Electrical Power and Energy Systems 82 (2016) 92–104

Contents lists available at ScienceDirect

Electrical Power and Energy Systems

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

Forecasting energy consumption using ensemble ARIMA–ANFIS hybrid algorithm

Sasan Barak [a,c,*], S. Saeedeh Sadegh [b]

[a] Faculty of Economics, Technical University of Ostrava, Ostrava, Czech Republic
[b] Department of Industrial Engineering, Tarbiat Modares University, Tehran, Iran
[c] Department of SAEQM, University of Bergamo, Via dei Caniana 2, 24127 Bergamo, Italy

ARTICLE INFO

Article history:
Received 11 May 2015
Received in revised form 8 March 2016
Accepted 9 March 2016
Available online 23 March 2016

Keywords:
Energy forecasting
ARIMA
ANFIS
AdaBoost
Ensemble algorithm

ABSTRACT

Energy consumption is on the rise in developing economies. In order to improve present and future energy supplies, forecasting energy demands is essential. However, lack of accurate and comprehensive data set to predict the future demand is one of big problems in these countries. Therefore, using ensemble hybrid forecasting models that can deal with shortage of data set could be a suitable solution. In this paper, the annual energy consumption in Iran is forecasted using 3 patterns of ARIMA–ANFIS model. In the first pattern, ARIMA (Auto Regressive Integrated Moving Average) model is implemented on 4 input features, where its nonlinear residuals are forecasted by 6 different ANFIS (Adaptive Neuro Fuzzy Inference System) structures including grid partitioning, sub clustering, and fuzzy c means clustering (each with 2 training algorithms). In the second pattern, the forecasting of ARIMA in addition to 4 input features is assumed as input variables for ANFIS prediction. Therefore, four mentioned inputs beside ARIMA's output are used in energy prediction with 6 different ANFIS structures. In the third pattern, due to dealing with data insufficiency, the second pattern is applied with AdaBoost (Adaptive Boosting) data diversification model and a novel ensemble methodology is presented.

The results indicate that proposed hybrid patterns improve the accuracy of single ARIMA and ANFIS models in forecasting energy consumption, though third pattern, used diversification model, acts better than others and model's MSE criterion was decreased to 0.026% from 0.058% of second hybrid pattern. Finally, a comprehensive comparison between other hybrid prediction models is done.

© 2016 Elsevier Ltd. All rights reserved.

Introduction

Energy is vital important for development of every country from the social, economic and environmental perspective. It has magnificent effect on industrial and agricultural products, health, sanitary, population, education and human life quality [1].

As energy is a crucial input to industrial part of country, energy demand increases along the industrial function increase. Rapid changes in industry and economy strongly affect energy consumption. Therefore, energy consumption is an important economical index that represents economic development of a city or a country [2]. According to the international energy agent report, there should be many transformations in amount and type of future energy consumption (year 2030). As over the past decade global energy consumption has increased rapidly because of population and economic growth [3,4]. According to wide growth of energy consumption in the last decade, energy demand management is very important for achieving economic success, environment preservation and suitable planning for existing resources that result in self-sufficiency and economic development. Therefore, various techniques have been used for energy demand management to forecast future energy demands accurately [4]. However, energy forecasting is difficult, because it is affected by rapid development of economy, technology, government decisions and other factors [5]. As far as energy prediction is concerned, especially in developing countries such as Iran, lack of data is a critical problem in forecasting. Moreover, missing values and lack of a standard and precise system for data collection raised other issues in such countries [6]. This study proposes a diversified hybrid ARIMA (Auto Regressive Integrated Moving Average)–ANFIS (Adaptive Neuro Fuzzy Inference System) model to deal with such problems in energy consumption.

The contribution of the paper is summarized as follows:

- Developing a hybrid ARIMA–ANFIS algorithm based on three different patterns.

* Corresponding author at: Faculty of Economics, Sokolská třída 33, Ostrava, Czech Republic. Tel.: +420 722459247; fax: +420 597 322 008.
E-mail addresses: Sasan.barak@gmail.com, sasan.barak@vsb.cz (S. Barak).

http://dx.doi.org/10.1016/j.ijepes.2016.03.012
0142-0615/© 2016 Elsevier Ltd. All rights reserved.

- Using diversification method to deal with data insufficiency.
- Finally, comparing all patterns with different prediction models.

This paper is organized as follows. A comprehensive literature for energy forecasting models such as ARIMA, fuzzy and ANFIS models as well as Ensemble models is reviewed in Section 'Literat ure review'. In Section 'The background' details of ARIMA, ANFIS and AdaBoost (Adaptive Boosting) models are described and our proposed algorithms with 3 patterns are explained in Section 'The proposed model'. In Section 'Application and results', the proposed models have been evaluated using energy consumption data from Iran. Finally, conclusions are given in the last section.

Literature review

Increasing global energy demand requires intelligent forecasting algorithms and models. Suganthi and Samuel [4] have surveyed many different models in the field of energy forecasting and introduced two types of models including the following: (1) Traditional forecasting models such as time series, regression, econometrics models, and ARIMA. (2) Soft computing models such as fuzzy logic, genetic algorithm, neural network, support vector regression models for forecasting national and regional energy demand.

