ARTICLE IN PRESS

Applied Energy xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Applied Energy

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

A novel hybrid system based on a new proposed algorithm—Multi-Objective Whale Optimization Algorithm for wind speed forecasting

Jianzhou Wang, Pei Du*, Tong Niu, Wendong Yang

School of Statistics, Dongbei University of Finance and Economics, Dalian 116025, China

HIGHLIGHTS

- We propose a new algorithm—Multi-Objective Whale Optimization Algorithm (MOWOA).
- A novel hybrid system based on MOWOA is proposed for wind speed forecasting.
- The new proposed model is compared to sixteen models for wind speed prediction.
- The proposed hybrid system demonstrates higher prediction accuracy and reliability.

ARTICLE INFO

Keywords:
Wind speed forecasting
Multi-Objective Whale Optimization Algorithm
Hybrid forecasting system
Forecasting accuracy and stability

ABSTRACT

In recent years, managers and researchers have paid increasing attention to accurate and stable wind speed prediction due to its significant effect on power dispatching and power grid security. However, most previous research has focused only on enhancing either accuracy or stability, with few studies addressing the two issues, simultaneously. This task is challenging due to the intermittency and complex fluctuations of wind speed. Therefore, we proposed a novel hybrid system based on a newly proposed called the MOWOA, which includes four modules: a data preprocessing module, optimization module, forecasting module, and evaluation module. An effective decomposing technique is also applied to eliminate redundant noise and extract the primary characteristics of wind speed data. In order to obtain high accuracy, and stability for wind speed prediction simultaneously, and overcome the weaknesses of single objective optimization algorithms, the optimization module of the proposed MOWOA is utilized to optimize the weights and thresholds of the Elman neutral network used in the forecasting module. Finally, the evaluation module, which includes hypothesis testing, evaluation criteria, and three experiments, is introduced perform comprehensive evaluation on the system. The results indicate that the proposed MOWOA performs better than the two recently developed MOALO and MODA algorithms, and that the proposed hybrid model outperforms all sixteen models used for comparison, which demonstrates its superior ability to generate forecasts in terms of forecasting accuracy and stability.

1. Introduction

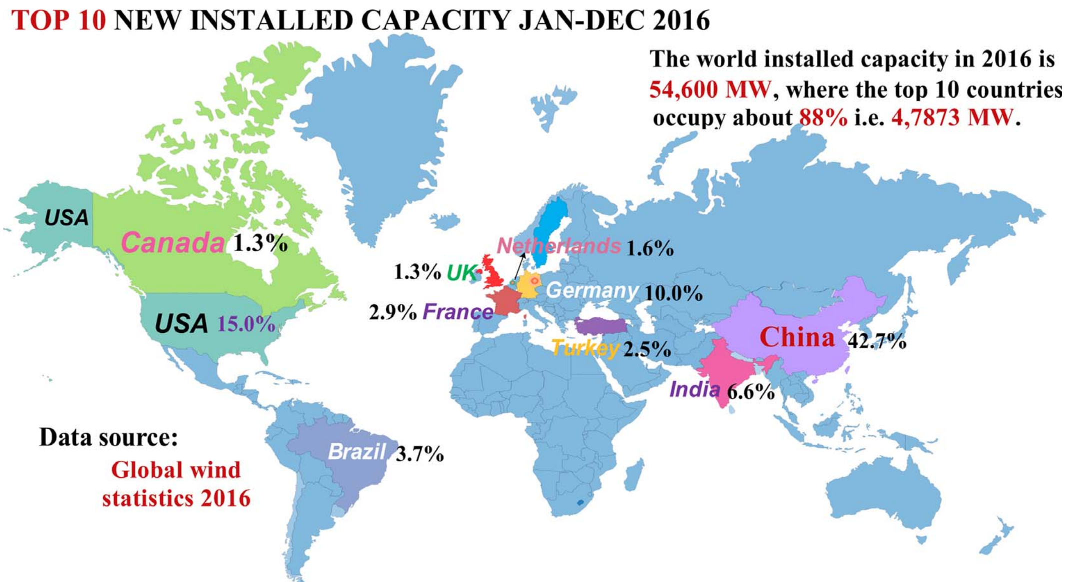
Wind energy is one type of the most promising renewable energy resources and an excellent alternative to fossil energy for addressing environmental problems and the current energy crisis [1], because it is clean, widely available, inexhaustible, and economical. More importantly, it has become the fastest growing renewable energy resource for electricity generation and is receiving increasing attention globally [2]. At the end of 2016, the global cumulative installed wind capacity reached approximately 486,749 MW [3]. Fig. 1 shows the global top 10 wind energy installation capacities from January to December 2016. However, the random and unstable characteristics of the wind speed tend to increase operating costs and reduce the reliability and stability of electricity grids [4]. Therefore, with the goal of addressing these problems and improving the utilization efficiency of wind power conversion, the accurate and stable forecasting of wind speed has become a popular research topic [5,6].

