ISSN (Print) : 2337-9030 ISSN (Online) : 2685-2608
PILLAR OF PHYSICS
JURNAL BERKALA ILMIAH FISIKA
Vol. 17 (1), 2024, page. 55-63
DOI : 10.24036/15381171074

DESIGN OF POWER MONITORING SYSTEM FOR 2 SOLAR PANELS BASED ON THINGSPEAK

Widya Sukma Hasanti [1], Mairizwan [1*], Yulkifli [1]

Department of Physics, Universitas Negeri Padang, Jl. Prof. Dr. Hamka Air Tawar Padang 25131, Indonesia

Corresponding author. Email: mairizwan@fmipa.unp.ac.id

ABSTRACT

Indonesia is one of the countries with large solar energy potential, namely around 3,294.4 GW recorded in 2022. However, solar energy utilization during 2022 is only 0,01%. Based on this problem, a research was carried out which aimed to combine the power produced by solar panels. This research emerged as a response to the need for energy efficiency and desires. With proper monitoring, solar panel owners can optimize their use of solar energy, reduce waste, and ensure that their solar panels are working at maximum capacity. This research is included in engineering research to determine the performance specifications and design specifications of the system that has been designed. Performance specifications cover a series of system electronic components and monitoring data displays displayed on Thingspeak. The design specifications in this research include sensor characterization, accuracy and precision of the Power Monitoring System For 2 Solar Panels Based On Thingspeak. From the results of the design specifications, the sensor used in the system has a high linearity value, good accuracy of 98,735% (voltage), 97,027% (current), and 97,994% (light intensity) and good precision of 99,905% (voltage), 99,549% (current), and 99,874% (light intensity). The system's high linearity, accuracy, and precision values, as indicated in the design specifications, confirm that it operates effectively and efficiently.

Keywords : Solar Panel; Monitoring; Power; Thingspeak.

I. INTRODUCTION

The use of solar panels as a renewable energy source is increasingly popular in various countries, including Indonesia. Solar panels can be used for various small-scale electricity generation purposes, such as lighting, operating household appliances, and so on. Indonesia is one of the countries that has enormous solar energy potential. This is because Indonesia is located on the equator, which means this country receives 6–10 hours of sunlight every day. Based on what was recorded by the Dewan Energi Nasional (DEN) in the 2022 Indonesian Energy Outlook released in December 2022, the potential for solar energy in 2022 is 3,294.4 GW . From this data, it can be seen that there is a very large potential for solar energy in Indonesia that can be utilized as a renewable energy source, namely solar panels. However, the use of solar energy recorded in the Outlook Energi Indonesia for 2022 is only 0.01% [1]. This research emerged in response to demands for energy efficiency and sustainability. With proper monitoring, solar panel owners can optimize their use of solar energy, reduce waste, and ensure that their solar panels are working at maximum capacity.

A solar panel is a collection of solar cells that can convert sunlight into electrical power by utilizing the photovoltaic effect [2][3]. Electric power, usually symbolized by P in the electrical equation, is the rate of delivery of electrical energy in an electrical circuit per unit time. The general equation used to calculate electrical power in an electrical circuit is [4]:

$$P = I \times V \qquad (1)$$

P is electric power in watts (W), I is electric current in amperes (A), and V is potential difference or electric voltage in volts (V).

Solar panels have three different varieties: monocrystalline, polycrystalline, and thin film. The monocrystalline solar panel type is created from thinly-sliced pure silicon crystal bars, which result in solar cell parts that are highly efficient and similar to one another [5]. In order to generate the same amount of electrical power, a polycrystalline solar panel needs a bigger surface area than a monocrystalline solar panel [6]. With a module efficiency of up to 8,5% and a thin layer structure of silicon and amorphous microcrystals, thin film solar panels require a larger surface area per watt of power generated than monocrystal and polycrystal solar panels [7].

The INA219 sensor is a circuit for measuring a power sources output. The INA219 sensor is used to calculate the power generated by solar panels. It has a resolution of 0.8 mA and can detect direct current up to 26 V/3.2 A. [8]. So that the power measured from the two solar panels is not combined, a two-channel relay is used to alternately cut off the panel current [9]. To determine indicators of changes in sunlight intensity, the BH1750 sensor is used. The BH1750 sensor is an IC sensor that is used to measure changes in light intensity in lux units. The detection range of this sensor is quite wide, namely between 1 and 65.535 lux [10][11].

