A Fuzzy Logic Based Short Term Load Forecast for the Holidays

Hasan H. Çevik and Mehmet Çunkaş

***Abstract*—Electric load forecasting is important for economic operation and planning. Holiday load consumptions are very different than normal days and does not follow the regular trend of normal days. Also data for the holidays less than other normal days. So making an accuracy holiday load forecast model is a difficult task. The purpose of this paper is presents different models using fuzzy logic method without weather information. Firstly holidays are classified according to their characteristics and historical load shapes. Each fuzzy model have three inputs and one output. While historical data from past years, consumption data from last week and the type of holiday (national, religious) are selected as inputs, the output is hourly forecasted holiday load. The data between the years 2009 and 2011 are used to design the forecasting models. The model performances are evaluated with the real data of the year 2012. The results of models are compared each other and show that proposed Model 2(scaled model) is more successful than Model 1. This paper shows that fuzzy logic can give good results for the holiday short term load forecast.**

***Index Terms*—Fuzzy logic, holiday load forecasting, short-term load forecasting.**

I. Introduction

The electricity used by the consumer should have some certain characteristics which are continuous, safe, reliable and minimum price. To perform all these characteristics, variety of plans should be prepared for power system. Electrical load forecasting is the first step of this plans and it is divided into four types: long term, medium term, short term and very short term. The short term load forecasting is a prediction of load from 1 hour to 1 week and provides these characteristics by helping the energy system operators to make efficient energy management operations and better power system planning. These operations and plans include energy purchasing, unit commitment; reduce spinning reserve capacity and T&D (transmission and distribution) operations [1]-[4].

The forecasting accuracy is very important factor for power system efficiency. If the forecast is overestimated, it leads to the start-up of too many units supplying an unnecessary level of reserve. Thus the production cost of is increased. In addition to that, it leads to substantial wasted investment in the construction of excess power systems. On the contrary if the forecast is underestimated, it may result in a risky operation and unmet demand persuading insufficient preparation of spinning reserve. Besides it may cause the system to operate in a vulnerable region to the disturbance. As a results, the frequency can drop and power outages can occur at power systems [5], [6].

The energy management system wants the hourly load consumption forecasts for next day from the distribution companies and the major consumer such as iron and steel factories one day in advance. This system, called day ahead program, helps to perform the following goals

- provide market participants the opportunity balance the generations and consumption
- provide the system operators a balanced system in the day ahead
- determine reference price for electric energy
- provide market participants some opportunities for the following day [7].

The trends of load consumption change according to the time. For example the weekdays load profiles and the weekends load profiles are different from each other, but holidays load profiles are very different than everything else. The electricity consumption decreases excessive amounts in holidays, therefore new forecasting models should be developed for holidays. In addition to these, holiday load forecasts are harder than normal days because of small number of available historical data for them compared to other days [8].

There are many studies under the umbrella of short term load forecasting but there are fewer studies on holiday load forecast. Holidays are also referred to as abnormal days or special days in some studies in the literature. A forecast for special days is carried out using artificial neural network (ANN) and fuzzy inference method [9]. While 24 hourly scaled load values of the same special day in the previous year and information of the special day type are selected for inputs ANN, the 24 hourly scaled load values are the outputs. In addition to that, the fuzzy logic is used for minimum and maximum load forecasting procedure. The forecasting results are obtained with combination of the two systems results. In another study, an hourly load forecast of the anomalous days is performed by means of self-organising map and ANN [10]. In addition there are some holiday forecasting studies using fuzzy linear regression method [11], fuzzy inference system [12], neural and fuzzy networks [13], Bayesian neural network [14], linear regression [15], support vector machines [16], fuzzy polynomial regression [8], semi-parametric additive model [5].

This paper focuses holiday load forecast of Turkey using different fuzzy models without weather information. Firstly holidays are classified according to their characteristics and historical load shapes. Previous year holiday data, previous load and the type of holiday (national, religious) are selected as inputs. The remainder of this paper is organized as follows.

