Short Term Load Forecasting using Fuzzy Logic of 220kV Transmission Line

At PSTCL 220kV Sub-Station Pakhowal, Ludhiana, Punjab

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***Abstract*— Electrical load demand is an important errand for the efficient operation and planning of power systems. Electricity demand forecasting is a vital and fundamental process for planning periodical operations and facility growth in the electricity sector. Short term load forecastingcan make easier to guesstimate load flows also to achieve the determination that can avoid overloading. In this paper the main objective is to minimize the error between the actual load value and forecasted value of the available data points. Fuzzy models are developed for crisp load power with fuzzy load parameters and for fuzzy load power with fuzzy load parameters. The fuzzy parameters are obtained for the model. These parameters are used to predict the load as fuzzy function for twenty four hours ahead. Data has been used from PSTCL, 220 kV Sub Station V.P.O. Pakhowal, Distt. Ludhiana, Punjab**

Key words —Fuzzy logic, Short Term Load Forecasting, Fuzzy Inference System, Curve Fitting.

I. INTRODUCTION

Load forecasting is very important for the electric industry in the decontrolled economy. Economic progress, throughout the world, depends on the state of availability of electric energy. Electrical load forecasting is a significant tool used to make sure that the power supplied by utilities meet the load as well as the power lost in the system. Load forecasting is essentially defined as the science or art of forecasting load on a given system for a specified period of time ahead. Load forecasting can help to guesstimate the load flows and to make determination that avoid overloading.

In power system many uncertainties arises due to aging of machines, fluctuations, losses in transmission lines, voltage and frequency instability, change of weather conditions. These factors make it difficult to effectively deal with power system problems through mathematical formulations. So in the recent years, fuzzy set theory based approach has come out as a supplement to mathematical method for solving the power system problems. By analysis of only historical load data, it is difficult to obtain accurate load demand for forecasting. The relation between load demand and the independent variables is complex and it is not always possible to fit the load curve using statistical models. The numerical aspects and uncertainties of this problem appear suitable for fuzzy methodologies.

In this paper, the problem of load forecasting is constrained to short term load forecasting and is expressed as fuzzy linear estimation problem. Different membership functions, for load parameters are used namely triangular membership and trapezoidal functions. The main objective is to minimize the error between the actual load value and forecasted value of the available data points. Short term load forecasting is an integral part of power system operation and is used to predict load demand up to a week ahead so that day to day operation of a power system can be efficiently planned and the operating cost can be minimized. Though Load forecasting is not an easy task to perform. The load on buyer side is complex. also there are numerous significant externally affecting variables that should be taken into account such as weather, time economic situation and random disturbance.

There are great varieties of mathematical methods employed for load forecasting. The growth and progress of appropriate mathematical tools will lead to the development of other precise load forecasting methods. Various techniques are used for short term load forecasting such as time series method, regression analysis, artificial neural networks and fuzzy logic approach. Among all the methods fuzzy logic for short term load forecasting is gaining importance nowadays.

II. DATA DESCRIPTION AND ANALYSIS

Data collected from PSTCL, 220KV Sub Station Pakhowal, Ludhiana is analyzed and then this data is fitted in to fuzzy logic based model. Economic and reliable operation of an electric utility depends to a significant extent on the accuracy of the load forecast. Proper load forecasting with less percentage error has to be made with the help of fuzzy logic approach. So as to decrease the load prediction error of the 24 hourly load the idea of fuzzy analysis is used in short term load forecasting obstacles. The results obtained are discussed and conclusions are drawn. Fuzzy logic based model is developed and presented for the short term load forecasting using the above data for Pakhowal, Ludhiana station. Various rules have been established in the development of fuzzy logic based model. Results of fuzzy logic based models are compared with the actual load demand of electricity for validation.

In general, the factor "Time" is also influencing the load at different points of the day, weekdays or weekend, holidays and seasonally. From the various observations of the load curves it is observed that the load varies time to time during a day. As observed that the load is low and stable around 2:00 a.m. to 6:00 a.m. and then it rises abruptly around 9:00 a.m and then becomes flat again until around 12:00 noon, after that it decreasing gradually until 5:00 p.m. thereafter it increases again until 7:00 p.m. and then after load descends until the end of the day. Thus load varies with respect to time. Actually this load varies with time due to the people's working time, leisure time, sleeping time etc. Thus due to these considerations the load curves for the weekend or holiday is lower than the weekday load curve.

