SHORT-TERM ELECTRICITY PRICE FORECASTING USING ARTIFICIAL NEURAL NETWORK

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DECLARATION

I declare that this report entitled "Short-Term Electricity Price Forecasting Using Artificial Neural Network" is the result of my own research except as cited in references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ABSTRACT

Electricity price forecasting has become a crucial job in energy market around the world. Hence, price forecasting also has become a major area of research in the electrical engineering field in recent years. However, predicting electricity price forecasting is a challenging task as the prices show complex volatility patterns. Price forecasting plays an important role in power system planning and operation as these are helpful for dispatch and short terms or spot trading. There are many methods in electricity price forecasting. One of the methods is artificial neural network. Artificial neural network is a computational system that inspired by the structure, ability to learn and method to learn by the human brain. Neural network is a good tool to forecast electricity price in deregulation energy market. Hence, neural network model for short term electricity price forecasting is developed in this project. The sensitivity analysis of neural network is performed to get better accuracy in price forecasting by varying learning rate, momentum rate and number of hidden neurons. Correlation analysis was performed to observe the strength of the relationship between input features and targeted output. The neural network model is examined on the Ontario energy market. The use of neural network to forecast electricity price is proven to produce better result compared to the other existing methods.

ABSTRAK

Peramalan harga elektrik telah menjadi perkara penting dalam pasaran tenaga di seluruh dunia. Oleh itu, ramalan harga juga telah menjadi bidang penyelidikan utama dalam bidang kejuruteraan elektrik dalam beberapa tahun kebelakangan ini. Walau bagaimanapun, meramalkan harga elektrik adalah satu tugas yang mencabar kerana harga menunjukkan pola turun naik yang kompleks. Peramalan harga memainkan peranan penting dalam perancangan dan operasi sistem kuasa kerana ini berguna untuk penghantaran atau perdagangan spot. Terdapat banyak kaedah dalam ramalan harga elektrik. Salah satu kaedah yang boleh digunakan adalah dengan menggunakan rangkaian neural buatan. Rangkaian neural tiruan dikenali sebagai sistem pengiraan yang diilhamkan oleh struktur, keupayaan untuk belajar dan kaedah untuk belajar oleh otak manusia. Rangkaian saraf adalah alat yang baik untuk meramalkan harga elektrik dalam pasaran tenaga deregulasi. Rangkaian neural menunjukkan ramalan yang tepat walaupun dalam keadaan tidak menentu. Analisis kepekaan dalam rangkaian saraf perlu dilakukan untuk mendapatkan ketepatan yang lebih baik dalam ramalan harga yang termasuk kadar pembelajaran, kadar momentum dan bilangan neuron tersembunyi. Analisis korelasi dilakukan untuk mengkaji kekuatan hubungan antara kedua pembolehubah tersebut. Permintaan menunjukkan pekali korelasi yang tinggi. Oleh itu, input pilihan untuk rangkaian saraf adalah permintaan. Ramalan harga elektrik jangka pendek bermaksud tempoh dari beberapa minit hingga satu minggu dan seterusnya. Untuk projek akhir tahun ini, rangkaian neural tiruan telah digunakan sebagai kaedah dalam ramalan harga elektrik jangka pendek. Model rangkaian saraf akan digunakan untuk ramalan harga elektrik jangka pendek di pasaran tenaga Ontario. Penggunaan rangkaian saraf untuk meramalkan ramalan harga elektrik telah menghasilkan hasil yang lebih baik berbanding dengan kaedah lain.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Electricity price forecasting has become one of the most important mechanisms in the electricity markets. In the deregulated power markets, the price is fluctuated because of rivalry among the power suppliers. Benefit expansion has turned into a noteworthy inspiration in the electricity market. The imbalance amongst free market activity brings about unpredictable power costs [1]. There are many entities in the energy market that are involved in the price forecasting such as generators, developers, investors, and customers.