The system is controlled using the Arduino Uno microcontroller. Arduino Uno is a combination of development tools and hardware, a programming language, and a sophisticated Integrated Development Environment (IDE) [12]. Arduino can work optimally on a voltage of 5 to 12 volts DC as input [13]. So that the Arduino can use the input voltage from a 12-volt battery, a Buck Converter is used to reduce the high battery voltage to a more suitable input voltage for the Arduino [14]. After being processed by the Arduino Uno, the data is transferred to Thingspeak using the open-source IoT platform NodeMCU ESP8266. It is composed of hardware, namely an ESP8266 System on Chip from Esperessif Systems [15]. NodeMCU can be analogous to an Arduino board connected to the ESP8622 [16]. Thingspeak is an Internet of Things platform that facilitates the gathering, storing, analyzing, visualizing, and acting upon sensor or actuator data. The channel, which has status, location, and data fields, is the primary component of Thingspeak activity [17].

Gunoto's research on the Internet of Things-based solar panel power monitoring system design served as the foundation for this research [18]. The ESP8266 microcontroller is connected to current and voltage sensors in the system. The voltage, current, and power generated by the solar panels are the data that is shown on the LCD and Blynk as a result of the monitoring results. The next research is design of a solar panel energy data logger system featuring an RTC and SD card by Hadi is the subject of the following study [19]. And the last study by Wardhana monitors 2 solar panels using 2 Solar Charge Controllers (SCC) and also 2 batteries [20]. From these studies, there is still a research gap in the integration of this technology. The current study focuses on individual aspects of solar panel monitoring, such as IoT-based real-time monitoring and data logging with RTC and SD cards. However, a comprehensive approach that combines both features to create an integrated and efficient monitoring and data recording system of 2 types of solar panels has not been explored. Addressing this research gap will contribute to the development of more sophisticated and holistic solutions for monitoring and recording solar panel performance, thereby increasing the overall efficiency and usability of such systems. This research introduces a stand-alone data logger device that can be used to measure solar panel power parameters. The energy produced by the solar panels is measured and then stored using the RTC and SD Card installed in the device. The data is recorded in CSV format compatible with MS Excel. The data logger was used to record measurement findings in a real-time power monitoring system designed for two different types of solar panels based on the research mentioned above.

II. METHOD

This research is included in the type of engineering research that has six steps of research procedures: ideas and task clarity; conceptual design; arrangement, geometry, and function; detailed design; creation of modeling tools; and testing [21]. In this research, the data collected is data on current, voltage, electrical power, and sunlight intensity. The measurement techniques used include two methods, namely direct and indirect. Direct measurements are measurements that do not depend on other quantities, namely measurements of current, voltage, and the intensity of sunlight. Meanwhile, indirect measurements are measurements whose value is influenced by another quantity, namely the power produced by the panel.

At the arrangement, geometry, and function stage, all components of the designed system will be arranged geometrically based on their function. The geometric arrangement of the block diagram of the Design Of Power Monitoring System For 2 Solar Panels Based On Thingspeak can be seen in Figure 1.

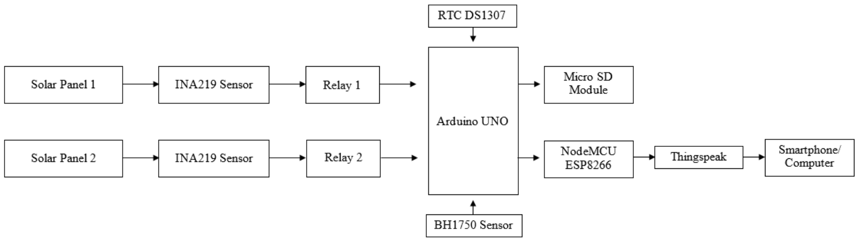

Fig. 1. Block diagram of solar panel power measurement and monitoring system design

From Figure 1, the INA219 sensor functions to measure the power produced by solar panels. The BH1750 sensor is used to measure the intensity of sunlight as a parameter for comparing the power produced by solar panels. Arduino UNO functions to process data received from sensors and send it to the ESP8266 nodeMCU. The RTC DS1307 functions to organize and store time data (seconds, minutes, hours, date, month, day of the week, and year) so that the data stored is in real time. Micro SD functions to store data that has been measured and processed by Arduino. NodeMCU ESP8266 functions as a WiFi module to send monitoring data to Thingspeak.

All components that make up the system are combined into one unit to form a related system to obtain the desired results. At this stage, a software program was also designed to monitor power and sunlight intensity. The following is the instrument design plan for the system, which can be seen in Figure 2.

