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Review

Application of support vector machine models for forecasting solar and wind energy resources: A review

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ABSTRACT

Conventional fossil fuels are depleting daily due to the growing human population. Previous research has proved that renewable energy sources, especially solar and wind, can be suitable alternatives to the conventional energy sources that could satisfy global demand and protect the atmospheric environment. There are many factors that influence the performance of solar and wind energy predicting tools. The accurate forecasting of solar and wind energy resources is highly needed for the optimum utilization of these resources. Different methods have been applied to forecast solar and wind energy resources. Prediction performance of the support vector machine modeling approach found to be better than other modeling approaches. The support vector machine is fast, simple-to-use, reliable and provides accurate results. Findings based on critical analysis suggests that the hybrid support vector machine models can reach much higher accuracies than other models for both solar and wind energy predictions for most of the locations. This investigation highlighted main problems, opportunities and future work in this research area. Novel hybrid models are proposed for further investigation for more accurate predictions of solar and wind energy resources.

Contents

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1. Introduction

Energy plays a substantial role in modern society. Conventional fossil fuels are expected to be depleted due to growing demand and rapid industrialization. Renewable energy generation has drawn much attention from industries and researchers in recent decades mainly due to the abundance and sustainability of wind and solar energy.

In recent decades, many wind turbines and photovoltaic cells have been installed worldwide (Xu et al., 2018; Menezes et al., 2018). However, there are still issues, including large-range variable amount of power generation, due to variation in wind speed and direction. For solar energy, different parameters, such as solar elevation angle, haze effect and cloud cover, will cause fluctuations in output (Ren et al., 2015). The intermittent and variable output could lead to heavy negative impacts on grid, electricity transmission and distribution equipment, which prevent widespread use of green energy generation. Output forecasting has thus become important for the generation and implementation of wind and solar power systems.

Conventional and empirical models have been applied in a traditional way to forecast the resources of wind and solar energy, but they have demonstrated insufficient accuracy as well as other important limitations (Qazi et al., 2015; Lawan et al., 2017). Fortunately, artificial intelligence-based techniques have addressed these issues effectively. Artificial intelligence methodologies are relatively a new sort of modeling approach that have shown very promising results in modeling and analysis of systems in various branches of science. Such methodologies have the potential to deal with the uncertainties and other shortcomings of the traditional methods to real-world applications. Related applications will likely become more and more prevalent due to their robust, fast and accurate responses. There are many artificial intelligence forecasting models that have been developed for highly accurate estimations. Artificial neural network (ANN) is one of them that has been widely implemented to forecast system outputs in different investigations. However, many investigations have revealed disadvantages of ANNs. In other words, in some cases the prediction results of the ANNs are incorrect and/or consume too much time for a large neural network. Moreover, there is no proven method for selecting the numbers and sizes of hidden layers as well as activation functions to develop a high-precision model (Zendehboudi, 2016; Fayazi et al., 2014). Fortunately, another artificial intelligence forecasting model—support vector machine (SVM) approach has been confirmed to have better accuracy and speed in solving nonlinear problems.

This paper aims to provide a rigorous and critical analysis of the state-of-the-art review on the application of support vector machine models for solar and wind energy forecasting. No studies were found to provide a comprehensive analysis of this subject in the available literature. This paper is organized into five sections: after passing through introduction in Section 1, Section 2 presents the research methodology procedures and the steps to select the publications analyzed. Section 3 explains relevant descriptive statistics, while a brief introduction of SVMs is presented in Section 4. In Sections 5 and 6, developments of SVMs in the fields of solar and wind energy are presented by considering subgroups of application of SVMs. Next, the research gaps in these fields are identified and discussed, and finally Section 7 concludes this study. This work allows recognizing the main problems from the current available literature.

2. Research methodology

The SVM approach to predict wind speed was first introduced 14 years ago. More and more investigations have been conducted in this field and lots of advances have been achieved for the last few years. To assess the performance of SVM in the field of renewable energy, the authors have carried out a comprehensive review on the SVM models in wind and solar energy resources. By adopting a systematic literature review methodology, firstly, the publications in the desired areas are extracted and selected; and, secondly, the analysis of the publications was carried out by grouping them into different categories based on the SVM methodology application. Previous published papers on application of SVM in solar and wind energy were collected by searching through ScienceDirect, Engineering Village, ISI Web of Science, and Google Scholar databases. Further, at the end, a search in the databases of the major international publishers, such as Elsevier, IEEE Xplore, Springer, Taylor & Francis, ASME, Hindawi and Wiley, was conducted to guarantee the accuracy of gathered related papers. Keywords to select the studies were chosen taking into consideration the main words referring to this field and the words that widely adopted by scholars. In each research string, the keywords used for the selection of articles are: ‘solar’ or ‘wind’ or ‘estimation’ or ‘forecasting’ or ‘data-driven’ or ‘artificial intelligence techniques’ or ‘support vector machine’ or ‘SVM’ or ‘regression’ or ‘soft computing’ or ‘self-organizing maps’. The research was carried out by limiting the database and searching for keywords in “article title, abstract, keywords” and then adding constraints concerning “document type” (“article” “article in press” and “review”) and “subject area” focusing on research areas related to the solar and wind energy. Data were collected in December 2017. Different criteria were adopted and implemented to filter the articles. We focused on contributions published in English peer-reviewed academic journals without any restriction on the publication date. However, it should be highlighted that in the review process, conference papers, masters and doctoral dissertations, and the articles without clear information regarding the publisher and page number were excluded. Articles were selected for further analysis if the paper assessed, discussed or pointed out to forecasting solar and wind energy resources. After this preliminary step, the selected full papers were read independently to increase the effectiveness of the collection process. The reviewed literature is mostly published between 2009 and 2017 and mainly related to critical review of forecasting models. The forecasting statistical accuracies are compared systematically for both solar and wind resources for various modeling approaches. Different spatial correlation models, artificial intelligence methods and hybrid models are systematically compared and prediction performances are reported.