Short Term Load Forecasting For Utility System Using Fuzzy Logic Approach

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Abstract

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. In this paper the 'time' of the day and 'temperature' of the day are taken as inputs for the fuzzy logic controller and the 'forecasted load' is the output. 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 triangular membership functions. They are Below Normal, Normal, Above normal and High. The 'forecasted load' as an 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. Case studies have been carried out for State Electricity System (SES), which is the utility system in India. The results are compared with the conventional controller and fuzzy controller. It is found that the fuzzy controller is more effective, economical and having lower forecasted value than the conventional controller. This fuzzy approach is much closer to people's decision-making process in real life.

Key Words: Defuzzifier, Fuzzifier, Fuzzy Logic, Membership Functions, Short Term Load Forecasting.

1. Introduction

The load requirements are to be predicted in advance so that the power system operates effectively and efficiently. Load forecasting helps an electric utility to make important decisions including decisions on purchasing and generating electric power, load switching and infrastructure development. Load forecasting is extremely important for energy suppliers, financial institutions and other participants in electric energy generation, transmission, distribution and markets. Short-term load forecasting can help to estimate load flows and to make decisions that can prevent overloading.

2. The Need for load forecasting in Power System

Power System operators use historical load data to schedule available generating units to meet hourly system loads in an economical and reliable manner. The load forecasting is done for planning, marketing, risk assessment, billing, dispatch or unit commitment purposes. It is used to maintain reliable high quality power supply. Load forecasting can be classified into three types. They are:

* Long term Load forecasting (longer than a year)
* Medium term forecasting (a week to one year)
* Short-term forecasting (one hour to one week).

Out of these Short Term Load Forecasting (STLF) is only considered for this paper. Load forecasting can help to estimate load flows and to make decisions that can prevent overloading. Timely implementations of such decisions lead to the improvement of network reliability and to reduce the occurrences of equipment failures and black outs. The load dispatcher at main dispatch center must anticipate the load pattern well in advance so as to have sufficient generation to meet the customer requirements. Over estimation may cause the startup of too many generating units and lead to an unnecessary increase in the reserve and the operating costs. Under estimation of the load forecasts results in failure to provide the required spinning and stand by reserve and stability to the system, which may lead into collapse of the power system network. Exact forecasting of the load is an essential element in power system.

3. Short Term Load Forecasting

Shot term load forecasting is needed to supply necessary information for the system management of day-to-day operations and unit commitment. The STLF is important for the economic and secure operation of power system. Many operations like real time generation control, security analysis spinning reserve allocation energy interchanges with other utilities, and energy transactions planning are done based on STLF [7].

A variety of methods like similar day approach, various regression models, time series, neural networks, statistical learning algorithms, fuzzy logic and expert systems have been developed for STLF. The conventional method has the advantage that we can forecast load power with a simple prediction model. However, since the relationship between load power and factors influencing load power is non-linear, it is difficult to identify its non-linearity by using conventional methods. The non-linearity is due to change in daily load pattern, change in weather conditions, due to weekend, special days and holidays. However there is a considerable error between the load power on a forecast day and that on similar days, hence we are not able to expect the good prediction for averaging the load power on similar days. Many uncertainties are present in similar day approach. The fuzzy logic is an effective approach that can be implemented to take into account of the uncertainty in the STLF [8].

The STLF with lead times helps the system operator to efficiently schedule spinning reserve allocation, can provide information for the energy interchanges with other utilities. For a particular region it is possible to predict the next day load with an accuracy of approximately 1-3%. A 24-hour load forecast is needed for successful operation of power system [7], [8].

3.1 Load characteristics of Utility System

Load means a device or set of devices, which taps energy from the power system networks. Load pattern is not constant for 24 hours in a day. It keeps on changes from hour to hour, minute to minute. The typical load curve pattern for 24 hours is shown in **Figure 1.**

It has overnight minimum, Midday peak, Day valley, Evening peak and late high. The load curve changes due to the customer's deliberate utility intervention. Similarly the week load is also not constant for all seven days. It changes from weekdays to weekend days. It also changes on the holidays and special events days [9].

All these areas many uncertainties persists. Hence the implementation of fuzzy logic to forecast the short-term load will be adopted choice.

