SHORT LOAD FORECASTING BY USING A HYBRID MODEL OF ADAPTIVE NEURO-FUZZY SYSTEM FOR ELECTRIC LOAD

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Abstract: Load forecasting is crucially necessary for the electric for any power system and real- life difficulty in industry in the deregulated economy. It has various applications including energy purchasing and generation, contract evaluation, load switching, infrastructure development and to forecast the load demand from the customers by rising or declining the power generated and to lessen the operating costs of producing electricity. Besides, the conventional traditional models, some models based on artificial intelligence have been purposed in the literature, specifically, neural network for their good performance. Other non-parametric approaches of artificial intelligence have also been applied. However, all these models are imprecise when used in real time operation. The purpose of this research is to present an electric system load forecasting model using an adaptive Neuro-Fuzzy interface system (ANFIS) and discuss in detail how ANFIS is effectively applied to weekly, short term load forecasting with respect to different day types. The outcome and forecasting performance obtained reveal the effectiveness of the proposed approach and shows that it has potential to build a high accurateness model with less historical data using a hybrid of neural network and fuzzy logic which can be used in real time.

Keywords: Short term, load forecasting, ANFIS, fuzzy logic, electric load.

I. INTRODUCTION

Numerous advances have been made in developing intelligence systems, some inspired by biological neural network, fuzzy system and combination of them. Many researchers from variety of scientific disciplines are designing Artificial Neural Network (ANNs) to mitigate a various problems in pattern recognition, prediction, optimization, associative memory and control. Conventional approaches have been proposed for solving these problems [1]. Although successful applications can be found in certain well constrained environments, none is flexible enough to perform well outside its domain. Artificial Neural Network has been replacing traditional methods in many applications offering, besides a better performance, a number of advantages: no need for system model, tolerance bizarre patterns, notable adaptive capability and etc.

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Substantially, its corresponding price forecasting models on order to make an appropriate market decision. A variety of types of load forecasting methodologies as It has being stated in advantages view. Thus, load forecasting can be performed using many techniques such as statistical methods, artificial neural network, genetic algorithm, fuzzy logic, Neuro-Fuzzy system and so on. Load forecasting is the most successful applications of ANN in power systems data [2]. Neuro-Fuzzy (NF) computing is a famous framework for solving complicated (complex) problems.

In the load forecasting the higher efficiency technique is needed to perform the quality and accuracy of the forecast which is the higher necessarily in managing the production and purchasing in an economically reasonable way. Thus, in the load forecasting, its play the important role in helping the electric utility to make unit commitment decisions, as to reduce the reserve capacity and to also essential to enhance the reliability of the power system [3]. Besides, the complex problem needs to obtain accurate load forecasting for electric utilities in a competitive environment created by the electric industry deregulation. There also exist large forecast errors using ANN method when there are rapid fluctuations in load and temperatures. In such cases, forecasting methods using fuzzy logic approach have been employed.

The inspiration of this paper is to analyze and discuss the load forecasting from different point of view. As the adaptive Neuro-Fuzzy inference system (ANFIS) using a input/output data set. The toolbox function ANFIS construct a fuzzy inference system (FIS) whose membership function parameter are tuned or adjusted using either a backpropagation algorithm alone, or in combination with a least squares type of method. This allow fuzzy system to learn the data modeling to the short term forecasting as the use of a lot of type historical data and to reduce the error in the forecasting analysis [4].

This paper is organized in four parts. In part 2, it will be the main objective and a description of load forecasting. Part 3 will be Overview of load forecasting while part 4 will be present regarding of methodology used for load forecasting follow with part 5 the result and discussion of the proposed model structure for load forecasting of electric load weekly load consumption and discussion then part 6 with present conclusion and finally part 7 will be recommendation and reference of research.