Fuzzy Logic

Fuzzy means "not clear, distinct, or precise; blurred". Fuzzy logic means a kind of information depiction appropriate for ideas that cannot be defined exactly but depend upon their situations. Fuzzy logic is a simplification of the usual Boolean logic used for digital circuit designs. An input in Boolean logic gets only value of `true' or `false'.fuzzy logic means a form of knowledge representation suitable for notions that cannot be defined precisely, but which depend upon their contexts. Fuzzy logic is a generalization of the usual Boolean logic used for digital circuit designs. An input under Boolean logic takes on a value of 'true' or 'false'. Fuzzy logic is a type of numerous-worth logic. It deals with way of thinking that is almost rather than fixed and precise. Evaluated to usual binary sets fuzzy logic variables may have a truth values that vary in degree between 0 and 1.

A Fuzzy Inference System (FIS) is a method of mapping an input space to an output space using fuzzy logic. FIS uses a compilation of fuzzy membership functions and rules as a replacement Boolean logic to reason about data. The rules in FIS are fuzzy production rules of the form:

if p then q, where p and q are fuzzy statements.

The antecedent describes to what degree the rule be significant, while the conclusion allocate a fuzzy function to each of one or more output variables. Most of the tools for working with fuzzy expert system allocate more than one inference per rule. The set of the rules in a fuzzy expert system is known as knowledge base. The working operations in fuzzy expert system proceed in the following steps.

- Fuzzification
- Fuzzy Inferencing
- Aggregation of all outputs
- Defuzzification

III PROBLEM FORMULATION

The short term load forecasting is important for the economic and secure operation of power system. To predict the load forecasting there are many types of methods in the present industry. STLF gives the accurate values to predict the load demand for a short period of one week. A number of methods and techniques have already been worked. In the developing country like India, there is a lot of wastage of power in the generation, transmission and distribution. It is mainly due to the lack of forecasting the daily load. STLF is needed to supply necessary information for the system management of day to day operation.

Data collected from PSTCL, 220KV Sub Station Pakhowal, Ludhiana is analyzed and then this data is fitted in to fuzzy logic based model. Economic and reliable operation of an electric utility depends to a significant extent on the accuracy of the load forecast. Proper load forecasting with less percentage error has to be made with the help of fuzzy logic approach.

Electrical load demand is influenced by many factors such as weather, economic and social activities and different loads. So as to decrease the load prediction error of the 24 hourly load the idea of fuzzy analysis is used in short term load forecasting obstacles. Many types of statistical and artificial intelligence systems have been build up for short term load forecasting so as to minimize the prediction error.

IV SOLUTION APPROACH

Fuzzification

Fuzzification is a progression of making a crisp quantity fuzzy. Fuzzy linguistic variables are used to exist for a type of inputs as well as output parameters as the member of fuzzy sets. The current work formulate the use of basic fuzzy inference in which the concept of the fuzzy rule is uttered in crisp number. Fuzzy inference deals with originate the mapping for a given input to the output using the fuzzy logic. The mapping gives a foundation from which choice can be made. The method of fuzzy inference comprises of all the components such as membership functions, logical operators and if-then rules. Basic arrangement of a fuzzy inference system consists of three existing components.

- A rule base which include a selection of fuzzy rules.
- A data base which describes the membership functions used in fuzzy rules.
- An analysis means which performs the inference process on the rules and known facts to develop a sensible conclusion.

Membership Function

There are number of membership functions have been proposed in the past few year's namely triangular membership functions and trapezoidal membership functions. A more exact fuzzy expert system is acquired by separating the region into intervals. The intervals for the time have been divided into eight membership functions and intervals of temperature have been divided into four triangular membership functions. The intervals for the forecasted load output has divided into eight triangular membership function as very low, low, sub normal, moderate normal, normal, above normal, high and very high.

In this paper two cases are there: One is by taking time and temperature as inputs and forecasted load as an output. Another case in which we take previous load, previous temperature, current load and current temperature as inputs and forecasted load as one of the output.

Case I: By taking time and temperature as the inputs and forecasted value as the output.