The main issues that connected with electricity prices in planning and operation of competitive market is to perform an accurate forecasting of electricity prices. This is because in nature the price is highly volatile. The volatility of electricity price give more uncertainties and complexities to power system operation and consequently affecting the behavior of generation, transmission and demand in electricity market. Therefore, it is important to forecast the electricity price accurately as it can help to develop well-functioning of power system operation and markets. Thus, it can give advantage to the market operator to compute various indices and measurements for market monitoring.

Forecasting is a planning tool that helps management in its attempts to cope with the uncertainty of the future, relying mainly on data from the past and present and analysis of trends. Furthermore, the forecasting starts with certain assumptions based on management's experience, knowledge and judgment. These estimates are projected into

the coming months or years using one or more techniques such as neural network, ARIMA and fuzzy.

Short-term electricity price forecasting considers as the duration from a few minute to one week onwards. These are helpful for dispatch and short terms or spot trading. Here and now exchanging is intended to benefit the transient varieties in a stack and genuine costs are just known in the wake of coordinating of offers and offers by the market administrators [2]. Therefore, price forecasting is complex tasks because of the agitated price.

In the bidding process, producers submit selling bids to the market operator with their minimum selling prices and in the same time, the consumers submit buying bids to the market operator. Then, the market operator clears the market using a proper market clearing procedure that results in hourly energy prices and accepted selling and buying bids.

Because of the specialized, physical and financial factors, the fluctuation is very common for electricity price. There are many factors that affect the prediction of the electricity price. The factors are weather, demand, supply, and fuel market.

There are many artificial intelligence techniques used in electricity price forecasting such as neural network, ARIMA and fuzzy inferences. Among the different techniques of forecasting, application of neural network for forecasting in power system has received much attention recent years. The main reason of neural network becoming so popular because its ability to learn complex and nonlinearity relationship that are difficult to model with conventional techniques.

1.2 Motivation

Nowadays, there are several changes in the electricity market around the world since the smart meter, real-time pricing and deregulation are introduced. Before deregulation was introduced, the energy market was controlled by the utility companies and the government. The customers can only accept the energy and electricity from the utility companies and need to pay the price that has been specified by the utility companies. After deregulation was introduced, the customers might choose their electricity suppliers. Thus, this situation creates rivalry among the electricity suppliers, provide extensive price flexibility and low electricity price. But, the utility companies still can set their market prices but need to buy the electricity during the stage of the generation before selling to the customers. The company that involved in energy market aggravate far-reaching utilization value prediction strategies whichever on bid alternately should support against instability [3]. That is why developers and electricity traders need to know the future electricity price for their profit.

Other than that, there are two mechanisms for trading which are the pool and bilateral contract. In the pool trading, the energy producers and the consumers submit their prices for bidding and selling respectively. In this condition, there are market operators that in charged to clears the market gives out clearing price on the next day. Developers and electricity traders need to know the future electricity price for their profit. Hence, the electricity price forecasting has become more important. Besides, the companies also want to hedge against the risk of daily price volatility using bilateral contracts. These two mechanisms exist at the same time.

In the deregulated energy market, there is market clearing price (MCP) where the independent system operator (ISO) will be using the market clearing algorithm by referring to the single round disposals to clear the biddings [4]. A good market clearing price (MCP) forecast and its certainty interim estimation can enable utilities independent system operator (ISO) to submit viable offers with low risks [3]. Hence, this forecasting gives benefit for the dispatch and spot trading where spot trading means to service short-

term variation in loads and the actual price only known after matching the bids and offers by market operator.

1.2 Problem Statement

Price forecasting plays an important role in power system planning and operation. Price forecasting is a difficult task. It is very challenging to predict the accuracy of electricity price because the price is highly volatile and non-linear. Based on the previous researchers, correlation analysis can show good relationship between input and output. Researches that have been conducted show the result of forecasting are still need to be improved.

In order to get a better forecast price, the sensitivity analysis needs to be determined. The sensitivity analysis includes learning rate, momentum rate and the number of hidden neurons. The network is able to extract higher statistics by using one or more hidden layer [8]. Furthermore, some researchers did not consider the number of hidden neurons, momentum rate and learning rate in price forecasting by using the neural network, which may lead to inaccurate forecasting.

