Application of Interval Type-2 Fuzzy Inference System and Big Bang Big Crunch Algorithm in Short Term Load Forecasting New Year Holiday

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Application of Interval Type-2 Fuzzy Inference System and Big Bang Big Crunch Algorithm in Short Term Load Forecasting New Year Holiday

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Abstract- Celebration of New Year In Indonesian is constituting one of the visits to Indonesian tourism. This event course changes the load of electrical energy. The provider's electrical power that control and operation of electrical in Java and Bali (Java, Bali Electrical System) are required to be able to assure continuity of load demand at this time, and forecast for the hereafter. Short-term load forecasting very needs to be supported by computational methods for simulation and validation. One of the computation's ways is *Interval Type – 2 Fuzzy Inference System (IT-2 FIS)*. It is appropriate to be used in load forecasting because it has a very flexible advantage in changing trace uncertainty*(FOU)*,thus supporting the formation of initial processing of time series, computing, simulation and system model validation. The method employed in this forecasting is to *IT-2 FIS*. The optimization of *FOU* (Foot Of Uncertainty) done by using the Big Bang-Big Crunch Algorithm obtained a better result.

The predict procedure has done analyzing the expenses incurred on that day and four days in the first place in the year before forecasting. Furthermore, the information will be an examination by using *IT- 2FIS*.And then, it will take the load forecasting value on the same day in the following year. From the effects of this research on getting the results of forecasting by using *IT-2 FIS- BBBC* has an error value that is smaller than when using *IT-2 FIS*. The outcomes of this survey show that the average Percentage Error forecast in 2014, 2015, 2016 and 2017 amounted to 0.56% by using *IT-2 FIS-BBBC*. Whereas when using *IT-2 FIS* obtained *Average Percentage Error* of 0,73%. It can reason that the *IT- 2 FIS-BBBC* can utilize for the short-term load forecasting process.

Keywords: Type-2 Fuzzy Inference System, Short Term Load Forecasting, New Year Holiday.

Background

An increase followed population growth in the world in electricity usage.Modern life always needs electricity. Began to wake up to sleep again; many activities require power [1][2][3]. Electrical energy is a primary requirement at this time, in addition to the needs of primary, secondary and tertiary. Without electric power in one second, modern society will not be able to conduct its activities [2][3][6] — all sectors of life, not only industry, public services, education, etc. Hospitals also use electric power, likewise, in Indonesia. To operationalize electricity divided into several areas, one of which is the Java-Bali electricity system.Each year a special Indonesian people who are Christian to celebrate Christmas (Day of the Nativity of Christ). Christmas is always adjacent to the New Year holiday. Holidays Christmas was coupled with new year's holidays.So that all production activities will stop approximately 7 days. At the time of this holiday, there was a decrease in electrical power in the Java Bali System by 16.28%[7][8][9].

The decrease in electric power must be known, and with careful planning, so that according to the generation plan.That was related to generation efficiency — this loading prediction associated with the generation of power systems.For example, load planning was done with long-term, short-term and very short-term load planning. Charging planning is related to planningelectricity generation[10]. Preparing electricity generation is linked toeconomic aspects, plant maintenance and associated with the stability of the system[11][12].

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More than two decades, widely used fuzzy logic to control, prediction and optimization in power systems [13]. By using the *IT-2 FIS* then load requirements in the coming years will be able to be predicted. Likewise, the New Year holiday.One of the computation's methods is Interval Type – 2 Fuzzy Inference System *(IT-2 FIS)*. It is appropriate to be used in load forecasting because it has the advantages that very flexible on the change of the footprint of uncertainty (FOU)[14][15],the researcher tried to optimize the very short time load forecasting using Fuzzy Type 2 Interval - Fuzzy Inference System hybridized with the BBBC algorithm, in the expectation of getting a smaller error value [16][17], so it supports to establish an initial processing of the time series, computing, simulation and validation of system models.Forecasting is necessary to perform the loading plan, maintenance plan units, and the planned use of human resources, which ultimately leads to the efficiency of the electrical power generation [18][19].

