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Fuzzy Ideology based Long Term Load Forecasting

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***Abstract*—** Fuzzy Load forecasting plays a paramount role in the operation and management of power systems. Accurate estimation of future power demands for various lead times facilitates the task of generating power reliably and economically. The forecasting of future loads for a relatively large lead time (months to few years) is studied here (long term load forecasting). Among the various techniques used in forecasting load, artificial intelligence techniques provide greater accuracy to the forecasts as compared to conventional techniques. Fuzzy Logic, a very robust artificial intelligent technique, is described in this paper to forecast load on long term basis. The paper gives a general algorithm to forecast long term load. The algorithm is an Extension of Short term load forecasting method to Long term load forecasting and concentrates not only on the forecast values of load but also on the errors incorporated into the forecast. Hence, by correcting the errors in the forecast, forecasts with very high accuracy have been achieved. The algorithm, in the paper, is demonstrated with the help of data collected for residential sector (LT2 (a) type load: Domestic consumers). Load, is determined for three consecutive years (from April-06 to March-09) in order to demonstrate the efficiency of the algorithm and to forecast for the next two years (from April-09 to March-11).

***Keywords*—**Fuzzy Logic Control (FLC), Data Dependant Factors(DDF), Model Dependent Factors(MDF), Statistical Error(SE), Short Term Load Forecasting (STLF), Miscellaneous Error(ME).

I. INTRODUCTION

THE load forecasting is an essential element of power system operation and planning involving prognosis of the future level of demand to serve as the basis for supply-side and demand-side planning. Power demands need to be estimated ahead of time in order to plan the generation and distribution schedule [2]. Estimation of future load demands is done for various lead times (forecasting intervals) ranging from few seconds to more than a year [7,8]. Long-term electric load forecasting is an important issue in effective and efficient planning. Overestimation of the future load may lead to spending more money in building new power stations to supply this load. Moreover, underestimation of load may cause troubles in supplying this load from the available electric supplies, and produce a shortage in the spinning reserve of the system that may lead to an insecure and unreliable system [2, 4]. The overwhelming majority of load forecasting research has been on the short-term. In fact, very little published work can be found on the long-term problem. Part of the reason is that the long-term forecasting requires years of economic and demographic data which may not be easy to gather or access. Long-term forecasting (even when the data is accessible) is complex in the sense that it is affected by environmental, economical, political, and social factors [8]. Research in this area in the past 50 years has resulted in the development of numerous forecasting methods. But, the shortcoming of various conventional/analytical techniques has slowly shifted the emphasis to the application of Artificial Intelligence (AI) based approaches to load forecasting [5]. Statistical techniques like auto-regression and time-series methods have the inherent inaccuracy of load prediction and numerical instability. Further, the non-stationarity of the load prediction process, coupled with complex relationship between weather variables and the electric load render such conventional techniques ineffective as these methods assume simple linear relationships during the prediction process [8]. The problems encountered in conventional techniques are overcome with the help of Artificial Intelligence techniques.

Fuzzy set theory is one of dominant technology in Artificial Intelligence (AI) and it has a broad application in load forecasting. Fuzzy Systems (FS) offer a very powerful framework for approximate reasoning as it attempts to model the human reasoning process at a cognitive level. FS acquires knowledge from domain experts and this is encoded within the algorithm in terms of the set of If-Then rules. Fuzzy systems employ this rule based approach and interpolative reasoning to respond to new inputs [3,6]. Fuzzy logic is a generalization of the usual Boolean logic used for digital circuit design. An input under Boolean logic takes on a truth value of "0" or "1". Under fuzzy logic an input has associated with it a certain qualitative ranges [9]. Among the advantages of fuzzy logic are the absence of a need for a mathematical model mapping inputs to outputs and the absence of a need for precise (or even noise free) inputs. With such generic conditioning rules, properly designed fuzzy logic systems can be very robust when used for forecasting. The accuracy of the prediction model constructed on the basis of fuzzy logic is better than those of forecasting models based on classical prediction methods as well as of models applying unconventional techniques [3, 4].

Keeping in view the vast range of advantages of Fuzzy logic over other techniques, it is made use of to forecast long term load in our work. The method used for short term load

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forecasting can be extended or made use of to forecast load long term basis. Also, detecting the errors in the forecasts and correcting them improves the accuracy of forecast.

