Very short term load forecasting peak load time using fuzzy logic

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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 characteristics 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]
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 Reshereaches 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 prepared daily 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<sub>MAX</sub>). 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<sub>max</sub>) on the previous four days at the same hour before the load time is analyzed.

\[
MaxWD_d(i) = \frac{WD_d(i)d-4 + WD_d(i)d-3 + WD_d(i)d-2 + WD_d(i)d-1}{4}
\]

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

\[
LD_{max}(i) = \frac{MaxSD(i) - MaxWD(i)}{MaxWD(i)} \times 100
\]

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

\[
VLD_{max}(i) = LD_{max}(i) - TLD_{max}(i)
\]

![Flow Chart of Research](image-url)

**Figure 2.** Flow Chart of Research
a) Electrical power at 22.00 First Friday in October 2013 \((R_1-2013)\)

\[
\begin{align*}
\text{Max WD}(R_1-2013)_{d,1} & = 22.345 \text{ MW} \\
\text{Max WD}(R_1-2013)_{d,2} & = 20.432 \text{ MW} \\
\text{Max WD}(R_1-2013)_{d,3} & = 19.700 \text{ MW} \\
\text{Max WD}(R_1-2013)_{d,4} & = 21.735 \text{ MW} \\
\text{Max SD} & = 20.564 \text{ MW} \\
\text{Max WD}(R_1-2013) & = 21.735 + 19.700 + 20.432 + 22.345 \\
& = 21.053 \text{ MW} \\
\text{LD}_{\text{MAX}}(R_1-2013) & = \frac{\text{Max SD}(R_1-2013) - \text{Max WD}(R_1-2013) \times 100\%}{\text{Max WD}(R_1-2013)} \\
& = \frac{20.564 - 21.053 \times 100\%}{21.053} \\
& = -0.02322 \\
\text{Max WD}(R_1-2013) & = 20.137 + 23.211 + 19.887 + 23.211 \\
& = 21.612 \text{ MW} \\
\text{LD}_{\text{MAX}}(R_1-2014) & = \frac{\text{Max SD}(R_1-2014) - \text{Max WD}(R_1-2014) \times 100\%}{\text{Max WD}(R_1-2014)} \\
& = \frac{21.437 - 21.612 \times 100\%}{21.612} \\
& = -0.00808 \\
\text{TLD}_{\text{MAX}}(R_1-2014) & = \frac{\text{LD}_{\text{MAX}}(R_1-2013) + \text{LD}_{\text{MAX}}(R_1-2014)}{2} \\
& = \frac{-0.02322 + (-0.00808)}{2} \\
& = -0.016 \\
\text{VLD}_{\text{MAX}}(R_1-2014) & = \frac{\text{LD}_{\text{MAX}}(R_1-2014) - \text{TLD}_{\text{MAX}}(R_1-2014)}{2} \\
& = \frac{-0.00808 - (-0.016)}{2} \\
& = -0.024 \\
\end{align*}
\]

b) Electrical power at 22.00 First Friday in October 2014 \((R_1-2014)\)

\[
\begin{align*}
\text{Max WD}(R_1-2014)_{d,1} & = 23.211 \text{ MW} \\
\text{Max WD}(R_1-2014)_{d,2} & = 19.887 \text{ MW} \\
\text{Max WD}(R_1-2014)_{d,3} & = 21.731 \text{ MW} \\
\text{Max WD}(R_1-2014)_{d,4} & = 20.137 \text{ MW} \\
\text{Max SD} & = 21.437 \text{ MW} \\
\text{Max WD}(R_1-2014) & = 20.137 + 23.211 + 19.887 + 21.731 \\
& = 21.612 \text{ MW} \\
\text{LD}_{\text{MAX}}(R_1-2014) & = \frac{\text{Max SD}(R_1-2014) - \text{Max WD}(R_1-2014) \times 100\%}{\text{Max WD}(R_1-2014)} \\
& = \frac{21.437 - 21.612 \times 100\%}{21.612} \\
& = -0.00808 \\
\text{TLD}_{\text{MAX}}(R_1-2014) & = \frac{\text{LD}_{\text{MAX}}(R_1-2013) + \text{LD}_{\text{MAX}}(R_1-2014)}{3} \\
& = \frac{-0.02322 + (-0.00808) + (0.03672)}{3} \\
& = 0.002 \\
\text{VLD}_{\text{MAX}}(R_1-2014) & = \frac{\text{LD}_{\text{MAX}}(R_1-2014) - \text{TLD}_{\text{MAX}}(R_1-2014)}{3} \\
& = \frac{-0.00808 - (0.002)}{3} \\
& = 0.035 \\
\end{align*}
\]

