OPEN ACCESS
JOURNAL OF TELECOMMUNICATION, ELECTRONICS, AND CONTROL ENGINEERING (JTECE) ISSN: 2654-8275 (ONLINE)
JTECE. VOL. 07, NO. 01, PP.77-87, JAN 2025 DOI: 10.20895/JTECE.V7I1.1636

IOT-BASED DUAL AXIS SOLAR TRACKER DESIGN ON MONOCRYSTALLINE PHOTOVOLTAIC FOR HYDROPONIC PLANT WATER PUMP POWER SUPPLY

RANCANG BANGUN SOLAR TRACKER DUAL AXIS BERBASIS IOT PADA FOTOVOLTAIK MONOKRISTALIN UNTUK CATU DAYA POMPA AIR TANAMAN HIDROPONIK

Andrizal Haryufathanan Danarparasaji*[1], Subuh Isnur Haryudo[2], Tri Wrahatnolo[3], Miftahur Rohman[4]

[1,2,3,4]*Program Studi S1 Teknik Elektro, Universitas Negeri Surabaya*
Jalan Ketintang, Gayungan, Surabaya, Jawa Timur, Indonesia

*[1]Corresponding author: andrizal.20063@mhs.unesa.ac.id
[2]subuhisnur@unesa.ac.id, [3]triwrahatnolo@unesa.ac.id, [4]miftahurrohman@unesa.ac.id

Received on 04-11-2024, accepted on 09-01-2025, published on 27-01-2025

Abstract

Hydroponic growing media requires a continuous flow of water usually powered by PLN electricity. If the electricity supply is interrupted, the supply of plant nutrients will be disrupted. The utilization of renewable energy, such as photovoltaic, is an alternative solution. The efficiency of energy conversion is highly dependent on the placement of photovoltaic towards the position of the sun. Solar trackers that direct solar panels to follow the movement of the sun can increase the efficiency of photovoltaic. This research compares the performance of solar panel systems with and without solar trackers and tests the working duration of batteries for hydroponic water pump power supply. The Internet of Things (IoT) concept encompasses the idea of expanding the network of internet-connected devices to control and monitor devices remotely. The results show that the panel with the tracker produces an average voltage of 13.87 Volts and a current of 0.85 Amperes higher than without the tracker (13.36 Volts and 0.63 Amperes), with an efficiency of about 2% between the solar panel using the tracker and the one not using the tracker system. In addition, the battery can work for 12 hours to power the hydroponic water pump without the power obtained by the solar panel. For further development, it is recommended to use more advanced Internet of Things (IoT) technology and improved methods to increase the efficiency of the tracker system

Keywords: Solar tracker, Internet of Things, Solar Panel, photovoltaic

Abstrak

Media tanam hidroponik memerlukan aliran air yang terus-menerus biasanya didukung oleh listrik PLN. Jika pasokan listrik terputus, suplai nutrisi tanaman akan terganggu. Pemanfaatan energi terbarukan seperti photovoltaic menjadi solusi alternatif. Efisiensi konversi energi sangat bergantung pada penempatan photovoltaic terhadap posisi matahari. Solar tracker yang mengarahkan panel surya mengikuti pergerakan matahari dapat meningkatkan efisiensi photovoltaic. Penelitian ini membandingkan kinerja sistem panel surya dengan dan tanpa solar tracker, serta menguji durasi kerja aki untuk catu daya pompa air hidroponik. Konsep Internet of Things (IoT) mencakup ide untuk memperluas jaringan perangkat yang terhubung dengan internet guna mengontrol dan memonitor perangkat secara jarak jauh. Hasil menunjukkan bahwa panel dengan tracker menghasilkan tegangan rata-rata 13,87 Volt dan arus 0,85 Ampere lebih tinggi daripada tanpa tracker (13,36 Volt dan 0,63 Ampere) dengan efisiensi sekitar 2% antara panel surya yang menggunakan tracker dan yang tidak menggunakan system tracker. Selain itu, aki mampu bekerja selama 12 jam untuk catu daya pompa air hidroponik tanpa daya yang didapatkan oleh panel surya. Untuk pengembangan lebih lanjut, disarankan penggunaan teknologi Internet of Things (IoT) yang lebih maju dan peningkatan metode untuk meningkatkan efisiensi sistem tracker.

Kata kunci: Pelacak surya, Internet of Things, Panel Surya, fotovoltaik

I. INTRODUCTION

Nowadays, with limited land, people utilize technology by using ever-flowing water to grow plants without using soil, but with water. Water pumps certainly require electricity as a power source. The source of energy that turns into electricity needed by electronic devices is also called a power supply [1]. Hydroponic growing media requires a continuous flow of water. Generally, the PLN electricity source is used to keep the water pump running. However, if the power PLN is off, the supply of nutrients for plants will also stop. Therefore, a solution is needed [2].

