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Application of the adaptive neuro-fuzzy inference system for prediction of the electrical energy production in Jakarta

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ABSTRACT

Jakarta, as a rapidly growing urban area, faces challenges in balancing energy demand with supply while addressing environmental concerns associated with traditional energy sources. Electrical energy production prediction in urban environments like Jakarta is crucial for effective energy management, ensuring stable supply, and promoting sustainable development. The prediction of electrical energy production in Jakarta is critical for ensuring stable and sustainable energy supply. This research proposed the application of the adaptive neuro-fuzzy inference system (ANFIS) as a predictive tool specifically tailored for Jakarta's energy production prediction context. The research methodology used in this study is the ANFIS. Five levels make up the architecture of the ANFIS model: output, normalization, defuzzification, rule evaluation, and fuzzification. The fuzzification layer converts input variables into linguistic terms using membership functions, while the rule evaluation layer calculates the activation strength of each rule based on the input values. The predicted results of Jakarta electrical energy production from 2023 to 2028 are 65,288 GWh and there is an annual increase of 5.25%. The error contained in ANFIS is with a root mean square error (RMSE) value of 0.0001058% and a mean absolute percentage error (MAPE) value of 0.00875%.

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1. INTRODUCTION

An electrical energy production is a cornerstone of modern civilization, providing the essential power needed for homes, businesses, industries, and technological advancements [1]. The process involves converting various primary energy sources into electricity, which is then distributed through the power grid to end-users. Understanding the diverse methods of generating electrical energy, their benefits, and their environmental impacts is crucial for developing sustainable energy strategies and addressing the challenges posed by climate change [2], [3]. As the global electricity demand continues to rise, the landscape of electrical energy production is undergoing a transformative shift. This change is driven by the need for sustainable and environmentally friendly energy sources to combat climate change and reduce our dependence on fossil fuels [4]. The future of electrical energy production will be characterized by advancements in technology, increased use of renewable resources, and the integration of innovative solutions to create a resilient and sustainable energy system [5].

The future of electrical energy production is poised for significant transformation, driven by technological innovation, environmental imperatives, and evolving energy demands. As the world grapples with the challenges of climate change and finite fossil fuel resources, the energy sector is shifting towards more sustainable and efficient means of generating electricity [6]. Predicting electrical energy production is crucial for various industries and policymakers to ensure efficient resource allocation and meet energy demands [7]. With the advent of renewable energy sources [8] like solar, wind, and hydroelectric power, accurate prediction becomes even more critical due to their intermittent nature [9]. In this research background, we'll discuss the importance of predicting electrical energy production, the challenges involved, and the methods commonly employed for accurate prediction [10].

The electricity demand continues to rise globally especially in Jakarta. Jakarta, the capital city of Indonesia, is a rapidly growing urban area with a burgeoning population and escalating energy demands. Meeting these demands while managing environmental sustainability and grid stability is a significant challenge. The city's energy production is a complex mix of traditional and renewable energy sources, influenced by various factors including population growth, economic activities, and climatic conditions. However, the generation of electricity relies on various factors, including weather conditions, fuel availability, and infrastructure capabilities. With the integration of renewable energy sources into the grid, predicting energy production becomes inherently more complex due to their dependence on weather patterns, which are often unpredictable. Therefore, it is very important to predict the production of electricity to develop a plan to develop the electricity system in Jakarta. To support the planning, we need an appropriate method for the calculation. The objective of this proposed research is to develop a predictive model using the adaptive neuro-fuzzy inference system (ANFIS) for the prediction of electrical energy production in Jakarta. This model will help in optimizing energy production where previous research used the regression method in the Simple E application, where the prediction results have a greater error rate than the actual results. So, this research uses the ANFIS method so that the ANFIS prediction results have a small error from the actual results.

