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Comparing the impact of uncertainties on technical and meteorological parameters in wind power time series modelling in the European Union

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HIGHLIGHTS

- We developed a technical data set of the wind farms composing the EU fleet.
- We used wind farms data and reanalysis wind fields to estimate wind power.
- We compared the uncertainties arising from the technical parameters and wind.
- We performed a sensitivity analysis at the continental scale.
- We found that a wind data are crucial for wind power estimation.

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ABSTRACT

The adequate modelling of power systems under heavily penetration of Renewable Energy sources crucially depends on the accurate representation of the spatial and temporal features of intermittent power resources supplying the system. In the case of wind energy, two main ingredients are needed for a suitable assessment of its temporal features: a detailed knowledge of the technical parameters of the power generators and the proper description of the physical parameters leading to actual power generation. In this paper we compare the relative weight of uncertainties in the wind power assessment arising from the limited knowledge of the wind farms technical parameters (namely hub height, turbine type and wind farm positioning) with uncertainties originated by the limited description of wind speed fields at hub height provided by meteorological reanalyses. The quantitative comparison of error sources has been achieved by means of a sensitivity analysis taking into consideration the most crucial parameters impacting wind power estimation. The analysis has shown the overwhelming importance of coupling an accurate data base of operating wind farms with a proper representation of the input wind fields at the most possibly detailed level. To our knowledge, this is the first time that the sources of uncertainties for wind power generation estimates have been compared on a continental scale.

1. Introduction

1.1. The need for accurate wind power time series in energy system analysis

Following the requirements arising from EU legislation [1] an increasing share of electricity generated by renewable sources (RES-E) is supplied to the European power system. A relevant fraction of RES-E is actually provided by intermittent sources such as wind and solar power, strictly linked to varying atmospheric variables. An accurate knowledge of the time and spatial features of these intermittent resources is then crucial for modelling the behaviour of the power system under different RES-E supply assumptions.

Limiting the discussion to wind power, atlases and online tools such as NREL's wind prospector,[1] IRENA global atlas[2] and DTU global wind atlas[3] can provide a first glance view of the most promising areas in which wind farms can be profitably installed. Such information is mostly useful for policy makers when drafting energy developments plans and to compare each other the availability different kind of resources. Nevertheless, as soon as wind production is put in the context of a complex and modern energy system, it becomes clear that the average parameters typically provided by traditional wind atlases (i.e., annual average wind speed and/or wind power class) are not detailed

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[1] https://maps.nrel.gov/wind-prospector/.
[2] https://irena.masdar.ac.ae/gallery/#gallery.
[3] http://globalwindatlas.com/.

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enough to describe the behaviour of power production facilities on the shorter time scales needed by the grid operators and the market actors.

Indeed, modern electricity markets work mostly on hourly or even finer time schedules and utilities need to understand how their intermittent "products" are expected to behave on this time scale. The growing share of intermittent electricity production increases the stochastic nature of the power system and has repercussions on the markets for electricity. Deviations from forecasted production schedules require balancing of a generator's position within the day. Products that are traded on power and/or reserve markets have been developed for this purpose, providing opportunities to actors who can offer flexibility in the short term. Flexibility is typically modelled using stochastic scenario extensions of dispatch models which require, as a first step, a deep understanding of the nature and the sources of the wind power simulations uncertainties.

On the other side, the complexity of Transmission Systems Operators routinely task of matching demand and supply is crucially depending on the expected outcome of intermittent power production plants located in large areas, ranging from regions to countries.

Under this context, the Joint Research Centre of the European Commission has developed the EMHIRES dataset European Meteorological HIgh resolution RES time series) [2–4].

EMHIRES provides RES-E generation time series for the EU-28 and neighbouring countries for both wind and PV power generation in the form of hourly time series spanning 30 years (1986–2015).

Both the wind and solar power time series are released at hourly granularity and at different aggregation levels: by country, power market bidding zone, and by the European Nomenclature of territorial units for statistics (NUTS) defined by EUROSTAT; in particular, by NUTS 1 and NUTS 2 level. The time series provided by bidding zones include special aggregations to reflect the power market reality where this deviates from political or territorial boundaries. In the case of wind power, onshore and offshore are also provided in separate files.

