Available *online* at : http://jnte.ft.unand.ac.id/

Jurnal Nasional Teknik Elektro

| ISSN (Print) 2302-2949 | ISSN (Online) 2407-7267 |

Design of Wiper Cleaner Prototype based on IoT for Solar Panels with Rooftop Installation

Fitriana, Darma Arif Wicaksono, Sofia Ariyani, Rais Nurwahyudin, Fahmi Aulia Ajie

University of Muhammadiyah Jember, Karimata No.49 Street, Jember, 68121, Indonesia

ARTICLE INFORMATION

Received: April 23, 2021
Revised: November 19, 2021
Available online: November 30, 2021

KEYWORDS

IoT, Solar Panels, Rooftop, Wiper Cleaner

CORRESPONDENCE

Phone: +62 85236538210
E-mail: darmaarifwicaksono@unmuhjember.ac.id

A B S T R A C T

Many factors that affect the efficiency of solar panels, one of which is environmental factors. Among the environmental factors that negatively affect the solar panels performance is the dust accumulation on the top surface of the solar panels. This is because dust will block solar radiation from entering directly into solar cells and can reduce the efficiency of solar panels. In this research, a wiper cleaner prototype has been designed to clean dust on solar panels with a rooftop installation. This wiper cleaner system is made by utilizing servo motor movement and Internet of Things (IoT) technology so that it can be controlled remotely using an android. This wiper cleaner prototype works with a response time of 1 second and a speed of 0.0254 m/s. The wiper cleaner control system via Android can work with a maximum range of 30 meters. In addition, based on research that has been done shows that wiper cleaner can increase the efficiency of solar panels by 8.5%.

INTRODUCTION

One source of alternative energy that has the potential to be used as a source of electrical energy in Indonesia is solar energy. PV generation is playing an important role as a clean, long-lasting, and maintenance-free electrical source [1]. The amount of solar energy that is large and tends to be abundant in Indonesia, which is around 4.8 kWh/m^2/day, causes solar energy to have the potential to meet Indonesia's energy needs both now and in the future. Solar energy is also an environmentally friendly energy source because no pollution is produced during the energy conversion process [2]. Currently, the government has issued a roadmap for the utilization of solar energy which targets the installed capacity of Solar Power Plants (PLTS) until 2025 is 0.87 GW or around 50 MWp/year [3]. This number represents a fairly large market potential in the development of solar energy in the future.

The process of converting solar energy into electrical energy is carried out using solar panels consisting of more than one solar cell. Research Richter et al [4] stated that the efficiency of solar panels with a single junction only has a maximum value of 29.4%. The relatively low efficiency is a weakness of solar panels to be applied as a substitute for electricity sources from fossil materials. Many factors will affect the efficiency of solar panels, one of which is environmental factors such as environmental temperature [5], humidity, rainfall [6], seasonal changes, dust, and wind speed [7] and direction. Beside environmental factors, installation factors such as orientation, seasonal slope adjustment, tilt angle [8], height, and installation location will also affect the performance of solar panels [9].

One of the environmental factors that negatively affects the solar cells performance is the dust accumulation on the top surface of the solar panels. This is because dust will block solar radiation from entering directly into solar cells [10]. Based on research conducted by Adinoyi and Said [11] it was found that there was a 50% decrease in power on solar panels that were left dirty for more than six months. Another researcher, Chen et al. [12] also stated that dust has an impact on the power and efficiency of solar panels. The decrease in the output power of solar panels due to dust can be avoided if the solar panels are cleaned regularly [13]. The accumulation of dust that accumulates does not really affect the installation of solar panels with small power, but if this happens in a large installation area (solar farm), the decrease in solar panel efficiency affects the quality of power on the PLN network reaching 8.41% when compared to solar panels which is clean without dust [14]. Research by Zorrilla-Casanova et al [15] stated that various types of dust such as ash, soot, cement, mining plant and all types of dust have a bad effect, even in a very thin layer of solar cells can result in a decrease in performance of up to 40%.

