Forecasting of Peak Load Current In Transformer Using Fuzzy Logic

Dewanto Indra Krisnadi, Rudy Setiabudy, Iwa Garniwa.

Abstract— In the operation of the transformer, peak load current control is crucial to maintaining the life of the transformer. The desire for information on forecasts for peak load currents for the expected days is needed. This research is attended to obtain the value of forecasts of peak load current on transformer by applying Fuzzy Logic which is carried out in short-term forecast method. Data employed for forecasting short-term loads are historical load current data and Temperature winding data. Historical data captures the peak load current data on a power transformer in the Substation employed as a reference for establishing the rules in Fuzzy Logic. The model is carried out by employing fuzzy logic where the forecast result of the peak load current is compared with the actual peak load current. The result is the percentage of error in fuzzy logic ranged from 0.374% to 15.789% with an average of 4.159%.

Index Terms— Load Forecasting , Peak Load Current, Power Transformer, Fuzzy Logic, Fuzzification, Fuzzy Inference System and Defuzzification.

1 Introduction

The method of estimating the electrical load is a method of estimating the amount of electrical load in the future based on historical data from the existing load history. Based on the forecast period can be split into three categories, particularly: short term, medium term, and long-term. In preparing forecasts there is no precise formula, accordingly, it is crucial to decide the proper technique or method in accommodating a forecast [1, 2].

Load forecasting is an essential aspect of establishing a model of electrical and operating system planning. Basic operating functions such as economic dispatch, fuel scheduling and maintenance of generating units can be performed efficiently with detailed estimates[3].

The nature of electricity demand depends on the type of planning and level of accuracy required. Therefore, demand can be described as annual demand, peak load demand, or load duration curves such as daily, weekly or yearly [4].

Forecasts about the load will ordinarily deal with to early data or historical data. Several factors can influence the quality of previous loads such as time, climate, load growth and so on. Climate factors consisting of temperature, humidity, and the weather ordinarily have a substantial effect.

In the operation of a power transformer, load monitoring is of particular concern especially during peak loads. Therefore it is necessary to predict the future peak load current value to anticipate the load state.

This research aims to set up a model with a fuzzy logic method to estimate the peak load current per day that will appear in a power transformer. The short-term forecast method is taken up to estimate the peak load current that will take place each day.

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2 Methodology

2.1 Fuzzy Logic Modeling Flow

Fuzzy logic is the science of systematically considering the rules of thinking with a value that is not absolute or fuzzy. In the understanding that a value determines not have to be black or white but can be in a range between the two or gray. In fuzzy logic known membership degrees that have a range of values 0 to 1. Unlike digital logic that involves merely 1 or 0 values (yes or no), fuzzy logic is a thing of logic that allows the value of fuzziness between right and wrong. In fuzzy logic theory a value can be true or false simultaneously. But how often the presence and error of thing depends on the substance of membership it has [5, 6].

Fuzzy Inference System (FIS) is a system that can carry out reasoning like human reasoning in principle. The transform in FIS can be considered at in Figure 1.

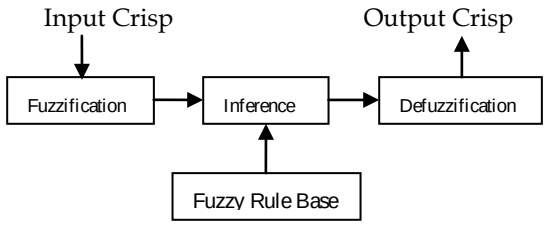

Fig. 1. Process in FIS

The peak load current forecasting method is based on the fuzzy logic method using Matlab software. The assessment proceeding of this fuzzy logic modelling is the approximate data of peak load current for one day ahead and later worked out to assess the peak load current forecast for the next few days. The estimation proceeding will be observed its error value by calculating Mean Absolute Percentage Error (MAPE) as the succeeding formula [4] :

$$MAPE = (1/N) \sum |[Actual - Forcasted] / Actual| \times 100\% \quad (1)$$

N = The number of forecasting periods

While the flow diagram of the Fuzzy Logic modelling process can be identified in Figure 2.

