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APPLICATION OF SHORT TERM LOAD FORECASTING ON SPECIAL DAYS USING INTERVAL TYPE-2 FUZZY INFERENCE SYSTEMS: STUDY CASE IN BALI INDONESIA

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ABSTRACT

This paper presents the application of interval type-2 fuzzy inference systems (IT2FIS) in short term load forecasting (STLF) on special days. This is a continuation work of application interval type-2 fuzzy systems (IT2FSs) using Karnik Mendel algorithm. Special days here mean local Balinese holidays such as national and local culture-based public holidays, consecutive holidays, and days preceding or following holidays. In general, the load values of special days tend to decrease due to unlike load behavior of holidays compare with ordinary weekdays during the year. IT2FIS has recently been considerable attention for a short term load forecasting problems due to their simple structure and high identification performance. IT2FIS is the process of formulating and mapping from a given input to an output using interval type-2 fuzzy logic. The Mamdani interval type-2 fuzzy inference models and the design of interval type-2 membership functions and operators are implemented in the interval type-2 fuzzy logic toolbox (IT2FLT). The method has been implemented on the historical peak load data to solve the short term load forecasting during holiday for the Bali electrical system, Indonesia. The results showed that the IT2FIS offer an accurate forecast of the peak load (in MW) on holidays, indicated by small mean absolute percentage error (MAPE) less than 1.5% for the estimation task of the year 2005 and 2006. More detail results and discussion are provided to show the eminence of these methods handling the short term load forecasting task.

Keywords: *STLF, Interval Type-2 FLS, Interval Type-2 FIS, MAPE*

1. INTRODUCTION

Nowadays electric power load forecasting techniques such as neural network and fuzzy theory are actively used to reduce the uncertainty and nonlinear behavior of load. Peak load without previous estimation, influences the operation such as scheduling and allocation of units to back up and can disrupt the reliability of electric power systems.

A characteristic of the peak load of special days in anomalous load conditions, such as public holidays, consecutive holidays, and days preceding or following holidays are quite dissimilar from those of normal days. In general, the load values of special days tend to decrease due to unlike load behavior of holidays compare with ordinary weekdays during the year. Special days in Bali are classified into five types; i.e. Public, Islamic, Christian, Hindus and Buddhist holidays. Within these types, there are 20 items of special days in Bali which consist of 14 items of national holidays and 6 items for special Hindu's holidays. The Hindu's holidays in Bali are unique because the use of three kinds of calendars i.e. Luni-solar, non astronomic called Pawukon and Gregorian calendar. Their holidays occur two times a year because it happens every 210 days, however, the peak load forecasting for these days is only chosen once in the course of one year. One important holiday is called Nyepi or silent day where four types of activity are mandatorily prohibited i.e. activities involving fire; work; entertainment or pleasure, and travel. Accordingly, almost all activities within the island is stopped for 24 hours [1], [2].

There have been several research works for developing accurate load forecasting techniques for special days [3]–[5], one of them was using fuzzy. Fuzzy set was first introduced by L.A. Zadeh in

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1965 to manipulate the unprobabilistic and uncertainty of data and information. Fuzzy sets and fuzzy logic are the basis of the fuzzy system aiming to mimic how human brain works in manipulating the non-exact information. Therefore, this method is suitable to model complex systems, non-linear and difficult model in uncertainty [6]–[8] and this method is implemented on short term load forecasting (STLF) [9]–[13]. In term of period of time, STLF is valid for load forecasts within one day to one week ahead of load occurrence [9]–[11], [14], [15].

More information on the development of type-1 fuzzy set (T1FS) can be obtained in the interval type-2 fuzzy set (IT2FS). IT2FS is better used to model uncertainty and imprecision. Interval type-2 fuzzy systems (IT2FSs) developed by Mendel is characterized with IT2FS as the footprint of uncertainty (*FOU*) is limited by the superior and inferior type-1 membership function [16]–[21] and the development of type1 to type-2 intervals in some cases, the results indicate better [19], [21].

In this paper interval type-2 fuzzy inference system (IT2FIS) by using interval type-2 fuzzy logic toolbox (IT2FLT) for use with Matlab is applied for STLF. This work is the development of interval type-2 fuzzy systems (IT2FSs) using Karnik Mendel algorithm. Step by step works is started from initial to final implementation phase is reported to accomplish the peak load STLF for special days in Indonesia especially at the Bali electrical system during the year 2005 and 2006. These years are important because the electrical authority of Bali started to anticipate islanding operation procedures if the power gets loss from Java-Bali interconnection system and for the security reasons. The predicted results obtained are compared with actual values.

