

Very Sort Term Load Forecasting Using Interval Type-2 Fuzzy Inference System (IT-2 FIS) (Case Study: Java Bali Electrical System)

by Jamaaluddin Jamaaluddin

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Very Short Term Load Forecasting Using Interval Type - 2 Fuzzy Inference System (IT- 2 FIS) (Case Study: Java Bali Electrical System)

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Abstract. One of the important things to do an electric power system operation is load forecasting. Load forecasting consists of short-term forecasting and short-term forecasting. The very short term load forecasting are required for regulating electrical energy generation, maintenance arrangements and regulating the labor involved. 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. The very short-term load forecasting is predicting electrical loads with time intervals every 30 minutes for the next day. In this study using Interval Type-2 Fuzzy Inference System (IT-2FIS) because it delivers a high flexibility that can be developed using other methods (hybrid). Laying out the footprint of uncertainty (FOU) membership function of the Interval Type-2 Fuzzy Inference System (IT-2FIS). This method has been applied for short-term load forecasting and will be employed for very short-term forecasting. In very short-term load forecasting IT-2 FIS has Mean Average Percentage Error (MAPE) around 0,729%.

1. Introduction

Electric power is needed by the world community at this end. In every side of his life always requires electrical energy[1]. Generation, transmission and distribution system in Indonesia also operates this electricity from generated to customer. Handling of this electric power operation, must be professional, meet the quality standards of electrical services and economic factors [2] [3]. On the distribution of electric power that is implementing is PT. PLN through P2B, the agency will generate power generation and load sharing, in which it includes both short loading and very short term loading plans[4]. Very short term load forecasting is required to conduct the generation planning in accordance with the estimated load requirement on the next day. Forecasting a very short term load is to plan the load every 30 minutes from 00.00 until 23.30 the next day. This should be done for economic considerations so that will get the planning of power generation, which should operate and which are not. This problem is related to generating efficiency, maintenance implementation and labor management. In these 2 decades to do load forecasting, have used computing. In this computation has been using Fuzzy Logic for short-term forecasting (Daily)[5] [6]. Both in development using Interval Type 1 - Fuzzy Inference System and Interval Type 2 - Fuzzy Inference System. In forecasting short-



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term IT-1 FIS and IT-2 FIS loads have resulted in a pretty good MAPE result. Therefore, at this time will try to do very short term forecasting [7].

2. Experimental Method

This research is done several stages of the process, are: 1. Stage before process, 2. Process, 3. After process with more detail explanation as follows:

2.1. Preprocessing

In this process is the stages grouping daily load data every 30 minutes for 24 hours on a predictable day [8], and three hours before the hour predicted at the same time started 3 years ago. In this study, an example is taken on the first Friday of October. This process is required to find Variation Load Difference (VLD_{MAX}). This is done to get the X, Y and Z value [1].

1. For example, to get a very short term forecasting value at 12:00 on the first Friday of October 2015, using data on the first Friday of October 2013, 2014 and 2015.
2. Identify the search for the load on the 4 days before to its at the same hour of the loaded time being analyzed

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

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

$$LD_{MAX}(i) = \frac{MaxSD(i) - MaxWD(i)}{MaxWD(i)} \times 100 \tag{2}$$

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

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

2.2. Processing

At this stage of the process, entering the very short-term forecasting forecast on the first Friday of October into IT-2FIS is as follows[1]:

1. The first stage is to build input Membership Function X and Y. The Z is the output membership function for the hour predicted, with the following explanation:

X: $VLD_{max}(i)$ Variable Load Difference time that will be predictable

Y: $VLD_{max}(i)$ Is a time load at second Friday on October that is adjacent to the same type of time that will be predictable.

Z: Forecast $VID_{max}(on)$ Variable Load Difference of a time load that would be predicted.

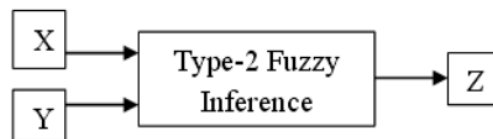


Figure 1. Process of IT-2FIS

2. Creating fuzzy rules as follows [6]:

IF X is A_i AND Y is B_i THEN Z is C_i

3. Applied on the (*IT-2 FIS*).
4. Applied the *MIN* function.
5. Applied *MAX* on each fuzzy, implication results.
6. Get the value Forecast VLD_{max} .

