Application of Neural Network to Load Forecasting in Nigerian Electrical Power System

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ABSTRACT

Load forecasting is very essential to the operation of electricity companies. It enhances the energy-efficient and reliable operation of a power system. This paper presents a study of short-term load forecasting using Artificial Neural Networks (ANNs) and applied it to the Nigeria Electric power system. This gives load forecasts one hour in advance.

Historical load data obtained from the Power Holding Company of Nigeria (PHCN, formerly NEPA) for the month of August 2003 were used.

The main stages are the pre-processing of the data sets, network training, and forecasting. The inputs used for the neural network are the previous hour load, previous day load, previous week load, day of the week, and hour of the day. The neural network used has 3 layers: an input, a hidden, and an output layer. The input layer has 5 neurons, the number of hidden layer neurons can be varied for the different performance of the network, while the output layer has a single neuron. An absolute mean error of 2.54% was achieved when the trained network was tested on one week's data. This represents, on average, a high degree of accuracy in the load forecast.

(Keywords: load forecasting, electricity generation, electric power system, neural network)

INTRODUCTION

There is a growing tendency towards unbundling the electricity system. This is continually confronting the different sectors of the industry (generation, transmission, and distribution) with increasing demand on planning management and operations of the network. The operation and planning of a power utility company requires an adequate model for electric power load forecasting. Load forecasting plays a key role in helping an electric utility to make important decisions on power, load switching, voltage control, network reconfiguration, and infrastructure development.

Methodologies of load forecasts can be divided into various categories that include short-term forecasts, medium-term forecasts, and long-term forecasts. Short-term forecasting which forms the focus of this paper, gives a forecast of electric load one hour ahead of time. Such forecast can help to make decisions aimed at preventing imbalance in the power generation and load demand, thus leading to greater network reliability and power quality.

Many methods have been used for load forecasting in the past. These include statistical methods such as regression and similar-day approach, fuzzy logic, expert systems, support vector machines, econometric models, end-use models, etc. [Engle, Mustafa, and Rice, 2001; and Eugene and Dora, 2004].

A supervised artificial neural network has been used in this work. Here, the neural network is trained on input data as well as the associated target values. The trained network can then make predictions based on the relationships learned during training. A real life case study of the power industry in Nigeria was used in this work.

In further sections of this paper, we discuss the load forecasting problem in greater detail, introduce the concept of artificial neural network and its application to load forecasting, address the pre-processing of the data series that were used in this study, and present the results and conclusions of the forecast presented through this work.

THE LOAD FORECASTING PROBLEM

The power industry in Nigeria is presently undergoing various structural and organizational changes. With the phasing out of the National Electric Power Authority (NEPA) and the coming on board of the Power Holding Company of Nigeria (PHCN), the power industry is being positioned for better services to the Nigerian population. Various generation companies, transmission and system operation companies, as well as distribution companies are getting ready to take their rightful place in the Nigerian power industry. The government itself is also determined to increase the power generated to 10,000MW by the year 2007.

All the developments highlighted above can only translate to better and efficient services if, among other vital factors, there is a good and accurate system in place for forecasting the load that would be in demand by electricity customers. Such forecasts will be highly useful in proper system planning and operations.

ARTIFICIAL NEURAL NETWORKS

Artificial Neural Networks (ANNs) refer to a class of models inspired by the biological nervous system. The models are composed of many computing elements, usually denoted neurons; each neuron has a number of inputs and one output [Bakirtzis, et al, 1996; Chen, Canizares and Singh, 2001; and Eugene, Mustafa and Rice, 1992]. It also has a set of nodes called synapses that connect to the inputs, output, or other neurons.

A linear combiner is used to produce a single value from all the inputs [James, 2002]. The single value is the weighted sum of the inputs from which the threshold value associated with the neurons is subtracted to compose the activation of the neuron. The activation signal is passed through an activation function to produce the output of the neuron. The chosen activation function is normally a non-linear function (for example, a sigmoid function), a feature that allows the ANN to represent more complex problems [Neto, et al., 1999].

Most ANN models focused in connection with short-term forecasting use multi-layer perceptron (MLP) networks. The attraction of MLP can be explained by the ability of the network to learn complex relationships between input and output patterns, which would be difficult to model with conventional methods [Lee, Cha, and Park, 1992]. Inputs to the networks are generally present and past load values. The network is trained using actual load data from the past.

LOAD FORECASTING USING NEURAL NETWORKS

The back-propagation algorithm is a supervised learning algorithm used to change or adjust the weights of the neural network. In back-propagation, the gradient vector of the error surface is calculated. This vector points along the direction of steepest descent from the current point, so that a movement over a short distance along it decreases the error. A sequence of such moves will eventually find a minimum error point [Senjyu et al, 2000; 2002].

The following data were selected as network inputs:

i. The load of the previous hour,
ii. The load of the previous day,
iii. The load of the previous week,
iv. The day of the week, and
v. The hour of the day.

This results in a total of 5 ANN input values.

