A Novel Approach to Short – Term Load Forcasting using Fuzzy Network" A Review

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Abstract – Load prediction is important for planning and function in energy organization. It enhances the Energy efficient with consistent operation of a power system. The energy abounding through utilities meets the load as well as the energy lost in the system is ensured via this tool. As in power system the next day's power production must be planned each day. The day-before small term load prediction/ forecasting (STLF) is a essential daily duty for power transmit. Small period load prediction is required for unit dedication, economic allocation of generation, maintenance schedules. At present study gives a brief review on a solution methodology using fuzzy logic for short term load forecasting. Fuzzy logic methods is implemented on weather sensitive data with historical load data for forecasting the load.

Keywords-- Short term load forecasting, fuzzy logic, membership function, Absolute percentage error.

I - Introduction

1.1 OVERVIEW

Load forecasting is the guess of upcoming loads of a power system. Electric load forecasting, otherwise short period load forecasting, comes under a range of synonyms: electricity load forecasting; electricity require forecasting; expenditure forecasting; electricity load prediction; load require; power require; load require prediction; and load estimation etc. Correctness in electricity load forecasting is essential in power system development and function with also will help market participants minimize running cost and develop a more dependable energy supply device (Quaiyum et al 2011). The major problem of the planning is the require awareness in the future. Basic operating functions like as hydro power with thermal power unit commitment, economic dispatch, fuel scheduling and unit maintenance may be performed professionally with an accurate prediction. Load forecasting is too imperative for contract evaluations as well as evaluations of different financial commodities on energy pricing offered through a de regulated market. Power system designers use various methods to optimally plan, monitor, as well as operate different aspects of presents complicated power systems. Some of those methods are economic dispatch, unit commitment, state estimation, automatic generation control, security analysis, optimal power flow, and load forecast.

Load forecasting can be measured long term, medium term, with also short term. Long term load forecast contain one to ten years forward, is functional in expansion planning, inter-tie tariff setting, and long-term capital investment return. Medium term load forecast, covers period of some weeks, is mainly used for scheduling fuel supply. Short term load forecast results, ahead hourly and daily, is needed in unit commitment, maintenance, and economic dispatch problems. For better service of electricity, the customers need a secure and continuous power supply. A poor service of load predicts misleads planners with also often results in incorrect and sometime expensive expansion plans. If any negative error in the forecast result might affect consumer's production stages, particularly for larger power users. Accurate forecasts are need for power system protection and its overall dependability.

1.2 OBJECTIVE OF THE STUDY

Load demand based on various parameters like as variation in ambient temperature, wind velocity, humidity, precipitation with also cloud cover. As electricity demand is closely subjective through those climatic parameters, there is similarly to be an impact on demand patterns. For each hour load demand based on these crucial role parameters.

In the past decade, various methods have been used for demand forecasting. Some of these methods are: the time series model, exponential smoothing method, state space method, and linear regression model, along with knowledge based approach. These methods have some drawbacks such as inaccurate calculation, complexity in modelling processes, numerical instability, and necessity of large historical database, with also demand of high human knowledge.

II - LITERATURE REVIEW

The various study have been carried out by different researchers, some of them are as follows:

- ***"Neural Network with Fuzzy Set-Based Classification for Short-Term Load Forecasting" by M. Daneshdoost, Senior Member, IEEE, IEEE***

Transactions on Power Systems, Vol. 13. No. 4. November 1998
A multi-layered feel forward ANN combined with the fuzzy set-based classification technique for short-term electric load forecasting has been proposed in this paper. The hourly data was classified into classes based on the fuzzy set representation of two weather variables; dry-bulb temperature and relative humidity. The classification is based on the fact that the power system load is heavily influenced by the weather condition. The fuzzy set was used to assist the classification process in order to achieve the smooth transition between the classes of weather condition. The proposed technique was tested and its performance was evaluated by the mean absolute percentage error (MAPE) of three measures of hourly load, peak load, and total daily energy. The set of ANN'S was shown to forecast the system's load up to 120 hours ahead with MAPE less than 2 percent for all three mixtures

