

Forecasting Electric Energy Demand for the Period 2020 – 2025 in West Rayon Semarang Region of Indonesia

Enda wista sinuraya^{*}, Yoshua Alvin Adi Sutrisno, Tedjo Sukmadi, Bambang Winardi, Erlin Dolphina, Yuli Christyono, Agung Nugroho, Sudjadi, Imam Santoso, Denis, Hermawan, and Nugroho Agus Darmanto

Department of Electrical Engineering, Diponegoro University
Semarang, Central Java
Indonesia

ABSTRACT

The planning process of the development of electric power systems needs a forecasting electrical energy consumption in the future. The forecasting results obtained can be considered for policymakers to formulate measures to be taken for the future. It aims to achieve optimization in the electricity production process. In this research, for the supply of electric energy in Rayon West Semarang, forecasting energy consumption from 2020 to 2025 using fuzzy logic and linear regression. This energy consumption forecasting using historical data / actual accumulated in some period of time from 2015 to 2019. The results of forecasting using fuzzy logic amounted to 825000 MWH in 2020 and 1180000 MWH in 2025. While the results of forecasting by using linear regression amounted to 807974,42 MWH in 2020 and 1054482,29 MWH in 2025. The forecasting results are already approaching the PLN actual data 2020 amounted to PLN 823568 MWH with an error value of 0,17% to fuzzy logic and 1,89% to linear regression.

Key words: Electricity, Consumption Forecasting, Fuzzy Logic, Linear Regression, Rayon West Semarang

1. INTRODUCTION

Electrical energy has a very important role and even becomes a parameter to support the success of a region's development. Therefore, planning and energy management in general, including electricity, need serious attention from local governments. This is also in line with and in line with the increasing role of local governments in managing energy resources [1]. The fulfillment of electrical energy consumption must be anticipated as early as possible by forecasting the consumption of electrical energy so that the supply of electrical energy can be available in sufficient quantities and at an adequate price [2]. Forecasting can be done using conventional statistical methods such as linear regression and some software such as LEAP. Currently, the method of forecasting the consumption of electrical energy has developed rapidly. Intelligent system (artificial intelligence) is a system that is most widely applied by experts for forecasting future electrical energy consumption. Fuzzy logic is a smart system that can be used for forecasting. The application of fuzzy logic as a method of forecasting energy consumption has been introduced by many experts, including E. Srinivas and Amit Jain [3], Kyung-Bin Song [4] and Dr.S. Chentur Pandian [5]. In this final project research will discuss 2 methods, namely the fuzzy logic method using matlab software R2013b and the linear regression method to predict electrical energy consumption in West Semarang District 2020 to 2025. By comparing the results of forecasting the consumption of electrical energy from the two methods it is expected to obtain forecasting results the best electrical energy to meet the consumption of electrical energy in West Semarang Rayon.

2. RESEARCH METHODS

2.1 Fuzzy logic

Fuzzy can also be called vague, fuzzy, or indistinct. Introduced for the first time by Prof. Lotfi A. Zadeh in 1965. In fuzzy logic modeling through several stages, namely fuzzification, rule evaluation, reasoning process (implication), and defuzzification.

In the fuzzification process, the determination of the area and type of the membership function curve is done using a trial and error system. The role of the degree of membership as a determinant of the existence of elements in a fuzzy set. The degree of membership or membership function is the main feature in reasoning with fuzzy logic using the rules that have been designed. To produce output, it is necessary to go through a defuzzification process by reasoning on certain related rule bases in making decisions.

2.2 Linear Regression

Linear regression model is a model that takes into account the cause and effect of each of the independent variables and the dependent variable. The linear regression variables to be correlated consist of variable X as the independent variable and variable Y as the dependent variable, so to estimate the linear regression it is necessary to estimate its parameters using a matrix model.