Various countries have implemented the utilization of new renewable energy to reduce energy raw materials derived from fossils (gas, petroleum and coal) [3]. One form of utilization of new renewable energy by utilizing light intensity sources that can be converted into electrical energy using photovoltaic [4]. Photovoltaic power output is not constant because its output capacity depends on the level of solar radiation where the position of the sun always changes every time. One example of a type of photovoltaic that has a relatively high efficiency is monocrystalline photovoltaic [5].

The placement of the photovoltaic surface towards the position of the sun is very effective in optimizing photovoltaic efficiency. The concept of solar trackers is suitable for directing the surface of solar panels in the direction of incoming sunlight so that the optimization of photovoltaic efficiency can be relatively higher [6]. There are two types of solar trackers based on the degree of freedom, namely single axis and dual axis. To produce greater power output, of course, the type of dual-axis solar tracker is used because the dual-axis motion system can move from east to west and from north to south simultaneously [7].

In order to make it easier for users to monitor the amount of power output produced by solar panels using the concept of a dual-axis solar tracker, the Internet Of Things (IoT) can be one solution. The Internet of Things is a collection of connected devices that are able to detect, perform actions, and communicate both among fellow devices and with the surrounding environment. This technology allows devices to share information and act independently in response to events in the real or physical world, as well as activate processes and create services, either with or without direct human intervention [8].

Previous researchers, Samsurizal et al., hove done research regarding the Utilization of Solar Power on Polycristaline Type Photovoltaic for Hydroponic Plant Power Supply [9]. In the study, researchers successfully designed and all systems can work properly. Conversion of electrical energy by utilizing solar energy sources can turn on the water pump on hydroponic plants, with the load used only an electric pump.

Based on the background and from previous research, this research designs an IoT-based dual-axis solar tracker design on monocrystalline photovoltaic for hydroponic plant water pump power supply. This research is an innovation that uses the Blynk application to integrate IoT technology as an interface for monitoring voltage, current and power generated by solar panels. This research uses the INA219 sensor to measure current and voltage on solar panel. The ESP32 microcontroller is used as the main control that can be connected to the IoT platform. The INA219 sensor reading results will be processed by ESP32 and sent to the internet to be displayed on the Blynk web server and the Blynk application. This tool can work automatically and the Blynk application will be notified if the tool is working and can monitor the current and voltage remotely using the website and android application in real time.

II. LITERATURE REVIEW

Solar panels, also known as photovoltaic panels, are semiconductor devices that convert sunlight energy into electrical energy. The intensity level of sunlight radiation and the ambient air temperature affect the voltage and current generated by the solar panel. The higher the intensity of sunlight, the higher the voltage and current that will be produced [10]. There are several types of solar panels. One of them is polycrystalline and monocrystalline. The solar panels used in this study are monocrystalline because monocrystalline solar panels have a higher energy conversion efficiency compared to polycrystalline panels. This is mainly because monocrystalline panels are cut from a single silicon crystal, thus allowing a more efficient flow of electricity through the panel.

A sensor is needed to determine the intensity of sunlight received on solar panels. One sensor that can read the intensity of sunlight is the LDR sensor module or (Light Dependent Resistor). LDR (Light Dependent Resistor) is a type of resistor that changes its resistance due to the influence of light. The magnitude of the resistance value on the LDR light sensor depends on the size of the light received by the

LDR itself. When the light is dark, the resistance value is getting bigger while the light is getting smaller. LDR is a type of resistor that is commonly used as a light detector or measuring the amount of light controversy. LDR consists of a semiconductor disk that has two electrodes on its surface [11]. One of the advantages of this LDR sensor module is the sensitivity of signal detection on the LDR sensor module can be adjusted using a potentiometer. LDR sensor modules are suitable for light-related projects, such as solar panels that can detect the direction of motion of the sun or solar trackers. LDR is very sensitive to light and can provide an appropriate response to changes in the intensity of the surrounding light.

ESP32 microcontroller is the successor to the ESP8266 microcontroller. If one wants to create a project that requires applying the Internet Of Things. In that case, this ESP32 Microcontroller has a WiFi module available so that it supports users to create an Internet Of Things application system. One of the advantages of the ESP32 microcontroller compared to previous microcontrollers is the pin out of the ESP32, which has larger memory and more analog pins and Wifi, which allows users to apply the Internet of Things with microcontrollers [12]. Talking quietly about the Internet of Things, one of the benefits of the Internet of Things is that we can exchange data or exchange information using a network that connects various objects that have identifiers and IP addresses so that they can use or produce services and work together to achieve common goals Internet of Things is everything or electronic devices that can interact directly with users who are used for monitoring or control needs on these devices via the internet [13].