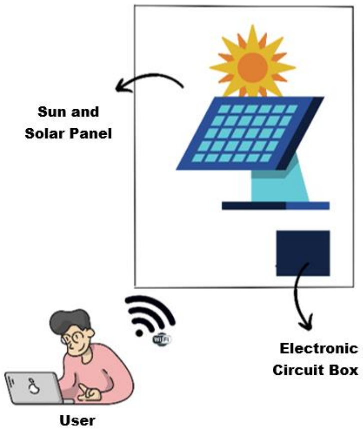

Fig. 2. Instrument design plan

The system consists of several electronic components, namely solar panels, a circuit box containing a series of current and voltage sensors, light intensity sensors, Arduino Uno, RTC, data logger, NodeMCU ESP8266, and PC/smartphone. The process of sending data to Thingspeak by the NodeMCU ESP8266 can be seen in Figure 3 below.

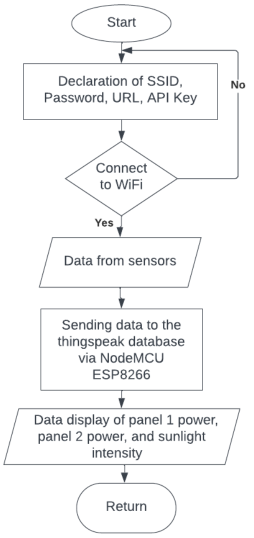

Fig. 3. Flowchart of sending data to thingspeak

Figure 3 shows the flowchart of sending data to Thingspeak via the ESP8266 nodeMCU. The program starts by declaring the SSID, WiFi password, URL, and API Key that have been input into the program. Next, there is a looping program that functions to declare the SSID and password if the ESP8266 nodeMCU is still not connected to the WiFi network. After the ESP8266 nodeMCU is connected to the appropriate WiFi network, the program will start sending sensor reading data to Thingspeak.

To describe the capability or performance of the measuring instruments that make up the system for measuring a parameter, characterization, accuracy, and accuracy tests are carried out on the sensor. Sensor characterization aims to determine the linearity of the sensor against standard measuring instruments. Sensor characterization aims to determine the linearity of the sensor against standard measuring instruments [22]. The characterization of the INA219 sensor is carried out by observing the linearity of the parameters measured by the sensor with the sensor output data. Meanwhile, the characterization of the BH1750 sensor was carried out by observing the linearity of sensor measurements with standard measuring instruments capable of measuring the same parameters, namely a lightmeter.

III. RESULTS AND DISCUSSION

The research results obtained in this research on Power Monitoring System For 2 Solar Panels Based on Thingspeak are performance specifications and design specifications. Performance specifications cover a series of system electronic components and monitoring data displays displayed on Thingspeak. Based on the system design block diagram in Figure 1, a circuit scheme is obtained, as shown in Figure 4 below.

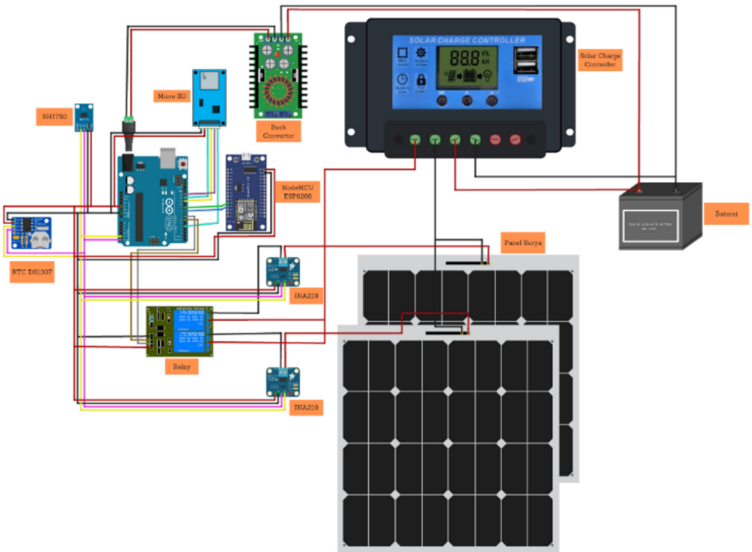

Fig. 4. Design electronic circuit systems

In the circuit shown in Figure 4, an Arduino Uno is used as a microcontroller that reads sensor measurement data, namely the INA219 sensor to measure panel output power and the BH1750 sensor to measure sunlight intensity. Apart from that, the Arduino also functions to control the switching of the 2-channel relay for changing solar panel measurements by the INA219 sensor every 1 second, recording the time from the RTC DS1307, saving the measurement results data to the Micro SD module in.txt format, and transferring the sensor measurement results data to the ESP8266 nodeMCU then be sent to Thingspeak. The system is also equipped with an SCC (Solar Charge Controller), which functions to control charging from the solar panel to the battery and also the load, as well as a Buck Converter, which functions to reduce the high battery voltage to a lower one so that it can be used as a source voltage for the Arduino.

