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Implementation of Mamdani Fuzzy Logic on PLN Electricity Sales in East Java

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Abstract

This research aims to provide innovation in the development of a smarter and more adaptive electricity distribution system, able to face the challenges that arise in the digital era. The results of this research can be a guide in improving the efficiency and reliability of electricity sales. The experimental method is applied by implementing mamdani fuzzy logic on PLN electricity sales data in East Java. From the results of the application of mamdani fuzzy by comparing the prediction results with the original data, the Mean Absolute Error (MAE) result is 0.17% and the Root Mean Squared Error (RMSE) value is 0.21%. So it can be concluded that fuzzy logic mamdani method can be used in predicting electricity sold and provide valuable guidance for PLN in improving the efficiency and reliability of electricity sales in the East Java region in a sustainable manner.

Keywords

Electricity Sales, Fuzzy Mamdani, Implementation

INTRODUCTION

In the rapid development of technology and digital transformation, the electricity sector has become one of the main pillars in supporting the sustainability of various aspects of life [1], [2]. The provision of electricity, as an important aspect of community infrastructure, is a priority in an effort to maintain the smooth running of various human activities, both at the household and industrial levels[1]-[7]. Increasing efficiency and optimizing electricity distribution management are the main challenges that need to be overcome, and this is where the role of advanced technology, such as fuzzy logic, where fuzzy logic is used to express data or information that is uncertain or vague so that it can make a positive contribution in forecasting future needs [8]-[10].

This research is focused on the implementation of fuzzy logic with the Mamdani method using the Mamdani method which is often known as the Max-Min Method [8], [11]-[13]. In this study, it is used as optimizing electricity sales by the State Electricity Company (PLN) in the East Java region. Fuzzy logic was chosen because it is able to overcome uncertainty and complexity in decision making, so that it can be an effective instrument in improving the performance of the electricity distribution system [3], [8], [11], [12], [14]-[17].

In previous studies [18]-[26], mamdani fuzzy logic is often applied to predict the amount of production and the amount of future market demand. This research is applied to predict electricity sales with the aim of facilitating production capacity planning, resource optimization, efficient tariff determination, load management, reducing financial losses, and improving customer service.

East Java was chosen as the research location because it is one of the regions with high population density and industrial activity. Therefore, increasing the efficiency of electricity sales can have a significant positive impact on the overall availability of electric power.

By applying fuzzy logic Mamdani method, it aims to find a solution that can improve the accuracy of decision making related to electricity sales. This research is directed to contribute to the development of a more intelligent and adaptive electricity distribution system, capable of overcoming the challenges that arise in this digital era. The results of this research are expected to provide valuable guidance for PLN in improving the efficiency and reliability of electricity sales in the East Java region in a sustainable manner.

RESEARCH METHODS

This research applies an experimental approach by implementing fuzzy logic using the Mamdani method on PLN electricity sales data in East Java. The experiment was conducted over a certain period. The research population involves the entire dataset of PLN electricity sales in East Java, with samples taken for three years to reflect significant fluctuations.

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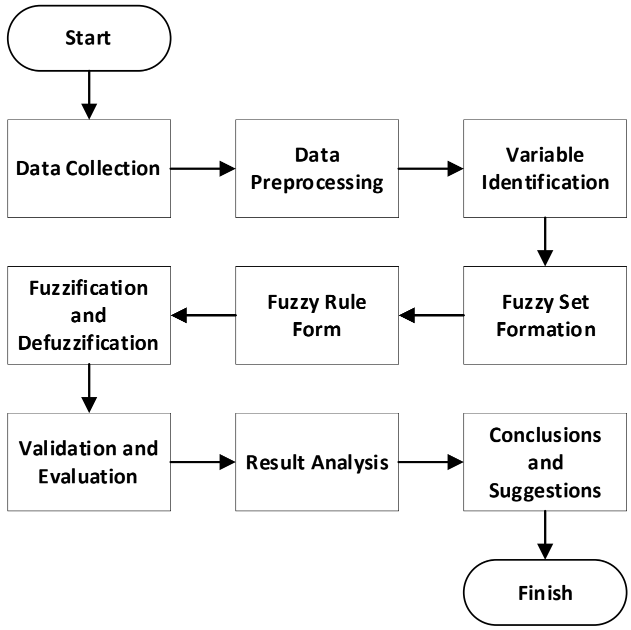

Figure 1. Research method

In the Fuzzyfication stage, input variables are formed into fuzzy sets to enable the calculation of premise truth values for each rule. The input and output variables are further divided into one or more fuzzy sets to continue the calculation process. The formation of fuzzy sets for each variable is through consultation with experts to determine the appropriate fuzzy set boundaries. Third, the formation of fuzzy rules based on domain knowledge and historical data. An example of a generated rule, for example, is "If electricity production is low, installed power is medium, and the number of customers is high then electricity sold is high".