As shown in fig 4.1 we take time as the input. The net range of the membership function is between 1 to 24. We define eight membership functions for input time and the range for each input

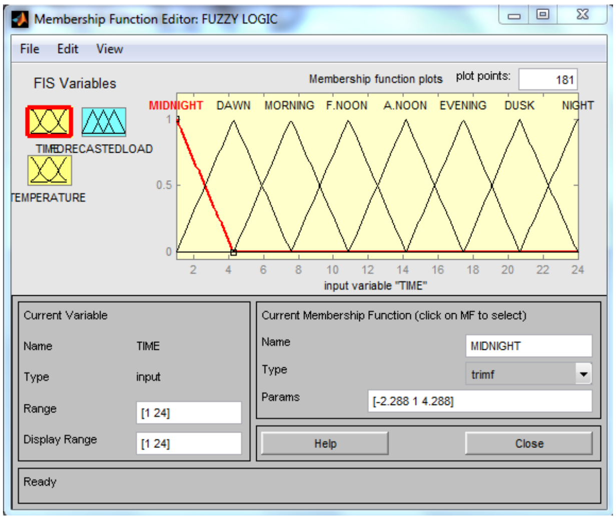

Fig. 4.1 Membership functions for Input time

Now the membership functions for the input 2 named as temperature are defined. Defining four membership functions for temperature with their ranges.

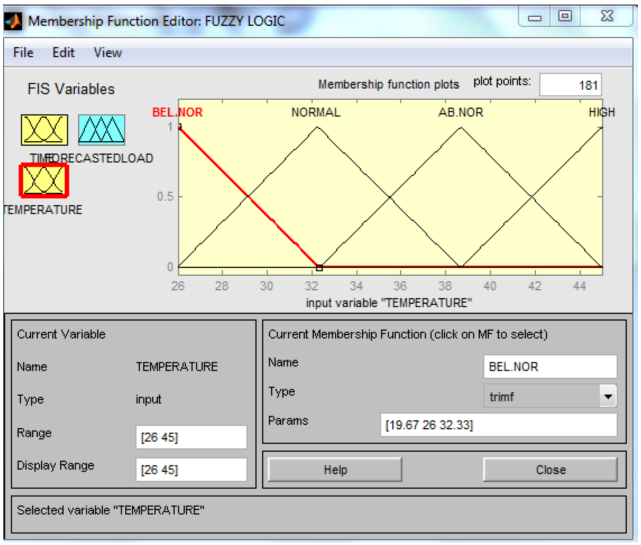

Fig. 4.2 Membership function for Input Temperature

After defining the membership functions for the inputs now its turn to define the membership functions for the outputs.

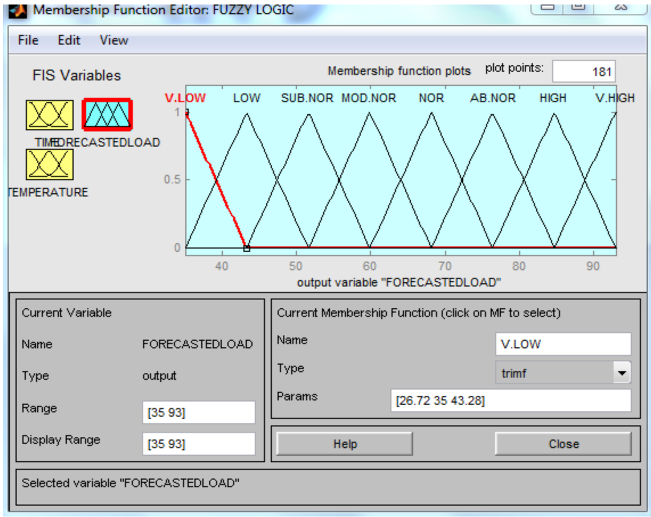

Fig 4.3 Membership function for Output Forecasted load

Development of rules is the main characteristics of fuzzy model. In this paper, the rule development relates the fuzzy input and required output. The fuzzy rule approach is designed to closely describe the input –output relationship of the actual problem using linguistic terms. The developed fuzzy model contains a set of rules which are developed from qualitative descriptions. In fuzzy, rules may be fired with some degree using fuzzy inference. For STLF problems, rules are defined to determine the accuracy in terms of relative error. Such rules can be expressed in this form