2.3 Data Collection

The data used in this study were obtained from the results of survey data on agencies or agencies that provide the required data such as BPS (Central Statistics Agency) and PLN (State Electricity Company) as well as other sources from textbooks, internet, journals, papers, final project, technical reports, laws and regulations regarding energy policy and government documents that support this research.

2.4 Data Processing

2.4.1 Classification of Statistical Data

Statistical data includes GRDP in the scope of West Semarang Rayon. The GRDP data used is the 2000 constant price GRDP data when the economy is considered stable so that the GRDP calculation is independent of the influence of the inflation factor.

Table 2.1 GDPRB of West Semarang District 2015-2019.

PDRB West Semarang District (million Rp)					
<i>Tahun</i>	2015	2016	2017	2018	2019
Agriculture	46869,74	47631,02	47420	47489,22	47455,03
Mining And Excavation	6296,56	6436,33	6498,32	6501,97	6536,99
Processing Industry	1114290,1	1174245,4	1236674,6	1300059,9	1367282,09
Electricity, Gas And Drinking Water	52704,48	55161,78	56676,94	60026,05	62933,36
Building	641842	686244,77	720546,05	757392	795992,58
Trade, Hotel and Restaurant	1280206,39	1364057	1446307,77	1521801,27	1609076,74
Transport And Communication	401691,36	425552,3	445044,12	467768,55	492826,42
Finance, Rental & Services	113358,36	119524,37	127161,47	135046,47	134393,12
Services	495728,82	535533,72	565690,36	586252,61	607562,07
TOTAL	4152988	4414387	4652021	4882338	5124058

2.4.2 Electrical Data

Electrical data obtained from PT. PLN (Persero) West Semarang District in the form of data on electric energy exploitation consisting of the number of customers and consumption of electrical energy. The following is the data of the West Semarang Rayon electricity business for 2015-2019

Table 2. 2 Data on the electricity business of West Semarang Rayon 2015-2019

Sector	West Semarang Rayon electricity company				
	2015	2016	2017	2018	2019
- Energy (MWH)	547450	602763	650795	702243	753589
RT	118502	127808	141834	164527	173089
Industri	348651	376193	393208	413405	445857
Commercial	53194	64548	78072	82606	88489
General	27103	34214	37681	41705	46154
- amount	75685	80546	83198	86815	89444
Customer	65196	69461	71736	74591	76182
RT	234	249	283	311	323
Industri	7695	8108	8351	8936	9854
Commercial	2560	2728	2828	2977	3085
General					

2.5. Fuzzy Logic Design

The fuzzy logic modeling process in this study uses the help of the fuzzy logic toolbox found in matlab. By using this toolbox, a Fuzzy Inference System (FIS) can be built in the Matlab work environment. In this study, the type used is the Mamdani type FIS. Fuzzification is the formation of input and output membership functions. In this final project, the design of the FIS system uses 5 input variables and 1 output variable. The input variables used are the number of household, industrial, commercial, public service, and GDP (Product Domestic Regional Gross) customers of PLN. For the output variable used is the forecasting of electrical energy consumption. Each variable has a language variable (fuzzy set). The set of language variables (fuzzy set) is represented in the form of a triangular membership function.

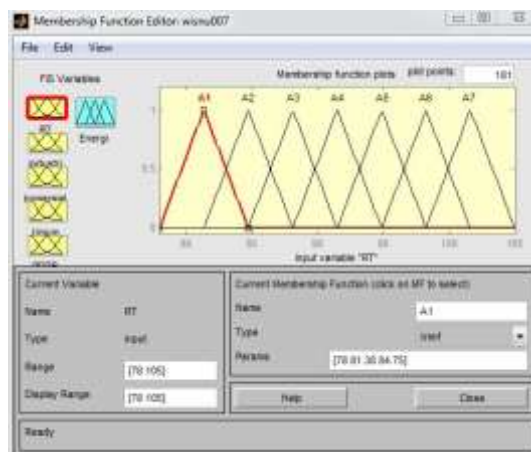


Figure 2.1 Membership function

By considering the relationship between various inputs and outputs, a rule base can be made for forecasting the following years.