TABLE 1

FUZZY VARIABLES AND SETS

Variables	Set
Input Variables	
Total Electricity Production	Low, Medium, and High
Total Installed Electricity Power	Low, Medium, and High
Number of Electricity Customers	Low, Medium, and High
Output Variables	
Electricity Sales	Low, Medium, and High

RESULT AND DISCUSSION

This research applies Mamdani fuzzy logic to optimize electricity sales management by formulating and managing sales data. This research aims to accurately model the relationship of variables, such as the amount of electricity production, the amount of installed electric power, and the number of electricity customers. Evaluation of model performance uses Mean Absolute Error (MAE) and Root Mean Squared Error (RMSE) metrics to measure prediction accuracy. The contribution of this research involves the development of new analytical methods in the context of electricity sales management by providing practical recommendations to improve the effectiveness of management strategies.

Mean Absolute Error (MAE) Formula:

$$MAE = \frac{1}{n}\sum_{t=1}^{n}|A_t - F_t| \tag{1}$$

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Where, A_t is the actual value in period t, F_t is the predicted value in period t, and n is the total number of periods. Root Mean Squared Error (RMSE):

$$RSME = \sqrt{\frac{1}{n}\sum_{t=1}^{n}(A_t - F_t)^2} \quad (2)$$

Where, A_t is the actual value in period t, F_t is the predicted value at period t,n is the total number of periods.

DATA COLLECTION RESULTS

The data used in this study is PLN data obtained from the East Java Central Bureau of Statistics. The data collected are data on the amount of electricity production, the amount of electric power, the amount of electricity sold, and the number of electricity customers.

TABLE 2

TOTAL ELECTRICITY PRODUCTION

No	Unit (UP3)	Total Electricity Production (KW)		
		2019	2020	2021
1	Surabaya Selatan	4.376.363	4.192.765	4.175.103
2	Surabaya Utara	2.716.864	2.570.060	2.521.112
3	Malang	2.652.838	2.648.381	2.692.484
4	Pasuruan	4.150.688	4.165.875	4.470.439
5	Kediri	2.426.475	2.510.958	2.603.562
6	Mojokerto	4.370.411	4.400.285	4.776.756
7	Madiun	1.319.794	1.384.742	1.427.490
8	Jember	1.572.614	1.715.898	1.860.891
9	Bojonegoro	3.377.163	3.343.589	3.390.033
10	Banyuwangi	1.079.365	1.150.500	1.188.380
11	Pamekasan	1.491.566	1.653.421	1.725.335
12	Situbondo	611.483	658.344	690.610
13	Gresik	2.399.524	2.441.965	2.512.630
14	Sidoarjo	3.873.016	3.808.354	4.050.161
15	Surabaya Barat	2.169.557	2.082.665	2.420.673
16	Ponorogo	818.319	882.427	898.742

TABLE 3

TOTAL INSTALLED ELECTRICITY POWER

No	Unit (UP3)	Total Installed Electricity Power (KW)		
		2019	2020	2021
1	Surabaya Selatan	2.363.603	2.430.122	2.512.546
2	Surabaya Utara	1.567.150	1.579.587	1.614.314
3	Malang	1.712.174	1.789.034	1.884.802
4	Pasuruan	1.822.071	1.887.414	1.962.159
5	Kediri	1.447.252	1.512.929	1.595.622
6	Mojokerto	2.054.507	2.157.137	2.280.775
7	Madiun	890.983	981.310	1.072.814
8	Jember	1.004.809	1.079.814	1.133.458
9	Bojonegoro	1.463.744	1.544.117	1.634.015
10	Banyuwangi	745.464	798.262	859.487
11	Pamekasan	768.889	821.127	874.615
12	Situbondo	405.172	433.093	457.441
13	Gresik	1.036.943	1.067.436	1.097.805
14	Sidoarjo	1.712.741	1.765.998	1.823.114
15	Surabaya Barat	1.062.735	1.099.076	1143..869
16	Ponorogo	591.429	640.411	688.035

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TABLE 4

NUMBER OF ELECTRICITY CUSTOMERS

No	Unit (UP3)	Number of Electricity Customers		
		2019	2020	2021
1	Surabaya Selatan	628.887	650.438	672.153
2	Surabaya Utara	374.628	385.649	395.930
3	Malang	1.177.385	1.215.250	1.254.329
4	Pasuruan	915.506	946.005	975.613
5	Kediri	1.200.779	1.231.846	1.266.968
6	Mojokerto	1.200.011	1.233.008	1.267.944
7	Madiun	807.461	837.180	869.500
8	Jember	1.002.807	1.031.248	1.060.209
9	Bojonegoro	1.038.881	1.073.339	1.106.881
10	Banyuwangi	549.216	570.015	591.290
11	Pamekasan	893.957	943.552	1.003.934
12	Situbondo	427.722	452.918	473.527
13	Gresik	323.502	334.250	344.330
14	Sidoarjo	548.918	567.565	588.436
15	Surabaya Barat	278.893	290.969	302.904
16	Ponorogo	644.829	668.357	690.836

