Applied Energy 199 (2017) 155–168

Contents lists available at ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

Simulating European wind power generation applying statistical downscaling to reanalysis data

I. González-Aparicio [a,*], F. Monforti [b], P. Volker [c], A. Zucker [a], F. Careri [a], T. Huld [b], J. Badger [c]

[a] European Commission, DG-Joint Research Centre, Knowledge for the Energy Union Unit, Energy, Transport and Climate Directorate, Petten, The Netherlands
[b] European Commission, DG-Joint Research Centre, Energy Efficiency and Renewables Unit, Energy, Transport and Climate Directorate, Ispra, Italy
[c] Technical University of Denmark, Department of Wind Energy, Denmark

HIGHLIGHTS

- Wind speed spatial resolution highly influences calculated wind power peaks and ramps.
- Reduction of wind power generation uncertainties using statistical downscaling.
- Publicly available dataset of wind power generation hourly time series at NUTS2.

ARTICLE INFO

Article history:
Received 7 December 2016
Received in revised form 24 April 2017
Accepted 26 April 2017
Available online 9 May 2017

Keywords:
Wind power generation
Hourly time series
High spatial resolution wind speed

ABSTRACT

The growing share of electricity production from solar and mainly wind resources constantly increases the stochastic nature of the power system. Modelling the high share of renewable energy sources – and in particular wind power – crucially depends on the adequate representation of the intermittency and characteristics of the wind resource which is related to the accuracy of the approach in converting wind speed data into power values. One of the main factors contributing to the uncertainty in these conversion methods is the selection of the spatial resolution. Although numerical weather prediction models can simulate wind speeds at higher spatial resolution (up to 1×1 km) than a reanalysis (generally, ranging from about 25 km to 70 km), they require high computational resources and massive storage systems: therefore, the most common alternative is to use the reanalysis data. However, local wind features could not be captured by the use of a reanalysis technique and could be translated into misinterpretations of the wind power peaks, ramping capacities, the behaviour of power prices, as well as bidding strategies for the electricity market. This study contributes to the understanding what is captured by different wind speeds spatial resolution datasets, the importance of using high resolution data for the conversion into power and the implications in power system analyses. It is proposed a methodology to increase the spatial resolution from a reanalysis. This study presents an open access renewable generation time series dataset for the EU-28 and neighbouring countries at hourly intervals and at different geographical aggregation levels (country, bidding zone and administrative territorial unit), for a 30 year period taking into account the wind generating fleet at the end of 2015.

1. Introduction

The European power sector is currently experiencing a structural transition. The goal of the European Union for Renewable Energy Sources for electricity (RES-E) to provide for at least 27% of the total energy consumption by 2030 could translate into 50% of total electricity production from renewables. The Energy Union strategy includes the aim of the European Union to become "the number one in renewables" continuing the significant growth of RES-E experienced during the last decade [1]. However, the growing share of generation from solar and mainly, wind resources constantly increases the stochastic nature of the power system, potentially jeopardizing the security of supply. As a consequence, planning and scheduling tools for the power sector have been improved to simulate the high share of RES-E. Particular care has been given to the adequate representation of the wind intermittency to better catch wind power generation peaks and ramping capacities, which are key aspects for understanding power system

* Corresponding author at: European Commission, DG-Joint Research Centre, Knowledge for the Energy Union Unit, PO Box 2, NL-1755 ZG Petten, The Netherlands.

E-mail address: iratxe.gonzalez-aparicio@ec.europa.eu (I. González-Aparicio).

http://dx.doi.org/10.1016/j.apenergy.2017.04.066
0306-2619/© 2017 The Authors. Published by Elsevier Ltd.

flexibility needs, as well as the behaviour of market participants in defining their bidding strategies in the different electricity markets.

However, before analysing or modelling the impact of the wind on the power system, it is this important to understand the wind resource characteristics, in particular the nature of their variability. The effects of the surface heterogeneities vary depending on the local area but also on larger scales (such as meso and continental scales). At wind farm level, the wind flows are influenced by the co-occurrence of meteorological variations and turbine wake effects and their nonlinear interactions, particularly over strongly heterogeneous surfaces like coastal areas or mountainous regions [2,3]. Considering that wind farms are often built over such heterogeneous surfaces, it is important to know the significance of the spatial variability as they influence power production at larger scales (countries, bidding zones and administrative territorial unit levels).

Thus, in order to analyse the European power system, the wind speed and direction data should keep a compromise between the geographical coverage accounting for European climate zones; the time intervals and a period long enough to capture the climate variability [4]. 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 interpolation method of the wind speed data at the hub height. All these factors crucially depend on the accuracy of the approach to convert the wind speed data into power and how the uncertainties are treated (Fig. 1). It also depends on the aggregation level of the study and the smoothness of those factors. For example, at wind farm level wake effects are the main drivers for modelling power generation and then, a wind power fluctuation parameterization is required to include in the conversion such as in [5–7]. When aggregating to a regional, bidding area or country level those effects are, to some degree, smoothed and existing studies are focused on the accuracy of wind speed data and derived wind generation by developing simplified models ([8,9]); by correcting the wind output biases with factors derived from the transmission system operators data [10]; by estimating the factors affecting the cascade of uncertainties [11–14].

