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A comparison between the ECMWF and COSMO Ensemble Prediction Systems applied to short-term wind power forecasting on real data

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HIGHLIGHTS

- ▶ A comparison between two ensemble models for wind power forecasting is shown.
- ▶ Novel application of COSMO-LEPS ensemble model for wind power forecasts.
- ▶ A full verification is performed with real power plant data in complex terrain.
- ▶ Higher spatial resolution leads to slightly better wind power probabilistic forecasts.
- ▶ A comparison between the ensemble mean and the deterministic model is shown.

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ABSTRACT

Wind power forecasting (WPF) represents a crucial tool to reduce problems of grid integration and to facilitate energy trading. By now it is advantageous to associate a deterministic forecast with a probabilistic one, in order to give to the end-users information about prediction uncertainty together with a single forecast power value for each future time horizon. A comparison between two different ensemble forecasting models, ECMWF EPS (Ensemble Prediction System in use at the European Centre for Medium-Range Weather Forecasts) and COSMO-LEPS (Limited-area Ensemble Prediction System developed within COnsortium for Small-scale MOdelling) applied for power forecasts on a real case in Southern Italy is presented. The approach is based on retrieving meteorological ensemble variables (i.e. wind speed, wind direction), using them to create a power Probability Density Function (PDF) for each 0–72 h ahead forecast horizon. A statistical calibration of the ensemble wind speed members based on the use of past wind speed measurements is explained. The two models are compared using common verification indices and diagrams. The higher horizontal resolution model (COSMO-LEPS) shows slightly better performances, especially for lead times from 27 to 48 h ahead. For longer lead times the increase in resolution does not seem crucial to obtain better results. A deterministic application using the mean of each ensemble system is also presented and compared with a higher resolution 0–72 h ahead power forecast based on the ECMWF deterministic model. It is noticeable that, in a deterministic approach, a higher resolution of the ensemble system can lead to slightly better results that are comparable with those of the high resolution deterministic model.

Contents

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1. Introduction

Deterministic forecasts of wind production for the next 72 h at a single wind farm or at the regional level are the main requirement for end-users. However, for an optimal management of wind power production and distribution it is important to provide, together with a deterministic prediction, a probabilistic one. A deterministic forecast consists in a single value for each time in the future for the variable to be predicted. Different methods for deterministic WPF can be found in Refs. [1,2] and a complete review of the state of the art is reported in Ref. [3]. At the opposite, probabilistic forecasting informs on probabilities for potential future events. This means providing information about uncertainty in addition to the commonly provided single-valued power prediction. Prediction intervals include then a practical and visual way to communicate information about forecast uncertainty to the end-users.

Recently, different energy-related applications have shown the advantages of using additional uncertainty information. These possibilities are well described in e.g. Refs. [3,4] and summarised hereafter. As a first operational example, probabilistic forecasts can be used to estimate the optimal level of reserves to be allocated in order to compensate wind power variability and limited predictability [5]. Another application is related to the trading of energy in day-ahead electricity markets. It has been shown that, when trading future wind energy production, using probabilistic wind power predictions can lead to higher benefits than those obtainable by using deterministic forecasts alone [6].

In this paper we propose an approach to issue the probability density function (PDF) of wind power generation for each forecast horizon (between 0 and 72 h in the future). It is based on transforming a PDF for a meteorological variable, supplied by an ensemble forecast meteorological model, into a PDF for wind power. In this application, the PDF of the meteorological variable is always defined by a set of a limited number of forecasts for each lead time, corresponding to the members of the ensemble meteorological model. Using this set of forecasts it is possible to define the PDF's moments to obtain prediction intervals, quantiles or single-valued predictions depending upon the specific interest of an end-user. The main scope of the paper is to suggest an approach on how to obtain wind power probabilistic forecasts from two commonly well-known ensemble meteorological models like ECMWF EPS and COSMO-LEPS. From this point of view, this paper suggests an original approach to probabilistic WPF considering that other known methods use different techniques, based for instance on linear quantile regression [7,8]. As already mentioned, a complete state of the art of the system can be found in Ref. [3] where none of the probabilistic methods described is based on ensemble meteorological models. In particular, no other applications of COSMO-LEPS model are known for wind power purposes. The paper aims also to compare the performances of the two models proposed by computing the most common skill indices with the power production data of an Italian wind farm as a reference. Clearly, using the ensemble mean data, the method proposed in this work allows obtaining deterministic forecasts too, with two different horizontal spatial resolutions. As a consequence, further considerations can be drawn about the influence of this characteristic on the final wind power prediction accuracy.

The paper is organised as follows. Section 2 presents the main characteristics of the two tested ensemble systems. Section 3 introduces the case study considered for the application, and Section 4 explains in details the methodology for the probabilistic WPF. Results are then gathered and discussed in Sections 5 and 6 along with the conclusions.

2. Ensemble systems description

2.1. EPS

The ECMWF EPS applies initial conditions perturbation using a mathematical method based on singular vector decomposition and stochastic parameterisation to represent model uncertainty [6]. The approach searches for perturbations that maximise the impact on a 2-day ahead forecast, as measured by the total energy above the reference hemisphere (at 30° latitude). The impact on individual weather systems can be either reinforcement or weakening. EPS consists of 50 different evolutions of the desired atmospheric variable, plus a non-perturbed member (the control run, which only differs from the deterministic run for its lower resolution). The horizontal resolution of EPS has been increased in January 2010 from T399/T255 (~60 km) to T639/T319 (~32 km) [9].

2.2. COSMO-LEPS

LEPS is created with 16 different integrations of the non-hydrostatic mesoscale model COSMO, which in turn is nested on selected members of the ECMWF EPS. The so-called "ensemble-size reduction" process is required to maintain affordable computational time. The selected global ensemble members provide initial and boundary conditions to the integrations, and the COSMO model is then run once for each selected member. The basic principle of COSMO-LEPS is to combine the advantages of a probabilistic approach based on the use of a global ensemble system with the details obtainable from high resolution mesoscale integration. COSMO-LEPS runs daily with a horizontal resolution of ~10 km and 40 vertical layers, starting at 12 UTC with a forecast range of 132 h [10].

3. Case study

The case study consists in a wind farm located in the province of Palermo, in Northern Sicily. The orography is fairly complex, with heights in the area around the plant ranging between 400 and 1800 m above sea level (a.s.l.) The highest peaks nearby the wind farm are the Madonie mountains, located approximately 20 km Northeast. The wind farm has 9 Vestas V52 equal turbines. The