ANFIS Design Based on Prediction Models for The Photovoltaic System

by Azriyenni Azhari

Submission date: 26-Aug-2019 07:15PM (UTC+0700)
Submission ID: 1163591126
File name: SIET19_Azriyenni_Revision.doc (3.78M)
Word count: 3164
Character count: 16538

ANFIS Design Based on Prediction Models for The Photovoltaic System

Azriyenni Azhari Zakri
Dept. of Electrical Engineering,
Faculty of Engineering
Universitas Riau
Pekanbaru, Indonesia
azriyenni@eng.unri.ac.id
(IEEE Member: 92012627)

Mohd Wazir Mustafa
School of Electrical Engineering,
Faculty of Engineering
Universiti Teknologi Malaysia
Johor Bahru, Malaysia
wazir@utm.my

Ibwalibi Tribowo
Dept. of Electrical Engineering,
Faculty of Engineering
Universitas Riau
Pekanbaru, Indonesia
ibwalibi.tribowo452@student.unri.ac.id

***Abstract*— Photovoltaic system has uncertain output in generating electrical energy, as it is intensely influenced by different weather condition. This study discusses the photovoltaics model to predict the output power precisely. This modeling system applies an Adaptive Neuro-Fuzzy Inference System (ANFIS) technique to gain data of power prediction, voltage, current, and temperature. The mathematical representation of the photovoltaic using Matlab/Simulink setting has been developed and presented by using the photovoltaic basic sequence equation, including solar irradiation effect and temperature changes. This model is divided into two systems run by ANFIS; ANFIS 1 and ANFIS 2. The design of ANFIS is expected to update its parameter to determine errors between output and target. MAPE (Mean Absolute Percentage Error) value for ANFIS 1 test of open circuit output voltage was 0.0384. This MAPE score is found to be excellent predictive data with less than 10% MAPE value. For the ANFIS 2 test, the AC output voltage was 0.026%, output current of 1.3035%, and 0.0046% of frequency. Based on the MAPE scores, very suitable data prediction has been produced with less than 10% MAPE value. Briefly, this study reveals that the ANFIS technique yields load prediction results that can improve the accuracy and rapidness of prediction as well as very minimum errors.**

***Keywords*—ANFIS, design, MAPE, photovoltaic, prediction**

I. Introduction

The photovoltaic system is developed to meet the electrical power demanded of society as alternative energy. However, the system has uncertain and inconstant towards the generated of output power. This is affected by the changeable weather condition in today's tropical climate. In this paper, photovoltaic system modeling for prediction of efficient output power will be established. As an electrical power supply, the modeling's dimension, identification, and simulation application must be adjusted initially. Meanwhile, the photovoltaic system modeling as the source of electrical energy is a first step to accustom several factors like size or dimension, identification, or the application of simulation [1].

Meijun Lin et al. proposed a prediction of solar cell production for power flow in the distribution network by developing renewable energy. He introduces the solar radiation model as a weather forecast to build a long term prediction of solar panel output. The result of the output of solar radiation utilizes an algorithm to measure the electrical power flow in the distribution system [2]. Furthermore, Abu Bakar Abdul Karim et al. have also informed that the prediction score of the solar cell system can be useful to predict the short-term output power. To produce the prediction score, Abu Bakar has used Fuzzy Logic technique as the short-range forecasting. Some variable values becoming the inputs are temperature and humidity. The result of that Fuzzy Logic known to be the correction factor in the power curve for forming approximated days [3]. Additionally, Mohammad H Alomari et al. [4] enlightened the output power of photovoltaic with indefinite data is influenced by weather condition. To forecast the output power accurately, Neural Network (NN) theory needs to be employed. The result obtained showed that the proposed prediction model is indeed efficient. Mustapha Ellyaqouti et al. [5] had presented a prediction of output I-V characteristics from photovoltaics generator to produce electrical output power. It is conducted through modeling, extracting the photovoltaic system parameter by estimating the global solar radiation on a surface horizontally and on a particular tilted angle. The mathematical model is advanced using the Matlab [6]. Several recent studies have been developed for estimating, forecasting, uncertainty of a system using the method; T-S method [7], adaptive fuzzy control for nonlinear MIMO systems [8], T-S identification model and fuzzy controller [9].

