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by Jamaaluddin Jamaaluddin

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J Jamaaluddin, D Hadidjaja, I Sulistiyowati, EA Suprayitno, I Anshory and S Syahrorini

Universitas Muhammadiyah Sidoarjo
Jl. Mojopahit 666B Sidoarjo
Jl. Raya Gelam 250 Candi Sidoarjo
+62-031-8945444

jamaaluddin@umsida.ac.id

Abstract. One of the important things to do in electric power system operation is load forecasting. Load forecasting consists short term load forecasting and very short term forecasting. The very short-term load forecasting is predicting electrical loads in every 30 minutes. This forecasting is done to decide which plant to operate. The capacity of the plant to be operated adjusts to the load plan to be supplied the next day One method utilized in this research is Fuzzy Logic. This method has been applied for short-term load forecasting and will be employed for very short-term forecasting peak load time. Fuzzy logic expected has a small MAPE (0,6244%).

Keywords: Very Short Term Load Forecasting; Fuzzy Logic; Main Average Percentage Error (MAPE)

1. Introduction

Electrical energy is a major requirement at this time. Almost all things are very dependent on electricity [1].One second without electricity, modern society will not be able to conduct its activities [2][3]. Likewise, in Indonesia,. electricity system is divided into several areas; one of which is the Java-Bali electricity system.
Very short term load forecasting can estimate electricity consumption over a certain time span. Accurate forecasting can improve safety and reliability in electric power system operations such as load flow, maintenance unit maintenance and unit commitment [4].

Load characteritics is very important to determine the load forecasting parameters. The power change characteristics received by the load of the electrical power system at any given time interval is known as the daily load curve, as shown in Figure 1.

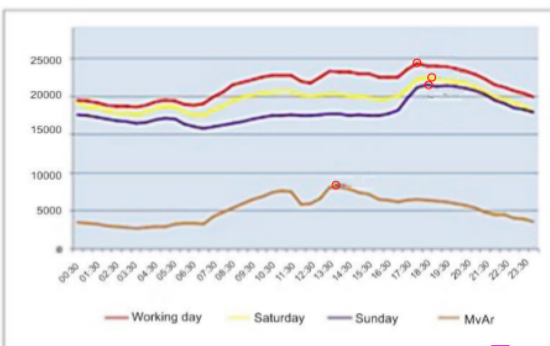

Figure 1. Daily Rhythm of Java Bali System 2015[6]

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Forecasting very short term load forecasting required data tape (data logger) because the accuracy of load forecasting depends on the data provided. Therefore we need tools (tools) that can monitor the load with accurate and flexible so that the load data can be anytime required. In this study case study was conducted on Java-Bali electricity system because in that place is the largest system available in Indonesia. More than two decades, widely used fuzzy logic to control, prediction and optimization in power systems [5]. Previous Reshearches about Very Short Term Load using Artificial Neural Network (ANN) have result (MAPE) between 0,89% – 1,25% [6]. Whereas if using Based on Autoregressive Integrated Moving Average Model (ARIMA) have result between 2.62% - 5,27%, If using Adaptive Neuro-Fuzzy Inference System (ANFIS) have result between 10,21% - 18,45%[7]. This research try using Fuzzy Logic to Very Short Term Load Forecasting so get the better MAPE.

Fuzzy logic is one of the methods in forecasting short-term expenses. Therefore, this study developed forecasting for short-term expenses using Fuzzy Logic The period outside the peak load will be forecasted, since at the time burden characteristic is not too big.

2. Methodology

The very short term load forecasting, referred in this study, is the hourly load planning for a certain time on the same day of each year, based on very short run time data at the same time in the previous 4 days in 3 years period., The Flow chart of Methodology Showed Fig.2.

2.1. Calculation of Value of Input Variable X

Preparation stage preparedaily load data in every 30 minutes 4 , with four days earlier in 3 past years. This temporary calculation is used by the working day represented by Friday. This process is done to find the actual Variation Load Deffrence (VLD_{MAX}). It is used to calculate Variable X.