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TABLE I: SOME INFORMATION OF HOLIDAYS IN YEARS 2009 TO 2012

Type	Name	Name	2009	2010	2011	2012
National	New Year's Day	1 January	Thursday	Friday	Saturday	Sunday
	National Sovereignty and Children's Day	23 April	Thursday	Friday	Saturday	Monday
	Labor Day	1 May	Friday	Saturday	Sunday	Tuesday
	Commemoration of Atatürk, Youth and Sports Day	19 May	Tuesday	Wednesday	Thursday	Saturday
	Victory Day	30 August	Sunday	Monday	Tuesday	Thursday
	Republic Day	29 October	Thursday	Thursday	Saturday	Monday
Religious	Ramadan Feast	Moves	19-22 September Saturday-Tuesday	9-11 September Thursday-Saturday	29 Aug-01 Sept Monday-Thursday	18-21 August Saturday-Tuesday
	Sacrifice Feast	Moves	26-30 November Thursday-Monday	15-19 November Monday-Friday	5-9 November Saturday-Wednesday	24-28 October Wednesday-Sunday

In Section II, holiday load profiles are analysed. While Section III presents the forecast model, the results are given in Section IV. Finally, the conclusions are in Section V.

II. HOLIDAY LOAD CHARACTERISTICS

The hourly holiday load consumption data are selected to create the model for the years 2009 through 2011. The load prediction is carried out for 2012 holidays. The load data are obtained from a utility company from Turkish Electricity Transmission Company (TEIAS), Turkey. As mentioned in the previous section, since the load trends of holidays are different, it is important to analyze the load data. Load data should be analyzed before developing a prediction model for achieving good forecast results. Public holidays vary from country to country. In Turkey, there are two kinds of holidays, national and religious. While national holiday dates do not change, religious holiday dates change each year. The holidays are presented in Table I and it can be seen some holiday load curves in Fig. 1 and Fig. 2. The following conclusions which help us to design forecast models can be made by the analysis of Table I and Figures:

- Each type of holidays' load consumptions are less than neighbor weeks'
- National and religious holidays have different characteristics. The reduction in load consumption is higher for religious holidays.
- Although some workplaces in private sector work on national holidays, they do not work on Sundays. So, if the national holiday is on Sunday, load consumption is reduced more than the other national holidays which are not on Sunday.
- A day can be both on national holiday and on religious holiday, because shifting in religious holidays each year. For example 30 August 2011. In such cases, the day can be considered as a religious holidays. The reason of this, reduction in load consumption is higher for religious holidays.
- A national holiday can come after a religious holiday and these effects the load curve of national holiday, for example, 29 October 2012. In such cases, the national holiday can be considered as a religious holidays.
- If four weekdays are on holiday, the government can officially announce that the whole week is holiday.

There are several factors which affect the load such as historical load, time factors (day type, holiday type), weather factor and random disturbances. We only use historical data and time factors. We did not consider weather factor for this forecast. This study presents two different fuzzy systems. Holidays are grouped with load characteristics and so four holiday types are determined.

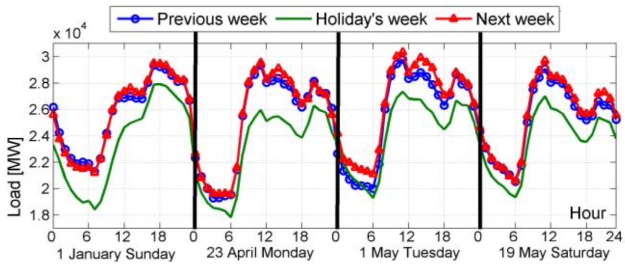

Fig. 1. Some national holiday load curves of 2012.