One of the things that IoT can monitor is current, voltage and power. Sensors that can help us to read voltage, current and power, which can later be monitored, are INA219 sensors. This equipment is capable of monitoring shunt voltage and bus voltage supply, with program times conversion and filtering, because the I2C interface supportes it. The maximum input amplifier of the INA219 is ±320mV, which means it can measure currents up to ±3.2A. The INA219 schematic has a clock, Vin +, Vin -, data I/O pins, analog 0, analog 1, ground and voltage supply [14]. When we want to monitor devices via the internet, of course we need an application or server. One of the iOS and Android applications that can control Arduino, NodeMCU, Raspberry Pi, via the internet is Blynk. Hardware control, viewing sensor data, saving data and others can be used using this application. The main components of this application are the application, library and server. Blynk is used to handle all communication between the smartphone and the hardware [15].

III. RESEARCH METHOD

This type of research is categorized as quantitative research, which was chosen because it involves the creation and implementation of a prototype solar tracker technology that can follow the movement of the sun in two axes, namely the horizontal and vertical axes. The initial stages of this research began with a literature study, in which researchers sought references from previous studies related to the research to be carried out to study and understand the theory related to the research. The next stage is tool design. This stage includes tool making, hardware design, and software design that has been integrated with the Internet of Things.

Next is implementing the tool by making a prototype or realizing it based on system and tool design. Tool testing is carried out after the above stages are completed to find out whether the prototype can work properly according to the program. Data analysis is carried out after the tool testing is completed. This stage collects data obtained from the performance of the IoT dual-axis solar tracker design on monocrystal photovoltaics for hydroponic plant water pump power supply. Finally, the conclusion or summary of the results of the research is made.

After going through the stages of making hardware systems and programming, the data that will be taken from testing the tool is the accuracy of the current and voltage sensor readings. Data analysis is used, namely comparing the results of voltage and current on solar panels and determining the performance and efficiency of solar panels that use trackers and those that do not use trackers. In sensor testing, there is still a difference in value (error), so the calculation of the error value is carried out using the following equation (1) Formula [16]:

$$\text{Percentage error} = \frac{|\,\text{SV} - \text{SV}\,|}{AV}\ X\ 100\% \tag{1}$$

SV : Sensor Value (see Table 1 column sensor)

AV : Accurate Value (see Table 1 column voltage)

To determine field area on solar panels using the following equation Formula (2) [17]:

$$\text{field area} = \text{Length } x \text{ width} \quad (2)$$

Radiation based on STC (Standard Test Condition) on the solar panel nameplate is 1000 W/m2 (global light intensity at maximum radiation), the panel produces a maximum power of 20 wp. For the calculation of the fill factor (FF), the following equation can be determined (3) [17]:

$$FF = \frac{Vmp\ .\ Imp}{Voc\ .\ Isc} \quad (3)$$

Vmp : Voltage at maximum power (Vmp) is the voltage at which the power output is greatest.
Imp : Imp is the current (amps) when the power output is greatest.
Voc : Open-circuit voltage (Voc) is the maximum voltage that a solar panel can produce without a load.
Isc : Imp is the current (amps) when the power output is greatest. Short-circuit current is the current that flows out of the panel when the positive and negative wires are connected together.

By knowing the area of the solar panel and the charging factor, the efficiency of the solar panel can be known with equation (3), namely (4) [17]:

$$\eta = \frac{Pout}{Pin}\ x\ 100\% \quad (4)$$

IV. RESULTS AND DISCUSSION

A. Results of Iot-Based Dual Axis Solar Tracker Design On Monocristalin Photocoltaics For Hydroponic Plant Water Pump Power Supply

Figure 1. System Design

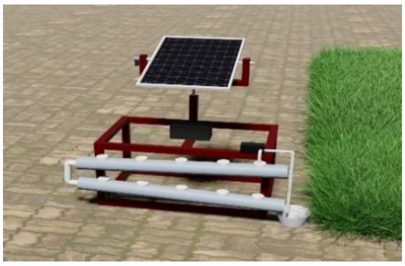

Figure 2. Sketch Design

B. Solar Tracker Algorithm

Four LDR sensors installed on each side of the photovoltaic will detect the intensity of sunlight. The microcontroller, which has been programmed, will send commands to the DC motor to move the photovoltaic in the direction of the brighter sunlight intensity.