- ***"Very Short-Term Load Forecasting Using Artificial Neural Networks" by Wiktor Charytoniuk, Member: IEEE, and Mo-Shing Chen, Fellow, IEEE, lEFF TRANSACTIONS ON POWR SYSTEMS, VOL. IS. NO. I, FEBRUARY 2000***
In a deregulated, competitive power market, utilities tend to maintain their generation reserve close to the minimum required by an independent system operator. This creates a need for an accurate instantaneous-load forecast for the next several dozen minutes.
This paper presents a novel approach to very short-time load forecasting by the application of artificial neural networks to model load dynamics. The proposed algorithm is more robust as compared to the traditional approach wilier actual louds are forecasted and used as input variables. It provides more re- liable forecasts, especially when the weather conditions are different from those represented in the training data. The proposed method has been successfully implemented and used for on-line load forecasting in a power utility in the United States. To assure relist performance and training times acceptable for on-line use, the forecasting system was implemented as a set of parsimoniously designed neural networks. Each network was assigned a task of forecasting bad for a particular time lead and a certain period of day with a unique pattern in load dynamics. Some details of this implementation are presented in the paper.

- ***"Short-Term Load Forecasting Methods: An Evaluation Based on European Data" by James W. Taylor and Patrick E. McSharry, Senior Member, IEEE, IEEE TRANSACTIONS ON POWER SYSTEMS, VOL. 22, NO. 4, NOVEMBER 2007***
This paper used intraday electricity demand data from ten European countries as the basis of an empirical comparison of univariate methods for prediction up to a day-ahead. A notable feature of the time series is the presence of both an intraweek and an intraday seasonal cycle. The forecasting methods considered in the study include: ARIMA modelling, periodic AR modelling, an extension for double seasonality of Holt-Winters exponential smoothing, a recently proposed alternative exponential smoothing formulation, and a method based on the principal component analysis (PCA) of the daily demand profiles. Our results show a similar ranking of methods across the 10 load series. The results were disappointing for the new alternative exponential smoothing method and for the periodic AR model. The ARIMA and PCA methods performed well, but the method that consistently performed the best was the double seasonal Holt-Winters exponential smoothing method.

- ***"A Novel Hybrid Method for Short Term Load Forecasting using Fuzzy Logic and Particle Swarm Optimization" Amit Jain, Member, IEEE, M. Babita Jain, Member, IEEE and E. Srinivas, 2010 International Conference on Power System Technology***
Load forecasting has become a very crucial technique for the efficient functioning of the power system. This paper presents a methodology for the short term load forecasting problem using the similar day concept combined with fuzzy logic approach and particle swarm optimization. To obtain the next-day load forecast, fuzzy logic is used to modify the load curves of the selected similar days of the forecast previous day by generating the correction factors for them. These correction factors are then applied to the similar days of the forecast day. The optimization of the fuzzy parameters is done using the particle swarm optimization technique on the training data set of the considered data set. A new Euclidean norm with weight factors is proposed for the selection of similar days. The proposed methodology is illustrated through the simulation results on a typical data set.

- ***"Short Term Load Forecasting using Fuzzy Adaptive Inference and Similarity" by Amit Jain, E. Srinivas, Rasmimayee Rauta***
The main objective of short term load forecasting (STLF) is to provide load predictions for generation scheduling, economic load dispatch and security assessment at any time. Thus, STLF is needed to supply necessary information for the system management of day-to-day operations and unit commitment. This paper presents a forecasting method based on similar day approach in conjunction with fuzzy rule-based logic. To obtain the next-day load forecast, fuzzy logic is used to modify the load curves on selected similar days. A

Euclidean norm considering weather variables such as 'temperature' and 'humidity' with weight factors is used for the selection of similar days. The effectiveness of the proposed approach is demonstrated on a typical load and weather data.

