USE OF FUZZY LOGIC TO INVESTIGATE WEATHER PARAMETER IMPACT ON ELECTRICAL LOAD BASED ON SHORT TERM FORECASTING

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ABSTRACT
Load forecasting guides the power company to make some decisions on generation, transmission and distribution of electrical power. This work presents a solution methodology, using fuzzy logic approach for short term load forecasting (STLF) for Adamawa State University, Mubi. The proposed methodology utilized fuzzy reasoning decision rules that use the nonlinear relationships between inputs and outputs. The fuzzy logic model was developed in the Simulink environment of a MATLAB software. The model developed was able to forecast a day ahead load (kW) with a mean absolute error (MAPE) of 6.17% and it was observed that weather parameter (temperature) has significant impact on electrical load.

Keyword: Load forecasting, Fuzzy Logic, Rule base, Fuzzy Inference system and Short term load forecasting.

1. INTRODUCTION.

Load forecasting is important for power system management; it helps in good planning, scheduling and operation of power system. Load forecasting is a technique used for predicting electrical load. Therefore, it has becomes an important tool for power companies [3, 5] as it gives foresight of consumers' hourly, daily, weekly and even seasonal demand. This in turn helps the company to plan maintenance schedule and operation, thereby guaranteeing energy satisfaction. Load forecasting can be divided into three categories: short–term, medium–term and long–term load forecasts [8]. In this work, design of logic system for short term electrical load forecasting is presented. STLF is a system or method of predicting electrical load with a leading time of one hour to some days. It is obvious that this method gives timely information about human activities and other factors such as weather sensitive parameters, following hourly, daily and weekly cycles [2, 4]. In most literatures, it is practically observed that, the load demand is usually higher during the day time and in the evening [13, 14]. Although, in the late evening, midnight and early morning the load demand is lower may be due to temperature variation. Putting this in mind short-term forecasting can help in understanding power

network reliability. Many methods have been proposed by different authors to forecast electrical load. This includes; linear regression, exponential smoothing, stochastic process, ARMA (autoregressive integrated moving average) models, and data mining models. In recent times fuzzy logic, neural network and Artificial intelligence are also used [1, 7, 9]. Fuzzy logic models have been developed as a solution forecasting method, because the weather parameters can be easily classified unlike the other techniques mentioned above [11, 6]. Also, it does not require a computational mapping of inputs to outputs or no need for precise inputs. Fuzzy logic is simply a means of representing human reasoning [12]. The main components of fuzzy logic are fuzzy set, membership function and fuzzy IF-THEN rule base. IF – THEN rule base is used to convert the fuzzy input into the fuzzy output [2]. In this research, the use of a time of the day, temperature and the previous day load will serve as the input parameters for the short term load forecasting to forecast a day ahead load. The aim of this work is to develop fuzzy logic methodology for short-term load forecasting with the following objectives: to formulate fuzzy logic rules that will facilitate the load forecasting, to compare the actual load and the forecasted load and to check the effect of

weather parameter (temperature) on electric load. Fuzzy logic approach has been widely used in short term load forecasting by considering different factors as input variables such as weather parameters (temperature, humidity, wind speed, sun shine, light intensity, rainfall etc), time and historical load data to forecast electric load demand. In [3] short-term load forecasting was carried out using fuzzy logic methodology by considering time and weather parameters to forecast a day ahead load. The model forecasted a day ahead load with error margin of +2.695659% to -1.884780%. Also [13] carried out a research work on "short-term load forecasting using fuzzy logic approach", in the work; short term load forecasting was proposed using time, temperature and similar previous day load as independent variables. Based on the data, rules were prepared using Mamdami implication. MATLAB SIMULINK Software was also used for system design and simulation. The research was carried out based on the load data obtained from Sudan network generation; forecasted load was obtained with an error of +12.14 to -9.48%. Also [5] proposed short term load forecasting using fuzzy logic based on weather sensitive data (temperature, humidity and wind speed) and historical load data for load forecasting. Load data used is from State Load Dispatch and Communication Centre, Rajasthan Vidyat Parasaran Nigam. The work focused on four different cases: Pre-holiday, holiday, post-holiday and working day. The forecasting performance was evaluated and MAPE (mean absolute percentage error) of the model for the four cases were presented as 10.55%, 9.05%, 10.05% and 11.74% respectively. Most of the works reviewed were presented based on the geographical factors affecting electrical load consumption and the available historical load data in their respective regions; hence their results may not be applicable to environments with different geographical factors. Therefore, this work is focused on weather parameter, temperature, time and previous day load of the area under study to forecast a day ahead load based on fuzzy logic approach for short term load forecasting.
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2. METHODOLOGY

2.1 Data collection and Implementation of Fuzzy Logic Procedures

Hourly data for three days (1st, 2nd and 3rd January, 2016) is collected from two departments, electrical load from maintenance unit and weather parameter (temperature) from geography department of Adamawa State University, Mubi, Adamawa state, Nigeria.