Time series models are the simplest models for trend analysis in energy forecasting. Some time series approaches such as traditional statistical models including the following: moving average, exponential smoothing and ARIMA are linear forecasting methods [7].

ARIMA model is one of the most popular time series models and has been broadly used [4,7]. Pappas et al. [8] proposed ARIMA model for forecasting Greek electricity consumption and compared the proposed model with three analytical time-series models. Results showed that ARIMA model is more efficient than the other time-series models.

From the other point of view, statistical forecasting methods usually require normal data, while large data sets are trendy or seasonal data pattern are often inadequate or noisy [2,9,10]. ARIMA models are linear but real time series rarely has linear structure.

Energy demand is forecasted based on economic and non-economic indexes. The nonlinearity of these indexes and energy demand have led to a search in the field of artificial intelligence approaches such as neural network and fuzzy models [11]. These methods are used because of high flexibility and power of forecasting, estimating and overcoming with noisy data [12].

Pao [13] forecasted Taiwan energy consumption by neural networks and linear models. Neural network has functioned better than the linear models.

But depending on situation, accuracy of ANN methods decreases because of several reasons. Forecasting accuracy of ANN depends on learning data set and their adequacy. Moreover ANN methods sometimes get stuck in local minimum, so choosing proper data set, is too critical in neural network models and these models get good results only when the number of data is high [14].

Fuzzy models have good results in varying situations with inadequate data. Recently, fuzzy logic has been widely used to deal with high level of uncertainty issues [15,16]. Accuracy of energy forecasting is usually impressed by data uncertainty and interdependency between model's variables. These relations are eliminated by classification of fuzzy model [17]. Mamlook et al. [18] forecasted short term electricity consumption of Jordan by fuzzy model and found that fuzzy model performed much better than the usual statistical forecasting models.

Yet, probabilistic consumption pattern cannot be correctly forecasted just by fuzzy based or time-series models. Azadeh et al. [6] proposed fuzzy-regression hybrid model to improve estimation and forecasting of energy consumption, with use of small set of (inadequate) data, population and GDP as inputs. They used annual data from Iran and some other countries from 1995 to 2005 and the results showed the superiority of proposed hybrid model compared to single models. The application of fuzzy models in energy is reviewed by [19]. The review indicates that fuzzy based models in energy field provide realistic estimates.

ANFIS

ANFIS (Adaptive Neuro Fuzzy Inference System) model is one of the most popular artificial intelligent models that have got advantages of both neural network and fuzzy model. The first application of ANFIS in time-series prediction is the Jang's work [20]. In ANFIS, the relations between variables are shown by fuzzy If-Then rules. Therefore it can interpret the obtained results, which is not possible with the structures such as neural network [21]. It is also one of the best models in estimation function among other neuro-fuzzy models [22].

Ying and Pan [23] applied ANFIS model to forecast annual regional electricity load in Taiwan with data of years from 1981 to 2000. According to MAPE criteria and statistical results, ANFIS model was found to perform better than regression, neural network, support vector machines, genetic model and fuzzy hybrid systems. Efendigil et al. [10] compared neural network and ANFIS model for forecasting demand with incomplete data. Results showed that ANFIS could be used in demand forecasting with limited data. Akdemir and Çetinkaya [24] proposed an ANFIS model to forecast the annual energy demand in Turkey with use of population, income level, peak load and energy demand data for 27 years. In spite of small number of data, good results were obtained. Al-Ghandoor et al. [25] forecasted energy demand in Jordan's transportation, with the use of two models: ANFIS and quadratic exponential smoothing. Annual data from 1985 to 2009 were used to forecast energy demand for years from 2010 to 2030 and results expressed efficiency of ANFIS model in energy demand forecasting. Thus, most of the results showed that ANFIS had good results in energy demand modeling and forecasting.

ARIMA–ANFIS

Recently, hybrid ANFIS models have been successfully used. Azadeh et al. [26] proposed a hybrid ANFIS model for forecasting monthly electricity demand in Iran and yielded good results compared to time series model, genetic algorithm and neural network. Li et al. [27] compared neural network and genetic-ANFIS hybrid model to forecast daily energy demand of a hotel. Results showed good performance of hybrid model, though hybrid model was complicated. Li and Hu [28] proposed an ARIMA–fuzzy system model for time series forecasting. First, a Sugeno fuzzy model was applied on input–output data to produce fuzzy rules. Then, ARIMA model was embedded in answer part of fuzzy rules and obtained good results. Babu and Reddy [29] proposed a hybrid model of ARIMA and ANN based on moving-average filter model. Then, using a simulated data set and experimental data sets such as sunspot data, electricity price data, and stock market data, the proposed hybrid ARIMA–ANN model was applied along with individual ARIMA and ANN models and some existing hybrid ARIMA–ANN models. Table 1 shows some features and results of the explained studies:

As can be seen from Table 1, the performance of hybrid ANFIS model in energy forecasting, is so brilliant especially in lack of data and varying situations and more precise results have been achieved after hybridization with other models. Also, using ensemble model as a new concept has improved the result of energy forecasting [40].

Download English Version:

https://daneshyari.com/en/article/398186

Download Persian Version:

https://daneshyari.com/article/398186

Daneshyari.com