https://doi.org/10.25077/jnte.v10n3.905.2021

There are several methods of cleaning solar panels, namely natural cleaning, manual cleaning, and automatic cleaning. The method of cleaning dirt on solar panels which is currently being further researched is using robots or automation systems. Natural cleaning is the cleaning of solar panels by rain. Rain can clean the surface of the solar panel from dust and restore the performance of the solar panel. However, the dust that has accumulated over the years on the solar cells will not be easily swept away by the rain which will eventually lead to the problem of permanent dust deposition on the solar cells [16].

In the manual cleaning technique, the top surface of the solar panel is cleaned manually using human power with the help of water and a mop or wiper. This technique is certainly very laborious and challenging especially for large solar panels installed at a height of 8 to 15 feet or more from the ground [17]. Automatic cleaning of solar panels can be done using mechanical equipment such as wipers, blowers, and brushes that can be controlled using a PLC, PIC, or microcontroller [18].

The simplest way to clean a pile of dust on a solar panel is to splash water on its surface. However, this step will be difficult to do if the PLTS installation is installed on the rooftop (solar panels are installed on the roof of the building/sectoral house). Research conducted by Mazumder et al utilizes magnetic fields to remove dust on solar panels. From the research that has been done, dust accumulation as much as 90% can be removed [19]. However, this method has a weakness, namely the need for high voltage to generate a magnetic field.

Another study by Shapsough et al [20] used IoT for online monitoring of solar panels. This system is designed to facilitate the study of the effect of impurities present in solar panels on the performance of solar panels in the Sharjah region and UAE. The solar panel fouling and cleaning index is evaluated to reduce cleaning costs and optimize power output. The results obtained show that dotting has a major impact on the efficiency of the PV module with a power loss of up to 40% after two months of dotting.

In rooftop installations, maintaining the efficiency of solar panels requires extra treatment because it makes it difficult for users. Therefore, in this study, a remote control of solar panel cleaning automation will be designed. The controls are made to adopt the performance of car glass cleaners (wiper cleaning) by utilizing the movement of the servo motor in cleaning the solar panels. Another convenience that was completed in this research was the use of industrial technology 4.0, namely the Internet of Things (IoT) module.

METHOD

In general, the design of the android wiper cleaner control in this study can be described through a blog diagram of the entire system as shown in Figure 1. The explanation of the system as shown in Figure 1 is as follows: The wiper cleaner is controlled remotely using the Blynk application that has been installed on the android smartphone. This control system is connected to the internet to send control signals from the Blynk application to the control box to instruct the wiper cleaner to carry out the cleaning process.

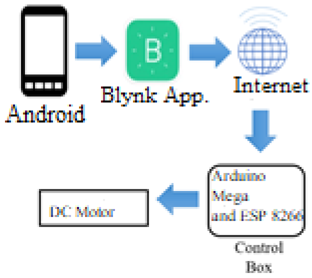


Figure 1. Overall System Diagram

The wiper cleaner control system can work based on the selected mode, namely automatic mode or manual mode. Manual cleaning mode is done by pressing the "WIPER" button on the Blynk application so that the wiper cleaner will carry out the cleaning process at that time. The cleaning mode is automatically carried out by entering the cleaning time in the Blynk application so that the system will run automatically at a pre-set time to carry out the solar panel cleaning process. The flow diagram for the wiper cleaner system can be seen in Figure 2.