The purpose of this paper is to develop a prediction of photovoltaic systems for the development of renewable energy that produces short-term predictions for 100 Wp photovoltaic output. Therefore, on the grounds of the previous study regarding of energy conservation, by employing artificial intelligent engineering concept, this research will develop renewable energy as an electrical power supply with the photovoltaic system for its output power prediction which is also using the intelligent technique. The artificial intelligent techniques proposed are the combination of Fuzzy Logic (FL) and NN, which is also known as the Adaptive Neuro-Fuzzy Inference System (ANFIS).

II. The Hybrid Intelligent Techniques

A. ANFIS

The method adopted in this research is photovoltaic system modeling, to gain input data for running the ANFIS technique. The designed modeling consists of two systems; System 1 (solar panel-regulator-battery) and System 2 (battery-inverter-load). Hence, it is crucial to building ANFIS structure for both systems. ANFIS is an intelligent hybrid technique that uses Takagi Sugeno (TS) or the Mamdani model. This method has been developed in early 1990. ANFIS learning technique offers Fuzzy model to study information related to set data. ANFIS is, on the other words, membership function parameter learning technique operated with backpropagation algorithm. This TS model of ANFIS uses a learning algorithm by identifying the Fuzzy Inference System (FIS) parameter type [10, 11].

The Neural Network (NN) adjustment can be conducted in three basic elements: fuzzification, fuzzy inference, and defuzzification. NN technique comprises of the weighting among input layers, the first and the second hidden layer as well as the output layers to ensure the input and output nodes. ANFIS is instructed by intelligent engineering combined application with a predetermined input signal. The ANFIS model combines the NN adjusting capability, and the qualitatively implemented FL approach. The ANFIS technique is described for neuron layer within the following steps [6, 12, 13]:

Layer 1: Fuzzification

The node of this layer runs membership degree included in every Fuzzy system by using membership function.

$O1,i = \mu A_i(x)$ for $i = 1, 2$ (1)

$O1,i = \mu B_{i-2}(y)$ for $i = 3, 4$ (2)

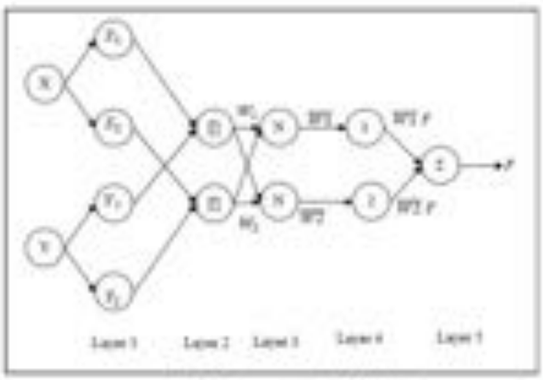

Fig. 1. Structure of ANFIS

The membership function can use function that is: *Gaussian, trapezoid, generalized bell and triangle.*

$$\mu Ai = \{1 - \frac{a_{i1} - x}{a_{i2}} \text{ if } a_{i1} - a_{i2} \le x \le a_{i1},\ 1 - \frac{x - a_{i1}}{a_{i3}} \text{ if } a_{i1} \le x \le a_{i1} + a_{i3},\ 0 \quad (3)$$

$$\mu Bi = \{1 - \frac{b_{i1} - y}{b_{i2}} \text{ if } b_{i1} - b_{i2} \le y \le b_{i1},\ 1 - \frac{y - b_{i1}}{b_{i3}} \text{ if } b_{i1} \le y \le b_{i1} + b_{i3},\ 0 \quad (4)$$

Layer 2: *If-Then rule*

A rule system with AND command used for an output shows the result of I.F command. The output layer is the corresponding product degree of membership.

$O2,k = wk = \mu A_1(x) * \mu A_2(y)$ (5)

Layer 3: Normal weighting

The normal weighting for weighting ratio of each rule in all rules of weight is that each one is taken as the weighting of that normal.

$$O_{3,1} = \overline{Wi} = \frac{wi}{w1+w2+w3+w4} \quad i = 1, 2, 3, 4 \quad (6)$$

Layer 4: Deffuzification

The node function in this fourth layer counts so that the identification of each rule to the total output can be formulated as follow:

$$O_{4,i} = \overline{Wi}\,\overline{Zi} = \overline{Wi}(P_i x + P_i y + r_i)\ i = 1, \ldots, 4 \quad (7)$$