Figure 1 shows the information about the data collected. These data will be used for formulation of fuzzy logic rules.
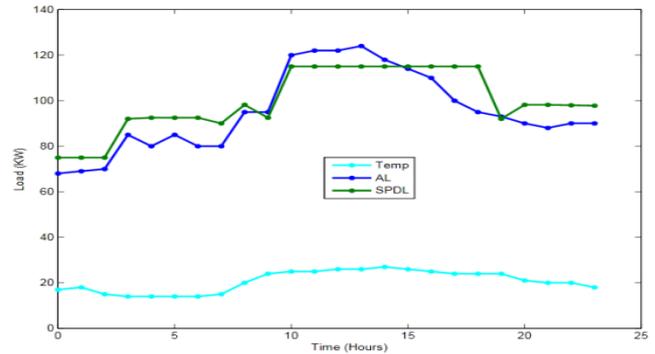
Figure 1: Previous load, Actual load Temperature vs. time

As shown in the Figure 1, it can be seen clearly that, electric load increases with increase in temperature as also shown in [10]. The minimum load obtained is at the midnight to 7.00am in the morning as the temperature is low. Figure 2 shows the proposed block diagram of the fuzzy model with three inputs: temperature, previous day load and time, these are fed into the fuzziffier, then the output of the fuzziffier and the fuzzy rule formulated are also fed into the fuzzy inference system (FIS) where all the information are processed. The output of the FIS is fed to the defuzzification where the crisp value of the forecasted load is produced.
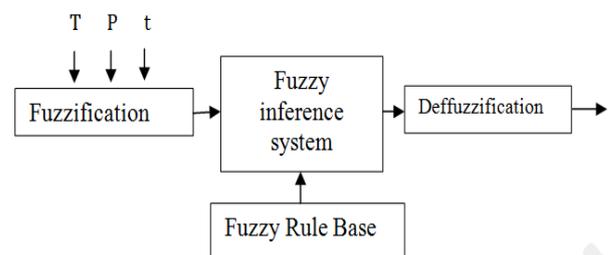
Figure 2: Block Diagram Fuzzy Logic Methodology for Short Term Load Forecasting

2.1.1 Fuzzification

Fuzzificationis the process whereby the crisp numerical values are fuzzified into degree of memberships related to the corresponding fuzzy sets. Several membership functions are used in fuzzy modeling, which includes trapezoidal, Gaussian, triangular etc.

Table 1: Time classification (Hours)

Classification	Midnight	Dawn	Morning	Noon	Evening	Dusk	Night
Time(Hours)	0.00-3.00am	4.00-6.00am	7.00-11.00am	12.00-14.00pm	15.00-17.00pm	18.00-20.00pm	21.00-23.00pm

In this work, the triangular membership function is adopted; this membership function is flexible on all kinds of data. This is the reason for its consideration. The input data are classified as shown in Table 1.

Table 2: Classifications of Temperature (ᵒC) and Previous Day Load (kW)

Classifications	Low	Medium	High
Load (kW)	60-95	90-115	110-125
Temperature (ᵒC)	20-24	23-27	26-30

2.1.2 Membership Function Assignment

Membership function is a graph that defined how each point in the input space is mapped to its member value. This is usually between 0 and 1. The membership function is mapped as depicted in Figures3 (a–d), as the time, temperature, previous day load and actual load respectively.

2.2 Formation of fuzzy rule base

This is the heart of the fuzzy inference system, the heuristic knowledge of the forecast is stored in terms of "IF – THEN" rules, it sends information to the fuzzy inference system, which evaluates the received information and compute the forecasted output, in this case load in kW. The rules base is composed based on the variation of the input parameters as shown in Figure1. The fuzzy rule base is developed as follows.