TABLE 5

TOTAL ELECTRICITY SOLD

No	Unit (UP3)	Total Electricity Sold (MWh)		
		2019	2020	2021
1	Surabaya Selatan	4.179.241	4.018.256	4.017.661
2	Surabaya Utara	2.641.850	2.503.748	2.485.990
3	Malang	2.497.148	2.520.185	2.589.342
4	Pasuruan	3.961.881	4.001.546	4.278.564
5	Kediri	2.245.946	2.339.688	2.462.536
6	Mojokerto	4.161.406	4.197.359	4.562.033
7	Madiun	1.226.920	1.307.013	1.340.649
8	Jember	1.434.672	1.600.296	1.708.877
9	Bojonegoro	3.186.427	3.141.773	3.185.617
10	Banyuwangi	998.438	1.062.501	1.102.507
11	Pamekasan	1.184.635	1.361.911	1.437.475
12	Situbondo	573.811	649.286	659.851
13	Gresik	2.360.404	2.404.432	2.514.127
14	Sidoarjo	3.726.480	3.661.405	3.904.263
15	Surabaya Barat	2103..281	2.020.926	2.354.223
16	Ponorogo	746.386	823.238	853.475

EVALUATION AND RESULTS

The evaluation and results in the study aim to calculate the amount of electricity sold. With input variables namely electricity production, installed power, number of customers and output variables namely electricity sold by adjusting the membership range on the input variables. The method used is the Mamdani method can be seen in Figure 2. After determining the input, output and method variables used. Then the membership function is formed for each input and output to describe the degree of membership of an element in the fuzzy set. Based on Figure 3, the membership function is divided into three, namely low, medium, and high with a range of 0-1. After the formation of the membership function, fuzzy rules are formed to describe the relationship between input conditions and output actions. In Figure 4 combines all input variables that state the output of each fuzzy set which produces a number in the domain of the fuzzy set.

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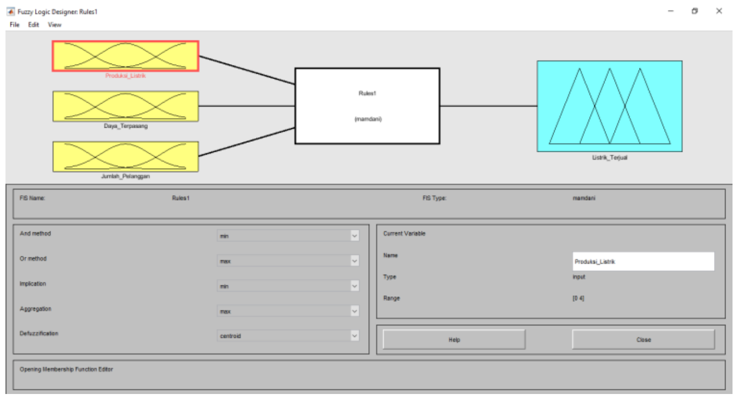
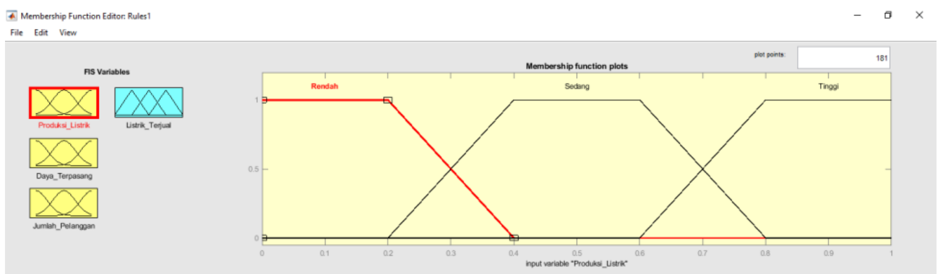
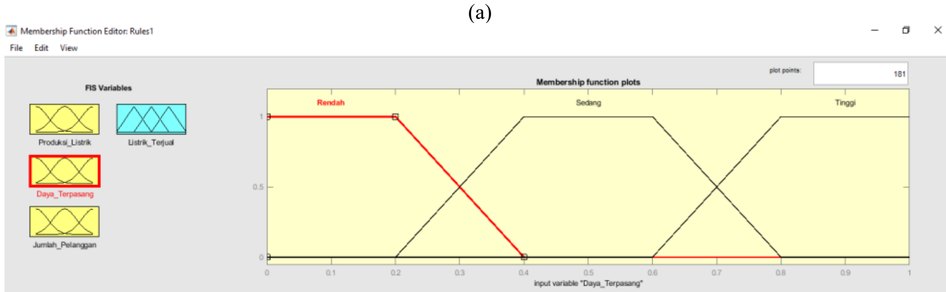


