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Modelling a combined method based on ANFIS and neural network improved by DE algorithm: A case study for short-term electricity demand forecasting

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ABSTRACT

Electricity demand forecasting, as a vital tool in the electricity market, plays a critical role in power utilities, which can not only reduce production costs but also save energy resources, thus making the forecasting techniques become an indispensable part of the energy system. A novel combined forecasting method based on Back Propagation (BP) neural network, Adaptive Network-based Fuzzy Inference System (ANFIS) and Difference Seasonal Autoregressive Integrated Moving Average (diff-SARIMA) are presented in this paper. Firstly, the combined method uses all the three methods (BP, ANFIS, diff-SARIMA) to forecast respectively, and the three forecasting results were obtained. By multiplying optimal weight coefficients of the three forecasting results respectively and then adding them up, in the end the final forecasting results can be obtained. Among the three individual methods, BP and ANFIS had the ability to deal with the nonlinearity data, and diff-SARIMA had the ability to deal with the linearity and seasonality data. So the combined method eliminates drawbacks and incorporates in the merits of the individual methods. It has the capability to deal with the linearity, nonlinearity and seasonality data. In order to optimize weight coefficients, Differential Evolution (DE) optimization algorithm is brought into the combined method. To prove the superiority and accuracy, the capability of the combined method is verified by comparing it with the three individual methods. The forecasting results of the combined method proved to be better than all the three individual methods and the combined method was able to reduce errors and improve the accuracy between the actual values and forecasted values effectively. Using the half-hour electricity power data of the State of New South Wales in Australia, relevant experimental case studies showed that the proposed combined method performed better than the other three individual methods and had a higher accuracy.

Contents

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1. Introduction

As people's living standard and social-economic level have improved significantly, natural energy consumption continues to grow. Energy shortage becomes increasingly serious, so that more and more countries have attached great significance to these hot issues. As the major impetus to improve the development of society, electricity, one of the most important energy resources, plays a crucial role in the power system. It is known that, electricity is a resource which is difficult to store; besides, the electric system is affected by various unstable factors, namely weather, population, holidays, emergency and more. All the enormous problems make it difficult for the electricity production industry to estimate their output. Thus, an accurate and precise forecasting method is needed in the electricity market. On the contrary, inappropriate electricity demand forecasting will be counterproductive. An overestimated method will increase the workload of the electricity production and dissipate the energy resources. Bunn and Farmer pointed out that 10 million dollars of extra costs will increase in operating because of the 1% increasing forecasting errors in electricity production [1]. Meanwhile an underestimated method will paralyze the electricity grid, and some regions will face power failure situations. It's quite clear that a good forecasting method which can avoid many disasters is the key to respond to the future electricity demand. Therefore, precise electricity demand forecasting is the prerequisite to meet the demand, no matter whether for developed countries or developing countries. No matter for what kind of electricity demand forecasts, long-term, midterm or others, developing a novel method which cannot only be effective but also improve the forecasting accuracy is a must [2].

More and more novel methods have been proposed in recent years because of the necessity for better forecasting performance. For example regression based methods and time series based methods. Among the regression methods, linear regression methods are the most widely used ones. Goia et al. [3] applied linear regression method to forecast the peak load. Bianco et al. [4,5] used the linear regression models to forecast the electricity consumption in Italy. ARIMA is the most commonly used method in time series models. For instance, Dong et al. [6] employed the time series approach to forecast long-term load, Erdogdu et al. [7] analyzed electrical demand by using ARIMA in Turkey, and Wang et al. [8] proposed seasonal ARIMA to forecast electricity demand in China. Because of the nonlinear characteristics which the electricity demand time series apparently experiences, even though these methods (regression based methods, time series based methods) are presently mature, they still have drawbacks so that they cannot properly forecast the nonlinear load series. Moreover, these methods are affected by reliability and availability of external factors to a great extent.

For the last several decades, Artificial Intelligence (AI) methods have demonstrated the formidable ability in dealing with the seasonal and nonlinear load data. More and more new methodologies and techniques have emerged, such as the fuzzy logic system [9,10], the expert system [11,12], the grey prediction models [13,14] the Artificial Neural Networks (ANN) [15–17], the fuzzy inference system [18–20]. Among all these methods, artificial neural networks and fuzzy theories are well received. Due to that they have the capacity to process the nonlinear data. Xiao et al. [21] developed a BP neural network with a rough set to forecast the short-term time series data, and the results proved the priority that BP had. Azwadi et al. [22] used the ANFIS to predict the temperature and flow fields in a lid-driven cavity.

Despite the introduction of artificial intelligence, each of the individual methods still cannot get rid of the fact that none of them are able to give birth to the desired outcomes because of their disadvantages. For instance, neural networks attain the results closer to local ones not the global optimal ones. Expert systems excessively rely on knowledge and cannot gain the optimal results all the time while the grey prediction systems are suitable for exponential growth models. Thus, by considering every method's merits, taking full advantage of them, the concept of the hybrid and combination methods developed rapidly. The thought of the combined method was first introduced by Bates et al. [23], who proved that the combined methods were more efficient and easier than the single ones. In addition, hybrid and combined methods aggregate the advantages of multiple separate methods. Because of these advantages, hybrid and combined methods are widely used in different applications. Xiong et al. [24] proposed a hybrid method based on the support vector regression with a firefly algorithm to forecast stock price index. Yu et al. [25] used a novel hybrid structure named MPSO-BP adaptive algorithm by using the Radial Basis Function Network (RBFN). Tan et al. [26] developed a combined method by using three individual methods namely wavelet transform, ARIMA and Generalized Autoregressive Conditional Heteroscedasticity (GARCH) to forecast the electricity price.

Although hybrid and combined methods have priorities, they focus on different aspects. Hybrid methods use a series of methods to process the data in advance, such as: noise reduction, seasonal adjustment and cluster, while combined methods use weight coefficients compared with the individual methods which constitute the hybrid methods. In reference to the merits of these two kinds of methods, this paper proposes a novel combined method whose advantage is not only linear time series data but also nonlinear time series data can be processed. The combined forecasting methods are as follows: diff-SARIMA method deals with the linear data, while BP method and ANFIS method deal with the nonlinear data. During the parameter optimization process, the DE optimization algorithm was utilized to optimize the weight coefficients of the combined methods. These three methods were used separately in different applications.

The BP neural network is a multilayer feedforward network using the input-output model mapping relation theory which was trained by error back propagation algorithm. By using the steepest grades descent or other methodologies to modulate all the weights and thresholds of the whole network, after several iterations, the least sum of square error can be procured. BP, as one of the most traditional models, was welcomed in many applications. Reliability forecasting models for electrical distribution systems considering component failures and planned outages was used based on BP

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