SHORT TERM LOAD FORECASTING NEW YEAR CELEBRATION HOLIDAY USING *INTERVAL TYPE-2 FUZZY INFERENCE SYSTEM* (CASE STUDY: JAVA – BALI ELECTRICAL SYSTEM)

Jamaaluddin [1,2], Imam Robandi[1]

1) Department of Electrical Engineering, Institut Teknologi Sepuluh Nopember
2) Universitas Muhammadiyah Sidoarjo Indonesia.
E-mail address: jamaaluddin15@mhs.ee.its.ac.id
E-mail address: robandi@ee.its.ac.id

Abstract

Celebration of New Year In the Indonesian is constituted the one of the visit Indonesian's tourism. This event course changes the load of electrical energy. The electrical energy providers that control and operation of electrical in Java and Bali (Java, Bali Electrical System) is required to be able to ensure continuity of load demand at this time, and forecast for the future. Short-term load forecasting very need to be supported by computational methods for simulation and validation. The one of computation's methods is *Interval Type – 2 Fuzzy Inference System (IT-2 FIS). Interval Type-2 Fuzzy Inference System (IT-2 FIS)* as the development of methods of Interval *Type-1 Fuzzy Inference System (IT-1 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), so it supports to establish an initial processing of the time series, computing, simulation and validation of system models. Forecasting methods used in this research are *IT-2 FIS*. The process for to know and analyzing the peak load a day is the specially day and 4 days before New year Celebration in the previous year continued analysis by *using IT-2 FIS* will be obtained at the peak load forecasting New Year Celebration in the coming year. This research shown the average of error value in 2012, 2013 and 2014 is 0,642%. This value is better than using the *IT-1 FIS* which has a value of error to 0.649%. This research concluded that *IT-2 FIS* can be used in Short Term Load Forecasting.

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

1. Background

At the end of the growing need for electricity load increased. Modern life cannot be separated from the mains. All things are very dependent on electricity (Demello and Concordia 1969). Electrical energy is a major requirement at this time, in addition to the needs of primary, secondary and tertiary. Without electric energy in one second, modern society will not be able to conduct its activities (Robandi 2006; Robandi 2009). 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. The Indonesian government

incorporates Day holiday this Christmas and new year. So that all production activities will be stopped approximately 7 days. At the time of this holiday a decline in electrical power to the Java, Bali system up to 16.28%.

The decrease electrical power must be known, and by planning carefully, so that in accordance with the plan pembangkitannya. This relates to the generation efficiency. This loading prediction related to the generation of power systems. For example, with regard to the loading plan, maintenance plan generating system and evaluation with regard to the feasibility of the stability of the power system (Song et al. 2005),(Amral, Ozveren, and King 2007).

More than two decades, widely used fuzzy logic to control, prediction and optimization in power systems (Ahmadi, Bevrani, and Jannaty 2012). By using the method of *IT-2 FIS*, load demand can be predicted in the upcoming Marry Christmas and happy new year celebrations. Forecasting is necessary to perform the loading plan, maintenance plan units, and the planned use of manpower which ultimately leads to the efficiency of power generation (A. Dharma, Robandi 2008).

2. Method

A. *Preprocessing.*

In the preprocessing stage is a grouping of data national holidays. Then calculate the peak load 4 days before national holidays (Kim et al. 2000)

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

The next step is calculating the difference in peak load (Load Difference) on national holidays will be predictable.

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

Then look for a Peak Load Variation (Variation Load Reference) on a day that would be predictable.

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

B. Processing

At this stage a short-term load forecasting model for the new years celebration holidays into *Interval Type-2 Fuzzy Inference Systems*. The steps as follows(Jamaaluddin;Imam Robandi 2016):

1. Build a membership function input *interval type-2 fuzzy logic system* that inputs *X* and *Y*, and *Z* that Output membership function for the day to be predictable. With the following conditions:
   X: VLD_{max} *(i)* the day of holidays in the year before forecasting.
   Y: VLD_{max} *(i)* previous holidays (adjacent) in the same type of holiday in forecasting
   Z: Forecast VID_{max} (on) a holiday that will forecast :