- ***"Load Forecasting Using Hybrid Models" by MadasuHanmandlu, Senior Member, IEEE, and Bhavesh Kumar Chauhan, Member, IEEE, IEEE TRANSACTIONS ON POWER SYSTEMS, VOL. 26, NO. 1, FEBRUARY 2011***
  This paper presents two hybrid neural networks derived from fuzzy neural networks (FNN): wavelet fuzzy neural network (WFNN) using the fuzzified wavelet features as the inputs to FNN and fuzzy neural network (FNCI) employing the Choquet integral as the outputs of FNN. The learning through FNCI is simplified by the use of q-measure and the speed of convergence of the parameters is increased by reinforced learning. The underlying fuzzy models of these hybrid networks are a modified form of fuzzy rules of Takagi-Sugeno model. The number of fuzzy rules is found from a fuzzy curve corresponding to each input-output by counting the total number of peaks and troughs in the curve. The model scan forecast hourly load with a lead time of 1 has they deal with short-term load forecasting. The results of the two hybrid networks using Indian utility data are compared with ANFIS and other conventional methods. The performance of the proposed WFNN is found superior to all the other compared methods.
- ***"Neural Network-Based Model Design for Short-Term Load Forecast in Distribution Systems" by Ni Ding, Clémentine Benoit, Guillaume Foggia, Yvon Bésanger, Senior Member ,IEEE, and Frédéric Wurtz***
  Accurate forecasts of electrical substations are mandatory for the efficiency of the Advanced Distribution Automation functions in distribution systems. The paper describes the design of a class of machine-learning models, namely neural networks, for the load forecasts of medium-voltage/low-voltage substations. The author focus on the methodology of neural network model design in order to obtain a model that has the best achievable predictive ability given the available data. Variable selection and model selection are applied to electrical load forecasts to ensure an optimal generalization capacity of the neural network model. Real measurements collected in French distribution systems are used to validate our study. The results show that the neural network-based models out per form the time series models and that the design methodology guarantees the best generalization ability of the neural network model for the load forecasting purpose based on the same data.
- **"Short-Term Load Forecasting Using ANN Technique" by Samsher Kadir Sheikh, M. G. Unde, International Journal of Engineering Sciences & Emerging Technologies, Feb 2012. ISSN: 2231 – 6604 doi: 10.7323/ijeset/v1_i2_12 Volume 1, Issue 2, pp: 97-107 ©IJESET**
  This work studies the applicability of this kind of models. The work is intended to be a basis for a real forecasting application .First, a literature survey was conducted on the subject. Most of the reported models are based on the so-called Multi-layer Perceptron (MLP) network. There are numerous model suggestions, but the large variation and lack of comparisons make it difficult to directly apply proposed methods. It was concluded that a comparative study of different model types seems necessary.
  Several models were developed and tested on the real load data of a Finnish electric utility. Most of them use a MLP network to identify the assumed relation. We carried out short-term load forecasting for P.D.V.V.P.COE, Ahmednagar college campus using ANN (Artificial Neural Network) technique ANN was implemented on MATLAB-10. MLP (Multi-layer Perceptions was made with input as days and hourly load. Hourly load means the hourly power consumption in college. Error was calculated as MAPE (Mean Absolute Percentage Error) and with error of about 0.956% this paper was successfully carried out. This paper can be implemented by any intensive power consuming company/ college for predicting the future load and would prove to be very useful tool while sanctioning the load.
- ***"Factor Affecting Short Term Load Forecasting" by Muhammad Usman Fahad and NaeemArbab, Journal of Clean Energy Technologies, Vol. 2, No. 4, October 2014***
  The basic objective of short term load forecasting is to predict the near future load for example next hour load prediction or next day load prediction etc. The total system load is the load seen at the generating end of the power system, which includes the sum of all types of loads connected to the system plus the losses. To design efficient and accurate forecasting model one must have good understanding of the characteristics of the system. There are various factors which influence the behaviour of the consumer load and also impact the total losses in transmission lines. These factors can be categorized as Time factor, weather, economy and random disturbances. In this research paper these factors and their impact on consumption of electric power and their significance in short term load forecasting is evaluated.
- ***"Use of Artificial Neural Networks for Short-Term Electricity Load Forecasting of Kenya National Grid Power System", Christopher A. Moturi , Francis K. Kioko, International Journal of Computer Applications (0975 – 8887) Volume 63– No.2, February 2013***

This paper developed a supervised Artificial Neural Networkbased model for Short-Term Electricity Load Forecasting, and evaluated the performance of the model by applying the actual load data of the Kenya National Grid power system to predict the load of one day in advance. Raw data was collected, cleaned and loaded onto the model. The model was trained under the WEKA environment and predicted the total load for Kenya National Grid power system.

The test results showed that the hour-by-hour approach is more suitable and efficient for a day-ahead load forecasting. Forecast results demonstrated that the model performed remarkably well with increased number of iterations. The result suggests that incremental training approach of a neural network model should be implemented for online testing application to acquire a universal final view on its applicability.

