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Implementation of Artificial Neural Network for Short Term Load Forecasting

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Abstract — In this paper an attempt has been made to solve nonlinear and complex problem of load forecasting using Artificial Neural Network (ANN). ANN are able to learn weather variables and the relationship among past, current and future load data. The standard optimization lavenberg-marquardt technique has been used as back propagation algorithm using MATLAB® R2010a ANN toolbox. A new approach has been proposed in the paper that first trains, validates and then tests the network using actual load data obtained from a utility company of Haryana (India). Forecasting performance of the proposed technique is obtained with a performance Mean Absolute Percentage Error (MAPE) and compares with the actual power utility data. The effectiveness of proposed method is successfully demonstrated to forecast the load of weekdays using regression analysis.

Keyword —Artificial Neural Network (ANN), Back-Propagation Algorithm (BPA), Multilayer Feed-Forward Network (MFFN), Short-term load forecasting.

1. INTRODUCTION

In last few decades, various techniques of load forecasting are proposed in the power system. The daily operation, planning and scheduling activities of an electric utility needs the predication of electricity demand of their consumers. In general, electric utility requires load forecast, which is categorized into short-term, mid-term and long term forecast. It can also provide information for possible energy interchange with other utilities. The time period for short-term load forecast refers from one hour to one week. The mid-term forecast can either be hourly or peak load forecast of one to several months ahead. Long-term forecast refers to several years in which load flow studies, contingency analysis and scheduling of fuel purchasing is studied. STLF has a significant impact on economic operation of a power system and provide secure and reliable strategies for power system [1]. Many decisions such as economic scheduling of generating capacity, transaction such as ATC (Available Transfer Capability) are based on these forecasts.

In deregulated environment, due to increase in competition in electricity market, the need for accurate load forecast will get importance in future. In deregulated environment, utilities must have to operate at highest possible efficiency which requires accurate load forecast. It can be performed using many types of methodologies such as statistical methods, regression approaches, fuzzy logic, genetic algorithms, time series methods and artificial neural network etc. [2]. Various type of load forecasting methods are given in [3] with their advantages. The load forecasting system was developed by Lijesen and Rosing in 1971 using statistical approaches [4]. Among modern and traditional techniques, artificial neural network is widely used, as it posses the ability to solve non linear relationship between load and the factors such as temperature, humidity obtained from historical load data. Many type of neural network models are used to solve load forecast problems for example, recurrent network, functional link and multi-layered feed forward network with one or more numbers of hidden layers. In this paper, multilayer feed forward network is used in short-term load forecasting. The most important aspect of artificial neural network in STLF is that a single architecture is used with same input-output structure for predicating hourly load of various size utilities in different region of a country. To determine some parameters of ANN model only customization is required. Therefore, there is no need to alter the other aspect of model.

For different operations within the utility, different time horizon forecast are important. For a particular region, the accuracy of load forecasting is approximately 1-3% for short term. However, with same accuracy it is impossible to predict the next year load since long-term weather forecast are not available with similar accuracy [5]. Due to change in weather conditions, supply and demand fluctuations the electricity price increases by a factor of ten or more during peak load condition which causes overloading [6]. STLF can help to prevent overloading and consequently reduces occurrence of blackouts and equipment failures. For accurate load

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forecasting various factors are considered as perquisite. These factors are given here under:
[i] Time factors
[ii] Historical load
[iii] Weather data
[iv] Consumer's class
The time factors include any day of week, hour of the day and time of the year [7]. There is a difference in load on weekdays and weekend days also. Similarly the behavior of the load is different on different weekdays. The predication of load on holidays is more difficult than non holidays.
In this paper, an algorithm is presented which utilizes a multilayered feed forward artificial neural network. ANN is also used as a tool in other applications of power system such as alarm processing, fault detection and security assessment [8]-[10]. In the next section, artificial neural network is discussed with back propagation algorithm.

2. ARTIFICIAL NEURAL NETWORK MODEL

McCulloch and Pitts are the first who introduce the concept of ANN in 1943. ANN have strong learning ability and good performance on unseen data i.e. generalization can be achieved through pattern recognition and function approximation, etc. Artificial Neural Network (ANN) is like a computing system having a number of simple and highly interconnected processing elements known as neurons. The information from one neuron to other is transmitted through axons and received by dendrites. The axon-dendrites contact is known as synapse which is used to adjust the weight in order to get desired output. To fire the neuron, the incoming pulse can be generated by neighboring neurons and by the neuron itself. A simple mathematical model of neuron is shown in Fig. 1[11]-[12].