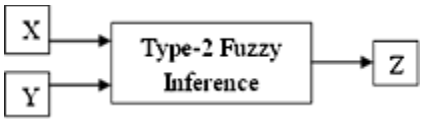

Fig. 1. Input and Output for Data Processing

2. Make a fuzzy rules (fuzzy, rules) *Interval Type-2 Fuzzy, Inference System (IT-2FIS)* as follows(Kim et al. 2000):

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

3. Applied operation on the (*IT-2 FIS*).
4. Applied the *MIN* function on fuzzy, implications.
5. Applied the composition *MAX* on each fuzzy, implication results.
6. Calculating firm output (non fuzzy, values) to get the value Forecast $VLD_{max.}$

C. Flowchart of Forecasting by Using IT-2

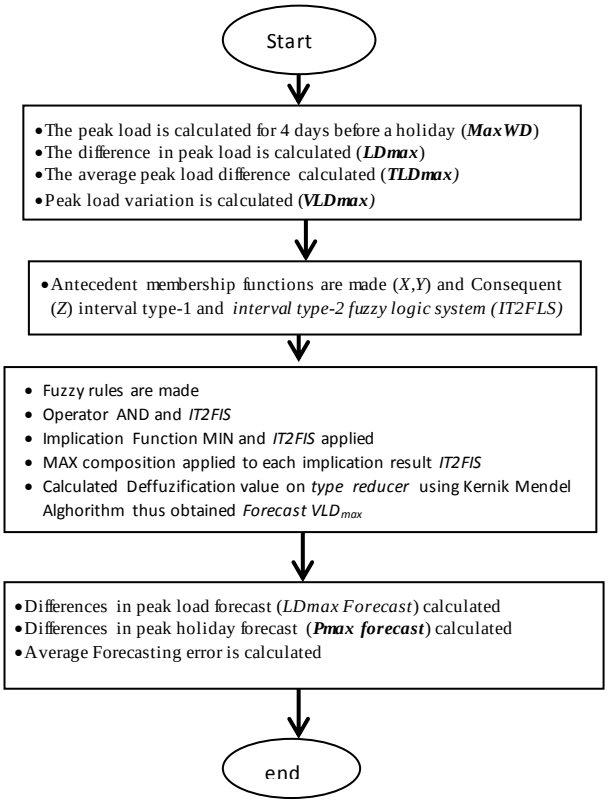

Fig. 2. Diagram of Forecasting for *IT-2 Fuzzy*

D. Post processing

In the post-processing stage of the calculation results of short-term load forecasting for a national holiday on the Java-Bali electrical system, the following:

1. Calculate the difference peak load forecast (load forecast reference) for a holiday of forecast:

$$Forecast\ LD_{MAX}(\mathrm{i}) = ForecastVLD_{MAX}(\mathrm{i}) - TLD_{MAX} \quad (4)$$

2. Calculate the difference of the holiday peak load forecast:

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

3. Calculating error forecasting results:

$$Error\% = \frac{P_{forecast} - P_{actual}}{P_{actual}} x100$$

$$Error\% = \frac{P'_{MAX}(i) - MaxSD(i)}{MaxSD(i)} x100 \quad (6)$$

3. Result

On The Table 1, shown the date of new year and marry christmas holiday (See Table 1.) and the data load on the holiday and four days before the holiday (See table 2.).

Table 1. Date of the Christmas and New year (2012, 2013, 2014)

1	Christmas	25 Des	25 Des	25 Des
2	New Year	1 January	1 January	1 January

Table 2. Load (in MW) during holiday and 4 days before it

		Days to				
	Holiday	H-4	H-3	H-2	H-1	H
2012	1. Cristmas	20066.00	18776.00	17971.00	19031.00	18079.00
	2.New Year	18827.00	18304.00	18076.00	15940.00	14128.00
2013	1. Cristmas	20120.00	18429.00	20732.00	20627.00	18782.00
	New Year	19782.00	18608.00	17525.00	16872.00	15780.00
2014	1. Cristmas	20106.00	22259.00	22230.00	21884.00	19652.00
	2. New Year	19786.00	19025.00	19462.00	18046.00	16720.00

Due to holidays are observed is New Year, the data of load and calendar displayed is New Year and holiday earlier and close to the holiday New Year day is Christmas.