C. Tool Testing

1. Sensor performance testing

Testing is done by recording the results of five sensor measurements at each voltage increase. Testing is carried out in Table 1

Table 1. Sensor Performance Testing

Voltage	Sensor	Multimeter	Error
3V	3,04V	3,08V	0,13%
5V	5,05V	5,09V	0,78%
7V	7,07V	7,11V	0,56%
9V	9,06V	9,11V	0,54%
12V	12,06V	12,11V	0,41%
average			0,48%

Based on the test results in Table 1, the percentage error is then calculated using equation (1). From the measurement results that have been carried out, the INA219 sensor has an average voltage error value of 0.48%. with these results the INA219 sensor is good to use.

2. Blynk server testing

Research using Blynk IoT was conducted to determine whether the Blynk cloud server can acquire and transmit ESP32-generated data for online and real-time monitoring.

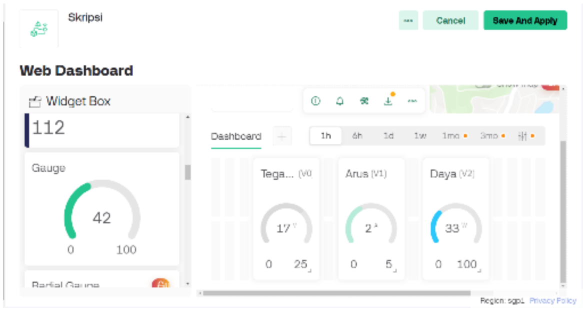

Figure 3. Blynk server testing

3. Connection testing on the app

This test is done to determine whether the Blynk application can display data from the device that has been made. A green indicator light is on, indicating that the application connection is connected to the internet.

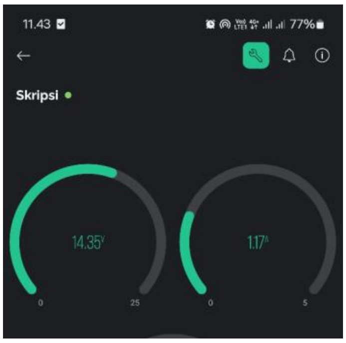

Figure 4. Connection testing on the app

D. Data Retrieval

The data can be monitored in real-time and online using a server or the Blynk app. This data consists of current and voltage on solar panels. Data collection is done by comparing the results of current and voltage output on solar panels that use tracker systems and those that do not use trackers, as well as data on how strong the battery works to support the hydroponic plant water pump. Comparison data of current and voltage output results on solar panels that use tracker systems and do not use trackers that the authors take data values, taken every 30 minutes at 09.00-15.00. In contrast, the data that the author takes to find out how strong the battery works to support the hydroponic plant water pump is taken from 15.00-09.00.

1. Voc, Isc testing without tracker

The tests in Figures 5, 6 and 7 below aim to determine the maximum voltage capacity and maximum current capacity of the solar panels used. Testing of open circuit voltage (Voc) and short circuit current (Isc).

Day 1 testing		
Voc, Isc testing without tacker		
time	Voc (V)	Isc (A)
09.00	18,67	0,73
09.30	18,71	0,77
10.00	18,75	0,83
10.30	18,79	0,84
11.00	18,84	0,88
11.30	18,88	0,91
12.00	18,93	0,93
12.30	18,96	0,95
13.00	19,03	0,97
13.30	19,07	1,01
14.00	19,1	1,04
14.30	18,73	0,83
15.00	18,7	0,81
	18,85846	**0,884615**

Figure 5. Voc, Isc testing without tracker Day 1

Day 2 testing		
Voc, Isc testing without tracker		
time	Voc (V)	Isc (A)
09.00	18,74	0,75
09.30	18,77	0,76
10.00	18,8	0,79
10.30	18,82	0,82
11.00	18,86	0,86
11.30	18,89	0,9
12.00	18,95	0,92
12.30	18,97	0,94
13.00	19,01	0,97
13.30	19,13	0,99
14.00	19,2	1,07
14.30	18,86	0,94
15.00	18,84	0,91
	18,91077	**0,893846**

Figure 7. Voc, Isc testing without tracker Day 2

Day 3 testing		
Voc, Isc testing without tracker		
time	Voc (V)	Isc (A)
09.00	18,57	0,67
09.30	18,62	0,69
10.00	18,66	0,72
10.30	18,69	0,74
11.00	18,71	0,77
11.30	18,67	0,71
12.00	18,7	0,75
12.30	18,76	0,77
13.00	18,79	0,79
13.30	18,75	0,76
14.00	18,68	0,72
14.30	18,63	0,7
15.00	18,59	0,68
	18,67846	**0,728462**

Figure 6. Voc, Isc testing without tracker Day 3

2. Testing Vm and Im in without tracker

Solar panels designed without a solar tracker are tested by making the solar panels face up not following the direction of sunlight. In Figures 8, 9 and 10 the solar panel is tested by measuring the loaded voltage (Vm) and the loaded current (Im).

