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Solar Panel Light Intensity and Voltage Measurement System Using Atmega328

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Abstract

The need for new renewable energy sources is growing because of several problems, such as high electricity costs, frequent power outages, and dependency on fossil fuels. It's critical to come up with solutions to this problem, like using solar power. Nonetheless, to guarantee a steady supply of energy, solar panels must be well controlled. The primary goal of this study was to create a system that would use an ATmega328 microcontroller, a logger module, and an INA219 voltage sensor, along with a BH1750 light intensity sensor, to detect the voltage and intensity of light on solar panels in real time. The study technique includes the steps of system definition, design, and development using a 4D approach that has been streamlined into 3D. The system's ability to make precise measurements and store data in a readily accessible and processable manner was demonstrated by the test results. Real-time solar panel state monitoring is made possible by the system's primary ATmega328 microprocessor, and data storage in CSV format enables easy analysis. In summary, this system was success for tracking and improving energy efficiency.

Keywords*: Light Intensity, Solar Panel, Voltage*

Abstrak

Kebutuhan akan sumber energi baru terbarukan semakin mendesak karena beberapa permasalahan, antara lain seringnya listrik padam, tagihan listrik yang tinggi, dan ketergantungan pada bahan bakar fosil. Menanggapi tantangan ini, penting untuk mencari solusi seperti penggunaan panel surya. Namun, pengendalian yang efektif terhadap panel surya ini diperlukan untuk memastikan pasokan energi yang stabil. Tujuan utama dari penelitian ini adalah untuk mengembangkan sistem pengukuran intensitas dan tegangan cahaya pada panel surya secara real-time dengan menggunakan mikrokontroler ATmega328 yang dilengkapi dengan sensor INA219 untuk mengukur tegangan, sensor BH1750 untuk mengukur intensitas cahaya, dan modul logger. Metodologi penelitian yang digunakan adalah pendekatan 4D yang telah disederhanakan menjadi 3D dan meliputi tahapan pendefinisian, perancangan, dan pengembangan sistem. Hasil pengujian menunjukkan bahwa sistem ini mampu melakukan pengukuran secara akurat dan menyimpan data dalam format yang mudah diakses dan diproses. Penggunaan mikrokontroler ATmega328 sebagai komponen utama sistem memungkinkan pemantauan kondisi panel surya secara real-time, sedangkan data disimpan dalam format CSV sehingga memudahkan analisis lebih lanjut. Dapat disimpulkan bahwa sistem ini telah sukses memantau dan mengoptimalkan efisiensi energi.

Kata kunci: Intensitas Cahaya, Panel Surya, Tegangan

Introduction

Electricity issues are common in public life and include equipment failures, overloads, storms, floods, and abrupt power outages brought on by disruptions in transmission or distribution networks [1], [2], [3]. In addition, unstable electrical system conditions can result in voltage and frequency fluctuations that damage electronic equipment [4]. Temporary power outages result from the state of power plants' inability to fulfill the increased demand for electricity. Thus, there needs to be a concerted effort to address the issue of electricity, one of which is to promote the usage of renewable energy using cutting-edge technologies [2], [5], [6], [7]. This award has been given in the Government of the Republic of Indonesia Regulation No. 79 of 2014 on Energy Conservation and Efficient Use of Energy has established a strategy to improve energy efficiency and promote the use of renewable energy in Indonesia [8].

New renewable energy technologies are evolving rapidly in this era, one of which is the use of solar energy [4], [9], [10], [11]. Through development of renewables, it becomes one of the efforts to reduce the energy crisis and the global warming impact caused by the combustion of fossil fuels [7], [12]. Sunlight is essential to renewable energy sources, particularly those that use solar panel technology [6], [11]. It helps reduce the carbon footprint and negative environmental impact compared to power plants that use fossil fuels. In maximizing the energy generated from solar panels, it need to be considered such as the power of the solar panel, the intensity of sunlight, seasons and weather [10], [13]. There are also factors of orientation and inclination of solar panels that also determine performance [5]. As a result, an instrument capable of measuring the current produced by solar panels and the intensity of solar energy was created in this study. This is done in order to provide people a solid grasp of how to operate renewable energy systems effectively and to maximize the usage of solar energy as a clean, sustainable energy source [12], [14].