Data from power measurements by the INA219 sensor and sunlight intensity by the BH1750 sensor are monitored via Thingspeak in graphic form, which can be seen in Figure 5.

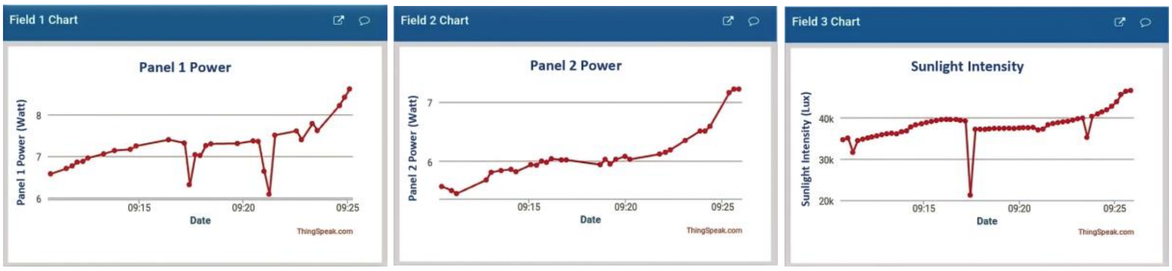

Fig. 5. Monitoring view on thingspeak

The first graph is a graph of the output power of solar panel 1, the second graph is a graph of the output power of solar panel 2, and the third graph is a graph of measuring the intensity of sunlight. The data sent to Thingspeak is in real-time, with a data sending time span of 15 seconds. The three graphs in Figure 5 above have a relationship with each other. The graph shows that panel 1 is very sensitive to changes in light intensity which causes a decrease in the power produced as the light intensity decreases. Meanwhile, panel 2 looks stable even though there is a decrease in light intensity.

Next, design specifications. The design specifications in this research include sensor characterization, accuracy and precision of the Thingspeak-based solar panel power monitoring system, which is an important factor in knowing the system's ability to measure each parameter [23]. In this system, there are two types of physical parameters whose design specifications will be explained, namely solar panel power parameters and light intensity. The first design specification is system characterization. The results of system characterization in power measurements can be known through system linearity tests in measuring voltage and current parameters. The results of the voltage measurement characterization are depicted in Figure 5.

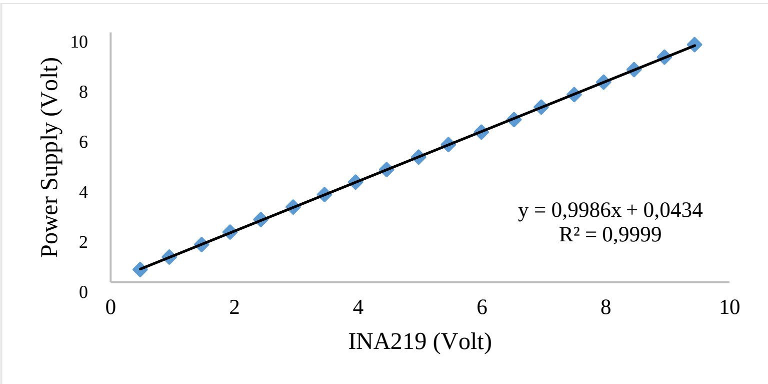

Fig. 5. Graph of the voltage measurement linearity test in the system

In characterization of voltage measurements on the system, it was found that the system has a very linear response to changes in voltage on the power supply. When the power supply voltage is increased or decreased, the system provides a reading that is very close to the actual voltage. This is reinforced by linearity graph analysis which shows an almost perfect linear curve, with an R-squared value of 0.9999, close to 1. These characterization results illustrate the system's ability to provide very accurate and linear readings. in measuring power parameters.

Next, to determine the characteristics of the system in measuring power, a system characterization is carried out in measuring current. The following are the results of the current measurement characterization in Figure 6.