Method

To carry out the process of short-term load forecasting by using *IT-2FIS*, through several stages: 1. Preprocessing, 2. Processing 3. Postprocessing, while the explanation of the process will be explained in more detail below:

A. Preprocessing.

At this preprocessing stage, the data that was grouped is holidays in Indonesia, which are directly bordered by the New Year holidays. Then calculate the value of the electricity load in less than 4 days, 3 days, 2 days, 1 day from the forecast day (the day before the national holiday).In more detail explained below:

1. Collecting daily electrical peak load data on the value of the electricity load in less than 4 days, 3 days, 2 days, 1 day from the forecast day (the day before the New Year holiday and Christmas Holiday) from 2012 until 2017.
2. Collecting load at the time of peak load days above
3. Load identification is soughtTD$_{(i)}$:

$$TD_{(i)} = \frac{TD_{(i)D-4} + TD_{(i)D-3} + TD_{(i)D-2} + TD_{(i)D-1}}{4} \quad (1)$$

TD$_{(i)}$ = Time Difference is the peak load at the same time as different less than 4 days, 3 days, 2 days, 1 day from the forecast day (the day before the New Year holiday and Christmas Holiday) from 2012 until 2017.

4. Calculating the Difference Load at the same time. These results can be obtained using the formula below:

$$LD_{(i)} = \frac{SD_{(i)} - TD_{(i)}}{TD_{(i)}} \times 100 \quad (2)$$

SD$_{(i)}$ is the load at the predicted time.

5. After that, *theTLD$_{(i)}$ (The typical Time Load Difference)* is calculated by calculating the average load of *LD$_{(i)}$* at each time predicted by the same time last year and before.

$$TLD_{(i)} = \frac{LD_{(i-1)} - LD_{(i-2)}}{2} \quad (3)$$

6. After that, *VLD* (Variation Load Difference at Time) can be calculated at the predictedtime.

$$VLD_{(i)} = LD_{(i)} - TLD_{(i)} \quad (4)$$

B. Processing

In processing, the *VLD* value obtained from the above calculation will be entered into the IT-2 FIS, at the membership function with the following steps[20]:

1. The first point is to build input Membership Function X and Y. The *Z* is the output membership function for the day predicted, with the following explanation:
   *X: VLD$_{max}$ (i)*Variable Load Difference holiday that will be predictable
   Y: VLD$_{max}$ (i) Is a holiday that is adjacent to the same type of holiday that will be predictable. In this case, chosen as a holiday that is adjacent to the new year is Christmas
   Z: Forecast *VID$_{max}$*(on) Variable Load Difference of a holiday that would be predicted.

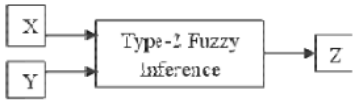

Fig. 1. Process of *IT-2FIS*

2. Creating fuzzy rules as follow [21]:

$$IF\ X \text{ is } A_i \text{ AND} Y \text{ is } B_i \text{ THEN } Z \text{ is } C_i$$

3. Optimizing the footprint of uncertainty on IT - 2 FIS by using the BBBC algorithm with the following mechanism:

   a) Initialization of the generation of N candidates from the results of randomization in the search room
   b) Calculating *the fitness* function of all solution candidates (find the *cost function*).
   c) Calculating *Center Of Mass* with the following equation.

$$\vec{x}^{c} = \frac{\sum_{i=1}^{N} \frac{1}{f^i} \vec{x}_i}{\sum_{i=1}^{N} \frac{1}{f^i}} \quad (5)$$

   Then the best fitnessthat has calculated is used as *a Center of Mass*.
   d) Calculatingthe new candidates heading to the *Center Of Mass* by adding or multiplying the scrambled number, the number or value will decrease each time iterates with the following equation:

$$x^{new} = x^{c} + lr/k \quad (6)$$

   x^c= *Center Of Mass*
   l = *Upper* limit of the parameter
   r = Normal random
   k = Iteration step
   X_{new} = *Upper* dan *lowerbounded*
   e) Return to step 2 until the criteria have founded, then stop.