A specialized monitor that can measure the intensity of sunlight and the current generated by solar panels is required to collect data about sunlight exposure at a particular location [1]. From the tools developed, simulations and evaluations were carried out to see if the location was suitable for the installation of solar panels until information was obtained about the exposure to sunlight. In addition, this data is essential to verify the operational quality of the system, ensuring that the power output is consistent with the expected level. The use of pyranometer sensors in the context of renewable energy and light measurement technology is no longer unfamiliar. Pyranometers have been designed to measure solar radiation from the range of ultraviolet wavelengths to near infrared wave lengths. However, these sensors are sold at high prices [4]. Thus, in research, this pyranometer sensor was replaced with the BH1750 sensor [5], [13], [15].

According to information, the BH 1740 sensor, which is a part of the digital light sensor family, has the benefit of immediately sensing light intensity and transforming it into a digital signal that can be handled by an ATmega328 microcontroller with ease. Concurrently, a gadget designed for measuring electrical current gains the INA219 sensor [5], [15]. Therefore, the accurate installation of solar panels becomes important, not only based on visual observations but also by considering the analysis of data recorded from several measurements of the current, voltage and intensity of sunlight.

Method

The type of research used is Research and Development (R&D), which used 4D modified into 3D namely Define, Design and Development [16], [17], [18]. At the Define stage, the process of identifying problems, formulating problems, setting goals, studying libraries, setting research limits and conducting needs analysis has been carried out.

Furthermore, certain tools and materials required for the instrument design have been obtained, including the BH1750 sensor for reading sunlight intensity values, the ATMega328 microcontroller for control, and the INA219 sensor for reading electrical voltage values. The data from the microcontrollers is stored in the logger module, and 16 x 2 alphanumeric LCDs are utilized to display the data values for voltage, current, and solar light intensity. Arduino Sketch, which is based on C programming, is the programming language used to read data. It is divided into multiple sections during the design phase. These include the BH1750 and INA219 sensors, a pair jack port-powered solar panel input system, the ATMega328 microcontroller-based process system, and an LCD module and logger for the output. Numerous tasks have been accomplished during the development phase, including the evaluation of tools that have been reviewed by media professionals and tested through trial runs on the developed devices.

The instrument used consists of a questionnaire by media experts and a performance testing sheet for the tool. In the media experts' questionnaire, several indicator items are assessed, including aspects of overall appearance, practicality, and tool quality. The questionnaire utilizes a Likert scale [19], [20]. The trials conducted included voltage sensor testing, light intensity sensor testing, and real-time testing over several days. In the analysis of the survey data, percentage calculations were used [21] The performance of the testing equipment created involves comparing the readings obtained from the device with those from the solar power meter SM-206. Subsequently, a calculation of the percentage error is carried out [22]:

$$Persen\ Error\ (\%) = \frac{Yn - Xn}{Yn} \times 100\%$$

where: Yn = The Actual Value on the Solar Power Meter

Xn = Testing Result on the Developed Tool

Results and Discussion

At the design stage, block diagrams and circuit designs have been created as shown in Figures 1 below.

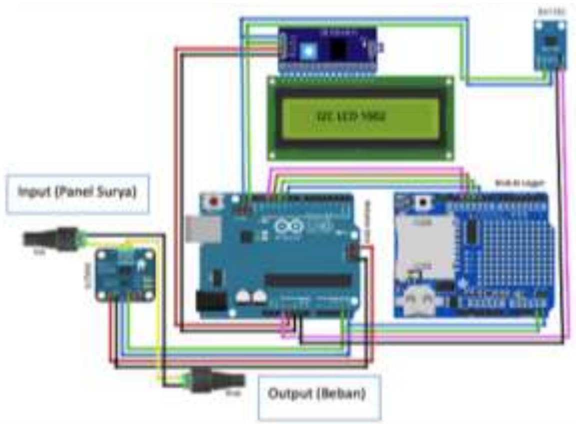

Figure 1. Design of the Developed Device Circuit

The physical form of the tool being developed is shown in the following Figure 2:

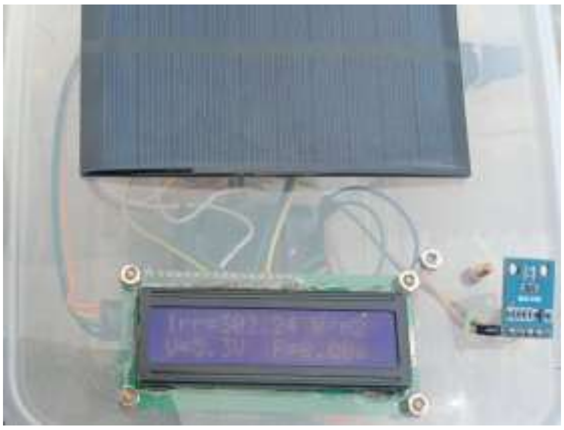

Figure 2. The Physical Form of the Developed Device

In this research, a system design has been carried out, consisting of both hardware and software design. The hardware design involved determining system specifications such as energy requirements, the sensors used, and the data collection environment; selecting components; creating a schematic design that outlines the connections between the ATMega328 microcontroller, the BH1750 sensor, the SD card module, and the INA 219 sensor; designing a PCB to ensure proper signal and ground pathways; building a prototype; and conducting tests to ensure all components function correctly. Meanwhile, the software design involved determining the functions for sensor reading, data storage, and data transmission; the software architecture design included sensor data acquisition, storage SD card, and communication with the microcontroller; programming; software testing, debugging; as well as integrating the software with hardware and thoroughly testing the entire system. Below is Figure 3 showing the testing of the INA219 Sensor, where the testing stages ensure that the device functions as expected and that the data recording procedure is accurate.

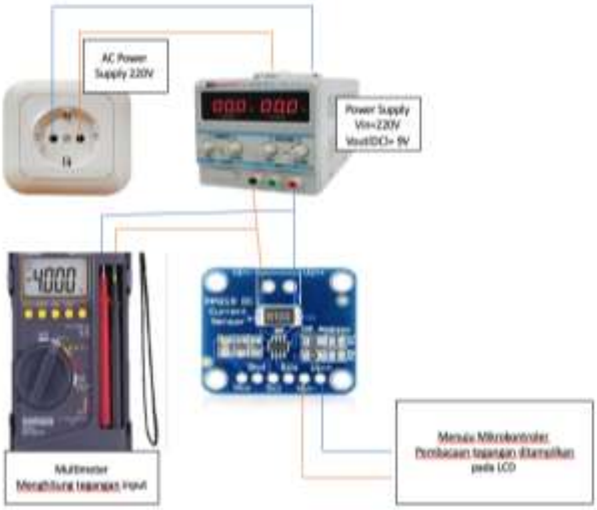

Figure 3. Testing the INA219 Sensor

After completing the testing of the equipment, data recording was conducted on the fourth floor of the Tarbiyah B Building at the Faculty of Tarbiyah and Teacher Training (FTK) of UIN Ar-Raniry Banda Aceh. The developed device was used to record data as shown in Figure 4, and the results obtained will be compared with the readings from the SM-206 solar power meter, which is based on photodiodes. Data recording of irradiance with the device took place over one day, from 9:30 AM to 4:00 PM WIB, under conditions where clouds were disregarded and it was considered sunny for each data collection. Data from the SM-206 solar power meter was collected and compared with the information displayed on the LCD.

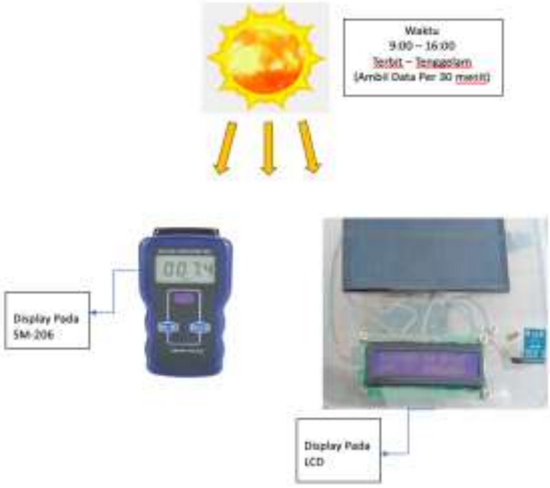

Figure 4. Illustration of Data Recording for Irradiance between the Developed Device and the Solar Power Meter