2.3. *Post Processing*

The In the post-processing stage calculated result of Very Short Term Load Forecasting for the time predict as follows[1]:

1. Calculating the time load forecasting :

$$ForecastLD_{MAX}(i)=ForecastVLD_{MAX}(i)-TLD_{MAX} \quad (4)$$

2. Calculating the difference of time load of forecast

$$P'_{MAX}(i) = MaxWD(i) + \frac{(ForecastLD_{MAX} \times MaxWD(i))}{100} \quad (5)$$

3. Comparing the value of forecasting results with the actual situation in the already running, namely in 2013, 2014 and 2015. By making the average value Mean Percentage Error (MAPE) on each year forecasting. The formula used is as follows :

$$Error\% = \frac{P_{forecast} - P_{actual}}{P_{actual}} \times 100$$

$$Error\% = \frac{P'_{MAX}(i) - MaxSD(i)}{MaxSD(i)} \times 100 \quad (6)$$

2.4. *Flowchart of Forecasting by Using IT-2*

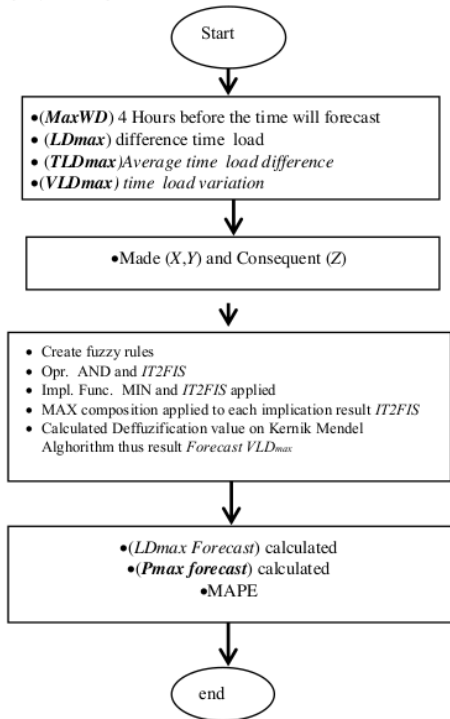


Figure 2. Flowchart of Forecasting by Using IT-2

2.5. Calculation X Value

X value at 2013, obtained from the calculation as below:

Electrical load at 12.00 First Friday in October 2013 (R₁-2013)

$$\begin{aligned}
 MaxWD(R_1-2013)_{d-4} &= 19.823 \text{ MW} \\
 MaxWD(R_1-2013)_{d-3} &= 20.008 \text{ MW} \\
 MaxWD(R_1-2013)_{d-2} &= 19.763 \text{ MW} \\
 MaxWD(R_1-2013)_{d-1} &= 19.539 \text{ MW} \\
 MaxSD &= 19.021 \text{ MW} \\
 MaxWD(R_1-2013) &= \frac{19.823 + 20.008 + 19.763 + 19.539}{4} = 19.738 \text{ MW} \\
 LD_{MAX}(R_1-2013) &= \frac{MaxSD(R_1-2013) - MaxWD(R_1-2013)}{MaxWD(R_1-2013)} \times 100\% \\
 Max_{WD}(R_1-2013) &= \frac{19.021 - 19.738}{19.738} \times 100\% = -3.854
 \end{aligned}$$

With the same calculation we can find $Max_{WD}(R_1-2013)$, $LD_{MAX}(R_1-2014)$, $TLD_{MAX}(R_1-2014)$, $VLD_{MAX}(R_1-2014)$, Then the results obtained as the table below :

Table 1. Calculation Forecasting First Friday on October 2013

	day	d-4	d-3	d-2	d-1	d	WDMAX	LDMAX
							2013	2013
Hour								
1	12.00	19.823	20.008	19.763	19.539	19.021	19.783	-3,854
2	11.00	20.768	20.754	20.892	20.465	20.938	20.720	1,055
3	10.00	20.459	20.566	20.526	20.096	20.551	20.412	0,679
4	09.00	19.812	20.087	20.022	19.350	19.963	19.818	0,736