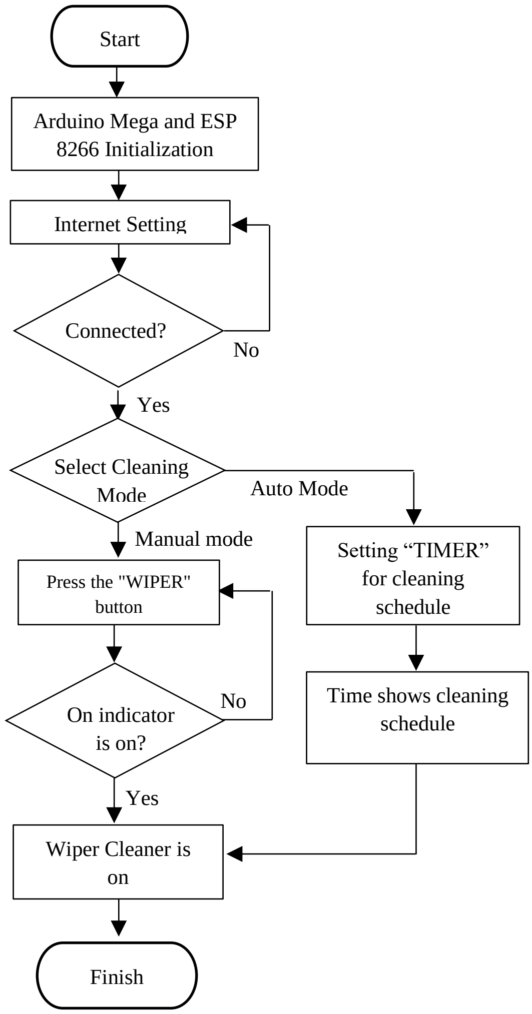


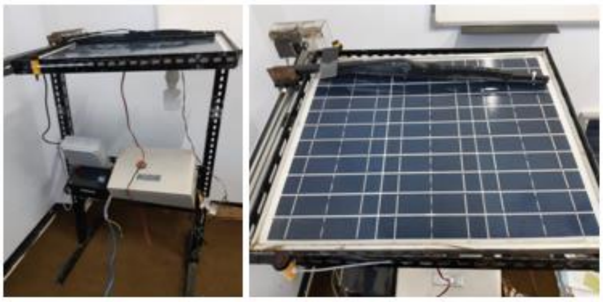
Figure 2. Flowchart of Wiper Cleaner System

https://doi.org/10.25077/jnte.v10n3.905.2021

RESULTS AND DISCUSSION

Hardware Design Results

The results of the hardware design produced in this study can be seen in Figure 3.



(a) (b)

Figure 3. Wiper cleaner prototype (a) side view (b) top view

The wiper cleaner drive system is made using 2 stepper motors equipped with ultrasonic sensors. This ultrasonic sensor is used as a distance reference to determine the direction of the cleaner's motion on the wiper cleaner. The wiper cleaner control system is carried out by connecting the wiper cleaner with the arduino mega and the ESP 8266 module so that it can be controlled remotely using android.

Software Design Results

The solar panel cleaning system using a wiper cleaner can be done manually and automatically through the Blynk application on Android as shown in Figure 4.

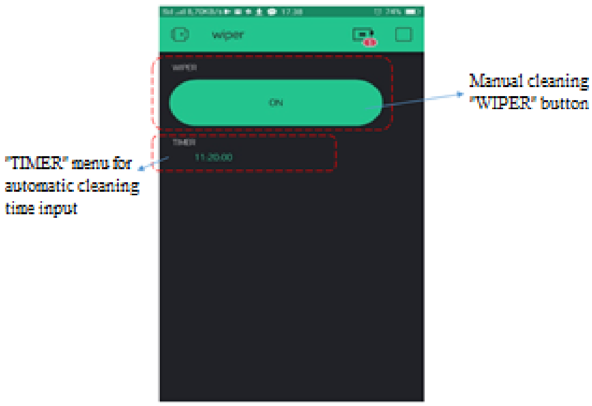


Figure 4. Display of the Blynk Application Menu for Wiper Cleaner

Manual cleaning can be done using the "WIPER" button on the Blynk application which when the button is pressed, the wiper cleaner will carry out the cleaning process at that time. Meanwhile, cleaning is automatically carried out by inputting the cleaning schedule in the “TIMER” menu so that the wiper cleaner will automatically carry out the cleaning process according to the schedule entered in the “timer” menu.