4. Making IT-2 FIS rules as follows :

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

5. Implementing the AND operation on IT-2 FIS.
6. Implementing the implications of the MIN function on Fuzzy rules.
7. Applying the MAX composition to the results of Fuzzy implications.
8. Calculating the Defuzzyfication to get the forecast valueof VLD_{max}.

C. Post-processing

In the post-processing stage calculated result of Short Term Load Forecasting for national holidays as follows:

1. Calculating the difference peak load forecasting for the holiday of forecast

$$ForecastLD_{MAX}(i) = ForecastVLD_{MAX}(i) - TLD_{MAX} \quad (7)$$

2. Calculating the difference in the peak load day of the forecast

$$P'_{MAX}(i) = MaxWD(i) + \frac{(ForecastLD_{MAX} x MaxWD(i))}{100} \quad (8)$$

3. Comparing the estimated value with the actual situation that has been running in 2014, 2015, 2016, and 2017. For the current year, the method used by IT-2FIS without comparing the estimated results, because it still hasn't happened.

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Result

After doing the forecasting process steps as above, then by the data, as shown in Table 1, the data are dated New Year's holidays and Christmas, fitted 3th a top load of data on New Year and Christmas in 2012, 2013, 2014, 2015, 2016 and 2017, as can be seen in table 1 and 2.

Table 1. Peak Load at New Year Holiday (in Mega Watt)

Year	Electrical Load at New Year (MW)				
	d-4	d-3	d-2	d-1	*SD*
2012	18.827	18.304	18.076	15.940	14.128
2013	19.782	18.608	17.525	16.872	15.780
2014	19.786	19.025	19.462	18.046	16.720
2015	20.225	19.550	19.782	18.567	16.799
2016	21.543	19.887	20.001	18.978	16.992
2017	21.782	20.112	20.224	19.324	17.231

d=day SD = Special Day

Table 2. Peak Load at Christmas Holiday (in Mega Watt)

Year	Electrical Load at Christmas (MW)				
	d-4	d-3	d-2	d-1	*SD*
2012	20.066	18.766	17.971	19.031	18.079
2013	20.120	18.429	20.732	20.627	18.782
2014	20.106	22.259	22.230	21.884	19.652
2015	20.344	22.566	22.654	22.032	19.998
2016	20.543	22.897	22.879	22.322	20.321
2017	21.675	23.001	22.122	22.455	20.433

d=day SD = Special Day

Due to holidays are observed is New Year, the dataof the load and calendar displayed is a New Year and holiday earlier, and close to the holiday New Year's day is Christmas.From tables 1 and 2 above, it can calculate the values of *TD(Time Difference*), *LD*(Load Differences), *TLD*(*The Typical Load Difference)*, *VLD*(*Variation Load Difference)* with the results as table 3 for the new year holiday and table 4 for Christmas.

Tabel 3. The value *TD, LD, TLD, VLD*of New Year Holiday

Year	*TD*	*LD*	*TLD*	*VLD*
2012	17.786,75	(20,57)		
2013	18.196,75	(13,28)		
2014	19.079,75	(12,37)	(12,8245)	0,4567
2015	19.531,00	(13,99)	(13,1779)	(0,8101)
2016	20.102,25	(15,47)	(14,7301)	(0,7421)
2017	20.360,50	(15,37)	(15,4213)	0,0509

Tabel 4. The value *TD, LD, TLD, VLD*of Christmas

Year	*TD*	*LD*	*TLD*	*VLD*
2012	18.958,50	(4,64)		

2013 19.977,00 (5,98)

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2014	21.619,75	(9,10)	(7,5418)	(1,5599)
2015	21.899,00	(8,68)	(8,8912)	0,2104
2016	22.160,25	(8,30)	(8,4903)	0,1905
2017	22.313,25	(8,43)	(8,3632)	(0,0634)

Tables 3 and 4. Above can be seen in the new year's peak load forecasting calculation, which takes into consideration the peak load every day in the New Year and Christmas and four days earlier. The value of the peak load during the new year will be the input for the value of *X*, whereas for the sort of vacation that was chosen is Christmas will be the value of *Y*, where information will be sought so that the value of the Variable Load Difference values obtained *Z*.