Day 1 testing			
Vm and Im measurements in without tracker			
time	Vm (V)	Im (A)	P (Watt)
09.00	13,29	0,81	10,7649
09.30	13,29	0,8	10,632
10.00	13,31	0,79	10,5149
10.30	13,49	0,78	10,5222
11.00	13,5	0,76	10,26
11.30	13,51	0,68	9,1868
12.00	13,53	0,61	8,2533
12.30	13,63	0,58	7,9054
13.00	13,67	0,53	7,2451
13.30	13,71	0,5	6,855
14.00	13,85	0,43	5,9555
14.30	13,34	0,39	5,2026
15.00	13,12	0,37	4,8544
	13,48	**0,617692**	**8,319392**

Figure 9. Testing Vm and Im in without tracker Day 1

Day 2 testing			
Vm and Im measurements in without tracker			
time	Vm (V)	Im (A)	P (Watt)
09.00	13,34	0,85	11,339
09.30	13,36	0,8	10,688
10.00	13,39	0,78	10,4442
10.30	13,41	0,74	9,9234
11.00	13,45	0,7	9,415
11.30	13,48	0,69	9,3012
12.00	13,53	0,66	8,9298
12.30	13,57	0,61	8,2777
13.00	13,6	0,58	7,888
13.30	13,71	0,56	7,6776
14.00	13,72	0,52	7,1344
14.30	13,45	0,5	6,725
15.00	13,4	0,47	6,298
	13,49308	**0,650769**	**8,772408**

Figure 8. Testing Vm and Im in without tracker Day 2

Day 3 testing			
Vm and Im measurements in without tracker			
time	Vm (V)	Im (A)	P (Watt)
09.00	13,11	0,78	10,2258
09.30	13,13	0,76	9,9788
10.00	13,17	0,73	9,6141
10.30	13,23	0,7	9,261
11.00	13,24	0,69	9,1356
11.30	13,19	0,65	8,5735
12.00	13,23	0,61	8,0703
12.30	13,27	0,58	7,6966
13.00	13,28	0,53	7,0384
13.30	12,98	0,5	6,49
14.00	12,91	0,43	5,5513
14.30	12,89	0,39	5,0271
15.00	12,83	0,3	3,849
	13,11231	**0,588462**	**7,731654**

Figure 10. Testing Vm and Im in without tracker Day 3

Based on the data in Figures 8, 9 and 10 the results of testing solar panels for 3 days without using a tracker obtained an average voltage value (Vm) of 13.36 Volts and an average current value (Im) of 0.63 Amperes.

Based on the test data in Figures 8, 9 and 10, the test results then calculated the efficiency of solar panels without using trackers using equations (3) (4). To determine the efficiency of solar panels we must know the total photon power (Pin) of the solar module and the filling factor (FF) for the calculation of the total photon power (Pin) as follows:

Vm (V)	Im (A)	Isc (A)	Voc (V)
13,36	0,63	0,84	18,81

To determine the area of the solar panel as follows:

determine the area = Length *x* width

= 0,5 x 0,35 m

= 0,175 m^2

For the calculation of the filling factor (FF) can be determined as follows

$$FF = \frac{Vmp\ .\ Imp}{Voc\ .\ Isc} \quad (3)$$

$$FF = \frac{13{,}36\ x\ 0{,}63}{18{,}81\ x\ 0{,}84}$$

$$FF = 0{,}53$$

By knowing the area of the solar panel and the fill factor, the static solar panel efficiency can be determined with equation (3):

$$\eta = \frac{Pout}{Pin}\ x\ 100\%$$

$$= \frac{18{,}81\ x\ 0{,}84\ x\ 0{,}53}{1000\ x\ 0{,}175}\ x\ 100\%$$

$$= 4{,}785\%$$

3. *Testing Voc, Isc state with tracker*

The tests in Figures 11, 12 and 13 below aim to determine the maximum voltage capacity and maximum current capacity of the solar panels used. Testing of open circuit voltage (Voc) and short circuit current (Isc) on solar panels using a solar tracker.