Table 1, above shows the calculations of $WDMAX$ and $LDMAX$ for the first Friday of 2013, after which the calculations for the first Friday of 2014, 2015 with the results as table 2 below:

Table 2. Calculation Forecasting First Friday on October 2014

	day	d-4	d-3	d-2	d-1	d	WDMAX	LDMAX	TLDMAX	VLDMAX
							2014	2014	2014	2014
Hour										
1	12.00	23.564	19.369	20.127	21.763	20.536	21.206	-3,160	-3,507	0,347
2	11.00	21.334	20.275	22.423	23.477	21.437	21.877	-2,013	-0,479	-1,534
3	10.00	18.675	19.563	21.897	22.843	21.288	20.745	2,619	1,649	0,970
4	09.00	19.002	19.343	21.453	24.322	20.932	21.030	-0,467	0,134	-0,601

Table 3. Calculation Forecasting First Friday on October 2015

	day	d-4	d-3	d-2	d-1	d	WDMAX	LDMAX	TLDMAX	VLDMAX
							2015	2015	2015	2015
Hour										
1	12.00	20.566	19.872	20.556	22.329	21.360	20.831	2,538	-1,492	4,030
2	11.00	22.800	19.879	22.121	22.899	22.214	21.925	1,320	0,120	1,199
3	10.00	24.101	20.544	22.017	23.243	22.175	22.476	-1,342	0,652	-1,994
4	09.00	21.637	18.564	19.324	22.887	21.613	20.603	4,904	1,724	3,179

2.6. Calculation of Value of Input Variable Y

To get the value of Y, then selected second Friday in each year starting 2013, 2014 and 2015, in the same way to get the value of X, then get the results as below:

Table 4. Calculation Forecasting second Friday on October 2013

	Day	d-4	d-3	d-2	d-1	d	WDMAX	LDMAX
							2013	2013
Hour								
1	12.00	19.112	18.973	22.145	19.570	19.348	19.950	-3,018
2	11.00	18.783	18.122	20.312	20.562	19.892	19.445	2,300
3	10.00	20.973	19.887	20.332	22.477	21.700	20.917	3,742
4	09.00	20.431	19.878	21.334	22.769	21.760	21.103	3,113

Table 5. Calculation Forecasting second Friday on October 2014

	Day	d-4	d-3	d-2	d-1	d	WDMAX	LDMAX	TLDMAX	VLDMAX
							2014	2014	2014	2014
Hour										
1	12.00	20.562	19.879	20.354	21.336	20.239	20.533	-1,431	-2,224	0,793
2	11.00	20.563	20.361	21.782	22.397	21.421	21.276	0,683	1,491	-0,809
3	10.00	20.113	21.785	22.766	23.578	22.488	22.061	1,938	2,840	-0,902
4	09.00	23.444	21.357	22.899	23.765	22.133	22.866	-3,207	-0,047	-3,160

Table 6. Calculation Forecasting second Friday on October 2015

	Day	d-4	d-3	d-2	d-1	d	WDMAX	LDMAX	TLDMAX	VLDMAX
							2015	2015	2015	2015
Hour										
1	12.00	19.378	19.700	20.765	21.113	20.456	20.239	1,072	-1,125	2,198
2	11.00	19.567	20.878	21.598	22.133	21.271	21.044	1,079	1,354	-0,275
3	10.00	19.789	20.846	22.539	23.782	22.349	21.739	2,806	2,829	-0,023
4	09.00	21.658	22.783	25.786	24.442	23.211	23.667	-1,928	-0,674	-1,254

2.7 Calculation of Value of Input Variable Z

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 below:

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

Time	WD_{MAX}	LD_{MAX}	WD_{MAX}	LD_{MAX}	TLD_{MAX}	VLD_{MAX}	WD_{MAX}	LD_{MAX}	TLD_{MAX}	VLD_{MAX}	
	2013			2014			2015				
First Friday on October											
1	12.00	19.783	(3,854)	21.206	(3,160)	(3,507)	0,347	20.831	2,538	(1,492)	4,030
2	11.00	20.720	1,055	21.877	(2,013)	(0,479)	(1,534)	21.925	1,320	0,120	1,199
3	10.00	20.412	0,679	20.745	2,619	1,649	0,970	22.476	(1,342)	0,652	(1,994)
4	09.00	19.818	0,736	21.030	(0,467)	0,134	(0,601)	20.603	4,904	1,724	3,179
Second Friday on October											
1	12.00	19.950	(3,018)	20.533	(1,431)	(2,224)	0,793	20.239	1,072	(1,125)	2,198
2	11.00	19.445	2,300	21.276	0,683	1,491	(0,809)	21.044	1,079	1,354	(0,275)
3	10.00	20.917	3,742	22.061	1,938	2,840	(0,902)	21.739	2,806	2,829	(0,023)
4	09.00	21.103	3,113	22.866	(3,207)	(0,047)	(3,160)	23.667	(1,928)	(0,674)	(1,254)

3. Results and Discussion

IT-2FIS to forecasting of peak load at the time which forecasting, that the membership function variable input and output of Interval Type-2 Fuzzy Inference System, as follows :

3.1 Membership Function for Input and Output Variable

The set of Interval Type-2 Fuzzy, fuzzy sets similar to the type-1. Interval Type-2 Fuzzy, done twice a fuzzy, membership function type-1. 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

Translation of antecedent membership functions (X , Y) and consequent (Z) is used for the manufacture of the Rules Base Fuzzy Inference System. Making the basic rules of Fuzzy (Fuzzy Rule Base) very short-term load forecasting in 2014-2015 is shown table 8. Through table 12.

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

	Hour	VLD_{MAX}	VLD_{MAX}	Input		output
		2014	2015	X	Y	Z
		1	12.00	0,347	4,030	0,347
2	11.00	-1,534	1,199	-1,534	-0,275	1,199
3	10.00	0,970	-1,994	0,970	-0,023	-1,994
4	09.00	-0,601	3,179	-0,601	-1,254	3,179

Table 9. Process Rules for Input X in 2016

	Hour	X	Membership function										X			
			NVB	NB	NM	NS	NVS	ZE	PVS	PS	PM	PB		PVB		
1	12.00	0,347						0,21	0,79							PVS
2	11.00	-1,534					0,13	0,87								ZE
3	10.00	0,970						0,32	0,68							PVS
4	09.00	-0,601					0,42	0,58								ZE

Table 10. Process Rules for Input Y in 2016

	Hour	Y	Membership Function										Y			
			NVB	NB	NM	NS	NVS	ZE	PVS	PS	PM	PB		PVB		
1	12.00	2,198							0,08	0,92						PS
2	11.00	-0,275					0,24	0,76								ZE
3	10.00	-0,023					0,07	0,93								ZE
4	09.00	-1,254					0,09	0,91								ZE

Table 11. Process Rules for Output Z in 2016

	Hour	Z	Membership Function										Z			
			NVB	NB	NM	NS	NVS	ZE	PVS	PS	PM	PB		PVB		
1	12.00	4,030							0,93	0,07						PVS
2	11.00	1,199						0,83	0,17							ZE
3	10.00	-1,994					0,72	0,28								NVS
4	09.00	3,179							0,85	0,15						PVS

Table 12. Basic Rules table (*fuzzy rules*) for forecasting the year 2016

X/Y	NVB	...	ZE	PVS	PS	...	PB
NVB							
...							
NS							
NVS							
ZE			ZE/PVS				
PVS			NVS	PVS			
PS							
....							
PVB							

If there is a fuzzy rule is the same for input values X and, but different Z output value, whichever is the greater the value of its output being more removed.