Layer 5: Addition of *Neuron*

The node calculates the whole outputs by adding up all entering signals. Consequently, defuzzification will create *fuzzy* decision process of each rule into the output layers so that:

$$O_{5,i} = \sum_{i=1}^{4} \overline{Wi}\,Zi = \frac{w_1 z_1 + w_2 z_2 + w_3 z_3 + w_4 z_4}{w_1 + w_2 + w_3 + w_4} \quad (8)$$

B. Developing Model of ANFIS

Modeling a photovoltaic system is divided into two systems. Namely; system 1 is aimed at observing the battery charging process, this part consisting of photovoltaic panels, Solar Charge Contoller (SCC), and battery. When, system 2 is intended for process of using electric power that has been stored on battery (off grid), this system consists of battery, inverter, and load. The modeling design in this research is grouped into two parts: System 1 and 2. Figure 2 consists of a photovoltaic module, SCC, and battery. The input parameters on this system are solar radiation (Ir) and temperature (T), and output circuit voltage (Voc) as the output.

Fig. 2. Diagram of system 1

Figure 3 contains a battery, inverter, and load. In this second system, the DC voltage is simulated from the battery into inverter output of AC voltage. System 2 consists of such inputs as battery voltage (V_b), battery current (I_b), SOC, and temperature (T_b). The outputs for this system are AC voltage (V_{AC}), the AC current (I_{AC}), and frequency (F).

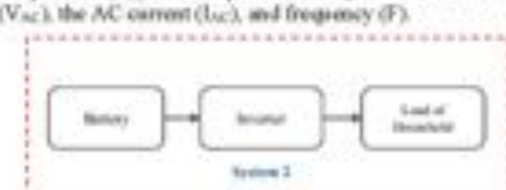

Fig. 3. Diagram of system 2

Figure 4 illustrates the ANFIS structure for System 1, which involves: solar panel ANFIS, ANFIS regulator, and battery. The input data of System 1 consist of solar radiation element (Ir) and temperature (T). From the solar panel for ANFIS, output data of open circuit voltage (V_{OC}), solar panel voltage (V_{PV}), and photovoltaics current (I_{PV}) are generated. Later, the solar panel output data will turn to be the input for the ANFIS regulator; they are the solar panel voltage (V_{PV}) and solar panel current (I_{PV}). The output data from the regulator- voltage regulator (V_R) and current regulator (I_R) will be the input for the battery; battery voltage (V_b), battery current (I_b), temperature (T), and SOC. The output for this System 1 is an open circuit voltage (V_{OC}) battery.

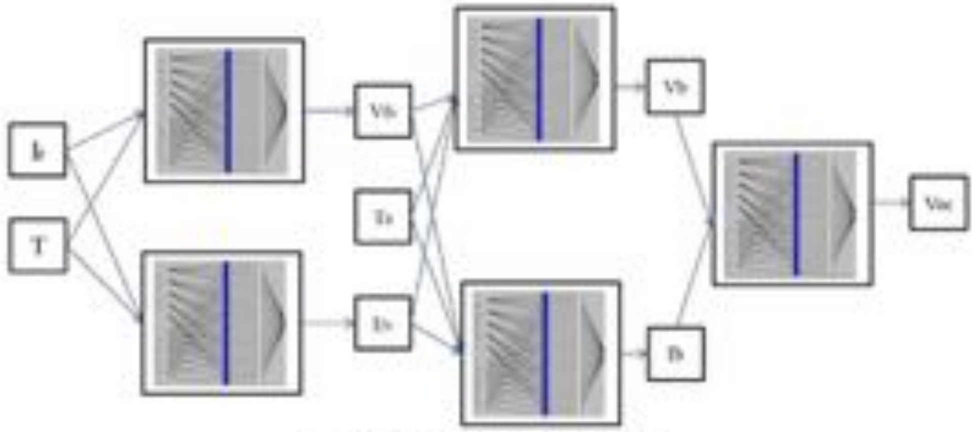

Figure 4. Structure of ANFIS for system 1

Figure 5 portrays the ANFIS for system 2, comprising of ANFIS battery and inverter. The input data for this system are battery voltage (V_b), battery current (I_b), temperature (T) and SOC, which will produce an output voltage battery (V_{ob}) and output current battery (I_{ob}). Then, the output data of the battery will be an input value for the inverter, and the inverter will generate output data; voltage (V_{AC}), current (I_{AC}).