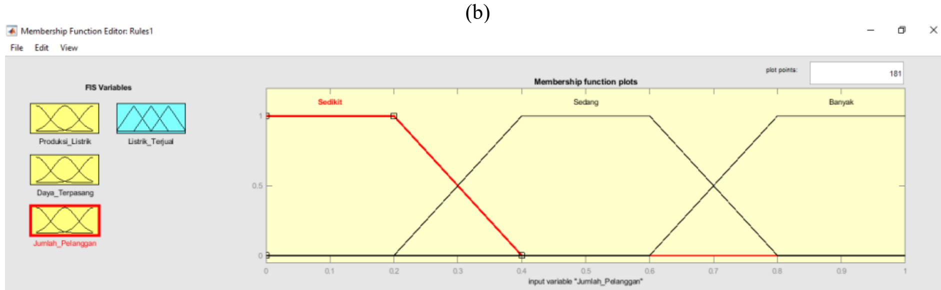
Figure 2. Input and Output Variables



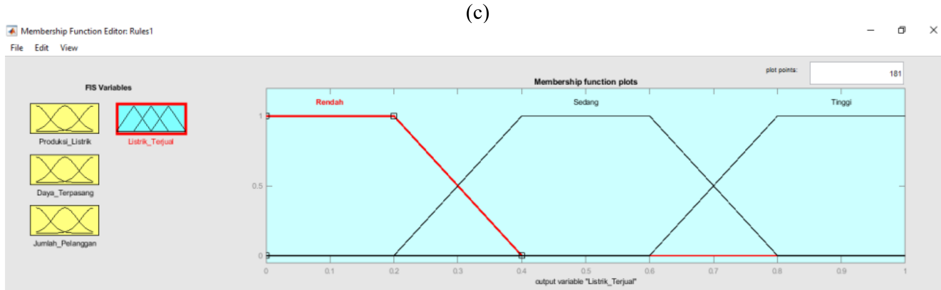
(a)



(b)



(c)



(d)

Figure 3. Membership Functions of Electricity Production (a), Installed Power (b), Number of Customers (c), and Electricity Sold (d)

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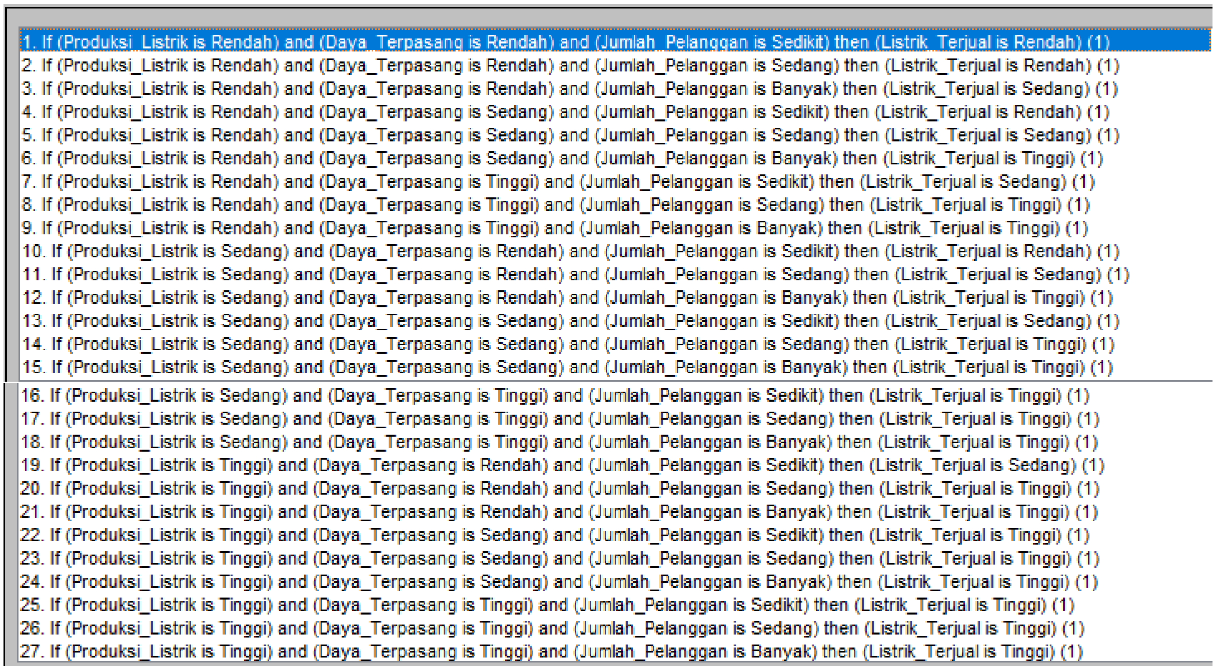
1. If (Produksi_Listrik is Rendah) and (Daya_Terpasang is Rendah) and (Jumlah_Pelanggan is Sedikit) then (Listrik_Terjual is Rendah) (1)
2. If (Produksi_Listrik is Rendah) and (Daya_Terpasang is Rendah) and (Jumlah_Pelanggan is Sedang) then (Listrik_Terjual is Rendah) (1)
3. If (Produksi_Listrik is Rendah) and (Daya_Terpasang is Rendah) and (Jumlah_Pelanggan is Banyak) then (Listrik_Terjual is Sedang) (1)
4. If (Produksi_Listrik is Rendah) and (Daya_Terpasang is Sedang) and (Jumlah_Pelanggan is Sedikit) then (Listrik_Terjual is Rendah) (1)
5. If (Produksi_Listrik is Rendah) and (Daya_Terpasang is Sedang) and (Jumlah_Pelanggan is Sedang) then (Listrik_Terjual is Sedang) (1)
6. If (Produksi_Listrik is Rendah) and (Daya_Terpasang is Sedang) and (Jumlah_Pelanggan is Banyak) then (Listrik_Terjual is Tinggi) (1)
7. If (Produksi_Listrik is Rendah) and (Daya_Terpasang is Tinggi) and (Jumlah_Pelanggan is Sedikit) then (Listrik_Terjual is Sedang) (1)
8. If (Produksi_Listrik is Rendah) and (Daya_Terpasang is Tinggi) and (Jumlah_Pelanggan is Sedang) then (Listrik_Terjual is Tinggi) (1)
9. If (Produksi_Listrik is Rendah) and (Daya_Terpasang is Tinggi) and (Jumlah_Pelanggan is Banyak) then (Listrik_Terjual is Tinggi) (1)
10. If (Produksi_Listrik is Sedang) and (Daya_Terpasang is Rendah) and (Jumlah_Pelanggan is Sedikit) then (Listrik_Terjual is Rendah) (1)