2. METHOD

Electrical energy is essential for policymakers, engineers, researchers, and consumers to make informed decisions regarding energy production, consumption, and sustainability. This underlies efforts to transition towards a cleaner and more efficient energy system, ensuring a reliable electricity supply while minimizing environmental impacts and increasing economic benefits. Continued advances in technology and policy frameworks are critical to achieving a sustainable energy future globally. Electrical energy production is a multifaceted process encompassing generation from diverse sources, efficient transmission and distribution, and consumption across various sectors. The evolution towards sustainable energy systems involves integrating renewable energy sources, enhancing grid reliability through smart technologies, and addressing environmental and operational challenges [11]. As global energy demand grows, innovation, policy support, and international cooperation will be pivotal in shaping a resilient and sustainable future for electrical energy production worldwide [12]. To predict electrical energy production in Jakarta, we can use a data-driven approach involving statistical modeling, artificial intelligence and machine learning techniques. In this research, the data-based approach method used is ANFIS. The ANFIS model can be used to predict future electrical energy production based on new input data. ANFIS models require sufficient data for accurate predictions. Ensure the dataset is representative and covers a wide range of scenarios as like as fuel consumption, economics, population, and industry.

This section will explain about the steps of the process of the course of research. The steps of this research process begin with a study of the previous research literature using the ANFIS and some parameters used as input data for this research. The steps of the research process can be seen in Figure 1. Figure 1 explains the steps of the research process using the ANFIS technique. Where ANFIS is a hybrid computing methodology that integrates the principles of fuzzy logic and neural networks [13]. MATLAB provides a comprehensive environment for implementing ANFIS models due to its built-in functions and toolboxes specifically designed for fuzzy logic and neural networks [14]. Methodology for implementing ANFIS using MATLAB [15].

Start by collecting or obtaining historical data relevant to the problem want to model. Ensure that the data is properly formatted and preprocessed, including handling missing values, scaling, and normalization if necessary. Design the architecture of the ANFIS model [16]. Determine the number of input variables, membership functions, rules, and output variables based on the characteristics of problem [17]. MATLAB provides functions for creating fuzzy inference systems and defining membership functions [18].

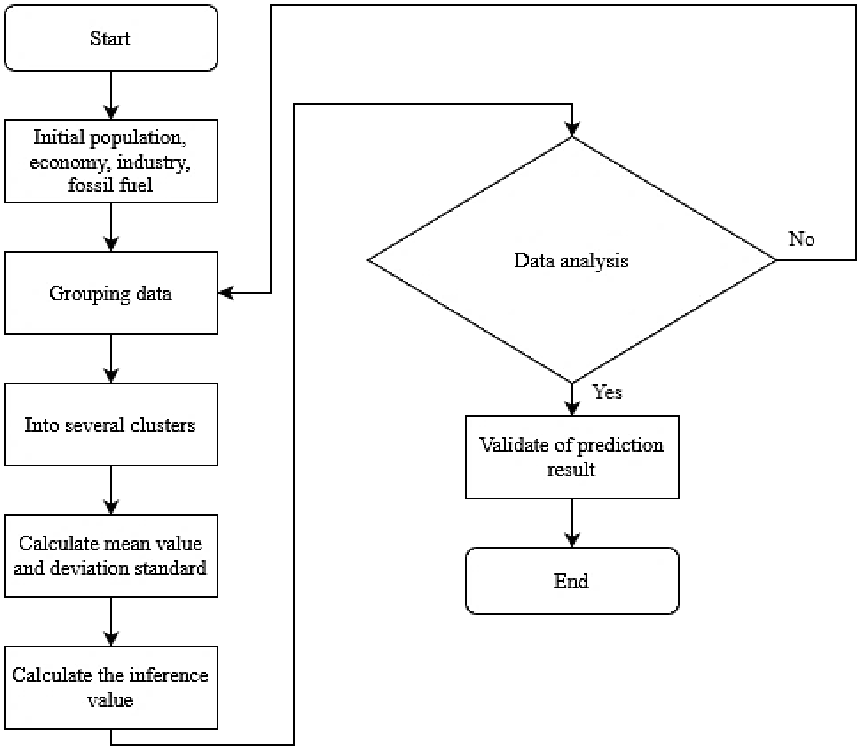

Figure 1. The step of the research process

Divide the dataset into sets for testing, validation, and training. The ANFIS model is trained using the training set, parameters are adjusted and over fitting is prevented using the validation set, and the trained model's performance is assessed using the testing set [19]. Train the ANFIS model using the training data. MATLAB provides functions such as 'anfis' or 'genfis' for training ANFIS models [20]. Specify parameters such as the number of epochs, learning rate, and optimization algorithms during training.

