FUZZY LOGIC METHODOLOGY FOR SHORT TERM LOAD FORECASTING

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Abstract

Load forecasting is an important component for power system energy management system. Precise load forecasting helps the electric utility to make unit commitment decisions, reduce spinning reserve capacity and schedule device maintenance plan properly and it also reduces the generation cost and increases reliability of power systems. In this work, a fuzzy logic approach for short term load forecasting is attempted. Time, temperature and similar previous day load are used as the independent variables for short term load forecasting. Based on the time, temperature and similar previous day load, fuzzy rule base are prepared using mandani implication, which are eventually used for the short term load forecasting. MATLAB SIMULINK software is used here in this work. For the short term load forecasting, load data from the specific area load dispatch center is considered.

Keywords: Load forecasting, short term load forecasting, Fuzzy logic, Fuzzy inference system.

1. INTRODUCTION

The prime duty of any utility is to provide reliable power to customers. Customer load demand in electric distribution systems is subject to change because human activities follow daily, weekly, and monthly cycles. The load demand is usually higher during the daytime and in evening, when industrial loads are high, lights are on, and lower in late evening and early morning when most of the population is asleep. Estimating the distribution system load expected at some time in the future is an important task in order to meet exactly any network load at whatever time it occurs. The estimation of future active loads at various load buses ahead of actual load occurrence is known as load forecasting. If it is done inappropriately, then the direct effect is on the planning for the future load and the result is the difference of the load that will develop from the planning done for the same, and eventually the entire planning process is at risk.

Therefore, load forecast plays a crucial role in all aspects of planning, operation, and control of an electric power system. It is an important task for operating a power system reliably and economically. So, the need and relevance of forecasting load for an electric utility has become an important issue in the recent past. It is not only important for distribution or power system planning but also for evaluating the cost effectiveness of investing in the new technology and the strategy for its propagation. However, in the deregulated market, load forecasting is of utmost importance. As the utility supply and consumer demand is fluctuating and the change in weather conditions, energy prices increases by a factor of ten or more during peak load, load forecasting is vitally important for utilities. Short-term load forecasting is a helping tool to estimate load flows and to anticipate for the overloading. Network reliability increases if the overloading effects are eliminated in time. Also, it reduces rates of equipment failures and blackouts.

Load forecasting is however not an easy task to perform. First, because the load on consumer side is complex and shows several levels of seasonality: the load at a given hour is dependent on the load at the previous hour as well as on the load at the same hour on the previous day, and also on the load at the same hour on the day with the same quantity in the previous week. Secondly, there are many important externally affecting variables that should be considered, particularly weather related variables [1].

There are large varieties of mathematical methods that are used for load forecasting, the development and improvements of suitable mathematical tools will lead to the development of more accurate load forecasting techniques. The accuracy of load forecasting depends on the load forecasting techniques used as well as on the accuracy of forecasted weather parameters such as temperature, humidity etc. As per the recent trends artificial intelligence methods are the most pronounced for the STLF. From different artificial intelligence methods, fuzzy logic and artificial neural network are the most used. Among the two methods fuzzy logic for STLF is gaining
importance nowadays, because of its some distinct advantages over ANN.

2. SHORT TERM LOAD FORECASTING

Short term load forecasting is basically is a load predicting system with a leading time of one hour to seven days, which is necessary for adequate scheduling and operation of power systems. For proper and profitable management in electrical utilities, short-term load forecasting has lot of importance [1].

High forecasting accuracy as well as speed is the two most vital requirements of short-term load forecasting and it is of utmost importance to analyze the load characteristics and identify the main factors affecting the load. In electricity markets, the traditional load affecting factors such as season, day type and weather, electricity price have a complicated relationship with system load [1].

3. BLOCK DIAGRAM AND FLOW CHART

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

Firstly, the historical data are examined and the maximum and the minimum range of different parameters are obtained. These ranges are used in the process of the fuzzification of different parameters such as time and temperature. After the fuzzification is done, based on the different parameter of load forecasting rule are prepared. This rules are the heart of the fuzzy system, so utmost care should be taken to prepare these rules. Once, the rules are prepared forecast the load of the desired hour. Figure (Fig.2) shows the flow chat of STLF using fuzzy logic.

The output obtained is compared with the actual load and the error in load forecasting is used to improve the rule base for future forecast. This improvement in rule of fuzzy logic increases the accuracy of the load forecasting.

![Flow chart of fuzzy logic methodology for short term load forecasting](image-url)

**Fig -1:** Block diagram of fuzzy logic methodology for short term load forecasting

**Fig -2:** Flow chart of fuzzy logic methodology for short term load forecasting
4. FUZZY LOGIC METHODOLOGY FOR SHORT TERM LOAD FORECASTING

4.1 Fuzzification

Fuzzification is the process of converting crisp numerical values into the degrees of membership related to the corresponding fuzzy sets. A MF will accept as its argument 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 membership functions. The relationship between several inputs and output may be nonlinear but linear membership functions have been used for simplicity. A rectangular 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 (Fig -3) time is divided into seven triangular membership functions which are as follows:

- Mid Night (MID-NIG)
- Dawn (DAWN)
- Morning (MORN)
- Noon (NOON)
- Evening (EVE)
- Dusk (DUSK)
- Night (NIGHT)

Figure (Fig -3) shows similar pervious day load divided into seventeen triangular membership functions which are as follows:

Figure (Fig -4) shows temperature divided into seven triangular membership functions which are as follows:

Figure (Fig -4) shows temperature divided into seven triangular membership functions which are as follows:

Figure (Fig -5) shows forecasted load (output) divided into seventeen triangular membership functions which are as follows:

4.2 Fuzzy Rule Base

This part is the heart of the fuzzy system. The heuristic knowledge of the forecasted is stored in terms of “IF-THEN” rules. It sends information to fuzzy inference system, which evaluates the gained information to get the load forecasted output. Some of the rules are as follows:

- If (time is MID.NIG) and (forecasted-Temperature is VL) and (similar-day-load is H1) then (forecasted-load is H1) (1)
- If (time is MID.NIG) and (forecasted-Temperature is VL) and (similar-day-load is H2) then (forecasted-load is H2) (1)
- If (time is MID.NIG) and (forecasted-Temperature is VL) and (similar-day-load is H3) then (forecasted-load is H3) (1)
If (time is MID.NIG) and (forecasted-Temperature is VL) and (similar-day-load is H4) then (forecasted-load is H4) (1)

If (time is MID.NIG) and (forecasted-Temperature is L) and (similar-day-load is H1) then (forecasted-load is H1) (1)

Similarly, 381 fuzzy rules are prepared based on the data obtained from ALDC, Jambuva, Vadodara

4.3 Simulation Work

Figure (fig -7) shows the simulation of fuzzy logic methodology short term load forecasting. MATLAB is used for the simulation purpose. As shown in the figure (fig -7) the input data’s as well as actual load occurred are loaded. The input data are given to fuzzy logic controller block. In fuzzy logic controller block “.fis” of fuzzy inference system is loaded. Based on the rules prepared the fuzzy logic controller give forecasted output corresponding to the input data. Then the permanent shut down block is added. If a substation is in working state for pervious similar day and there is a permanent shutdown for the forecasted day, then the megawatts supplied by the substation need to be subtracted from the forecasted load and vice versa. Thus, final forecast of the day is obtained. Also, the error is calculated along with the forecasting as shown in figure (fig -7).

4.4 Results

Table 1 and Table 2 show the actual load, forecasted load and also the percentage error in the forecasted load. The load forecast is done for the day 8th May 2013 and 9th May 2013 respectively. The percentage error in forecast can be calculated as

\[
\% \text{ Error} = \frac{\text{Actual Load} - \text{Forecasted Load}}{\text{Actual Load}} \times 100
\]

<table>
<thead>
<tr>
<th>Time (Hrs.)</th>
<th>Forecasted Temp. (°C)</th>
<th>Pervious Similar Day Load (MW)</th>
<th>Actual Load (MW)</th>
<th>Fuzzy Forecasted Load (MW)</th>
<th>% Error</th>
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<tr>
<td>1</td>
<td>32</td>
<td>2058</td>
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<td>2013</td>
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<tr>
<td>4</td>
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<td>1933</td>
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<tr>
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<td>9</td>
<td>32</td>
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<td>2013</td>
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<td>-0.282</td>
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<tr>
<td>10</td>
<td>35</td>
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<td>11</td>
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</table>
The results obtained from the fuzzy logic are compared with the conventional method of short term load forecasting and it is found that there is an error is between +2.695659% and -1.884780%. The load curve is plotted which is the comparison between the actual load (green and magenta colour) and the fuzzy forecasted load (red and cyan colour). Figure (Fig-8) and figure (fig-9) shows the load curve plot for 8th May 2013 and 9th May 2013 respectively. From the curve it is observed that fuzzy forecasted load curve is very close to the actual load curve.

**Fig-8:** Load curve of 8th May 2013

**Table-2:** Hourly load forecast of 9th May 2013

<table>
<thead>
<tr>
<th>Time (Hrs.)</th>
<th>Forecasted Temp. (°C)</th>
<th>Pervious Similar Day Load (MW)</th>
<th>Actual Load (MW)</th>
<th>Fuzzy Forecasted Load (MW)</th>
<th>%Error</th>
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<td>1970</td>
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<tr>
<td>13</td>
<td>40</td>
<td>2036</td>
<td>2088</td>
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</table>
14 42 2105 2141 2118.66 1.0650
15 43 2122 2187 2144.67 1.9187
16 43 2090 2160 2125.87 1.5781
17 43 2030 2062 2043.28 0.9307
18 42 1971 2043 2005.62 1.8454
19 39 1957 2010 2002.95 0.3383
20 36 2014 2105 2075.03 1.4449
21 34 2025 2072 2094.16 -1.0611
22 33 1989 2102 2045.00 2.6956
23 33 2024 2093 2085.89 0.3560
24 31 2050 2168 2121.64 2.1436

Fig. 9: Load curve of 9th May 2013

5. CONCLUSIONS
In this paper fuzzy methodology for short term load forecasting is discussed. It is concluded that using time, temperature and similar previous day load as the inputs and by formulating rule base of fuzzy logic using available data, load forecasting is done with an error margin of +2.695659% and -1.884780%. Moreover, it is also concluded that fuzzy logic approach is very easy for the forecaster to understand as it works on simple “IF-THEN” statements. It also helps in unit commitment decisions, reduce spinning reserve capacity and schedule device maintenance.

ACKNOWLEDGEMENTS
I extend my thank to Mr. Pareshkumar J. Bhatt, Executive Engineer in Operation and Management, Rural Division Office, Ankleshwar, for his support in giving through knowledge in load forecasting; also I like to thank Mr. Kunvarji M. Vasava, Junior Engineer in Demand Side Management, Area Load Dispatch Centre, DGVCL, Jambuva, for his help and support.

REFERENCES

BIOGRAPHIES

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