Energy 157 (2018) 327–335

Contents lists available at ScienceDirect

Energy

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

Using a novel multi-variable grey model to forecast the electricity consumption of Shandong Province in China

Lifeng Wu [a, *], Xiaohui Gao [a], Yanli Xiao [a, **], Yingjie Yang [b], Xiangnan Chen [a]

[a] College of Economics and Management, Hebei University of Engineering, Handan, 056038, China
[b] Centre for Computational Intelligence, De Montfort University, Leicester, LE1 9BH, UK

ARTICLE INFO

Article history:
Received 9 June 2017
Received in revised form
13 April 2018
Accepted 22 May 2018
Available online 26 May 2018

Keywords:
Electricity consumption forecasting
Multi-variable grey model
Population
Fractional order accumulation

ABSTRACT

The electricity consumption forecasting problem is especially important for policy making in developing region. To properly formulate policies, it is necessary to have reliable forecasts. Electricity consumption forecasting is influenced by some factors, such as economic, population and so on. Considering all factors is a difficult task since it requires much detailed study in which many factors significantly influence on electricity forecasting whereas too many data are unavailable. Grey convex relational analysis is used to describe the relationship between the electricity consumption and its related factors. A novel multi-variable grey forecasting model which considered the total population is developed to forecast the electricity consumption in Shandong Province. The GMC(1,N) model with fractional order accumulation is optimized by changing the order number and the effectiveness of the first pair of original data by the model is proven. The results of practical numerical examples demonstrate that the model provides remarkable prediction performances compared with the traditional grey forecasting model. The forecasted results showed that the increase of electricity consumption will speed up in Shandong Province.

1. Introduction

Energy plays an important role in the course of economy development and social progress. Energy forecasting constitutes a vital part of energy policy of a country, especially for a developing country like China whose economy is in a stage of energy consumption structure adjustment [1]. This has motivated many researchers to focus on energy forecasting. Such as, Chai et al. used Bayesian combination model to forecast energy demand of China [2]. Ji predicted the petroleum consumption in China by comparing three models [3]. Niu and Meng predicted annual electricity consumption in China [4]. Zhang et al. forecasted Chinese transport energy demand based on partial least square regression [5], Li et al. used the least squares support vector machine with a fruit fly optimization algorithm to predict the annual electricity load [6]. Zhu et al. provided a seasonal hybrid procedure for electricity demand forecasting in China [7]. Li et al. combined the adaptive grey model with intelligence computation to predict the short-term electricity consumption [8]. Hu and Jiang used a neural-network-based grey residual modification to forecast the energy demand [9]. He et al. proposed a hybrid model equipped with the minimum cycle decomposition concept for forecasting electrical load over a short term [10]. Ma and Liu put forward a novel time-delayed polynomial grey model to predict the natural gas consumption in China [11]. Tsai et al. confirmed that the modified grey model had a higher forecasting accuracy for renewable energy than the original grey model [12]. Xu et al. discussed the grey prediction model with the nonlinear optimized time response method for forecasting electricity consumption in China [13]. Grey Verhulst model and the nonlinear grey Bernoulli model have forecasted that the Chinese natural gas demand will reach 315 billion m^3 by 2020 [14]. Turkey's sectoral energy demand is forecasted by using a fuzzy grey regression model [15]. The electricity demand across different countries is forecasted 24 months in advance [16]. The real monthly electricity consumption and macroeconomic data from China have been studied to verify the effectiveness of the vector error correction model [17]. A comprehensive review and summarization of decomposition based approach for the electricity demand forecasting is conducted [18]. The week day/weekend/holiday consumption profiles to infer the proportion of industrial and domestic electricity consumption is discussed [19]. The bottom-up approach is used to evaluate the trajectory of long term annual electricity

* Corresponding author.
** Corresponding author.
E-mail addresses: wlf6666@126.com (L. Wu), 84536065@qq.com (Y. Xiao).

https://doi.org/10.1016/j.energy.2018.05.147
0360-5442/

consumption of a sector of the Brazilian industry up to 2050 considering energy efficiency scenarios [20]. Two deep recurrent neural network models are proposed for electricity forecasting [21].

The conventional energy consumption prediction models can be roughly divided into three types: regression model, intelligence computational technologies and time series method. However, the prediction accuracies of the time series method and regression method rely on the distribution of the original series as well as a large amount of observed data. The successes of intelligence computational technology needs a large amount of training data. In many practical situations, because of limitation for time and cost, it is very difficult to obtain the complete information from the analyzed system. In order to accurately analyze and predict the uncertain systems, many studies on energy consumption forecasting using grey models and improved grey models have been reported. Kumar and Jain clearly demonstrated that the time series models (grey-Markov model, grey-model with rolling mechanism and singular spectrum analysis) have enormous potential for forecasting energy consumption [22]. Zhou presented a trigonometric grey prediction approach for forecasting electricity demand by combining the traditional grey model with the trigonometric residual modification technique [23]. Lee and Tong developed an improved grey forecasting model that combined residual modification with genetic programming sign estimation [24]. Diyar and Mehmet proposed grey rolling mechanism approach to predict the Turkey's total and industrial electricity consumption [25]. Pao and Tsai compared the forecasting ability of the grey model with that of the autoregressive integrated moving average model over the out-of-sample period between 2002 and 2007 [26]. Pao et al. proposed a numerical iterative method to optimize the parameters of the nonlinear grey Bernoulli model [27]. Li et al. applied the cubic spline function and Taylor approximation method to optimize the grey model for achieving a high power system load forecasting accuracy [28]. An overview of energy demand grey forecasting methods published in 2005–2015 is given [29]. However, these models are all first-order grey models with one variable and only contain the information relating to the predicted series during modelling. Therefore, these models have significant limitations [30].

The multi-variable grey forecasting model is represented by GM(1,N), GM(1,N) is composed of a system characteristic sequence (or dependent variable sequence) and (N-1) related factor sequences (or independent variable sequences). The modeling process takes full account of the effect of the relevant factors on the system change, and it is a typical causal forecasting model. It can make full use of the information contained in the associated series. In the view of the available additional information, GM(1,n) is likely to show higher forecasting accuracy than GM(1,1) [31]. Therefore, in this paper, a new multi-variable grey model is used to forecast energy consumption.

The main contributions of this paper are summarized below. 1) The first pair of original data by the model is effectiveness. Practical examples demonstrate that the model provides remarkable predictive performance. 2) To obtain more valuable data, the grey convex relational method is applied to identify the key factor associated with electricity consumption. 3) A multi-variable grey forecasting model that considered total population is implemented to forecast the electricity consumption in Shandong Province. 4) The proposed forecasting method can effectively predict the future electricity consumption and outlook the consumption trend in Shandong province.

The rest of the paper proceeds as follows. Section 2 is a compendium of annual electricity consumption in Shandong Province, China. A novel grey model is presented in Section 3. The electricity consumption of Shandong Province in China is predicted in Section 4. Some conclusions and discussion are given in the final Section.

Fig. 1. Shandong Province and its location in China.