

FUZZY LOGIC CONTROL SYSTEM FOR SHORT TERM LOAD FORECASTING

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Abstract: Fuzzy Logic technique is used for the prediction of the load here in this work. A control system using fuzzy logic is modeled which shows that this technique is superior to the conventional techniques when accuracy and process time is considered. To predict the load we need different load forecasting methods. In this paper a system is designed which predicts the load of every hour of the year. Analysis and examination was done on previous data, taken from Hayatabad 132 kV grid station, Peshawar, Pakistan. Temperature, Season and Time (of day/night) are inputs while output is the forecasted load of the fuzzy logic system. All of the variable (inputs and outputs) are represented by triangular membership functions. Variable season is set in such a way that it varies from month to month among 12 months of the year. Time and temperature changes during 24 hours of day/night. As temperature depends on time of day and night and it varies from time to time, so, different groups of temperature are assigned to each hour. Fuzzy rules are made according to strategize formulation to get proper forecasted load which is in accordance with the variable time.

Keywords: Fuzzy logic system, membership functions, groups of temperatures, Fuzzy rules

Introduction

In the world there are various types of energy. Among all these types has a distinct characteristic. That characteristic is the storage of electrical, unavailable in wide range (Ahmadi, *et al*, 2012). Most important key for Planning of a power system is predictions of future load necessities and demands. In power system the two constituents on which the magnitudes of Generation, Transmission and Distribution are dependent, are load forecasting and perfection of energy (Sachdeva, 2008). For better planning and developing of electric power supply the management of power system must be well organized. Thus proper decisions are required. So, the precise prediction of electrical load demands will

help power system in proper decision making of energy sector. It shows that Load forecasting has positive impacts on the economy of a power system, and, helps in different utility issues (Ramos, *et al*, 2013).

In power system many phenomena occurs such as fluctuations, unforeseen load, transmission line Losses, instability in voltage and frequency, weather conditions and machines lives, due to these, uncertainties arises in power system. They are also very dangerous for the security of a power system. Load forecasting is the one among the solutions to overcome these uncertainties.

The power system should allow secure supply of electric energy which shouldn't have voltage and frequency fluctuations. The

precision and accuracy of the load forecasting system has a very much dependency on the load, the factors affecting the load and their relation (Ahmadi, S., *at al*, 2012). In conventional methods the load, identification of factors affecting the load and their relation is modeled. In such methods identification of those relations are very difficult because their relation is nonlinear. So such models are not accurate. Unlike conventional methods some new methods (neural networks, fuzzy logic) have the ability to identify the nonlinearities among different variables and also work on large amount of data available.

Load forecasting

Load Forecasting is categorized in three terms. Short Term Load Forecasting as hourly, daily or weekly, and is used in system information and unit commitment for the system. Mid Term Load Forecasting, extends from month to a year, and is used normally in the peak months of summer and winter. Long Term Load Forecasting ranging from one year to ten years and is usually used to plan the volume of the growth of power generation (Farhat, 2004; Liao, 2004).

Load sequence is not a uniform in 24 hours. It keeps changing at any instant of time. These variations in load characteristics are due to customer involvement in utility intentionally. Similarly the load on week days and weekend days are different (Mori, H., 1996). It is also noted that on some days the load is dramatically changed from other days like Eid day, Sports day, Friday (at the time of Friday prayers). All such situations rise uncertainties and STLF is the best choice for all such uncertain situations.

Materials and Methods

Implementation of Fuzzy Logic System

Fuzzy Logic is a model of sets of input and output variable in which they are mapped. Inputs and Outputs are represented in natural language rather by numerical values. The variables are expressed by their degree of contribution (Ranaweera, *at al*. 1996) like if we take temperature, it may be expressed as “very high”, “low” or “moderate”. Variables of Input with outputs are Mapped, with the help of If-Then Rules like “If temperature is moderate then load will be high”.

The two pretty characteristics of fuzzy logic, the outcome of fuzzy rules is demonstrated in a single crisp value and addition of membership functions to the existing ones or to change one another are in application of the fuzzy inference system used in this work. The membership functions are designed graphically, so, the whole inference system is designed according to the profiles of membership functions, rather than on one valued numerical point (Ross, 1995; Klir, 2000). Which shows that it is in resemblance with the human decision making process.

In this research work input variables are Season, Time and Temperature, and, output is Load (forecasted). Membership functions of all variables are triangular. Region of all variables are divided with membership functions of very small intervals among them except for the variable season, which has only four membership functions.