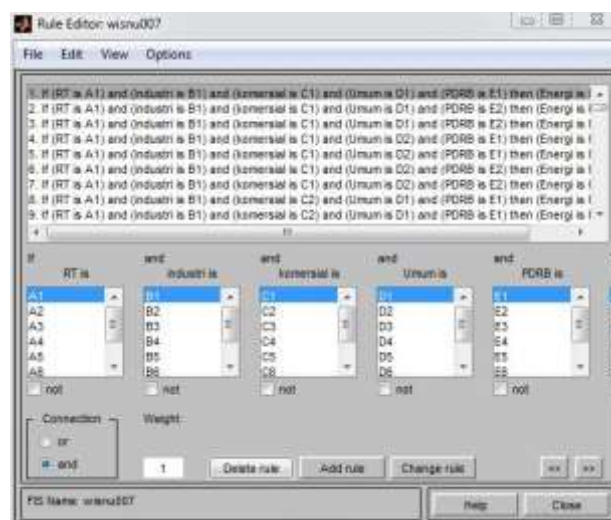


Figure 2.2 Rule editor

2.6. Linear Regression Design

In linear regression modeling, it is obtained by using historical data from previous years. The calculation of the coefficients a and b can be described as follows

$$a = \frac{\sum Y - b \sum X}{n}$$

$$b = \frac{\sum XY - \frac{\sum X \sum Y}{n}}{\sum X^2 - \frac{(\sum X)^2}{n}}$$

So that the linear regression equation is obtained:

$$Y = a + b X$$

3. RESULTS AND ANALYSIS

3.1. Fuzzy Logic

The results of forecasting energy consumption using the fuzzy logic method in West Semarang District from 2020 to 2025 can be seen in Table 3.1.

Table 3.1 Forecasting energy consumption using fuzzy logic method

Year	Energy Consumption (MWH)
2015	825000
2016	890000
2017	9980000
2018	1080000
2019	1180000

From the results of forecasting energy consumption using fuzzy logic in Table 3.1

Based on the results of forecasting the consumption of electrical energy in West Semarang District in 2025 with fuzzy logic, the result is 1180000 MWH, while the electricity consumption in 2020 is 825000 MWH. This shows that there is an increase of 355000 MWH in the span of 5 years. This can be caused by an increase in the number of customers and an increase in the GDP (Gross Domestic Product) economic sector figure.

3.2 Regresi Linear

The results of forecasting energy consumption using the linear regression method in West Semarang District from 2020 to 2025 can be seen in Table 3.2

Table 3.2 Forecasting energy consumption by linear regression method

Sector	Forecasting Electrical Energy Consumption (MWH)				
	2021	2022	2023	2024	2025
household	189363	205430	222293	239992	258566
Industry	468800	496137	524877	555093	586861
Commercial	100639	110644	121174	132259	143926
General	49173	52952	56867	60925	65130
TOTAL	807974	865163	925212	988269	1054482

From the results of forecasting energy consumption using linear regression in Table 3.2, a graph can be made as shown in Figure 3.1

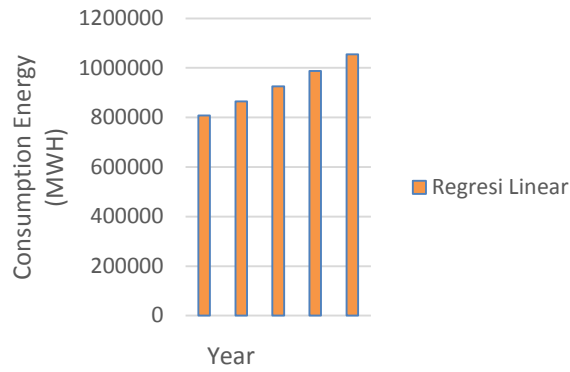


Figure 3.1. Forecasting energy consumption by linear regression method.