The neural network architecture used has only one hidden layer. Networks with more than one hidden layer are generally more complex and network training is more time-consuming. The number of neurons in the hidden layer must be carefully chosen; too many neurons make the network overspecialized, leading to loss of generalizing capability. If there are not enough hidden layer neurons, the network may find it difficult to learn the behaviour of the series. In this present work, varying number of hidden layer neurons was experimented with, the number ranging from five to eleven. Eleven neurons were finally utilized because it offered a better model characteristic.

An analysis of the load series data for the month of August 2003 shows that basically two load patterns were observable: one for weekends (Saturday and Sunday) and another for week days (Monday through Friday). Figure 1 shows that the load demand is lowest on Sunday (1), there is little variation in the load for Monday (2) through Thursday (5) and the peak load demand was recorded on Friday (6). The load on Saturday (7) was lower than that recorded on weekdays.

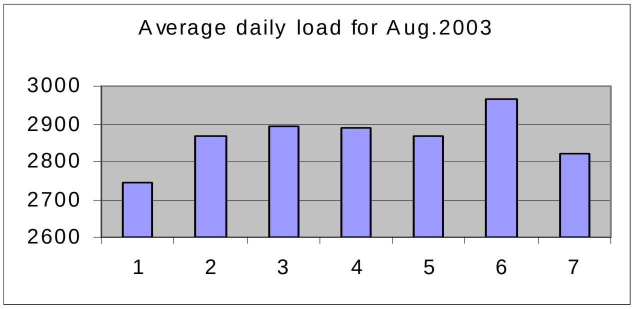


Figure 1: Average Daily Load for August 2003.

The different load patterns could be due to the high industrial load demand during the week (which is greatly reduced over the weekend), the peak recorded on Friday can easily be attributed to the social activities that peaks up on Friday evenings.

After the neural network is trained on the input data set, a new data set is presented at its input, and the network provides a forecast of the load for the next one hour.

PRE-PROCESSING

The data employed for training and testing the neural network were obtained from the PHCN for the month of August 2003. The network was trained on data for the first two weeks of the month.

Due to wrong measurements and other human errors, some out-of- range values were observed in the historical load data as obtained from the PHCN. Corrections were made to such outlier values by replacing them with the average of both the preceding and succeeding values in the series. Principal Component Analysis (PCA) of the data was then carried out using MATLAB® functions "prepca" and "trapca".

PCA has these effects: it orthogonalizes the components of the input data (so that they are uncorrelated with each other), it orders the resulting orthogonal (principal) components, and it eliminates those components that contribute the least to the variation in the data set [Mathworks , 2004].

After the series had been corrected, the data were normalized so that their values would be between the values 0 and 1, this was achieved by using the sigmoid function and the effect of this is to avoid a saturation of the neural network. The sigmoid function acts as an output gate that can be opened (1) or closed (0). Since the function is continuous it is possible for the gate to be partially opened (i.e. somewhere between 0 and 1). Models incorporating the sigmoid transfer function show good generalized learning characteristics and yield models with excellent accuracy.

Other transfer functions that can be used include the hyperbolic tangent and the hyperbolic secant functions. These functions exhibit different learning dynamics during training but may not achieve the same accuracy as sigmoid-based models.

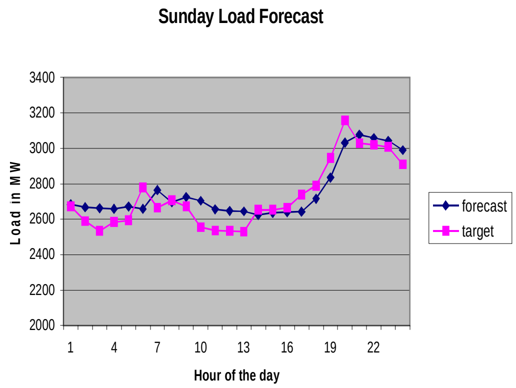
RESULTS

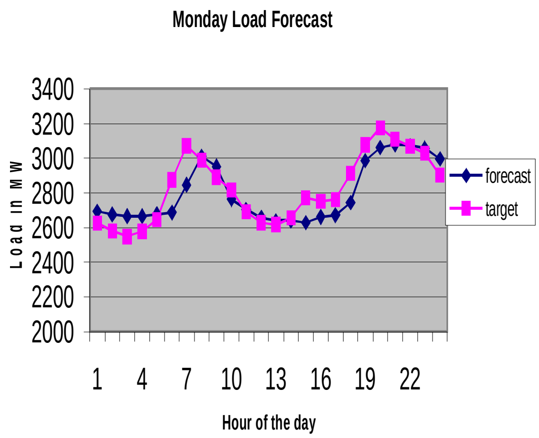
A back-propagation network with momentum and with an adaptive learning rate was trained and the neural network can forecast future load one hour ahead given the various inputs to the network. A sigmoid transfer function was used in the hidden layer while a linear transfer function was used in the output layer.