1. Search examples for the load value at peak Load time 22:00 on the first Friday of October 2015, using data on the first Friday of October 2013, 2014 and 2015.
2. Identify the load to search (P_{max}) on the previous four days at the same hour before the load time is analyzed.

$$MaxWD_{(i)} = \frac{WD_{(i)d-4} + WD_{(i)d-3} + WD_{(i)d-2} + WD_{(i)d-1}}{4} \qquad (1)$$

3. Calculate the difference in load sought (Load Difference) on the clock to be predicted.

$$LD_{MAX}(i) = \frac{MaxSD(i) - MaxWD(i)}{MaxWD(i)} x100 \qquad (2)$$

4. Looking for load difference characteristics on typical load hours or TLD_{MAX} (i) by averaging the same LD_{MAX} peak load (i) in previous years.
5. Search for Variation Loads on the clock to be predicted (Variation Load Difference) at each hour

$$VLD_{max}(i) = LD_{max}(i) - TLD_{max}(i) \qquad (3)$$

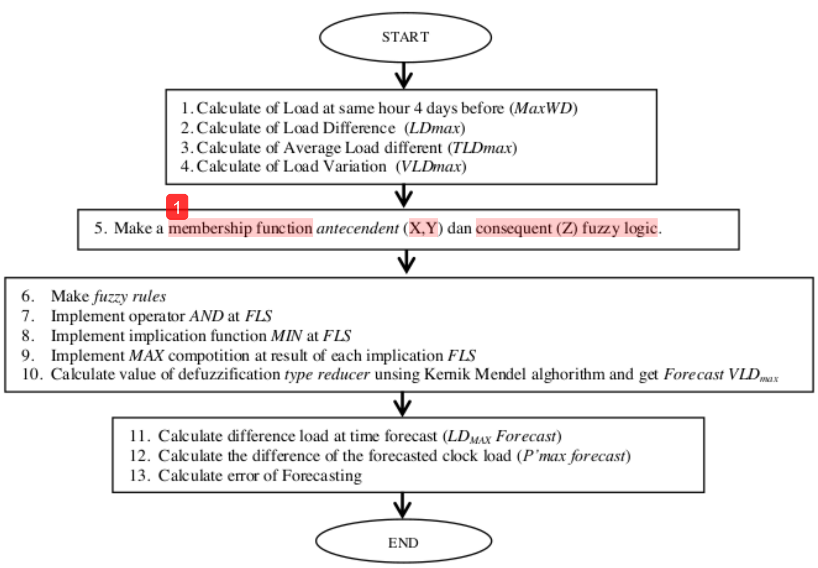

Figure 2. Flow Chart of Research

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a) Electrical power at 22.00 First Friday in October 2013 $(R_1\text{-}2013)$

$MaxWD(R_1\text{-}2013)_{d\text{-}4} = 22.345$ MW

$MaxWD(R_1\text{-}2013)_{d\text{-}3} = 20.432$ MW

$MaxWD(R_1\text{-}2013)_{d\text{-}2} = 19.700$ MW

$MaxWD(R_1\text{-}2013)_{d\text{-}1} = 21.735$ MW

$MaxSD = 20.564$ MW

$$MaxWD(R_1\text{-}2013) = \frac{21.735 + 19.700 + 20.432 + 22.345}{4} = 21.053 \text{ MW}$$

$$LD_{MAX}(R_1\text{-}2013) = \frac{MaxSD(R_1\text{-}2013) - MaxWD(R_1\text{-}2013)}{MaxWD(R1\text{-}2013)} \times 100\%$$

$$Max_{WD}(\text{R1-2013}) = \frac{20.564 - 21.053}{21.053} \times 100\% = -0{,}02322$$

b) Electrical power at 22.00 First Friday in October 2014 $(R_1\text{-}2014)$

$MaxWD(R_1\text{-}2014)_{d\text{-}4} = 23.211$ MW

$MaxWD(R_1\text{-}2014)_{d\text{-}3} = 19.887$ MW

$MaxWD(R_1\text{-}2014)_{d\text{-}2} = 23.211$ MW

$MaxWD(R_1\text{-}2014)_{d\text{-}1} = 20.137$ MW

$MaxSD = 21.437$ MW

$$MaxWD(R_1\text{-}2014) = \frac{20.137 + 23.211 + 19.887 + 23.211}{4} = 21.612 \text{ MW}$$

$$LD_{MAX}(R_1\text{-}2014) = \frac{MaxSD(R_1\text{-}2014) - MaxWD(R_1\text{-}2014)}{MaxWD(R_1\text{-}2014)} \times 100\% = \frac{21.437 - 21.612}{21.612} \times 100\% = -0{,}00808$$