If premise, then conclusion

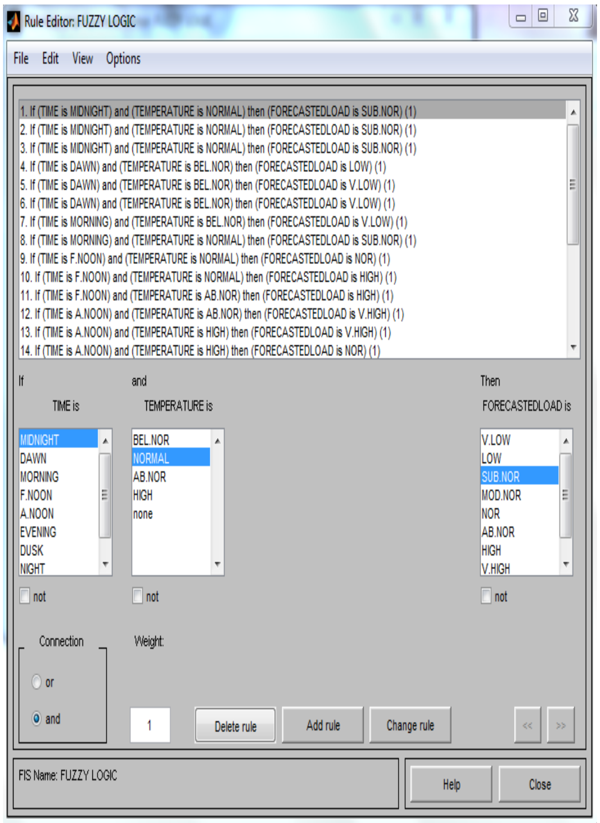

Fig. 4.4 Rule Development for calculating Fuzzy Forecasted Load

The inference rules relate the input to the output and every rule represents a fuzzy relation. Rules for fuzzy load forecasting are described as below:

If time is Dawn and temperature is below normal then forecasted load is low

Fuzzy relation for these rules is given by rule view. Fuzzy logic membership function and fuzzy rules are designed to provide a simple technique to directly implement experience and intuition into a computer program. For 24 hour the fuzzy forecasted value for the given data is shown in the table 4.1. By giving the values of the input time and temperature for the given data the fuzzy forecasted values for the output are obtained. For various input values of the time and temperature the fuzzy forecasted value for the output is given in the table 5.1.

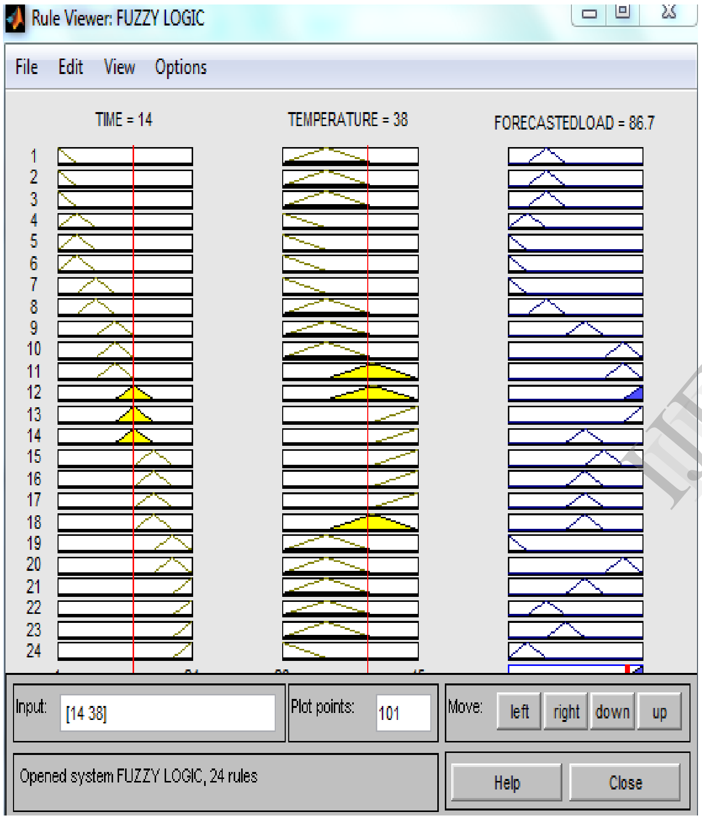

Fig. 4.5 Rule view for the given Inputs and output

Case II: By taking previous temperature, previous load, current temperature and current load as inputs and forecasted load as output.

Now considering another case in which a membership functions for the inputs and outputs are defined. Defining four inputs called previous load, previous temperature, current load and current temperature and output is forecasted load.