2. INTERVAL TYPE-2 FUZZY LOGIC SYSTEMS (IT2FLSS)

2.1. Interval Type-2 Fuzzy Sets (IT2FSs)

An IT2FS $\tilde{A}$ is characterized as:

$$\tilde{A} = \int_{x\in X} \int_{u\in J_x \subseteq [0,1]} 1/(x,u) = \int_{x\in X} \left[\int_{u\in J_x \subseteq [0,1]} 1/u \right] / x \qquad (1)$$

where x, the *primary variable*, has domain X; $u \in U$, the *secondary variable*, has domain J_x, at each $x \in X$; J_x is called the *primary membership* of x and is defined in Eq.(5); and, the *secondary grades* of $\tilde{A}$ all equal 1. Note that in Eq.(1) means: $\tilde{A}$: $X \to \{[a,b] : 0 \le a \le b \le 1\}$. Uncertainty about $\tilde{A}$ is conveyed by the union of all the primary memberships, which is called the *footprint of uncertainty* (*FOU*) of $\tilde{A}$ (see Fig. 1), i.e.

$$FOU(\tilde{A}) = \bigcup_{\forall x \in X} J_x = \{(x,u) : u \in J_x \subseteq [0,1]\} \qquad (2)$$

The *upper membership function* (UMF) *and lower membership function* (LMF) of $\tilde{A}$ are two type-1 MFs that bound the *FOU* (Fig. 1). The UMF is associated with the upper bound of *FOU*($\tilde{A}$) and is denoted $\bar{\mu}_{\tilde{A}}(x), \forall x \in X$, and the LMF is associated with the lower bound of *FOU*($\tilde{A}$) and is denoted $\underline{\mu}_{\tilde{A}}(x), \forall x \in X$ i.e.

$$J_x = \{(x,u) : u \in [\underline{\mu}_{\tilde{A}}(x)]\} \qquad (3)$$

$$\underline{\mu}_{\tilde{A}} \equiv \underline{FOU(\tilde{A})} \qquad \forall x \in X \qquad (4)$$

Note that J_x is an *interval set*, i.e.

$$J_x = \{(x,u); u \in [\underline{\mu}_{\tilde{A}}(x), \bar{\mu}_{\tilde{A}}(x)]\} \qquad (5)$$

so that *FOU*($\tilde{A}$) in Eq.(2) can also be expressed as

$$FOU(\tilde{A}) \equiv \bigcup_{\forall x \in X} [\underline{\mu}_{\tilde{A}}(x), \bar{\mu}_{\tilde{A}}(x)] \qquad (6)$$

For continuous universes of discourse X and U, and embedded IT2FS $\tilde{A}$ is

$$\tilde{A}_e \equiv \int_{x\in X} [1/u]/x \quad u \in J \qquad (7)$$

Note that Eq. (7) means: $\tilde{A}_e: X \to \{u : 0 \le u \le 1\}$ The set $\tilde{A}_e$ is embedded in $\tilde{A}$ such that at each x it only has one secondary variable (i.e., one primary membership whose secondary grade equals 1). Examples of $\tilde{A}_e$ are $1/\bar{\mu}_{\tilde{A}}(x)$ and $1/\underline{\mu}_{\tilde{A}}(x), \forall x \in X$.

Reference to a complete descriptions above is given in [22].

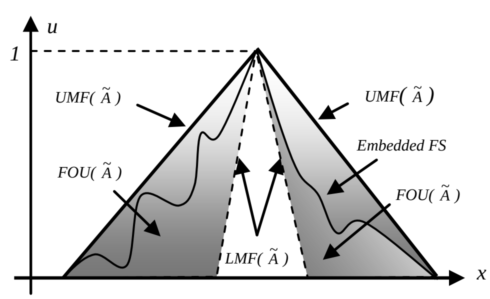

Figure. 1: FOU (Shaded), LMF (Dashed), UMF (Solid) And An Embedded FS (Wavy Line) For IT2FS Ã [22]

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2.2. Structure IT2FLS

An IT2FLS contains five interconnected components are fuzzifier, rules base, inference engine, type-reducer and defuzzifier has shown in Fig.2. Mapping process from crisp inputs *x* to crisp output can be expressed quantitatively as *Y=f(x)*.