$$TLD_{MAX}(R_1\text{-}2014) = \frac{LD_{MAX}(R_1\text{-}2013) + LD_{MAX}(R_1\text{-}2014)}{2} = \frac{-0{,}02322 + (-0{,}00808)}{2} = -0{,}016$$

$$VLD_{MAX}(R_1\text{-}2014) = LD_{MAX}(R_1\text{-}2014) - TLD_{MAX}(R_1\text{-}2014) = -0{,}00808 - (-0{,}016) = -0{,}024$$

c) Electrical power at 22.00 First Friday in October 2015 $(R_1\text{-}2015)$

$MaxWD(R_1\text{-}2015)_{d\text{-}4} = 19.789$ MW

$MaxWD(R_1\text{-}2015)_{d\text{-}3} = 23.789$ MW

$MaxWD(R_1\text{-}2015)_{d\text{-}2} = 20.764$ MW

$MaxWD(R_1\text{-}2015)_{d\text{-}1} = 21.367$ MW

$MaxSD = 22.214$ MW

$$MaxWD(R_1\text{-}2015) = \frac{21.367 + 20.764 + 23.789 + 19.789}{4} = 21.427 \text{ MW}$$

$$LD_{MAX}(R_1\text{-}2015) = \frac{MaxSD(R_1\text{-}2015) - MaxWD(R_1\text{-}2015)}{MaxWD(R_1\text{-}2015)} \times 100\% = \frac{22.214 - 21.427}{21.427} \times 100\% = 0{,}03672$$

$$TLD_{MAX}(R_1\text{-}2015) = \frac{LD_{MAX}(R_1\text{-}2013) + LD_{MAX}(R_1\text{-}2014) + LD_{MAX}(R_1\text{-}2015)}{3} = \frac{-0{,}02322 + (-0{,}00808) + (0{,}03672)}{3} = 0{,}002$$

$$VLD_{MAX}(R_1\text{-}2015) = LD_{MAX}(R_1\text{-}2015) - TLD_{MAX}(R_1\text{-}2015) = 0{,}03672 - (0{,}002) = 0{,}035$$

In the same way we will get the values of LD_{MAX}, TLD_{MAX} and VLD_{MAX} as shown in Table 1, Table 2 and Table 3.

Table 1. Calculation Forecasting First Friday on October 2013

2	21.00	19.619	19.900	22.173	21.500	20.684	20.798	-0,548
3	20.00	22.987	20.564	19.988	21.800	21.464	21.335	0,606
4	19.00	21.800	20.684	23.341	22.983	22.173	22.202	-0,131

Table 2. Calculation Forecasting First Friday on October 2014

	day / Hour	d-4	d-3	d-2	d-1	d	WDMAX 2014	LDMAX 2014	TLDMAX 2014	VLDMAX 2014
1	22.00	23.211	19.887	23.211	20.137	21.437	21.612	-0,807	-1,565	0,757
2	21.00	21.100	21.900	20.451	21.378	21.404	21.207	0,928	0,190	0,738
3	20.00	20.342	23.898	23.455	22.843	22.452	22.635	-0,806	-0,100	-0,706
4	19.00	22.452	21.404	20.275	22.965	22.483	21.774	3,256	1,563	1,693

Table 3. Calculation Forecasting First Friday on October 2015

	day / Hour	d-4	d-3	d-2	d-1	d	WDMAX 2015	LDMAX 2015	TLDMAX 2015	VLDMAX(2015
1	22.00	19.789	23.789	20.764	21.367	22.214	21.427	3,672	0,181	3,491
2	21.00	20.400	21.324	23.008	21.700	21.286	21.608	-1,490	-0,370	-1,120
3	20.00	21.286	20.477	23.236	23.008	22.357	22.002	1,615	0,471	1,143
4	19.00	23.900	24.112	22.134	23.236	23.008	23.346	-1,446	0,560	-2,006

2.2. Calculation of Value of Input Variable Y

In the same way as finding the value of variable X, then we can the value of variable Y as set out in Table 4, Table 5 and Table 6.