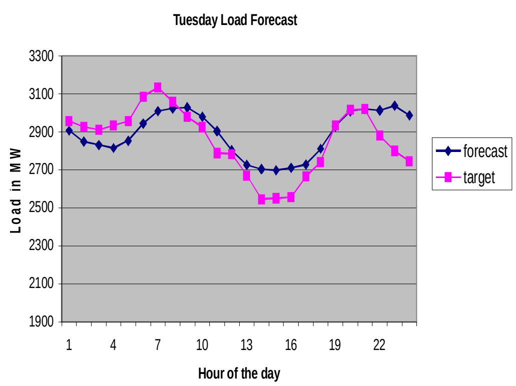
The results obtained from testing the trained neural network on new data for 24 hours of a day over a one-week period are presented below in graphical form (Figure 2). Each graph shows a plot of both the 'target' and 'forecast' load in MW values against the hour of the day.

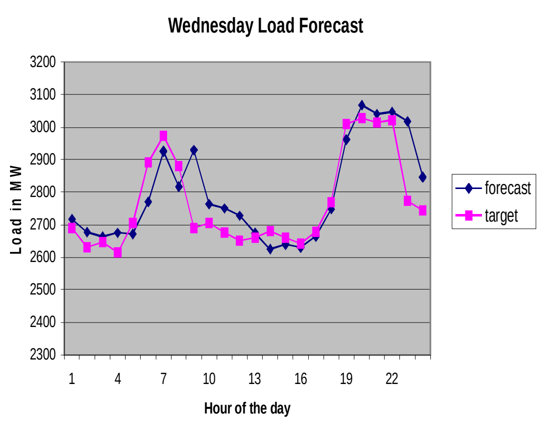
The absolute mean error AME (%) between the 'forecast' and 'target' loads has been calculated and presented in Table 1. The highest AME (%) values were recorded for Tuesday and Saturday. This is due to the greater deviation about the minimum demand point in addition to errors in the forecast for the peak demand periods.

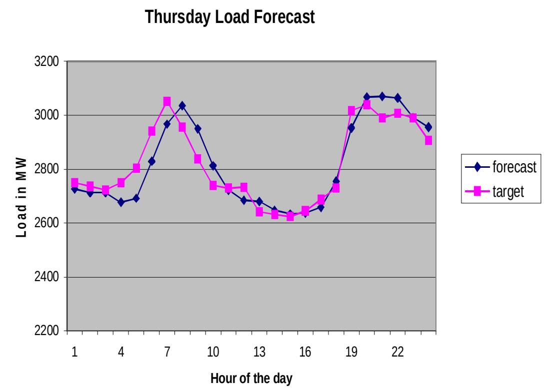
Overall, the above error values translate to an absolute mean error of 2.54% for the network. This represents a high degree of accuracy in the ability of neural networks to forecast electric load.

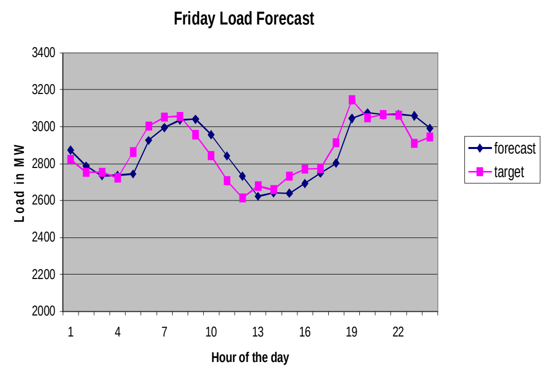












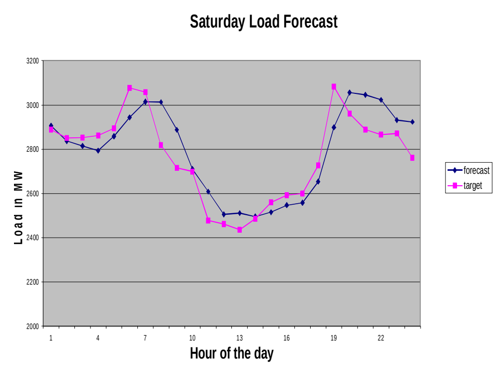


Figure 2: Plots of the 'Target' and 'Forecast' Load in MW Values against the Hour of the Day.

Table 1: Absolute Mean Error (%).

Day	AME(%)
Sunday	2.90
Monday	2.34
Tuesday	3.27
Wednesday	2.24
Thursday	1.73
Friday	2.25
Saturday	3.02

CONCLUSION

The results obtained in this work confirm the applicability as well as the efficiency of neural networks in short-term load forecasting. The neural network was able to determine the nonlinear relationship that exists between the historical load data supplied to it during the training phase and on that basis, and make a prediction of what the load would be in the next one hour. It must, however, be ensured that the network is not over-trained as this will lead to a loss of its generalizing capability.

RECOMMENDATION

Future studies on this work can incorporate information about the weather as well as customer class into the network so as to obtain a more representative forecast of future load. Network specialization (i.e. the use of one neural network for the peak periods of the day and another network for the hours of the day) can also be experimented upon.

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