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Temperature Sensitive Short Term Load Forecasting: Fuzzy Logic Approach

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ABSTRACT

Load forecasting is an essential aspect for planning and operation of power system to have efficient and reliable power operation. It is needed for unit commitment, economic allocation of generation and maintenance schedules. Short Term Load Forecasting (STLF) is a necessary daily tool for power dispatch. It also assists for prevention of overloading. Though there are some techniques available for such forecasting, they do have certain limitations particularly where data is vague and imprecise. Therefore, the present paper employs Fuzzy Logic Approach in Short Term Load Forecasting dealing with sensitivity of daily temperature as input variable. The proposed model has been validated with actual daily load.
Keywords: Power System Operation, Short Term Load Forecasting,Temperature, Fuzzy Logic Technique.

I. INTRODUCTION

Load forecasting has been an integral part in the efficient planning, operation and maintenance of a power system. Short term load forecasting is necessary for the control and scheduling operations of a power system and also acts as inputs to the power system analysis functions such as load flow and contingency analysis. Short term load forecasting is basically a load predicting system with a leading time of one hour to seven days, which Systems for proper and profitable management in electrical utilities. Short-term load forecasting has lot of importance. High forecasting accuracy as well as speed is the two most vital requirements of short-term load forecasting and it can be extended further to analyze the load characteristics. The various methods of load forecasting include linear regression, exponential smoothing, stochastic process etc. However, there exists large errors when there is a fluctuations in temperature which is a function of time. Under such cases load forecasting using fuzzy logic technique is preferred. In this paper, fuzzy logic approach has been proposed for short term load forecasting problems, taking into consideration of time and varying temperatures as inputs. This paper contributes to the short term load forecasting, as it shows how the forecast can include the effect of weather variables of the temperature variation to consider sensitivity.

II. FUZZY MODEL SRUCTURE

The significance of this paper is to do short term load forecasting for a day ahead by taking into considerations time and temperature. The classification of the load data is done using fuzzy set techniques.

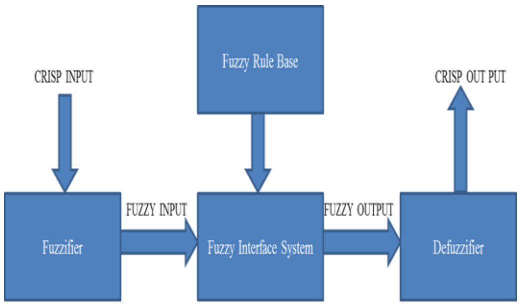

Figure 1. Fuzzy logic methodology

Figure 1 shows the basic Fuzzy Model structure of the proposed work. The model is structured in three sequential parts: Fuzzifier, Fuzzy inference system (FIS) and Defuzzifier. The input data of forecasted temperature and time are given to the fuzzy inference block through fuzzifier. Model inputs are in fuzzy sets of linguistic variables in triangular membership functions (MF). FIS is the heart of the system, as it processes the inference system and accomplishes the task of forecasting. The accuracy of the forecast depends on the experience of the forecaster, the rules prepared by the forecaster and the number of rules prepared. After, the inference system gives output; the defuzzification block converts the fuzzified output to the crisp output which can be further displayed on a graph known as the load curve.

Firstly, the historical data are examined and the maximum range of different parameters are used in the process of the fuzzification such as time and temperature. After the fuzzification If-Then rule are prepared. These rules are the heart of the fuzzy system, so utmost care should be taken to prepare these rules. Mamdani or Takagi-sugeno implication techniques can be applied. In the present study Mamdani method is adopted. In defuzzification aggregation of fuzzy outputs are carried by center of gravity approach. Step wise operations of the proposed model is as shown in Figure. 2.

Figure 2. Flow chart of fuzzy logic operations

2.1Fuzzy Logic Framing: Fuzzification

Fuzzification is the process of converting crisp numerical values into the of membership values through membership functions (MF). A MF will accepts a crisp value and return the degree to which that value belongs to the fuzzy set the MF represents. In order to express the fuzziness of data, this paper makes an arrangement of fuzzy subsets for different inputs and outputs in complete universe of discourse as MF's. The relationship between several inputs and output may be nonlinear but linear membership functions have been used for simplicity. A triangular membership function is used for the inputs as well as the output. The two inputs taken for STLF are time and temperature. As shown in Figure 3, time of 24 hours is divided into seven fuzzy sets with triangular membership functions for convenience:

- Mid Night
- Dawn
- Morning
- Noon
- Evening
- Dusk
- Night

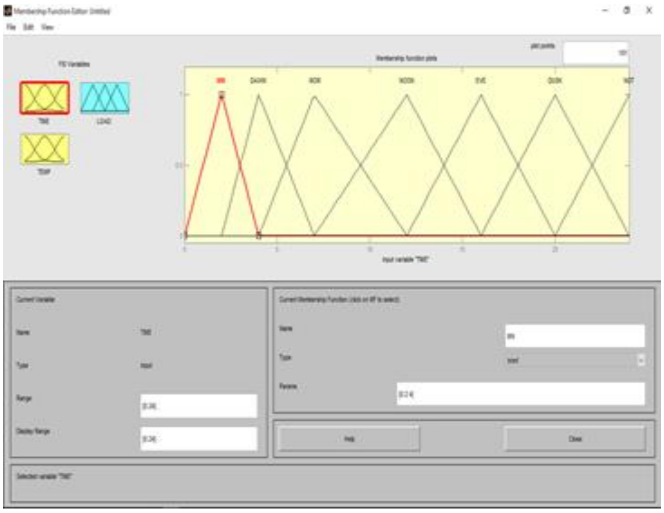

Figure 3. Triangular membership function of time input

Similarly, hour wise temperature divided into seven triangular membership functions as shown in Figure 4 with necessary overlapping on trial basis.

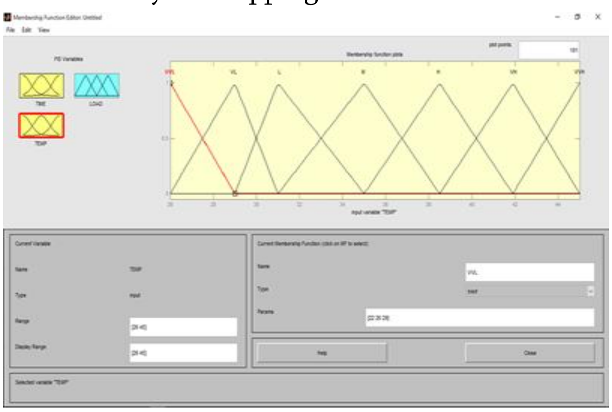

Figure 4. Triangular membership function for Temperature

The output loads are converted into eighteen fuzzy sets in triangular membership functions as shown in Figure 5, so as accuracy of forecasting of loads is enhanced

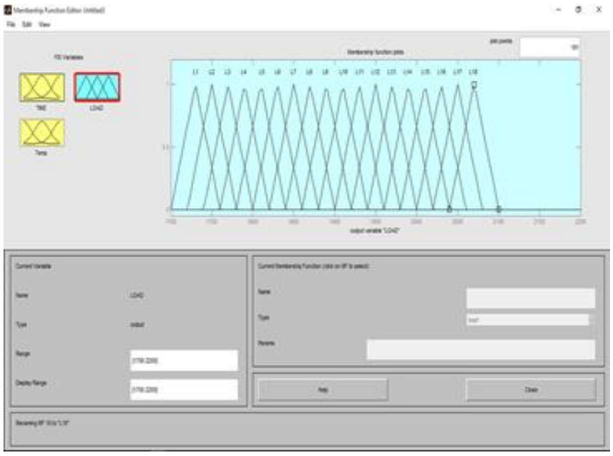

Figure 5. Triangular membership function for Forecasted load

2.2 Developing Fuzzy Rule Base

This is the heart of the fuzzy logic model. The knowledge of forecasted is stored in terms of "IF…THEN…" rules. The rule is in two parts. (a) Subsequent. (b) Consequent.

The information from the fuzzifier is passed to the fuzzy inference system for forecasting process. Following are few rules framed are mentioned here for illustration purpose:

- **IF** time is Midnight(MN) **AND** temperature is Low(L) **THEN** load is L-16
- **IF** time is Midnight(MN) **AND** temperature is Low(L) **THEN** load is L-17
- **IF** time is Midnight(MN) **AND** temperature is Low(L) **THEN** load is L-15

The number of rules depend on number of fuzzy sets in each input. Here 7x7 = 49 rules are framed to cover seven fuzzy sets in two inputs. Mamdani implication technique has been adopted on fuzzy set operations as:

If there are two sets A and B,

$$\mu_{A\cap B}(X) = \min\ [\mu_A(X), \mu_B(X)]$$

i.e. $\mu_A(X) \wedge \mu_B(X)$

Here intersection of two sets A and B i.e. fuzzy set of time A, Fuzzy set of Temperature B i.e. A ∩ B. and $\mu_A(X)$ is degree of membership.