Table 4. Calculation Forecasting second Friday on October 2013

	Day / Hour	d-4	d-3	d-2	d-1	d	WDMAX 2013	LDMAX 2013
1	22.00	19.213	19.111	18.900	20.400	19.332	19.406	-0,381
2	21.00	19.567	19.954	19.265	20.178	19.890	19.741	0,755
3	20.00	20.517	19.998	19.786	21.762	20.700	20.516	0,898
4	19.00	21.138	21.776	21.563	22.321	21.900	21.700	0,924

Table 5. Calculation Forecasting second Friday on October 2014

	Day / Hour	d-4	d-3	d-2	d-1	d	WDMAX 2014	LDMAX 2014	TLDMAX 2014	VLDMAX 2014
1	22.00	20.116	19.800	20.891	21.400	20.200	20.552	-1,712	-1,046	-0,665
2	21.00	20.200	22.911	20.883	21.789	21.400	21.446	-0,213	0,271	-0,484
3	20.00	22.989	19.899	22.911	23.348	22.400	22.287	0,508	0,703	-0,195
4	19.00	22.400	21.400	24.321	23.783	22.833	22.976	-0,622	0,151	-0,773

Table 6. Calculation Forecasting second Friday on October 2015

	Day / Hour	d-4	d-3	d-2	d-1	d	WDMAX 2015	LDMAX 2015	TLDMAX 2015	VLDMAX(2015
1	22.00	21.977	20.864	19.121	19.562	20.450	20.381	0,339	-0,585	0,923
2	21.00	20.450	22.787	20.231	22.113	21.270	21.395	-0,585	-0,015	-0,571
3	20.00	21.966	20.450	23.222	22.114	22.353	21.938	1,892	1,099	0,792
4	19.00	23.322	23.114	21.347	23.222	22.999	22.751	1,089	0,464	0,625

2.3. Calculation of Value of Input Variable Z

The calculation of the variable very short term forecasting at 22.00 The first Friday of October 2015 is to find the value of Variable Load Deference (VLD_{MAX}) forecasting hours. With the same calculation for the second Friday of October between 2013 - 2015 in get the value (VLD_{MAX}) which results can be seen as Table 7.

Table 7. Value of WD_{MAX}, LD_{MAX} and VLD_{MAX} 2013-2015

2	21.00	20.798	(0,548)	21.207	0,928	0,190	0,738	21.608	(1,490)	(0,370)	(1,120)
3	20.00	21.335	0,606	22.635	(0,806)	(0,100)	(0,706)	22.002	1,615	0,471	1,143
4	19.00	22.202	(0,131)	21.774	3,256	1,563	1,693	23.346	(1,446)	0,560	(2,006)
	Second Jumat on October										
1	22.00	19.406	(0,381)	20.552	(1,712)	(1,046)	(0,665)	20.381	0,339	(0,585)	0,923
2	21.00	19.741	0,755	21.446	(0,213)	0,271	(0,484)	21.395	(0,585)	(0,015)	(0,571)
3	20.00	20.516	0,898	22.287	0,508	0,703	(0,195)	21.938	1,892	1,099	0,792
4	19.00	21.700	0,924	22.976	(0,622)	0,151	(0,773)	22.751	1,089	0,464	0,625

2.4. Membership Function for Input and Output Variable

Input variables (X, Y) and output variables (Z) consists of 11 fuzzy sets are described as follows:

Negative Very Big (NVB) range of values -12 s/d -8
Negative Big (NB) range of values -10 s/d -6
Negative Medium (NM) range of values -8 s/d -4
Negative Small (NS) range of values -6 s/d -2
Negative Very Small (NVS) range of values -4 s/d 0
Zero (ZE) range of values -2 s/d 2
Positive Very Small (PVS) range of values 0 s/d 4
Positive Small (PS) range of values 2 s/d 6
Positive Medium (PM) range of values 4 s/d 8
Positive Big (PB) range of values 6 s/d 10
Positive Very Big (PVB) range of values 8 s/d 12

The mathematical description of the antecendent membership function (X, Y) and concequent (Z) is used for the manufacture of Rules Base for the Fuzzy Inference System process. The establishment of Fuzzy Rule Base for very short term forecasting for 2015 is shown in Table 8 up to Table 13.