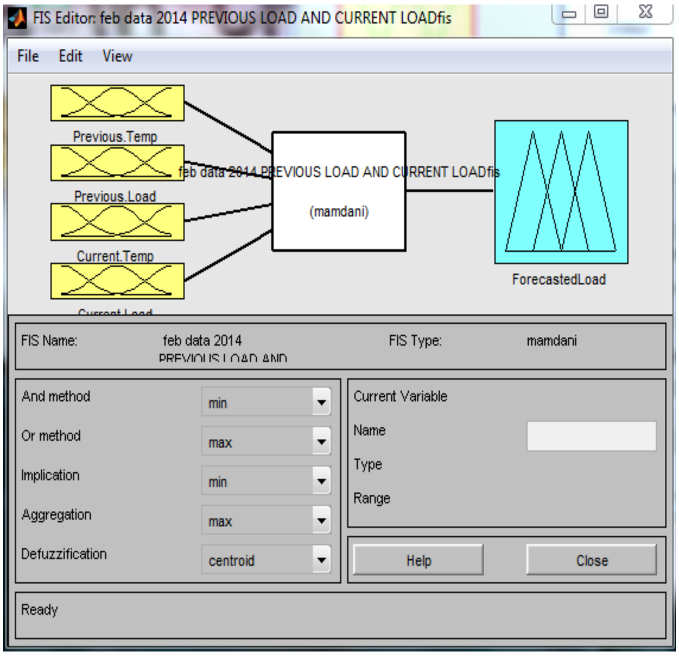

Fig. 4.6 Fuzzy model using four inputs and one output

By defining the membership functions for all the input and outputs and can set the range of each of the membership function

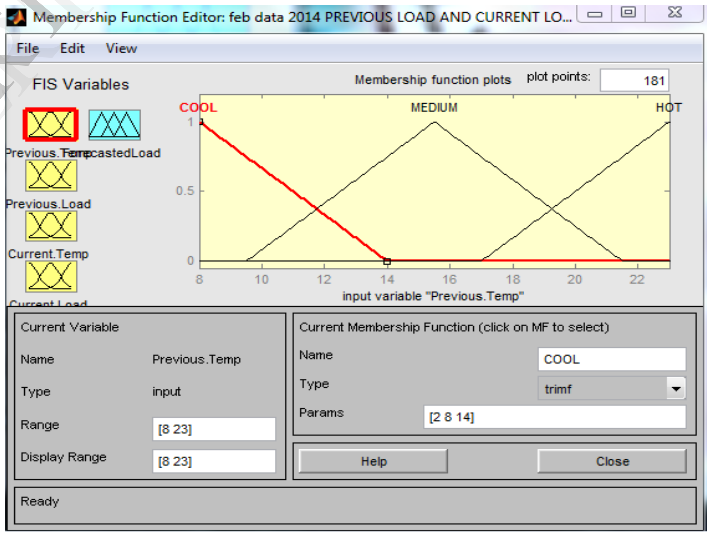

Fig. 4.12 View of membership functions for the input previous temperature.

Now membership functions for the input loads and output loads i.e. previous load, current load and forecasted load with their ranges for each membership function are defined and are named as very low, low, medium, high, very high. The inference rules relate the input to the output and every rule represents a fuzzy relation. Rules for fuzzy load forecasting are described as below:

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If previous temperature is cool and previous load is medium and current temperature is cool and current load is medium then the forecasted load is medium.

Similarly we can define the 24 rules for the 24 hours of the time. Now the fuzzy rule views for these rules are shown below from where the forecasted load value can be calculated.

In the fuzzy logic approach, the partiality calculation is based on the whole profile of the membership functions rather than base on the point value. Fuzzy logic approach is greatly nearer to the people's decision making process in reality.

By giving the values of the inputs previous load , previous temperature, current load and current temperature for the given data the fuzzy forecasted output load are obtained.