Based on Figure 5, the results of forecasting total electrical energy consumption in West Semarang District in 2025 with the linear regression method, the results are 1054482.29 MWH, while energy consumption in 2020 is 807974.42 MWH. This means that there is an increase of 246507.87 MWH in the span of 5 years. This can be caused by an increase in the economy of the Gross Regional Domestic Product.

3.3 Comparison of Forecasting Results of Electric Energy Consumption with PLN 2020 Actual Data

The results of the forecasting of electrical energy consumption obtained are then compared with the actual data in 2020. The complete comparison of the forecast results with the actual data for 2020 West Semarang Rayon is shown in Table 3.3

Table 3.3 Comparison of the results of forecasting energy consumption with actual data for 2020

Comparison of Forecasting Results of Electrical Energy	
Year	2020
Data Aktual (MWH)	823568
LEAP (MWH)	826799
Error LEAP(%)	0,39
Logika Fuzzy (MWH)	825000
Error Logika Fuzzy (%)	0,17
Regresi Linear (MWH)	807974,42
Error Regresi Linear (%)	1,89

Based on Table 3.3, a comparison graph of energy consumption forecasting against PLN 2020 actual data can be made as shown in Figure 3.2. The results of forecasting electricity consumption for 2020 are close to the actual data with an error of 0.39% for the LEAP method, 0.17% for fuzzy logic method and 1.89% for linear regression method. From these results it can be concluded that the fuzzy method shows the most accurate forecasting results with the smallest error value. Forecasting results using the LEAP method are said to be good because they have an error value of 0.39% so that they can be used as a reference in the comparison of electrical energy forecasting between fuzzy logic and linear regression methods.

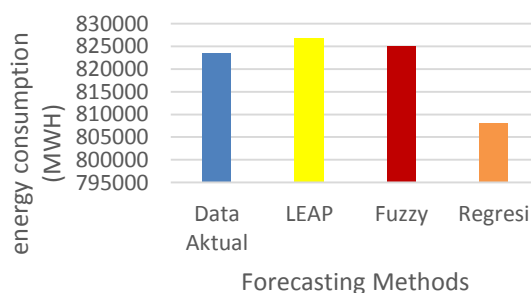


Figure 3.2 Forecasting energy consumption with linear regression method.

3.4 Comparison of the results of forecasting energy consumption with fuzzy method and linear regression on LEAP

The results of forecasting the electricity consumption of West Semarang Rayon in 2021 to 2025 using fuzzy logic and linear regression are then compared with forecasting energy consumption of West Semarang Rayon in 2021 to 2025 using the LEAP method from previous research. The complete comparison of the results of forecasting energy consumption for West Semarang Rayon in 2021 to 2025 is shown in Table 3.4

Table 3.4 Comparison of the results of forecasting energy consumption with fuzzy method and linear regression on LEAP

Year	Energy Consumption Forecasting (MWH)				
	LEAP	Fuzzy	Regresi linear	Error Fuzzy (%)	Error Regresi Linear (%)
2021	826799	825000	800147,75	0,218	3,223
2022	906985	890000	856855,65	1,873	5,527
2023	994616	998000	916398,10	0,340	7,864
2024	1090381	1080000	978917,63	0,952	10,223
2025	1195034	1180000	1044563,98	1,258	12,591
	Rata-rata error (MAPE)			0,928	7,886

From the comparisons shown in Table 6. It can be seen that the electrical energy consumption between LEAP and fuzzy software does not differ much. This can be seen in Table 4.11 shows that the small error average value is 0.928%, while forecasting energy consumption using linear regression has an average error of 7.886%. This shows that forecasting the energy consumption of West Semarang Rayon in 2021 to 2025 using the fuzzy logic method has greater accuracy than the linear regression method.