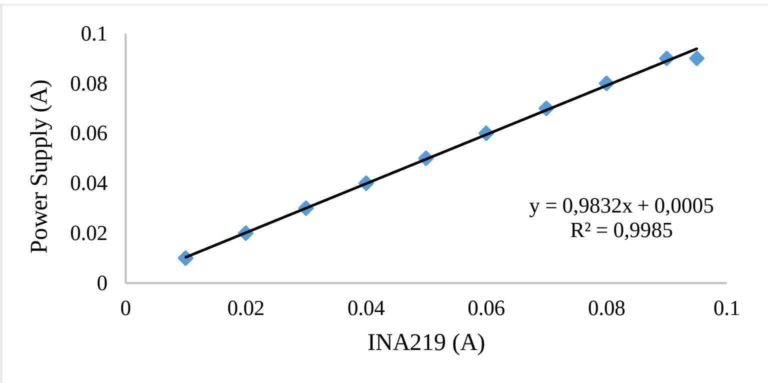

Fig. 6. Graph of the current measurement linearity test in the system

In the process of system characterization in measuring power supply current, test results show that the sensor shows a high level of linearity in responding to changes in current. As the current in the circuit increases or decreases, the system gives a reading that is close to the actual current value. Analysis of the linearity graph shows an almost perfect linear curve, with an R-squared value of 0,9985, close to 1. This shows that the system is able to provide accurate and linear readings in current measurements. From figures 5 and 6, the results of the voltage and current characterization show that the power measurements carried out on the system are very linear, this is indicated by the linearity value which is close to 1 [24]. Next, the results of system characterization in measuring light intensity can be seen in Figure 7.

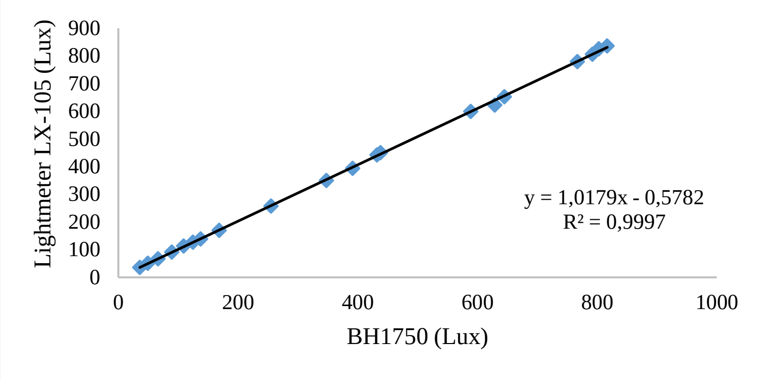

Fig. 7. Graph of the light intensity measurement linearity test in the system

Figure 7 shows the characterization results of the system which shows a high level of linearity in the sensor response to variations in light intensity. When the lux level is increased or decreased, the system shows a reading that is close to the actual light intensity. Analysis of the linearity graph shows an almost perfect curve, with an R-squared value of 0,9997, close to 1. This shows that the system is able to provide accurate and linear measurements of light intensity.

The second design specification is the accuracy of the system. The accuracy of every parameter measured by the system is seen by comparing the measurement results obtained by the system with standard measuring instruments [25][26]. The accuracy of the system in measuring each parameter can be seen in table 1.

Table 1. Data on Measurement Accuracy by the System

No	Voltage			Current			Light Intensity		
	System (Volts)	**Multimeter (Volts)**	**Accuracy (%)**	**System (mA)**	**Multimeter (mA)**	**Accuracy (%)**	**System (Lux)**	**Lightmeter (Lux)**	**Accuracy (%)**
1	0,55	0,54	98,524	5,7	5,55	97,297	35,8	36	99,528
2	1,04	1,03	99,029	10,6	10,36	97,683	37,5	39	96,154
3	1,44	1,42	98,592	14,8	14,35	96,864	47,5	48	98,958
4	1,96	1,94	98,969	20	19,42	97,013	49,4	51	96,765
5	2,4	2,36	98,305	24,5	23,73	96,755	66,3	67	98,881
6	2,91	2,84	97,571	29,8	28,78	96,456	89,2	92	96,957
7	3,35	3,33	99,399	34,3	33,17	96,593	109,3	113	96,752
8	3,85	3,81	98,950	39,3	38,08	96,796	124,5	127	98,008
9	4,35	4,31	99,072	44,7	43,90	98,178	137,5	139	98,921
10	4,78	4,73	98,943	49,1	47,50	96,632	168,3	170	99,018
	Average		98,735			97,027			97,994

The accuracy of the system in measuring power can be determined by looking for the accuracy of voltage and current measurements. The accuracy of voltage and current measurements is carried out by comparing the system measurement results with the multimeter measurement results which are considered as an accurate standard or reference. Based on Table 1, the test results show that the system is able to provide power supply voltage and current measurements that are very close to the results provided by a multimeter. The accuracy of voltage measurements by a system with 10 variations of voltage sources obtained quite high accuracy values with an average accuracy percentage of 98,735%. Current measurements by a system with 10 variations of current sources also obtained quite high accuracy values with an average accuracy percentage of 97,027%. The measurements produced by the system are consistent and have very small differences with multimeter measurements. This shows that the system has a high level of accuracy in measuring power.

