INTERNATIONAL ENERGY AGENCY

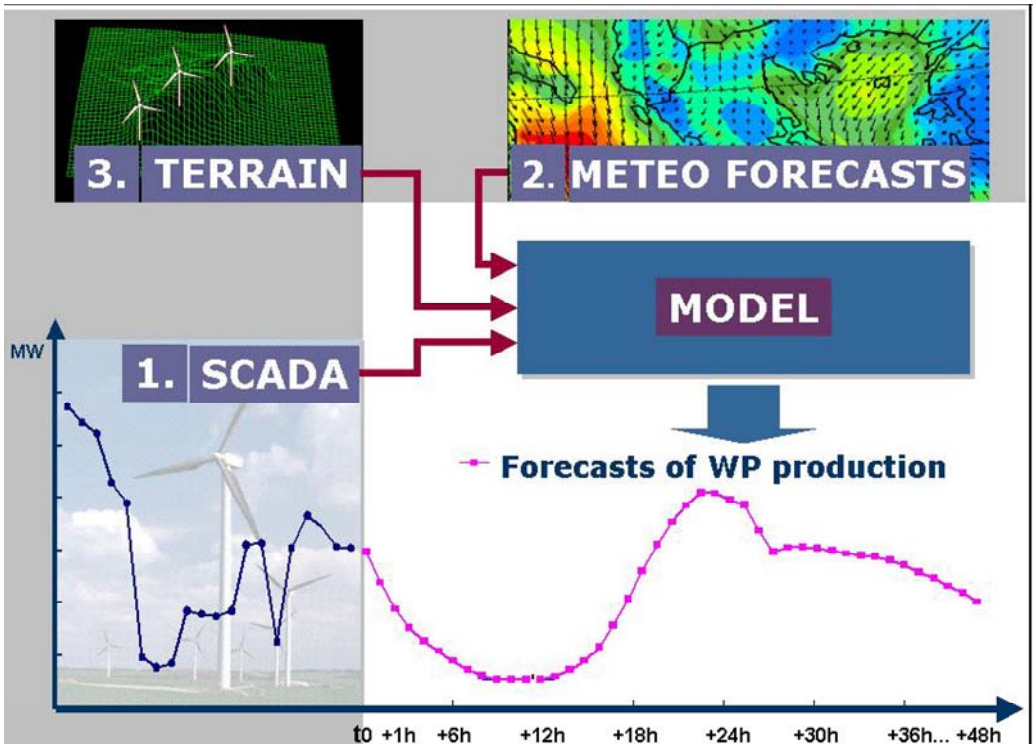
Implementing Agreement for Co-operation in the Research, Development and Deployment of Wind Turbine Systems
Task 11

IEA R&D Wind Task 11 - Topical Expert Meeting

"Forecasting Techniques"

Federation of the Scientific and Technical Associations (FAST Center), Milan, Italy

23th and 24th April 2013



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Milan, Italy.

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International Energy Agency

Implement Agreement for Co-operation in the Research, Development and Deployment of Wind Turbine Systems: IEA Wind

The IEA international collaboration on energy technology and RD&D is organized under the legal structure of Implementing Agreements, in which Governments, or their delegated agents, participate as Contracting Parties and undertake Tasks identified in specific Annexes.

The IEA's Wind Implementing Agreement began in 1977, and is now called the Implementing Agreement for Co-operation in the Research, Development, and Deployment of Wind Energy Systems (IEA Wind). At present, 24 contracting parties from 20 countries, the European Commission, and the European Wind Energy Association (EWEA) participate in IEA Wind. Australia, Austria, Canada, Denmark, the European Commission, EWEA, Finland, Germany, Greece, Ireland, Italy (two contracting parties), Japan, the Republic of Korea, Mexico, the Netherlands, Norway (two contracting parties), Portugal, Spain, Sweden, Switzerland, and the United States are now members.

The development and maturing of wind energy technology over the past 30 years has been facilitated through vigorous national programs of research, development, demonstration, and financial incentives. In this process, IEA Wind has played a role by providing a flexible framework for cost-effective joint research projects and information exchange.