There are many forecasting methods that have been applied to the short-term price forecasting (STPF). The method that has been applied to price forecasting is the neural network. There are many advantages of using the neural network. The neural network has the possibilities to use a great number of input variables that affect the price and low errors of forecast under high volatility of considered time series [9]. The conventional model did not have the abilities that neural network have where the neural network has the ability to learn complex and nonlinear relationship [5]. Neural network shows an accurate prediction even in volatile situations [5]. This final year project developed short-term electricity price forecasting by using an artificial neural network (ANN) to forecast the future price for 24 hours ahead or one week ahead.

1.4 Project Objective

The main objective of this project is:

1. To analyze the correlation between forecast input and future price by using correlation analysis.
2. To perform sensitivity analysis of a the neural network by varying learning rate, momentum rate, and the number of the hidden neurons.
3. To develop neural network electricity price forecasting model.

1.5 Project Scope

The scopes and limitations of this project are:

1. Neural network model is developed in MATLAB software as a price forecasting method.
2. Sensitivity analysis of neural network is performed by varying learning rate, momentum rate and number of hidden neuron.
3. The future electricity price are predicted for 24 hours ahead.
4. Short-term electricity price forecasting model using neural network is examined on the Ontario energy market.
5. The objective function of this project is mean absolute percentage error (MAPE).

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

There are many methods for electricity price forecasting. The common methods that were used by researchers are time series, data mining and simulation method. The most popular time series method is autoregressive integrated moving average (ARIMA) method. However, neural network is widely used as it can work under non-linearity conditions.

2.2 ARIMA Model

Time series model also can be classified as an old traditional method to predict electricity price. The most common used by the researchers in the linear model is autoregressive integrated moving average (ARIMA) which were introduced by Box and Jenkins. It is a stochastic process that is built into time series data to get more understanding of the data and predict the future series [23].

ARIMA is used to capture linear patterns in the data. The advantage of ARIMA is the flexibility but its major limitation is it can only capture linear correlation. The approach of linear models to a complex real-world problem is not suitable. Other

researchers stated although some modification has been implemented with non-linear models such as neural network, the results of using them for general forecasting problems is limited [3].

Based on the literature review, ARIMA model has been used to predict gas, oil and load forecasting in power system. Norwegian, Spain and California used this method to predict their electricity price [23]. For Californian power market also the ARIMA was used to forecast daily averages prices based on historical data was done [23].

ARIMA model was developed for the Australian national electricity market [10]. A case study presented with the historical data in 2006 to forecast the next 168 hours or one-week electricity prices. It was tested on different seasons; summer, fall, winter, and spring. The mean absolute percentage error produced are 10.46% to 16.06%.

Furthermore, in ARIMA model, the future value of a variable is assumed to be linear function of several past observations with random error. ARIMA model also has been tested for the Czech Republic electricity market in 2014. The mean absolute percentage error (MAPE) was 11.41% [3].

Generally, due to the complex pattern existing in price series and also inherent limitations, just a part of price signal's features can be captured by ARIMA. This model has been tested on Spain electricity market on four different seasonal; summer, fall, winter, and spring. The model was examined in 2002 and the mean absolute percentage error (MAPE) resulted from 6.71% to 21.86%.

From the literature review, ARIMA model is less appropriate to be implemented in the real-world problem because it can only capture linear pattern instead of a non-linear pattern.

2.3 Neural Network Model

The most popular artificial intelligence method is neural network. Many researchers use this method as the neural network has the capability to predict price accurately even in the volatile situation [1, 8, 11, 12, 15, 16, 18, 19]. Artificial neural network (ANN) was inspired by human nervous system which can be handle complex system with the adjustment of the weights in the iterative learning process [12]. Neural network consists of three layers that consist of input layer, hidden layer and output layer [6]. Feed Forward Neural Network (FFNN) is the most preferred neural network type and usually used in the short term electricity price forecasting [5, 6, 12, 16].