- IF (time is MID-NIG), Temperature is low and the Previous Day load is low, THEN the forecasted Load is Low Load
- IF (time is MID-NIG), Temperature is low and the Previous Day Load is Medium. THEN the forecasted load is Medium Load
- IF (time is MORN), Temperature is Medium and the Previous Day Load is Low, THEN the forecasted Load is Medium Load
- IF (time is MORN), Temperature is Medium and the Previous Day Load is Medium, THEN the forecasted load is Medium Load
- IF (time is MORN), Temperature is High and the Previous Day Load is High, THEN the forecasted load is High Load
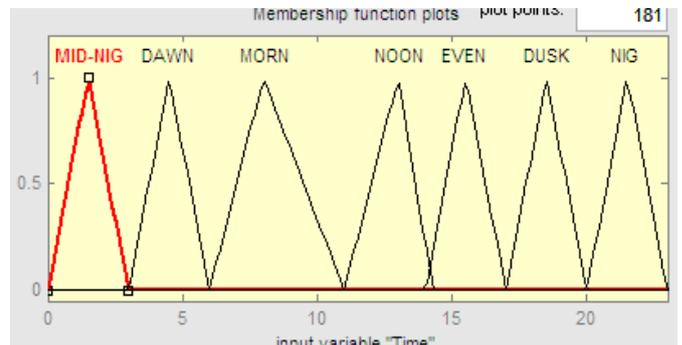
Figure3a;Membership Functions for Time
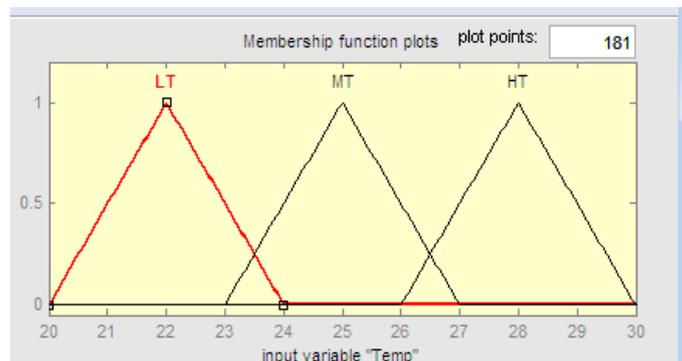
Figure 3b; Membership Function for Temperature
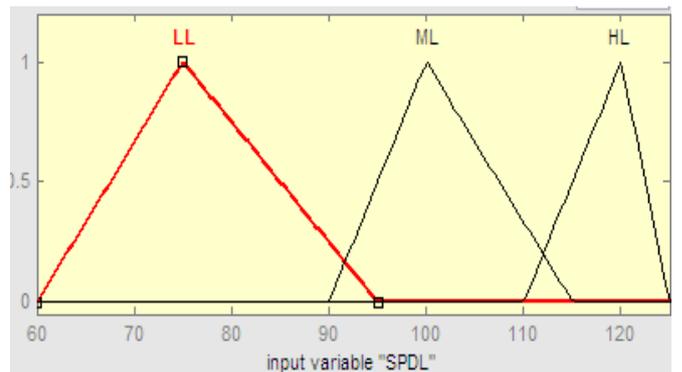
Figure 3c: Memberships Function for Previous Day Load
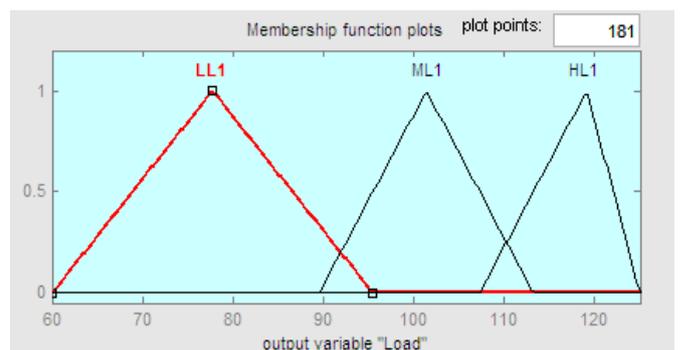
Figure 3d: Membership Functions for Actual Load

- IF (time is NOON), Temperature is High and the previous Day Load is High, THEN the forecasted Load is High Load
- IF(time is EVEN), Temperature is Medium and The Previous Day Load is High , THEN the forecasted load is High Load
- IF (time is DUSK), Temperature is Low and the Previous Day Load is Medium , THEN the forecasted Load is High Load
- IF (time is DUSK), Temperature is Low and the Previous Day Load is Low, THEN the forecasted load is Medium Load
- IF(time is NIG), Temperature is low and the Previous Day Load is low, THEN the Forecasted Load is low Load

