international pre-standard (an IEA Recommended Practice) on how to select an optimal wind power forecast solution for a specific application. The focus of WP3 is on the engagement of end users to disseminate the best practice in the use of wind power predictions, especially probabilistic forecasts.

The paper presents an overview of the recently completed first phase and the ongoing second phase of IEA Task 36 on Wind Power Forecasting, which provides a forum for international collaboration in this important field for meteorologists, wind power forecasters and end users. For collaboration, please contact the author (grgi@dtu.dk) and see the website at www.ieawindforecasting.dk.

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 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 [1].

The flow of data in a typical wind power forecasting context is shown in figure 1. The online power (and possibly other) data from the wind farms is the starting point for both some version of time series analysis prediction for the first hours, and the (typically recursive) tuning of the power conversion step. For any forecast beyond a look-ahead period of a few hours, the use of Numerical Weather Prediction (NWP) is paramount. The NWP data is available as a deterministic forecast (just one realization of the forecast) or an ensemble of forecasts (multiple realizations of forecasts). In ensemble forecasts, initial conditions, the model physics, or boundary conditions of limited area models are varied, so that the variation in outcome reflects the uncertainty of the forecasts.

In some cases, high-resolution modelling of the wind farm surroundings is employed. The resulting forecasts of wind speed and direction are then converted to power, typically by a wind farm power curve depending on NWP wind speed and direction. The results are then transferred to the end users, and used in trading, power grid management or O&M (see e.g. this still comprehensive report [2] or the new Technical Report from the IEC [3], 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.

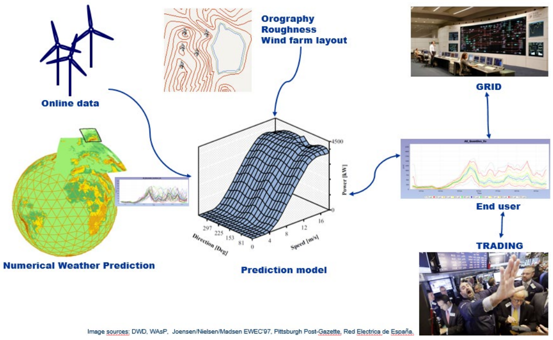

Figure 1: The general data flow in a short-term forecasting model.

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 [4] 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.

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 an invite to a mini-symposium at WESC in 2021.

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

The main outcome of WP2 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 WIW20 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 [5].

Another effort of WP2 is the catalog and analysis of existing standards for data exchange for forecasting products, and the way forward to define a solution for data transfer for both large and small users. An overview of this effort is also presented in a separate paper at WIW20 [6].

Finally, a list of freely available data sets was published 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.

A peer reviewed journal published in the open access journal, Energies [7] in 2017, 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.

One of the gaps of understanding uncertainty in the power industry is the definition of uncertainty and the methodologies that provide forecast uncertainty information. An analysis of forecast user interviews conducted in 2016 indicated that many users had difficulties distinguishing among some of the main characteristics of uncertainty forecasting:

(1) forecast error spread
(2) confidence interval
(3) forecast uncertainty
(4) forecast interval

One of the objectives was therefore to define and document these characteristics for the industry. This definition was described in a paper presented at the 2017 Wind Integration Workshop [8].

A schema of high-level methodologies that are available today as industry standards was presented in a review article [7].

V. Other results

We communicated the major results in the form of webinars on the IEA Wind Forecasting YouTube channel, where the public workshops sponsored by Task 36 can also be seen in their entirety [9]. For a quick overview, the Task itself, the RP and the probabilistic end use were condensed to a handout onto two A4 pages, which are available from our website.

VI. Currently underway

Besides the already finished works, there are several current activities where your help and input would be appreciated:

A. *Online verification and benchmarking of current NWP models with met mast data*

Recently, a number of dedicated datasets from meteorological campaigns became available for model improvement, especially in the US Wind Forecast Improvement Project in Complex Terrain (WFIP2). We aim at defining and running a benchmark for meteorological models for wind power forecasting. We will use a formal Validation and Verification (V&V) framework, which is already used in the US Atmosphere2Electrons research programme. For more details, please refer to the Task homepage or the paper at this conference [10].

B. *Detailed review of uncertainty propagation through the modeling chain.*

The preparation of state-of-the-art wind power forecasts is based on chains of several models to get to the final outcome. A project is underway to perform a literature overview that will attempt to quantify the propagation of uncertainty through the components of the modelling chain, from the numerical weather prediction inputs and the data uncertainties to the probabilistic forecasts. The aim is a position paper.

C. *Assessment of the value of probabilistic forecasts*

An important driver for improving forecast methodologies is the added value for the user. The value for different stakeholders (e.g. TSO, DSO, balancing authority, producer, traders etc.) will depend on the specific market design. A subtask of WP3 focuses on evaluating the value of probabilistic forecasts, and ways to increase the value by appropriately applying probabilistic information in different market structures. The value will be assessed by developing a market and forecast simulation that uses input from realised and forecasted wind generation and market prices.

D. *Development of an IEA Recommended Practice for the requirements of data and instrumentation for real-time forecasting*

State of the art wind power forecasting methodologies utilise, besides forecasted meteorological data from weather models, onsite real-time power measurements from SCADA systems and meteorological measurements from met masts or alternative remote sensing devices to compute wind power. The use of information about the measured and forecasted trends of meteorological variables is primary basis for state-of-the-art wind power predictions as well as high speed shut-down and critical ramping events, for the next few hours. This is the basis for the need for high quality measurements, even though similar considerations are applicable in the management of dispatch. Today, there are no standards or guidelines on the quality requirements for instrumentation or on the type of instrumentation itself that would help system operators to develop their grid codes. A number of guidelines and standards provide recommendations for instrument, measurement and reporting for all main meteorological variables. However, only one of the guidelines deal with real-time usage and this is only for meteorological modelling. These guidelines and practices are being analyzed by a task group together with system operators [11] and will be adjusted for the real-time usage in the power industry in order to develop recommended practices for the real-time environment of system operators and utilities.

E. *Enhanced understanding of probabilistic forecasts through gamification*

As the penetration levels of RES increase together with an increasing frequency of extreme weather conditions associated with the changing climate, the weather-related uncertainty in power production forecasts can no longer be ignored for the grid operation.

In order to support the power industry in the adoption of uncertainty forecasts in their business practices, the IEA Wind Task 36 has started an initiative in collaboration with the Max-Planck Institute of Human Resources to 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 16 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 shut-down 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 had been played by 129 participants, as of the time it was closed to perform the 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 choice of forecast type. 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 that sense, the 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 [12].

The next step is an enhanced experiment that builds upon the first setup, but with a different decision structure and a larger sample of cases.

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

All Danish contributors thank EUDP for funding from project 64018-0515.

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