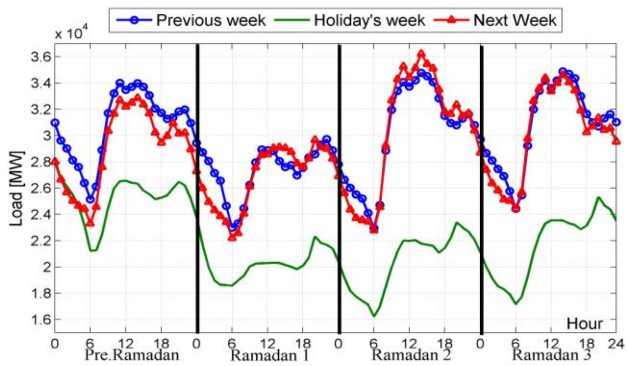

Fig. 2. Ramadan feast holiday load curve of 2012.

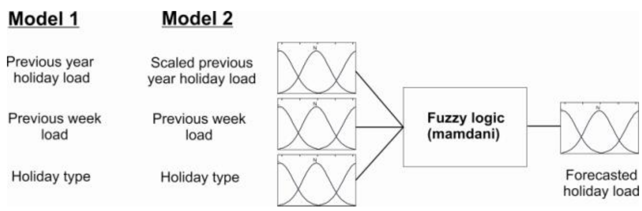

Fig. 3. Inputs/output of fuzzy models.

- National holiday
- National Sunday holiday
- Preparation day of religious holiday
- Religious holiday

III. FUZZY LOGIC MODELS

Fuzzy logic is a powerful method with successive results and it has been studied in many power system problems such as load forecasting, electricity price forecasting and power system planning.

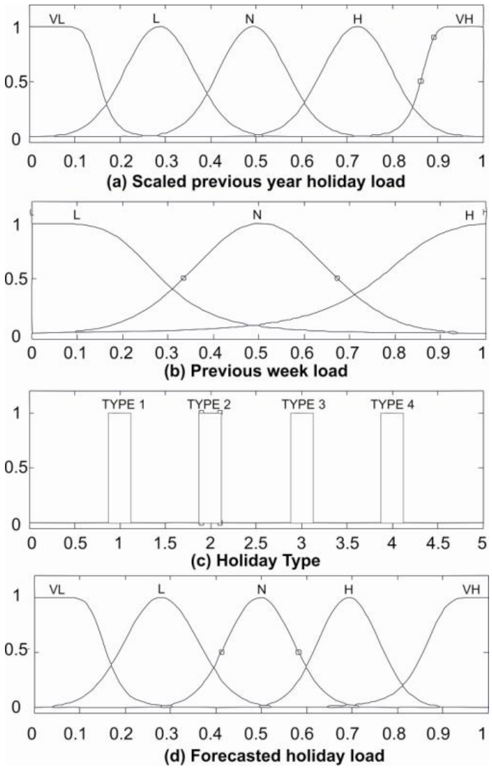

Fig. 4. Membership functions of input/output for Model 2.

In this study two different fuzzy logic models are developed and tested for each holiday types using Matlab Fuzzy Logic Toolbox. Each fuzzy model having three inputs and one output are shown in Fig. 3. While inputs of Model 1 are previous year holiday load, previous week load and holiday type, the inputs of Model 2 are scaled previous year holiday load, previous week load and holiday type. The output, hourly forecasted holiday load, is same for the models. Also the previous year load data, previous week data and forecasted load are normalized in both models. Each models have different membership functions and rule bases.

As mentioned in previous section, there are some similarities in terms of load decrease and increase time although each type of holiday load consumptions are less than neighbor weeks'.

It looks like they have only level difference between them especially for national holidays. For this reason previous week data from holiday can be scaled for using these similarities. We developed a scaled factor for each forecast hours on the previous week data before using the data for an input for Model 2. Therefore we had the proportional information from past year data and applied this information to the data of this year. Scaled factor was calculated by using Eq.(1).

$$SP = \left[1 - \frac{P_{N-1} - H_{N-1}}{P_{N-1}} \right] * P_N \tag{1}$$

where, P is previous week hourly load data, H is holiday hourly load data, N is forecast year and SP is scaled previous week hourly load data.