Fig.2. shows that the crisp inputs are fuzzified into either type-0 (known as singleton fuzzification), type-1 or IT2FSs, which then the inference engine and the rule base to produce output of IT2FSs. These IT2FSs are then processed by a type-reducer (which combines the output sets and then performs a centroid calculation), leading to an IT1FS called the type-reduced set. A defuzzifier then defuzzifies the type-reduced set to produce crisp outputs. The process of formulating the mapping from a given input to an output using interval type-2 fuzzy logic called IT2FIS. The IT2FIS structure is the MATLAB object that contains all the IT2FIS information. This structure is stored inside each GUI tool [23].

2.3. Membership functions and fuzzy rules

The advantages of fuzzy inference is easily formulate the experience and knowledge of experts and very flexible in forecasting by changing in their rules. The Fuzzy Rules IF-THEN used in this method for the maximum load is expressed by Eq. (8) as follows in [4]:

$$IF\ X\ is\ A_i\ AND\ Y\ is\ B_i\ THEN\ Z\ is\ C_i \quad (8)$$

The values of input variable Y are obtained from the neighboring holiday in the year. If the holiday are the days preceding and following holiday, then those values are obtain from the preceding and the following days of the previous holiday.

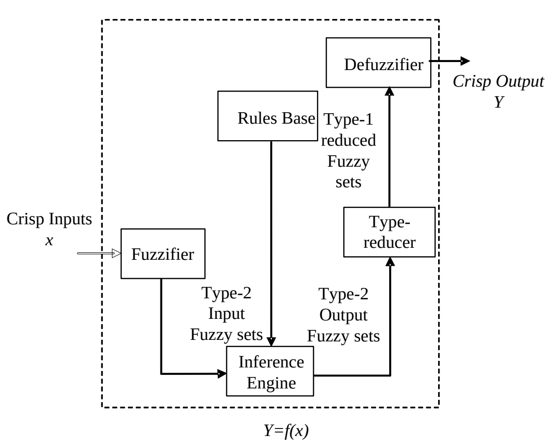

Figure 2: Type-2 Fuzzy Logic System (T2fls) [22]

Fuzzy sets *Ai, Bi, Ci* take the following eleven-term set, where each fuzzy set is composed of fuzzy type-1 upper and lower, then bounded as *FOU* and is called IT2FSs:

Negative Very Big (UNVB and LNVB)
Negative Big (UNB and LNB)
Negative Medium (UNM and LNM)
Negative Small (UNS and LNS)
Negative Very Small (UNVS and LNVS)
Zero (UZE and LZE)
Positive Very Small (UPVS and LPVS)
Positive Small (UPS and LPS)
Positive Medium (UPM and LPM)
Positive Big (UPB and LPB)
Positive Very Big (UPVB and LPVB)

2.4. Centroid and Karnik-Mendel Algorithms

Defuzzification is a process of mapping the control action fuzzy logic through type-reducer by iterative methods for computing its centroid i.e. Karnik Mendel algorithms to control the action non-fuzzy (crisp). This was possible because the centroid of an IT2FSs is an interval type-1 FSs (IT2FSs) and such sets are completely characterized by their left and right end points; hence, computing the centroid of an interval type-2 FS only requires computing those two end points. Defuzzification process using the centroid method in the IT2FLS has been proposed by Karnik and Mendel [16], [17], [19], [21], [24].

The c_l and c_r are important in centroid calculation. The centroid can be obtained through Eq. (9).

$$Centroid = (c_l + c_r)/2 \quad (9)$$

Even though centroid calculation is an iteration process, the number of iteration will not exceeds *N*, where *N* equals the number of sampled values of the primary variable [21].

By using IT2FLT for use with Matlab the systems for short term load forecasting is implemented, where all processes provided from design the initial description phase to the final implementation phase in IT2FIS environment [24]. It so powerful because the toolbox provides a number of interactive tools trough a GUI is the fact that most of human reasoning and concept formation is linked the use of interval fuzzy rules. In this paper, crisp output values given by IT2FIS using centroid method then is used for the next processing in forecasting.