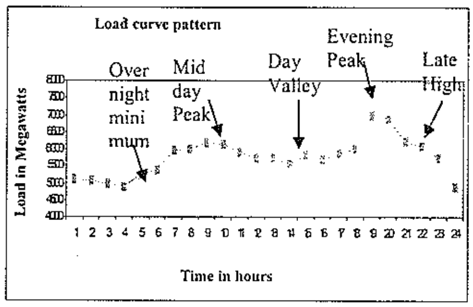


Figure 1 Typical Load Curve pattern for a day

4. Fuzzy Logic Implementation

Fuzzy set theory provides a means for representation of uncertainties. It is quite like the conventional systems but the main difference is that the fuzzy systems contain fuzzifiers which convert input into their fuzzy representations and defuzzifiers which convert the output of the fuzzy process logic into the crisp solution variables [1]. IF-THEN rules are the fuzzy rules. These rules can be extracted from common sense, intuitive knowledge, survey results, general principles and laws and other means that reflect the real world situations [2]. The human operator's experience is taken as the linguistic variable input to the fuzzy system [4]-[6].

This paper makes use of simplified fuzzy inference in which the consequence of the fuzzy rule is expressed in crisp number. One of the attractive features in fuzzy is that the fuzzy rule is capable of easily adding the new memberships function to the existing ones. Fuzzy approach proposed can be used as an aid to forecast the loads with different lead times [3].

A fuzzy expert system can be developed using the method applied for the statistical model. A more accurate fuzzy expert system can be obtained by dividing the region into intervals [4]-[6]. The intervals for the Time (Input 1) has been divided into eight triangular membership functions which are as follows:

* Mid Night (MID NIG), * Dawn (DAWN)
* Morning (MORN), * Fore Noon (F.NOON)
* After Noon (A.NOON), * Evening (EVEN)
* Dusk (DUSK), * Night (NIG).

The triangular membership function is shown below in **Figure 2.**

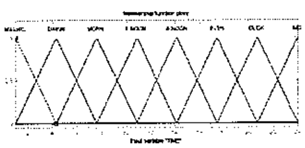


Figure 2 Triangular membership functions for time (Input 1)

The intervals for Temperature (Input 2) has been divided into four triangular membership functions which are as follows:

* Below Normal (BEL.NOR),
* Normal (NOR)
* Above normal (AB.NOR), * High (HIGH)

The triangular membership function is shown below in **Figure 3.**

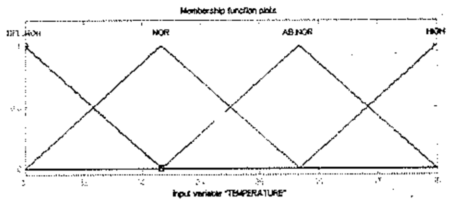


Figure 3 Triangular membership function for temperature (Input 2)

The intervals for the Forecasted load (Output) has been divided into eight triangular membership functions which are as follows:

* Very Low (V.LOW), * Low (LOW)
* Sub Normal (SUB.NOR)
* Moderate Normal (MOD.NOR)
* Normal (NOR),
* Above Normal (AB.NOR)
* High (HIGH), * Very High (V.HIGH)

The triangular membership function is shown below in **Figure 4.**

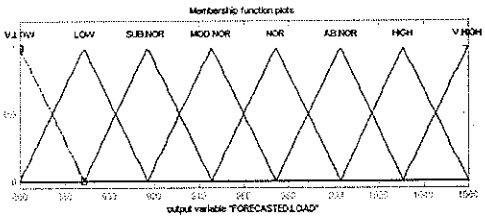


Figure 4 Triangular membership function for forecasted load (Output)

Fuzzy logic membership functions and fuzzy rules are designed to provide a simple technique to directly implement experience and intuition into a computer program. In the fuzzy logic approach, the preference calculation is based on the entire profile of the membership functions rather than base on point values. This approach is much closer to people's decision-making process in real life **[9], [10]**.

5. Case Study

Case Study has been carried out for the State Electricity System (SES) of one generation circle in India which known as the utility system. The case studies have been carried out for Winter on 30.01.2005, for Summer on 23.06.2004 and for the Rainy season on 25.08.2004. The various values of fuzzy forecasted values, actual load and the percentage of errors between the forecasted and actual load values for these three seasons are shown in **Table 1.**