The main objective of this research paper is to develop digital simulation software on a MATLAB platform for long term load forecasting using fuzzy techniques to improve the accuracy of forecasting.

II. Calcifications of Load Forecasting

Load forecasting results have been used for operation planning of electric system as well as maintenance and fuel reserved planning [8]. The load forecasting can be classified into three different types according to the forecast period.

1. Short-term load forecasting,
2. Mid-term load forecasting,
3. Long-term load forecasting

In each load forecasting, period of time, forecasted values and aims of forecasting are noticeably different. Because of the difference of time period, forecasted values and aims of each load forecasting type, researchers in the past proposed many different algorithms and methods in order to obtain the precise load forecasting values.

In 1987, [9] described about short-term load forecasting survey and comparing load forecasting in short term,, mid-term and long-term. In this paper, each research article has used differential techniques for determining the accurate output value. In [10-16], neural network for short-term load forecasting are used based on historical load and temperature input data. Moreover, some paper use additional input data from day types, humidity, wind speeds and seasons. This method is performed in compared with conventional method. Training network is achieved by supervise learning and back propagation algorithm. Another technique for short-term load forecasting is using fuzzy logic and neural network [17]. This paper presents that the neuro-fuzzy method that gives more accuracy results compared to one of the neural network method. In [18-19], types of input data using in fuzzy logic and neural network algorithms are historical load and weather. The case study is Electric company in China (Hang zhou Electric Power Company) In this paper, the principle of fuzzy rough sets is used to help neural network in forecasting. In [20], fuzzy logic with back propagation algorithm (BP) is used for short-term load forecasting in the uncertainty of the data input case. In this paper, the network composes of 51 inputs and 24 outputs and it is simulated by MATLAB. [21] presents short-term load forecasting by combining neural network and genetic algorithm with the case study in Taiwan while [22] presents the implementation of genetic algorithm method for fastening computation and increasing forecasting accuracy. The time period of this load forecast value is in 24 hours. In year 2001, [23] presents load forecasting model using the principle of wavelet decompositions to bring to more accuracy in electric load forecasting. In year 2006, [24] presents short-term load forecasting using fuzzy logic algorithm and input data of time and temperature. The input variable time has been divided into eight triangular membership functions. The membership functions are Mid Night, Dawn, Morning, Fore Noon, After Noon, Evening, Dusk and Night. Another input variable temperature has been divided into four triangle membership functions. They are Below Normal, Normal, Above Normal and High. The forecasted load as output has been divided into eight triangular membership functions. They are Very Low, Low, Sub Normal, Moderate Normal, Normal, Above Normal, High and Very High. The case studies have been carried out for the Neyveli Thermal Power Station Unit-II (NTPS-II) in India. In 2004, [25] proposes a short term load forecasting using autoregressive integrated moving average (ARIMA) and artificial neural network (ANN) method based on non-linear load. It is concluded that using both methods can help each other in short-term load forecasting of the system. In 2007, [26] proposes a novel method approach to load forecasting using regressive model and artificial neural network (ANN model) with the case study carried out for Turkey. In this research, two methods are separately performed and compared. It shows that both methods give high accuracy results. In [27-29], combination of artificial neural network (ANN), Genetic algorithm and Fuzzy logic (Fs) method are proposed for adjusting short-term load forecasting of electric system. Genetic algorithm is used for selecting better rules and back propagation algorithm is also for this network. The papers show that they give more accuracy results and faster processing than other forecasting methods. Based on they literature survey the load forecasting algorithms are categorized as discussed in next section.

III. Various Load Forecasting Algorithms

Previous research has led to the development of a number of STLF algorithms. These include both conventional techniques & AI techniques. A few of them have been listed below [7].