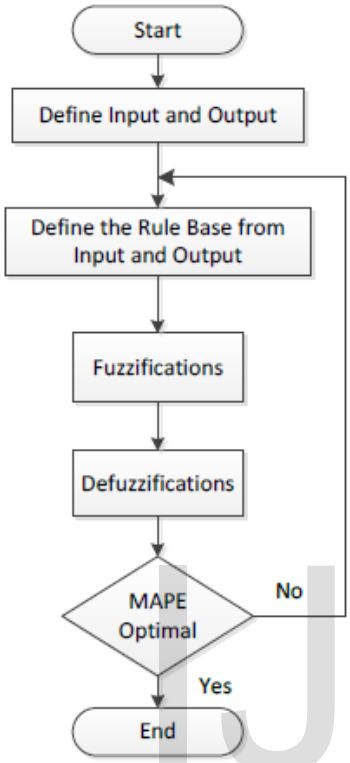

Fig. 2. Flow Chart of Fuzzy Logic Modelling Process

3 Forecasting Model

This short-term forecast computing model is set up employing fuzzy logic using Matlab software. The procedure of establishing Fuzzy logic system on Matlab using Fuzzy toolbox starts with creating Input and output of Fuzzy Inference System (FIS), representing fuzzy rule, defuzzification with Mamdani rule and determining forecasting result.

3.1 Sistem Fuzzy Inference System (FIS).

the input of this system is the historical load current and temperature, thus the output is the estimated load current. The design is worked out employing Fuzzy Logic Designer (FLD) involved in Matlab, as illustrated in Figure 3.
FLD consists of 3 major chart particular input, FIS process and output. In constructing this model, 2 inputs are employed ie Historical Load and Temperature. In input, historical load and output variables, the load forecast involves a variable value between 1000-1420. While the variable input temperature takes a variable value 50-80. The type of design that employs Mamdani FIS method with defuzzification process is adopted Centroid method.

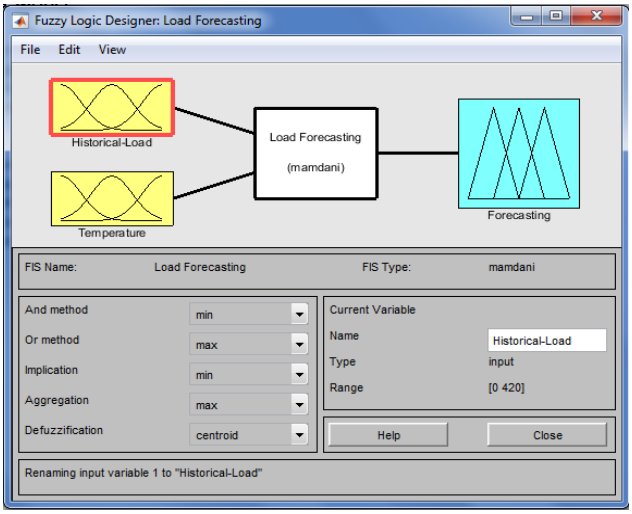

Fig. 3. FIS designer forecasting load with Fuzzy

The next step is to figure out the membership function of the Historical Load variable. In this case, membership function consists of 7 membership functions are {Minimum (Min), Very Small (VS), Small (S), Medium (M), Big (B), Very Big (VB), Maximum (Max)}. This process is set up using the Membership Function Editor as illustrated in Figure 4.

Fig. 4. Membership Function Editor Historical Load

The type of curve representation applied for each membership function for this historical load input variable is a triangular curve. While the values for each of the membership functions employed in the historical load variable are derived from the equation below:

$$\mu(x) = \begin{cases} 0; & x \le a \text{ or } x \ge c \\ (x-a)/(b-a); & a \le x \le b \\ (c-x)/(c-b); & b \le x \le c \end{cases} \quad (2)$$

The membership function of the temperature variable is split into: low, average and high. The temperature membership function is set up in the same sense as the early step, but the temperature curve representation taken up is a combination of diminished linear, triangular, and elevated linear curve (figure 5), so there are three types of formulas for membership function.