Calculation of X value

To get the value of *X*, it is necessary to input values, which form the peak load when the New Year holiday and four days earlier in 2012, 2013, 2014, 2015, 2016 and 2017 so it will get its value *Variable Load Difference*(VLD_{MAX})[20].The stages of the process are as follows:

VLD_{MAX} value calculation New Year *2013* calculated based on equation 2, 3 and 4:

1.1. New Year, 2012

Perform a search and LDMAX value MaxWD peak load new year in 2012 and peak load four days before the new yr. In the following manner:

SD_{d-4} = 18827 Mega Watt
SD_{d-3} = 18304 Mega Watt
SD_{d-2} = 18076Mega Watt
SD_{d-1} = 15940Mega Watt
SD = 14128 Mega Watt

$$\text{TD (New Year2012)} = \frac{18827.00 + 18304.00 + 18076.00 + 15940.00}{4}$$
$$= 17786.75 \text{ MW}$$

$$\text{LD} = \frac{14128.00 - 17786.75}{17786.75} \text{x} 100\% = -20.57\ \%$$

1.2. New Year, 2013

Perform a search and LDMAX value MaxWD peak load new year in 2013 and peak load four days before the new yr. In the following manner:

SD_{d-4} = 19782 Mega Watt
SD_{d-3} = 18608 Mega Watt
SD_{d-2} = 17525 Mega Watt
SD_{d-1} = 16872 Mega Watt
SD = 15780 Mega Watt

in the same process, we find the results as Tables 1 and 2.

1.3. New Year, 2014

Perform a search and LDMAX value MaxWD peak load new year in 2014 and peak load four days before the new yr. In the following manner:

SD_{d-4} = 19786 Mega Watt
SD_{d-3} = 19025 Mega Watt

SD_{d-2} = 19462 Mega Watt
SD_{d-1} = 18046 Mega Watt
SD = 16720 Mega Watt

In the same process, we find the results in Tables 3 and 4. To determine the value *TLD*new year 2014, using the following formula:

$$\text{TLD} = \frac{-13.28 + (-12.37)}{2} = -12.82$$

$$\text{VLD} = -12.37 - (-12.82) = 0{,}46$$

Calculation of Y value

To get the value of Y, it is necessary to input values, Adjacent holiday, the day of Christmas. Data needed for the analysis of input Y, which is the peak load on Christmas day, and four days before the celebration of Christmas. New Year holiday and four days earlier in 2014, 2015, 2016 and 2017 so it will get its value Variable Load Difference (*VLD*) as Table4.

Calculation of Z Value

To get the value of *Z*, then the results of the analysis of input values *X* and *Y* value of *Variable Load Difference(VLD)* sought to forecast the peak New Year 2014 – 2017 [20]. Even found some process to specify the value of *Z* is as Table5:

Table 5. The Value of *X, Y* and *Z* for the input Fuzzy

Year	New Year	Christmas	X	Y	Z
2014	0,4567	(1,5599)	0,4567	0,2104	(1,5599)
2015	(0,8101)	0,2104	(0,8101)	0,1905	0,2104
2016	(0,7421)	0,1905	(0,7421)	(0,0634)	0,1905
2017	0,0509	(0,0634)	0,0509	(1,5599)	(0,0634)

Table 5 can be used as a Fuzzy input on an Interval Type-2 Fuzzy Inference System.

Membership Function for Input and Output Variable

To execute the setup value of *X, Y* and *Z*, the *IT-2FIS* is the same as the setup value in the *IT-2FIS-BBBC*as follows [20],Set of *X, Y and Z* variables at Figure3:

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

The process of the input (*X, Y*), which produces an output form of *Z*, it uses the Rules Base Fuzzy Inference System.