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3. IMPLEMENTATION OF INTERVAL TYPE-2 FIS INTO STLF ON SPECIAL DAYS

3.1. Data Collection and Bali's Electrical System

By using the calendar of Bali written by Bambang Gde Rawi in [1], [25] and Joint Decree of The 3 Ministers Republic of Indonesia [10], the dates and hours of 20 items of holidays in Bali is setup with the peak load data were collected from the period of year 2002 to 2006.

The secondary data is taken from the state electricity company of Indonesia on Transmission and Center for Load Dispatching East Java and Bali Sub-Region Bali located at Kapal grid station, Denpasar city, province of Bali, Indonesia. Peak load data from the Day-4 to MaxSD on the day of holidays based on the date used for forecasting the peak load of each holiday. Peak load data from Day-4 up to MaxSD on special day based on the date of the year 2003-2004 is used to forecast in the same holiday in 2005 and the years 2004-2005 data are used to forecast the peak load the same holiday in 2006. Actual peak load on special days in 2005 and 2006 is used as a comparison target forecasting.

Electrical system in the Province of Bali is part of the electric power system interconnecting from Madura to Java Island, and from Java to Bali Island (JAMALI) used 150 kV sea cables. Electricity generation in the Province of Bali, is supplied not only by the interconnection transmissions using sea cables which is laid on sea bed from Banyuwangi to Gilimanuk with the capacity of generation 200 MW but also is generated from Pesanggaran, Gilimanuk and Pemaron power station with each total capacity of 152, 130 and 80MW respectively. Thus the total power system generation of Bali Island was 562 MW. It consists of 13 grids, connected under 150 kV voltage system. Load shedding is applied when the excessive load is sensed by under frequency relays (UFR) on each grid. The one line Diagram 150kV Transmission System in the Province of Bali can be seen in Figure 3 [10].

3.2. Preprocessing Peak Load Data

Preprocessing data is started firstly by computing some expression and its explanation indicated in Eq. (10), Eq.(11) and Eq.(12) respectively [4]. In order to quantify the difference between the load behavior of special days in this case the holidays and that of normal weekdays. Load Differences (*LDs*) for maximum loads on special days *i* is defined as the difference between the special day and the previous four weekdays is expressed by Eq. (10), while *MaxWD (i)* is the average maximum load of previous four weekdays which is given on Eq. (11),

$$LD_{MAX}(i) = \frac{MaxSD(i) - MaxWD(i)}{MaxWD(i)} \times 100 \quad (10)$$

where LD_{Max} *(i)* is the maximum load on holidays *(i)*

$$MaxWD(i) = \frac{WD(i)_{Day-4} + WD(i)_{Day-3} + WD(i)_{Day-2}}{4} + \frac{WD(i)_{Day-1}}{4} \quad (11)$$

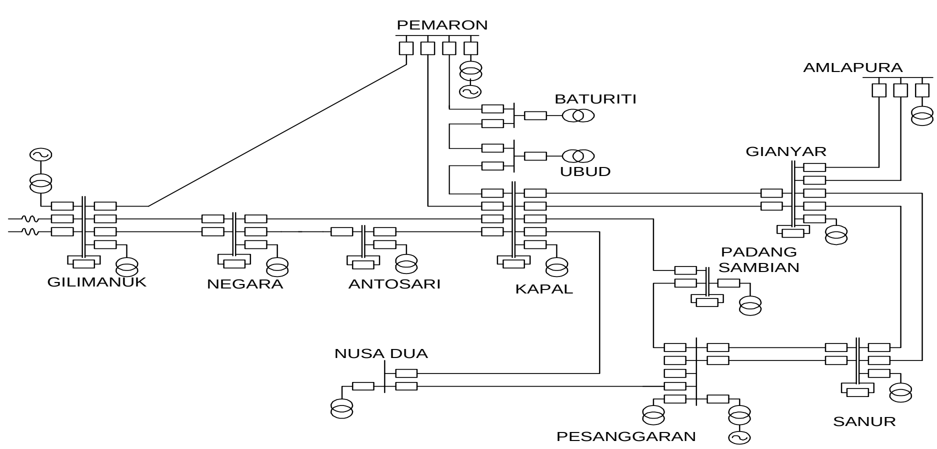

Figure 3: One Line 150kv Transmission System In Bali Island, Indonesia [10]

Based on historical load data, the same holidays with the same day-type showed a tendency to have similar value of *LD*. The Typical *LDs* (*TLDs*) is calculated by averaging the *LDs* of the same

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holidays in the same day-type collected from the historical data. *TLDs* is used as a basis to predict the value of the maximum load on holidays.