Furthermore, the results of system accuracy testing in measuring light intensity using a lightmeter as a standard measuring instrument. Based on table 1, the test results show that the system is able to provide light intensity measurements that are very close to the results provided by the lightmeter. From the results of data analysis, an average accuracy percentage of 97,994% was obtained. The measurement results produced by the system are consistent and have very small differences with lightmeter measurements. This shows that the system has a high level of accuracy in measuring light intensity.

The second design specification is the precision of the system. System precision is obtained from repeated measurements of a parameter 10 times under the same conditions. Based on the measurement results, the average value and precision percentage can be analyzed [27]. The accuracy of the system in measuring each parameter can be seen in table 2.

Table 2. Data on Measurement Precision by the System

No	Voltage			Current			Light Intensity		
	System (Volts)	Error (%)	Precision (%)	System (mA)	Error (%)	Precision (%)	System (Lux)	Error (%)	Precision (%)
1	5,04	0,8	99,881	23,9	0,998	99,833	275,83	0,999	99,910
2	5,04	0,8	99,881	24,1	0,993	99,332	275,83	0,999	99,910
3	5,04	0,8	99,881	23,8	0,994	99,415	275,83	0,999	99,910
4	5,04	0,8	99,881	23,9	0,998	99,833	275	0,998	99,789
5	5,03	0,6	99,921	24,1	0,993	99,332	275	0,998	99,789
6	5,03	0,6	99,921	24	0,997	99,749	275,83	0,999	99,910
7	5,03	0,6	99,921	23,9	0,998	99,833	275	0,998	99,789
8	5,03	0,6	99,921	23,9	0,998	99,833	275,83	0,999	99,910
9	5,03	0,6	99,921	24,1	0,993	99,332	275,83	0,999	99,910
10	5,03	0,6	99,921	23,7	0,990	98,997	275,83	0,999	99,910
Average	5,03	0,68	99,905	23,94	0,995	99,549	275,58	0,999	99,874
SD		0,005			0,135			0,401	
KR		0,103			0,564			0,145	

System precision testing in power measurements can be seen from the results of voltage and current precision testing. The test results in table 2 show that the system is able to provide consistent voltage and current measurement results for ten repetitions. These measurements show slight variations from one measurement to the next. This variability is very low and indicates a good level of precision. Furthermore, in data analysis it was found that the average percentage precision of ten measurements was very high, namely 99,905% for voltage and 99,549% for current. Apart from that, the data that shows the system precision is very good is the relatively small error results, namely 0,103% for voltage and 0,5645 for current. This shows that the system consistently provides results that are very close to the actual values in electrical power measurements. This is characterized by a high average accuracy and a relatively small error value.

The results of the light intensity precision test in table 2 show that the light intensity measurement results are very consistent over ten repetitions. The results of ten measurements show that the measured light intensity is relatively stable, with almost the same value in each repetition. The average value of light intensity from ten measurements is 275,58 lux. Apart from that, in the analysis of the test results it was found that the percentage of error in each measurement was very small, namely ranging from 0,998% to 0,999%. These results show that the measurement results are close to the actual value in measuring light intensity. Precision percentages in the range of 99,789% to 99,910% in measurement results were also found. This shows low fluctuations in the light intensity measurements between different iterations, indicating good precision in the system. Standard Deviation (SD) of 0,401 and Relative Error (KR) of 0,145% indicate a low level of variation in measurement results. This confirms that the light intensity measurements carried out by the system are consistent and have good accuracy.

From the results of the analysis of the data obtained, it can be seen that the research results are in accordance with the research objectives. The research results obtained are in the form of design specifications and performance specifications for the solar panel power monitoring system. Performance specifications are known by identifying the function of each component that makes up the system. The results of the performance specifications can help in assembling the system. The assembly of this system is carried out by building an electronic circuit from the system's electronic components into a tool that can be used to measure and monitor the power of two solar panels and as an indicator of changes in light intensity.

The next result is the design specification. Based on the results of the measurement data analysis that has been carried out, starting from sensor characterization, sensor accuracy, and accuracy, it can be seen that the two solar panel power measurement systems have good capabilities in measuring each parameter. This is supported by a number of previous studies which have proven that sensor characterization in measuring solar panel power is a critical step that influences the accuracy of measurement results. For example, a study in a journal written by Qomaruddin in 2016 investigated sensor characterization in measuring solar panel power [28]. The results of this research show that careful and precise characterization of the sensors used in solar panel power measurement systems can produce accurate measurement results, with a minimal error rate. In addition, another research conducted in 2022 by Gunoto highlighted the importance of sensor accuracy and precision in solar energy applications [18]. This research provides empirical evidence that well-calibrated, high-fidelity sensors can measure solar panel power with low error rates, which in turn improves overall system performance. Therefore, the results of the measurement data analysis indicate that the system has a strong ability to measure critical parameters, which aligns well with findings from previous research. Furthermore, the above research results also signify that the system can function effectively according to its intended purpose.