The inputs that fire the subset of the inputs are considered for the above set operations and consequently are aggregated as per Mamdani method.

III. RESULTS AND DISCUSSION

A. Defuzzification

It is the process of transforming fuzzy outputs on FIS into crisp outputs. Here center of consequent areas are considered and crisp output are worked out. A typical MATLAB snapshot of input and output relations are shown in Figure. 6.

Figure 6. MATLAB snapshot of output.

B. Simulation Process

MATLAB is used for the simulation purpose (Figure. 7). The input data are given to the fuzzy logic controller block. The model input data of time, forecasted temperature and actual load on previous day are shown in Table 1 for simulation purpose. The actual load mentioned for the previous day refer to a field station. In fuzzy logic controller block "FIS" of fuzzy inference system is loaded. Here, the time slots and the corresponding temperatures and loads are simulated for forecasting process. Based on the rules prepared the fuzzy logic controller gives the crisp outputs corresponding to the input of time and hourly temperatures with due process on the basis of Mamdani steps. These aggregative fuzzy output are further defuzzified and crisp output are obtained.

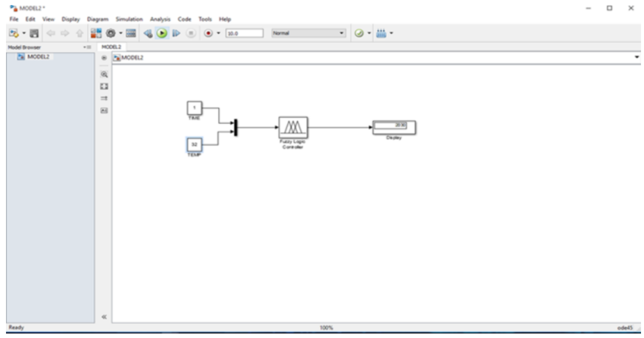

Figure 7. Simulation model of STLF.

C. Simulation Results.

The forecasted loads as simulation output for the next day are shown in Table 1 in fourth column for all the 24 hours of the day with variation in temperatures in range from 29° c to 44° c. The model results are further validated with actual load of the previous day in terms of percentage error as given below.

$$\% \text{ error} = \frac{\text{Actual Load} - \text{Forecasted load}}{\text{Actual Load}} * 100$$

The error can be positive or negative. Average percentage error is compiled for absolute output as:

$$Average\ \%\ error = \frac{\sum_1^{24} |\ \%\text{error}\ |}{24}$$

and found quite reasonable for its 0.182% value .

Table 1. Fuzzy modeled hourly load forecast.

Input Data			Output Data	
Time (Hrs)	Forecasted Temp.(°C)	Actual Load(MW) Previous day	Fuzzy Forecasted Load (MW) Next day	Error percentage (%)
1	32	2035	2030	0.245
2	31	2006	2030	-1.196
3	30	1989	1970	0.955
4	30	1938	1920	0.928
5	30	1935	1970	-1.808
6	29	1942	1920	1.132
7	29	1900	1950	-2.63
8	31	1888	2030	-7.521
9	32	2013	2030	-0.844
10	35	2050	2060	-0.487

11	37	2094	2030	3.56
12	39	2076	2030	2.215
13	41	2002	2010	-0.399
14	42	2050	2070	-0.975
15	43	2091	2070	1.00
16	44	2076	1950	6.069
17	43	1959	1950	0.459
18	42	1929	1950	-1.088
19	39	1930	1940	-0.518
20	37	2019	2000	0.941
21	37	2038	2000	1.903
22	36	1975	2000	-1.265
23	34	2020	2010	0.495
24	33	2100	2040	2.257
			Average	0.182

Average error % = 0.182%.

IV. CONCLUSION

This paper presents the short term load forecasting methodology using fuzzy logic, which takes into account of time and temperature as inputs. The proposed fuzzy logic model for short term load forecasting is recommended as it accounts the vague expressions of inputs and provide reasonably accurate predictions of load which is quite temperature sensitive which varies from morning to late night. The predicted temperatures and likely loads for the same guide the control engineers to operate the power system effectively.

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