Validate the trained ANFIS model using the validation dataset to ensure that it generalizes well to unseen data. Adjust model parameters if necessary, based on validation performance [21]. Test the final ANFIS model using the testing dataset to evaluate its performance and assess its accuracy in predicting outputs. Use relevant measures, such as mean squared error (MSE), root mean square error (RMSE), or coefficient of determination, to assess the ANFIS model's performance. To understand how the ANFIS model predicts, visualize the input-output linkages, membership functions, and rule activation. Plotting functions for fuzzy inference systems and neural networks are available in MATLAB.

2.1. ANFIS

The ANFIS is a hybrid intelligent system that combines the capabilities of fuzzy logic and neural networks to perform tasks such as classification, regression, and control [22]. The learning process is then carried out against the data in order to generate the output as a prediction result [23]. The training algorithm for ANFIS is a hybrid learning technique that uses gradient descent and error backpropagation (EBP) on reverse streams to compute errors occurring on each layer, and least-squares estimator (LSE) approach to determine consequent values on advanced streams [24].

Five layers make up ANFIS. The fuzzification method maps the input and target data in the degree of membership, constituting the first layer [25]. The inference procedure that determines fuzzy rules is carried out by the second and third layers using Sugeno inference, and the results are handled in the computation that follows. LSE is used at layer 4 to conduct the ensuing value search procedure. Layer 5 processes the two outputs from layer 4 in a summary manner.

Layers 1-4 of ANFIS contain the fuzzy inference system, which is responsible for identifying the neural network system's hidden nodes [26]. Gradient descent is used to adjust the input parameter values after the forward flow computation, and the error value for each layer is obtained by doing a backward flow computation [27]. The computing process described above will continue until the error value approaches the maximum error value that has been set [10].

The ANFIS used to predict is initialize the ANFIS parameters, namely learning rate (lr), momentum (mc), error limit (err), and maximum iteration (max epoch). The first stage carried out is a forward path which contains several stages to find the consequent value of the rule created and add up all the input in the last layer [28]. The stages of the forward lane are as follows:

– Layer 1 (input layer): this represents the input variables of the system with node functions as in (1).

$$O_{1,i} = \mu A_i(x) \; or \; O_{1,i} = \mu B_{i-2}(x) \tag{1}$$

Where x or y is input from node i, A_i or B_i is a linguistic label connected to node i, and $O_{1,i}$ is degree of membership of a fuzzy set with the Gbell curve function.

– Layer 2 (fuzzy layer): this layer computes the degree of membership for each input variable to each fuzzy set. It applies fuzzy logic operations [29].

$$O_{2,i} = w_i = \mu A_i(x) \; \mu B_i(y) \tag{2}$$

– Layer 3 (normalization layer): it normalizes the membership grades obtained from the fuzzy layer [30].

$$O_{3,1} = \hat{w}_i = \frac{\hat{w}_i}{\hat{w}_1 + \hat{w}_2} \tag{3}$$

– Layer 4 (consequent layer): this layer computes the output by combining the normalized membership grades with parameters called consequent parameters.

$$O_{4,i} = \hat{w}_i f_i = \hat{w}_i(p_i x + q_i y + r_i) \tag{4}$$

– Layer 5 (output layer): it produces the final output of the ANFIS system.

$$O_{5,i} = \sum_i^n \hat{w}_i f_i = \frac{\sum_i^n \hat{w}_i f_i}{\sum_i^n \hat{w}_i} \tag{5}$$

$$f = (\hat{w}_1 x)p_1 + (\hat{w}_1 y)q_1 + (\hat{w}_1)r_1 + (\hat{w}_2 x)p_2 + (\hat{w}_2 y)q_2 + (\hat{w}_2)r_2 \tag{6}$$

Where *f* is forecast/prediction result, $\hat{w}_1$, $\hat{w}_2$ is 3rd layer output value, *p, q, r* is consequent parameter value, and *x, y* is independent variable.

– After carrying out training, the error in the prediction results is calculated using mean absolute percentage error (MAPE) [31], [32] and RMSE [33], the following is the formula used:

$$MAPE = \frac{\sum_{i=1}^{n} \left| \frac{(y_i - y_i')^2}{yi} \right|}{n} \tag{7}$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(y_i - y_i')^2}{n}} \tag{8}$$

Where y_i is actual value of electrical energy production, y_i' is predicted value of electrical energy production, and n is number of observations.