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12. If (Produksi_Listrik is Sedang) and (Daya_Terpasang is Rendah) and (Jumlah_Pelanggan is Banyak) then (Listrik_Terjual is Tinggi) (1)
13. If (Produksi_Listrik is Sedang) and (Daya_Terpasang is Sedang) and (Jumlah_Pelanggan is Sedikit) then (Listrik_Terjual is Sedang) (1)
14. If (Produksi_Listrik is Sedang) and (Daya_Terpasang is Sedang) and (Jumlah_Pelanggan is Sedang) then (Listrik_Terjual is Tinggi) (1)
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18. If (Produksi_Listrik is Sedang) and (Daya_Terpasang is Tinggi) and (Jumlah_Pelanggan is Banyak) then (Listrik_Terjual is Tinggi) (1)
19. If (Produksi_Listrik is Tinggi) and (Daya_Terpasang is Rendah) and (Jumlah_Pelanggan is Sedikit) then (Listrik_Terjual is Sedang) (1)
20. If (Produksi_Listrik is Tinggi) and (Daya_Terpasang is Rendah) and (Jumlah_Pelanggan is Sedang) then (Listrik_Terjual is Tinggi) (1)
21. If (Produksi_Listrik is Tinggi) and (Daya_Terpasang is Rendah) and (Jumlah_Pelanggan is Banyak) then (Listrik_Terjual is Tinggi) (1)
22. If (Produksi_Listrik is Tinggi) and (Daya_Terpasang is Sedang) and (Jumlah_Pelanggan is Sedikit) then (Listrik_Terjual is Tinggi) (1)
23. If (Produksi_Listrik is Tinggi) and (Daya_Terpasang is Sedang) and (Jumlah_Pelanggan is Sedang) then (Listrik_Terjual is Tinggi) (1)
24. If (Produksi_Listrik is Tinggi) and (Daya_Terpasang is Sedang) and (Jumlah_Pelanggan is Banyak) then (Listrik_Terjual is Tinggi) (1)
25. If (Produksi_Listrik is Tinggi) and (Daya_Terpasang is Tinggi) and (Jumlah_Pelanggan is Sedikit) then (Listrik_Terjual is Tinggi) (1)
26. If (Produksi_Listrik is Tinggi) and (Daya_Terpasang is Tinggi) and (Jumlah_Pelanggan is Sedang) then (Listrik_Terjual is Tinggi) (1)
27. If (Produksi_Listrik is Tinggi) and (Daya_Terpasang is Tinggi) and (Jumlah_Pelanggan is Banyak) then (Listrik_Terjual is Tinggi) (1)