2. DESCRIPTION AND OBJECTIVE OF LOAD FORECASTING

The main objective of load forecasting is to present the power load consumption for operation and planning. However, it help electric company producer to make decisions in purchasing, load switching, power generating, infrastructure development and for timely dispatcher information. Load forecasting play also an important role for contact evaluations of various financial products on energy price offered by the market. Moreover, load forecasting is a difficult task because of complexity, nonlinearity and many important exogenous variables that must be considered. For the type of time load series under study, model development should take into account seasonal patterns. The objective of the work is to develop an algorithm to forecast hourly load, by incorporating weather conditions like temperature, humidity, etc. In this work, an attempt is made to implement the above forecast using fuzzy set classified neural network approach.

The core scope of the project is to develop a system that using modern methods that are intelligent and able to learn and adapt to changes in the circumstances surrounding the forecasts have been developed. Thus, load affecting factors include the day type, time of day and etc. Since most days have different load profiles, it is necessary to have a day type. Time of day is an important factor in short term load forecasting because it is required to know what time of day the forecast is for because the level demand at any time of day is different. Weather conditions are vital in short-term forecasting as there is a variation of load demand as the condition. So combination of Neural Network and Fuzzy logic toward this project has been suggested. The significant of the project is to improve the result data by using the Neuro-Fuzzy technique in the Short Load Term Forecasting. Moreover, for the evaluating to the proposed load forecasting, the model will be implemented in MATLAB2013b software simulation. The model will be trained by using ANFIS tool.

2.1 The Dataset

The data used for this example are historical hourly temperatures, system loads and day-ahead electricity prices from the New England Pool region.

3. OVERVIEW OF LOAD FORECASTING

3.1 Type of load forecasting

Depending the period of the forecast done, it is classified into three different types which are:

- Short term load forecasting: forecasts within a time period of one day to one month.
- Medium term load forecasting: forecasts within a time period of one month to one year.
- Long term load forecasting: with a time period of more than one year.

In this paper, the research is focusing on the short term load forecasting. Thus, in the literature of research it can find a wide range of methods for electric load forecasting. The classification is based on certain characteristics, for instances, the type of model, and the type of data to provide the model, the computational time required, prediction algorithm and the availability of experimental results. A variety of methods and ideas have been tried for load forecasting, with varying degrees of success. They can be parted into two categories which are statistical method and artificial intelligence technique.

3.2 Techniques of load forecasting

3.21 Statistical methods

Electricity load consumption is sampled and train within 24 hours a day, 365 days a year. So, it represents a following measurement taken at equally intervals what gives an opportunity to apply statistical methods including exponential smoothing, time series and regression methods. These statistical methods are attractive and allowing researcher to understand the system behavior under research study. Consequently, the drawback of these methods is their limit ability to model the nonlinearity of load consumption [5].

3.22 Artificial neural network

An artificial neural network is a mathematical model of computational model that is inspired by the structure and/or functional aspects of biological neural networks.

The motivation for the development of neural network technology stemmed from the desire to develop an artificial system that could perform "intelligent" task similar to those performed by human brain. When load forecasting is dealt by using neural networks, we must select one of the numbers of the available architectures (such as Hopfied, Kohonon, back propagation, Bolzmann, etc), the number of layers and elements, the connectivity between them, usage of unilateral or bilateral links and the number format to be used by inputs and outputs.

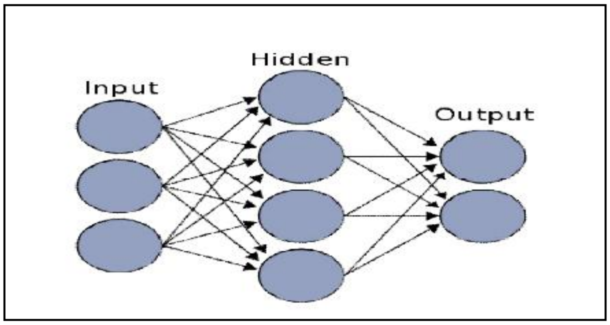

Fig.1 Artificial neural network

There will be differences in the evaluation of performance depending on the different models. Generally back propagation is used. A backpropagation network topology includes 3 or 4 layers, the transfer function may be linear or non linear or a combination of both. The network may be fully connected or non-fully connected. The application of neural network in power utilities has been growing in acceptance over the years. The main reason behind this is because the capability of the artificial neural networks in capturing process information in a black box manner [6].