The Variations of *LD* (*VLD*) is defined as the amount of difference between the load behavior of the holiday and typical behaviors of the same holidays with the same day type. Then the values of VLD_{MAX} are calculated simply by subtracting TLD_{MAX} from LD_{MAX} as shown in Eq. (12).

$$VLD_{MAX}(i) = LD_{MAX}(i) - TLD_{MAX}(i) \quad (12)$$

Fig. 4. shows one example on New Year day of consecutive peak load curve 4 days before holidays (in MW) in the year 2002 to 2006. These peak load data is used to calculate the *MaxWD* and *LDmax* based on Eq. (10) and (11) respectively and the results is presented on Table I.

Table II present the calculation results trough the whole 22 holidays data by using Eq. (12).

3.3. Processing of Interval Type-2 FLS

In this stage, operation of Interval Type-2 fuzzy set is identical with an operation on Type-1 fuzzy set, however on interval type-2 fuzzy system; fuzzy operator is done at two type-1 membership function which limits the FOU, UMF and LMF to produce firing strength.

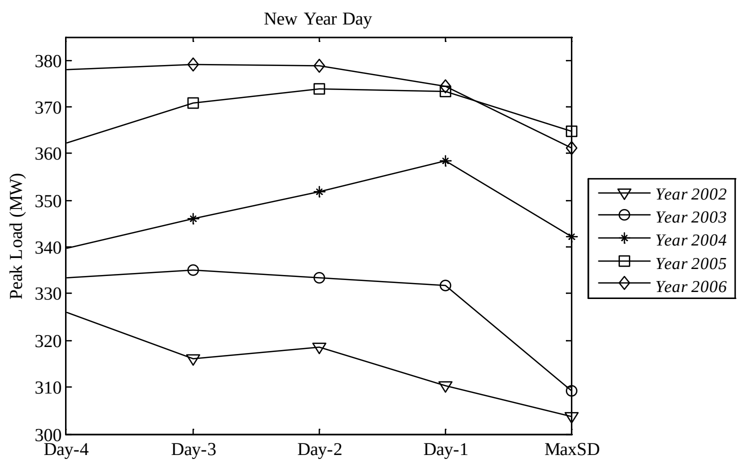

Figure 4: Peak Load Curve 4 Days Before Special Days (Day-4 To Day-1) And Maxsd In Consecutive Year From The Year 2002 To 2006

Table I: Maxwd And LD_{MAX} On New Year Day Results In Consecutive Years From The Year 2002 To 2006

Type of Holiday	Name	Year									
		2002		2003		2004		2005		2006	
		MaxWD	LD_{MAX}	*MaxWD*	LD_{MAX}	*MaxWD*	LD_{MAX}	*MaxWD*	LD_{MAX}	*MaxWD*	LD_{MAX}
Public	**New Year Day**	317.7500	-4.3902	333.4000	-7.2586	349.0250	-1.9268	370.0250	-1.4121	377.5500	-4.3306

Table II: VLD_{MAX} Calculation Results Trough The Whole 22 Special Days Data

Type of Holidays	Name	Year in 2004		Year in 2005		Year in 2006	
		TLD_{MAX}	VLD_{MAX}	TLD_{MAX}	VLD_{MAX}	TLD_{MAX}	VLD_{MAX}
Public	**New Year**	-5.8244	3.8976	-4.5252	3.1131	-3.5325	-0.7981
	Independence Day	-3.5154	0.3985	-3.3826	3.5013	-1.3333	1.7188
Islamic	**'Idul Adha**	-2.0134	2.1532	-1.2957	-1.1975	-1.3969	0.8137
	Muharram (Islamic New Year)	0.1228	3.1867	1.1850	-0.7824	1.1706	-2.2136
	Maulid	3.9680	-5.5438	2.1201	-2.0429	0.2675	-0.5552
	Isra' Mi'raj	3.0611	-3.1450	2.0128	-1.0730	0.9998	-1.6895