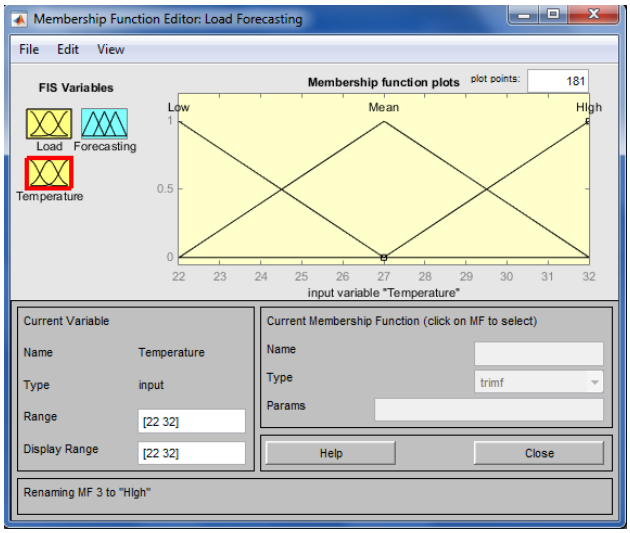

Fig. 5. Membership Function Editor Temperature

The low Fuzzy set :

$$\mu(x) = \begin{cases} (x-a)/(b-a); & a \le x \le b \\ 0; & x \ge b \end{cases} \quad (3)$$

where: a = minimum x value, b = maximum x value

The average fuzzy set :

$$\mu(x) = \begin{cases} 0; & x \le a \text{ or } x \ge c \\ (x-a)/(b-a); & a \le x \le b \\ (c-x)/(c-b); & b \le x \le c \end{cases} \quad (4)$$

where: a = minimum x value, b = value of x with maximum membership function value, and c = maximum x value

High fuzzy set:

$$\mu(x) = \begin{cases} 0; & x \le a \\ (x-a)/(b-a) & a \le x \le b \\ (c-x)/(c-b) & x \ge a \end{cases} \quad (5)$$

where: a = minimum x value, b = value of x with maximum membership function value, and c = maximum x value

The membership function of the load forecast output variable is carried out in the same way as the preceding step. The membership function for the output variable forecasting the load current is broken into: Minimum (Min), Very Small (VS), Small (S), Medium (M), Big (B), Very Big (VB), Maximum (Max)).

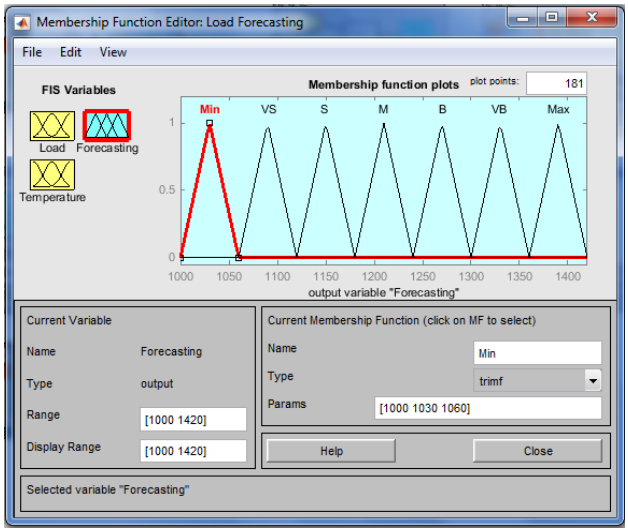

Fig. 6. Membership Function Editor Load Forecasting

The type of curve representation employed for each membership function for the forecast output variable is the triangle curve, equal to the curve adopted for the input variable Historical Load. The value for each of the membership functions applied in this Historical Load variable is corresponding to equation (2).

3.2 Rule Editor Fuzzy

The fuzzy rules applied are the predefined rules based on the load characteristics to be predicted. These fuzzy rules are set up applying the Rule Editor as illustrated in Figure 7.