Figure 4. Fuzzy Rules

Figure 5. Rule View (Defuzzification)

In Figure 5, the data of electricity production, installed power, and number of customers can be applied to estimate the amount of electricity sold. For example, in Figure 5, when the input values of electricity production, installed power, and number of customers are 0.136, 0.055, and 0.511 respectively, the result shows the amount of electricity sold as 0.153. The red vertical lines on the input variables reflect the fuzzy set values of each fuzzy rule, while the thick red vertical lines on the output variable electricity sold represent the prediction results (defuzzification). By modifying the values of the electricity production, installed power, and number of customers variables in the input column, information related to electricity sales volume can be accessed, as presented in Table 6.

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TABLE 6

MAMDANI FUZZY LOGIC RESULT DATA

Electricity Production		Electrical Power		Customer		Electricity Sold		Electricity Sold	MAE (%)	RSME (%)
Before Normalization	After Normalization	Before Normalization	After Normalization	Before Normalization	After Normalization	Before Normalization	After Normalization	Fuzzification		
4376363	0.818	2363603	0.825	628887	0.47	4179241	0.854	0.847	0.01	0.00
2716864	0.501	1567150	0.435	374628	0.215	2641850	0.453	0.516	0.06	0.00
2652838	0.487	1712174	0.495	1177385	0.824	2497148	0.43	0.847	0.42	0.17
4150688	0.792	1822071	0.55	915506	0.673	3961881	0.783	0.832	0.05	0.00
2426475	0.455	1447252	0.384	1200779	0.888	2245946	0.617	0.844	0.23	0.05
4370411	0.818	2054507	0.672	1200011	0.887	4161406	0.851	0.833	0.02	0.00
1319794	0.246	890983	0.097	807461	0.561	1226920	0.155	0.273	0.12	0.01
1572614	0.309	1004809	0.172	1002807	0.73	1434672	0.26	0.545	0.29	0.08
3377163	0.624	1463744	0.4	1038881	0.759	3186427	0.639	0.839	0.20	0.04
1079365	0.178	745464	0.018	549216	0.411	998438	0.076	0.153	0.08	0.01
1491566	0.293	768889	0.035	893957	0.622	1184635	0.193	0.394	0.20	0.04
611483	0	405172	0	427722	0.321	573811	0	0.169	0.17	0.03
2399524	0.443	1036943	0.157	323502	0.22	2360404	0.487	0.21	0.28	0.08
3873016	0.732	1712741	0.496	548918	0.409	3726480	0.731	0.833	0.10	0.01
2169557	0.396	1062735	0.237	278893	0	2103281	0.367	0.252	0.12	0.01
818319	0.102	591429	0	644829	0.486	746386	0.033	0.153	0.12	0.01
4192765	0.779	2430122	0.83	650438	0.494	4018256	0.789	0.843	0.05	0.00
2570060	0.474	1579587	0.443	385649	0.283	2503748	0.434	0.601	0.17	0.03
2648381	0.485	1789034	0.55	1215250	0.9	2520185	0.438	0.847	0.41	0.17
4165875	0.791	1887414	0.605	946005	0.7	4001546	0.787	0.826	0.04	0.00
2510958	0.465	1512929	0.375	1231846	0.918	2339688	0.403	0.842	0.44	0.19
4400285	0.82	2157137	0.741	1233008	0.919	4197359	0.854	0.835	0.02	0.00
1384742	0.259	981310	0.122	837180	0.58	1307013	0.147	0.3	0.15	0.02
1715898	0.334	1079814	0.201	1031248	0.755	1600296	0.283	0.614	0.33	0.11
3343589	0.616	1544117	0.391	1073339	0.798	3141773	0.622	0.838	0.22	0.05
1150500	0.193	798262	0.076	570015	0.422	1062501	0.126	0.153	0.03	0.00
1653421	0.318	821127	0.09	943552	0.696	1361911	0.21	0.515	0.31	0.09
658344	0.055	433093	0.004	452918	0.342	649286	0.028	0.164	0.14	0.02
2441965	0.45	1067436	0.237	334250	0.229	2404432	0.496	0.308	0.19	0.04
3808354	0.708	1765998	0.545	567565	0.419	3661405	0.693	0.828	0.14	0.02
2082665	0.379	1099076	0.219	290969	0.088	2020926	0.342	0.208	0.13	0.02
882427	0.128	640411	0.007	668357	0.505	823238	0.062	0.153	0.09	0.01
4175103	0.787	2512546	1	672153	0.508	4017661	0.788	0.848	0.06	0.00
2521112	0.467	1614314	0.483	395930	0.273	2485990	0.429	0.587	0.16	0.02
2692484	0.5	1884802	0.604	1254329	0.933	2589342	0.455	0.846	0.39	0.15
4470439	0.833	1962159	0.651	975613	0.721	4278564	0.856	0.831	0.03	0.00
2603562	0.479	1595622	0.461	1266968	0.941	2462536	0.426	0.847	0.42	0.18
4776756	1	2280775	0.814	1267944	0.942	4562033	1	0.847	0.15	0.02
1427490	0.267	1072814	0.199	869500	0.609	1340649	0.162	0.331	0.17	0.03
1860891	0.361	1133458	0.269	1060209	0.776	1708877	0.304	0.676	0.37	0.14
3390033	0.628	1634015	0.496	1106881	0.827	3185617	0.638	0.842	0.20	0.04
1188380	0.202	859487	0.108	591290	0.433	1102507	0.12	0.159	0.04	0.00
1725335	0.335	874615	0.117	1003934	0.731	1437475	0.259	0.581	0.32	0.10
690610	0.073	457441	0.033	473527	0.357	659851	0.033	0.161	0.13	0.02
2512630	0.465	1097805	0.217	344330	0.236	2514127	0.437	0.283	0.15	0.02
4050161	0.754	1823114	0.55	588436	0.431	3904263	0.753	0.838	0.09	0.01
2420673	0.454	1143869	0.282	302904	0.154	2354223	0.398	0.343	0.06	0.00
898742	0.136	688035	0.055	690836	0.511	853475	0.077	0.153	0.08	0.01
Average (%)									**0.17**	**0.21**

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After applying Mamdani fuzzy logic to electricity sales prediction, a comparison of the prediction results with actual electricity sales data was conducted. To measure the accuracy of the prediction, two evaluation methods are used, namely Mean Absolute Error (MAE) to calculate the average absolute error between actual and predicted values, and Root Mean Squared Error (RMSE) which places greater emphasis on highly inaccurate predictions. In this context, PLN's original data has been normalized first to facilitate scaling analysis. The comparison between the normalized electricity sold data and the prediction results using Mamdani fuzzy logic shows a total MAE value of 0.17% and an RMSE value of 0.21%. The results of this evaluation provide greater insight into the accuracy and performance of Mamdani fuzzy logic in modeling and forecasting electricity sales data.