For various values of the inputs for the 24 hours of the day the output is given in the table 5.2

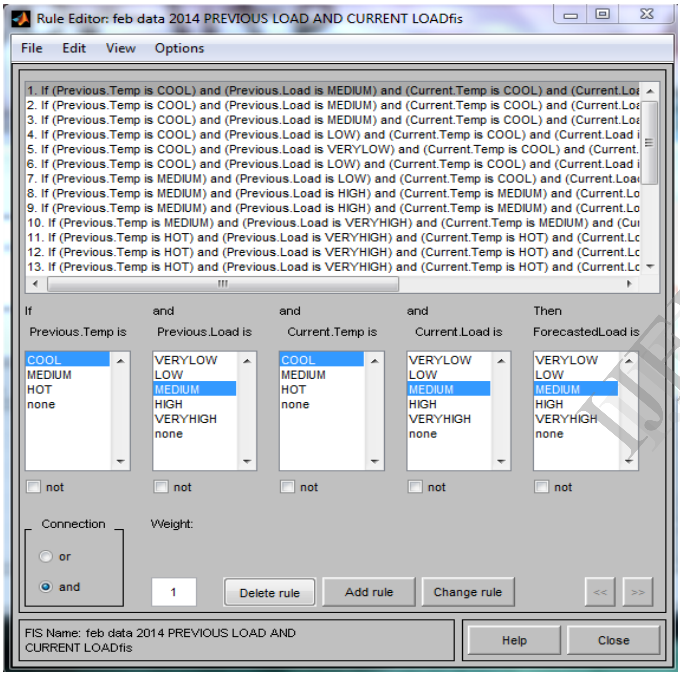

Fig 4.13 Rule Development for fuzzy forecasted output.

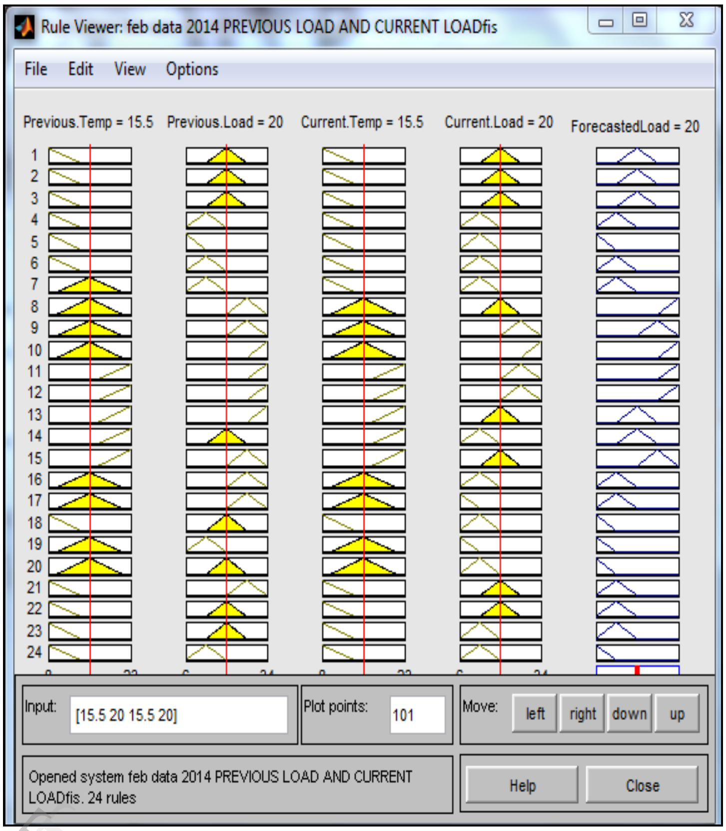

Fig. 4.14 Rule View for the given Inputs and Outputs

V. RESULTS

The key feature of the proposed methodology is the development of fuzzy logic approach to solving forecasting problems with uncertainty data such as day type, different patterns and temperature. Using the data from Punjab State Transmission Corporation Limited 220kV Transmission line Pakhowal. The results obtained are demoralized to get the forecasted electrical load. Results of fuzzy logic based models are compared with the actual load demand of electricity. The prediction result are obtained and presented using data from PSTCL 220kV Sub-Station Pakhowal.

This table presents the output in comparison with the actual data. The performance of the model is evaluated on the basis of absolute percentage error which can be determined by using formula given below

$$\% APE = \frac{|P_{actual} - P_{forecasted}|}{P_{actual}} \text{ x } 100$$

Where
Pactual is the actual recorded load
Pforecasted is the forecasted or estimated load.
The estimated parameters during the twenty four hours are used to predict the load for twenty four hours ahead.

Table 5.1 data for the 24 hours load with fuzzy forecasted load and percentage error.

