WIRE: Weather Intelligence for Renewable Energies

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Abstracts

Renewable energies such as wind and solar energy will play an important, even decisive role in order to mitigate and adapt to the projected dramatic consequences to our society and environment caused by climate change. Due to shrinking fossil resources, the transition to more and more renewable energy shares is unavoidable. But, as wind and solar energy are strongly dependent on highly variable weather processes, increased penetration rates will also lead to strong fluctuations in the electricity grid which need to be balanced. Therefore, it is today appropriate to scientifically address the requirements to provide the best possible specific weather information for forecasting the energy production of wind and solar power plants within the next minutes up to several days. Weather Intelligence in the sense of specific accurate forecasting of 'energy weather' is a key component for this.

Towards such aims, Weather Intelligence will first include developing dedicated post-processing algorithms coupled with weather prediction models and with past and/or online measurement data especially remote sensing observations. Second, it will contribute to investigate the difficult relationship between the highly intermittent weather dependent power production and concurrent capacities such as transport and distribution of this energy to the end users.

Selecting, resp. developing surface-based and satellite remote sensing techniques well adapted to supply relevant information to the specific post-processing algorithms for solar and wind energy production short-term forecasts is a major task with big potential. It will lead to improved energy forecasts and help to increase the efficiency of the renewable energy productions while contributing to improve the management and presumably the design of the energy grids in the future.

The second goal will raise new challenges as this will require first from the energy producers and distributors definitions of the requested input data and introduction of new technologies dedicated to the management of power plants and electricity grids and second from the meteorological community to deliver suitable, short term high quality forecasts to fulfill these requests with emphasis on highly variable weather conditions and spatially distributed energy productions often located in complex terrain.

This topic has been selected for a new COST[1] Action ES1002 under the title "Weather Intelligence for Renewable Energies" which has started November 2010 for a duration of 4 years.

1. Introduction

The world's economic and environmental development will presumably be deeply influenced by the effects of the forecasted climate change. The emissions of greenhouse gases will have to be reduced in order to keep the global temperature increase below 2°C and to avoid dramatic

[1] COST : European Cooperation in Science and Technology

consequences, especially as the society and economy have become more and more dependent on hazards triggered by meteorological events. The worlds' electricity consumption will strongly increase, while fossil fuel reserves are being rapidly depleted. In order to meet the increasing demand of electricity, to decrease the emission of greenhouse gases and to overcome the dependency of energy imports, the promotion of wind and solar power production will play a major role as indicated by the EU objectives by 2020 [COM(2008) 30 final].
Wind and solar energy have a specific common characteristic: a high variability in space and time. Wind energy production is highly dependent on regional wind patterns and local topography. Solar energy is highly dependent on the cloud structure, day/night cycles, the humidity and the aerosol load of the atmosphere. Due to intermittent weather patterns, renewable energy power production plants cannot guarantee the amount of energy which is requested by the electrical grid operators in order to respond at any time to the end users' demands. Therefore, secondary energy sources have to be considered locally or on a regional scale. Furthermore, the variability can be partly smoothed by considering Europe as a whole: most of the time, the wind is blowing and/or the sun is shining somewhere in Europe. Therefore, a combined treatment of solar and wind energy on a trans-national level will significantly increase the stability and efficiency of the energy supply.
Additionally, weather has a major impact on the electricity transmission and distribution grids, from the risk of outages and transmission capacity on one side and to the end users' highly variable and weather dependant demands on the other side. Finally, the weather dependant capacity of energy transmission - called thermal rating - is a general topic for electric utilities. Accurate local weather forecasts are a highly important tool for improved planning and marketing decisions. An increased production of solar and wind energy will lead to a higher number of decentralised production sites with a highly variable weather dependant energy production which is fed into the medium and lower voltage grids. In such systems, production forecasts for the next minutes up to several days ahead are of high importance as they enable the utilities and the grid operators to adapt a "load schedule" in order to optimise the energy transport through the partly limited line capacities in the low voltage grid, avoid outages and congestion, allocate the needed balance energy from other sources if no wind or no solar energy is available, plan maintenance activities at the production sites and take the necessary measures to protect the production sites from extreme events

2. Current state of knowledge

Wind and solar forecasting systems are based on data from numerical weather forecast models. Currently operational weather forecast models are used with spatial resolutions of a few kilometers. The output of the weather prediction models is then post-processed and improved with statistical combination of past and/or online measurement data. To achieve this goal, a number of statistical methods can be used to reduce the systematic forecast errors (e.g. Model Output Statistics, Kalman filter, fuzzy logic, neural network...).
Wind power forecasts have a high level of quality driven by the strong development of wind energy in countries like Germany, Denmark or Spain. There exist already a number of providers of operational forecasts, but the forecast systems are mainly focussing on large wind park areas in flat terrain and mid-latitudes, though potential for wind energy production is also very high in mountainous/hilly areas and arctic conditions (e.g. in northern Scandinavia, the Alps and in

South-Eastern Europe).
Solar forecasting is not yet as advanced as wind forecasting. But following the constant and strong increase of solar energy production the interest in solar forecasts is growing and research activities increased during the last years. The basic principles of solar power forecasts are more or less similar to wind power forecasts but other parameters need to be considered. At present time, one major short-coming is the accurate prediction of the 3D cloud field which is crucial for a good solar production forecast. Furthermore, the implementation of ad-hoc measurement data, especially yielded by remote sensing techniques such as satellites, ceilometers, cloud radars or LIDARs is expected to provide a large potential to improve the forecasts.