IV. CONCLUSION

From the research results, a conclusion was obtained, namely that the results of the design specifications showed that the system had high linearity values, good accuracy and good precision. First, the accuracy of the measuring instruments in the system has a good value, with a percentage accuracy value of 98.735% (voltage), 97.027% (current), and 97.994% (light intensity). Second, the measuring instruments in the system have good precision, with precision percentages of 99.905% (voltage), 99.549% (current), and 99.874% (light intensity). These findings lead to the conclusive conclusion that the power monitoring system effectively fulfills its primary objective – to measure and monitor the power of both types of solar panels and the intensity of sunlight. The system designed is capable of monitoring two different types of solar panels simultaneously. It adapts to its specific needs while operating under the same conditions.

REFERENCES

[1] DEN, *Energi Outlook Indonesia 2022*. Jakarta: Dewan Energi Nasional, 2022.

[2] A. Zahedi, *Solar Photovoltaic Energy System: Design and Use*. Melbourne: The New World Publishing, 1998.

[3] W. Audia, Yulkifli, Mairizwan, and A. Rinaldi, "Automatic Transfer Switch System Design on Solar Cell-Grid Hybrid Based on Android Application," *Eksakta Berk. Ilm. Bid. MIPA*, vol. 23, no. 04, pp. 266–283, 2022.

[4] F. S. Raheem and N. Basil, "Automation intelligence photovoltaic system for power and voltage issues based on Black Hole Optimization algorithm with FOPID," *Meas. Sensors*, vol. 25, pp. 1–14, 2023, doi: 10.1016/j.measen.2022.100640.

[5] N. Safitri, T. Rihayat, and S. Riskina, *Teknologi Photovoltaic*, 1st ed., no. Juli. Banda Aceh: Yayasan Puga Aceh Riset, 2019.

[6] B. H. Purwoto, J. Jatmiko, M. A. Fadilah, and I. F. Huda, "Efisiensi Penggunaan Panel Surya sebagai Sumber Energi Alternatif," *Emit. J. Tek. Elektro*, vol. 18, no. 1, pp. 10–14, 2018, doi: 10.23917/emitor.v18i01.6251.

[7] A. Maalouf, T. Okoroafor, Z. Jehl, V. Babu, and S. Resalati, "A comprehensive review on life cycle assessment of commercial and emerging thin-film solar cell systems," *Renew. Sustain. Energy Rev.*, vol. 186, pp. 1–17, 2023, doi: 10.1016/j.rser.2023.113652.

[8] T. Instruments, "INA219 data sheet, product information and support | TI.com," *Www.Ti.Com*, 2015.

[9] D. A. O. Turang, "PENGEMBANGAN SISTEM RELAY PENGENDALIAN DAN PENGHEMATAN PEMAKAIAN LAMPU BERBASIS MOBILE," *Semin. Nas. Inform. 2015 (semnasIF 2015)*, pp. 75–85, 2015, doi: 10.1007/978-3-540-24653-4_8.

[10] M. PAMUNGKAS, H. HAFIDDUDIN, and Y. S. ROHMAH, "Perancangan dan Realisasi Alat Pengukur Intensitas Cahaya," *ELKOMIKA J. Tek. Energi Elektr. Tek. Telekomun. Tek. Elektron.*, vol. 3, no. 2, pp. 120–132, 2015, doi: 10.26760/elkomika.v3i2.120.

[11] W. Sunanda, Y. Tiandho, R. F. Gusa, M. Darussalam, and D. Novitasari, "Monitoring of photovoltaic performance as an alternative energy source in campus buildings," *Instrum. Mes. Metrol.*, vol. 20, no. 3, pp. 153–159, 2021, doi: 10.18280/i2m.200305.

[12] Y. Yulkifli, F. Afriani, Y. Yohandri, and R. Ramli, "The Design of Display Digital Data Interface Clamp-Meter Complemented By Sensor GMR (Giant Magnetoresistance)," *Spektra J. Fis. dan Apl.*, vol. 5, no. 1, pp. 53–60, 2020, doi: 10.21009/spektra.051.06.

[13] Sutono, "Design Trainer Mikrokontroler Arduino Board As Media Learning in Vocational High School (Smk)," *Pros. Saintiks FTIK UNIKOM*, vol. 3, no. 1, pp. 49–60, 2017.