Hours	Temperature	Actual Load(MW)	Forecasted Load(MW)	APE%	Fuzzy Forecasted Load (MW)	APE % with fuzzy
1	29.0	51.8	51.0	-1.6	51.6	-0.47
2	32.0	51.5	50.0	-2.9	50.9	-1.10
3	32.0	51.1	50.2	-1.7	50.6	-0.96
4	29.0	44.5	50.7	13.9	43.2	-2.96
5	26.0	35.0	44.1	26.1	41.9	19.65
6	27.0	36.8	27.5	-25.3	44.1	19.88
7	28.0	44.7	28.8	-35.6	45.1	0.95
8	29.0	54.0	40.8	-24.4	55.7	3.12
9	31.0	64.6	58.8	-8.9	64.8	0.29
10	32.5	80.0	73.2	-8.4	71.5	-10.59
11	35.0	87.4	71.0	-18.8	76.5	-12.50
12	38.0	91.1	74.4	-18.4	82.4	-9.58
13	39.0	92.6	102.5	10.7	84.6	-8.69
14	38.0	73.4	98.2	33.8	86.7	18.10
15	38.0	74.6	76.0	1.9	79.7	6.88
16	39.0	76.7	65.7	-14.3	75.1	-2.05
17	38.0	70.5	67.6	-4.1	70.6	0.11
18	35.0	66.9	72.1	7.8	68.5	2.39
19	33.0	50.2	64.9	29.3	68.6	36.67
20	34.0	71.2	45.3	-36.3	68.4	-3.92
21	34.0	72.1	61.0	-15.4	66.6	-7.63
22	30.0	58.9	74.2	26.1	63.0	7.03
23	29.0	59.1	69.8	18.1	60.4	2.18
24	28.0	53.5	63.3	18.3	53.4	-0.18

Table 5.1

The load graphs and curves for table 5.1and table 5.2 using fuzzy forecasted value are also shown below:
Now the results obtained from rule view are evaluated in the table 5.2 which shows the fuzzy forecasted load output for the given data is shown below:

Hours	Previous Load(MW)	Previous Temperature (°C)	Current Load(MW)	Current Temperature (°C)	Actual Load(MW)	Fuzzy Forecasted Load(MW)
1	18.58	10	19.26	10	18.51	16.4
2	18.45	11	19.06	10	18.32	16.4
3	18.32	10	19.2	11	18.26	16.4
4	15.96	10	19.2	11	16.77	16.4
5	12.55	11	15.02	11	12.47	12.1
6	13.19	12	15.23	12	13.18	13.5
7	16.01	13	17.25	11	14.84	17.2
8	19.36	16	17.76	17	23.47	20
9	23.16	15	23.62	16	24.27	27.8
10	28.67	16	27.22	15	27.76	27
11	31.34	19	28.25	20	29.04	28
12	32.67	20	29.16	18	27.87	27.9
13	33.21	21	16.43	22	22.95	21.3
14	26.32	21	16.29	21	23.88	24.3
15	26.73	20	16.69	20	22.59	22.2
16	27.48	18	15.23	18	16.08	18.4
17	25.28	18	12.63	18	14.84	14.4
18	23.98	16	15.56	17	8.04	17
19	17.99	16	12.16	16	6.87	8.41
20	25.52	15	15.89	14	12.87	18
21	25.85	11	19.25	10	15.23	16.9
22	21.10	11	19.95	10	14.5	19.9
23	21.19	10	18.64	10	13.3	19.9
24	19.18	9	18.99	10	10.73	19.9