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	'Idul Fitri	2.1746	-2.6312	1.2975	-2.4930	-0.2388	0.1112
		3.7830	-2.7060	2.8810	-3.3964	0.3905	-0.9466
Christian	**Good Friday**	0.5480	1.0794	0.9078	-0.5073	1.1643	0.7536
	Ascension	1.0357	-1.0569	0.6835	-1.4198	0.5943	1.9199
	Easter	-3.1812	1.4583	-2.6951	-2.0381	-3.5286	1.6437
	Christmas	0.0337	-1.8720	-0.5903	2.3532	0.8595	0.0794
Hindus	**Penampahan Galungan**	-0.8678	2.5647	-0.0129	-0.8651	0.4503	-3.0854
	Galungan	-3.0190	-3.0450	-4.0340	1.3020	-4.2866	-1.0864
	Manis Galungan	-3.2199	3.4759	-2.0613	-6.4073	-3.3701	3.0244
	Kuningan	-2.9131	-0.9199	-3.2198	-1.6003	-4.6559	-1.0926
	Nyepi or Silent Day (Hindus New Year)	-45.6250	3.5163	-44.4529	5.6868	-42.2113	-3.7591
	Saraswati	7.7901	-17.9412	1.8097	-5.0768	0.3739	-4.9299
	Pagerwesi	-0.9419	1.1834	-0.5474	0.5677	0.4694	-0.6562
Buddhist	**Imlek (Chinese New Year)**	2.0878	-2.3232	1.3134	-2.1976	0.3516	2.0679
		0.8752	2.9449	1.8568	-1.6439	0.4210	0.3967
	Waisak	-1.8665	4.6011	-0.3328	-1.3423	-0.3426	-5.4059

By using Eq. (8), firstly, all input values of variables *X*, *Y* and output values of variable *Z* by definition were changed into its values, where *X* is $VLD_{MAX}(i)$ for the same holidays on previous forecasted years, *Y* is $VLD_{MAX}(i)$ the previous holiday next to forecasted year and *Z* is *forecast* $VLD_{MAX}(i)$. Secondly, A_i, B_i and C_i were grouped into 22 regions upper and lower of triangle membership function as mention on Sub-section 2.3, then the fuzzy rule base for maximum load were completely made as shown on Table III.

Table IV. shows that one example of choosing fuzzy set using max rule by taking the biggest value of corresponding membership degree ***(μ)*** of variable input *(X,Y)* and output *(Z)* in New Year day. After all some basic requirement for variable input and output is determined then it's implemented on IT2FLS toolbox use in Matlab environment by typing it2fuzzy in command line. This toolbox relies heavily on graphical user interface (GUI) tools to help accomplish the work. IT2FIS with Mamdani method, Max-Min method was applied. On Mamdani FIS, 5 steps it needs to produce an output: fuzzification of the input variables, application of the interval type-2 fuzzy operator (AND) in antecedent, implication from the antecedent to the consequent, aggregation of the consequents across the rules, type reduction and Defuzzification by using KM algorithm through Eq. (9). This crisp value obtained finally called *Forecast* VLD_{MAX} *(i)*.

Table III: The Fuzzy Rule Base For Maximum Load In Year 2005

X\Y	NVB	NB	NM	NS	NVS	ZE	PVS	PS	PM	PB	PVB
NVB					NS		NVB				
NB											
NM				NVS	NS/ NM/ PVS =**PVS**						
NS				PS	NS						
NVS				NVS							NS
ZE									PB		
PVS	PVS				NVS/ NS =**NS**						
PS					NVS						
PM					NVS /NS =**NVS**		NVS/ NVB =**NVB**				
PB	PVB									PM	
PVB				NVS							
Total Rules base	**Before reduced using Max rule = 22 After Reduced using Max rule= 17**										

Fig. 5 to 6, show the design of fuzzification of input for *X* and *Y* using IT2MF Editor, there were 2 trapezoidal and 9 triangular membership functions within the range of -6 to 6 for input processes, while all 11 triangular membership functions is used for output *Z* can be seen on Fig. 7.