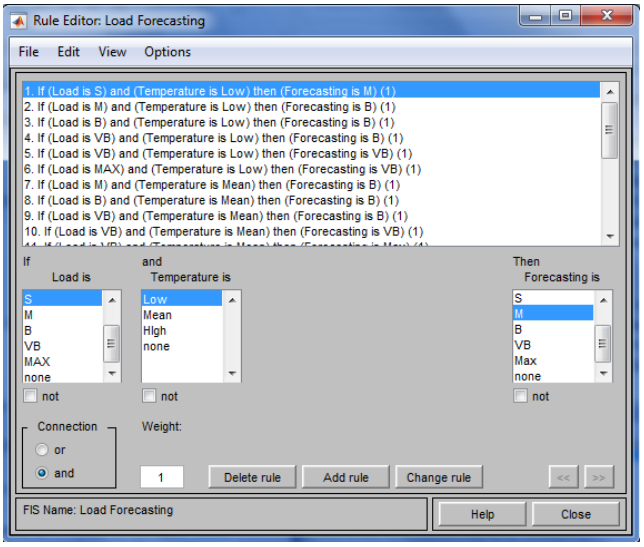

Fig. 7. Rule Editor Load Forecasting

The Fuzzy rule base consists of fuzzy logic statements, which are IF-THEN statements. Rule base is a compilation of rules based on fuzzy logic to describe a certain condition. Arrangement of the rule base is extremely prominent on the precision model, the decision-making stage is worked out based on the rule base design. The If-then rule is correlated with the AND and OR operation logic.

From the exceeding illustration can be identified fuzzy rules signed in the first rule is: "If" historical data is S "and" temperature is low "thus" forecasting is M.

3.3 DEFUZZIFIKASI

After all the rules have been carried out, thus worked out defuzzyfication process using Centroid method. The Centroid method is a crisp solution taken by picking up the centre point (z *) of the fuzzy region as illustrated in Figure 8.

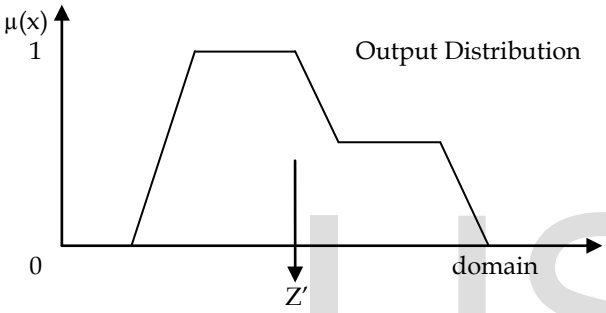

Fig. 8. Defuzzification using center of mass

and formulated:

For the continuous universe $z^* = \frac{\int_Z z.\mu(z)dz}{\int_Z \mu(z)dz}$ (6)

For a discrete universe $z^* = \frac{\sum_{j=1}^{n} z_j \mu(z_j)}{\sum_{j=1}^{n} \mu(z_j)}$ (7)

The formulation of the centroid method will be used to calculate the output value of the fuzzy logic system ie the approximate value of peak load current. The output can be seen in Figure 9.

Once the rule is completed, the rules can be looked at in the Rule Viewer, as presented in Figure 9. In this Rule Viewer we can assess the results of the rules we have set up to forecast the short-term electrical load by entering the values input variables in the input field.

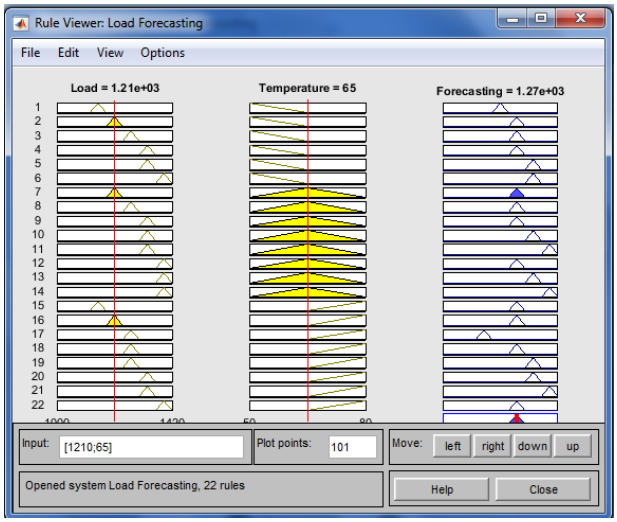

Fig. 9. Rule Viewer Load Forecasting

In Figure 10 can be viewed Surface Viewer in the set up of 3 dimensional output. In the picture can be seen the relationship between the three variables, Temperature, load current and output load forecast. So that can be seen form from various opportunity value of input to its output value.