The mission of the IEA Wind Agreement continues to be to encourage and support the technological development and global deployment of wind energy technology. To do this, the contracting parties exchange information on their continuing and planned activities and participate in IEA Wind Tasks regarding cooperative research, development, and demonstration of wind systems.

Task 11 of the IEA Wind Agreement, Base Technology Information Exchange, has the objective to promote and disseminate knowledge through cooperative activities and information exchange on R&D topics of common interest to the Task members. These cooperative activities have been part of the Wind Implementing Agreement since 1978.

Task 11 is an important instrument of IEA Wind. It can react flexibly on new technical and scientific developments and information needs. It brings the latest knowledge to wind energy players in the member countries and collects information and recommendations for the work of the IEA Wind Agreement. Task 11 is also an important catalyst for starting new tasks within IEA Wind.

IEA Wind TASK 11: BASE TECHNOLOGY INFORMATION EXCHANGE

The objective of this Task is to promote disseminating knowledge through cooperative activities and information exchange on R&D topics of common interest. Four meetings on different topics are arranged every year, gathering active researchers and experts. These cooperative activities have been part of the Agreement since 1978.

Two Subtasks

The task includes two subtasks.

The objective of the first subtask is to develop recommended practices (RP) for wind turbine testing and evaluation for each topic needing recommended practices. In June 2011 was edited the RP on "Consumer Label for Small Wind Turbines". A new RP about "Performance and Load Conditions of Wind Turbines in Cold Climates" is expected to be edited this year.

The objective of the second subtask is to conduct topical expert meetings in research areas identified by the IEA R&D Wind Executive Committee. The Executive Committee designates topics in research areas of current interest, which requires an exchange of information. So far, Topical Expert Meetings are arranged four times a year.

Documentation

Since these activities were initiated in 1978, more than 68 volumes of proceedings have been published. In the series of Recommended Practices 11 documents were published and five of these have revised editions.

All documents produced under Task 11 and published by the Operating Agent are available to citizens of member countries participating in this Task.

Operating Agent

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COUNTRY	**INSTITUTION**
Denmark	Danish Technical University (DTU) - Risø National Laboratory
Republic of China	Chinese Wind Energy Association (CWEA)
European Commission	European Commission
Finland	Technical Research Centre of Finland - VTT Energy
Germany	Bundesministerium für Unwelt , Naturschutz und Reaktorsicherheit -BMU
Ireland	Sustainable Energy Ireland - SEI
Italy	Ricerca sul sistema energetico, (RSE S.p.A.)
Japan	National Institute of Advanced Industrial Science and Technology AIST
Republic of Korea	POHANG University of Science and Technology - POSTECH
Mexico	Instituto de Investigaciones Electricas - IEE
Netherlands	SenterNovem
Norway	The Norwegian Water Resources and Energy Directorate - NVE
Spain	Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas CIEMAT
Sweden	Energimyndigheten
Switzerland	Swiss Federal Office of Energy - SFOE
United Kingdom	The National Renewable Energy Centre (NAREC)
United States	The U.S Department of Energy -DOE

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CONTENTS

SUMMARY

1. INTRODUCTORY NOTE

Background

Wind installations are growing very fast in Europe and also in other countries such as U.S. and China. One of the most important issue is the integration into the electrical grid, that, in general, has been developed for gathering more stable regimes of electricity production. The higher is the percentage of wind power in the energy mix, the more important is the prediction of its variability. The problem of grid integration has become more important in recent years because of the concentration of large wind farms onland and, moreover, offshore, where the production is higher and the grid is still in the development stage.

Even if wind power forecasting is a well-developed research field, many studies are still on-going to improve its contribution to easing large-scale integration of wind energy into the power systems: furthermore, in many countries, the producers that can deliver better wind power forecasts (especially for the forecast horizon up to 48 hours ahead) can get more favourable prices when trading energy in the electricity markets.

Forecasting products available today are very diverse, with the forecasting methods following a number of different approaches. Such approaches permit the generation of wind power forecasts dedicated to the specific wind farm environment. For example some methods have been specifically developed for complex terrain conditions and the resulting complex wind fields, while others are more relevant for offshore conditions where the focus is more on wind profiles and wakes depending upon thermal stratification.

