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Forecasting Short Term Electricity Price Using Artificial Neural Network and Fuzzy Regression

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Abstract

It is very important to forecast electricity price in a deregulated electricity market for choosing the bidding strategy, and it is the most important signal for other players. It engulfs information for both customers and producers in order to maximize their profit. Thus, choosing the best method of price forecasting is a crucial task to have the most accurate forecast. In this paper the price forecasting is done based on different methods including autoregressive integrated moving average (ARIMA), artificial neural network (ANN) and fuzzy regression. The method is examined by using data of Ontario electricity market. The results of different methods are compared and the best method is chosen. Fuzzy regression model is a new method in forecasting and it is rare in the literature review; it is showed that it leads to the best results.

Keywords: ARIMA, Artificial neural network, Fuzzy regression, forecasting

Introduction

In today's deregulated electricity market price forecast is key information. Companies that trade in the electricity market extensively use price forecast techniques either to bid or hedge against volatility. When bidding in a pool of electricity market, the participants are expressed their bid in the term of prices and quantities. Until the total demand is met, the bids are accepted in the increasing form, so that the company that have the ability to forecast the pool price can adjust its own production schedule and price depending on its hourly pool prices and its own production costs. Also transmission constraints limit the transportation of electricity from one region to another. These constraints in the electricity market make the extreme price volatility or even price spikes of electricity market [1]. in the past two decades many methods have used in order to forecast electricity price. These methods are fall into three categories. These three groups are game theory based models, Time series models and simulation based models. The first method is based on game theory and it is of great interest to model the

strategies of the market participants and identify solution of those games [2]. In the simulation based models for price forecasting the exact model of the system is built [3]. Simulation methods are intended to provide detailed insights into system prices. However, these methods have some drawbacks, they need a detailed data and also they are complicated to implement and their computational cost is very high [4]. Time series methods focuses on the past behavior of the dependent variable and sometimes exogenous variables [5].these methods are very popular in the field of price forecasting. Different time series techniques are used in order to predict electricity price. In this category, one of the most important and widely used method is auto regressive integrated moving average (ARIMA) model. It is popular due to its statistical properties. Other methods such as mixed ARIMA models and generalized auto regressive conditional heteroskedastic (GRACH) have been proposed for this purpose [6]. Besides these methods artificial intelligent methods have been used in this field recently. Artificial neural networks (ANNs) have been applied in many researches for forecasting electricity price [7]. the most important advantages of this method is its flexibility in using nonlinear models, using ANN there is no need to introduce a particular model form. And they adaptively formed based on the features presented from the data. This feature is suitable for many empirical datasets where there is no specific theoretical guidance presented. Other methods such as fuzzy neural network methods [8], support vector machines (SVMs) [9] in this field. The hybrid methods such as combination of similar day and neural network techniques [10], extended Kalman filter based neural network [11], weighted nearest neighbors (WNN) method [12], and fuzzy interference system and least squares estimation [13] are used to predict electricity price. The fuzzy regression models have not been applied in this field yet and this method can be very useful. In this paper, there different methods including ARIMA model, artificial neural network model and fuzzy regression model have been used. These techniques have been applied on the information of Ontario electricity market.

Methodology

A time series is a sequence of data points. Time series can be analysis in order to extract meaningful data and characteristics of data. Time series can be used for forecasting future events based on past events that they are known in time series models, time series forecasting is a very popular issue in econometrics. Auto regressive models can be used to forecast electricity price, these models have a good performance and they have been used in the literature. Generally time series models are linear models and forecasting values which produce by time series models like ARMA and ARIMA models are produced by linear functions; these functions are very common in forecasting methods. Series of AR and MA with the parameters of $\theta_j, (j = 1,2, \dots, q)$ and $\emptyset_i, (i = 1,2, \dots, p)$ respectively are autoregressive and moving average. A none stationary series of $\emptyset p(B)\ (1 - B)^d Yt = \theta 0 + \theta q(B) Zt$ called autoregressive integrated moving average model ARIMA (p,d,q) which $\theta_j, (j = 1,2, \dots, q)$ and $\emptyset_i, (i = 1,2, \dots, p)$ are the parameters of AR and MA series which d is the difference degree and p,q are the order.