3.23 Fuzzy logic system

Fuzzy logic is a form of many- valued logic; it deals with reasoning that is approximate rather than fixed and exact. In contrast with traditional logic theory, where binary sets have two- valued logic: true or false, fuzzy logic variables may have a truth value that ranges in degree between 0 and 1. Furthermore, when linguistic variable are used, these degrees may be manage by specific function [7]. Under fuzzy logic an input is associated with certain qualitative values. For instance the temperature of a day is "Low", "Medium" or "High".

In the operation and management of power systems, fuzzy load forecasting plays a paramount role. Fuzzy logic usage has got several advantages. There is no need of a mathematical model mapping inputs to outputs and the absence of a need for precise inputs. Properly designed fuzzy logic systems can be very robust when used for forecasting with such generic conditioning rules. An exact output is needed of fuzzy inputs is followed by "defuzzification" to produce precise outputs.

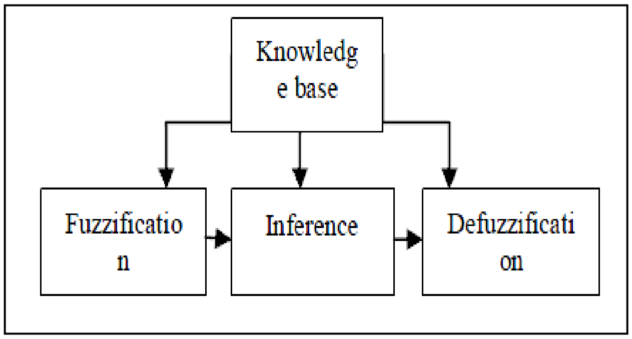

Fig.2 Block diagram of a fuzzy system

3.24 Neuro-Fuzzy system

Alternatively, in the field of artificial intelligence, Neuro-Fuzzy refers to combinations of artificial neural networks and fuzzy logic. Neuro- fuzzy was proposed by J.S.R. Jang. Neuro-fuzzy hybridization result in a hybrid intelligence system that synergizes these two techniques by combining the human-like reasoning style of fuzzy systems with the learning and connectionist structure of neural networks. Neuro-fuzzy hybridization is widely termed as Fuzzy Neural Network (FNN) or Neuro-Fuzzy System (NFS) in the literature. Neuro-fuzzy system incorporates the human-like reasoning style of fuzzy systems through the use of fuzzy sets and a linguistic model consisting of a set of IF-THEN fuzzy rules [8]. The main strength of Neuro-fuzzy system is that they are universal approximations with the ability to solicit interpretable IF-THEN rules [15].

Several different ways to combine fuzzy logic with neural networks technique have been proposed by researcher in order to improve the overall forecasting performance. A neuro fuzzy system is about taking an initial fuzzy inference systems and tuning it with a back propagation algorithm based on the collection of input-output data[9].

3.25 ANFIS structure

An adaptive Neuro-Fuzzy inference system is an intercept between an artificial neural network and a fuzzy inference system. It is a fuzzy Takagi-Sugeno type of model put in the framework of adaptive systems to facilitate learning and adaptive.The ANFIS architecture for two input variables X and Y with two fuzzy sets A1, A2,A3, B1 and B2,B3 as indicate in figure 5.In this architecture, the first layer is formed by adaptive nodes that give the degree of Fuzzy membership function properties of the input. The second compute the firing strength of the associated rules. Neurons constituting the third layer are fixed neurons and play a normalization role to the firing strength from the previous layer. Fourth layer is adaptive who give the product of the normalized firing level and a first order polynomial [10. Conversely, the last layer presents a summation of all incoming signals.