Wifi Connectivity Test

In the IoT (Internet of Things) system, wifi connectivity is the main parameter needed to run the entire tool system so that the Wiper Cleaner control system application must be connected or connected to the internet. In this study, the wifi module used in the IoT Wiper Cleaner system is the ESP8266 module. Therefore, it is necessary to test the connectivity between the wiper cleaner application and the ESP8266 module. The test is carried out by operating the wiper cleaner through the Blynk application at different distances. In this test, connectivity is said to be connected if the application is able to control the device at a specified distance. The results of this wifi connectivity test can be seen in Table 1.

Table 1. Wifi Connectivity Test Results Data

No. Test	Distance	Connectivity
1	1 meter	connected
2	15 meter	connected
3	20 meter	connected
4	25 meter	connected
5	30 meter	connected
6	35 meter	not connected
7	40 meter	not connected
8	50 meter	not connected

Based on the results of the tests carried out, it appears that the maximum distance where wifi on Android can be connected to the ESP module on Arduino is 30 meters. This means that the Blynk application can be used to control the wiper cleaner at a maximum distance of 30 meters from the position of the ESP8266 module and the application will not work at a distance of more than 30 meters.

Delay Test

The delay test in this study aims to find out how long it takes the wiper cleaner to respond to the control signal given through the Blynk application on Android. This control signal is given by pressing the "WIPER" button in the Blynk application. This delay test was carried out 5 times with the results as shown in Table 2.

Table 2. Data of Delay Test Results

No. Test	Time the “WIPER” button is pressed	Time of Wiper cleaner time ON	Delay
1	11.15.00	11.15.01	1 s
2	11.20.00	11.20.01	1 s
3	11.25.00	11.25.01	1 s
4	11.30.00	11.30.01	1 s
5	11.35.00	11.35.01	1 s
	Average Delay		1 s

From Table 2 it can be seen that the average delay value is 1 second. This means that the time required for the wiper cleaner to respond to the control signal given through the Blynk application is 1 second, so it can be concluded that the Blynk application takes about 1 second to turn on the wiper cleaner.

Wiper Cleaner Speed Measurement Results

The wiper cleaner speed measurement aims to determine the speed of the wiper cleaner in carrying out the solar panel cleaning process. Wiper cleaner speed measurement is done by measuring the time required by the wiper cleaner to perform one cleaning process. The next step is to measure the speed of the wiper cleaner using the formula:

$$Speed = \frac{x}{t} \tag{1}$$

Information:
x = solar panel width (m)
t = time required by the wiper cleaner to perform one cleaning process (s)

The wiper cleaner speed measurement was carried out five times with the measurement results as shown in Table 3 below:

Table 3. Data of Wiper Cleaner Speed Measurement Results

No. test	x (m)	t (s)	Speed (m/s)
1	0.35	15	0.023
2	0.35	12	0.029
3	0.35	15	0.023
4	0.35	15	0.023
5	0.35	12	0.029
Average			0.0254

Based on the measurement results shown in Table 3, it is known that the speed of the wiper cleaner in carrying out the solar panel cleaning process is 0.0254 m/s

Wiper Cleaner Manual System Test

Wiper cleaner manual system testing is done to find out whether the manual system that has been made can control the wiper cleaner as expected or not. Testing is done by pressing the "WIPER" button on the Blynk application on Android so that on the "WIPER" button the "ON" or "OFF" indicator appears. The test is said to be successful if the wiper cleaner moves to carry out the cleaning process when the "WIPER" button is pressed and the "ON" indicator appears and stops the cleaning process when the "WIPER" button is pressed and the "OFF" indicator appears. The results of the manual wiper cleaner system test can be seen in Table 4.