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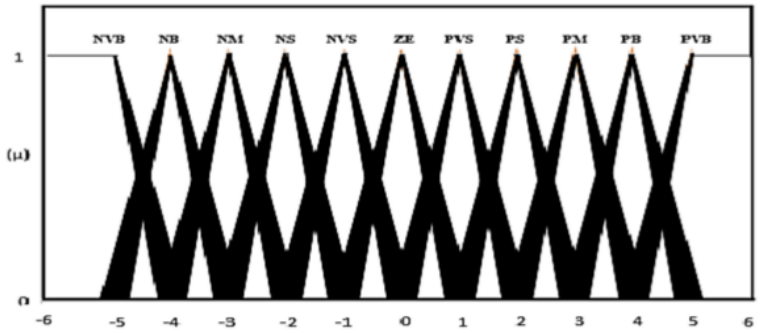

Fig.3. Set of *X, Y and Z* variables

From table 5, we can arrange the rule base for X, Y and Z values as in tables 6, 7 and 8.

Table 6. Process of Rule Base for Variable *X*

Year	Value	NVB	NB	NM	NS	NVS	ZE	PVS	PS	PM	PB	PVB	X
2014	0,4567						0,5433	0,4567					ZE
2015	(0,8101)					0,1899	0,8101						ZE
2016	(0,7421)					0,7421	0,2579						NM
2017	0,0509						0,9491	0,0509					ZE

Table 7. Process of Rule Base for Variable *Y*

Year	Value	NVB	NB	NM	NS	NVS	ZE	PVS	PS	PM	PB	PVB	Y
2014	0,2104						0,7896	0,2104					ZE
2015	0,1905						0,8095	0,1905					ZE
2016	(0,0634)					0,0634	0,9366						ZE
2017	(1,5599)				0,5599	0,4401							NS

Table 8. Process of Rule Base for Variable *Z*

Year	Value	NVB	NB	NM	NS	NVS	ZE	PVS	PS	PM	PB	PVB	Z
2014	(1,5599)				0,5599	0,4401							NS
2015	0,2104						0,7896	0,2104					ZE
2016	0,1905						0,8095	0,1905					ZE
2017	(0,0634)					0,0634	0,9366						ZE

From tables 6, 7 and 8, the basic rules of *X, Y* and *Z* can be made as can be seen in table 9.

Table 9. The Value of *X, Y* and *Z* as input MATLAB

No of Rules	Antc. X	Antc. Y	Cons Z	No of rules	Antc. X	Antc. Y	Cons. Z
2014	ZE	ZE	NS	**2014**	6	6	4
2015	ZE	ZE	ZE	**2015**	6	6	6
2016	NM	ZE	ZE	**2016**	3	6	6
2017	ZE	NS	ZE	**2017**	6	4	6

Implementation

Short-term load forecasting using *IT-2FIS* and *IT-2FIS-BBBC*executed by using Matlab software to hold the value of forecasting by using Equation 7, 8,which has obtained, it will get the results of the comparison table as shown in Table 10 and 11, the following: The results of short-term load forecasting error method *IT-2FIS* in 2014 through 2017 can seen in Table. 10, then comparison with *IT-1 FIS*as Table 11.

Table 10. Error Forecasting using *IT-2 FIS*

Year	IT-2 FIS – 2017				
	Output Forecast	***Forecast LD***	***Forecast P'(MW)***	***Actual (MW)***	***Error (%)***
2014	-0,9987	(13,82)	16.442,31	16.720,00	1,66
2015	0	(13,18)	16.957,22	16.799,00	0,94
2016	(0,9504)	(15,68)	16.950,12	16.992,00	0,25
2017	0	(15,42)	17.220,65	17.231,00	0,06
				Sum	**2,91**
				Average	**0,73**

