Artificial Neural Network Based Short Term Load Forecasting for the Distribution Utilities

Gautham P. Das, Chandrasekar S., Piyush Chandra Ojha

Abstract: The load forecasting is a tool of utmost importance for the power industry as it can influence areas like power generation and trading, infrastructure development planning etc. Implementation of the load forecasting tool in the distribution utilities has a wider impact up to the power generation level. The load forecasting has been an area in power systems where the human experts are still performing better than the algorithms which have been put forward as alternatives. Many techniques have been put forward for the accurate load forecasting. Different Artificial Neural Networks (ANN) with different architectures have been proposed in the last few years for load forecasting purpose resulting in a large number of publications on this subject. In this paper a new Feed Forward Neural Network has been proposed for the short term load forecasting in correlation with the variations in weather, for distribution management systems. The proposed neural network can forecast the load profile with a lead time of one to seven days.

Keywords: Short term load forecasting, Artificial Neural Networks, Weather sensitive load forecast, Availability Based Tariff

1. Introduction

The power industry has been in an evolving phase in which the advances that are taking place in Information Technology (IT) are incorporated to make the power generation, transmission and distribution scenario is performing in an efficient way both in terms of cost and in terms of energy. Availability Based Tariff (ABT) concerns itself with the tariff structure for bulk power and is aimed at bringing about more responsibility and accountability in power generation and consumption through a scheme of incentives and disincentives [1].

In the earlier scenario the generating utilities used to generate as much as they could generate and the transmission companies distributes it to the distribution companies. As the electrical power is such that it is not able to store it in bulk for longer durations, this mode of operation is totally inefficient. In the new scenario the generating stations are generating only the power that is required by the optimal hydro thermal co-ordination and unit commitment. This forces the transmission utilities and the distribution companies to predict their load demand and give the same to the generating stations. The incentives and disincentives force them to give accurate load demand to the generating stations.

The business drivers for the unbundled distribution utilities are profitability coupled with improved service to the end customers. In general the distribution utilities buy power from the transmission companies and are primarily responsible for delivering it to the consumers. It is the obligation of the distribution company to provide uninterrupted service to the consumers by having enough power to meet the requirements of the consumers. If the distribution company doesn’t have enough power to meet the customer requirement, it may lead to problems that may arise from the overloading. The overloading of the system may lead to partial or complete breakdown of the distribution system. To overcome the situation they might be forced to draw more power from the transmission company, than what they had agreed to buy which may in turn affect the stability of the transmission network itself. Usually this addition power drawn will be charged higher with a penalty by the transmission companies. The distribution companies can overcome this difficulty in an optimal way if they have idea of the load demand that will be required for a period of time in the future. This can be done with the help of load forecasting.

2. Load Forecasting

Depending on the period of forecasting, there are three types of load forecasting, namely short term load forecasting (STLF) which is generally for a time period varying from one hour to one week, medium term load forecasting which is usually for a period varying from a week to a year and long term load forecasting which is for periods longer than a year. Of these the long term forecasts are utilised in the infrastructure development planning [2]. The short term load forecasting influences the short term objectives like energy generation and purchasing.
The load demand fluctuates with the changes in weather. Short term load forecasts can help to estimate the load demand according to the changes in the weather conditions and this information can be used to increase the system reliability and economic operation. The short term load forecast founds a variety of applications such as unit commitment, economic dispatch, hydrothermal co-ordination etc. Over-prediction causes increase in operating costs by unnecessary use of reserves, while under-prediction results in failure of meeting demand which could have met easily with the reserved [3].

Various techniques have been put forward for the short term load forecasting [4-12]. There are the conventional techniques and the non-conventional techniques. The main conventional techniques that are in use are the similar day approach, the regression analysis and the time series analysis. In the similar day approach the historical load data of the previous one or two years is searched for a similar day in terms of day of the week, weather and date. This technique fails most often as it might be difficult to find such a similar day. In the time series analysis, the historical load is considered as a time series data and the future data is forecasted by using the extrapolation technique. There is high chance that the extrapolation technique fails due to the varying weather conditions or due to some random events that may happen. Regression analysis technique tries to find a relation between the input and output variables. Once the relation is identified the outputs for a given input set can be easily calculated. But finding an exact mathematical relationship is difficult and because of this reason this method also fails many a time.

According to Kolmogorov theorem neural networks can approximate any non linear continuous function with a good precision [9]. Because of this feature the artificial neural networks are extensively used in areas like prediction, system modeling and control. One of the examples for the application of ANN for prediction is STLF.

3. Load data analysis

Electrical load is a combination of different components as shown in the equation (1) [11].

\[
\text{Load} = \text{L}_{\text{NORMAL}} + \text{L}_{\text{WEATHER}} + \text{L}_{\text{SPECIAL}} + \text{L}_{\text{RANDOM}}
\]  

(1)

Each day of the week is having a particular load pattern. This component is represented by \( \text{L}_{\text{NORMAL}} \). Each Sunday is having a common basic pattern, each Monday is having another base pattern and so and so. Usually in the weekends the power consumption is far less compared to that in weekdays. Mondays and Fridays are having different load pattern from other weekdays as they are closer to the weekends.

There is a component of load which depends on the weather denoted by \( \text{L}_{\text{WEATHER}} \). In winter the power consumption is high in residential areas because of increased use of heaters and in summers due to the increased use of coolers. The weather parameters which affect the load are temperature, humidity, rainfall and wind. The effect of these weather parameters is different depending on the type of consumers and the geographical features of the area under consideration.