EMHIRES provides a view of the impact of meteorological and climate variability on the generation of solar and wind power in Europe and does not model the actual evolution of solar power production in the latest decades. For this reason, the hourly solar and wind power generation time series are released for meteorological conditions of the years 1986–2015 (30 years) without considering any changes in the installed capacity for both the PV and wind fleets. As only meteorological aspects of power variability are considered, wind and solar installed capacities are fixed as the ones installed at the end of 2015. Data are available for download at the EMHIRES data set web page.[4] In particular, the steps followed in the EMHIRES – wind dataset project are fully detailed in Gonzalez-Aparicio et al. [2] and Gonzalez-Aparicio et al. [3].

In last years, more and more research teams have been developing accurate hourly profiles of wind power production on extensive geographical areas. In these studies, including EMHIRES, wind resource (usually wind speed data from weather models or observations) is generally converted into power generation or load factors using suitable wind turbines power curves. Although such an approach is quite widely used, fewer studies can be found devoted to study the cascade of uncertainties in the whole conversion process. The contribution of the biases starts in the selection of the characteristics of the primary wind speed and direction data; the wind speed data should reproduce the diversity of the local effects due to the orography and wind features at hub height. Attention should also be given to technical data parameters of wind turbines (e.g., hub height and power curves), the losses of performance due to the age of the turbines and the vertical interpolation method the hub height. So far, while the impact of the wind resource spatial and time resolution on the total electricity generation has been recently addressed by different studies [3,5–6] the comparison of the uncertainties coming from the wind resource or from the technological aspect to the total uncertainty cascade has not been gauged yet.

During the development of the EMHIRES dataset, a special attention has been paid in the reduction of the uncertainties, coming from the wind resource spatial and temporal resolution, but also in the impact of the uncertainties of the technological aspect to the total power generation. This study is then focused on the importance of evaluating the different contributions to the uncertainty cascade and the significance of each error in the wind generation conversion chain.

1.2. Technical versus meteorological parameters in wind power assessment

When assessing wind power production in a given area, the accurate description of wind features is just a part of the problem as power production from a wind farm also depends on the proper knowledge of its technical parameters. Obviously, the highest possible accuracy of both technical and meteorological data is needed to reach the highest possible level of accuracy in modelling the actual power series.

For this reason, in the framework of the development of EMHIRES, a special care has been devoted to both aspects. On the one hand, the meteorological parameters have been statistically downscaled from the global scale offered by reanalysis products to the farm level by means of the innovative statistical methodology fully detailed in Gonzalez-Aparicio et al. [3]. On the other hand, the technical parameters of the European wind farm fleet available from partially incomplete commercial data bases had to undergo a data gap filling procedures to achieve the best possible quality.

This paper investigates the impact that uncertainties in the two groups of data, i.e. m meteorlogical and technical parameters, have on the precision of the final total power generation calculated. Although wind power time series reconstruction is a field in which several researchers and projects have provided relevant results (see again Gonzalez-Aparicio et al. [3] and references therein), very few publications discuss our main research question: "In simulating time series of wind power at the national and continental level, what set of data is more crucial to care about? The wind speeds or the key technical parameters of the wind farms fleet (such as the hub height, power curve, rotor diameter, etc.)?"

The answer to this question is probably the most original contribution of this paper. Very few authors have wondered if they were devoting time and attention to the most influential and crucial set of parameters.

Most of the studies developing wind power time series have focussed on obtaining the best possible accuracy for one or the other of the two sets of parameters we are going to compare, more often pointing their attention to meteorological parameters. A detailed review about the methods and advances in estimating and forecasting wind power generation can be found in Aoife and Foley [7], Alessandrini et al. [8] and Gonzalez-Aparicio and Zucker [9].

In general, researchers have often assessed the influence of either meteorological or technical parameters separately or have focused their studies on a limited number of turbines. For instance, de Giorgi et al. [10] have assessed the impact of varying the main meteorological parameters (wind speed, pressure and temperature) on their wind power production model based on neural networks. Bak [11] has investigated the sensitivity of power performance to some aerodynamic parameters in order to provide guidelines for a proper rotor design. McKay et al. [12] have applied the global sensitivity analysis methodology suggested by Saltelli et al. [13] to evaluate the sensitivity of power production to a set of parameters, including wind speed and rotor rotation speed. The authors have investigated the cases of a single turbine and a set of turbines linked by a wake effect, finding that both parameters play a major role, but the most influential parameter changes when the wind array configuration is changed.

On the atmospheric physical aspect, other authors have investigated the impact of a specific process related to atmosphere complexity, most

[4] https://setis.ec.europa.eu/EMHIRES-datasets.