Table 5.2

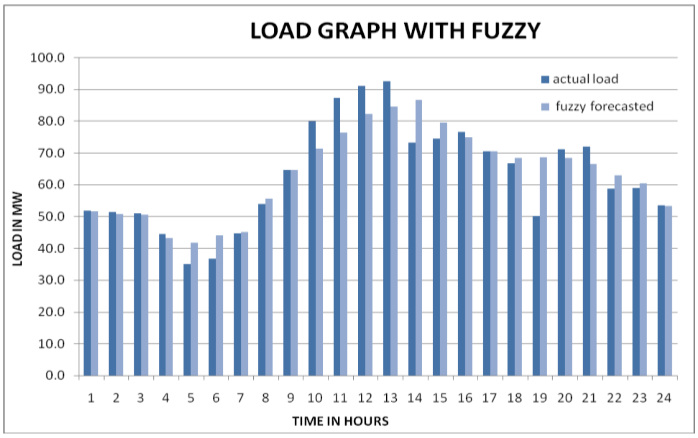

Fig. load graph for table 5.1

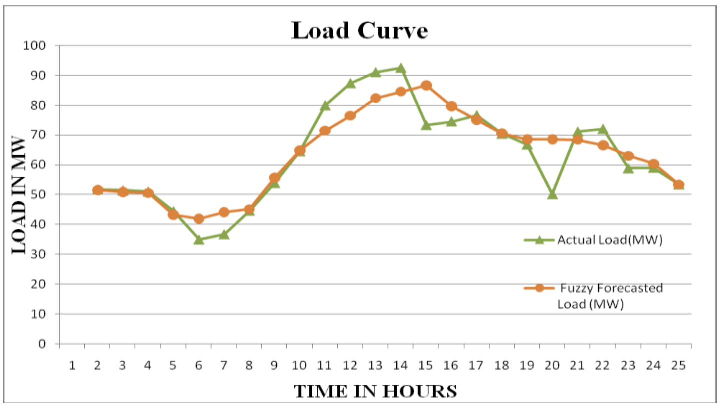

Fig. load curve for table 5.1

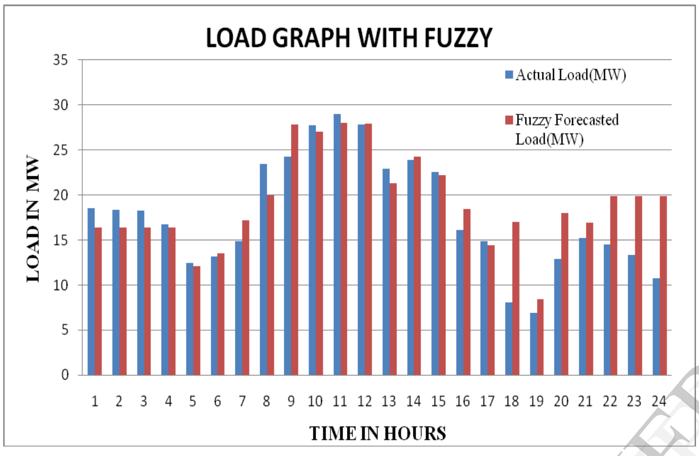

Fig. load graph for table 5.2

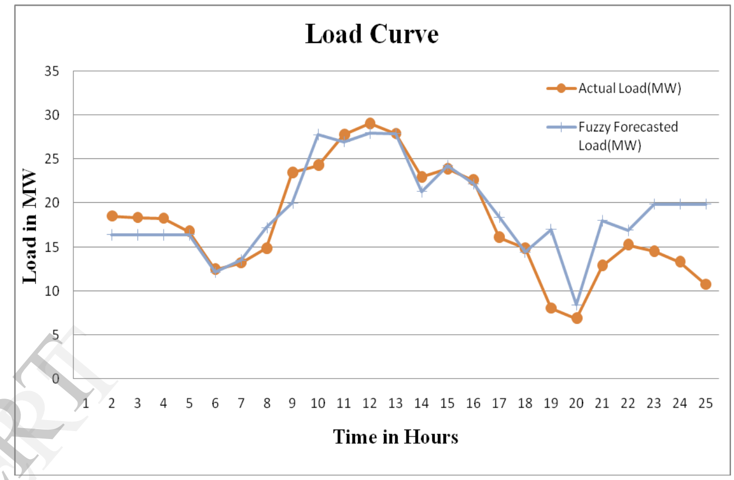

Fig. load curve for table 5.2

VI CONCLUSION

The important characteristic of the proposed methodology is the expansion of fuzzy logic approach to solve the forecasting problem with ambiguity of data such as temperature day types and load pattern etc. In this thesis the study shows that the fuzzy approach gives the better forecasting performance but it has easy process to deal with forecasting. . In this paper, short term load forecasting using fuzzy is formulated and solved. The forecasted results are obtained and presented using data from PSTCL 220kV Sub-Station Pakhowal, Ludhiana. The study shows that the fuzzy approach gives the better forecasting performance but it has easy process to deal with forecasting. For all the above cases discussed in this study fuzzy based load forecasting is much better method and fuzzy forecasting is very close to the actual load. Thus we conclude that for Short term load forecasting fuzzy logic provides better and improved solutions.

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