Short term load forecasting (STLF) refers to forecasts of electricity demand or load, from one to several days ahead. In the daily operations of a power utility, the short term load forecasting is of vital importance. It is required for unit commitment, energy transfer scheduling and load dispatch. The short term load forecasting has played a greater role in utility operations with the emergence of load management strategies. The development of an accurate, fast and robust short-term methodology is of importance to both the electric utility and its customers.

4. METHODOLOGY

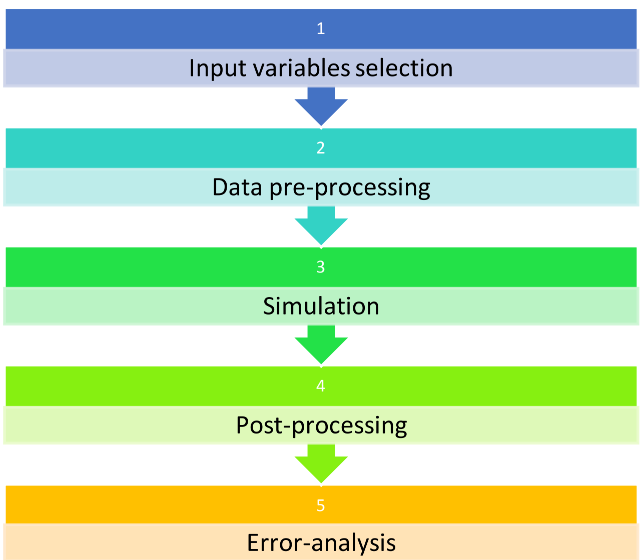

Fig.3 methodology of forecasting procedure

Work accessible here is divided into three steps:

1. The ANFIS Set Based Classification: Classification of training using Neuro-Fuzzy Set.
2. Training of Neural Network: Training of the neural network for each hour of each day for which the load is to be forecasted using the training data of that particular class to which hour belongs.
3. Short term load forecasting: Forecasting of hourly load using trained neural network.