3. RESULTS AND DISCUSSION

The Jakarta region yearly electrical energy production, population, economy (GRDB), industry, and fossil fuel usage from 2017 to 2022 were utilized to assess the suggested ANFIS effectiveness (see Table 1). In total there are 5 annual data and during the experiment it consists of 117 parameters, 6 pairs of training data, 0 checking data, and 81 fuzzy rules. We used MATLAB tools to run the experiments.

To enable the algorithm to recognize the data in Table 1, the first round of pre-processing is carried out. One of the simplest ways to preprocess data is to divide all historical data by a constant, and then, when making a prediction, return the data to its original value. The data contained in Table 1 will be entered into the ANFIS structure form which can be seen in Figure 2. ANFIS generates 193 nodes, 81 linear parameters, and 36 non-linear parameters, as shown in Figure 3. These results should be shown in Figure 3.

Table 1. Yearly electrical energy production (GWh), population, economy (GRDB), industry and fossil fuel usage from 2017 to 2022 Jakarta region

Year	2017	2018	2019	2020	2021	2022
Electrical energy production (GWh)	36,365	38,988	41,284	44,119	47,039	49,647
Population (million people)	10,374	10,467	10,557	10,562	10,644	10,640
Economics (GRDB)	1,635.35	1,735.20	1,836.24	1,792.40	1,856.30	1,453.32
Industry	2,582	2,118	1,792	1,825	1,628	559
Fossil fuel usage	164.2	165.7	176.0	188.3	204.2	218.2

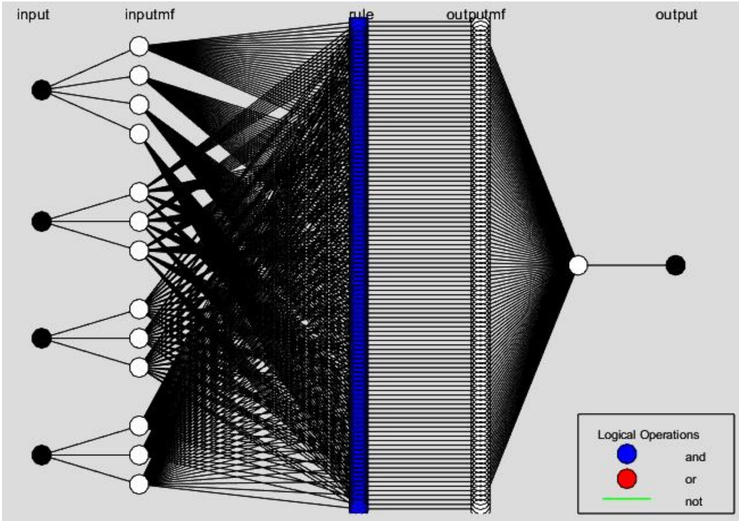

Figure 2. The structure of ANFIS

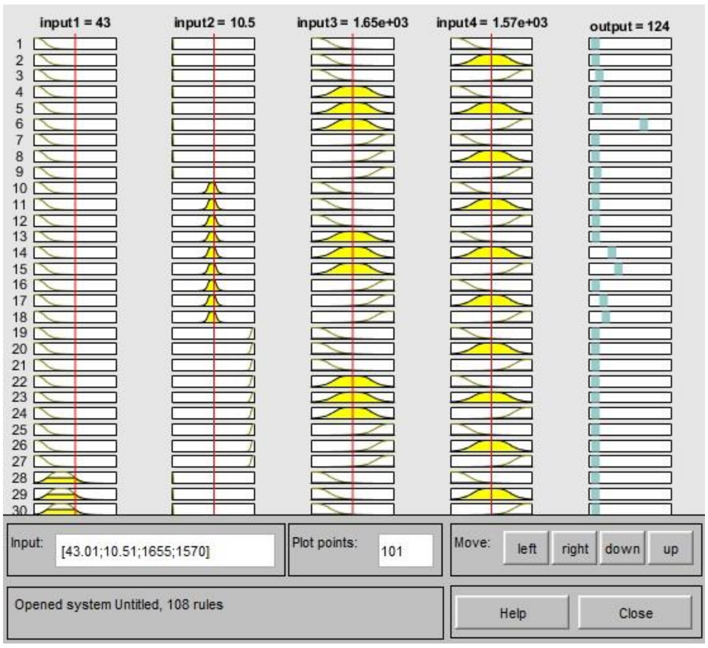

Figure 3. Fuzzy rules

The fuzzy rules are depicted in Figure 3, whereby 53 rules are formed based on testing and experimentation with data on power production projections for the province of Jakarta. We obtained 1 fuzzy rule with correct results out of 53 rules generated by fuzzy, which is the 41st fuzzy rule. Therefore, we had an inaccuracy of 0.0001058% when we tested the data. Figure 4 shows the results of these mistakes. The prediction results of the ANFIS have a very tiny error value with the actual data, as shown in Figure 4. The predicted value results for electrical energy production in Jakarta in 2022-2028 can be shown in Table 2.