Table 4 Data of Manual Wiper Cleaner System Test Results

No test	Indicator in "WIPER" button	Wiper Cleaner Respone	Description
1	ON	Move to do the cleaning process	succeed
2	OFF	Stop doing the cleaning process	succeed
3	ON	Move to do the cleaning process	succeed
4	OFF	Stop doing the cleaning process	succeed
5	ON	Move to do the cleaning process	succeed
6	OFF	Stop doing the cleaning process	succeed
7	ON	Move to do the cleaning process	succeed
8	OFF	Stop doing the cleaning process	succeed
9	ON	Move to do the cleaning process	succeed
10	OFF	Stop doing the cleaning process	succeed
Success Percentage			100%

Based on the test results in Table 4 above, it can be concluded that the manual wiper cleaner system can work well with a success rate of 100%.

Wiper Cleaner Automated System Testing

Wiper cleaner system testing aims to determine whether the system created can work as planned or not. System testing was carried out 5 times at different times. The test is said to be successful if the wiper cleaner is working or ON according to the time entered in the wiper cleaner application. The test results of the wiper cleaner application can be seen in Table 5.

Table 5. Data of Wiper Cleaner Application Test Results

No. test	Time	Duration	Wiper Cleaner Response	Description
1	12.05.31	2 minute	On for 2 minutes	succeed
2	15.37.34	5 minute	On for 5 minutes	succeed
3	13.11.01	10 minute	On for 10 minutes	succeed
4	14.03.45	12 minute	On for 12 minutes	succeed
5	17.50.44	20 minute	On for 20 minutes	succeed
Success Percentage				100%

Based on the test results in Table 5 above, it can be concluded that the wiper cleaner system can work well with a success rate of 100%.

Wiper Cleaner Ability Testing

Testing the ability of the wiper cleaner system on IoT-based Solar Panels is carried out using a 30 WP solar panel that is projected in the real state on a Rooftop installation and is connected to a 30 ohm resistor. In this test, data is collected on the output power of the solar panel in a state of dust (dirty) and in a state without dust or has been cleaned. The following test results can be seen in Table 6 and Table 7.

Table 6. Experimental data of solar panel output power with dust

Test	Output voltage (v)	Current (A)	Power (Watt)
1	1.14	1.6	1.82
2	1.17	1.5	1.75
3	1.10	1.6	1.76
Average Power			1.78

Table 7. Experimental data of dustless solar panel output power

Test	Output voltage (v)	Current (A)	Power (Watt)
1	3.45	1.3	4.49
2	3.4	1.3	4.42
3	3.4	1.2	4.08
Average Power			4.33

Calculation of the efficiency of the output power (output) of solar panels in conditions with dust (dirty):

$$Efficiency = \frac{1.78Watt}{30Watt} x100\% = 5.93\% \quad (2)$$

Calculation of solar panel output power efficiency in a dust-free or cleaned condition:

$$Efficiency = \frac{4.33Watt}{30Watt} x100\% = 14.43\% \quad (3)$$

 https://doi.org/10.25077/jnte.v10n3.905.2021

The calculation of the efficiency of the solar panel output power is carried out in two different conditions, namely in conditions with dust and in conditions without dust or has been cleaned using a wiper cleaner. Setting the working time of the wiper cleaner system in cleaning dust/dirt in the solar panel field is done when there is no sunlight, it can be done at night or in the morning before sunrise. Based on the results of measurements of current, output voltage, and power performed three times for each condition, then the average power is calculated as a percentage to determine the efficiency of the output power. In a solar panel that is in a dusty condition, the solar panel can produce an average power of 1.78 Watts from the 30-watt peak power rating, which means that the solar panel output power efficiency is 5.93%. In the condition that the solar panels are clean without dust or have been cleaned with a wiper cleaner, the solar panels can produce an average power of 4.33 watts from the 30-watt peak power rating, which means that the solar panel output power efficiency in this condition is equal to 14.43%. Previous studies have shown that the presence of dust or dirt on the surface of the solar panel will affect the amount of voltage converted and result in a decrease in the power generated. This decrease in efficiency will be even greater if there is more dirt or dust on the surface of the solar panel. Based on the results of the research conducted this time, it is known that there is an increase in efficiency of 8.5% after the solar panels are in a dustless condition or have been cleaned with wiper cleaner microcontroller technology based on the IoT module that has been designed in this study. It is hoped that this IoT module-based wiper cleaner will make it easier for operators to clean the surface of solar panels, especially on rooftop installations.