Table 11. Error Forecasting using *IT-2 FIS-BBBC*

Year	IT-2 FIS-BBBC - 2017				
	Output Forecast	***Forecast LD***	***Forecast P'(MW)***	***Actual (MW)***	***Error (%)***
2014	-0,9975	(13,82)	16.442,54	16.720,00	1,66
2015	-2,653	(15,83)	16.439,06	16.799,00	2,14
2016	(1,9870)	(16,72)	16.741,74	16.992,00	1,47
2017	(1,4590)	(16,88)	16.923,59	17.231,00	1,78
				Sum	**2,26**
				Average	**0,56**

In tables 10 and 11. It was known that the average error value is used *T2-FIS* are:0.73 %, whereas using*IT2-FIS-BBBC* obtained: 0.56 %.Tables 10 and 11 make a comparison chart between actual and forecasting using *IT-2 FIS* and using *IT-2 FIS-BBBC*, as in Figures 4 and 5. At the same time, the comparison of errors using *IT-2 FIS* and *IT-2 FIS-BBBC* can seen as in Figure 6.

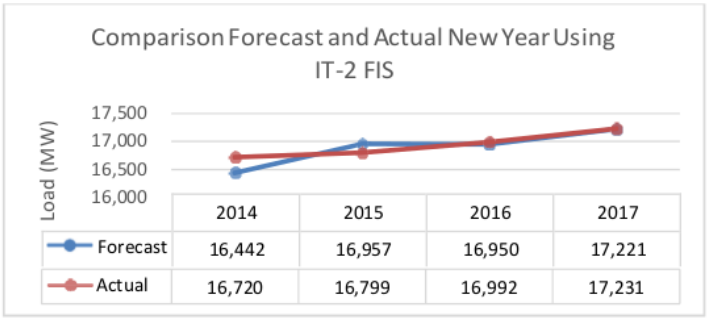

Fig. 4. Forecast and Actual New Year Holiday by using *IT-2 FIS*

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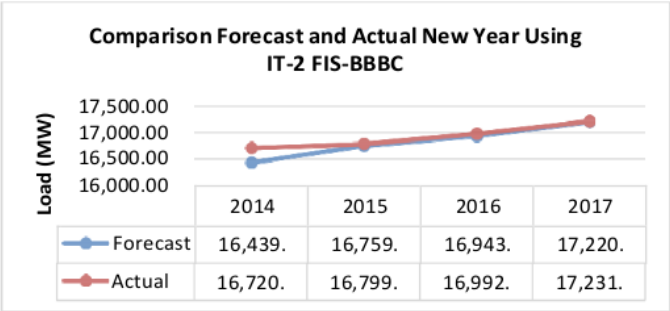

Fig. 5. Forecast and Actual New Year Holiday by using *IT-2 FIS-BBBC*

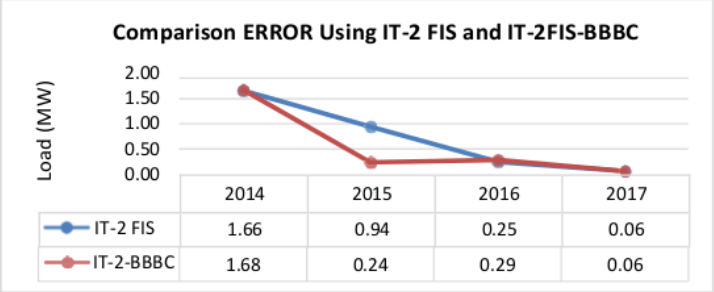

Fig. 5. Comparison Error New Year using *IT-2 FISand IT-2 FIS-BBBC*

Conclusion

From the above analysis and calculation through the stages of a process that has determined, then get the conclusion that the short-term load forecasting new year holiday with the use of *IT-2FIS-BBBC* has an average error value 0.56% (smaller than *IT-2 FIS*). Whereas if the use of *IT-2FIS*, it will get the value of average error 0.73%

With the above explanation, the *IT-2 FIS-BBBC* can nominated as one of the methods employed to conduct short-term load forecasting. To increase the accuracy of the model, it can done to expand the membership function of the current forecast model. When doesexpansion, membership function, then the data will have a smaller range and will obtain more accurate forecasting results.

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