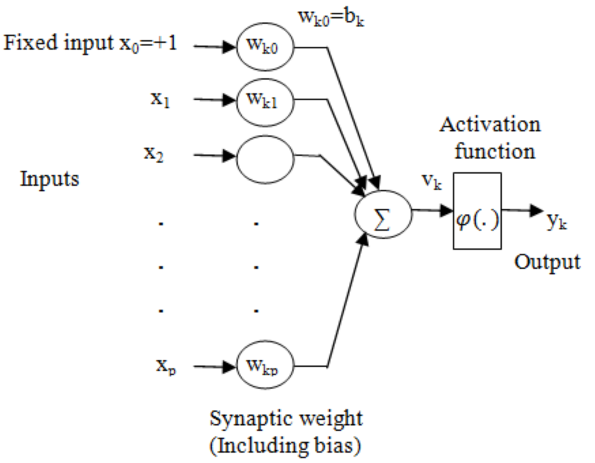

Fig.1: Mathematical model of a neuron

As shown in Fig.1 the input x_i for I = 1, 2...n are 0 or 1, depend on the presence or absence of input impulse at instant k. The firing rule for this model is expressed as follows:

$$O^{k+1} = \begin{cases} 1 & if \ \sum_{i=1}^{n} w_i x_i^k \geq T \\ 0 & if \ \sum_{i=1}^{n} w_i x_i^k < T \end{cases}$$

and

$$v_k = \sum_{j=0}^{p} w_{kp} X_j$$

$$Y_k = \varphi(v_k)$$

Where k = 0, 1, 2……. Denotes the discrete-time instant and w_i
is the connecting weight with neuron membrane. The weights are adjusted via some kind of learning process.
In artificial neural network, multi-layer feed forward network is most popular neural network and most of STLF models are based on it. A multilayer feed forward network is shown in Fig. 2.
The MFFN has many layers of neurons and each neuron in a certain layer connected to each neuron of the next layer. No feedback connection is provided. Many types of activation functions are used to control the magnitude of output to get better results.

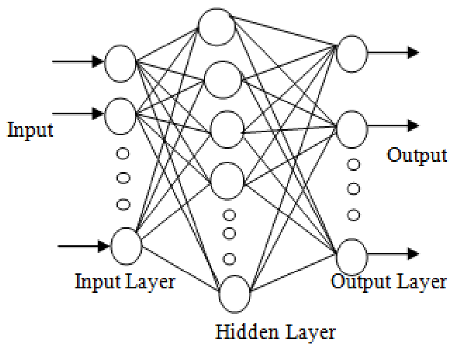

Fig.2: Multilayer feed forward network

In this paper, 'tansig' and 'purelin' activation functions are used because the output of a neural network must be linear. It can be represented as:

$$S(t) = \frac{1}{1 - e^{-t}}$$

3. BACK PROPAGATION ALGORITHM

In artificial neural network, BPA has a great importance and a supervised learning method. The algorithm is called 'error back propagation training algorithm'. In forward pass, the input data is propagated, layer by layer and all the weights are fixed. During backward pass, all weights are adjusted to reduce the error in accordance with error correction rule. The error signal is propagated backward through the network against the direction of synaptic connections [13]-[16]. Fig.3 presents the computation procedure of proposed method. Different steps of the algorithm are described as follows:

Step 1: Historical load data is first collected and given as input to the network. The input and output are normalized with respect to their maximum values.

Step 2: Before train the network, some preprocessing functions are performed such as mapping of deviation to 1 and mean to 0. Value of each row of input to make each row highly uncorrelated principle component analysis of matrices are done.

Step 3: Then the input is fed to the network and after sufficient training of neural network, the load demand for the next week is predicated.