By now, a lot more information can be used as an input to improve forecasting methods compared to the past. The current modelling approaches allow obtaining a wealth of meteorological parameters regarding a site of interest; in parallel, it is common to have detailed information about wind farm layouts and topography, local wind conditions and measured wind and power data to be used in the forecasting processes.

It is crucial to make optimal use of the wealth of information available in this context, which may mean:

- the optimal selection of input variables for forecasting methods,
- the development of effective statistical techniques to appropriately post-process the forecasted variables and to carry out the power predictions,
- the combination of input information, or alternatively the combination of alternative wind power forecasts based on different input information and eventually the combination of ensemble prediction members,
- the use of alternative models for some weather regime classification (eventually with models dedicated to extreme conditions), or with statistical regime-switching approaches,
- the use of spatially distributed information for improving the accuracy of power forecasts at wind farm or larger level,
- the resolution increase of probabilistic forecasts by further characterization of weather-induced forecast uncertainty.

Aim of meeting

The aim of this Workshop is to gather a group of experts in the field of forecasting with interest in exchanging their expertise regarding optimal use of information in wind power forecasting.

Expected Outcomes

One of the goals of the meeting is to gather the existing knowledge on the subject and come up with suggestions/recommendations on how to proceed. This will involve the definition of necessary research activities for "Recommendations" to the IEA Wind Agreement and the governments involved.

Agenda

Tuesday 23th April

>09:00 **Registration**. Collection of presentations

>09:30 **Introduction by Host**

Laura Serri, RSE SpA - Power Generation System Department

>09:45 **Recognition of Participants**

>10:00 **Introduction by Task 11 Operating Agent.**

Felix Avia, Operating Agent Task 11 IEAWind R&D

>10:15 **Forecasting Techniques: State of the Art**

Dr Stefano Alessandrini, RSE Spa, Italy

●*10:40 Coffee Break)*

1st Session Individual Presentations:

>11:00 **A System's Approach to Wind Power Forecasting**

Dr Sue Ellen Haupt, NCAR -National Center for Atmospheric Research, USA

>11:30 **An hybrid neural network and CFD based method for Wind energy production forecast in complex terrains.**

Prof. Francesco Castellani, Dott. Emanuele Piccioni, University of Perugia, Italy

>12:00 **Wind power forecasting accuracy and uncertainty in Finland**

Jari Miettinen, VTT Technical Research Centre of Finland, Finland

>12:30 **Probabilistic power predictions and uncertainty quantification with an analog ensemble**

Dr Luca Delle Monache, NCAR -National Center for Atmospheric Research, USA

●*13:00 Lunch*

2nd Session Individual Presentations:

>14:00 **Overview of model improvements and results from the Wind Forecasting Improvement Project**

Dr. Kirsten Orwig, NREL -National Renewable Energy Laboratory, USA

>14:30 **A Belt and Brace Approach to Offshore Wind Energy Resource Estimation. Part I**

Dr. Aoife M Foley, Queen's University Belfast, United Kingdom

>15:00 **A Belt and Brace Approach to Offshore Wind Energy Resource Estimation & Forecasting. Part II: Atmospheric Stability and Vertical Wind Profiles Offshore**

Dr. P.G Leahy, University College Cork, Ireland

●15:30 Coffee Break

>16:00 **Analysis of the Performance of Short-term Wind Ramp Forecasts Produced by an Ensemble of Advanced Rapid Update Atmospheric Modeling Systems in the Wind Forecast Improvement Project (WFIP).**

Dr. John W. Zack, AWS Truepower, USA

>16:30 **Simultaneous improvement of weather and power forecasts for the grid integration of renewable energies**
Dr. Malte Siefert, Fraunhofer IWES, Germany
Dr. Kristina Lundgren, DWD (Deutscher Wetterdienst), Germany

●17:00 End of the Tuesday meeting

●19:00 - 20:30 Walking guided tour to see the monuments of Milan (starting from meeting center and ending at the restaurant).