4. CONCLUSION

Based on the results of forecasting the consumption of electrical energy in West Semarang District in 2025 using the fuzzy logic method, the forecast results are 1180000 MWH, while the electricity consumption in 2021 is 825000 MWH. This shows that there is an increase of 355000 MWH in the span of 5 years. Forecasting using the linear regression method, the forecast results are 1054483.29 MWH in 2025 and 807974.42 MWH in 2021, so that in the span of 5 years there is an increase of 246507.87 MWH. This is due to an increase in population so that customers will increase, as well as an increase in the GDP (Gross Domestic Product) sector of the economy. The results of forecasting fuzzy logic, linear regression and LEAP compared to the actual PLN data in 2020 obtained an error value of 0.17% in fuzzy logic, 1.89% in linear regression, and 0.39% in LEAP. From these results it can be concluded that the fuzzy method shows the most accurate results with an average error value of 0.928, while the linear regression has an average error value of 7.886%.

REFERENCES

- [1] Suhono, "Study of Planning for Electrical Energy Demand and Supply in Sleman Regency Using LEAP Software". Gadjah Mada University, Yogyakarta, 2010.
- [2] Sulasno. 2001. Electrical Power Distribution Engineering and System Edition I. Semarang: Diponegoro University Publishing Agency.
- [3] E. Srinivas and Amit Jain. "A Methodology for Short-Term Load Forecasting Using Fuzzy Logic and Similarity". The Conference on advances in Computational Intelligence Applications in Power, India, March, 2009.
- [4] Song, Kyung-Bin. "Short-Term Load Forecasting for the Holiday Using Fuzzy Linear Regression Method". IEEE Trans.Power syst., vol PWRS-3, pp.50-55, 1997.
- [5] Pandian, S. Chenthur, "Fuzzy Approach for Short Term Load Forecasting". The Conference on advances in Computational Intelligence Applications in Power, India, September, 2005
- [6] Albab, Muhammad Hassan. "Projection of APJ Pekalongan's 2014-2018 Electrical Energy Demand Using Fuzzy Logic Method", Final Project Report, Department of Electrical Engineering, Diponegoro University, Semarang, 2015.
- [7]PT.PLN (Persero) West Semarang Rayon "West Semarang Rayon working area".
- [8]PT.PLN (Persero) West Semarang Rayon "Electricity Concession Data 2015-2019"
- [9] Central Statistics Agency (BPS) Semarang City, Semarang City in Figures 2020.
- [10] Kartika, Meigy Restanaswari, "Projection of APJ Pekalongan's 2014-2018 Electrical Energy Demand Using Leap Software", Final Project Report, Department of Electrical Engineering, Diponegoro University, Semarang, 2015.
- [11] Naba, Agus, "Fast Learning Fuzzy Logic, Using Matlab", Yogyakarta: Andi. 2008.

- [12] Nhurkoliq, Nahar. "Comparative Analysis of Fuzzy Logic Methods with Backpropagation Requirements Network in Forecasting Long-Term Electrical Energy Demand in Indonesia Until 2022", Final Project Report, Department of Engineering Electrical Engineering, Diponegoro University, Semarang, 2014.
- [13] Yasa, I Nyoman Sudharma, "Peak Load Analysis Based on Projection of Electricity Demand for West Semarang District 2015-2019 Using LEAP Software", Final Project Report, Department of Electrical Engineering, Diponegoro University, Semarang, 2015.
- [14] Gujarati, Basic Econometrics, Jakarta: Erlangga, 2002.
- [15] Sudjana, Statistical Methods, Bandung: Tarsito, 2002.
- [16] Gujarati, Fundamentals of Econometrics, Jakarta: Erlangga, 2006.
- [17] Supranto, J. Statistical Theory and Applications. Graedia. Jakarta. 2001.
- [18] R. Munir. "Numeric Method", Informatics, Bandung, 2010.
- [19] Hermawan and Karnoto. Electrical Power System Development Planning. Semarang: Diponegoro University Publishing Agency.2008.
- [20] Nugroho, Agung, Information System of Electricity Demand Forecasting Electrical Power Distribution System of PT PLN (Persero) APJ Semarang. Semarang : Diponegoro University.2010.