4.1 Flow chart

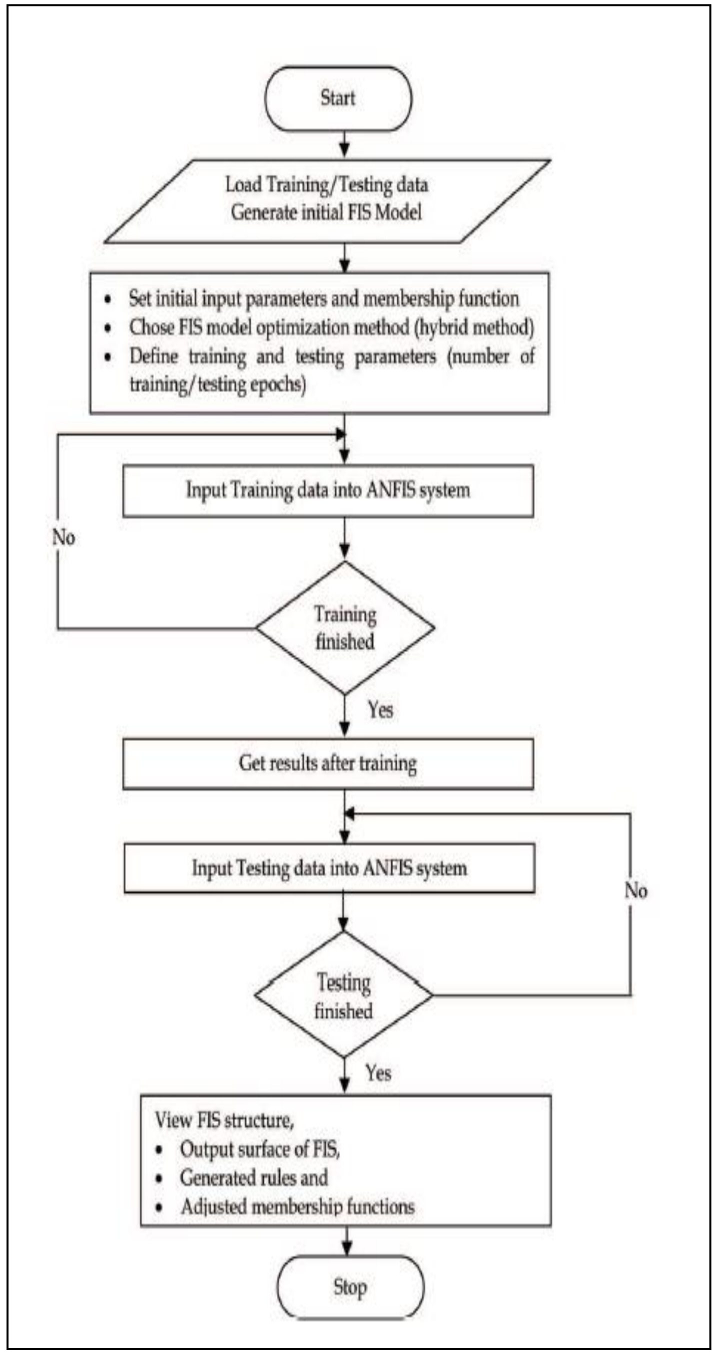

Fig.4 Flow chart of training methodology of ANFIS system

Figure 4 show the flowchart of the project. The methodology of this project will cover from the process flow from the beginning of the system until the end.

5. RESULTS AND DISCUSSIONS

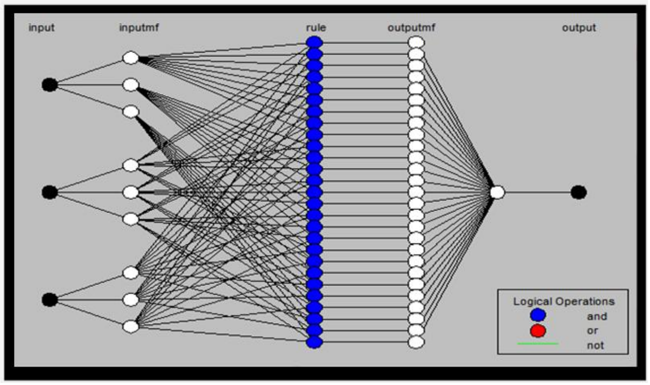

Fig.5 ANFIS structure: Neuro-fuzzy, with three input parameters and 27 rules. Layer-1 represents inputs,layer-2 input membership function, layer-3 rules,layer-4 output membership function,layer-5 weighted sum output and layer-6 output.

Neuro-fuzzy forecasting model has been tested firstly for modeling and forecasting weekly load. For model development of weekly time series data using ANFIS system, the time series data Z = $\{Z_1, Z_2, \ldots, Z_q\}$ has to be rearranged in a multi input single output. However, for the given weekly data points modeling and forecasting the Neuro-Fuzzy predictor is supposed to work with ten inputs and one output only. The input is directly extracted from the data sets. Here, the weekly load data is used. There are 1400 data samples. Hence, In order to overcome and mitigate the increasing computation time and avoid the large number of rules and parameters of learning we must select the input vectors according to the minimal error in the first epochs of learning phase. In training phase, only the first 175 data each input-data sets are used whereas, the remaining 175 data were used for prediction test represented in fig.5. the presented data demonstrates that the training and checking data do not cover the same region.

The desired weekly load consumption and the neuro-fuzzy prediction were shown in fig.11. Results clearly show the excellent training as well as prediction performance of Takagi-Sugeno Neuro-Fuzzy network.