2.3 Building of Fuzzy Logic Simulation Model

The fuzzy model is developed as shown in Figure 2, where the three inputs are multiplexed and send to the fuzzy logic controller with rule viewer, which will process the whole information and produces a crisp output value as shown on the display of Figure4.
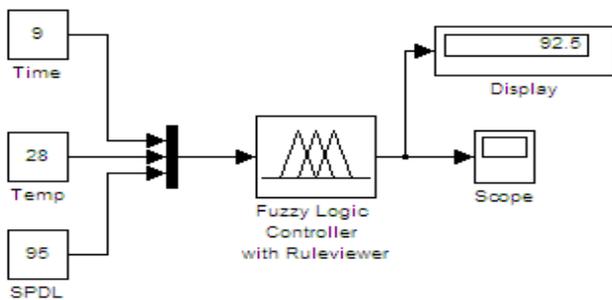
Figure 4: Fuzzy Model

For example, a sample input of Temperature (28^0C), the previous day load of 95kW at 9.00amwas simulated and the forecasted load obtained is 92.5kW. This can also be seen on rule viewer in Figure 5

Figure 5: Fuzzy Rule Viewer

The rule viewer above shows the plots of antecedent (time, temperature and previous day load) and consequent (forecasted load).

2.4 Error Analysis

The absolute percentage error (APE) and the Mean Percentage Error are calculated using Eqn. (1) and (2)

$$APE = \frac{Actual\ Load - Forecasted\ Load}{Actual\ Load} \times 100\% \quad (1)$$

$$MAPE = \frac{1}{n}\sum_{i=1}^{n} \frac{Actual\ Load(i) - Forecast\ Load(i)}{Actual\ Load(i)} \times 100\% \quad (2)$$

Where n = 24

3. RESULT AND DISCUSSION

Table 3 and Table 4 show the actual load, forecasted load and the previous day load while Table 5 shows their average values.

Table 3: Hourly Load Forecast of 2nd January 2016

Time(Hours)	T (^{0}C)	P(kW)	AL (kW)	F L (kW)	APE (%)
0.00am	17	68.00	70.50	92.50	23.33
1.00am	18	69.00	72.00	87.10	16.13
2.00am	15	70.00	69.00	87.10	16.13
3.00am	14	85.00	80.00	92.50	0.54
4.00am	14	80.00	75.50	92.50	0.00
5.00am	14	85.00	70.50	95.00	2.70
6.00am	14	80.00	90.00	92.50	0.00
7.00am	15	80.00	88.00	89.00	18.67
8.00am	20	95.00	89.50	98.00	0.20
9.00am	24	95.00	95.00	92.50	0.00
10.00am	25	120.00	105.00	117.00	1.74
11.00am	25	122.00	110.00	116.00	0.87
12.00pm	26	122.00	120.00	117.00	1.74
13.00pm	26	124.00	125.00	116.00	0.87
14.00pm	27	118.00	120.00	115.00	0.00
15.00pm	26	114.00	118.00	117.00	1.74
16.00pm	25	110.00	115.00	92.50	19.57
17.00pm	24	100.0	110.00	92.50	19.57
18.00pm	24	95.00	100.00	92.50	19.57
19.00pm	24	93.00	95.00	93.00	1.09
20.00pm	21	90.00	90.00	92.50	5.80
21.00pm	20	88.00	90.00	92.50	5.80
22.00pm	20	90.00	88.00	92.00	6.12
23.00pm	19	90.00	80.00	92.50	5.42
				MAPE	6.98

From Table 3, Mean Absolute Percentage Error (MAPE) is evaluated as 6.98% while the highest Absolute Percentage Error (APE) obtained is 23.33%.To further justify the relationship between the forecasted load and the actual load; a comparison graph is plotted as shown in Figure 6.
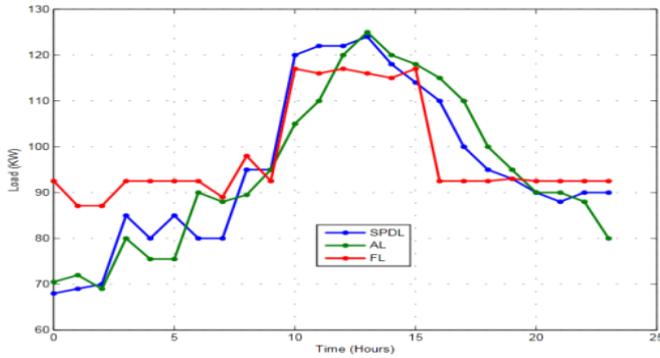
Figure6: Plots of Loads Vs Time

It is observed that, from midnight to early morning the load is low, from 10.00am, the load increases gradually till 2.00pm and it starts to decrease toward the evening, it can also be seen that, the load increases as temperature increases and vice - visa. Figure 7 shows the relationship between load and time of the day as obtained in Table 4.