CONCLUSIONS

Based on the results of the research that has been done, it can be concluded that the wiper cleaner has succeeded in cleaning the solar panels manually and automatically with a response time (delay) of 1 second and a speed of 0.0254 m/s. The wiper cleaner control system via android can work with a maximum range of 30 meters provided that it has a connection that is constantly connected to the internet. In addition, the wiper cleaner can increase the efficiency of solar panels by 8.5%.

ACKNOWLEDGMENT

The authors are grateful for the financial support of Lembaga Penelitian dan Pengabdian Masyarakat (LPPM) University of Muhammadiyah Jember and various parties who have helped carry out this research.

REFERENCES

[1] G. S. A. Pratama, H. E. H. Suharyanto, and Y. C. Arif, “Identify and Locating the Faults in the Photovoltaic Array Using Neural Network,” *J. Nas. Tek. Elektro*, vol. 10, no. 2, pp. 77–86, 2021.

[2] A. Rahayuningtyas, S. I. Kuala, and I. F. Apriyanto, “Studi Perencanaan Sistem Pembangkit Listrik Tenaga Surya (PLTS) Skala Rumah Sederhana Di Daerah Pedesaan Sebagai Pembangkit Listrik Alternatif Untuk Mendukung Program Ramah Lingkungan Dan Energi Terbarukan,” *Pros. SNaPP2014 Sains, Teknol. dan Kesehat.*, pp. 223–230, 2014.

[3] M. Effendy, “Rancang Bangun Maximum Power Point Tracking (MPPT) Solar Sel Untuk Aplikasi Pada Sistem Grid Pembangkit Listrik Tenaga Angin (PLTAg),” *J. Gamma*, vol. 9, no. 1, pp. 170–178, 2015.

[4] A. Richter, M. Hermle, and S. W. Glunz, “Reassessment of the limiting efficiency for crystalline silicon solar cells,” *IEEE J. Photovoltaics*, vol. 3, no. 4, pp. 1184–1191, 2013.

[5] A. Pawawoi and V. A. Pranata, “Peningkatan Daya Output Photovoltaik Dengan Penambahan Lapisan Kaca Film Pada Permukaannya,” *J. Nas. Tek. Elektro*, vol. 9, no. 3, pp. 124–130, 2020.

[6] E. Simsek, M. J. Williams, dan L. Pilon, “Effect of dew and rain on photovoltaic solar cell performances,” *Sol. Energy Mater. Sol. Cells*, vol. 222, no. 1–10, hal. 110908, 2021, doi: 10.1016/j.solmat.2020.110908.

[7] T. Bhattacharya, A. K. Chakraborty, and K. Pal, “Effects of Ambient Temperature and Wind Speed on Performance of Monocrystalline Solar Photovoltaic Module in Tripura, India,” *J. Sol. Energy*, vol. 2014, pp. 1–5, 2014.

[8] G. Hailu and A. S. Fung, “Optimum tilt angle and orientation of photovoltaic thermal system for application in Greater Toronto Area, Canada,” *Sustain.*, vol. 11, no. 22, pp. 1–21, 2019.

[9] V. Gupta, M. Sharma, R. Kumar, and K. N. D. Babu, “Comprehensive review on effect of dust on solar photovoltaic system and mitigation techniques,” *Sol. Energy*, vol. 191, pp. 596–622, 2019.

[10] R. Karmouch and H. EL Hor, “Solar Cells Performance Reduction under the Effect of Dust in Jazan Region,” *J. Fundam. Renew. Energy Appl.*, vol. 07, pp. 10–14, 2017.