The membership functions input/output are shown in Fig. 4 for Model 2. The scaled previous year holiday load input has five membership functions. Where *VL* is very low, *L* is low, *N* is normal, *H* is high and *VH* is very high. *VL* and *VH* membership functions are the generalized bell function and the others are Gaussian functions. The membership functions of the previous week load have three memberships (Fig. 6(b)). These are *L*=low, *N*=normal and *H*=high. *L* and *H* memberships are the generalized bell function and *N* membership is Gaussian function. Holiday type has four membership functions as mentioned in previous section and their memberships are trapezoidal.

TABLE II: HOURLY FORECASTING RESULTS OF 1 JANUARY AND 23 APRIL

	1 January Sunday					23 April Monday				
Hours	Actual [MW]	Model 1 [MW]	Model 2 [MW]	Model 1 Error(APE)	Model 2 Error(APE)	Actual [MW]	Model 1 [MW]	Model 2 [MW]	Model 1 Error(APE)	Model 2 Error(APE)
1	23312	22372	24592	4,03	5,49	21112	19525	19872	7,52	5,87
2	22168	20173	21911	9,00	1,16	19710	18910	18753	4,06	4,85
3	20815	19212	19172	7,70	7,89	18946	18869	18753	0,41	1,02
4	19904	18977	18753	4,66	5,78	18545	18857	18753	1,68	1,12
5	19327	18898	18753	2,22	2,97	18456	18861	18753	2,20	1,61
6	18940	18867	18753	0,39	0,99	18310	18865	18753	3,03	2,42
7	19066	18883	18753	0,96	1,64	17825	18872	18753	5,88	5,21
8	18416	18817	18753	2,18	1,83	19323	19027	18753	1,53	2,95
9	18997	18975	18753	0,11	1,28	22658	23316	23078	2,91	1,86
10	20376	20006	20154	1,82	1,09	24653	25248	24140	2,41	2,08
11	22138	22349	22491	0,95	1,59	25367	25564	24827	0,78	2,13
12	23644	24070	24054	1,80	1,73	25970	25886	25683	0,32	1,11
13	24638	23846	24598	3,22	0,16	25115	25293	24613	0,71	2,00
14	24965	24179	24653	3,15	1,25	25413	25372	24809	0,16	2,38
15	25143	23953	24665	4,73	1,90	25470	25449	25239	0,08	0,91
16	25316	23882	24727	5,66	2,33	25120	25250	24596	0,52	2,09
17	26516	26853	25347	1,27	4,41	24794	25157	24759	1,46	0,14
18	27889	27978	25780	0,32	7,56	24117	24416	23947	1,24	0,71
19	27919	27894	25779	0,09	7,66	23866	24026	23729	0,67	0,57
20	27784	27730	25779	0,19	7,21	24848	24731	24211	0,47	2,56
21	27317	27558	25779	0,88	5,63	26306	25284	25455	3,88	3,24
22	26836	26994	25780	0,59	3,94	25932	24905	24642	3,96	4,98
23	26392	27006	25780	2,33	2,32	25782	24862	24634	3,57	4,45
24	25353	24589	25336	3,01	0,07	24303	24044	23789	1,07	2,12

IV. RESULTS

This study proposes two different fuzzy logic models for holiday sort term load forecasting using real data. Four different holiday types have been determined according to do load curve rhythms. The forecasted results are compared with the actual load. The fuzzy models and forecast accuracy should be measured using some statistical functions. Mean absolute percentage error (MAPE) widely used in load forecasting studies and is selected to validate the proposed models as follows:

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{R_t - F_t}{R_t}\right| * 100 \qquad (2)$$

where, R is actual value, F is the forecasting value and n value is the number of forecasting.