![Figure 1. Load – Temperature scatter diagram.](image)

There are some special occasions like festival seasons, elections, big athletic event etc, which in turn will cause changes in the load pattern. This corresponds to the \( \text{L}_{\text{SPECIAL}} \). There are some random factors which affect load and this load component is \( \text{L}_{\text{RANDOM}} \).

The data used for this study was from the state of Illinois, USA. The load and weather variables were analyzed for any correlation between them. Figure 1 shows the Temperature – Load scatter diagram. From the analysis the electrical load and the weather were found to have a strong parabolic relationship. Other weather variables like humidity, rainfall, wind etc were found to have very weak relation to the load and hence they were not considered in the forecasting procedure.

4. Artificial Neural Network (ANN)

Neural networks are modeled similar to the human brain. The basic building blocks are known as neurons. In each neuron the inputs coming to it are added together and this sum is then passed through an activation function which is the transfer function of the neuron. The neural network is a network formed using the neurons and the weights connecting these neurons form the memory of the network. The general architecture is shown in Figure 2.

The process by which the neural network is tuned to perform to the particular application is known as training. The neural network training is similar to the learning process of human beings. Once the network is trained with a variety of patterns of input and output combinations ideally it should be able to predict the correct output when an input pattern is given randomly. The most commonly used training algorithm is the back-propagation with gradient descent algorithm.
Generally the network is having three or more layers of neurons. The inputs are fed directly to the input layer. The output of the network can be obtained from the output layer. Usually only one hidden layer is used and in some particular cases two hidden layers are also used. The number of neurons in the hidden layers is also a factor to be considered. According to the Kolmogorov theorem the network should have one neuron extra than double the number of neurons in the input layer. But usually the numbers of hidden layer neurons are found out by hit and trial method. Genetic Algorithm (GA) can be utilized for hidden neural network architecture optimization. But it can be really time-consuming as training of the network also has to be done in each of the iterations.

Even though the performance of the neural network is depended upon the network architecture parameters like hidden layers, hidden layer neurons and activations functions used in the network, the selection of the input parameters holds the key to get the best performance out of the network.

The network structure selected here is having 31 inputs, one hidden layer and one output layer with 24 neurons. Only one hidden layer is selected. In the output layer the load forecast for the each hour of the day is obtained from each neuron in the output layer. The historical load and temperature forms the main parts of the input to the network and the remaining are the temperature forecasts and the information of the day of which the demand network is going to predict the load. Details about the 31 inputs and the 24 outputs of the network are shown below in Table 1.

### Table 1. ANN inputs and outputs

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 24</td>
<td>L(d-h); h = 1 to 24</td>
</tr>
<tr>
<td>25 - 27</td>
<td>Tmax-7, Tmin-7, Tavg-7</td>
</tr>
<tr>
<td>28 - 30</td>
<td>Tmax(d), Tmin(d), Tavg(d)</td>
</tr>
<tr>
<td>31</td>
<td>Day Type</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Outputs</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 - 24</td>
<td>L(d, h); h = 1 to 24</td>
</tr>
</tbody>
</table>

L – Load
Tmax – Maximum temperature
Tmin – Minimum temperature
Tavg – Average temperature
d – The current day
h – Hour of the day

Scaling of the input and output variables was done to prevent saturation of the neuron outputs. The output of the network was then scaled back to the original range by doing the reverse process to get the forecasted loads in the actual range.

The network was trained with one year’s data using the back propagation algorithm. Once the training of the network was complete the weights and bias terms were kept fixed for current year. To meet with the periodic load growth, the network is configured for automatic yearly training.

Like 24 hour forecast, one week ahead forecasts are also required for unit commitment, hydrothermal co-ordination and transaction evaluation. The weekly forecasting model provides this capability. Six additional daily load forecasting networks are added to form a week ahead load forecasting model with each network forecasting for each of the next seven days. As the same network is used the same accuracy is assured for the weekly forecast also.

### 5. Results

The network was trained with data comprising of loads and corresponding temperatures of 365 days using the back propagation algorithm. After completion of the training the network was tested with data comprising of loads and corresponding temperatures of 122 days. The accuracy of the result was calculated using the Mean Absolute Percentage Error (MAPE) as calculated using the equation (2).

$$\text{MAPE} = \frac{1}{N} \sum_{i=1}^{N} \left| \frac{\text{Actual}_i - \text{Forecasted}_i}{\text{Actual}_i} \right| \times 100$$

The MAPE obtained after testing the network with four months’ load and temperature data was 2.33%. Figure 3 shows the forecasting results for a one week.

### 6. Conclusion

With the introduction of availability based tariff the distribution companies will be forced to buy power from the transmission companies in an optimal way with less wastage.
because of the incentives and disincentives involved with ABT. This in turn forces the end customer to use the power in an optimal way because of the high price for the power at peak hours. The use of short term load forecasting by the distribution companies helps them to buy power from transmission utility in an optimal way by improving their distribution network reliability and service to the customer. An ANN based short term load forecasting technique based on the weather variation for use in the distribution utilities has been proposed. The network is having two modes of operations, the next day forecast mode and next week forecast mode, both giving hourly load forecasts.

An important parameter in this load forecasting is the weather forecast. As the weather variable which is considered for this network is temperature and the temperature forecasts are readily available, the inputs of the network are easily available at the disposal of the distribution utilities. Test results shows that the network is able to forecast the load with sufficient accuracy which helps in better planning.

7. References