The graphs show similar behavior as that of 2nd January, 2016, with low load from midnight to early morning and high load in the afternoon.

Table 4: Hourly Loads Forecasted for 3rd January 2016

Time(Hours)	T (^{0}C)	P (kW)	AL (kW)	F L (kW)	APE (%)
0.00am	21.00	70.50	69.25	90.00	29.96
1.00am	22.00	72.00	70.50	90.00	27.66
2.00am	23.00	69.00	69.50	90.00	29.50
3.00am	23.00	80.00	82.50	90.00	9.09
4.00am	23.00	75.50	77.75	90.00	15.76
5.00am	24.00	90.00	87.50	90.00	2.86
6.00am	24.00	88.00	84.00	90.00	7.14
7.00am	26.00	89.50	84.75	90.00	6.19
8.00am	26.00	95.00	95.00	90.00	5.26
9.00am	28.00	95.00	95.00	98.20	3.37
10.00am	29.00	105.00	112.50	112.00	0.44
11.00am	30.00	110.00	116.00	113.00	2.59
12.00pm	28.00	120.00	121.00	112.00	7.44
13.00pm	28.00	125.00	124.50	112.00	10.04
14.00pm	26.00	120.00	119.00	112.00	5.88
15.00pm	25.00	118.00	116.00	112.00	3.45
16.00pm	24.00	115.00	112.50	112.00	0.44
17.00pm	24.00	110.00	105.00	90.00	14.29
18.00pm	24.00	100.00	97.50	90.00	7.69
19.00pm	23.00	95.00	94.00	90.40	3.83
20.00pm	23.00	90.00	90.00	90.00	0.00
21.00pm	24.00	90.00	89.00	90.00	1.12
22.00pm	22.00	88.00	89.00	90.00	1.12
23.00pm	22.00	80.00	85.00	90.00	5.88
				MAPE	8.36

Figure 7: Relationship between the Loads

Table 5: Average Hourly Load Forecasted 2nd and 3rd January, 2016

Time(Hours)	T (^{0}C)	P (kW)	AL (kW)	F L (kW)	APE (%)
0.00am	19.0	69.25	72.13	90.00	24.78
1.00am	20.0	70.50	72.75	85.00	16.84
2.00am	19.0	69.50	72.75	85.00	17.65
3.00am	18.0	82.50	87.25	90.00	3.15
4.00am	18.0	77.75	85.13	90.00	5.73
5.00am	19.0	87.5	90.0	90.0	0.00
6.00am	19.0	84.0	88.3	90.0	1.98
7.00am	20.5	84.8	79.9	98.2	22.94
8.00am	23.0	95.0	96.6	98.2	1.66
9.00am	26.0	95.0	93.7	96.0	2.40
10.00am	27.0	112.5	113.7	112.0	1.54
11.00am	27.5	116.0	115.6	113.0	2.16
12.00pm	27.0	121.0	118.0	112.0	5.08
13.00pm	27.0	124.5	119.7	113.0	5.64
14.00pm	26.5	119.0	117.0	112.0	4.27
15.00pm	25.5	116.0	115.5	112.0	3.03
16.00pm	24.5	112.5	113.8	112.0	1.54
17.00pm	24.0	105.0	110.0	100.0	9.09
18.00pm	24.0	97.5	100.2	101.0	4.94
19.00pm	23.5	94.0	93.0	93.6	0.65
20.00pm	22.0	90.0	94.1	90.0	4.36
21.00pm	22.0	89.0	93.6	90	3.85
22.00pm	21.0	89.0	93.5	90	3.74
23.00pm	20.5	85.0	91.4	90.0	1.53
				MAPE	6.19

Figure 8: Average Load for 2nd and 3rd January, 2016

Figure 8 presents the variation of loads with temperature and time of the day. As it can be seen, the peak load was recorded from 10.00am to 4.00pm; this may be attributed to the temperature being high at that time.

4. CONCLUSION

In this work, fuzzy methodology for short term load forecasting is discussed. Short term load forecasting gives general information about what to generate, transmit and distribute. In this work, the following observations were made; load increases with increase in temperature and forecasted load is higher than the actual load. It is recommended that, in order to have a reliable power supply weather parameter such as temperature must be considered so that adequate information on load can be provided.

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