Day 1 testing		
Voc, Isc testing with tracker		
time	Voc (V)	Isc (A)
09.00	18,9	0,84
09.30	18,93	0,86
10.00	18,96	0,9
10.30	18,99	0,93
11.00	19,04	0,97
11.30	19,13	1,01
12.00	19,21	1,03
12.30	19,42	1,09
13.00	19,57	1,12
13.30	19,64	1,15
14.00	19,82	1,19
14.30	18,99	1,05
15.00	18,95	1
	19,19615	**1,010769**

Figure 11. Testing Voc, Isc state with tracker Day 1

Day 2 testing		
Voc, Isc testing with tracker		
time	Voc (V)	Isc (A)
09.00	18,83	0,93
09.30	18,88	0,95
10.00	18,9	0,98
10.30	18,94	1,01
11.00	18,97	1,03
11.30	19,01	1,04
12.00	19,22	1,08
12.30	19,54	1,12
13.00	19,66	1,15
13.30	19,74	1,17
14.00	19,85	1,06
14.30	19,17	0,96
15.00	18,99	0,91
	19,20769	**1,03**

Figure 13. Testing Voc, Isc state with tracker Day 2

Day 3 testing		
Voc, Isc testing with tracker		
waktu	Voc (V)	Isc (A)
09.00	18,76	0,8
09.30	18,79	0,83
10.00	18,81	0,87
10.30	18,85	0,91
11.00	18,89	0,94
11.30	18,82	0,9
12.00	18,84	0,91
12.30	18,88	0,95
13.00	18,95	0,99
13.30	18,84	0,89
14.00	18,8	0,87
14.30	18,71	0,82
15.00	18,66	0,8
	18,81538	**0,883077**

Figure 12. Testing Voc, Isc state with tracker Day 3

4. Vm and Im testing in the state with tracker

Solar panel testing uses a solar tracker circuit. In Figures 14, 15 and 16 the solar panel is tested by measuring the value of the loaded voltage (Vm) and the loaded current (Im).

Day 1 testing			
Vm and Im measurement in the state with tracker			
time	Vm (V)	Im (A)	P (Watt)
09.00	13,78	1,15	15,847
09.30	13,8	1,1	15,18
10.00	13,84	1,05	14,532
10.30	13,87	1,01	14,0087
11.00	13,89	0,99	13,7511
11.30	13,92	0,94	13,0848
12.00	13,99	0,91	12,7309
12.30	14,27	0,86	12,2722
13.00	14,3	0,82	11,726
13.30	14,35	0,77	11,0495
14.00	14,38	0,75	10,785
14.30	13,58	0,73	9,9134
15.00	13,47	0,69	9,2943
	13,95692	**0,905385**	**12,62884**

Figure 14. Vm and Im testing in the state with tracker Day 1

Day 2 testing			
Vm and Im measurement in the state with tracker			
time	Vm (V)	Im (A)	P (Watt)
09.00	13,72	1,21	16,6012
09.30	13,74	1,14	15,6636
10.00	13,76	1,09	14,9984
10.30	13,8	1,05	14,49
11.00	13,84	1,01	13,9784
11.30	13,89	0,97	13,4733
12.00	14,24	0,93	13,2432
12.30	14,26	0,88	12,5488
13.00	14,33	0,85	12,1805
13.30	14,41	0,8	11,528
14.00	14,56	0,75	10,92
14.30	13,62	0,73	9,9426
15.00	13,47	0,7	9,429
	13,97231	**0,931538**	**12,99977**

Figure 15. Vm and Im testing in the state with tracker Day 2

Day 3 testing			
Vm and Im measurement in the state with tracker			
time	Vm (V)	Im (A)	P (Watt)
09.00	13,69	1,11	15,1959
09.30	13,72	1,08	14,8176
10.00	13,75	1,02	14,025
10.30	13,79	0,93	12,8247
11.00	13,81	0,9	12,429
11.30	13,73	0,81	11,1213
12.00	13,84	0,79	10,9336
12.30	13,89	0,77	10,6953
13.00	13,95	0,7	9,765
13.30	13,67	0,61	8,3387
14.00	13,53	0,58	7,8474
14.30	13,45	0,51	6,8595
15.00	13,38	0,49	6,5562
	13,70769	**0,792308**	**10,87763**

Figure 16. Vm and Im testing in the state with tracker Day 3

Based on the data in Figures 14, 15 and 16 the results of testing solar panels for 3 days without using a tracker obtained an average voltage value (Vm) of 13.87 Volts and an average current value (Im) of 0.85 Amperes.

Based on the test data in Figures 14, 15 and 16, the test results then calculated the efficiency of solar panels without using trackers using equations (3) (4). To determine the efficiency of solar panels, we must know the total photon power (Pin) of solar modules and the filling factor (FF) for the calculation of total photon power (Pin) as follows:

Vm (V)	Im (A)	Isc (A)	Voc (V)
13,87	0,85	0,97	19,06

To determine the area of the solar panel as follows:

determine the area = Length *x* width

= *0,5 x 0,35 m*

= *0,175 m*^{2}

The calculation of the filling factor (FF) can be determined as follows:

$$FF = \frac{Vmp\ .\ Imp}{Voc\ .\ Isc} \quad (3)$$

$$FF = \frac{13{,}87\ x\ 0{,}85}{19{,}06\ x\ 0{,}97}$$

$$FF = 0{,}64$$

By knowing the area of the solar panel and the fill factor, the static solar panel efficiency can be determined with equation (3):

$$\eta = \frac{Pout}{Pin}\ x\ 100\%$$

$$= \frac{19{,}06\ x\ 0{,}97\ x\ 0{,}64}{1000\ x\ 0{,}175}\ x\ 100\%$$

$$= 6{,}761\%$$

5. *Testing how long a strong battery works to power a hydroponic plant water pump*

The test in Table 2 below aims to find out how long the strong battery works to support the hydroponic plant water pump power supply. Testing was carried out from 15.00-09.00

Tabel 1. Testing how long a strong battery works to power a hydroponic plant water pump

No	hours	Voltage (V)
1.	15.00	12,8
2.	16.00	12,7
3.	17.00	12,64
4.	18.00	12,59
5.	19.00	12,55
6.	20.00	12,46
7.	21.00	12,44
8.	22.00	12,40
9.	23.00	12,36
10.	00.00	12,33
11.	01.00	12,30
12.	02.00	12,26
13.	03.00	12,24

14.	04.00	12,21
15.	05.00	12,17
16.	07.00	12,13
17.	08.00	12,09
18.	09.00	12,05

E. Web and Application Monitoring

IoT has been integrated with the Internet of Things, showing the concept of Internet of Things communication. The system has been integrated with the Internet of Things and has worked well using the Blynk application so that the system can be monitored remotely. Monitoring data based on testing is the value of voltage, current, and power. This test can be seen in Figures 15 and 16.

Figure 17. Application Maonitoring

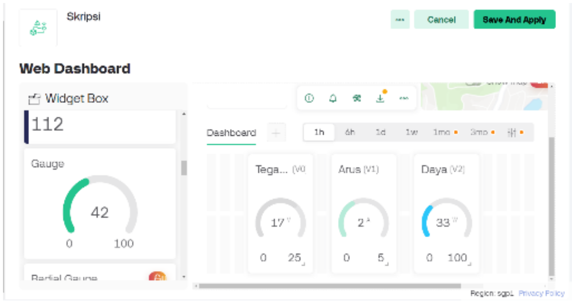

Figure 18. Web Monitoring

V. CONCLUSION

Based on the test results that have been carried out during this research, several conclusions can be drawn, among others. Systems using trackers and without using trackers have differences from higher voltage and current values using the tracker system. Solar panels that use trackers have an average voltage and current value that is higher than solar panels that do not use trackers. Solar panel systems using trackers have an average value of 13.87 Volts and an average current of 0.85 Amperes during 3 days of data collection. Solar panels that do not use the tracker system have an average value of 13.36 Volts and an average current of 0.63 Amperes during 3 days of data collection. From the test results of solar panels using solar trackers, there is a 2% difference between solar panels that use trackers and those that do not use the tracker system. So, solar panels that use the tracker system have an effect on the absorption of solar panels. While testing to measure how long a strong battery works to support the hydroponic plant water pump power supply also works well. Testing to measure how long a strong battery works to support the hydroponic plant water pump power supply is carried out for 12 hours, and the results show that for 12 hours, the battery can still turn on without any power obtained by the solar panel.

REFERENCES

[1] Hendra, M. Indriana, N. T. Artika, R. Ismayani, D. J. M. Sembiring, and M. Tamba, "Perancangan Sistem Otomatisasi Peternakan Ayam Broiler Berbasis Internet Of Things," *J. Inform. dan Peranc. Sist.*, vol. 5, no. 1, pp. 1–9, 2023.

[2] L. S. Setiawan, David, Hamzah Eteruddin, "Sistem Pembangkit Listrik Tenaga Surya untuk Tanaman Hidroponik," *Teknik*, vol. 14, no. 2, pp. 208–215, 2020.

[3] M. Ali and J. Windarta, "Pemanfaatan Energi Matahari Sebagai Energi Bersih yang Ramah Lingkungan," *J. Energi Baru dan Terbarukan*, vol. 1, no. 2, pp. 68–77, 2020, doi: 10.14710/jebt.2020.10059.

[4] H. Romadhon and B. Budiyanto, "Pemanfaatan Intensitas Radiasi Cahaya Lampu dengan Reflektor Panel Surya sebagai Energi Harvesting," *Resist. (Elektronika Kendali Telekomun. Tenaga List. Komputer)*, vol. 3, no. 2, p. 45, 2020, doi: 10.24853/resistor.3.2.45-56.