Table 2. Prediction results for Jakarta region electrical energy production from 2022-2028

Year	2022	2023	2024	2025	2026	2027	2028
Prediction results of electrical energy production (GWh) with RMSE 0.0001058%	49,647	53,253	54,860	57,467	60,074	62,681	65,288
Prediction results of electrical energy (GWh) with MAPE 0.00875%	49,642	52,250	54,858	57,466	60,074	62,682	65,290
Prediction results of electrical energy (GWh) from PLN	49,647	44,315	46,395	48,544	51,025	53,623	56,358

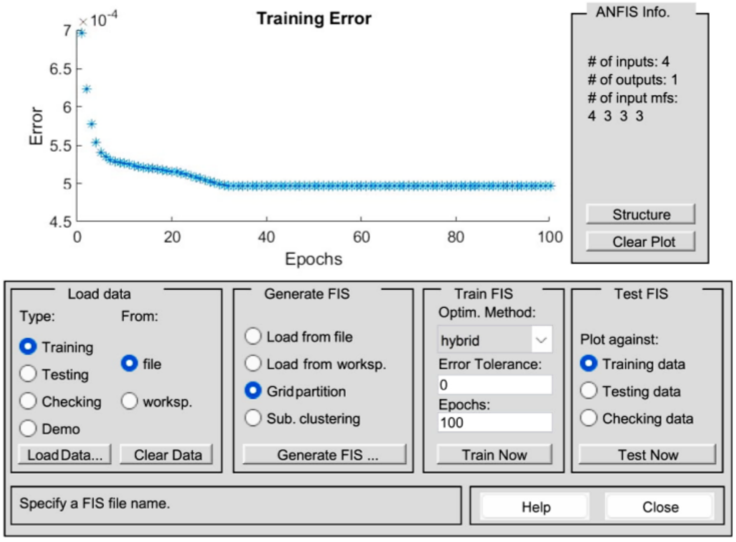

Figure 4. ANFIS results

From the Table 2, the calculations produced by the ANFIS method have a RMSE value=0.0001058% while the MAPE value is=0.00875%. So, the results of this ANFIS method have small errors from the actual results and have a growth in electrical energy production in Jakarta of 5.25% every year from the actual data. Meanwhile, the prediction results made by PT. PLN (Persero) regarding electrical energy production uses Simple E application were 4.80%. So, from the results shown in Table 2, it will be presented in Figure 5 which is a comparison of the results of ANFIS predictions, predictions from PT. PLN (Persero) with actual data. From the prediction results issued by ANFIS according to Figure 5, the author suggests to PT. PLN (Persero) to use this method, because this method provides very precise and accurate results and has very small errors.