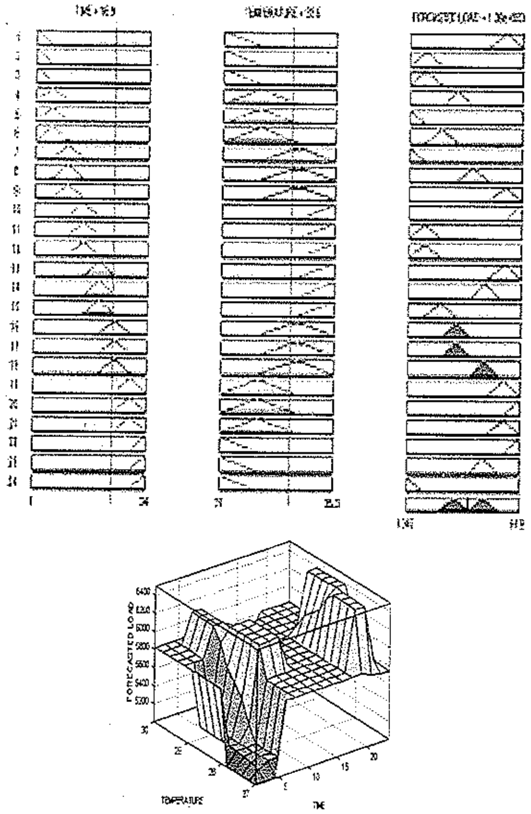


Figure 5. Winter season Fuzzy Membership Functions for Inputs and Output & Three Dimensional Surface views

The simulation has been carried out on MATLAB with two inputs (Time, Temperature) and one output (Forecasted Load). The fuzzy membership functions for inputs and output and their three dimensional surface views for Winter, Summer and Rainy seasons are shown in **Figures 5,6,7** respectively.ectivelyrespectively.

Time Hrs	Winter			Summer			Rainy		
	Fuzzy Forecasted Load MW	Actual Load MW	Error %	Forecasted Load MW	Actual Load MW	Error %	Fuzzy Forecasted Load MW	Actual Load MW	Error %
1	5130	5180	0.96	6236	6104	2.11	6294	6163	2.08
2	5060	5123	1.23	6134	5995	2.26	6119	6013	1.73
3	4975	5109	2.62	5623	5771	2.56	5736	5875	2.36
4	4877	4864	0.26	6178	6080	1.58	5816	5993	2.95
5	5260	5174	1.63	6230	6199	0.49	6172	6027	2.34
6	5360	5212	2.76	6447	6556	1.66	6342	6511	2.59
7	5970	5902	1.13	6581	6624	0.65	6425	6600	2.65
8	6010	5912	1.63	6709	6675	0.51	6687	6630	0.85
9	6150	5997	2.48	6792	6660	1.94	6532	6383	2.28
10	6130	5983	2.39	6887	6756	1.90	6412	6222	2.96
11	5880	5977	1.62	6595	6451	2.18	6520	6369	2.31
12	5730	5692	0.66	6670	6559	1.66	6375	6226	2.33
13	5709	5656	0.92	6300	6441	2.18	6428	6335	1.44
14	5560	5424	2.44	6216	6352	2.14	6239	6163	1.21
15	5820	5777	0.73	6566	6534	0.48	6243	6327	1.32
16	5660	5559	1.78	6589	6674	1.27	6327	6235	1.45
17	5830	5775	0.94	6353	6496	2.20	6521	6348	2.65
18	5995	5890	1.75	6827	6700	1.86	6575	6418	2.38
19	6965	6824	2.02	6636	6790	2.26	6612	6775	2.40
20	6875	6809	1.01	7216	7022	2.68	7284	7156	1.75
21	6220	6236	0.26	6798	6658	2.05	6896	6736	2.32
22	6180	6193	0.21	6399	6582	2.78	6679	6519	2.39
23	5730	5623	1.86	6423	6589	2.51	6752	6632	1.77
24	4860	4777	1.73	6209	6166	0.69	6384	6223	2.54

Table 1 Percentage Error Calculation between fuzzy forecasted and actual load for winter, summer & rainy seasons of SES (One-Generation Circle)

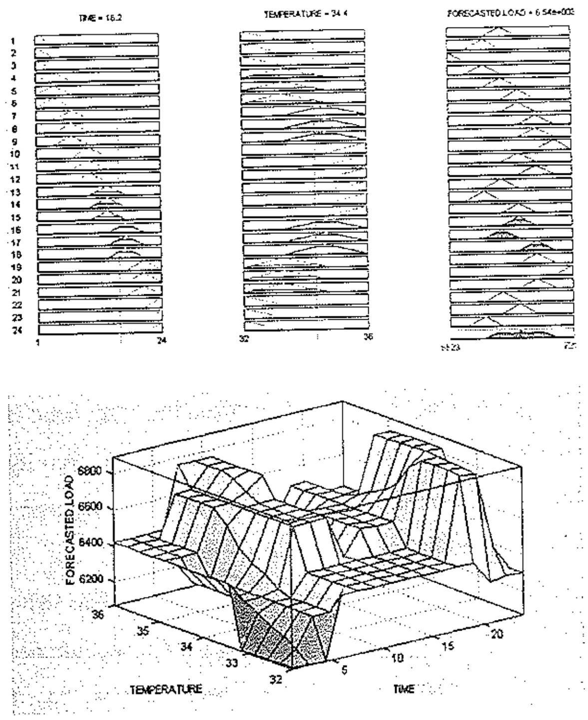


Figure 6. Summer season Fuzzy Mem bership Functions for Inputs and Output & Three Dimensional Surface views