Based on the previous researches, neural network can give many advantages in price forecasting where it can deal with a great number of input variables that affect the price and resulted in low error although under high volatility [9]. Furthermore, neural network also can be trained by historical data of a time series in order to capture the characteristics of the time series [7] however, other researchers observed that neural network does not have mechanism to avoid local minimum [14].

Furthermore, neural network able to resolve indeterminate relation between input and output variables, approximate complex nonlinear functions and can implement multiple training algorithms. Neural network requires huge data but can face over-fitting when huge data are trained.

Besides, in the learning process of the neural network, there is the relationship between input and output according to the set of inputs and corresponding output that have been given [6]. Furthermore, one of the researchers have conducted the Principal Component Analysis (PCA) during the data preparation process because the dimension of the input vector is large but components of vectors are highly correlated [7]. Other than that, the accuracy of the price forecasting can be determined by using Mean Absolute Percentage Error (MAPE).

In [5], neural network has been performed in New England is with hourly historical data of temperature, demand and natural gas price. The neural network is trained with data from 2007 to 2011 and tested on data 2012. During the training, 28 hidden neurons for the hidden layer is used. It has been observed that during the testing, the average mean absolute percentage error (MAPE) is 9.14% and demand data is the most important variable affecting the electricity price [5].

In [12], researchers utilizes various parameter such as weather, population, economic and demographic data in RBFN model. The model presented is less complex and produces satisfactory results.

Based on the research that using the neural network on the Ontario energy market during summer, the researchers developed six forecast models that represent six types of input where the input are the price of past 14 days, demand and price for 14 days and, demand for the previous day. The learning rate and momentum rate are varied from 0.05 to 1 with the step of 0.05. The number of hidden neurons are varied for 2,5,10 and 15. The MAPE was 18.74% where the input are price and demand of the previous day. The number of hidden neuron is 2, learning rate and momentum rate are 0.6. The researchers state that the selection of input data is the most important in forecasting [18].

In particular, other researchers also use neural network on the Ontario with 13 inputs including previous day average load, load from same hour and same day of the previous week, previous day average price and price for same hour of the previous day for. Data from 2007 to 2011 of Ontario energy market were tested and the resulted MAPE is 13.29% [19].

To capture chaotic character of price, an optimum neural network is developed in California market [23]. Combination of feature selection technique and neural network is used to remove the non-stationary and time variance in price behavior. The model is examined on Pennsylvania, Jersey, Maryland Power Pool or JPM electricity market for forecasting day-ahead locational marginal price (LMP). Another researches used neural

network model based on similar days method is used for predicting day ahead electricity price in JPM electricity market.

In addition, authors in [23] developed neural network model with four layered perceptron with one input layer, two hidden layers and one output layer. Levenberg-Marquardt back propagation method is used that illustrates its high capability and performances. Meanwhile, recurrent neural network (RNN) is applied to eliminate complex and rough fluctuations in price in New York. The result shows high accuracy with less computation time [23]. To get a better performance, the number of hidden neuron need to be reduced if during the training of neural network it shows a good performance but during the test of neural network it shows a worse performance [5] while other researchers stated that number of hidden layers can be increased to get best results [1].

The selection of the input is the important thing to forecast the price. The input that always used is demand and price which is the most variable affecting the electricity price. Most of the time, neural network is forecasting with minimum possible error and high absolute error at one or two instances may occur but the effectiveness of neural network remains good most of the time. Conclusively, previous research showed that using neural network can give less mean absolute percentage error (MAPE) in the prediction of price forecasting compared to time series model.

2.4 Fuzzy Logic

In 1965, fuzzy set was introduced by Lofti Zadeh. The characteristic of fuzzy system is a mathematics calculus to translate the subjective human knowledge of the real processes. Linguistic terms were applied in the fuzzy system. Other speculative and mathematical methods cannot use the linguistic terms [21]. The researchers state that the fuzzy inference mechanisms consist of three stages where the first stage is fuzzyfication which is values of the numerical inputs are mapped by a function according to the degree of compatibility of the respective fuzzy sets. Meanwhile, the second stage is fuzzy system processes the rules in accordance with firing strengths of the inputs. The third stage is defuzzyfication where the resultant fuzzy values are transformed again into the numerical value.