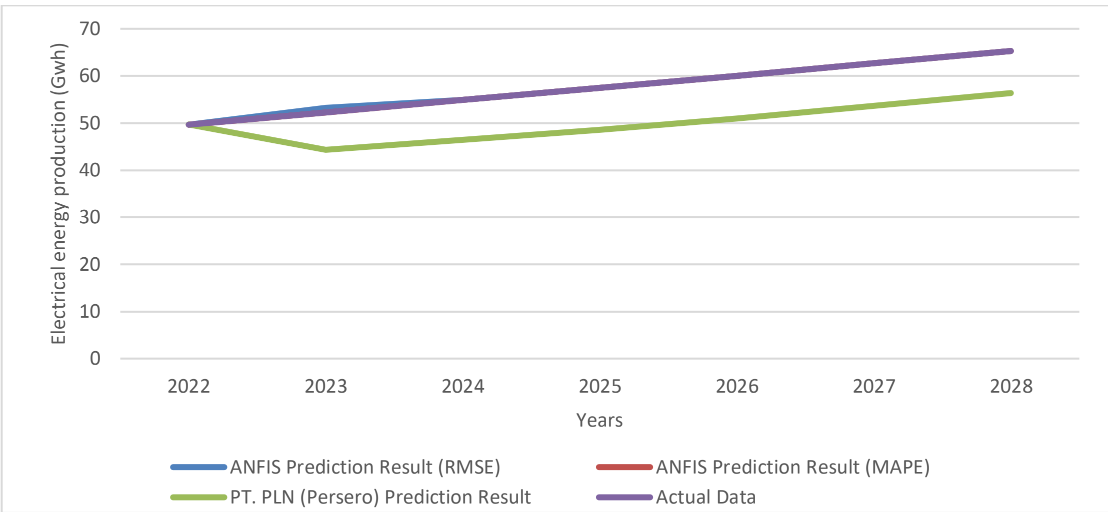

Figure 5. The comparison of the results of ANFIS predictions, predictions from PT. PLN (Persero) with actual data

4. CONCLUSION

The production of electrical energy is at a pivotal juncture, driven by the need for sustainable practices, technological advancements, and increasing global energy demands. As like as Jakarta, the future of electrical energy production hinges on balancing reliable supply, environmental sustainability, and economic viability. Jakarta, Indonesia's capital, and a dynamic metropolis faces significant challenges in meeting its growing energy demands while addressing environmental and infrastructural concerns. The city's current energy mix predominantly relies on fossil fuels, with a growing but still limited contribution from renewable energy sources. This research proposed on prediction of electrical energy production in Jakarta. The application of the ANFIS for the prediction of electrical energy production in Jakarta offers a sophisticated and effective approach to addressing the city's energy challenges. The results of calculations carried out using the ANFIS method obtained an RMSE of 0.0001058%, while the MAPE was 0.00875%. And the results of the prediction analysis of electrical energy production in Jakarta in 2028 are 65,288 GWh and have growth of 5.25%. The results obtained using the ANFIS method have a small error compared to the actual results rather than the prediction results made by PT. PLN (Persero) uses the regression method in the Simple E application, where the prediction results have a greater error rate and the author suggests to PT. PLN (Persero) to use this method, because this method provides very precise and accurate results and has very small errors.

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Margie Subahagia Ningsih		✓			✓			✓	✓					✓
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Indra Roza	✓	✓	✓	✓			✓			✓		✓	✓	

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that this paper is the result of joint research between Universitas Al-Azhar Medan with Politeknik Penerbangan Medan, Universitas Dharma Agung and Universitas Harapan Medan.

DATA AVAILABILITY

The authors confirm that the data supporting the findings of this research are available within the article.

REFERENCES

[1] S. Y. Kandemir, M. O. Yayli, and E. Acikkalp, "Assessment of electric energy generation using wind energy in Turkey," *7th Iran Wind Energy Conference, IWEC 2021*, 2021, doi: 10.1109/IWEC52400.2021.9467019.

[2] D. Celik, M. E. Meral, and M. Waseem, "Restrictions and driving forces for renewable energy production development and electrical energy demand in general and during COVID-19," *12th International Symposium on Advanced Topics in Electrical Engineering, ATEE 2021*, 2021, doi: 10.1109/ATEE52255.2021.9425216.