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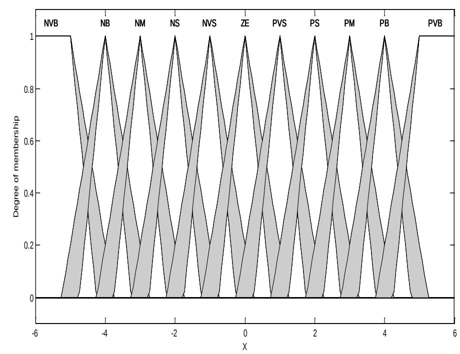

Figure 5: The Fuzzy Membership Function For Input Variables Of X

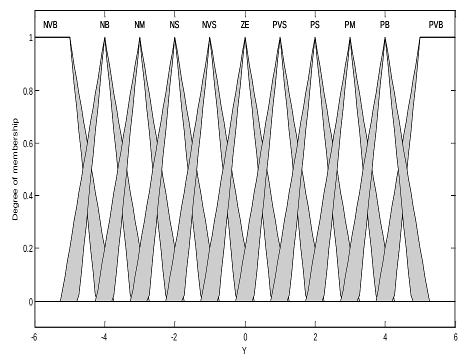

Figure 6: The Fuzzy Membership Function For Input Variables Of Y

FOU is design within the range of 50% uncertainty by giving ± 25% of their upper and lower fuzzy type-1 membership function.

Base on Table III, the antecedent (X,Y) and consequent (Z) is chosen depend on the max value of their membership degree. There are 17 rules base after reduction of their membership degree in year 2005 as an example and it's accomplish in the IT2 Rule Editor FIS:

[R1] IF X is PB AND Y is PB THEN Z is PM
[R2] IF X is ZE AND Y is PM THEN Z is PB
[R3] IF X is PS AND Y is NVS THEN Z is NVS
[R4] IF X is PM AND Y is NVS THEN Z is NVS
[R5] IF X is NVB AND Y is NVS THEN Z is NS
[R6] IF X is NM AND Y is NS THEN Z is NVS

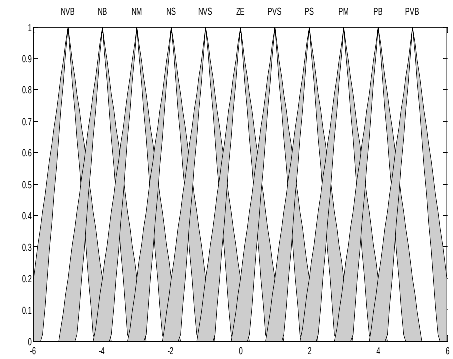

Figure 7: The Fuzzy Membership Function For Output Variable Of Z

[R7] IF X is NVS AND Y is NS THEN Z is NVS
[R8] IF X is PVS AND Y is NVS THEN Z is NS
[R9] IF X is NS AND Y is NS THEN Z is PS
[R10] IF X is NM AND Y is NVS THEN Z is PVS
[R11] IF X is PM AND Y is PVS THEN Z is NVB
[R12] IF X is NVS AND Y is PVB THEN Z is NS
[R13] IF X is PB AND Y is NVB THEN Z is PVB
[R14] IF X is NVB AND Y is PVS THEN Z is NVB
[R15] IF X is PVS AND Y is NVB THEN Z is PVS
[R16] IF X is NS AND Y is NVS THEN Z is NS
[R17] IF X is PVB AND Y is NS THEN Z is NVS.

The interval type-2 rule viewer displays a roadmap of the whole interval type-2 fuzzy inference process by giving their input values and shows one calculation at a time in great detail.

3.4. Post processing of Interval Type-2 FLS

In this section forecast load difference is calculated by Eq. (13) i.e.

$$Forecast\ LD_{MAX}(i) = Forecast\ VLD_{MAX}(i) + TLD_{MAX}(i) \quad (13)$$

To calculate the peak load forecasted in the year ith (MW) is expressed by Eq. (14)

$$P'_{MAX}(i) = MaxWD(i) + \frac{(ForecastLD_{MAX}(i) \times MaxWD(i))}{100} \quad (14)$$

Table IV: The Biggest Value (Max Rule) Of Membership Degree Is Used To Choose Their Fuzzy Set

Type of Holiday	**Holiday forcasted in year 2005**	**Variable**	VLD_{Max}	**Membership Degree Type-1 Fuzzy set (μ)**											**Max rule**
				NVB	**NB**	**NM**	**NS**	**NVS**	**ZE**	**PVS**	**PS**	**PM**	**PB**	**PVB**	
Public	**New Year Day**	**Input *X***	3.89760	0	0	0	0	0	0	0	0	0.1024	**0.8976**	0	PB
		Input *Y*	3.50129	0	0	0	0	0	0	0	0	0.4987	**0.5013**	0	PB
		Output *Z*	3.11313	0	0	0	0	0	0	0	0	**0.8869**	0.1131	0	PM

