Electricity Market Prediction Using Improved Neural Network

1H. Chahkandi Nejad, 2M. Mahvy, 3R. Jahani

1Electrical Engineering Department, Islamic Azad University, Birjand Branch, Birjand, Iran.
2Department of Electrical Engineering, Amirkabir University of Technology (Tehran Polytechnic),
Tehran, Iran.
3Islamic Azad University, Birjand Branch, Birjand, Iran.

Abstract: General analysis of Electricity markets shows that development and improvement of
predicting price solutions play a vital role in increasing the profit of generators and also causes better
and high operation for consumers. Also long-term prediction of market declaration in power system is
one of the most essential and fundamental needs of any decision making in market including
generation expansion planning (GEP) which has brought about uncertainties due to restructuring. In
this paper an improved neural network with back propagations error mechanism is applied to predict
market price. The proposed initial neural network is a three layer Perceptron that back propagations
error algorithm using Lumberg-Markwart and apply to speed up its training and accuracy. To reduce
error and improve proposed neural network operation, a multiple neural network is presented using
classification of input data with fuzzy methods and finally from PJM electricity market data used to
validate proposed method. Results demonstrate that the introduced solution has an exact and reliable
prediction of market clearing price not only in short-time scheduling by electricity generating
companies, but also in long-term scheduling, including generating development scheduling.

Key word: Neural network, Electricity market, Price prediction, Fuzzy logic, Lumberg-Markwart back
propagation method.

INTRODUCTION

With restructuring power systems, electrical energy is transacted well. The existing condition of electrical
energy causes electricity price to suffer more instability in comparison to the other markets. General analysis of
electricity markets shows that solutions for prediction of electrical energy price are considered as the most
critical need in market. Market clearing price (MCP) enables electricity generating companies to make correct
business decisions in an uncertain environment and its exactness help GENCOs in better determination power
system scheduling including generation development. MCP prediction is done by independent system operator
(ISO) and can be used as a new investment strategy in electricity markets capacity and also in generation
expansion planning. If the predicted price is be less than the real amount, it will result in generation
development decrease and causes services incline and the lack of response to the load demand in future.
Besides, if predicted price is greater than real price, too much investment is wasted and leads to extra generation
development. As a result, GENCOs go bankrupt. Anyhow without price prediction in restructured systems,
optimal operation of power systems would be impossible.

Electrical engineers have been familiar with load prediction for years. With restructuring in power industry
new concepts have entered the price prediction. Physical factors can affect electricity market. These factors are
complicated and non-linear but some of them are more effective. So as for prediction, selected factors are
required to have the highest effect on the price. To determine physical factors in prediction process, sensitivity
analysis study is done.

Amongst these factors, climate and seasonal changes can be pointed out. Some traditional methods that are
used for prediction have either complicated application or they are very simple and are not that exact to rely on
it. From those, simulation methods, time series analysis and regression analysis can be named. Generally almost
all traditional methods rely on mathematics models and are parametric which have different stages likewise
modeling, identification, model parameters estimation and verification. And after selecting an appropriate
model, its parameters alter by condition changes. Therefore the realization of these methods is complicated and
requires setting as many as parameters. Nowadays neural networks are a simple and powerful tool for prediction
in practical systems. Thus the aim of this paper is to introduce an improved neural network with back
propagations error mechanism is applied to predict market price. The proposed initial neural network is a three
layer perceptron that back propagations error algorithm using Lumberg-Markwart is applied to speed up its
training and accuracy
In (F. Gao, et al. 2000) a three layer neural network with back propagation error mechanism is used for short time electricity price prediction. In (Z. Hu, et al. 2004) a neural network with back propagation mechanism and a linear model for medium term and long term prediction of MCP are used.

An obvious feature in this paper is that prediction models can examine the effects of market power on the price. In (Y. Hong, et al. 2002) a method for short term prediction of locational marginal price using return neural network is presented. Among different neural networks used for electricity price prediction, recurrent neural networks can present acceptable results for variable time series.

In (A. Wang., & B. Ramsay. 1997) and (B. R. Szkuta, et al. 1999) MCP prediction and system marginal price are introduced for restructured markets. In (M. P. Moghaddam, et al. 2005) LMP prediction is introduced as GENCOs price solution for GEP.

In this paper a new and simple method is introduced for MCP prediction which can be used as a solution in generation expansion planning in competitive electricity markets. For this prediction method a three layer neural network with back propagation learning method and Lunberg-Markwart due to its higher speed in training is used. And for improving accuracy regarding to different price levels, with classifying input data using fuzzy method, a multiple neural network for different load levels is presented. Results of PJM market data analysis shows that the proposed method satisfies the desired accuracy and confirms the validation of the applied algorithm.