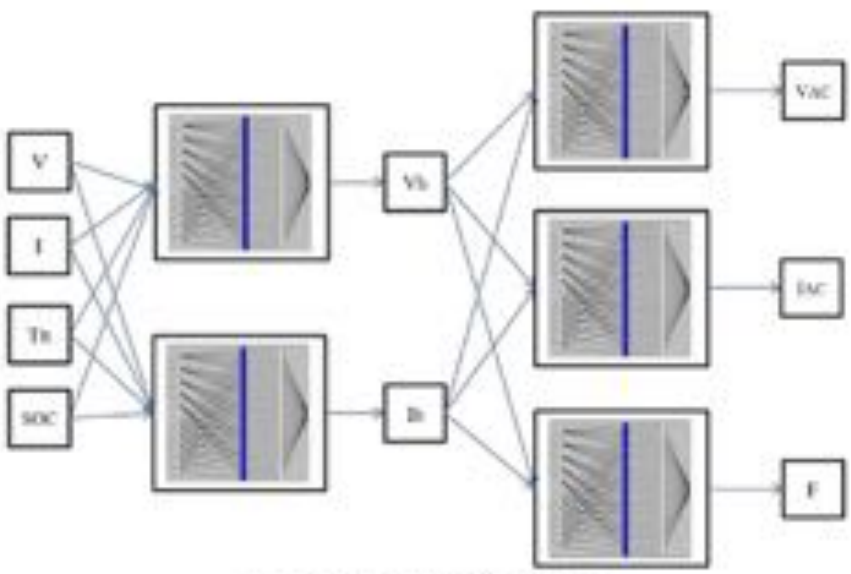

Fig. 5. Structure of ANFIS for system 2

III. RESULT & DISCUSSION

The solar panel utilises the S-series type with generating capacity of 100 Watt-Peak. This panel has a polycrystalline cell type and 12 Volt power output. The specified modeling solar panel can be seen in Table 1. There are three parts of System 1, a solar panel system, regulator, and battery. Figure 6 was presented System 1 simulation result, and input data for system 1 are sunlight radiation and panel temperature. While the output data of system 1 is the open circuit voltage (V_{OC}) battery. The experiment of the solar radiation absorption system on the photovoltaic module expressed on the measured temperature was between 28°C to 50°C [14]

TABLE I. SPECIFICATION MODEL OF PHOTOVOLTAIC

Model Panel	SP-100-P36
Maximum Power Average	100 W
Open Circuit Voltage (V_{oc})	22.6 V
Open Circuit Current (I_{sc})	6.09 A
A voltage at Maximum Power (V_{m})	17.6 V
Current at Maximum Power (I_{m})	5.69 A
System maximum voltage	700 V
Nominal temperature	-45°C- +80°C
Dimensions	1020*670*35 mm
Number of cells	36

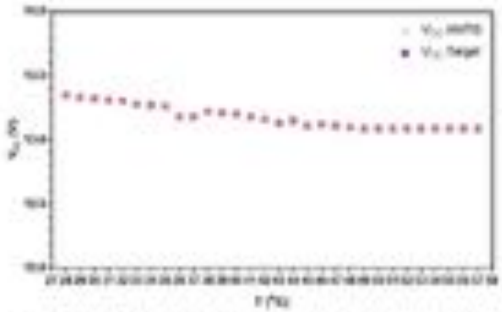

Fig. 6. The simulation result using ANFIS (system 1)

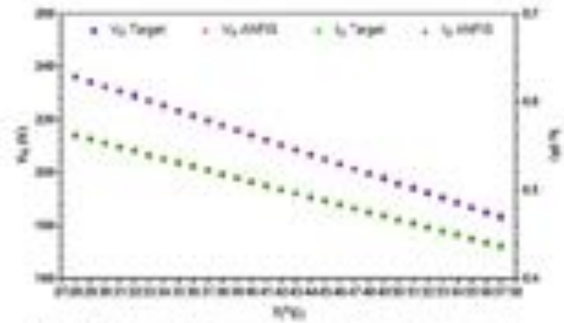

Fig. 7. The simulation result using ANFIS (system 2)