Table 8. Input (X, Y) and output (Z) By VLD_{MAX} in 2014 and 2015

	Hour	*VLDMAX*	*VLDMAX*	Input		output
		2014	*2015*	X	Y	Z
1	22.00	0,757	3,491	0,757	0,923	3,491
2	21.00	0,738	-1,120	0,738	-0,571	-1,120
3	20.00	-0,706	1,143	-0,706	0,792	1,143
4	19.00	1,693	-2,006	1,693	0,625	-2,006

Tabel 9. Process Rules for Input X in 2015

			Derajat Keanggotaan										Himp
	Hour	Nilai X	NVB	NB	NM	NS	NVS	ZE	PVS	PS	PM	PB	PVB	X
1	22.00	0,757						0,737	0,263					ZE
2	21.00	0,738						0,77	0,23					ZE
3	20.00	-0,706					0,21	0,79						ZE
4	19.00	1,693						0,48	0,52					ZE

Tabel 10. Process Rules for Input Y in 2015

			Derajat Keanggotaan										Himp
	Hour	Nilai Y	NVB	NB	NM	NS	NVS	ZE	PVS	PS	PM	PB	PVB	Y
1	22.00	0,923						0,69	0,31					ZE
2	21.00	-0,571					0,18	0,82						ZE
3	20.00	0,792						0,71	0,29					ZE
4	19.00	0,625						0,83	0,17					ZE

Tabel 11. Process Rules for Output Z in 2015

			Derajat Keanggotaan										Himp
	Hour	Nilai Z	NVB	NB	NM	NS	NVS	ZE	PVS	PS	PM	PB	PVB	Z
1	22.00	3,491							0,68	0,32				PVS
2	21.00	-1,120					0,35	0,65						ZE
3	20.00	1,143						0,35	0,65					PVS
4	19.00	-2,006					0,12	0,88						ZE

Tabel 12. Basic Rules table (fuzzy rules) for forecasting the year 2015

NVS											
ZE						PVS/ZE					
PVS											
PS											
PM											
PB											
PVB											

Tabel 13. Conversion Table Basic Rules Forecasting the Year 2015 for Matlab Software Code

no	Antecendent		Cons
rules	X	Y	Z
1	ZE	ZE	ZE
2	ZE	ZE	PVS

no	Antecendent		Cons
rules	X	Y	Z
1	6	6	6
2	6	6	7

Very Short-term load forecasting using Fuzzy Logic Executed by using Matlab software to obtain the va forecasting. by using Equation VLD_{MAX} which has been obtained, it will get the results of the comparison tal shown in Table 14.

Table 14. Comparison Forecasting and Actual load on First Friday October 2015

	pukul	*h-4*	*h-3*	*h-2*	*h-1*	*h*	*WDMAX*	*LDMAX*	*TLDMAX*	*VLDMAX*	*Output Forecast*	*Forecast LDMAX*	*Forecast P'MAX*	*Actual (MW)*	Error (%)
							2015								
	First Jumat on October 2015														
1	22.00	19.789	23.789	20.764	21.367	22.214	21.427	3,6720	0,1809	3,4911	2,7625	2,943388	22.058	22.214	0,7028
2	21.00	20.400	21.324	23.008	21.700	21.286	21.608	(1,4902)	(0,3702)	(1,1200)	-2,0028	-2,3729899	21.095	21.286	0,8962
3	20.00	21.286	20.477	23.236	23.008	22.357	22.002	1,6146	0,4714	1,1433	0,7683	1,2396907	22.275	22.357	0,3690
4	19.00	23.900	24.112	22.134	23.236	23.008	23.346	(1,4457)	0,5600	(2,0056)	-2,5276	-1,9676388	22.886	23.008	0,5296
													MAPE average		0,6244

In Table 14, We can find the average error value used Fuzzy Logic Load at First Friday October 2015 (; 21.00; 19.00:18) have MAPE arround 0,6244 %. Actual and forecast Peak Load Time First Friday on Oc 2015 (22.00 ; 21.00; 19.00:18) is shown in Figure 3.

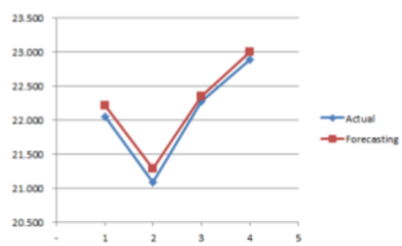

Figure 3. Actual and forecast Peak Load Time First Friday on October 2015 (22.00 ; 21.00; 19.00:18)

3. Conclusion

From the analysis we can conclude that the Very short-term load forecasting at First Friday on October 2015 (: 22.00; 21.00; 20.00) has an error value 0,6244 % of MAPE.

Thus the Fuzzy Logic can be proposed as one of the methods used to conduct very short-term load foreca The membership function can be expanded to increase the accuracy of the model.t model. Expanded memb function may shrink the data range for resulting more accurate forecasting results.

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