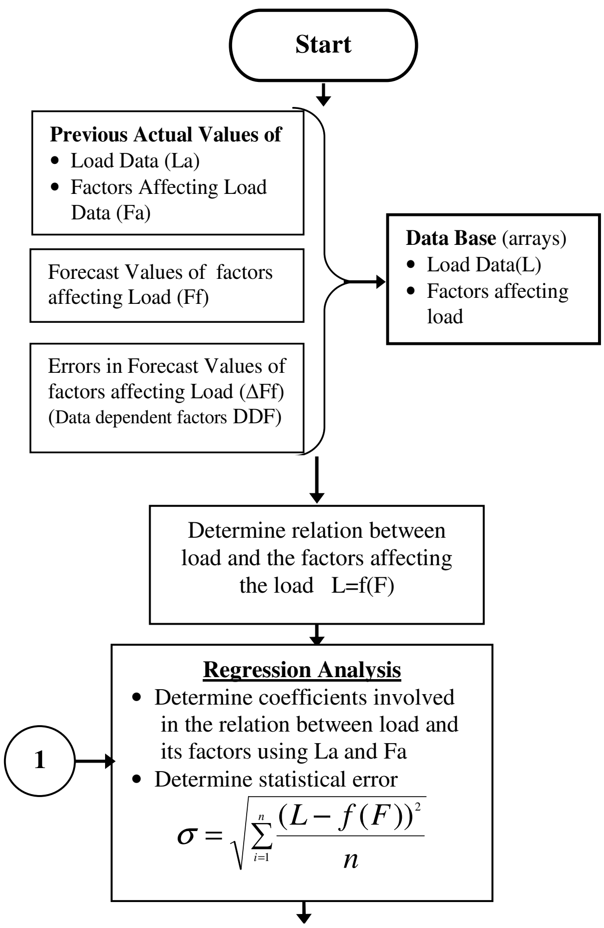
1. Similar day approach
2. Regression method
3. Time series : ARIMA
4. Support vector machines
5. Fuzzy logic approach
6. Neural network approach
7. Neuro-fuzy approach etc .

The first four techniques are conventional ones and the last three make use of AI to forecast load. Fuzzy logic, a dominant AI technique, proves superior to the other conventional methods [10]. Fuzzy logic approach concentrates not only on the forecast load value but also on the errors in the forecast & corrects them leading to better forecasts. Also, the vast advantages of fuzzy logic over other conventional/AI techniques are well known (mentioned earlier). Thus, we have used Fuzzy logic in our work to forecast load & the fuzzy logic approach for STLF has been adapted to develop the algorithm for long term load forecasting.

Long term load forecasting plays a very important role in power system planning & scheduling. Efficient forecasting techniques are very essential in forecasting Long term load accurately [1]. Artificial intelligence techniques prove superior to conventional techniques in forecasting Long term load accurately. Fuzzy Set theory is one of dominant technology in Artificial Intelligence [8]. Among the advantages of fuzzy logic is the absence of a need for a mathematical model mapping inputs to outputs and the absence of a need for precise inputs [4]. Keeping in view the vast range of advantages of Fuzzy logic over other techniques, it has been made use to forecast long term load abased on fuzzy techniques is proposed in this paper.

IV. Strategy of Fuzzy Techniques based Long Term Load Forecasting

The algorithm developed for long term fuzzy load forecasting can be represented as a flowchart in Fig.1. In order to demonstrate the algorithm, load data & data regarding factors influencing load for domestic consumers (LT(2(a)) Type load) was collected for a period of 7 years (from April-04 to March-11). The two main factors which effect the load consumption of domestic consumers are maximum temperature and number of domestic consumers. The relationship between load and these factors is linear.