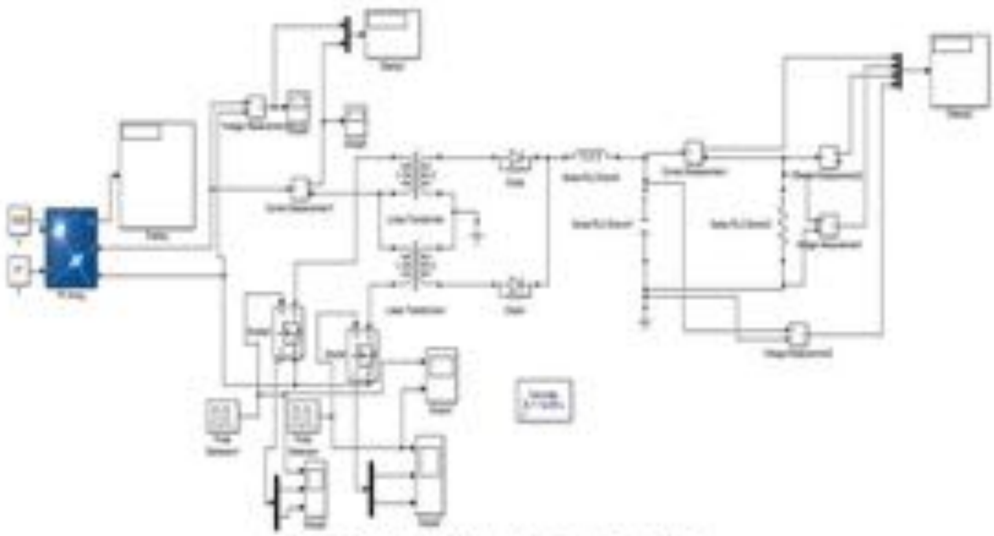

Fig. 8. System of photovoltaic using Simulink

Figure 7 showed that System 2 is decomposed into three parts: battery, inverter, and load. The input data of System 2 come from the battery, which is the ambient temperature of battery voltage and battery current. The System 2 inputs contain battery voltage (V_B), it's current (I_B), temperature (T), and SOC. Then, the output of System 2 consists of three parameters: AC voltage (V_{AC}), AC current (I_{AC}), and frequency (F). The output data of system 2 are just an inverter, AC voltage and current. The drill conducted using ANFIS generates V_{AC} output with average error is $5.8*10^{-2}$.

A. Simulation Based on Simulink Environment

The photovoltaic system based on simulink environment aims to get more and varied data to be used as input from ANFIS. So, this data can also be collected as a comparative data for system performance between two tests of direct measurement and simulink environment.

The two systems have been simulated using the ANFIS technique, namely; the test of data is 28, and the simulation environment of data is 150. Figure 8 shows a model of a photovoltaic system using Matlab/Simulink. In this photovoltaic system, there are three main components, namely; photovoltaic modules, regulators, and batteries. The specification of the photovoltaic modules is used in the prototype. The regulator design is modeled using a type of push-pull converter. The process of retrieving simulation data is to provide variations in the value of solar irradiation and temperature of photovoltaic modules which are taken from 100 W/m^2 up to 1000 W/m^2, and the temperature is varied from 28°C to 56°C. Furthermore, the output obtained is the open circuit voltage (V_{OC}), photovoltaic voltage (V_{Pv}), and photovoltaic current (I_{Pv}).

B. Mean Absolute Percentage Error (MAPE)

To validate a system that focuses on forecasting or prediction can use MAPE. This method aims to calculate value of the absolute error for each period and, divided by value of real observation in that period [11]. Figure 9 shows the MAPE value in each data comparison for systems 1 and 2. MAPE for System 1 from the direct test for open circuit voltage output (V_{OC}) is $1*10^{-2}$ %. Based on the MAPE calculation, it is obtained that the short-term prediction results achieved by the results of the error value are excellent, this indicator shows that the error value obtained by MAPE is below 10%. ANFIS modeling has been run for System 1. It has different data between training and testing as 150 data; thus can be said that the model has produced well. Furthermore, the MAPE for System 2 direct testing is generated the output voltage (AC) is $2.6*10^{-2}$ %, the current output (AC) is 1.3 %, and the frequency output is $4.6*10^{-3}$ %. The MAPE obtained when the predicted data produced is very good, because the value of MAPE is below 10%. The modeling of ANFIS for direct test System 2 has been developing is great. ANFIS data training for direct measurement or measurement from the software environment will be found ANFIS output value. Then, the error value will be calculated on the actual value of the ANFIS output. This error value will determine whether the ANFIS network has been built. The lower error value is, the better the structure is constructed. The lowest error value will be achieved by calculating the value of MAPE. MAPE value will show the results of ANFIS network training, the lower MAPE value is the ANFIS network will get better, and vice versa.