A. Time series models based on neural networks

ANN models have been used in many different fields in the last few years. The ANN models consist of an input layer, an output layer and one or more hidden layers. The ANN model should

be trained, this training process is the procedure to obtain the weights of each connection and the neurons threshold value. There are many training algorithms were developed, including the back-propagation (BP) algorithm, the Levenberg Marquardt (LM) and so on. The aim of all these algorithms is to achieve the minimal value of network error. The ANN trained time series are capable to model arbitrarily linear and nonlinear functions. ANN models properties make them utilizing in the various different fields such as time series forecasting and specially it has been used in electricity price forecasting. In most cases an ANN is an adaptive system that changes its structure based on external or internal information that flows through the network during the learning phase. Modern neural networks are non-linear statistical data modeling tools. Basic computational element of model neuron is a node or unit. Its input comes from other units, or from an external source. These inputs together are considered as a vector. Each signal is multiplied to its weight. The sum of these weighted inputs is showed the net input to unit.

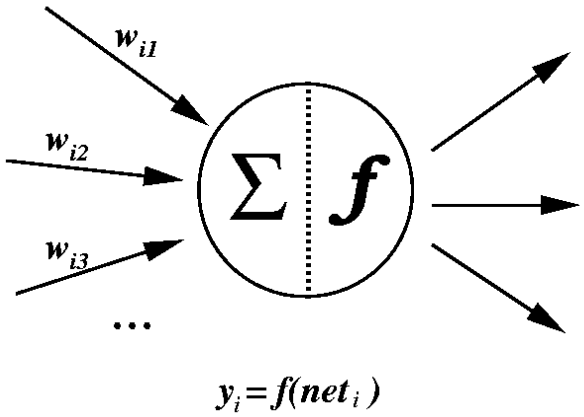

Fig.1. The Artificial Neural Network

The function f is the unit's activation function. The simplest case is that *f* is the identity function, and the output of the unit is just its input. This is called a linear unit. In the cases that function *f* compresses the net function in which with the varying in net the output doesn't change significantly the activation function is usually a sigmoid function. Neural networks can be multiple layers, these layers called hidden layers. Layers can be cascaded to form multiple layers. In this case the output of each layer can be the input of the next layer, multiple layer networks have more capacity and ability to calculate in comparison with a single layer network. The network is learned in order to have a desired output with the specific group of data, these inputs and outputs can be considered as vectors. The network is trained through the sequential input vectors and adjusting the weights with a specific methods that have been known. In the training procedure the weights of network are going to be convergent gradually, and with the obtained weights; output data can be obtained by the input data. In this study the electricity price is forecasted through time series forecasting and neural network time series methods in Ontario electricity market.

B. Fuzzy regression model

Fuzzy regression model is the extension of the classic regression in which some elements like input or output or both of them is fuzzy numbers. The purpose of the fuzzy regression models is to find the best solution with the least error. Hojati et al. proposed the fuzzy regression model, named HBS1, which minimize the summation of the total deviation of the upper points

of H-certain predicted and associated observed intervals and deviation of the lower points of H-certain predicted and the associated observed intervals. The proposed model is as below [14]:

$$\text{Minimize} \quad \sum_{i=1}^{n}\left(d^{+}_{iU}+d^{-}_{iU}+d^{+}_{iL}+d^{-}_{iL}\right)$$

$$\text{subject to}: \quad \sum_{j=0}^{k}\left(\alpha_j+(1-H)\times c_j\right)\times x_{ij}-d^{-}_{iU}\geq \bar{y}_i+(1-H)\times e_i-d^{+}_{iU} \qquad i=1,\cdots,n,$$

$$\sum_{j=0}^{k}\left(\alpha_j-(1-H)\times c_j\right)\times x_{ij}-d^{-}_{iL}\leq \bar{y}_i-(1-H)\times e_i+d^{+}_{iL} \qquad i=1,\cdots,n,$$

$$\sum_{i=1}^{n}\sum_{j=0}^{k}c_j x_{ij}\leq \upsilon,$$

$$d^{+}_{iU},d^{-}_{iU},d^{+}_{iL},d^{-}_{iL}\geq 0, \qquad i=1,\cdots,n,$$

$$\alpha_j=\text{free}, \quad c_j\geq 0, \quad j=0,\cdots,k,$$

In this model, at most one of the d^{+}_{iU} and d^{-}_{iU} is positive, and also, at most one of the d^{+}_{iL} and d^{-}_{iU} is a positive number and another one will be zero. In fact $|d^{+}_{iU}-d^{-}_{iU}|$ is the distance between upper point of H-certain predicted interval and the upper point of the H-certain observed interval and $|d^{+}_{iL}-d^{-}_{iL}|$ is the distance between lower point of H-certain predicted interval and the lower point of the H-certain observed interval. The summation of these two absolute value distance is the objective function of the model. In this paper this fuzzy regression model is used which has the crisp inputs and fuzzy outputs.