Fuzzy neural network has been used in Australian New-South Wales electricity market to test the forecasting model [2] where past demand, price and weather are selected as input feature. The resulted MAPE were 8% to 21%.

Adaptive Neuro-fuzzy Inference System (ANFIS) has been carried out on Spanish energy market where four seasonal week were tested. The MAPE were range from 6.41% to 19.8%.

Other than that, the Fuzzy Neural Network has been tested for Spanish energy market in 2002 data. It was tested four weeks on four different seasonal; summer, fall, winter, and spring. The MAPE range is 4.8% to 10.7%.

Based on the literature review, it shows that the fuzzy system has some disadvantages. Instead of easy interpretation of the results because of the natural rules representation, the fuzzy system is unable to generalize or it only answers to what is written in its rule base. Meanwhile, fuzzy system depends on the existence of an expert to determine the interference logical rules [23].

2.5 Conclusion of Overall Literature Review

Through the literature review, the ARIMA model can only be used for linear data and it is not suitable for the real situation in deregulation of energy market where the price are volatile and non-linear. Besides, neural network are the good tools to forecast the electricity price as it shows low error compared with the other methods such as time series and fuzzy logic. Therefore, this project are proposed to use neural network as the method of electricity price forecasting.

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter discusses on the theory of neural network and flowchart of the developed neural network model.

3.2 Theory of Neural Network

The theory of neural network is discussed in this section.

Artificial neural network is a computational system that inspired by the structure, ability to learn and method to learn by the human brain. One of the neural network model is multilayer perceptron (MLP). Neural network consists of input, output and hidden layer. Each layer contains specific number of computational elements called a neuron [13]. The neuron inside the neural network operates in parallel where the model of neural network consists of three simple elements which are a set of weights, an adder for summing the input signals and activation function for limiting the amplitude of the output of neuron [5]. Neural network has many advantages for price forecasting where it has possibility to use huge number of input variables that affect the price and resulted in low error although under high volatility [9].

There are many types of neural network such as radial basis function (RBF), feed forward neural network (FFNN) and recurrent neural network (RNN). The radial basis

function is derived from the theory of function approximation. The characteristics of the radial basis function (RBF) are contains of two layer feed forward networks, the hidden nodes implement Gaussian function and the output layer implement linear summation functions. Furthermore, radial basis function (RBF) are very good at interpolation.

Meanwhile, recurrent neural network (RNN) can analyze the data dynamically over time and can forecast the next sequence of the element in the data series. For the input of the recurrent neural network (RNN), the previous output data can be used as the input. Furthermore, the decision of the recurrent neural network (RNN) depends on the decision that the network gained from the previous moment. Therefore, the current output of the network depends on both current input and previous output. The input and output of the recurrent neural network (RNN) need to be in the three dimensional which is different for output in feed forward neural network (FFNN) that need to be in two dimensional.

Conventionally, feed forward neural network can be defined as the connection between units that do not form in a loop. Feed forward neural network has an input, output layer, and at least one hidden layer. There is no theoretical limit on the number of hidden layers but usually, the researchers set one or two for the hidden layer.

Feed forward neural network is the most preferred neural network type and usually used in the short term electricity price forecasting [5, 6, 12, 16]. FFNN uses supervised learning algorithm. It consists of the number of the neurons that organized in a layer. Each neuron in certain layer is connected to each neuron to the next layer and no feedback connections.

In neural network, the activation function is used as a decision maker at the output of a neuron. The neuron determined the linear on non-linear decision boundaries based on the activation function. Furthermore, to prevent the output neuron to become very large due to cascading consequence, the neural network has the normalization. There are three types of activation function that quite used in the neural network which are sigmoid, tanh, and rectified linear unit (ReLU).