However, the cascade of the uncertainties in the whole conversion process starts in the selection of the characteristics of the primary wind speed and direction data. Generally, the trend is to use weather derived data from Numerical Weather Prediction (NWP) models or from reanalyses. The use of NWP models could perform higher spatial resolution wind speed data (generally, ranging from 1 × 1 km to 5 × 5 km) than the reanalysis (so far, ranging from 25 to 70 km) but requires high computational resources and massive storage systems and therefore, most of studies use the reanalyses [15]. A good comparison between the methods using NWP models can be found in [16]; the assessment of what a reanalysis can provide for wind power and the bias associated is published in [17] and a summary of publicly available reanalysis can be found in ([18,15]). One of the most used reanalysis for power system analysis comes from the NASA atmospheric reanalysis dataset which was generated within the Modern Era Retrospective-Analysis for Research and Applications (MERRA) project [19]: in [18] the description of the local wind climate in terrain with low complexity has shown good correlation with wind measurements at relevant heights with Pearson's correlation coefficients values around 0.85 on an hourly basis and 0.94 on a monthly basis for Nordic countries and Baltic states; in [20,21] the wind power production modelling has been studied for Sweden and Great Britain, respectively; in [22] a wind energy index for site assessment, turbine selection and local feed-in tariffs has been developed for Germany; in [23] the results of offshore wind energy resource simulations forced by different reanalysis have been compared for the Iberian Peninsula; flexibility options for systems with high renewables penetration have been studied for Ireland [24] and Europe ([25,26]); a techno-economic analysis of the effects of North African electricity import on the European power system was carried out in [27]; the cost-potentials for large onshore wind turbines in Europe has been analysed in [28] while the validation of Danish

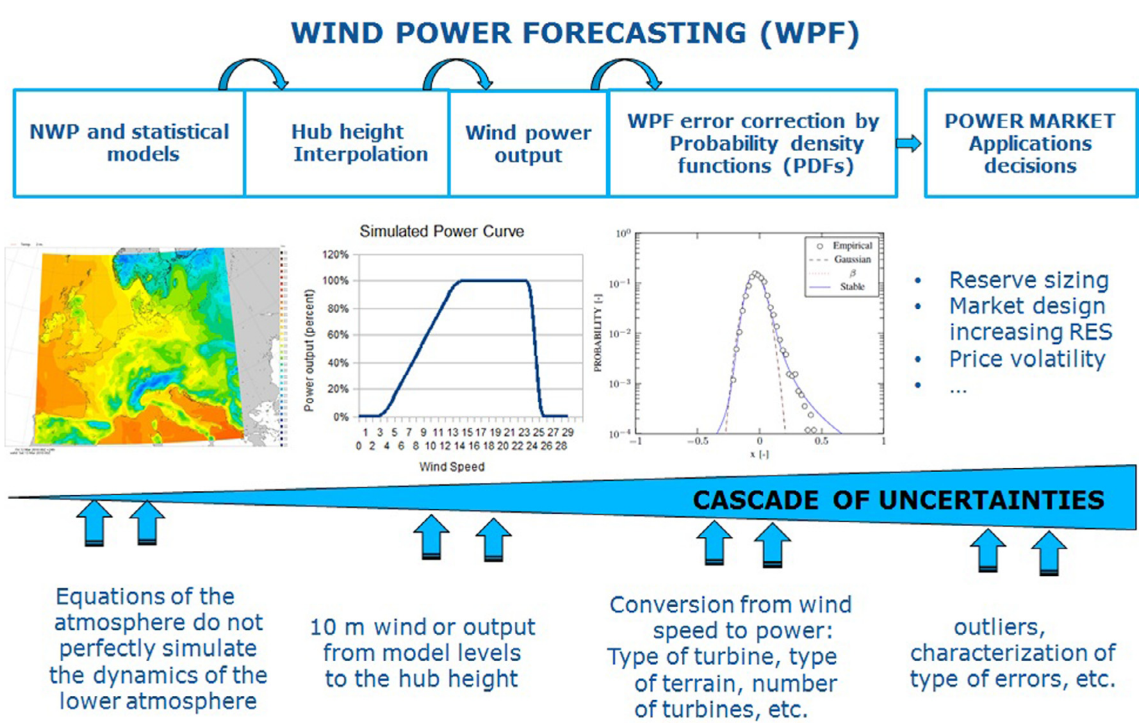

Fig. 1. General approach for the conversion of wind speed data into power and the main factors contributing to the cascade of uncertainties.