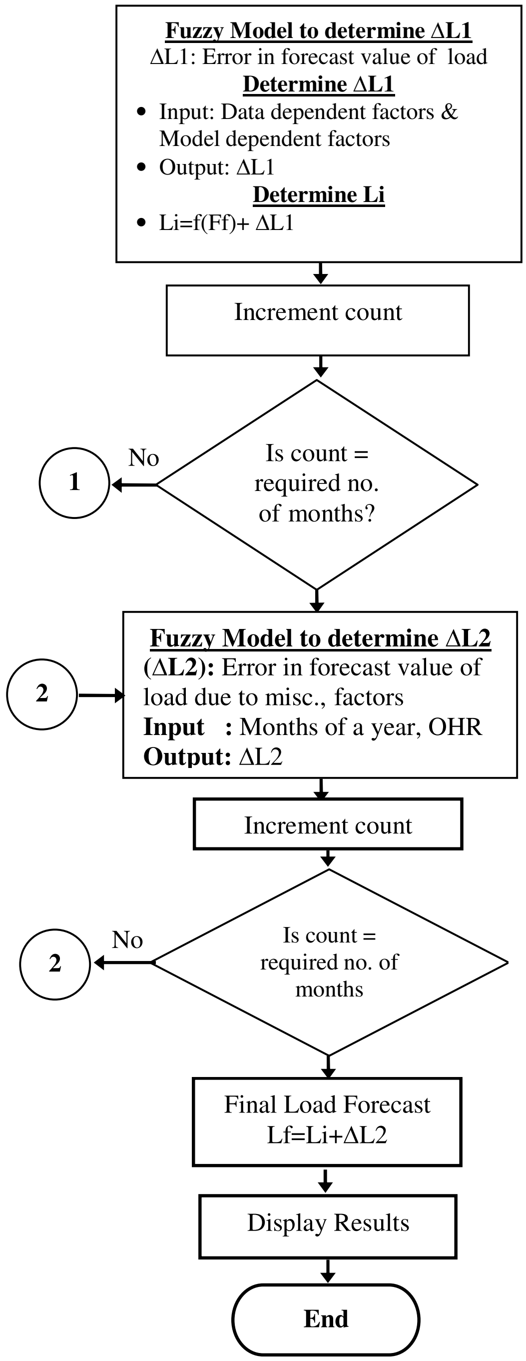


Fig. 1 Flowchart for long term fuzzy load forecasting

A. Data base development

1) Load data (in KW)

- Actual values from April-04 to March-09.

2) Number of consumers data

- Actual values from April-04 to March-09.
- Forecast values from April-06 to March-11.
- Forecast values of ΔC from April-06 to March-11.

3) Temperature data (^{o}C)

[1] Actual values from April-04 to March-09.
[2] Forecast values from April-06 to March-11.
[3] Forecast values of ΔT from April-06 to March-11.

ΔT & ΔC are forecast values of error in forecast values of factors affecting load. Here, using the first two years of load data & data of factors affecting it (from April-04 to March-06), next three years of load data were determined (from April-06 to March-09) inorder to demonstrate the efficiency of the algorithm by comparing the determined values of load with available actual values. Further, load values for next two years were also forecast (from April-09 to March-11). Here, Fuzzy model-I is used to determine error in forecast load value due to DDF & MDF & Fuzzy model-II is used to determine error in forecast load value due to ME.

B. Fuzzy Model-I

The MDFcould be determined and fuzzified as follows;

Inputs : ΔT & ΔC

MDF : Due to regression analysis

Output: ΔL1

The fuzzification of the inputs, ΔT & ΔC and the output ΔL1 has been done on the basis of the information collected after consulting the experts as shown in Fig.2 to Fig.4. Then the fuzzy If-Then rules base is developed properly for the fuzzy model-I. Centroid method is used for defuzzification which gave the crisp values of error in forecast load value. These errors are used to correct the forecast load values thus resulting in accurate forecast. To forcast the load for given crisp input values a Fuzzy Extension principle has been applied on MDF & ΔL1 to fire the rule base of fuzzy model-I. Employing this fuzzy model Li can be determined using the equation.