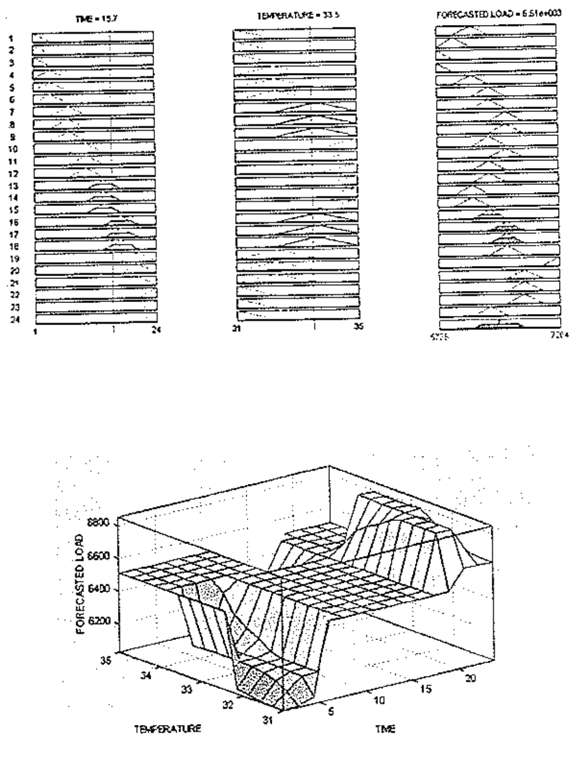


Figure 7. Rainy season Fuzzy Membership Functions for Inputs and Output & Three Dimensional Surface views

6. Result Analysis

The fuzzy rule approach is designed to closely describe the input, output relationship of the actual problem by using linguistic terms. Forecast errors result in increased costs, or "regret". For instance, if loads turn out to be lower than forecast, then:

* units may have been unnecessarily committed, raising fuel costs and, perhaps, maintenance expenses, hydropower may have been produced which would have been more valuable if generated at a later time.
* unnecessary interruptions or load controls might be invoked, annoying consumers and lowering revenue.

On the other hand, if loads are greater than anticipated, the following types of regret might result:

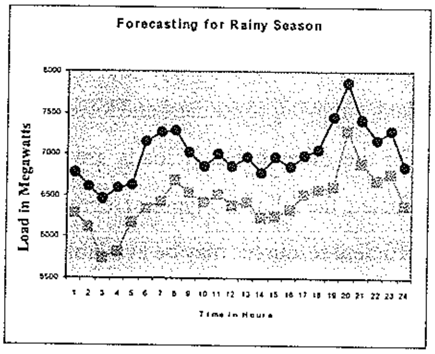
* Insufficient resources may be available for meeting security constraints, such as spinning reserve margins, thus endangering system reliability.
* Commitments to sell power may have been made at a price less than the value of that power to the utility.
* Too low real-time prices might have been quoted, resulting in revenue falling short of the utility's cost.

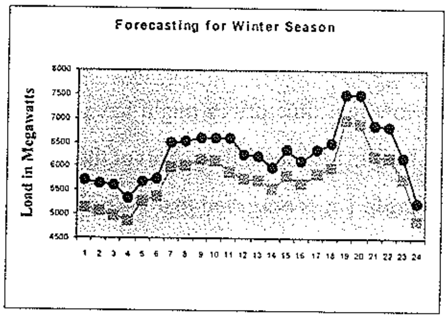
From **Table 1** it is observed that the percentage error from the forecasted load and the actual load is less than $\pm$ 3%. Hence it is closely fitting to the actual load. The results are compared between the conventional forecasted load and the fuzzy forecasted load for the utility system (SES) for the Winter, Summer and Rainy Seasons. The values are shown in **Table 2**. The compared results are plotted in the graph, which is shown in **Figure 8**