It shows the fuzzy rule architecture of ANFIS when the Product Sigmoidal membership function is adopted. The membership function of each input was tuned using hybrid method consisting of backpropagation for the parameters associated with the input membership function and combination of the least square estimation for the parameters associated with the output membership functions. The computations of the membership function parameters are facilitated by a gradient vector which provides a measure of how well the fuzzy inference system (FIS) is modeling the input/output data. For a given set of parameters, the numbers of nodes in the training data were found to be 78. The numbers of linear parameters and non-linear parameters were found to be 27 and 36 respectively. The hypothesized initial number of membership functions and the type used of each input were 3 and Product Sigmoidal (Psigmf) Membership Function respectively. Now, the hypothesized FIS model is trained to emulate the training data by modifying the membership functions parameter according to the chosen error criterion. A suitable configuration has to be chosen for the best performance of the network. Goal for the error was set to 0.00 and number of training epochs was given 1500. After the training (with 1500 epochs) was complete final configuration for the FIS are:

1. No. of input = 3
2. No. of membership functions for each input = 5
3. Type of membership functions for each Input = Psimf (Product Sigmoidal MFs)
4. No. of fuzzy rules = 27
5. Type of membership functions for each output = constant
6. No. of output membership function = 27
7. No. of training epochs = 1500
8. No of training data sets = 175
9. No of testing data = 175
10. Error goal = 0.00

5.1 Training error

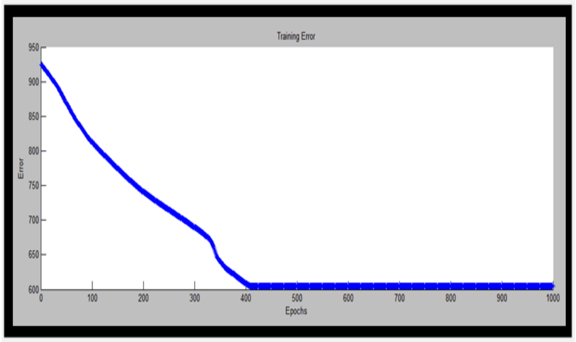

Fig.6 Performance graph of the neuro fuzzy model for a week (01 Mac – 14 Mac 2004)

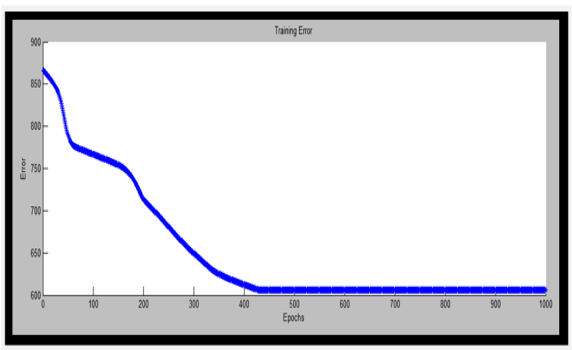

Fig.7 Performance graph of the neuro fuzzy model for a week (06 Sept – 19 Sept 2004)

5.2 plot againttraining dataset

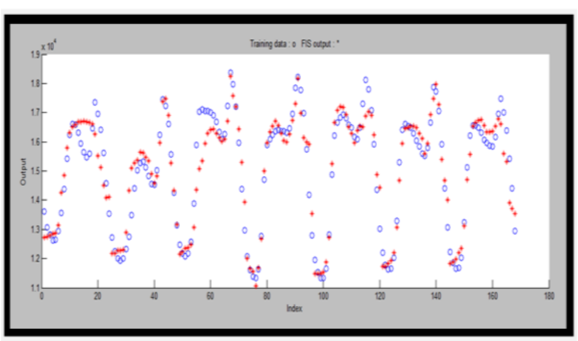

Fig.8 plot against training data for a week (01 Mac – 14 Mac 2004)

