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Short-term wind power forecasting using wavelet-based neural network

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Abstract

Wind power generation highly depends on the atmospheric variables which itself depend on the time of the day, months and seasons. The intermittency of wind hinders the accuracy of wind forecasting, which is important for safe operation and reliability of future power grid. One way to address this problem is to consider all these atmospheric variables which can be obtained from Numerical Weather Prediction (NWP) models. However, using NWP parameters increases the complexity of the forecast model and it requires a large amount of historic data. Additionally, different models are required for different seasons or months. This paper presents a wavelet-based neural network (WNN) forecast model which is robust enough to predict the wind power generation in short-term with significant accuracy, and this model is applicable to all seasons of the year. With reduced complexity, the model requires less historic data as compared to that in available literatures.

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Keywords: Wind power forecasting; Discrete Wavelet Transform; neural network

1. Introduction

Wind energy is one of the most promising and mature technologies among the renewable energy resources. In most of the countries including India, the wind power integrated into the electrical grid is relatively a small fraction of the total installed capacity as compared to the conventional resources. However, with progressive installation of wind turbines (WTs), the amount of electricity generated by wind is continuously increasing and has started replacing the conventional synchronous generators. For instance, in Denmark, approximately 40% of its energy resources are

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from wind generation. As a consequence, it has begun to influence the overall grid behaviour [1]. The growing utilization of wind power brings new challenges for frequency regulation, voltage control and reactive power compensation.

Hence, to ensure the safe operations and reliability of grid, it is very important for the system operator to foresee what is expected to happen in time ahead. This can be secured by obtaining relatively accurate wind generation forecasting along with the demand forecasting. However, the intermittency of wind does not allow very accurate wind forecasting. Thus, the role of short-term wind forecasting with as minimum error as possible is very critical to maintain the load generation balancing and the stability of the system, particularly when the wind penetration is high.

1.1. Indian Electricity Grid Code (IEGC) requirements for Renewable energy (RE) generation

Central Electricity Regulatory Commission (CERC), the regulatory body of power sector in India has laid down some regulations for power systems operations, known as IEGC [2]. According to IEGC, every wind farm with aggregate generation capacity of 50 MW and above must perform wind energy forecast with an interval of 15 minutes for the next 24 hours. To assure that the forecasting models are aligned to minimize the actual MW deviations, CERC defines the percentage error normalized to the rated capacity of the plant.

Additionally, the load dispatch center allows the wind farm operators to submit a total of 8 revisions throughout the day, up to 3 hours before the actual schedule. This helps in improving the forecast as latest data are available. This benefits the farm owners in minimizing their forecast errors and subsequently, the economic losses. Hence, it is crucial to perform short-term wind forecasting with 15-minutes time interval in accordance with IEGC.

1.2. Related works

The intermittency present in the wind is due to its complex dependence on various atmospheric variables such as temperature, pressure gradient, humidity etc. which brings the non-linearity in the wind signal and uncertainties in the prediction. Various literature proposes methods to deal with the uncertainties. A two-step wind power forecasting has been proposed in [3], where authors have used adaptive wavelet neural network (AWNN) for wind speed forecasting and then mapped the wind power using past wind speed, past power output and forecasted wind speed using feed-forward neural network (FFNN).

In [4], temporally local “moving window” technique is used in Gaussian process (GP) to examine estimated forecasting errors. Ref [5] used an optimal loss function for heteroscedastic regression and develop a framework of ν-SVR for learning tasks of Gaussian noise (GN) and obtained a 30 min ahead forecast. A heterogeneous ensemble predictor consisting of combination of decision trees (DT) and support vector regression (SVR) has been implemented in [6]. K-means clustering-based bad data detection module and a neural network (NN)-based forecasting module has been developed in [7] to obtain up to 48 hours ahead prediction. Various Neural Network based hybrid techniques have been implemented in [8]-[10]. A data mining based approach has been implemented in [11], which uses a hybrid of time-series based k-mean, discrete wavelet transform (DWT) and harmonic analysis time-series (HANTS) for clustering the NWP data and a MLPNN for wind power forecast. DWT based data processing and hybrid of NN and fuzzy model is proposed in [12]. A probabilistic short-term wind power forecast method is implemented in [13] using componential Sparse Bayesian Learning (SBL) and DWT.

Many of the above discussed literatures used Numerical Weather Prediction (NWP) data along with the historic wind power data which makes the forecast model complex and requires a large amount of historic dataset. This paper aims to present a simple and robust wind forecast model that would be able to predict the wind power using a minimum amount of historic wind power data only. It implements wavelet-based neural network (WNN) and a single forecast model is sufficient enough to predict the wind power for short-term forecasting with significant accuracy.

2. Wavelet-based Neural Network

Wavelet decomposition can be utilized to analysis the non-linearity present in the historic wind power signal. Fig. 1 (a) shows the architecture of the wavelet-based Neural Network (WNN) approach. First, the wind power data is decomposed into an approximate part (associated with the general trend of original signal with low frequency) and