- ***"Very short term load forecasting of a distribution system with high PV penetration" by Saeed Sepasi , EhsanReihani, Abdul M. Howlader, Leon R. Roose, Marc M. Matsuura, Renewable Energy Volume 106, June 2017, Pages 142–148***

A battery energy storage system (BESS) is an available solution for utilities to deal with intermittency issues resulting from renewable energy resources. A BESS needs to have a control algorithm to provide a very good estimation of the load on the grid at each time step. A short-term load forecast (STLF) is necessary for efficient and optimized control of BESSs that are connected to the grid. In this work, two parallel-series techniques for load forecasting are proposed to optimize the performance of a grid-scale BESS (1 MW, 1.1 kWh) in 15-min steps within a moving 24-h window. In both techniques, a complex-valued neural network (CVNN) is used for parallel forecasting.

The parallel component is based on the search for similar days of historical data that have a weekly index comparable to the forecast day. For series forecasting, historical data of each day is used within a moving forecast window by CVNN along with the spline method. For both techniques, parallel forecasting is mixed with series forecasting by an adjustment coefficient. Both techniques are tested on a set of real data for a grid with high PV penetration, and the obtained results are compared.

- ***"Short-term electric load forecasting based on singular spectrum analysis and support vector machine optimized by Cuckoo search algorithm" by Xiaobo Zhanga, Jianzhou Wanga , Kequan Zhang, Electric Power Systems Research 146 (2017) 270–285***

Short-term electric load forecasting (STLF) has been one of the most active areas of research because of its vital role in planning and operation of power systems. Additionally, intelligent methods are increasingly popular in forecasting model applications. However, the observed data set is often contaminated and nonlinear by as a result of such that it becomes difficult to enhance the accuracy of STLF. Therefore, the novel model (CS-SSA-SVM) for electric load forecasting in this paper was successfully proposed by the combination of SSA (singular spectrum analysis), SVM (support vector machine) and CS (Cuckoo search) algorithms.

First, the signal filtering technique (SSA) is applied for data pre-processing and the novel model subsequently models the resultant series with different forecasting strategies using SVM optimized by the CS algorithm. Finally, experiments of electric load forecasting are used as illustrative examples to evaluate the performance of the developed model. The empirical results demonstrated that the proposed model(CS-SSA-SVM) can improve the performance of electric load forecasting considerably in comparison with other methods (SVM, CS-SVM, SSA-SVM, SARIMA and BPNN)

"Short-term load forecasting method based on fuzzy time series, seasonality and long memory process" by Hossein Javedani Sadaei, Frederico Gadelha Guimarães, ,Cidiney José da Silva, Muhammad Hisyam Lee , Tayyebeh Eslami, International Journal of Approximate Reasoning Volume 83, April 2017, Pages 196–217

Seasonal Auto Regressive Fractionally Integrated Moving Average (SARFIMA) is a well-known model for forecasting of seasonal time series that follow a long memory process. However, to better boost the accuracy of forecasts inside such data for nonlinear problem, in this study, a combination of Fuzzy Time Series (FTS) with SARFIMA is proposed. To build the proposed model, certain parameters requires to be estimated. Therefore, a reliable Evolutionary Algorithm namely Particle Swarm Optimization (PSO) is employed.

As a case study, a seasonal long memory time series, i.e., short term load consumption historical data, is selected. In fact, Short Term Load Forecasting (STLF) plays a key role in energy management systems (EMS) and in the decision making process of every power supply organization. In order to evaluate the proposed method, some experiments, using eight datasets of half-hourly load data from England and France for the year 2005 and four data sets of hourly load data from Malaysia for the year 2007, are designed. Although the focus of this research is STLF, six other seasonal long memory time series from several interesting case studies are employed to better evaluate the performance of the proposed method. The results are compared with some novel FTS methods and new state-of-the-art forecasting methods. The analysis of the results indicates that the proposed method presents higher accuracy than its counterparts, representing an efficient hybrid method for load forecasting problems.

- ***"A local search algorithm to allocate loads predicted by spatial load forecasting studies", by Joel D. Meloa, Sergio Zambrano- Asanzab, Antonio Padilha -Feltrinc, Electric Power Systems Research, Volume 146, May 2017, Pages 206–217***

In recent years, spatial load forecasting studies have helped to direct the expansion of the distribution systems in cities with rapid urban growth, providing maps that showing the spatial distribution of expected load. However, these maps do not allow to determine how load varies on the existing network elements.