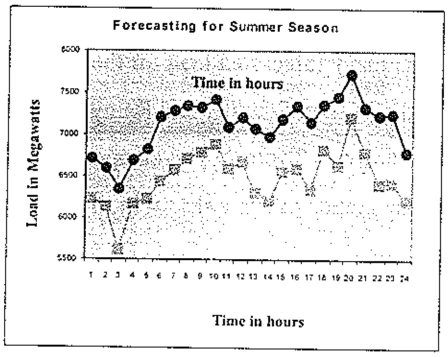
Time hrs	Winter Season (30.01.05)		Summer Season (23.06.04)		Rainy Season (25.08.04)	
	Conventional	Fuzzy	ConVenTional	Fuzzy	ConVenTional	Fuzzy
1	5698	5130	6714	6236	6779	6294
2	5635	5060	6595	6134	6614	6119
3	5620	4975	6348	5623	6463	5736
4	5350	4877	6688	6178	6592	5816
5	5691	5260	6819	6230	6630	6172
6	5733	5360	7212	6447	7162	6342
7	6492	5970	7286	6581	7260	6425
8	6503	6010	7343	6709	7293	6687
9	6597	6150	7326	6792	7021	6532
10	6581	6130	7432	6887	6844	6412

11	6575	5880	7096	6595	7005	6520
12	6261	5730	7215	6670	6849	6375
13	6222	5709	7085	6300	6969	6428
14	5966	5560	6987	6216	6779	6239
15	6355	5820	7187	6566	6959	6243
16	6115	5660	7341	6589	6859	6327
17	6353	5830	7146	6353	6983	6521
18	6479	5995	7370	6827	7060	6575
19	7506	6965	7469	6636	7453	6612
20	7490	6875	7724	7216	7872	7284
21	6860	6220	7324	6798	7410	6896
22	6812	6180	7240	6399	7171	6679
23	6185	5730	7248	6423	7295	6752
24	5255	4860	6783	6209	6845	6384

Table 2 State Electricity System (SES) Fuzzy and Conventional Method Comparison for Load Forecasting in Mega Watts







Conventional **Fuzzy**

Figure 8 Comparison of Results between the conventional and Fuzzy Forecasted load for Winter, Summer and Rainy Seasons for SES

From the figure it is observed that the fuzzy based load forecasting is having much lower forecasted value than the conventional method. Hence the fuzzy logic approach is more effective and economical.

7. Conclusion

It is concluded that if the loads turn out to be lower than forecast, then the power generated is going to be costlier one and uneconomical and on the other hand if the loads are greater than anticipated, then the security constraints such as spinning reserve margins, frequency and the reliability of the system are in danger.

In this SES case the percentage error is less than $\pm 3\%$. For SES the comparison is carried out for Winter, Summer and Rainy seasons. For all these cases the fuzzy based load forecasting is having much lower value than the conventional method. Hence it is concluded that for short-term load forecasting the fuzzy logic is a better choice.

References

[1] R.C.Bansal, "*Bibliography on the fuzzy set theory applications in power systems*", 1994-2001, IEEE Transactions on power systems, vol 18, No.4, pp. 1291 - 1299, Nov. 2003.

[2] S.ChenthurPandian and Dr. K.Duraiswamy, "*Fuzzy Logic*", National conference at Annamalai Univ. Chidambaram, India, pp.147 - 156, 2nd & 3rd March 2002.

[3] R. C. Bansal, T. S. Bhatti, and D. P. Kothari, "*Artificial intelligence techniques for monitoring and control of power systems: an overview*," in Proc. Contr. Instrumentation Inform. Common. Conf., Calcutta, India, pp.91-95, Dec.13-15. 2001.

[4] G. J. Klir and T. A. Folger: *Fuzzy Sets, Uncertainty and Information*(1988), Prentice-Hall.

[5] George. J. Klir, Boyuan, "*Fuzzy Sets and Fuzzy Logic*", Prentice Hall of India Private Limited, New Delhi – 2000.

[6] StamatiosV. Kartalopoulos, "*Understanding Neural Networks and Fuzzy Logic*", Prentice Hall of India Private Limited, New Delhi-2000, IEEE Press.

[7] X. Wang, et al, "*A new methodology for nodal load forecasting in Deregulated Power Systems*", IEEE Power Engineering review, pp.48–51, May2002.

[8] T. Semjyu, et al, "*One hour – Ahead Load forecasting using neural network*", IEEE transactions on power system, vol. 17, No.1, Feb. 2002.

[9] S.ChenthurPandian, Dr.K.Duraiswamy and A.A.Sadagopan, "Implementation of fuzzy logic for short term load forecasting", International conference by JNNCE, Shimoga India in collaboration with MIT, Cambridge USA on 20th to 23rd Dec. 2004.

[10] S. Chenthur Pandian and Dr. K. Duraiswamy, "*Fuzzy logic approach for the Load forecasting*", International conference by Pentagram Research Centre, Hyderabad. India, 6th to 9th Jan. 2005.