CONCLUSION

From the results of the application of fuzzy mamdani by comparing the prediction results with the sold electricity data, the Mean Absolute Error (MAE) result is 0.17% and the Root Mean Squared Error (RMSE) value is 0.21%. So it can be concluded that the fuzzy logic mamdani method can be used in predicting electricity sold in East Java. and provide valuable guidance for PLN in improving the efficiency and reliability of electricity sales in the East Java region on an ongoing basis. However, further research may be needed to improve the accuracy of specific predictions. Some steps that can be taken for further development are incorporating additional data such as weather factors, economic activities or demographic changes, and conducting comparisons with other prediction methods to evaluate the effectiveness of fuzzy mamdani.

REFERENCES

[1] N. Nuryati, "Faktor yang Memengaruhi Konsumsi Listrik Pelanggan Industri Di Pulau Jawa," *J. SEKURITAS (Saham, Ekon. Keuang. dan Investasi)*, vol. 5, no. 2, p. 169, 2022, doi: 10.32493/skt.v5i2.12434.

[2] H. Suprapto and P. Simanjuntak, "Fuzzy Logic Untuk Memprediksi Pemakaian Listrik Menggunakan Metode Mamdani," *Comput. Sci. …*, vol. 2, no. 1, pp. 29–37, 2020.

[3] E. V. Haryanto and F. Nasari, "Perbandingan Penerapan Metode Fuzzy Mamdani Dan Sugeno Dalam Memprediksi Tingginya Pemakaian Listrik (Studi Kasus Kelurahan Xyz)," *Semin. Nas. Inform.*, p. 534, 2015, [Online]. Available: http://e-journal.potensi-utama.ac.id/ojs/index.php/SNIf/article/view/317%0Ahttp://e-journal.potensi-utama.ac.id/ojs/index.php/SNIf/article/view/317/264

[4] I. L. Zulfa, "Peramalan Beban Listrik Jangka Pendek di Jawa Timur Menggunakan Metode ARIMA dan ANFIS," vol. 4, no. 1, pp. 91–96, 2015.

[5] U. Khasanah, D. C. R. Novitasari, W. D. Utami, and P. K. Intan, "Analisis Peramalan Beban Listrik Jangka Pendek Menggunakan Metode Adaptive Neuro Fuzzy Inference System (Studi Kasus : Pt. Pln (Persero) Area Pengaturan Distribusi Jawa Timur)," *Math Vis.*, vol. 01, no. 01, pp. 17–24, 2019.

[6] F. D. Rosalina, Y. Farida, and A. Hamid, "Metode Logika Fuzzy Sebagai Evaluasi Distribusi Daya Listrik Berdasarkan Beban Puncak Pembangkit Tenaga Listrik," *J. Mat. "MANTIK,"* vol. 2, no. 1, p. 22, 2016, doi: 10.15642/mantik.2016.2.1.22-29.

[7] A. A. Musyafiq and R. Purwanto, "Peramalan Permintaan Pasokan Energi Berdasarkan Intensitas Konsumsi Listrik dan Kapasitas Pembangkit Listrik Terpasang," *Infotekmesin*, vol. 12, no. 1, pp. 65–70, 2021, doi: 10.35970/infotekmesin.v12i1.442.

[8] [8] G. Selvachandran et al., "A New Design of Mamdani Complex Fuzzy Inference System for Multiattribute Decision Making Problems," *IEEE Trans. Fuzzy Syst.*, vol. 29, no. 4, pp. 716–730, 2021, doi: 10.1109/TFUZZ.2019.2961350.

[9] H. Ying et al., "Typical Takagi-Sugeno and Mamdani fuzzy systems as universal approximators:," *IEEE Int. Conf. Fuzzy Syst.*, vol. 1, pp. 824--828, 1998.

[10] A. Ramadhan, Z. Efendi, and Mustakim, "Perbandingan K-Means dan Fuzzy C-Means untuk Pengelompokan Data User Knowledge Modeling," *Semin. Nas. Teknol. Informasi,Komunikasi dan Ind.*, p. hal. 219-226, 2017.

[11] D. M. Sukandy, A. T. Basuki, and S. Puspasari, "Penerapan Metode Fuzzy Mamdani Untuk Memprediksi Jumlah Produksi Minyak Sawit Berdasarkan Data Persediaan Dan Jumlah Permintaan (Studi Kasus Pt Perkebunan Mitra Ogan Baturaja)," *Progr. Stud. Tek. Inform.*, pp. 1–9, 2014.

[12] A. W. F. Much Junaidi, Eko Setiawan, "Penentuan Jumlah Produksi Dengan Aplikasi Fuzzy – Mamdani," pp. 95–104, 2005, [Online]. Available: http://eprints.ums.ac.id/198/1/JTI-0402-06-OK.pdf.