●20:30 Informal dinner at the restaurant "Al Mercante", Piazza Mercanti, 17 very close to the central Duomo Square (15 min walking from the meeting center and easy to be reached)

Wednesday 28th November

3rd Session Individual Presentations

>09:00 **Simultaneous improvement of weather and power forecasts for the grid integration of renewable energies**
Dr. Malte Siefert, Fraunhofer IWES, Germany
Dr. Kristina Lundgren, DWD (Deutscher Wetterdienst), Germany

>09:30 **The GSE activities in managing the VRES production forecast**
Mr. Luca Colasanti, GSE S.p.A. - Gestor dei Servizi Energeitici, Italy
Mr. Gennaro Niglio, GSE S.p.A. - Gestor dei Servizi Energeitici, Italy

>10:00 **CFD simulation of wind farm flow field and wind turbine wake**
Dr. XD Zhang, North China Electric Power University, China

●11:00 Coffe Break

>11:30 **Forecasting icing conditions at a Swedish wind farm**
Mr. Andrea N. Hahmann, DTU Wind Energy, Denmark

>12:30 **Discussion**

●13:00 Lunch

>14:00 **Discussion (Cont)**

>14:45 **Summary of Meeting**

>15:00 **End of the meeting**

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DR. P.G LEAHY

Summary of IEA Wind – 72nd Topical Expert Meeting: "FORECASTING TECHNIQUES"

Laura Frías and Félix Avia, CENER

Dr Kristen Orwwig, NREL

a) Participants

The meeting took place on April 2013 in Milan, Italy and was attended by 234 participants from 10 countries (China, Denmark, Finland, Germany, Ireland, Italy, Norway, Spain, United Kingdom and USA). Table 1 lists the participants and their affiliations.

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Haupt	**Dr Sue Ellen**	National Center for Atmospheric Research	USA	haupt@ucar.edu
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Avia	**Félix**	Task 11 Operator Agent / CENER	Spain	favia@cener.com

Table 1 Participants in IEA Wind TEM on FORECASTING TECHNIQUES

Thirteen presentations were given:

1. **Forecasting Techniques: State of the Art**
Dr Stefano Alessandrini, RSE Spa, Italy

2. **A System's Approach to Wind Power Forecasting**
Dr Sue Ellen Haupt, National Center for Atmospheric Research, USA

3. An hybrid neural network and CFD based method for Wind energy production forecast in complex terrains.
Prof. Francesco Castellani, Dott. Emanuele Piccioni, University of Perugia, Italy

4. Wind power forecasting accuracy and uncertainty in Finland
Jari Miettinen, VTT Technical Research Centre of Finland, Finland

5. Probabilistic power predictions and uncertainty quantification with an analog ensemble
Dr Luca Delle Monache, National Center for Atmospheric Research, USA

6. Overview of model improvements and results from the Wind Forecasting Improvement Project
Dr. Kirsten Orwig, NREL -National Renewable Energy Laboratory, USA

7. Belt and Brace Approach to Offshore Wind Energy Resource Estimation & Forecasting. Part I
Dr. Aoife M Foley, Queen's University Belfast, United Kingdom

8. **Belt and Brace Approach to Offshore Wind Energy Resource Estimation & Forecasting. Part II: Atmospheric Stability and Vertical Wind Profiles Offshore**
Drs P.G Leahy, Kevin Coffey and Edward Mc Garrigle, School of Engineering, University College Cork, Ireland

9. Analysis of the Performance of Short-term Wind Ramp Forecasts Produced by an Ensemble of Advanced Rapid Update Atmospheric Modeling Systems in the Wind Forecast Improvement Project (WFIP).
Dr. John W. Zack, AWS Truepower, USA

10. Simultaneous improvement of weather and power forecasts for the grid integration of renewable energies
Dr. Malte Siefert, Fraunhofer IWES, Germany

Dr. Kristina Lundgren, DWD (Deutscher Wetterdienst), Germany

11. **The GSE activities in managing the RES production forecast**
Mr. Luca Colasanti, GSE S.p.A. - Gestor dei Servizi Energeitici, Italy
Mr. Gennaro Niglio, GSE S.p.A. - Gestor dei Servizi Energeitici, Italy

12. CFD simulation of wind farm flow field and wind turbine wake
Dr. Zhang Xiadong, North China Electric Power University, China

13. Forecasting Icing Conditions at a Swedish Wind Farm – or on the use of "intermediate" physical models
Mr. Andrea N. Hahmann, DTU Wind Energy, Denmark

b) Discussion

Following the two days of presentations a short discussion took place ontopics of general interest, which included:

