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A comparative study of optimal hybrid methods for wind power prediction in wind farm of Alberta, Canada

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A B S T R A C T

In the recent years, by rapid growth of wind power generation in addition to its high penetration in power systems, the wind power prediction has been known as an important research issue. Wind power has a complicated dynamic for modeling and prediction. In this paper, different hybrid prediction models based on neural networks trained by various optimization approaches are examined to forecast the wind power time series from Alberta, Canada. At first, time series analysis is performed based on recurrence plots and correlation analysis to select the proper input sets for the forecasting models. Next, a comparative study is carried out among neural networks trained by imperialist competitive algorithm (ICA), genetic algorithm (GA), and particle swarm optimization approach. The simulation results are representative of the out-performance of ICA in tuning the neural network for wind power forecasting.

Contents

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1. Introduction

Electrical power generation is increased caused by population growth and its subsequent aggressive electrical energy demands [1]. Thermal pollution is increased and greenhouse gases are produced more, due to the growth of electrical energy generation resulting from thermal power plants. It causes more interest in power generation based on renewable energies [2]. Electrical power generation based on wind energy has been fastest growing among the renewable energy sources [3]. It is estimated that in 2020, about 12% of the world electrical energy will be supplied from wind energy [4]. Therefore, the electricity generated by wind power will play an important role in electricity supply.

Wind power depends on weather conditions such as wind speed, wind direction, temperature, air pressure and environmental obstacles. As a dynamic system, wind power has a correlation with its past values at any time, as well [3]. Due to the dependence of wind power on the atmospheric parameters, it has been recognized as a non-dispatchable source [5]. This feature introduces a wind power as an uncertain variable and reduces the system reliability. Therefore, an accurate prediction of wind power variations can moderate this problem to some extent [6,7].

Wind power prediction based on meteorological variables is encountered with some difficulties. That is, sufficiently accurate measurements of meteorological variables are commonly unavailable and their measurement equipments are so expensive to be supported, elsewhere. Inaccurate measurements or estimations can, on the other hand, results in aggressive errors in the wind power forecasting. As another fact, the true model of the wind power generating unit is not in hand, commonly. Therefore, achieving a low wind power forecasting error via a relatively simple black-box model with a low number of measurable inputs/input variables is perfectly desired.

Based on the above discussion, in this paper, wind power forecasting based on its historical data as the forecasting model inputs is considered. That is, the optimal training of neural networks is proposed as our modeling approach and four seasonal wind power data sets of Alberta, Canada [8] wind farm are studied as the real data for model construction and evaluation. In order to construct the neural network model for forecasting of the wind power, at first, time series analysis is performed based on recurrence plots and correlation analysis to the available wind power time series. In the next stage, a comparative study is carried out among various neural networks trained by imperialist competitive algorithm (ICA) [9], genetic algorithm (GA) [10], and particle swarm optimization (PSO) [11,12] approach. The simulation results are representative of out-performance of ICA in tuning the neural network for wind power forecasting.

This paper is organized as follows. In Section 2, the related researches are introduced. In Section 3, the data properties and the input selection approach is described. In Section 4, the proposed wind power prediction engine is presented. In Section 5, design and evaluation of the forecasting models for the wind power time series of Alberta, Canada are described. Finally, Section 5 concludes the paper.

2. The related researches

Wind power forecasting methods can be categorized as the physical and time series or statistical models [13,14]. In the physical modeling, someone tries to estimate the wind speed time series taking into account the physical characteristics of the environment conditions [15]. The statistical model is attempted to find a relationship between the parameters of the historical data to predict the future wind speed and wind power [16]. Commonly, physical models are used for long-term prediction and statistical model are used for short-term prediction [17].

In the literature, there are different attempts for short-term wind power forecasting via hybrid time series methods. In [18], wind power prediction has been done via a composition of modified hybrid neural network and enhanced particle swarm optimization algorithm. In [19], wavelet transform support vector machine in conjunction with statistic-characteristics analysis has been employed for short-term wind power prediction. In [20], a method has been presented to improve the short-term wind power prediction at a given turbine using information from numerical weather prediction and from multiple observation points. In this paper, the prediction of wind power is achieved in two stages; in the first stage wind speed is predicted using the proposed method. In the second stage, the wind speed to output power conversion is accomplished using power curve model. In [21], a useful model based on wavelet transform, chaotic time series and the GM (1,1) method has been presented for wind farm power forecasting. A new approach based on clustering has been proposed in [22] and in [23], the ultra-short term prediction of wind power based on chaotic time series has been considered. Artificial neural networks (ANN) optimized by Tabu search algorithm [24], hybrid PSO-ANFIS approach [25], wind farm power generation based on fuzzy modeling [26], and a hybrid strategy of short term wind power prediction based on the physical strategy and ANN technique [27] have been addressed in the literature as well. Besides, comprehensive reviews about the methods and models of wind power may be found in [28–30].

3. The data properties and selection of appropriate input set

As stated earlier, in this paper, the prediction of wind power experimental data from Alberta, Canada wind farm [8] is considered. The available data are four seasonal data sets for year 2007, each one containing 1368 hourly stored data. The wind power is predicted using feed-forward neural networks trained by some optimization algorithms being ICA, GA and PSO. In the feed-forward neural networks, the outputs at any moment only depend on the neural weights and the input signals to the neural network at that moment. Therefore, proper selection of inputs is essential to obtain good performance of the trained neural network. To do that, in this paper, two stages are followed to determine the neural network inputs for each seasonal data set. At the first stage, the characteristics and predictability of the wind power time series is investigated via recurrence plots. Based on the derived results, in the next stage, the correlation analysis is performed to choose proper input sets for the four seasonal data sets.

3.1. The available data and its properties

Seeking for the proper inputs for our models, in this section the experimental data from Alberta, Canada wind farm [8] for year 2007 will be examined, closely. As mentioned earlier, the available data are four seasonal data sets, each one containing 1368 hourly stored data. The mentioned data have been shown in Fig. 1(a)–(d). As shown in this figures, severe fluctuations is observed in the wind power time series while no hallmark of strong periodicity is demonstrated. However, such fluctuations may be due to the chaotic or stochastic nature of a nonlinear process [31–33]. Since, we are interested in predictability, it is important for us to distinguish between these two types of processes. This property has been closely examined by the authors in [34] via time series analysis methods, where the results are representative of stochastic nature and so short-term predictability of wind power time series in short-term time scale. In order for briefly representing