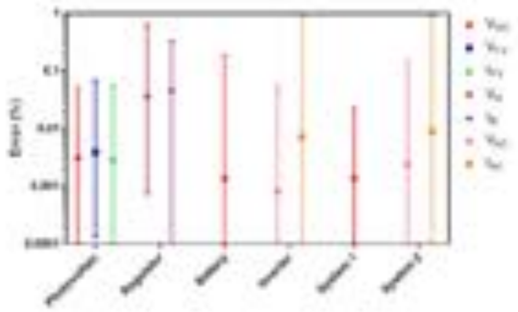

Fig. 9. The result of the MAPE

Based on the ANFIS techniques that have been carried out, it is necessary to obtain a comparison of MAPE values between training data and test data from each system. Figure 10 describes MAPE value for data test system 1 with $1*10^{-2}$ % open circuit voltage output data, $5.5*10^{-3}$ % solar panel voltage, and $1.7*10^{-2}$ % of solar panel current. Based on MAPE value analysis, prediction data was gained for no more than 10%. Thus, the successful implementation of ANFIS technique for system 1 that has been established is very good.

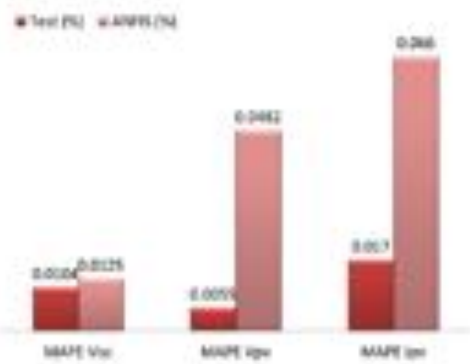

Fig. 10. The MAPE for system 1

Figure 11 shows information on MAPE value for data test system 2, where AC voltage output data is $2.6*10^{-2}$ % and AC current output is $13.04*10^{-2}$ %. Based on the MAPE value obtained that is less than 10%, it can be concluded that the prediction data was excellent. Hence, the ANFIS network for a direct test data of system 2 is good. Based on the MAPE value analysis, it was discovered that the prediction data generated does not exceed 10%. Therefore, the successful implementation of ANFIS technique for system 2 that has been built is very good.

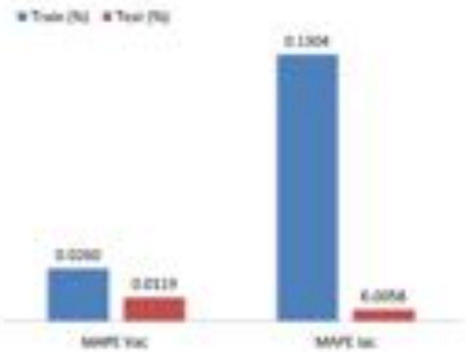

Fig. 11. The MAPE for system 2

IV. Conclusion

The MAPE value for testing photovoltaic data directly from the open circuit voltage output (VOC) is 11.93%, the MAPE value has exceeded 10%, this shows the less good results of direct testing. Ideally MAPE values found below 10% provide excellent predictive data. The ANFIS technique application has been operated using system 1 and 2 along with ANFIS structure design. The average score of errors of systems 1 and 2 are $1.04*10^{-4}$ % and $5.8*10^{-2}$ % respectively. After the data training, data test is immediately carried out by using new data. Moreover, MAPE value of ANFIS data test of system 1 and 2 is accomplished to gain the best result under 10%, this means that the performance of system 1 and system 2 is very good. The ANFIS technique result can be used as a reference for future research in designing any solar power system for generating capacity corresponding to the household necessity.

Acknowledgment

The authors would like to thank the Institute for Research and Community Services (*LPPM*), Riau University.

References

[1] Kenmo Mizuki, H.Y., et al., *Maximizing Power-Supply Time of DC Power System with Photovoltaics and Fuel Cells*, in *IEEE*. 2014.