This information is important to define the reinforcements or the installation of new facilities in the electrical distribution network. In order to help planners in such decisions, a search method to allocate the loads resulting from spatial load forecasting studies is presented. This method treats each of these forecast loads as new load centre to be connected to an existing distribution feeder. To find the path from a load centre, the proposed method uses a list of its nearby feeders.

III - ADAPTIVE NEURO-FUZZY INFERENCE SYSTEM & FUZZY

3.1 About ANFIS

The acronym ANFIS is Adaptive Neuro - Fuzzy Inference System. Which is an integrated system, comprising of fuzzy logic with Neural Network was used to model the upcoming hour load, since it can address with solve problems correlated to randomness, non-linearity along with uncertainty of data.

ANFIS is one of the artificial intelligent techniques that could be used in electric load forecasting. ANFIS is a hybrid system which combines the human reasoning style of fuzzy logic with the connectionist as well as learning technique of neural network.

ANSYS is an adaptive network. An adaptive network is a network structure consisting of a number of nodes attached through directional links. Every node presents a process unit with the links specifying the association among the nodes. A number of the nodes in ANFIS are adaptive although others are fixed. The output of the adaptive nodes based on some modifiable parameters significant to the nodes.

Using several of the learning rules connected to adaptive networks, the parameters connected with the membership functions will be repeatedly modified via the learning process to model directly the relation explained through a set of known input or output pairs.

The model obtained with neural network is not understandable in terms of physical parameters (black box model) and it is impossible to interpret the result in terms of natural language. On the other hand, the fuzzy rule base consists of if-then statements that are almost natural language, but it cannot learn the rules itself. To obtain a set of if-then rules two approaches are used.

First, transforming human expert knowledge and experience, and second, automatic generation of the rules the second method is fully investigated. The fusion of neural networks with fuzzy logic in neuro-fuzzy models achieves readability along with and learning ability i.e. extracting rules from data at once. On 1993, Roger Jang developed the ANFIS technique that could overcome the shortcoming of the ANNs and fuzzy systems.

ANFIS is constructing a fuzzy inference system (FIS) whose membership function parameters are tuned using either a back propagation algorithm or hybrid method (which is a combination of back propagation and least squares method). FIS is the process of formulating the mapping from a given input to an output using fuzzy logic. ANFIS are a class of adaptive networks that are functionally identical to fuzzy inference systems.

A fuzzy inference system consists of fuzzy rules and membership functions and fuzzification and defuzzification operations as shown in figure 3.1.

Adaptive Network based Fuzzy Inference System is implemented as a Sugeno fuzzy inference system. ANFIS system allows the user to choose or modify the parameters of the membership functions based on the data. The parameters are adjusted automatically by the neuro adaptive learning techniques like back propagation algorithm or hybrid method. These techniques allow the fuzzy inference system to learn information about the data set.

Through the learning procedure, the parameters of the membership functions shall be transformed. The computations of these parameters may be controlled through the optimization process which is explained by the sum of squared difference between actual and desired outputs. As compare to Mamdani system, Sugeno systems are more compact and computationally efficient.

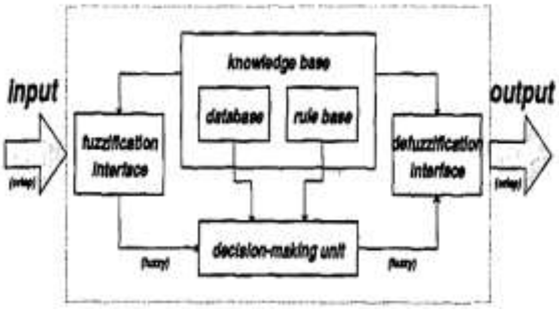

Figure 3.1Components of fuzzy inference system

3.2 Membership Functions

The membership functions of the system are the functions which can explain the fuzzy sets. The fuzzy rules contain a form of if-then rule with also describe how the output must be for a specific value of membership of its inputs.

The triangular, pi shaped, trapezoidal, Gaussian, generalized bell shaped, z shaped, s shaped, to mention but a few, are the various membership function that exist on the ANFIS graphic user interface. In present study, the ANFIS applied Gaussian membership functions on each input.

Two basic steps are concerned in the ANFIS processes, two steps are involved which are identified as the training with testing step correspondingly. During training, membership function parameters are modified in a manner that causes the desired input/output relationship to be learned. The training set is shown to the network many times (iterations or epochs), until converge is obtained or mean square error between output and target is minimized.