$$L_i = pT_f + qC_f + r + \Delta L_1 \qquad (1)$$

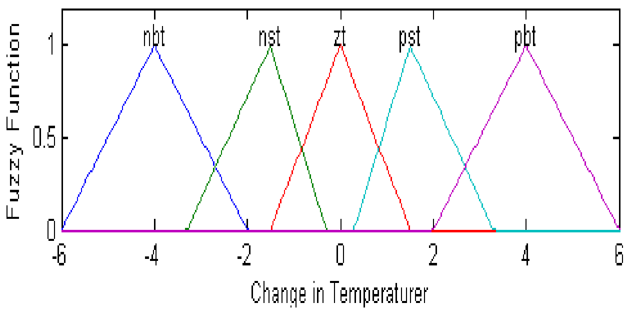


Fig. 2 Fuzzification of Change in temperature

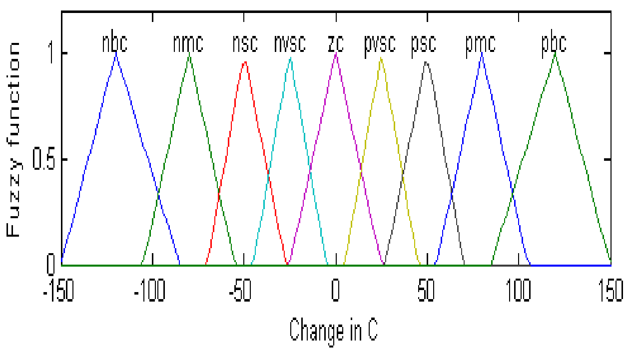


Fig. 3 Fuzzification of Change in C

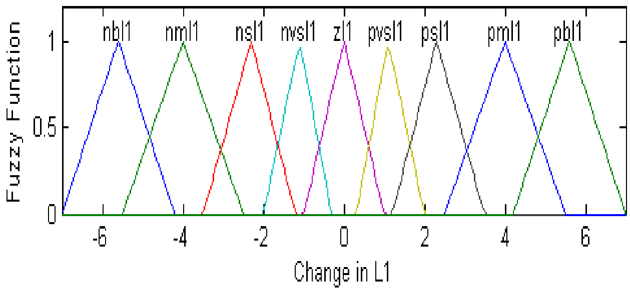


Fig. 4 Fuzzification of Change in L_1

C. Fuzzy Model-II

Inputs: OHR (the level of confidence of the operator) & Months (months of a year)

Output: Confidence of operator about closeness (ΔL2) to a particular value due to ME

The fuzzification of the inputs OHR & months and the output ΔL2 has been done on the basis of the information collected after consulting the experts as shown in Fig.5 to Fig.7. Then the fuzzy If-Then rule base is developed properly for the fuzzy model-II. Centroid method is used for defuzzification which gave the crisp values of error in forecast load value. These errors are used to correct the forecast load values thus resulting in accurate forecast. To forecast the load for given crisp input values a Fuzzy Extension principle has been applied on OHR & ΔL2 to fire the rule base of fuzzy model-II.

Hence, the data collected has been analyzed and the Fuzzy Models for long term forecasting were designed properly then a software program has been developed on MATLAB Fuzzy logic toolbox. Then the final load forecast can be calculated using the equation.

$$L_f\,(count) = L_i\,(count) + \Delta L_2\,(count) \qquad (2)$$

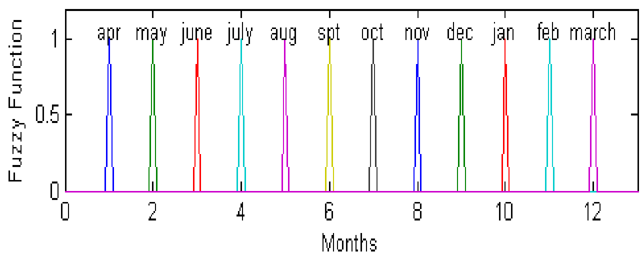


Fig. 5 Fuzzification of months

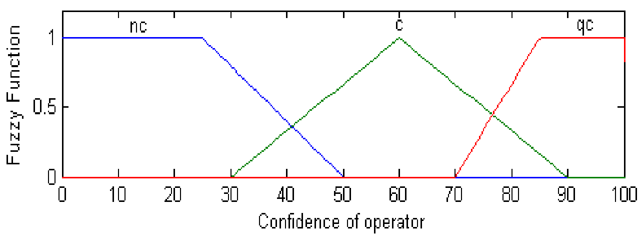


Fig. 6 Fuzzification of confidence of operator

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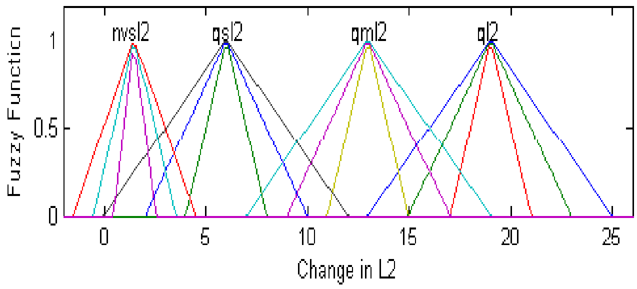

Fig. 7 Fuzzification of change in L_2

Thus, once the entire fuzzy system is implemented as explained in above sections for the collected data, the long term load forecasting algorithm can be coded and simulated in MATLAB fuzzy tool box as per the flowchart of Fig.1.