[11] M. Benghanem, A. Almohammedi, M. Taukeer Khan, dan A. A. Al-Mashraqi, “Effect of dust accumulation on the performance of photovoltaic panels in desert countries: A case study for Madinah, Saudi Arabia,” *Int. J. Power Electron. Drive Syst.*, vol. 9, no. 3, hal. 1356–1366, 2018.

[12] J. Chen, G. Pan, J. Ouyang, J. Ma, L. Fu, and L. Zhang, “Study on impacts of dust accumulation and rainfall on PV power reduction in East China,” *Energy*, vol. 194, 2020.

[13] A. Tylim, “The importance of a PV system washing program,” *Renew. Energy World*, vol. 11, 2013.

[14] M. Dida, S. Boughali, D. Bechki, and H. Bouguettaia, “Output power loss of crystalline silicon photovoltaic modules due to dust accumulation in Saharan environment,” *Renew. Sustain. Energy Rev.*, vol. 124, pp. 1–13, 2020.

[15] J. Zorrilla-Casanova *et al.*, “Analysis of Dust Losses in Photovoltaic Modules,” *Proc. World Renew. Energy Congr. – Sweden, 8–13 May, 2011, Linköping, Sweden*, vol. 57, no. May, pp. 2985–2992, 2011.

[16] J. Lopez-Garcia, A. Pozza, dan T. Sample, “Long-term soiling of silicon PV modules in a moderate subtropical climate,” *Sol. Energy*, vol. 130, pp. 174–183, 2016.

[17] E. Gooré Bi, F. Monette, and J. Gasperi, “Analysis of the influence of rainfall variables on urban effluents concentrations and fluxes in wet weather,” *J. Hydrol.*, vol. 523, pp. 320–332, 2015.

[18] L. A. Lamont and L. El Chaar, “Enhancement of a stand-alone photovoltaic system’s performance: Reduction of soft and hard shading,” *Renew. Energy*, vol. 36, no. 4, hal. 1306–1310, 2011.

[19] M. Mazumder *et al.*, “Electrodynamic removal of dust from solar mirrors and its applications in concentrated solar power (CSP) plants,” *2014 IEEE Ind. Appl. Soc. Annu. Meet. IAS 2014*, pp. 1–7, 2014.

[20] S. Shapsough, M. Takrouri, R. Dhaouadi, and I. Zualkernan, “An IoT-based remote IV tracing system for analysis of city-wide solar power facilities,” *Sustain. Cities Soc.*, vol. 57, pp. 1–10, 2020.

AUTHOR(S) BIOGRAPHY

Fitriana

Fitriana is a Lecturer in Electrical Engineering Departement at University of Muhammadiyah Jember. Fitriana completed her Bachelor's degree at University of Jember in 2014. Master's degree obtained Fitriana at the Bandung Institute of Technology. Her current research interests include renewable energy, sensor, and Internet of Things (IoT).

Darma Arif Wicaksono

Darma Arif Wicaksono received his Bachelor's degree at University of Jember and Master's degree at Sepuluh Nopember Institute of Technology. He has been with the Electrical Engineering Department, Faculty of Engineering, University of Muhammadiyah Jember, since 2019, where is currently a lecturer. His current research interests is power system.

Sofia Ariyani

Sofia Ariyani is a lecturer in the Department of Electrical Engineering, University of Muhammadiyah Jember. Her Bachelor's degree and Master's degree were completed at Sepuluh Nopember Institute of Technology.

Rais Nurwahyudin

Rais Nurwahyudin currently is a Bachelor degree student at Electrical Engineering Department, University of Muhammadiyah Jember. His research interest is Internet of Things (IoT).

Fahmi Aulia Ajie

Fahmi Aulia Ajie currently is a Bachelor degree student at Electrical Engineering Department, University of Muhammadiyah Jember. His research interest is Internet of Things (IoT).

https://doi.org/10.25077/jnte.v10n3.905.2021