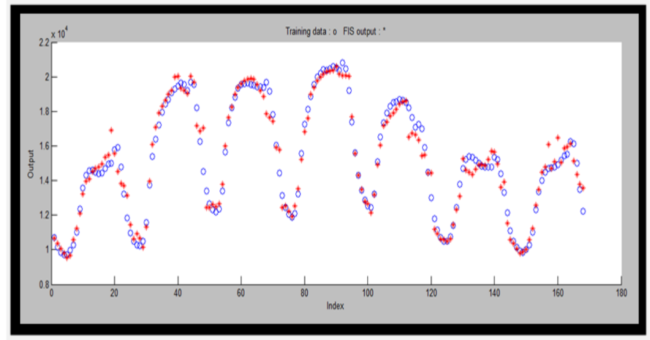

Fig.9 plot against training data for week (06 Sept – 19 Sept 2004)

5.3 plot againt testing dataset

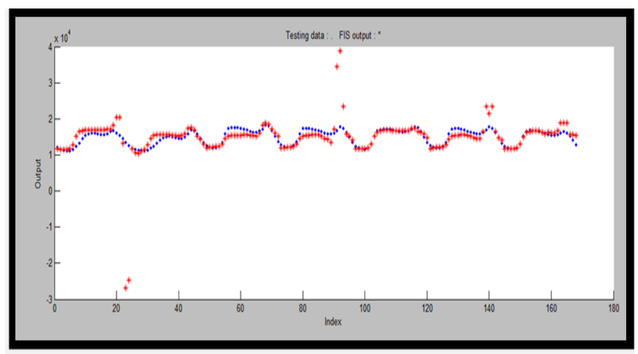

Fig.10 plot against testing data for week (01 Mac – 14 Mac 2004)

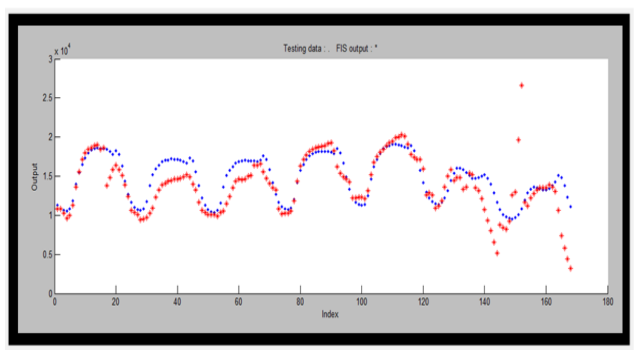

Fig.11 plot against testing data for week (06 Sept – 19 Sept 2004)

5.4 Surface graph

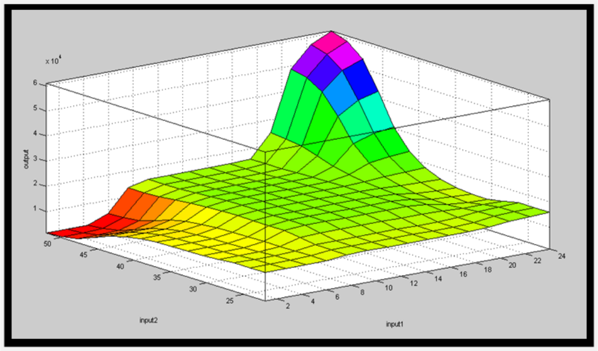

Fig.12 input 1 and input 2 (01 Mac – 14 Mac 2004)
(a)

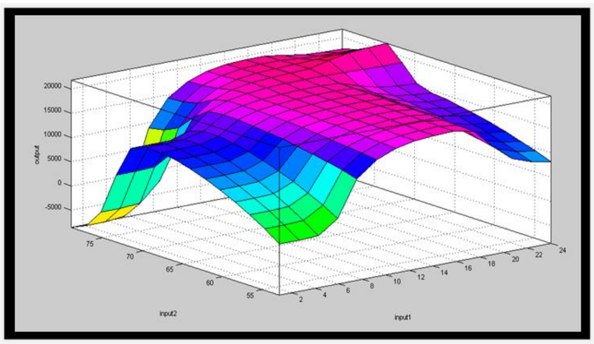

Fig.13 input 1 and input 2 (06 Sept – 19 Sept 2004)
(b)