A. Calculation of X value

The calculation of the value of the input variable X at the peak load forecasting of New Year holiday in 2014 is to find the value of *Variable Load inference (VLD_{MAX})* year before (New Year *2013)*.(Jamaaluddin;Imam Robandi 2016).

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

1. *New Year, 2012*
   Looking for *MaxWD* and LD_{MAX} value from data of load peaks 4 days before holidays and on New Year 2012 holidays as follows:
   $MaxWD_{H-4}$ = 18827 Mega Watt
   $MaxWD_{H-3}$ = 18304 Mega Watt
   $MaxWD_{H-2}$ = 18076 Mega Watt
   $MaxWD_{H-1}$ = 15940 Mega Watt
   MaxSD = 14128 Mega Watt

$$MaxWD\ (New\ Year 2012) = \frac{MaxWD_{H-4} + MaxWD_{H-3} + MaxWD_{H-2} + MaxWD_{H-1}}{4}$$

$$MaxWD\ (New\ Year 2012) = \frac{18827.00 + 18304.00 + 18076.00 + 15940.00}{4}$$
$$= 17786.75\ MW$$

$$LDMAX\,(New\ Year\ 2012) = \frac{MaxSD\,(New\ Year\ 2012) - MaxWD\,(New\ Year\ 2012)}{MaxWD\,(New\ Year\ 2012)} x100\%$$

$$= \frac{14128.00 - 17786.75}{17786.75} x100\% = -20.57\ \%$$

2. *New Year, 2013*
   Looking for *MaxWD* and LD_{MAX} value from data of load peaks 4 days before holiday and on New Year 2013 holiday as follows:
   $MaxWD_{H-4}$ = 19782 Mega Watt
   $MaxWD_{H-3}$ = 18608 Mega Watt
   $MaxWD_{H-2}$ = 17525 Mega Watt
   $MaxWD_{H-1}$ = 16872 Mega Watt
   MaxSD = 15780 Mega Watt
   in the same process, we find the results as Table 3.

3. *New Year, 2014*
   Looking for *MaxWD* and LD_{MAX} value from data of load peaks 4 days before holiday and on New Year 2014 holiday as follows:
   $MaxWD_{H-4}$ = 19786 Mega Watt
   $MaxWD_{H-3}$ = 19025 Mega Watt
   $MaxWD_{H-2}$ = 19462 Mega Watt
   $MaxWD_{H-1}$ = 18046 Mega Watt
   MaxSD = 16720 Mega Watt
   in the same process, we find results as Table 3. To find the value TLD_{MAX} *(New Year 2014*) as follows:

$$TLDMAX\,(New\ Year\ 2014) = \frac{LDMAX\,(New\ Year\ 2013) + LDMAX\,(New\ Year\ 2012)}{2}$$

$$= \frac{-13.28 + (-20.57)}{2} = -16.93$$

$$VLDMAX\,(New\ Year\ 2014) = LDMAX\,(New\ Year 2014) - TLDMAX\,(New\ Year\ 2014)$$
$$= -12.37 - (-16.93) = 4.56$$

B. *Calculation of Y value*

The calculation of the value input variable Y forecasting the peak load of New Year holiday in 2014 is looking for value difference of variable load *(VLD_{MAX})* holiday approaching that kind VLD_{MAX} *(Christmas 2014*) (Jamaaluddin;Imam Robandi 2016).

1. *Christmas 2012*
   Looking for the value of *MaxWD* and LD_{MAX} load peaks data 4 days before holiday and on Christmas 2012 holiday as follows:
   $MaxWD_{H-4}$ = 20066 Mega Watt