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To find out how far a method to process a particular value when compared with other methods that have been used, or with a value that already exists is successful, one needs to count the difference between values with the calculation method that has real value. This is often called the calculation of the percentage errors in accordance with Eq. (15).

$$Error(\%) = \left| \frac{P'_{MAX}(i) - MaxSD(i)}{MaxSD(i)} \right| \times 100 \quad (15)$$

4. VERIFICATION AND RESULT

Table V presents the calculation results of forecasting error IT2FLS using data from various types of load conditions for the holidays in year 2005 and 2006 respectively. The implementation of IT2FLS has been presented briefly on Table V.

The test results showed a very accurate forecasting with the mean absolute percentage error (MAPE) of 1.033% and 1.424% in the year 2005 and 2006 respectively. The highest and lowest of forecasting percentage error of holidays in Bali in year 2005 were 4.162% and 0.043% and in year 2006 were 8.309% and 0.025% respectively.

The actual load presents on Table V had the lowest and highest electric load demand where on Nyepi has the smallest amount of power demand compare among others holidays. However, during this day, public service such as hospital and hotel continue to operate with possibly minimum activities, including the use of power. This indicates that throughout the island, the amount of power is used only for important load. Contrast phenomena can be observed on Christmas and New Year holiday where the demand of power usually reaches the highest amount. This is not surprising because during this festive season, many local people and tourists celebrate the events without any rules such as those in Nyepi Day

5. CONCLUSION

It is concluded that STLF for holidays in Bali electrical system using the method of IT2FIS in this case is found on MAPE were relatively small, less than 1.5%. This result was relatively small compare to standard MAPE permitted, in addition this value less than MAPE values of other researches using fuzzy method.

Holiday in Bali are unique because they have many kind of celebrations (some sacred days) but Nyepi is the most important of the island's religious days, because the activities in all over the Bali island is stopped for 24 hours.

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Table V: Short Term Load Forecasting Results On Holidays In Year 2005 And 2006

Types of Holidays	Name	Year 2005			Year 2006		
		P'Max IT2FIS (MW)	Actual Load MaxSD (MW)	Error (%)	P'Max IT2FIS (MW)	Actual Load MaxSD (MW)	Error (%)
Public Holidays	New Year	364.381	364.800	0.115	360.438	361.200	0.211
	Independence Day	381.390	379.500	0.498	372.140	371.100	0.280
Islamic Holidays	'Idul Adha	356.402	355.900	0.141	364.245	366.500	0.615
	Muharram (Islamic New Year)	385.662	386.500	0.217	367.048	365,300	0.479
	Maulid	389.067	388.900	0.043	379.599	381.300	0.446
	Isra' Mi'raj	382.860	381.300	0.409	373.229	374.400	0.313
	'Idul Fitri	383.568	374.000	2.558	387.888	391.400	0.897
		390.328	376.400	3.700	389.071	388.900	0.044
Christian Holidays	Good Friday	389.638	394.800	1.308	385.157	391.900	1.721
	Ascension	397.711	394.300	0.865	380.121	389.400	2.383
	Easter	380.881	378.900	0.523	372.865	378.700	1.541
	Christmas Day	373.815	378.100	1.133	413.575	413.900	0.079
Hindu's Holidays	Penampahan Galungan Day	346.265	361.300	4.162	384.382	381.500	0.755
	Galungan Day	347.405	349.800	0.685	367.535	367.200	0.091
	Manis Galungan Day	327.900	322.900	1.548	381.906	382.000	0.025
	Kuningan Day	372.628	374.200	0.420	361.778	383.000	5.540
	Nyepi or Silent Day (Hindus New Year)	209.489	211.900	1.138	202.394	203.300	0.446
	Saraswati	363.025	362.700	0.090	411.247	379.700	8.309
	Pagerwesi	372.604	371.000	0.432	373.847	374.000	0.041
Buddhist Holidays	Imlek (Chinese New Year)	387.770	381.100	1.750	367.840	370.400	0.691
		390.795	388.300	0.643	379.600	382.200	0.680
	Waisak	375.503	374.200	0.348	380.965	360.300	5.736
			Max	**4.162**		**Max**	**8.309**
			Min	**0.043**		**Min**	**0.025**
			MAPE	**1.033**		**MAPE**	**1.424**

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