In the same way we will get the values of \(\text{LD}_{\text{MAX}}, \text{TLD}_{\text{MAX}}\) and \(\text{VLD}_{\text{MAX}}\) as shown in Table 1, Table 2 and Table 3.
# Table 1. Calculation Forecasting First Friday on October 2013

| Day | 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 | 19.00 | 21.800 | 20.684 | 23.341 | 22.983 | 22.173 | 22.202 | -0.131 |
|-----|-------|--------|--------|--------|--------|--------|--------|--------|
| 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 3. Calculation Forecasting First Friday on October 2015

| Day | 19.00 | 21.800 | 20.684 | 23.341 | 22.983 | 22.173 | 22.202 | -0.131 |
|-----|-------|--------|--------|--------|--------|--------|--------|--------|
| 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 |

2.2. Calculation of Value of Input Variable Y

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

# Table 4. Calculation second Forecasting second Friday on October 2013

| Day | 12.00 | 19.213 | 19.111 | 18.900 | 20.400 | 19.332 | 19.406 | -0.381 |
|-----|-------|--------|--------|--------|--------|--------|--------|--------|
| 3   | 20.00 | 19.567 | 19.954 | 19.255 | 20.178 | 19.890 | 19.741 | 0.755  |
| 4   | 19.00 | 20.517 | 19.988 | 19.786 | 21.762 | 20.700 | 20.516 | 0.898  |

# Table 5. Calculation second Forecasting second Friday on October 2014

| Day | 12.00 | 19.213 | 19.111 | 18.900 | 20.400 | 19.332 | 19.406 | -0.381 |
|-----|-------|--------|--------|--------|--------|--------|--------|--------|
| 3   | 20.00 | 19.567 | 19.954 | 19.255 | 20.178 | 19.890 | 19.741 | 0.755  |
| 4   | 19.00 | 20.517 | 19.988 | 19.786 | 21.762 | 20.700 | 20.516 | 0.898  |

# Table 6. Calculation second Forecasting second Friday on October 2015

| Day | 12.00 | 19.213 | 19.111 | 18.900 | 20.400 | 19.332 | 19.406 | -0.381 |
|-----|-------|--------|--------|--------|--------|--------|--------|--------|
| 3   | 20.00 | 19.567 | 19.954 | 19.255 | 20.178 | 19.890 | 19.741 | 0.755  |
| 4   | 19.00 | 20.517 | 19.988 | 19.786 | 21.762 | 20.700 | 20.516 | 0.898  |

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 (VLDMAX) forecasting hours. With the same calculation for the second Friday of October between 2013 - 2015 in get the value (VLDMAX) which results can be seen as Table 7.
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 antecedent membership function (X, Y) and consequent (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\textsubscript{MAX} in 2014 and 2015

| Hour | VLD\textsubscript{MAX} | VLD\textsubscript{MAX} | Input | Output |
|------|---------------------|---------------------|-------|-------|
|      | 2014                | 2015                |       |       |
| 22.00| 0.757               | 3.491               | 0.757 | 0.923 | 3.491 |
| 21.00| 0.738               | -1.120              | 0.738 | -0.571| -1.120|
| 20.00| -0.706              | 1.143               | -0.706| 0.792 | 1.143 |
| 19.00| 1.693               | -2.006              | 1.693 | 0.625 | -2.006|