[3] A. Harrouz, D. Belatrache, K. Boulal, I. Colak, and K. Kayisli, "Social acceptance of renewable energy dedicated to electric production," *9th International Conference on Renewable Energy Research and Applications, ICRERA 2020*, pp. 283–288, 2020, doi: 10.1109/ICRERA49962.2020.9242904.
[4] A. Qazi *et al.*, "Towards sustainable energy: a systematic review of renewable energy sources, technologies, and public opinions," *IEEE Access*, vol. 7, pp. 63837–63851, 2019, doi: 10.1109/ACCESS.2019.2906402.
[5] R. T. Ginting, Y. T. Nugraha, D. P. -Angin, T. T. Gultom, W. P. Nainggolan, and D. Sitanggang, "Short-term forecast for the growth of Indonesia's new renewable energy using the adaptive neuro-fuzzy inference system," *Jurnal Sistem Informasi dan Ilmu Komputer Prima (JUSIKOM PRIMA)*, vol. 6, no. 2, pp. 57–60, 2023, doi: 10.34012/jurnalsisteminformasidanilmukomputer.v6i2.3477.
[6] G. Perveen, M. Rizwan, and N. Goel, "An ANFIS-based model for solar energy forecasting and its smart grid application," *Engineering Reports*, vol. 1, no. 5, 2019, doi: 10.1002/eng2.12070.
[7] O. N. Oyakhilomen and A. S. Emeka, "Comparing the electricity forecast performance of the ANFIS and the LSSVM models for a case of suppressed," *International Journal of Research in Engineering and Science (IJRES)*, vol. 11, no. 3, pp. 168–175, 2023.
[8] A. M. Salim and I. Alsyouf, "Renewable energy in the United Arab Emirates: status and potential," *2020 Advances in Science and Engineering Technology International Conferences, ASET 2020*, 2020, doi: 10.1109/ASET48392.2020.9118220.
[9] Y. T. Nugraha and M. Irwanto, "Modelling demand for energy sources as alternative energy in the Province of North Sumatra," *Journal of Renewable Energy, Electrical, and Computer Engineering*, vol. 2, no. 2, pp. 84-89, 2022, doi: 10.29103/jreece.v2i2.9278.
[10] X. Huang, D. Wu, and B. Boulet, "Ensemble learning for charging load forecasting of electric vehicle charging stations," *2020 IEEE Electric Power and Energy Conference, EPEC 2020*, 2020, doi: 10.1109/EPEC48502.2020.9319916.
[11] Tumiran *et al.*, "The masterplan for developing electricity systems for archipelagic area by considering local energy resources: a case study of Maluku Islands," *Proceedings of 2019 the 7th International Conference on Smart Energy Grid Engineering, SEGE 2019*, pp. 290–293, 2019, doi: 10.1109/SEGE.2019.8859915.
[12] E. T. Sayed *et al.*, "A critical review on environmental impacts of renewable energy systems and mitigation strategies: wind, hydro, biomass and geothermal," *Science of the Total Environment*, vol. 766, 2021, doi: 10.1016/j.scitotenv.2020.144505.
[13] F. Kahwash, B. Barakat, and A. Maheri, "Coupled thermo-electrical dispatch strategy with AI forecasting for optimal sizing of grid-connected hybrid renewable energy systems," *Energy Conversion and Management*, vol. 293, 2023, doi: 10.1016/j.enconman.2023.117460.
[14] D. Li, G. Sun, S. Miao, Y. Gu, Y. Zhang, and S. He, "A short-term electric load forecast method based on improved sequence-to-sequence GRU with adaptive temporal dependence," *International Journal of Electrical Power and Energy Systems*, vol. 137, 2022, doi: 10.1016/j.ijepes.2021.107627.
[15] X. Wu and N. Zhang, "The application of MATLAB teaching in the cultivation of non-professional quality of undergraduates," *2020 International Conference on Information Science and Education,* pp. 577–581, 2020, doi: 10.1109/ICISE51755.2020.00129.
[16] D. K. Ghose, K. Tanaya, A. Sahoo, and U. Kumar, "Performance evaluation of hybrid ANFIS model for flood prediction," *8th International Conference on Advanced Computing and Communication Systems,* 2022, doi: 10.1109/ICACCS54159.2022.9785002.
[17] A. H. Nurcahyono, F. Nhita, D. Saepudin, and A. Aditsania, "Price prediction of chili in bandung regency using support vector machine (SVM) optimized with an adaptive neuro-fuzzy inference system (ANFIS)," *2019 7th International Conference on Information and Communication Technology, ICoICT 2019*, 2019, doi: 10.1109/ICoICT.2019.8835367.
[18] P. P. Manoj, "Fuzzy logic methodology for short term load forecasting," *International Journal of Research in Engineering and Technology*, vol. 3, no. 4, pp. 322–328, 2014, doi: 10.15623/ijret.2014.0304058.