3. Objectives

The new COST Action ES1002 will lead to increased coordination on regional, national and European levels, and enhanced collaboration between solar and wind energy communities for the development of accurate production forecasts: it will make production and management of solar and wind energy more efficient, reduce the costs of electricity production and render renewable energy more competitive compared to classical, centralized energy sources. The combined approach to wind and solar energy is a main benefit as there are many common aspects for both channels: intermittent character, time-scale of the forecasts, weather forecasting models, remote installations, connections to the grid and the same numerical weather models which provide the main atmospheric parameters.
Post-processing is an efficient and flexible way to increase the accuracy and reliability of the forecasts. It allows the best possible adaptation of the output of a weather forecast model to the prevailing local conditions and still has a large potential for improvements especially in the field of solar energy.
The implementation of real-time ad-hoc measurements in the post processing schemes is expected to further increase the accuracy of the predictions. Together with standard surface measurements, remote sensing instruments – ground-based and satellite borne – will be evaluated for their suitability to increase the quality of the energy production forecasts. Furthermore, the careful validation of the results of weather models coupled with post processing schemes will give important information on the accuracy of the forecasts and their dependency on local climatic conditions.
Furthermore**,** the needs of the industry will have to be clearly specified. In many countries the industry is not yet fully aware of the limitations of today's weather forecasts and the potential of upcoming forecasting technologies. An exchange platform is necessary and important to collect the available information and to coordinate such activities in Europe.
One important aspect of this Action is its multi-disciplinary character: it will bring together different communities which are not necessarily used to work with another: meteorologists, physicists, measurement specialists, engineers, power traders and electrical grid operators: it will help to clarify the needs of the power industry and the possibilities and limits of meteorology. Additionally, this Action will promote the knowledge transfer between the fields of solar and wind power forecasting as well as from advanced to technologically less advanced countries. This harmonization of capacities will promote renewable energy all over Europe.
Finally, the concept of "Smart Grid" is very young and it will need major efforts to be implemented. For the time being, clear requirements are still missing and have to be analyzed in

the framework of a European network such as this COST Action.
In order to bring together the different communities, a "kick-off" workshop will be organized in March 2011: it will be dedicated to the preparation of a State-of-the-Art report to be published within months and more specifically to the definition of the requirements needed by the renewable energy production and electrical grid management for the parameters delivered by the forecasts as well as their temporal and spatial resolution.

4. Benefits

The main fields for improvement of the forecasts lie in the area of enhancing and developing advanced post-processing schemes using ensemble predictions and in the intensified use of ad-hoc measurement data. In particular, surface based remote sensing techniques such as SODAR, LIDAR, Wind-Profilers or passive microwave sounders, which are available on the market and operational, have a large potential. Furthermore, the new generation of operational space-born infrared and microwave sounders give the possibility to improve the accuracy of observations of wind, moisture, clouds and aerosols. However, more research needs to be performed to integrate the information delivered by the remote sensing systems in the post-processing modules. Forecasts in complex terrain and the inclusion of secondary effects such as icing of wind turbines and power lines as well as thermal rating are still major challenges. Finally, the use of newest generation forecast models with high spatial and temporal resolution and sophisticated microphysics will also contribute to improved parameterization of processes important for wind and solar energy forecasting, as turbulence and clouds.
Based on the findings of the State of the Art phase, further development of different statistical post-processing schemes will be undertaken in order to improve the forecasts delivered by the existing numerical weather models for different forecasting ranges. Similarities and differences between the modules used for solar and for wind energy production will be assessed and analysed. Evaluation and development of existing and new methods (Model Output Statistics, Kalman Filter, Ensemble Forecasts, Spatial Averaging, Fuzzy Logic, Cressman technique, Neural networks, Learning machines...) will be performed.
Depending on the forecast horizon, different methods have to be considered. In the first domain ("Now-casting", 0-3hrs), a numerical weather model cannot be applied: the forecast has to be based on extrapolations of real-time measurements. In the second domain ("Short-Term Forecasting", 3-6hrs), numerical weather models are coupled with post-processing modules in combination with real-time measurements. In the third time domain ("Forecasting", 6-72 hrs or more), only the numerical weather model in combination with specific post-processing modules and satellite information is applied.
The optimised use of real-time measurement data carried out at the production sites or at meteorological stations for implementation in the post-processing schemes has to be evaluated. Ground-based or satellite-borne remote sensing technologies will be investigated for their suitability to enhance the production forecasts and tested with existing operational systems.
The Action will select existing test facilities and promote their extension with specific measuring systems in order to validate the post-processing modules and to evaluate the accuracy of the forecast systems. Their average uncertainty will be determined in general as well as their strengths and weaknesses under different weather conditions. The validation processes will be

harmonized in order to obtain comparable results. For this purpose, ad-hoc measurements performed in situ will be used as well as meteorological networks for selected periods of time (case studies). A data base containing these validation data will be set up and appropriately formatted for direct use by the modellers' community.

The effects of the intermittent character of renewable energies on the operation of specific power plants and on the electrical grid management in combination with the potential of forecasting information will be assessed. The resulting consequences on the operation of those systems will be carefully analyzed in terms of the delivered information from the forecasts (numerical models and post-processing) and of the achieved accuracy.

From the beginning of the Action, a strong weight will be put on the establishment of a high level interdisciplinary collaboration between science and industry. This will essentially contribute to clarify the needs of the power industry and the possibilities and limits of weather forecasting.

At the same time, the communities of wind and solar energy will be brought together in order to launch an intense capacity building in both communities. Finally, the knowledge transfer from advanced to technologically less advanced countries in that field will be emphasized.

5. Participation

At present time, 25 COST countries are participating to the COST Action ES1002 or declared their intention to participate (see Action's website (www.wirw1002.ch) or the COST official website (http://www.cost.esf.org/domains_actions/essem/Actions/wire).