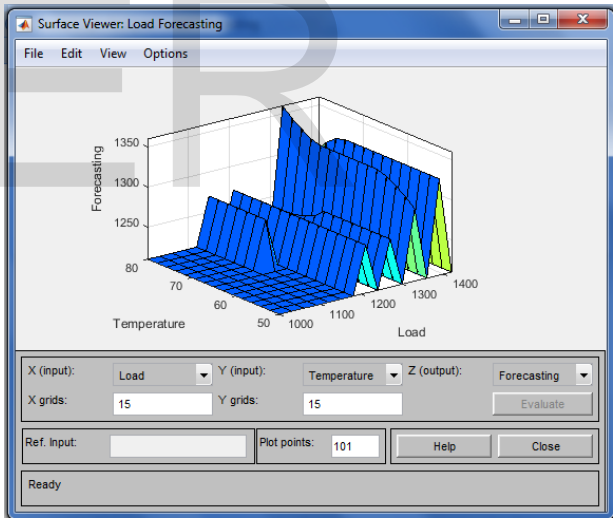

Fig. 10. Surface Viewer Load Forecasting

4 RESULT

The created Fuzzy Inference System (FIS) is assessed by applying it to forecast the peak load current in the short term for several days. In this research will be assessed with sample peak load current on the week day from Monday to Friday 3 March until 7 March 2014.

Table 1 is a forecast result of short-term electrical load current for 5 week days on pre-defined sample days using fuzzy logic. The table consists of information on the actual load, the forecasting load, the difference between the actual and the forecast load, and the percentage of forecasting errors.

In Table 1 the results of load forecasting for the week days by employing fuzzy logic are represented. From the table shows up that the average forecasting error is 4.159%. The biggest forecast errors took place on Thursday ie 15.789% and the smallest error appeared on Monday and Friday with the error percentage of 0.374%. The graph of the difference between forecasting results applying fuzzy logic to the actual load for the weekdays forecast can be looked at in Figure 11.

TABLE 1
Forecast on weekdays

Day	Actual Peak Load Current (A)	Forecasting Peak Load Current (A)	Error (%)
Mon	1335	1330	0.374
Tue	1365	1333	2.344
Wed	1305	1330	1.915
Thu	1045	1210	15.789
Fri	1335	1330	0.374
Mean			4.159
Max			15.789
Min			0.374

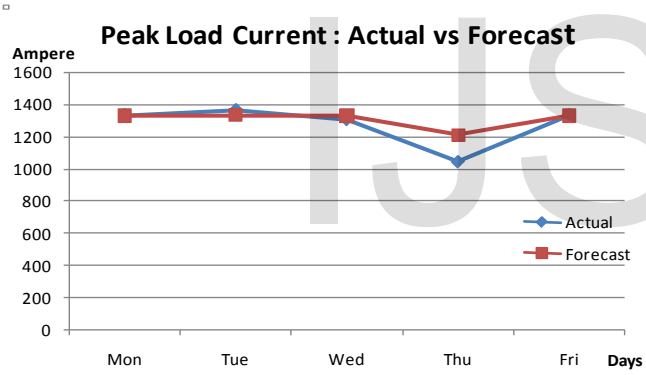

Fig. 11. Graph of peak load current

5 CONCLUSION

The fuzzy logic model developed for the short-term forecasting of the peak load current that will take place on a power transformer provides an appropriate estimation of the error value or Mean Absolute Percentage Error (MAPE) of 4.159%, so that the forecast certainty rate is 95.841%.

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