C. Statics measures to determine the accuracy of the forecast

In order to evaluate the accuracy of the forecast, some error measures are used to evaluate the forecast procedure. Two of the most popular errors that are used to evaluate the accuracy are the Mean absolute percentage error (MAPE) and the mean absolute error (MAE).If y_t is the actual observation for a time period t and F_t is the forecasted value in that period, the mean absolute error is

$$MAE=\frac{1}{n}\sum_{t=1}^{n}|y_t-F_t\ | \qquad (1)$$

Where the number of period times is *n*. And, the mean absolute percentage error is

$$MAPE=\frac{1}{n}\sum_{t=1}^{n}|y_t-F_t\ /y_t| \qquad (2)$$

Case study

The day-ahead electricity market of Ontario, Canada is considered in the real-world case study. Fig. 2 shows hourly price of electricity in 1 week from January 21, 2011 to January 27, 2011 which consists of 168 samples.

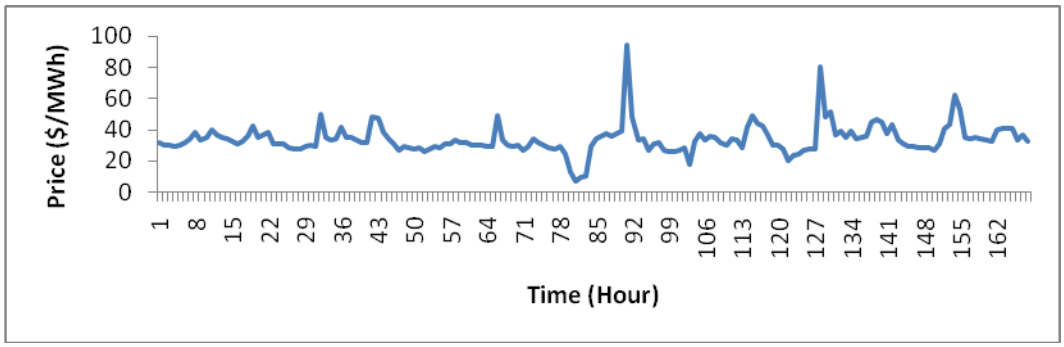

Fig.2. Hourly electricity price in a week

Using classical time series ARIMA model the one hourly electricity price values have been forecasted using models that are explained in the previous section. Accordingly, ARIMA(1, 1, 1) model is the fittest model, the forecasted model and regarding errors can be seen in fig. 2. As it can be seen the first 140 samples are used to estimate the equation and the following 28 samples are forecasted. As it is elucidated in the previous section for forecasting electricity price in the market, three layer neural network, which includes input layer, hidden layer and output layer, is suggested. The proposed model has five inputs, which are the actual electricity price, one hour ago price, the same hour in the previous day price, demand of electricity in that time, and hours of ahead in the same day. t has been tested that the demand of electricity has a direct relation with the temperature, so using demand factor in the input layer of the model implies considering temperature.

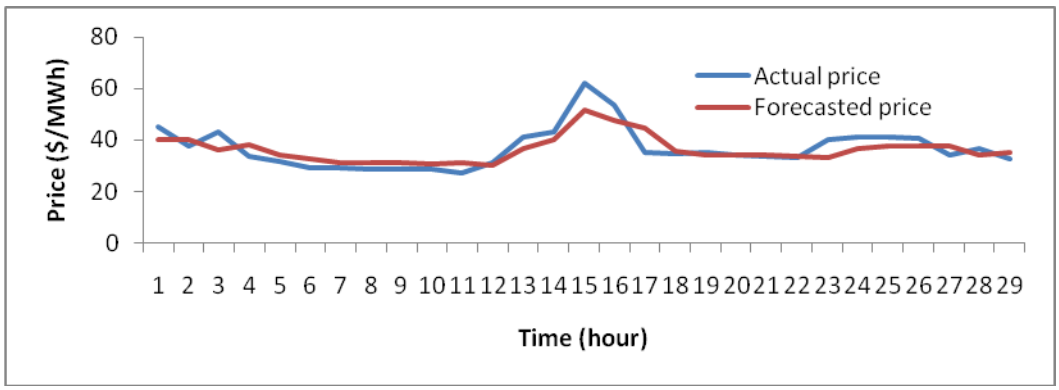

Fig.3. Forecasting using ARIMA model

According to the previous section, using the explained method the forecasted results can be seen in fig. 4. Similar to time series model, the first 140 samples are used for training and the following 28 samples are predicted.