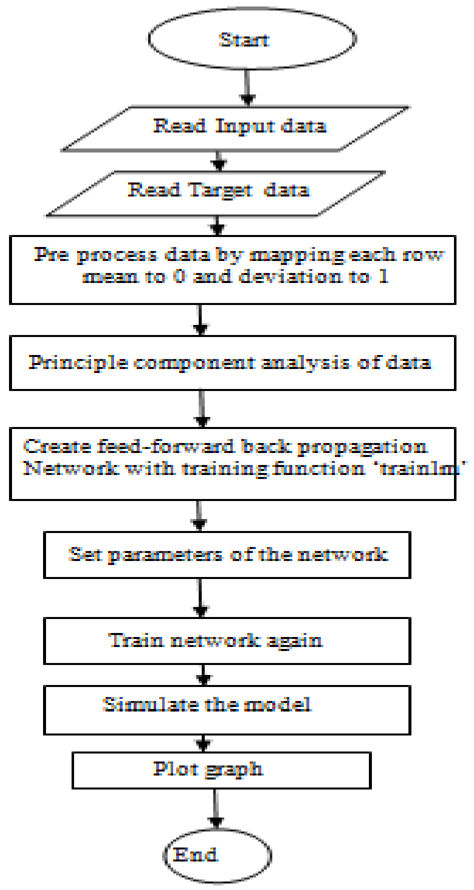

Fig.3: Flow chart of the proposed scheme

Fig.3: Flow chart of the proposed scheme

Step 4: To train the input data according to target value and to know how much data is actually trained, regression plot in network toolbox is drawn. For perfectly fitting input values to output, the regression must be 0.998-1.000.

Step 5: Plot the graph and find Mean Absolute Percentage Error (MAPE). Errors are compared to get best technique to get more accurate results.

4. Training and Discussion of Results

In training process, transfer functions used are 'tansig' for hidden layer and 'purelin' for output layer. The learning function Levenberg-Marquardt is used due to its better learning rate as compared to other functions in forecasting problems. In training process, the following parameters are used:

No. of Epochs = 700
Momentum = 0.02
Learning rate parameter = 0.3

The results obtained from trained ANN model includes the general network error performance, regression analysis between output and target vector and also include training state. The input data set is divided into three parts: 70% data is used to train the network, 15% used for testing and another 15% used for validation. During training process, training data set is used for obtaining weight and bias value of neural network. To test periodically ability of network, validation data set are required. Finally, test data set used to evaluate the error (MSE & MAPE). The input data of 24 hourly loads are taken from utility of Haryana in the month of March, 2013. After the completion of training process of network, following graphs are drawn:

i. Performance plot (MSE vs. Epochs)
ii. Training state plots
iii. Regression plot
iv. Comparison plot of forecast and actual data

The performance plot describes the plot of mean square error against the number of epochs or iterations. As the no. of iterations increases computational error considerably improves.

Training plot consist three different plots. First plot describes the learning functions against number of epochs. The second plot shows the learning rate Vs increasing numbers of iterations. This plot shows that the network error reduce as training progress takes place. Finally, third plot shows the validation checks that occur when any change is observed into the network.

Regression plot shows the correlation between output and target data. This plot also shows that network is learned to what extant from complex relationship of data used.

The error was formulated by this formula:

MAPE= $[\{\sum (|A_L-P_L|/A_L)\}/N]*100$

Where

A_L: Actual Load.

P_L: Predicted Load

N: No. Of Hours for Which Load is predicted.

MAPE

Monday $= [\{|(285.7-371)|/285.7\}*100]/24\%$
$= 1.24\%$

Forecasted results for weekdays are shown below:

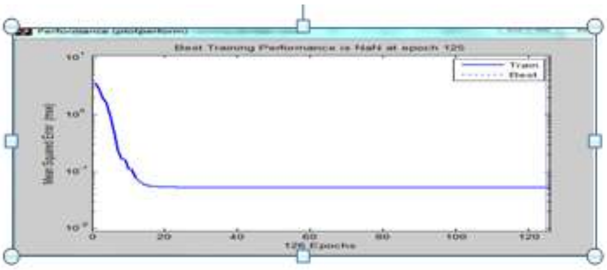

Fig.4: Performance plot

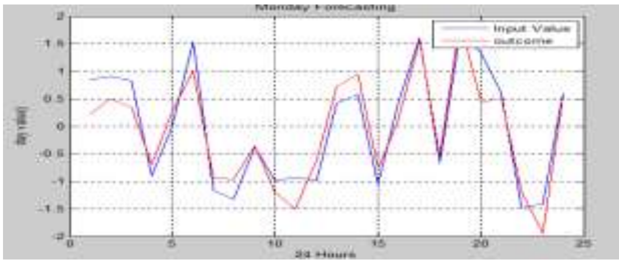

Fig.5: Comparison Plot between actual and forecast load for Monday

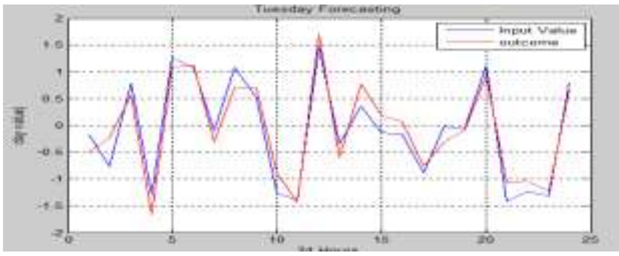

Fig.5: Comparison Plot between actual and forecast load for Tuesday

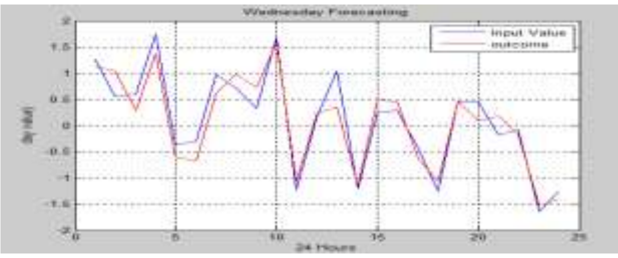

Fig.7: Comparison Plot between actual and forecast loads for Wednesday

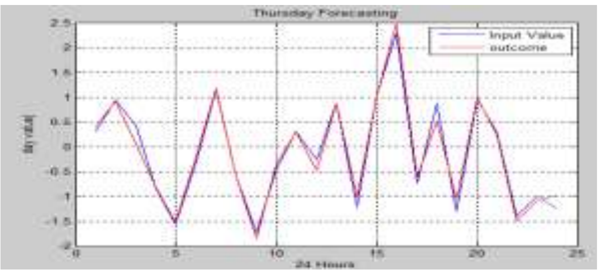

Fig.8: Comparison Plot between actual and forecast loads for Thursday

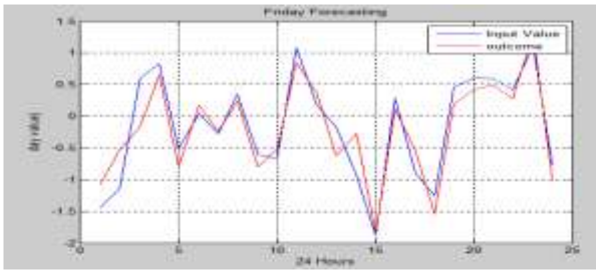

Fig.9: Comparison Plot between actual and forecast loads for Friday

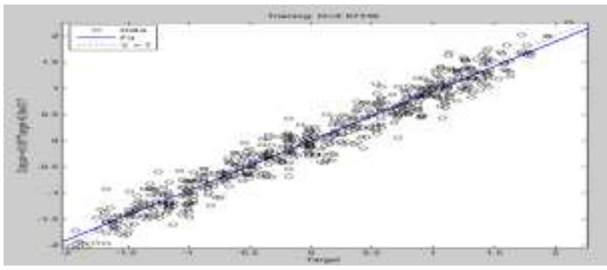

Fig.10: Regression Analysis

5. Conclusion

A method of calculating short-term load forecasting by incorporating artificial neural network with back propagation algorithm is proposed in this paper. From the inspection of graphs, it is inferred that use of any computational intelligence technique, particularly artificial neural network reduces the error substantially. Therefore, it is concluded that ANN can offer an effective and promising solution to solve complex problems in power system. The accuracy of the forecasts is verified by comparing the simulated outputs from the ANN Model with obtained results from the utility company. Several models architectures are trained and simulated before arriving at the best Mean Absolute Percentage Error (MAPE) of 1.24%.

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