Table 13. Conversion Table Basic Rules Forecasting the Year 2016 for Matlab Software Code

no	Antecedent		Cons	no	Antecedent		Cons
rules	X	Y	Z	rules	X	Y	Z
1	PVS	PS	PVS	1	5	6	6
2	ZE	ZE	ZE	2	5	7	8
3	PVS	ZE	NVS	3	7	6	5
4	ZE	ZE	PVS	4	7	6	8

Membership Function for Input and Output Variable

3.2 Implementation forecasting of Very Short Term Load On Electrical Systems Java Bali using Method Interval Type-2 Fuzzy Inference System (IT2FIS) at 3 Years of data taking into account the Year Actual Data Forecasting

Very Short-term load forecasting using the Interval Type-2 Fuzzy Inference System (IT2FIS) executed through m.file program in Matlab using the given function in the Toolbox *IT-2FLT*, to obtain the value of forecasting VLD_{max} . Value of VLD_{max} forecasting results continued (post processing) using software MS.Excell to get the time load forecasting and forecasting error value. The results of short-term load forecasting error method *IT-2FIS* in 2013 through 2015 can be seen in Table. 14 below.

Table 14. Comparison of Forecasting and Actual load on 2016

Time	h-4	h-3	h-2	h-1	h	WDMAX	LDMAX	TLDMAX	VLDMAX	Output Forecast	Forecast LDMAX	Forecast P'MAX	Actual (MW)	Error (%)	
						2016									
First Friday on October 2016															
1	12.00	19.823	20.008	19.763	19.539	19.021	20.831	2,538	(1,492)	4,030	-5,763	-7,254	19.319,61	19.020,72	1,571
2	11.00	20.768	20.754	20.892	20.465	20.938	21.925	1,320	0,120	1,199	-5,003	-4,882	20.854,30	20.938,33	0,401
3	10.00	20.459	20.566	20.526	20.096	20.551	22.476	(1,342)	0,652	(1,994)	-8,668	-8,016	20.674,54	20.550,66	0,603
4	09.00	19.812	20.087	20.022	19.350	19.963	20.603	4,904	1,724	3,179	-3,728	-2,003	20.190,24	19.963,47	1,136
											IT-IFIS	MAPE average		0,928	
First Friday on October 2016															
1	12.00	19.823	20.008	19.763	19.539	19.021	20.831	2,538	-1,492	4,030	-6,763	-8,254	19.111,31	19.020,72	0,476
2	11.00	20.768	20.754	20.892	20.465	20.938	21.925	1,320	0,120	1,199	-5,128	-5,008	20.826,85	20.938,33	0,532
3	10.00	20.459	20.566	20.526	20.096	20.551	22.476	-1,342	0,652	-1,994	-8,068	-7,416	20.809,40	20.550,66	1,259
4	09.00	19.812	20.087	20.022	19.350	19.963	20.603	4,904	1,724	3,179	-4,200	-2,475	20.093,01	19.963,47	0,649
											IT-2FIS	MAPE average		0,729	

While for the error value can be seen in the picture. Fig. 3 below :

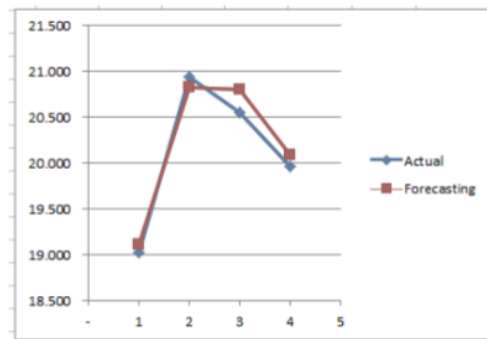


Figure 3. Actual and forecast Load by using *IT-2 FIS* (First October – 2016 ; 09.00 am-12.00 am)



Figure 4. The value of error *IT-2 FIS*

4. Conclusions

After doing this research, then get the results forecasting very short-term daily load every hour by using Interval Type-2 Fuzzy Inference System has better results compared if using Interval type-1 Fuzzy Inference System. With MAPE value if using IT1-FIS equal to 0,928%, whereas if using IT-2 FIS get MAPE 0,729%. It can be concluded that IT-2 FIS can be used to perform very short-term forecasting forecasting of Java Bali system by making in the form of simple and concise software.

Acknowledgements

We acknowledged P3I Universitas Muhammadiyah Sidoarjo.

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