Among 24 hours (of day/night) the temperature varies in between extreme max and extreme min values. As the temperature varies from hour to hour, so, each hour of the

24 hours is given a group of temperature. The group is according to the analysis done on temperature conditions of every hour in different seasons. Like in January time 2 PM is given the group is 18 °C to 21 °C. It means that at that time temperature is probably varies from 18 °C to 21 °C. Each group is different from one another. Also the same group of that time is different in other months.

Variable Season is divided into four membership functions. The horizontal axis of the region of variable season is calibrated from 0 to 11 with period of 1 unit. These values represent the months of the year like 3 represents March, 4 April and so on. December is represented by 0. The groups of temperatures are produced which are in accordance with the seasonal conditions of Peshawar. Groups for one season are different from other seasons.

There are 24 membership functions are used for time variable. Each one represents one hour. They are uniformly placed in the region. The names of membership functions start from 1 to 24 showing the time starts from 1 AM to 12 AM. Output variable is calibrated from 350 kW to 1970 kW with 31 regular membership functions. Each membership function is represented by numerical number starting from 1 to 31.

Another input variable is time. Load profile if you see is the function of time, varies with time. Besides load dependency on time, temperature also varies its value when time passes. Each hour in day and night have almost different temperatures and loads. The then part of if then rules is decided by considering all these impacts. If then rules are created in order to have a straight forward implementation of a computer program

(Barsal, R.C., 2003). This is another pretty characteristic of fuzzy inference system. One rule among the set of rules designed in the controller is:

“If time is 15 and temperature is t21 and Season is S3 then load is 23”

15 of time, t21 of temperature, S3 of Season and 23 of load are actually the names of the membership functions of each variable. In every rule the degree of each variable is defined by its membership function. In this work it is done by studying and analyzing the data of year 2014 and 2015. When all the rules are given to the controller now you can give the values of the input variable in rule viewer window. The system will give a single crisp value in kilowatt.

Results and Discussion

Analysis of the data taken from Hayatabad 132 kV Grid Station, Peshawar, Pakistan for the year 2014 and 2015 was done. 24 hours load of the three days January 18, 2015, April 9, 2015 and June 20, 2014 is forecasted in this research work. Tables 1-3 shows the forecasted loads, actual loads and percentage error values of the three days, the system established in this research work can be used to forecast the load of any hour throughout the year.

Fuzzy rules are used to mapped I/O variables for any real problem. Membership functions and fuzzy rules give instinctive, direct and uncomplicated mode to comprise heuristics into the load forecasting.

Simulation is done in MATLAB. The results form rule viewer were taken and compared with the actual loads. The plots of actual and forecasted loads are sketched in MATLAB. It can be seen in the Figures 1-3.

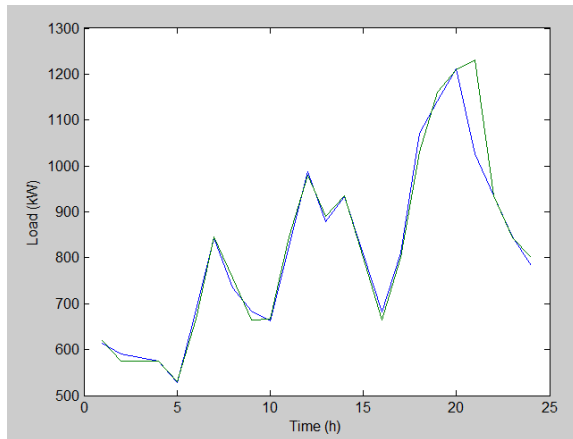


Fig.1. Comparison of Actual and Forecasted Loads (18 January 2015)

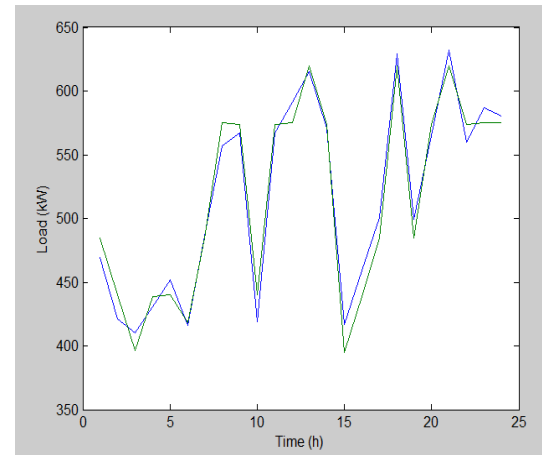


Fig.2. Comparison of Actual and Forecasted Loads (9 April 2015)