[5] M. A. Rahmanta, A. Syamsuddin, F. Tanbar, and ..., "Analisis Perkembangan Teknologi Modul Photovoltaic (PV) Untuk Meningkatan Penetrasi Pusat Listrik Tenaga Surya (PLTS) Di Indonesia," *J. Offshore Oil, Prod. Facil. Renew. Energy*, vol. 7, no. 1, pp. 22–33, 2023, [Online]. Available: https://ejournal.up45.ac.id/index.php/Jurnal_OFFSHORE/article/view/1509%0Ahttps://ejournal.up45.ac.id/index.php/Jurnal_OFFSHORE/article/download/1509/891

[6] D. Christian, D. Budhi Santoso, and R. Rahmadewi, "Implementasi Digital Image Processing Sebagai Pendeteksi Posisi Matahari Pada Perancangan Dual Axis Solar Tracker," *Teknokom*, vol. 6, no. 2, pp. 116–122, 2023, doi: 10.31943/teknokom.v6i2.150.

[7] A. I. Saputra, I. Hidayat, and W. Priharti, "Perancangan Single Axis Solar Tracker Menggunakan Fuzzy Logic Berbasis Arduino Guna Mengoptimalkan Output Daya Pada Panel Surya," *e-Proceeding Eng.*, vol. 9, no. 5, pp. 2225–2233, 2022.

[8] R. Komalasari, "Manfaat Aplikasi Teknologi IoT di Masa Pandemi Covid-19 : Studi Eksploratif," *Tematik*, vol. 7, no. 2, pp. 196–210, 2020, doi: 10.38204/tematik.v7i2.469.

[9] S. Samsurizal, M. T. Aji, and K. T. M, "Pemanfaatan Tenaga Surya Pada Photovoltaic Jenis Polycristaline Untuk Catu Daya Tanaman Hidroponik," *Energi & Kelistrikan*, vol. 13, no. 1, pp. 58–66, 2021, doi: 10.33322/energi.v13i1.984.

[10] D. Suryana and M. M. Ali, "The Effect Of Temperature On Voltage Produced By Monocrystalline Solar Panel (Case Study : Baristand Industri Surabaya)," *J. Teknol. Proses dan Inov. Ind.*, vol. 2, no. 1, pp. 49–52, 2016.

[11] A. Zulfia, C. A. Asha, D. Pradana, R. Rifandika, M. B. Ginting, and N. Harahap, "Sistem Papan Monitoring Penggunaan Kelas dan Peralatan Elektronik Terintegrasi Internet of Things," *J. Inform. Dan Peranc. Sist.*, vol. 5, no. 1, pp. 45–54, 2023.

[12] Muliadi, A. Imran, and M. Rasul, "Pengembangan Tempat Sampah Pintar Menggunakan Esp32," *J. Media Elektr.*, vol. 17, no. 2, pp. 2721–9100, 2020, [Online]. Available: https://ojs.unm.ac.id/mediaelektrik/article/view/14193

[13] D. Wijayanto, S. I. Haryudo, T. Wrahatnolo, and ..., "Rancang Bangun Monitoring Arus Dan Tegangan Pada Plts Sistem On Grid Berbasis Internet Of Things (IoT) Menggunakan Aplikasi Telegram," *J. Tek. …*, pp. 447–453, 2022, [Online]. Available: https://ejournal.unesa.ac.id/index.php/JTE/article/view/49288%0Ahttps://ejournal.unesa.ac.id/index.php/JTE/article/download/49288/41004

[14] N. Soedjarwanto, "Prototipe Smart Dor Lock Menggunakan Motor Stepper Berbasis Iot (Internet Of Things)," *Electrician*, vol. 15, no. 2, pp. 73–82, 2021, doi: 10.23960/elc.v15n2.2167.

[15] I. W. Nursatriya, S. Hariyadi, L. D. Kusumayati, and P. P. Surabaya, "Rancangan Monitoring Arus Dan Tegangan Lampu Penerangan Jalan Umum Berbasis IoT Menggunakan NodeMCU Via Aplikasi Blynk," *Pros. SNITP*, vol. 6, no. 1, pp. 1–6, 2022.

[16] A. Wisnu, A. Kristanto, S. T. Elektro, F. Teknik, and U. N. Surabaya, "Pemodelan Automatic Transfer Switch (ATS) Pada System Smartgrid Pembangkit Photovoltaic," *J. Tek. Elektro*, vol. 11, pp. 351–360, 2022.

[17] K. W. Fauzi, T. Arfianto, and N. Taryana, "Perancangan dan Realisasi Solar Tracking System Untuk Peningkatan Efisiensi Panel Surya Menggunakan Arduino Uno," *TELKA - Telekomun. Elektron. Komputasi dan Kontrol*, vol. 4, no. 1, pp. 63–74, 2018, doi: 10.15575/telka.v4n1.63-74.