[19] Y. Kassa, J. H. Zhang, D. H. Zheng, and D. Wei, "Short term wind power prediction using ANFIS," *2016 IEEE International Conference on Power and Renewable Energy, ICPRE 2016*, pp. 388–393, 2017, doi: 10.1109/ICPRE.2016.7871238.
[20] T. Inan and A. F. Baba, "Prediction of wind speed using artificial neural networks and ANFIS methods (observation buoy example)," *2020 Innovations in Intelligent Systems and Applications Conference, ASYU 2020*, 2020, doi: 10.1109/ASYU50717.2020.9259894.
[21] I. M. El-Hasnony, S. I. Barakat, and R. R. Mostafa, "Optimized ANFIS model using hybrid metaheuristic algorithms for Parkinson's disease prediction in IoT environment," *IEEE Access*, vol. 8, pp. 119252–119270, 2020, doi: 10.1109/ACCESS.2020.3005614.
[22] H. Suyono, D. O. Prabawanti, M. Shidiq, R. N. Hasanah, U. Wibawa, and A. Hasibuan, "Forecasting of wind speed in Malang City of Indonesia using adaptive neuro-fuzzy inference system and autoregressive integrated moving average methods," *2nd International Conference on Technology and Policy in Electric Power and Energy,* pp. 131–136, 2020, doi: 10.1109/ICT-PEP50916.2020.9249867.
[23] A. A. Zakri, M. W. Mustafa, and I. Tribowo, "ANFIS design based on prediction models for the photovoltaic system," *2019 4th International Conference on Sustainable Information Engineering and Technology,* 2019, doi: 10.1109/SIET48054.2019.8986133.
[24] F. M. A. Hadi, H. H. Aly, and T. Little, "Harmonics forecasting of wind and solar hybrid model driven by DFIG and PMSG using ANN and ANFIS," *IEEE Access*, vol. 11, pp. 55413–55424, 2023, doi: 10.1109/ACCESS.2023.3253047.
[25] E. Akarslan and F. O. Hocaoglu, "A novel short-term load forecasting approach using Adaptive neuro-fuzzy inference system," *2018 6th International Istanbul Smart Grids and Cities Congress and Fair,* pp. 160–163, 2018, doi: 10.1109/SGCF.2018.8408964.
[26] A. Azeem, I. Ismail, S. M. Jameel, and V. R. Harindran, "Electrical load forecasting models for different generation modalities: a review," *IEEE Access*, vol. 9, pp. 142239–142263, 2021, doi: 10.1109/ACCESS.2021.3120731.
[27] H. Khan, M. J. Khan, and A. Qayyum, "Neural network-based load forecasting model for efficient charging of electric vehicles," *2022 7th Asia Conference on Power and Electrical Engineering,* pp. 2068–2072, 2022, doi: 10.1109/ACPEE53904.2022.9783828.
[28] H. Wang *et al.*, "Electric vehicle charging load clustering and load forecasting based on long short term memory neural network," *2022 IEEE 5th International Electrical and Energy Conference,* pp. 3196–3200, 2022, doi: 10.1109/CIEEC54735.2022.9846570.
[29] A. A. Nassar, K. Gandhi, and W. G. Morsi, "Electric vehicles load forecasting considering the effect of COVID-19 pandemic," *2021 IEEE Electrical Power and Energy Conference, EPEC 2021*, pp. 440–444, 2021, doi: 10.1109/EPEC52095.2021.9621740.
[30] P. Almaleck, S. Massucco, G. Mosaico, M. Saviozzi, P. Serra, and F. Silvestro, "Electrical consumption forecasting in sports venues: a proposed approach based on neural networks and ARIMAX Models," *Sustainable Cities and Society*, vol. 100, 2024, doi: 10.1016/j.scs.2023.105019.
[31] Al-Khowarizmi, S. Efendi, M. K. M. Nasution, and M. Herman, "The role of detection rate in MAPE to improve measurement accuracy for predicting FinTech data in various regressions," *ICCoSITE 2023 - International Conference on Computer Science, Information Technology and Engineering: Digital Transformation Strategy in Facing the VUCA and TUNA Era*, pp. 874–879, 2023, doi: 10.1109/ICCoSITE57641.2023.10127820.
[32] A. R. Lubis, S. Prayudani, Y. Fatmi, M. Lubis, and Al-Khowarizmi, "MAPE accuracy of CPO forecasting by applying fuzzy time series," *International Conference on Electrical Engineering, Computer Science and Informatics (EECSI)*, pp. 370–373, 2021, doi: 10.23919/EECSI53397.2021.9624303.
[33] M. I. M. Isham, H. N. Hj Haron, F. B. Mohamed, and C. V. Siang, "VR welding kit: accuracy comparison between smartphone VR and standalone VR using RMSE," *2021 IEEE International Conference on Computing, ICOCO 2021*, pp. 341–346, 2021, doi: 10.1109/ICOCO53166.2021.9673577.

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