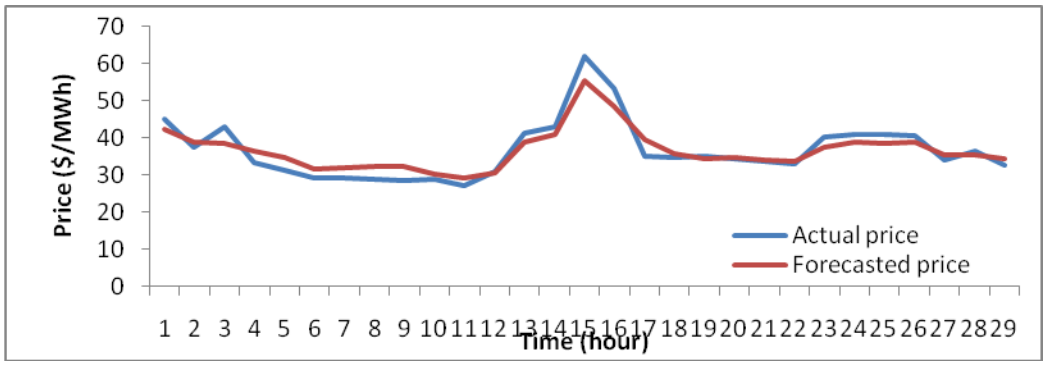

Fig.4. Forecasting using ANN model

Now using fuzzy regression which is clarified before, the price of electricity is predicted. In order to perform fuzzy regression the input variables should be indicated, here the input variables are the same as input nodes of the ANN model. Similar to neural network model data have classified in two groups, train data and test data. Train data are used for training model including almost 80% of the data. Test data which are applied for testing the model and including almost 20% of data have used for calculating the errors of the model. Inputs of fuzzy regression model are the actual electricity price, one hour ago price, the same hour in the previous day price, demand of electricity in that time, and hours of ahead in the same day; these data are crisp data, with the HBS1 model, outputs of the model are fuzzy numbers. In this paper after finding the results of the model, the fuzzy output defuzzified and the forecasted values are obtained. The obtained result can be seen in fig. 5.

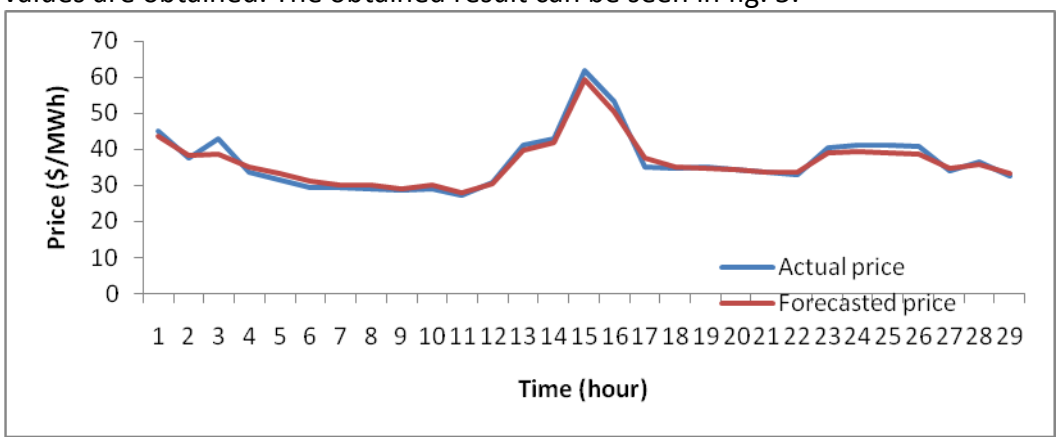

Fig.5. Forecasting using fuzzy regression model

It can be seen that this model obviously has the best result. For comparing the accuracy of discussed models, their accuracy is compare in the table 1.

Table 1. Accuracy comparison between different models

	MAE	MAPE
ARIMA Model	3.523	0.0926
ANN Model	2.55	0.0759
Fuzzy Regression Model	1.854	0.049

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It is clear in the above table the suggested neural network and fuzzy regression model show significant improvement. The suggested fuzzy regression model has a good efficiency comparing to related work.

Conclusion

In this paper Ontario electricity market is used to predict one hour a head electricity price that is a very important issue for power generation and electricity markets, from the statistical analysis the ARIMA model is obtained and decided to determine the input neurons of the ANN model, it is recommended to use three inputs network as ANN network which may have the best performance and it is the most suitable model for the estimation and forecasting. Also, Fuzzy regression model is suggested to predict the electricity price, inputs of this model are chosen the same as ANN model. Selecting the input of model in the ANN and fuzzy regression model has a great importance which can capture the dynamics of the problem, so it is necessary to choose the inputs precisely. After solving these models it can be seen that the ANN and fuzzy regression models are much more efficient. The fuzzy regression model is the new approach in predicting electricity in literature and it has a good efficiency. Using different input variables is recommended to improve the efficiency of the prediction; also other soft computing methods might have the good efficiency in this field.

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