$MaxWD_{H-3}$ = 18776 Mega Watt
$MaxWD_{H-2}$ = 17971 Mega Watt
$MaxWD_{H-1}$ = 19031 Mega Watt
$MaxSD$ = 18079 Mega Watt

$$MaxWD\ (Christmas2012) = \frac{MaxWD_{H-4} + MaxWD_{H-3} + MaxWD_{H-2} + MaxWD_{H-1}}{4}$$

$$MaxWD\ (Christmas2012) = \frac{20066.00 + 18776.00 + 17971.00 + 19031.00}{4} = 18961.00\ MW$$

$$LDMAX\,(Christmas2012) = \frac{MaxSD\,(Christmas2012) - MaxWD\,(Christmas2012)}{MaxWD\,(Christmas2012)} x100\%$$

$$= \frac{18079.00 - 18961.00}{18961.00} x100\% = -4.65$$

2. *Christmas 2013*
   Looking for the value of *MaxWD* and *LDMAX* load peaks data 4 days before holiday and on *Christmas* 2013 holiday as follows:
   $MaxWD_{H-4}$ = 20120 Mega Watt
   $MaxWD_{H-3}$ = 18429 Mega Watt
   $MaxWD_{H-2}$ = 20732 Mega Watt
   $MaxWD_{H-1}$ = 20627 Mega Watt
   $MaxSD$ = 18782 Mega Watt
   in the same way, the obtained results as Table 3.

3. *Christmas 2014*
   Looking for the value of *MaxWD* and LD_{MAX} load peaks data 4 days before holiday and on Christmas 2014 holiday as follows:
   $MaxWD_{H-4}$ = 20106.00 MW
   $MaxWD_{H-3}$ = 22259.00 MW
   $MaxWD_{H-2}$ = 22230.00 MW
   $MaxWD_{H-1}$ = 21884.00 MW
   $MaxSD$ = 19652.00 MW
   in the same process, we find the results as Table 3. To find the value TLD_{MAX} (Christmas 2014) is as follows:

$$TLDMAX\,(christmas2014) = \frac{LDMAX\,(Christmas\ 2013) + LDMAX\,(Christmas\ 2012)}{2}$$

$$= \frac{-5.98 + (-4.65)}{2} = -5.32$$

$$VLDMAX\,(Christmas2014) = LDMAX\,(Christmas2014) - TLDMAX\,(Christmas2014)$$

$$= -9.10 - (-5.32) = -3.78$$

Table 3. Value Of *MaxWD, LD_{MAX}* at 2012 – 2014

No	Holiday	2012		2013		2014	
		MAXWD	LDMAX	MAXWD	LDMAX	MAXWD	LDMAX
1	New Year	17786.75	-20.57	15780.00	-13.28	19079.75	-12.37
2	Christmas	18961.00	-4.65	19977.00	-5.98	21619.00	-9.10

C. Calculation of Z Value

The calculation of the value output variable Z is forecasting the peak load of New Year holiday in 2014 is looking for value difference of *Variable Load (VLD_{MAX})* in forecasting New Year 2014(Jamaaluddin;Imam Robandi 2016):

1. Membership Function for Input and Output Variable

The set of *Interval Type-2 Fuzzy*, fuzzy sets similar to the type-1. The value of *i*nput variables (*X, Y*) and output variables (*Z*) consists of 11 *fuzzy* sets as follows (Jamaaluddin;Imam Robandi 2016):

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)* short-term load forecasting in 2012 is shown table 4. Through table 9.

Table. 4. Input (*X, Y*) and output (*Z*) By VLD_{MAX} in 2012 and 2013

Name of Holiday	2012	2013	Input		Output
	VLD_{MAxX}	VLD_{MAX}	X	Y	Z
1. Christmas	-3.126	-2.063	-3.126	0.963	-2.063
2. New Year	2.998	-3.278	2.998	4.8004	-3.278

Table. 5. Process Rules for Input X in 2012

Holiday	Value	Membership Function (μ)											Membership
	X	NVB	NB	NM	NS	NVS	ZE	PVS	PS	PM	PB	PVB	X
1, New Year	2,998							0,50076	0,49924				PVS
2. Christmas	-3,126				0,563021	0,436979							NS

Table. 6. Process Rules for Input *Y* in 2012

Holiday	Value	Membership Function (μ)											Membership
	Y	NVB	NB	NM	NS	NVS	ZE	PVS	PS	PM	PB	PVB	Y
1,New Year	4,800								0,599	0,40			PS
2. Christmas	0,962						0,518	0,481					ZE

Table. 7. Process Rules for Output *Z* in 2012

Holiday	Value	Membership Faunction(μ)											Membership
	Z	NVB	NB	NM	NS	NVS	ZE	PVS	PS	PM	PB	PVB	Z
1, New Year	-3,278				0,639189	0,360811							NS
2. Christmas	-2,063				0,031826	0,968174							NVS