[14] M. R. P. Yusrifal, Y. S. Akil, and Yusran, "Rancang Bangun Buck-Boost Converter Dengan Catu Daya Panel Surya," *J. EKSITASI*, vol. 1, no. 1, pp. 22–27, 2022.

[15] Y. S. Parihar, "Internet of Things and Nodemcu," *JETIR*, vol. 6, no. 6, pp. 1085–1088, 2019, doi: 10.31031/rmes.2018.06.000636.

[16] M. F. Pela and R. Pramudita, "Sistem Monitoring Penggunaan Daya Listrik Berbasis Internet of Things Pada Rumah Dengan Menggunakan Aplikasi Blynk," *Infotech J. Technol. Inf.*, vol. 7, no. 1, pp. 47–54, 2021, doi: 10.37365/jti.v7i1.106.

[17] A. I. Abdul-Rahman and C. A. Graves, "Internet of Things Application using Tethered MSP430 to Thingspeak Cloud," *Proc. - 2016 IEEE Symp. Serv. Syst. Eng. SOSE 2016*, pp. 352–357, 2016, doi:

10.1109/SOSE.2016.42.
[18] P. Gunoto, A. Rahmadi, and E. Susanti, "Perancangan Alat Sistem Monitoring Daya Panel Surya Berbasis Internet of Things," *Sigma Tek.*, vol. 5, no. 2, pp. 285–294, 2022, doi: 10.33373/sigmateknika.v5i2.4555.
[19] M. S. Hadi, A. N. Afandi, A. P. Wibawa, A. S. Ahmar, and K. H. Saputra, "Stand-Alone Data Logger for Solar Panel Energy System with RTC and SD Card," *J. Phys. Conf. Ser.*, vol. 1028, no. 1, pp. 1–9, 2018, doi: 10.1088/1742-6596/1028/1/012065.
[20] M. I. A. Wardhana, H. Priyatman, and H. Judiarto, "Monitoring System Design of Tracking System on Solar Panel Following the Sun Rotation Based on Internet of Things," *Telecommun. Comput. Electr. Eng. J.*, vol. 1, no. 1, pp. 63–72, 2023, doi: 10.26418/telectrical.v1i1.69944.
[21] L. Kirkup, *Experimental Methods for Science and Engineeering Students*. Cambridgeshire: Cambridge University Press, 2019.
[22] B. E. Cahyono, I. D. Utami, N. P. Lestari, and N. S. Oktaviany, "Karakterisasi Sensor LDR dan Aplikasinya pada Alat Ukur Tingkat Kekeruhan Air Berbasis Arduino UNO," *J. Teor. dan Apl. Fis.*, vol. 7, no. 2, pp. 179–186, 2019, doi: 10.23960/jtaf.v7i2.2247.
[23] E. Wiyadi, A. Wati, Y. Hamzah, and L. Umar, "Simple I-V Acquisition Module with High Side Current Sensing Principle for Real Time Photovoltaic Measurement," *J. Phys. Conf. Ser.*, vol. 1528, no. 1, pp. 0–6, 2020, doi: 10.1088/1742-6596/1528/1/012040.
[24] A. B. Khudhair, F. I. Hussein, and M. A. Obeidi, "Creating a LabVIEW Sub VI for the INA219 Sensor for Detecting Extremely Low-Level Electrical Quantities," *Al-Khwarizmi Eng. J.*, vol. 19, no. 3, pp. 88–97, 2023, doi: 10.22153/kej.2023.05.001.
[25] F. M. Dewadi *et al.*, *FISIKA DASAR I (MEKANIKA DAN PANAS)*, 1st ed., no. June. Padang: PT GLOBAL EKSEKUTIF TEKNOLOGI, 2023.
[26] R. Rahmatullah *et al.*, "Design and Implementation of IoT-Based Monitoring Battery and Solar Panel Temperature in Hydroponic System," *J. IlmiahTeknik Elektro*, vol. 9, no. 3, pp. 810–820, 2023, doi: 10.26555/jiteki.v9i3.26729.
[27] B. J. Setiawan, G. A. Pauzib, A. Riyantoc, and A. Surtono, "Design and Build Voltage and Current Monitoring Parameters Device of Rechargeable Batteries in Real-Time Using the INA219 GY-219 Sensor," *J. Energy, Mater. Instrum. Technol.*, vol. 4, no. 2, pp. 58–71, 2023, doi: 10.23960/jemit.v4i2.137.
[28] Q. Qomaruddin, A. Setiono, and M. I. Afandi, "Karakterisasi Panel Sel Surya 100 Wp Untuk Sumber Energi Wireless Sensor Di Lapangan," *Pros. Semin. Nas. Fis. SNF2016*, vol. 5, pp. 79–82, 2016, doi: 10.21009/0305020116.