Table 9. Process Rules for Input X in 2015

| Hour | Nilai X | Derajat Keanggotaan | Hemp | Z     |
|------|---------|---------------------|------|-------|
| 22.00| 0.757   | 0.737               | 0.263| ZE    |
| 21.00| 0.738   | 0.77                | 0.23 | ZE    |
| 20.00| -0.706  | 0.22                | 0.79 | ZE    |
| 19.00| 1.693   | 0.48                | 0.52 | ZE    |

Table 10. Process Rules for Input Y in 2015

| Hour | Nilai Y | Derajat Keanggotaan | Hemp | Z     |
|------|---------|---------------------|------|-------|
| 22.00| 0.923   | 0.69                | 0.31 | ZE    |
| 21.00| -0.571  | 0.18                | 0.62 | ZE    |
| 20.00| -0.792  | 0.75                | 0.29 | ZE    |
| 19.00| 0.625   | 0.81                | 0.17 | ZE    |

Table 11. Process Rules for Output Z in 2015

| Hour | Nilai Z | Derajat Keanggotaan | Hemp | Z     |
|------|---------|---------------------|------|-------|
| 22.00| 3.491   | 0.68                | 0.12 | PVS   |
| 21.00| -1.120  | 0.35                | 0.65 | ZE    |
| 20.00| 1.143   | 0.35                | 0.65 | PVS   |
| 19.00| -2.006  | 0.12                | 0.88 | ZE    |
Table 12. Basic Rules table (fuzzy rules) for forecasting the year 2015

| Antecedent | Cons | Output |
|------------|------|--------|
| ZE ZE ZE | 6 6 6 | PVS/ZE |
| ZE ZE ZE | 6 6 7 | PVS |

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

| Antecedent | Cons | Output |
|------------|------|--------|
| ZE ZE ZE | 6 6 6 | LDMAX |
| ZE ZE PVS | 6 6 6 | PMAX |

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 ta\' 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   | $VLD_{MAX}$ | $LDMAX$ | $VLDMAX$ | $WDMAX$ | $P'MAX$ | $\text{Forecast LDMAX}$ | $\text{Forecast PMAX}$ | $\text{Actual Load}$ | $\text{Error (%)}$ | $\text{MAPE Average}$ |
|-------|-----|-----|-----|-----|-----|------------|---------|-----------|---------|--------|--------------------------|--------------------------|------------------------|----------------|-------------------|
| 22.00 | 19.789 | 23.789 | 20.764 | 21.367 | 22.214 | 21.427 | 3.6720 | 0.1809 | 3.4911 | 2.7625 | 0.5296 | 22.008 | 22.144 | 0.7026 |
| 23.00 | 20.400 | 21.324 | 23.008 | 21.700 | 21.286 | 21.608 | 1.4900 | 0.3702 | 1.1200 | 2.0028 | 2.725899 | 21.095 | 21.286 | 0.3962 |
| 20.00 | 21.286 | 20.477 | 23.236 | 23.008 | 22.357 | 22.002 | 3.6146 | 0.4714 | 1.1433 | 0.7618 | 1.239687 | 22.175 | 22.357 | 0.3960 |
| 29.00 | 23.900 | 24.112 | 22.134 | 23.236 | 23.008 | 23.346 | 1.4457 | 0.5600 | 2.0056 | 2.5276 | 1.907649 | 22.008 | 23.008 | 0.5296 |

In Table 14, we can find the average error value used Fuzzy Logic load at First Friday October 2015 (22.00; 21.00; 19.00:18) have MAPE around 0.6244 %. Actual and forecast peak load time First Friday on October 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 forecasting. The membership function can be expanded to increase the accuracy of the model and model. Expanded membership function may shrink the data range for resulting more accurate forecasting results.

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