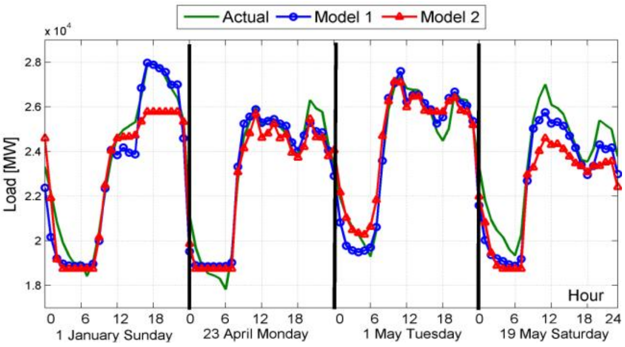

Fig. 5. Actual and forecasted values for some national holidays.

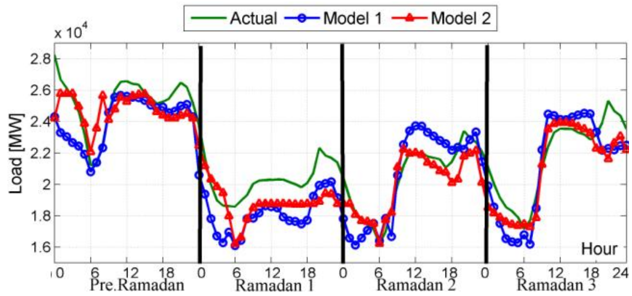

Fig. 6. Actual and forecasted values for Ramadan holiday.

TABLE III: MAPE VALUES OF MODEL 1 AND MODEL 2 FOR 2012 HOLIDAYS

Type	Name	Date	MAPE	
			Model 1	Model 2
National	New Year's Day	1 January Sunday	2,55	3,25
	National Sovereignty and Children's Day	23 April Monday	2,10	2,43
	Labor Day	1 May Tuesday	2,03	2,32
	Commemoration of Atatürk, Youth and Sports Day	19 May Saturday	3,68	5,58
	Victory Day	30 August Thursday	9,03	9,38
	Republic Day	29 October Monday	11,29	7,16
Religious	Preparation day of Ramadan Feast	18 August Saturday	4,59	4,57
	Ramadan Feast	19-21 August Sunday-Tuesday	7,54	5,24
	Preparation day of Sacrifice Feast	24 October Wednesday	7,04	5,13
	Sacrifice Feast	25-28 October Thursday-Sunday	4,66	6,16
		Weighted Average	5,57	5,34

Load forecasting was carried out totally for 13 days (312 hours). Some forecasting results are presented in Fig. 5, Fig. 6 and Table II. As can be seen from the figures, trends of actual load curve and forecasted load curves are similar. The national holidays' consumptions were forecasted well than the Ramadan holiday consumptions in each model.

The comparison of 2012 holiday results for Model 1 and Model 2 are shown in Table III. Maximum MAPE value and minimum MAPE value are obtained as 11.29 and 2.03, respectively, for all holidays. Also the weighted MAPE values are obtained as 5.57 and 5.34, respectively, for Model 1 and Model 2. We can say that while Model 1 has been more successful on national holidays, Model 2 has been more successful on religious holidays.

V. CONCLUSION

In this study, load forecasting models for holidays is developed by using fuzzy logic. Holidays are grouped with load characteristics. Two hourly holiday load forecast models are developed and the results of models are compared. We did not consider weather factor for this forecast. Inputs of Model 1 are previous year holiday load, previous week load and holiday type. The previous year holiday load input is scaled for Model 2 unlike Model 1. The sample averages of MAPEs for Model 1 and Model 2 are 5.57 % and 5.34 %, respectively for all holidays of 2012. It can be said that both models find close values to the real data and produce good forecasting results. The results show that Model 2 could have better forecasting accuracy than Model 1 in terms of MAPE values.

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