Table 8. Basic Rules table (*fuzzy rul*es) for forecasting the year 2012

X/Y	NVB	NB	NM	NS	NVS	ZE	PVS	PS	PM	PB	PVB
NVB											
NB											
NM											
NS						NVS					
NVS											
ZE											
PVS								NS			
PS											
PM											
PB											
PVB											

Table 9. Conversion Table Basic Rules Forecasting the Year 2012 for Matlab Software Code

No.	Antecendent		Consequen
Aturan	X	Y	Z
1	PVS	PS	NS
2			
....			
10			
11	NS	ZE	NVS
.....			
14			

No.	Antecendent		Consequen
Aturan	X	Y	Z
1	7	8	4
2			
.....			
10			
11	4	6	5
.....			
14			

2. Implementation

Short-term load forecasting using the *Interval Type-2 Fuzzy Inference System* executed through m.file program in Matlab, to obtain the value of forecasting VLD_{MAX}. *Value of* VLD_{MAX} *forecasting* results continued (post processing) using MS.Excell to get the peak load forecasting and forecasting error value. The results of short-term load forecasting error method *IT-2FIS* in 2012 through 2014 can be seen in Table. 10 below, then comparison with *T-1 FIS*.

Table 10. Comparison of Forecasting and Actual load on the holiday of New Year, 2012, 2013 and 2014

YEAR	T1-FIS			IT2-FIS		
	FORC (MW)	ACT (MW)	ERR (%)	FORC (MW)	ACT (MW)	ERR (%)
2012	14012.24	14128.00	0.818	14015.34	14128.00	0.798
2013	15870.82	15780.00	0.576	15870.82	15780.00	0.576
2014	16627.35	16720.00	0.554	16627.70	16720.00	0.552
		Sum	1.948		Sum	1.926
		Average	0.649		Average	0.642

In table 10. We can find the average error value used *T1-FIS* are : 0.649 %, whereas used *IT2-FIS* obtain : 0.642 %.

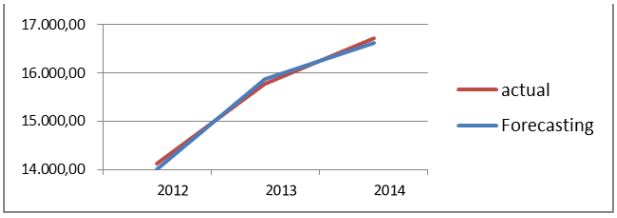

Fig. 3. Graph of comparison between actual and forecast by using *T-1 FIS*

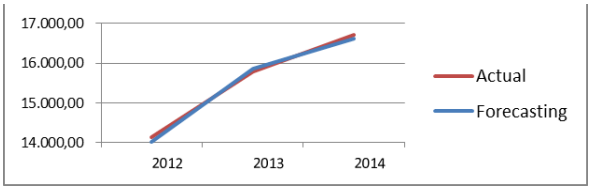

Fig. 4. Graph of comparison between actual and forecast by using *IT-2 FIS*

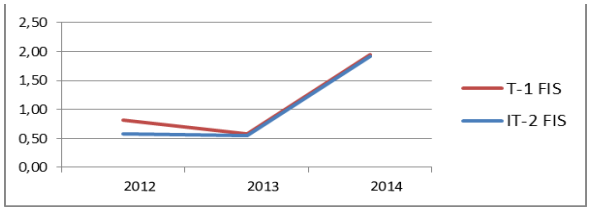

Fig. 5. Graph of comparison error value forecast between *T-1 FIS* and *IT-2 FIS*

4. CONCLUSION

This research presented Short Term Load Forecasting New Year celebretion holiday by using *Interval Type-2 Fuzzy Inference System (IT-2 FIS)*. Load forecasting is done is to predict the peak of the load. In the process of analysis in the form of daily peak load value and calendar information. The value of input this analysis is the daily peak load and calendar information. This research obtained by using the *IT-2 FIS*, load forecasting in 2012, 2013 and 2014 have an average value of 0.642 % error, Whereas when using *Type-1 FIS* has an average value of 0.649 % error.

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

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