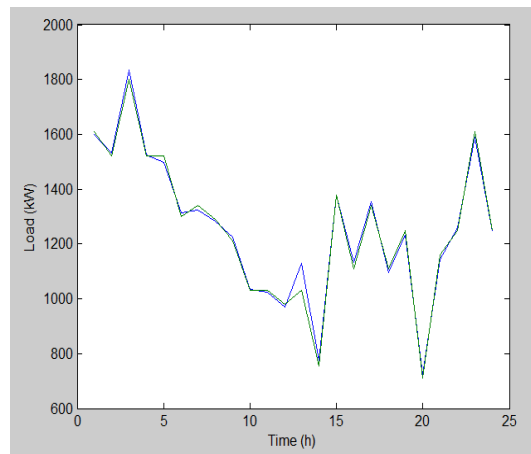


Fig.3. Comparison of actual and Forecasted Loads (20 June 2014)

Table 1 Actual Load, Forecasted Load and percentage error for January 18, 2015

Time	Actual Load (kW)	Forecasted Load (kW)	% age error
			$\frac{AL-F.L}{AL} \times 100$
1	613	620	1.14
2	591	575	2.70
3	583	574	1.54
4	575	575	0
5	529	531	0.37
6	686	666	2.91
7	844	845	0.11
8	734	755	2.86

Fuzzy Logic Control System for short term Load Forecasting

9	684	665	2.77
10	662	666	0.60
11	824	845	2.54
12	987	980	0.70
13	879	890	1.25
14	934	936	0.21
15	808	800	0.99
16	682	665	2.49
17	810	801	1.11
18	1071	1030	3.82
19	1141	1160	1.66
20	1211	1210	0.082
21	1027	1230	0.29
22	936	935	0.10
23	846	844	0.23
24	783	800	2.17

Average % age error: 1.36 %

Table 2 Actual Load, Forecasted Load and percentage error for April 9, 2015

Time	Actual Load (kW)	Forecasted Load (kW)	% age error
			$\frac{AL-FL}{AL} \times 100$
1	469	485	3.41
2	421	440	4.51
3	410	396	3.41
4	431	439	1.85
5	452	440	2.65
6	416	418	0.48
7	486	485	0.20
8	557	575	3.23
9	567	574	1.23
10	419	440	5.01
11	567	574	1.23
12	591	575	2.70
13	615	620	0.81
14	571	574	0.52
15	417	395	5.27
16	459	439	4.35
17	501	485	3.19
18	629	620	1.43
19	499	485	2.80
20	565	574	1.59
21	632	620	1.89
22	560	574	2.50
23	587	575	2.04
24	580	575	0.86

Average % age error: 2.83 %

Table 3 Actual Load, Forecasted Load and percentage error for June 20, 2014

Time	Actual Load (kW)	Forecasted Load (kW)	% age error $\left \frac{A.L - F.L}{A.L} \right \times 100$
1	1601	1610	0.56
2	1531	1520	0.71
3	1834	1800	43.8
4	1526	1520	0.39
5	1498	1520	1.46
6	1314	1300	1.06
7	1325	1340	1.13
8	1282	1290	0.62
9	1226	1210	1.30
10	1033	1030	0.29
11	1023	1030	0.68
12	970	979	0.92
13	1131	1030	8.93
14	776	755	2.70
15	1380	1380	0
16	1133	1110	0.20
17	1356	1340	1.17
18	1096	1110	1.27
19	1231	1250	1.54
20	723	710	1.79
21	1143	1160	1.48
22	1259	1250	0.71
23	1591	1610	1.19
24	1246	1250	0.32

Average % age error: 1.34 %

Conclusion and Future Recommendations

Next hour load around a year can be forecasted using this system, which is modeled in a MATLAB. It is also shown that the error is very small i.e less than 3 % using this method, therefore, it is best in accuracy than any other conventional method. Hence the utility company does not face any difficulty economically due to less percentage of error.

If the progression in variations of the load data is more composite, complex and not regular then for accurate execution of a

system more membership functions are required.

For future work it is recommended to make the system automatic. The work discussed here is manually controlled. User changes the input values manually. For automatic system Temperature sensor and a timer will be required, which could be modeled in MATLAB.

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