**MPL Neural Network Structure:**

Multi layer perceptron is the most common neural network. The simplest structure of multi layer perceptron consists of three layers: input layer, output layer and hidden layer. (fig.1). There is no analytic method for determination of hidden layers and neurons of each layer. This number is found heuristically and each hidden layer’s neurons are considered as number of input layer neurons in addition to the number of output neurons divided by two.

For each hidden layer in MPL neural network structure with back propagation error mechanism, input-output relationship is defined as follow:

\[ y = w_2 \cdot \delta(w_1 x + \beta_1) + \beta_2 \]  

which

- \( x \): \( n \) dimensional input vector of neural network
- \( y \): \( n \) dimensional output vector of neural network
- \( w_1, w_2 \): weigh matrices
- \( \beta_1, \beta_2 \): bias vectors for input and hidden layers respectively

Hidden layer transfer function is considered as tangent hyperbolic and it is defined as follow:

\[ \delta(x) = \frac{1 - e^{-x}}{1 + e^{-x}} \]  

**Fig. 1:** A three layer perceptron neural network
Output of this function is between -1 and 1. Transfer function for output layer is a linear function. It is proved that if the hidden layer would have sufficient neurons, the relationship between input and output can simply be defined. When the hidden layer has only one neuron, behavior of the network tends to be linear. Therefore by a neural network with BP mechanism we can apply a linear model. In this paper selective method for training is BP. The common BP is not fast enough for practical applications. And due to this, a training method based on Lundberg-Markwart which is a typically a BP method is used.

**Input Selection of Neural Network:**

There are many factors exist to affect MCP price. In general the factors are considered in price prediction can be presented as below:

- Time: hour, day, week, month, year, special days
- Historical and predicted reserve
- Price: historical prices
- Load: historical and predicted loads
- Power exchange with neighbor areas: Power exchange through long term contracts can affect electricity market prices.
- Climate: Temperature changes can cause increase or decrease in power demand and this can affect electricity market prices.

If the above data were available, they can be used as input variables of a neural network. Due to different dimensions of each variable and according to the range of transfer function which is \([-1, 1]\), these data are normalized using relation number (3) in which \(x_{\text{normalized}}, x_{\text{actual}}, x_{\text{max}}, x_{\text{min}}\) are the normalized, real, maximum, and minimum value respectively.

\[
x_{\text{normalized}} = 2 \times \left( \frac{x_{\text{actual}} - x_{\text{min}}}{x_{\text{max}} - x_{\text{min}}} \right)
\]

**Price Spike Truncation:**

For a recurrent neural network, spikes in input data can unsettle the network performance. The price spikes in electricity market are caused by GENCOs that exercise market power or suddenly changes in effective factors of market price prediction. Thus to reduce the price spike impact on prediction results, spike truncation is used. To implement the truncation an upper limit \(\pi_{\text{max}}\) is defined to limit price. The below trend is used to consider the prices more than \(\pi_{\text{max}}\).

\[
\pi = \begin{cases} 
\pi & \text{if } \pi \leq \pi_{\text{max}} \\
\pi_{\text{max}} + \log \left( \frac{\pi}{\pi_{\text{max}}} \right) & \text{if } \pi \geq \pi_{\text{max}}
\end{cases}
\]

Also pro-proceeding trend for price restoring after price spike truncation is defined as follow.

\[
p = \begin{cases} 
p' & \text{if } \pi \leq \pi_{\text{max}} \\
p_{\text{max}} \times 10^{\frac{\pi - \pi_{\text{max}}}{\pi_{\text{max}}}} & \text{if } \pi \geq \pi_{\text{max}}
\end{cases}
\]

In which \(p'\) is the predicted price and \(p\) is the corrected prediction price. So, if we put away the days along with price spikes from training data, the training and testing performance in neural network improves considerably. Totally price spikes express unusual states in electricity market system. Since we don’t intend to omit price spikes from input data of training, we limit their range and then use them for training.

**Neural Network Improvement**

As mentioned previously, the most important factors affecting electricity price, are hour of day and load. Therefore, to enhance the prediction accuracy it is proposed to use a multiple neural network.

5-1- Multiple Neural Network

Due to different load levels during the week, the weekdays classified into following three classes based on sensitivity analysis:

- Saturdays
- Sundays
- Monday to Friday (work days)
For each load pattern mentioned above, a different neural network is considered. The input historical data of each class network is different from others.