The symmetric Gaussian function depends on two parameters σ and c as given by:

F(x; σ, c) = e -(x-c)2 /2σ 2 …………(3.1)

The parameters for gauss mf represent the parameters σ and c listed in order in the vector [sig c]

3.3 Structure of ANFIS System

Structure of the Sugeno model is designed in such a way that the input is mapped to input membership function, the input membership function is mapped to rule, then the rule is mapped to output membership function and then the output membership function is mapped to the output. The system takes five layers. The first layer of each node generates a membership grade. Every node in the second layer measures the firing strength of the rule. Every node in the third layer calculates the ratio of the ith rule’s firing strength to the total of all firing strength. All node in the fourth layer is an adaptive node which maps to the output membership functions. The node in the fifth layer gives the overall output.

3.4 Training

Training is a learning process of the developed model. The model is trained till the results are obtained with minimum error. For design an ANFIS system to real world problems, it is required to choose the parameters for the process of instruction. It is necessary to have suitable training with testing data sets. If the datasets are not selected properly, then the testing data set will not validate the model. If the testing data set is completely different from the training dataset, then the model cannot capture any of the features of the testing data. In MATLAB, the two ANFIS parameter optimization methods are first is hybrid i.e. the default, mixed least squares and back propagation with second one back propagation. Error tolerance is used as training stopping criterion, which is related to the error size. The training will stop after the training data error remains inside this tolerance.

For a first-order Sugeno fuzzy model, a typical rule set with two fuzzy if-then rules can be articulated as:

Rule: 1 If x1 is A1 and x2 is B1,
Then y1 = p1 x1 + q1 x2 + r1,

Rule: 2 If x1 is A2 and x2 is B2,
Then y2 = p2 x1 + q2 x2 + r2,

Where [A1, A2, B1, B2] are known as the premise parameters. [pi, qi, ri] are known as the consequent parameters, where i = 1,2... The consequent parameters (p, q, and r) of the n^{th} rule contribute follows a first order polynomial of the variety:

Yn = pn x1 + qn x2 + rn ……… (3.2)

here xn are the inputs, Yn are the outputs within the fuzzy region specified by the fuzzy rule, pn, qn, and rn are the design parameters that are determine through the learning process.

- ANFIS Hybrid Training Rule

ANFIS developed a fuzzy inference system (FIS) whose membership function parameters are tuned through either a back propagation algorithm alone, otherwise hybrid kine of method. ANFIS is such more difficult than the fuzzy inference systems, with also it is not available for all of the fuzzy inference system options.

Particularly, ANFIS single supports Sugeno -type systems, with also having the following properties:

1. Be first or Zeroth order Sugeno-type systems.
2. Have a single output, obtained using weighted average defuzzifcation. All output membership functions must be the same type and either be linear or constant.
3. Have no rule sharing. Dissimilar rules cannot share the same output membership function, namely the number of output membership functions must be equal to the number of rules.

4. Have unity weight for each rule.

The ANFIS architecture consists of five kinds of layers with the output of the nodes in every respective layer represented through O i 1, where i is the i^{th} node of layer l.

3.5Fuzzy Logic

Fuzzy logic is a logic contain various values, estimated reasoning with having a vague boundary. The variables in fuzzy logic system might have any value in between 0 and 1, hence this type of logic system is capable to address the values of the variables known as linguistic variables those lie among completely truths otherwise completely false. Every linguistic variable is described through a membership function whose has a certain degree of membership at an exacting occasion. The human information is included in fuzzy rules. The fuzzy inference system formulates appropriate rules with based on those rules the decisions are made. That whole procedure of decision making is essentially the combination of concepts of fuzzy set theory, fuzzy IF-THEN rules along with fuzzy reasoning.

Conclusion

As electricity demands have deregulated over the last some years, precise load forecasts have become an essential part of a utility's long, medium, and short-term generation with also procurement planning. An incorrect load forecast can has severe penalty for customers in the form of higher rates. At present study fuzzy along with ANFIS methodology for short term load forecasting is presented. ANFIS is definitely superior to fuzzy logic algorithm as it inherits adaptability with learning. The learning period of ANFIS is too short than Fuzzy logic case. It means that ANFIS reaches to the target more early than fuzzy logic. In training of the data, ANFIS gives results with the least of total error as compared to other techniques. This shows that the best learning method is ANFIS among the all other techniques.

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