- Probabilistic Forecasts -Application and evaluation
- Data Quality, Availability, and Assimilation
- Link to Market and Grid Reliability
- Extreme Events Forecasting

Forecast Probabilistic -Application and evaluation

Wind power forecasting is essential to large-scale integration of wind energy into power systems. However, a deterministic prediction, providing only single values at single points in time, lacks information about the error magnitude and distribution. Probabilistic forecasts address this problem by enabling the quantification of the uncertainty, in form of quantiles, probability distributions, scenarios and so forth. These kinds of forecasts are more useful for risk management, generator scheduling and dispatch and electrical markets. Joint to the probabilistic forecasts, the identification of standardized methodologies to evaluate forecast performance is needed. It is important to use a set of procedures or criteria to evaluate the quality of a probabilistic prediction. These methods should take into account how the stakeholders utilize the forecasts and each stakeholder's unique circumstances. For example, a power system operator will have different needs compared to a wind plant operator.

Data Quality, Availability, and Assimilation

The level of accuracy of the wind power forecasts is related to the observational data quality and availability. Real-time data availability enables forecasters to utilize the information to train their forecasts using sophisticated statistical post-processing methods, which improve the overall accuracy of the forecast. Forecasts can still be made without this data, but they tend to be less accurate and less reliable. Not only is the availability an important issue to obtain more accurate forecasts, but the quality of data is also critical. If poor quality data are used in the training models, the forecasts can be negatively impacted resulting in greater forecast errors. Therefore, quality data control is essential, and must take into account the data continuity, data availability, time frequency, wrong values, power limitation, etc. Additionally, the availability and quality of the data affects the forecast performance evaluation. If observational data is used to verify the forecast uncertainty in retrospect, but that data is of poor quality, then accurate benchmarking of the forecast cannot be adequately completed. Data assimilation into numerical weather prediction models is another area of interest. Improved data assimilation methods are needed, as well as more targeted observations to benefit numerical weather prediction of turbine-level winds.

Link to Market and Grid Reliability

It is impossible to optimize aggregate large-scale wind power without a suitably interconnected grid. The grid plays a crucial role in aggregating the various wind farm outputs installed at a variety of geographical locations. The larger the integrated grid the more pronounced this effect becomes. In order to make best use of this effect, the transmission system needs to be upgraded, the interconnection capacity should be increased, and the rules governing the power exchange between countries should be adapted to ensure that interconnectors are always available for physical flow. Additionally, the overall market structure has implications on integration of wind power, as well as the value of forecasting to optimize this integration. Hourly or real-time markets take advantage of the fact that wind power is relatively more predictable in this time period and the variability becomes much more manageable as a result. Finally, the full benefits of forecasting can only be realized if they are fully incorporated into energy management systems.

Extreme Events Forecasting

Due to the high penetration of wind energy in a large number of countries,the stability of electrical systems also depends on the prediction errors of extreme ramp events. These extreme events are defined as those generated by rapid and large increases of wind power due to large-scale weather systems, as well as the sudden decrease of wind generation due to plant cut-out, icing, or other conditions.These events can cause challenging power system operating conditions. Therefore, it is very important to predict and alert of upcoming extreme events as a complement to daily operational wind power predictions. The prediction of extreme events has to be given attention to ensure grid stability with high wind power penetration, and accurate forecasts of these situations is a critical task to avoid the problems that these events generate. The value of these extreme event, or ramp, forecast systems, though, is somewhat dependent on the overall flexibility of the power system itself. More flexible systems with a broad geographic distribution of wind plants may not be as affected by large wind ramps, as a less flexible system with less geographic distribution of wind plants.

c) Conclusions and Future Actions under the Umbrella of IEA Wind

The continuation of interchange of information between the participants was proposed for some of the participants. The majority of the participants decided that more development is required before a specific task covering the priorities selected could be lunched. However, after the meeting Kirsten Orwig, from the Transmission National Renewable Energy Laboratory has spoken with several of the attendees, and found that there is broad interest in establishing an IEA Task on Wind Power Forecasting to further international collaboration on R&D.