[13] H. Hellendoorn, "rules in Mamdani-Controllers," no. 2, pp. 103–108, 1995.

[14] S. F. W. Utama and H. A. Wibawa, "Implementasi Logika Mamdani dalam Simulasi Memancing," *Din. Rekayasa*, vol. 11, no. 2, pp. 48–53, 2015.

ISSN: 2720-9598

[15] H. A. Rustan, I. Ruslianto, and I. Nirmala, “Determine the Eligibility Level of Village Fund Direct Cash Assistance Recipients using Fuzzy Mamdani Method,” *CESS (Journal Comput. Eng. Syst. Sci.*, vol. 7, no. 2, p. 526, 2022, doi: 10.24114/cess.v7i2.36136.

[16] Rahmawati, Rahima Dina, and Wartono, “Penerapan Metode Fuzzy Mamdani untuk Menentukan Jumlah Pendapatan Pegadaian Berdasarkan Jumlah Omset Harga Emas dan Kurs,” *Buana Mat. J. Ilm. Mat. dan Pendidik. Mat.*, vol. 10, no. 1, pp. 89–104, 2020, doi: 10.36456/buanamatematika.v10i1.2420.

[17] G. Prakarsa and V. M. Nasution, “Penerapan Logika Fuzzy Menggunakan Metode Mamdani Pada Prediksi Jumlah Kasus Positif Covid-19,” *J. Media Inform. Budidarma*, vol. 5, no. 4, p. 1660, 2021, doi: 10.30865/mib.v5i4.3282.

[18] A. N. M. Yusuf, E. Widayat, and A. Hatip, “Penerapan Logika Fuzzy Dalam Memperkirakan Jumlah Produksi Telur Terhadap Permintaan Pasar,” *Limits J. Math. Its Appl.*, vol. 14, no. 2, p. 81, 2017, doi: 10.12962/limits.v14i2.3082.

[19] E. R. Y. SAHULATA, H. J. Wattimanela, and M. S. Noya Van Delsen, “Penerapan Fuzzy Inference System Tipe Mamdani Untuk Menentukan Jumlah Produksi Roti Berdasarkan Data Jumlah Permintaan Dan Persediaan (Studi Kasus Pabrik Cinderela Bread House Di Kota Ambon),” *BAREKENG J. Ilmu Mat. dan Terap.*, vol. 14, no. 1, pp. 079–090, 2020, doi: 10.30598/barekengvol14iss1pp079-090.

[20] M. A. Triwinanto, B. I. Nugroho, and G. Gunawan, “Penerapan Fuzzy Mamdani Untuk Sistem Pendukung Keputusan Pemilihan Telepon Seluler,” *E-Link J. Tek. Elektro dan Inform.*, vol. 18, no. 2, p. 67, 2023, doi: 10.30587/e-link.v18i2.5893.

[21] E. Sufarnap and S. Sudarto, “Penerapan Metode Fuzzy Mamdani dalam Penentuan Jumlah Produksi,” *Semin. Nas. Sains dan Teknol. Inf.*, no. Juli, pp. 379–382, 2019, [Online]. Available: https://s.id/1SHDL

[22] M. Dary Daffa Haque, “Penerapan Logika Fuzzy Mamdani Untuk Optimasi Persediaan Stok Makanan Hewan,” *Media Online*, vol. 4, no. 1, pp. 427–437, 2023, doi: 10.30865/klik.v4i1.1160.

[23] Y. R. Sari, “Penerapan Logika Fuzzy Metode Mamdani dalam Menyelesaikan Masalah Produksi Garam Nasional,” *JATISI (Jurnal Tek. Inform. dan Sist. Informasi)*, vol. 8, no. 1, pp. 341–356, 2021, doi: 10.35957/jatisi.v8i1.647.

[24] Dynes Rizky Navianti, I Gusti Ngurah Ray, Farida Agustini W, “Penerapan Fuzzy Inference System Pada Prediksi Curah Hujan di Surabaya Utara,” *J. Sains dan Seni ITS*, vol. I, no. 1, p. I, 2012.

[25] I. L. H. D *et al.*, “Penerapan Fuzzy Logic Pada Sistem Pengaturan Jumlah Air Berdasarkan Suhu Dan Kelembaban,” *Semin. Nas. Inform. (semnasIF 2011)*, vol. 3, no. April, pp. 358–365, 2015, [Online]. Available: http://biodiversitas.mipa.uns.ac.id/M/M0102/M010232.pdf

[26] D. L. Rahakbauw, F. J. Rianekuay, and Y. A. Lesnussa, “Penerapan Metode Fuzzy Mamdani Untuk Memprediksi Jumlah Produksi Karet (Studi Kasus: Data Persediaan Dan Permintaan Produksi Karet Pada Ptp Nusantara Xiv (Persero) Kebun Awaya, Teluk Elpaputih, Maluku-Indonesia),” *Jurnal Ilmiah Matematika Dan Terapan*, vol. 16, no. 1. pp. 51–59, 2019. doi: 10.22487/2540766x.2019.v16.i1.12764.