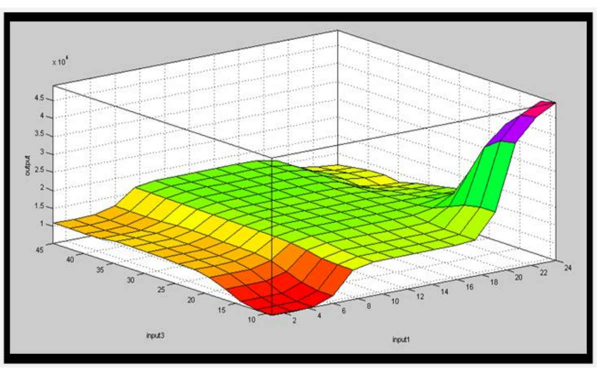

Fig.14 input 1 and input 3 (01 Mac – 14 Mac 2004)
(c)

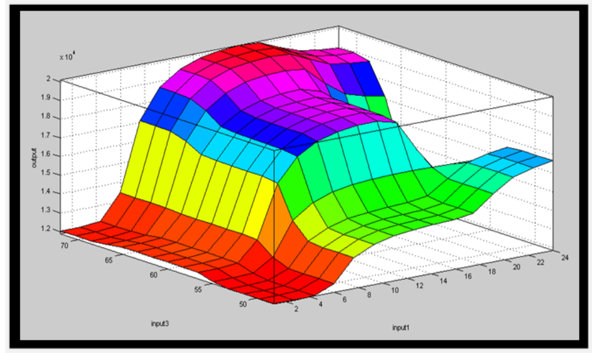

Fig.15 input 1 and input 3 (06 Sept – 19 Sept 2004)),
(d)

The figure 6-7 shows that the performance of graph of the neuro fuzzy model for a week (01 Mac – 14 Mac 2004) and graph of the neuro fuzzy model for a week (06 Sept – 19 Sept 2004) respectively.the 1500 epoch have been implemented for both data type with arbitrary five membership function to each variable chosen empirically by examining the desired input-output data.

In figure 8-11 above presents the load curve for the weekly. It is found that the daily consumption usually begins with load values early the week day consumption. Hence, The power demand decreases significantly toward the end of the day of the week. It shows also that the power demand on weekend is different from workdays. For a good prediction of the load series, electric load system a model must take into account variations as well as the various factors that affecting the load system, for instances, historical hours temperature, dry bulb, dew point and etc.

Fig.12-13 shows that the Surface graph showing relationship of (a) input 1 and input 2 and (c) input 3 and input 1 with predicted output for the neuro fuzzy model for week (01 Mac – 14 Mac 2004), and Fig.14-15 shows that the Surface graph showing relationship of Surface of (b) input 1 and input 2 and (d) input 3 and input 1 with predicted output for the neuro fuzzy model for week (06 Sept – 19 Sept 2004), input 1 is historical hourly temperature, input 2 is dry bulb, input 3 is dew point, and output is predicted electric system load in Mwh unit.

6. CONCLUSIONS

In this research study, application of Neuro-fuzzy technique is presented for the prediction of the weekly load curve. ANFIS architecture is successfully used to predict electric load system forecasting. Results obtained are satisfactory and shows that the good accuracy of developed model is not affected by rapid fluctuations in the output which is the main drawback hybrid of neural network and fuzzy logic which is Neuro-Fuzzy models. Thus, the forecasting performance obtained reveal the effectiveness of the proposed approach and shows that it is possible to build a high accuracy model with less historical data using a combination of neural network and fuzzy logic which can be used in real time.

7. RECOMMENDATION

The load forecasting model can be further improved by including other type of parameter such as humidity, windfall and etc. This project also can enhance by changing and adjusting the variation the behavior of membership function properties of each plot graph through the FIS editor to manage the plot function become more precise accurate result to the output data. Thus, the forecasting method can be further the research by using the medium and long forecasting method.

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