[2] Meijun Liu, Z., Y.L. W., and F.M. Meng Chen, *Power Prediction Model of Grid Connected Photovoltaic and Power Flow Analysis*. 2012. IEEE.

[3] Muhim, A.B.A.K.A. and H. Cordova, *Rancang Bangun Sistem Pembangkit Listrik Tenaga Surya Secara Mobile Berbasis Logika Fuzzy di PT. GMN Tuban Jawa Timur*. 2013. Institut Sepuluh Nopember: Surabaya.

[4] H.Alomari, M. and O.Y. Jehad Adeeb, *Solar Photovoltaic Power Forecasting Jordan using Artificial Neural Networks*. International Journal of Electrical and Computer Engineering (IJECE), 2018. **8**(1): p. 497 – 504.

[5] Diyaparti, M., L. Boubouch, and A. Dilal, *Modeling and Predicting of the Characteristics of a Photovoltaic Generator on a Horizontal and Tilted Surface*. International Journal of Electrical and Computer Engineering (IJECE), 2016. **6**(6): p. 2557-2576.

[6] Reddy, M.J. and D.K. Mohanta, *Adaptive-neuro-fuzzy inference system approach for transmission line fault classification and location incorporating effects of power swings.IET Generation, Transmission & Distribution*, 2008. 2(2): p. 235. IET Generation, Transmission & Distribution, 2008. **2**(2): p. 235.

[7] Sofianos, N.A. and Y.S. Boutalis, *Stable Indirect Adaptive Switching Control for Fuzzy Dynamic System Based on T-S Multiple Models*. International Journal of Systems Science, 2013. **44**(8): p. 1546-1565.

[8] W, S., *Adaptive Fuzzy Control fo MIMO Nonlinear System with NonSymmetric Control Gain Matrix and Unkown Control Direction*. IEEE Transactions on Fuzzy Systems, 2014. **22**(5): p. 1288-1300.

[9] Sofianos, N.A. and Y.S. Boutalis, *Robust adaptive multiple models based fuzzy control of nonlinear systems*. Neurocomputing, 2016. **173**(15): p. 1733-1742.

[10] Sallama, A., M. Abbod, and F. Turner, *Neuro-Fuzzy System Quality Improvements*. *In Universities Power Engineering Conference (UPEC), 47th International*. 2012.

[11] Bahramifar, A., *An ANFIS-based Approach for Predicting the Manning Roughness Coefficient in Alluvial Channels at the Bank-full Stage*. International Journal of Engineering, 2013: p. 177-186.

[12] Chai, Y., et al., *Model-based Adaptive Neural Fuzzy Inference System and its Application*, in *World Academy of Science, Engineering and Technology*. 2009.

[13] Azriyenni and M.W.Mustafa, *Application of ANFIS for Distance Relay Protection in Transmission Line*. International Journal of Electrical and Computer Engineering (IJECE), 2015. **5**(6): p. 1311-1318.

[14] Zaki, A.A., I.H. Rosma, and D.P.H. Simanullang, *Effect of Solar Radiation on Module Photovoltaics 300 Wp With Variation of Module Slope Angle*. Indonesian Journal of Electrical Engineering and Informatics (IJEEI), 2018. 6(1): p. 45-52., 2018. **6**(1): p. 45-52.

ANFIS Design Based on Prediction Models for The Photovoltaic System

ORIGINALITY REPORT

6%	3%	3%	5%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Universitas Riau Student Paper	2%
2	Azriyenni Azhari Zakri, Syukri Darmawan, Jafaru Usman, Iswadi Hasyim Rosma, Boy Ihsan. "Extract Fault Signal via DWT and Penetration of SVM for Fault Classification at Power System Transmission", 2018 2nd International Conference on Electrical Engineering and Informatics (ICon EEI), 2018 Publication	1%
3	M. Quamruzzaman, Nur Mohammad, M.A. Matin, M.R. Alam. "Highly efficient maximum power point tracking using DC–DC coupled inductor single-ended primary inductance converter for photovoltaic power systems", International Journal of Sustainable Energy, 2014 Publication	1%
4	Submitted to ABV-Indian Institute of Information Technology and Management Gwalior	1%

Student Paper

5	Submitted to HELP UNIVERSITY Student Paper	<1%
6	media.neliti.com Internet Source	<1%
7	pnrsolution.org Internet Source	<1%
8	Submitted to VIT University Student Paper	<1%