V. Simulation and Results

Fuzzy logic forms the heart of the program in this paper. The long term load forecasting algorithm is an extension of short term load forecasting technique. Emphasis is not only given to the forecast values of load but also on the errors in them. Thus, correcting these errors in the forecast values of load with the help of Fuzzy Logic, forecasts with very high accuracy have been achieved.

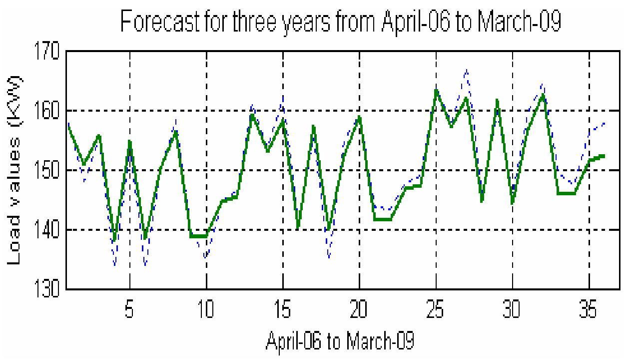

Fig. 8 Fuzzy load forecasted response (April-2006 to March-2009)

- - - - - Actual load (in KW)
——— Fuzzy determined load (in KW)

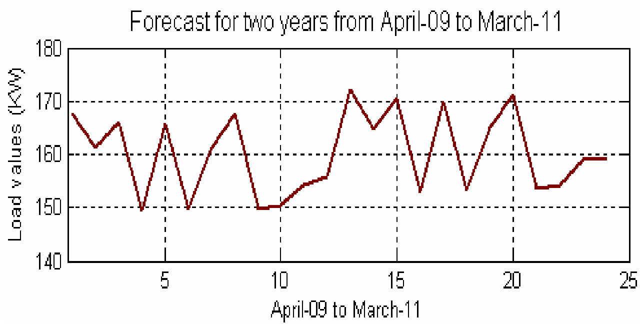

Fig. 9 Fuzzy load forecasted response (April-2009 to March-2011)

This has been demonstrated using the data collected for residential sector load. Efforts has been made to improve the accuracy of long term load forecasting by studying the data, recognizing more factors affecting load and factors responsible for errors in forecast values of load and incorporating them in the Fuzzy System properly and Fuzzifying the inputs and outputs and developing the suitable rule-base of If-Then rules of the Fuzzy System more efficiently. The simulated result obtained for fuzzy load forecast for the load values from April-06 to March-09 is as shown in Fig.8 and for the load values from April-09 to March-11 is as shown in Fig.9.

The accuracy of the fuzzy load forecast for a particular month is calculated as follows;

$$Accuray = \frac{(AL(month) - FL(month))}{AL(month)} \times 100 \quad (3)$$

Where,

AL → Actual load value for a particular month

FL → Forecast load value for the same month

Thus, for the obtained load values,

Minimum accuracy: 96.3907 %

Average accuracy: 98.5710 %

Maximum accuracy: 99.8764 %

VI. Conclusion

In this paper, the proposed fuzzy based long term forecasting has been demonstrated on a relatively smaller scale/magnitude. But, the algorithm is capable of forecasting load with very good accuracy even when forecasting is done on a larger magnitude (i.e. for around 25 years over a large area). All it needs is an intensive study of the load data, factors affecting the load data & factors responsible for errors in the forecast value of load. Long term load forecasting plays a very important role in power system planning and scheduling. Efficient forecasting techniques are very essential in forecasting Long term load accurately. The algorithm not only demands the forecast values of factors affecting load as input data but also the forecast values of errors in the forecast values of factors affecting load and other factors responsible for errors in the forecast value of load. Thus, acquiring the above mentioned data when forecasting load for long term becomes very difficult. Even experts might find it difficult to prepare/gather the required input data for the system. Hence, this can be considered as an inherent demerit of the algorithm which is mainly due to the use of Fuzzy logic in it. Fuzzy logic demands large inputs from experts only. The results obtained by proposed fuzzy techniques based long term load forecasting proves superior to conventional techniques in forecasting Long term load accurately. Thus, the algorithm described in this paper is very efficient and is capable of forecasting load with very high accuracy as compared to any of the existing long term load forecasting methods.

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