**Price Classification using Fuzzy Logic:**

The price changes according to daily load levels. Load levels are classified into two classes: peak load hours and low load hours. To achieve more improvement in accuracy of neural network and reduce error, a simple fuzzy logic is used to classify price data. The proposed algorithm is as follow:

**Step 1:** putting the initial values in membership function matrix:

\[ U^{(0)}_{ci} = \left[ U^{(0)}_{ci} \right] \in \mathbb{R}^{C \times N} \]  

In which \( h \) is the iteration index and in this step \( h = 0 \).

**Step 2:** Putting \( h = h+1 \) and calculating center of class \( c \):

\[ V_c = \frac{\sum_{i=1}^{N} \left( U^{(h)}_{ci} \right)^2 x_i}{\sum_{i=1}^{N} \left( U^{(h)}_{ci} \right)^2} \quad 1 \leq c \leq C, 1 \leq i \leq N \]  

**Step 3:** calculating \( U^{(h)}_{ci} \) for all \( x_i \) as follow:

\[ U^{(h)}_{ci} = \frac{1}{\sum_{j=1}^{C} \left| x_i - V_c-j \right|} \]  

**Step 4:** if \( \left| U^{(h)}_{ci} - U^{(h-1)}_{ci} \right| < \varepsilon \), then the calculation is over, otherwise, with returning to step 2 the steps are repeated.

Which \( x_i \) is the \( i \)-th load pattern vector of \( N \) days and \( C \) is the classes’ numbers in which the classes’ numbers are 2. These two classes include load levels in peak load hours and also, in low load hours. \( V_c \) is the fuzzy center of these classes and \( U^{(h)}_{ci} \) is a weighted factor expressing the distance between \( x_i \) and fuzzy center.

**MCP Prediction with Improved Neural Network:**

The proposed method is examined with PJM market data of year 2002. For predicting a weekly market price, the data of previous 48 days before the prediction day are used. This examination is done for a two month period and the results are represented. The two periods are selected from two different seasons of the year, comprised of summer (January and February) and winter (June and August), to investigate the impact of load pattern on the prediction accuracy. The results are showed in Table 1 and Figs 2-4. The results show that the classification of weekdays and also, the individual training of each class lead to improvement in prediction accuracy. The reason for this improvement is that the classification of data in the classes with the same characteristics, improves the neural network ability of exploring the relations between the input-output data.

<table>
<thead>
<tr>
<th>Error Day type</th>
<th>MAPE (%)</th>
<th>MAE ($/ MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Peak load</td>
<td>Normal load</td>
</tr>
<tr>
<td>Summer Working days</td>
<td>10.820</td>
<td>8.281</td>
</tr>
<tr>
<td>Saturdays</td>
<td>11.303</td>
<td>6.475</td>
</tr>
<tr>
<td>Sundays</td>
<td>11.286</td>
<td>11.847</td>
</tr>
<tr>
<td>Saturdays</td>
<td>2.924</td>
<td>4.046</td>
</tr>
<tr>
<td>Sundays</td>
<td>4.137</td>
<td>8.117</td>
</tr>
</tbody>
</table>

**Conclusion and Recommendations:**

In this paper an improved neural network is proposed to predict MCP. Using PJM electricity market price data, a multiple neural network is developed and the hourly MCP is predicted based on weekly load pattern and a simple fuzzy tool to classify the load into peak hours and low demand hours. The results showed that the proposed method has desired accuracy and reliability in addition to its simplicity and calculation speed. The introduced method, in addition to its ability to be applied by GENCOs in short time generation scheduling, can
be applied in generation expansion planning as price solution. For future works, some recommendations are as follow:

1. Using different wavelet transforms in pre-processing of input data for neural network.
2. Using modern methods for neural network training such as Bayesian method.

The analysis of electricity market prices fluctuations and volatility by probabilistic studying of price signal.

**Fig. 2:** The price prediction results with MAPE= 8.576% (Summer 2002).

**Fig. 3:** The price prediction results with MAPE=7.412% (Winter 2002).
Fig. 4: MAPE of PJM market price prediction by applying triple classification.

ACKNOWLEDGMENT

This article is extracted from a research plan in the Islamic Azad University of Birjand (South Khorasan Province – Iran). I would like to appreciate and thank, the respected authorities of the Islamic Azad University of Birjand (IAU: Birjand)

REFERENCES