During the past few decades, an increasing number of technologies have been proposed for predicting wind speed. These approaches can largely be divided into five categories [7]: physical models, conventional statistical models, spatial correlation models, artificial intelligence models, and hybrid forecasting models. Physical models, which are suitable for long-term wind speed forecasting, consider not only historical data, but also make use of physical parameters,

* Corresponding author.
E-mail address: renshengdp@126.com (P. Du).

http://dx.doi.org/10.1016/j.apenergy.2017.10.031
Received 4 July 2017; Received in revised form 2 September 2017; Accepted 5 October 2017
0306-2619/ © 2017 Elsevier Ltd. All rights reserved.

Please cite this article as: Wang, J., Applied Energy (2017), http://dx.doi.org/10.1016/j.apenergy.2017.10.031



The values of the new installed capacity Jan-Dec 2016.

Country	China	USA	Germany	India	Brazil
MW	23328	8203	5443	3612	2014
Country	France	Turkey	Netherlands	UK	Canada
MW	1561	1387	887	736	702

Fig. 1. Distribution of wind power all over the world in 2016.

including temperature, density, speed, and topography information [8,9]. In contrast, statistical models, such as the autoregressive (AR) model, autoregressive moving average (ARMA) model, and the widely used autoregressive integrated moving average (ARIMA) model, are more appropriate for short-term wind speed prediction, which is simple to implement by various historical data. However, these models cannot handle the non-linear features of wind speed due to their linear correlation structure [10]. Typically, spatial correlation models primarily utilize the spatial relationships between wind speeds at different sites. In some cases, they can achieve satisfactory prediction accuracy [11]. However, their information requirements, including wind speed and delay times, add complexity and cost to the implementation of spatial correlation forecasting [12]. Fortunately, with the rapid development of soft-computing techniques, many different intelligent algorithms, including artificial neural networks (ANNs), support vector machines (SVMs) [13], and other mixed models have been successfully developed and widely applied for wind speed forecasting [14–16].

Due to the inherent weakness of each model, as well as the intermittency and complex fluctuations of wind speed, individual forecasting model cannot always capture the characteristics of time series, especially when comes to the non-linear traits of wind speed. Thus, in order to obtain an advanced forecasting method for higher accuracy levels and wider forecasting horizons, approaches, called hybrid models [17] have emerged. These models incorporate the individually superior features of multifarious algorithms, including forecasting models (i.e., SVM, ANNs, etc.), intelligent optimization algorithms (i.e., the bat algorithm (BA) [18], Whale Optimization Algorithm (WOA) [19], etc.), and data-processing algorithms (i.e., singular spectrum analysis (SSA) [20], variational mode decomposition (VMD) [21], complete ensemble empirical mode decomposition with adaptive noise (CEEMDAN) [22], etc.). Recently, with the aim of achieving superior forecasting results, many hybrid forecasting models have been successfully presented and have improved the precision of wind speed predictions to some extent. For example, Wang et al. [23] employed ensemble empirical mode decomposition (EEMD), genetic algorithm (GA) and ANNs to predict short-term wind speed and ultimately achieved higher precision than previous methods. Similarly, Xiao et al. [24] developed a novel hybrid forecasting architecture, which integrated improved BA, SSA, and a general regression neural network (GRNN) for multi-step wind speed forecasting. Numerical experiments demonstrated that their proposed hybrid model can obtain the most accurate forecasting results for one-step to three-step wind speed forecasting. Sun et al. [25] proposed a new dynamic integrated approach by utilizing phase space reconstruction, data preprocessing approaches, and a core vector regression model, optimized by the competition over resource heuristic algorithm, for wind speed forecasting. The results indicated that their proposed integrated method can significantly improve forecasting effectiveness and statistically outperform the benchmark models used for comparison.

However, to the best of our knowledge, most previous studies are based on single-objective optimization algorithms for improving prediction accuracy, which neglect the importance of forecasting stability improvement, despite it being vital to the effectiveness of forecasting models. More importantly, both accuracy and stability are very significant, especially when evaluating the prediction performance of different models. It is noteworthy that the problem of achieving high accuracy and strong stability simultaneously for wind speed forecasting belongs to the set of multi-objective optimization problems (MOPs) rather than the set of single-objective optimization problems (SOPs). Therefore, multi-objective optimization algorithms should be introduced into the field of time series forecasting to achieve more accurate and stable prediction results, simultaneously.

Fortunately, recent soft-computing technique development has yielded many new multi-objective algorithms, such as the multi-objective BA (MOBA) [26], binary coded elitist non-dominated sorting GA (NSGA-II) [27], multi-objective ant lion optimizer (MOALO) [28], multi-objective dragonfly algorithm (MODA) [29], etc. Currently, the application of multi-objective optimization techniques can be observed in many fields of research, such as mechanical engineering [30], the design of water distribution networks [31], and other fields [32].

Download English Version:

https://daneshyari.com/en/article/6681673

Download Persian Version:

https://daneshyari.com/article/6681673

Daneshyari.com