The results of the data recording for that 1 day are shown in Table 1 below:

Table 1. Testing Solar Light Intensity with Tools and a Solar Power Meter

No	**Time**	**Sensor BH1750 (W/m^2)**	***Solar Power Meter (W/m^2)***	**Percentage *Error* %**
1	09:46	364.55	370.6	1.6%
2	10:21	417.95	420.2	0.5%
3	11:01	640.44	645.7	0.8%
4	12:17	875.35	880.8	0.6%
5	14:05	617.44	619.3	0.3%
6	15:33	608.15	612.0	0.6%
7	16:02	438.33	441.4	0.6%
Average				0.8%

The results of the testing and measurement of irradiance (W/m^2) using the BH1750 sensor and solar power meter, as shown in Table 1, indicate an average percentage error of 0.8%. In this case, the difference in readings between the two instruments is minimal, resulting in a low percentage error from the readings of the developed device. A complete graphical representation of the readings from both instruments for sunlight intensity over every 30-minute interval is displayed in the following Figure 5.

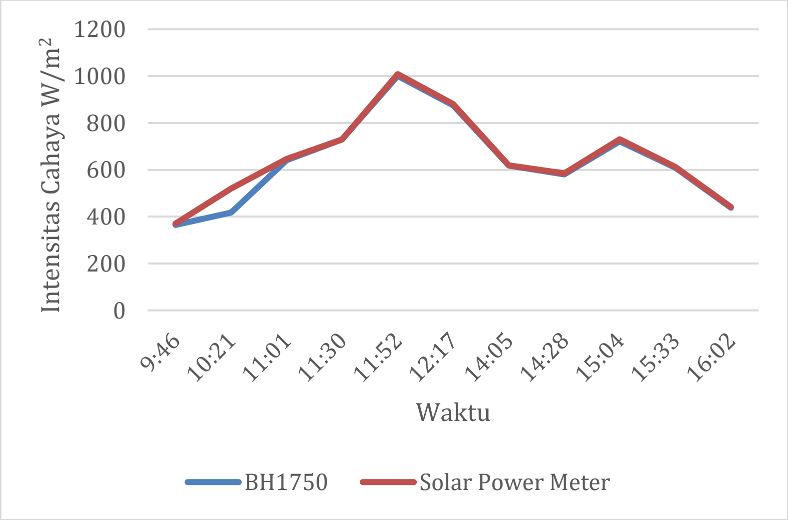

Figure 5. Data Reading Graph from The Developed Device and Solar Power Meter

The output from the developed device reading is shown on the LCD screen, as depicted in Figure 6 below. The testing results of the LCD screen indicate that the characters displayed align with the screen design. The LCD can display all data presented, including output power, voltage, and solar radiation, with no characters hidden or omitted.

Figure 6. The Output Display of the Developed Device on LCD Screen

The incoming data is recorded using a data logger, then transferred to an SD card and formatted in Excel. The CSV format is used for data entry to facilitate the inclusion of large amounts of data into tables that can be read by Microsoft Excel applications. The developed tool outputs the results by reading data at each distance delimiter. Real-time testing has also been conducted over several days, and the results indicate that the system is functioning well. The table shows the real-time measurement results from four days of testing the developed device.

Table 2. Results of the Real-Time Testing of the Developed Tool

No	Date	Time	***Irradiance* (W/m²)**	Voltage (V)
1	30/11/2023	10:21:50	412.74.	5.5
2	30/11/2023	10:22:51	339.59	5.4
3	1/12/2023	9:21:50	281.09	5.01
4	1/12/2023	9:22:52	280.02	5.01
5	5/12/2023	13:15:28	431.4	5.8
6	5/12/2023	14:26:27	391.2	5.5
7	6/12/2023	10:6:18	411.2	5.7
8	6/12/2023	10:8:49	341.3	5.3

Based on the validation results from two media experts, the feasibility data for the developed tool is shown in Table 3 as follows:

Table 3 Results of Expert Validation for the Feasibility of the Developed Tool

No	Indicator	Questionnaire item	Expert 1	Expert 2	Average	Assessment Criteria
1	General Appearance	• The measuring instrument is assembled in an orderly and systematic manner.	4	4	4	Indicator Average: 4,5 = 4 “Eligible”
		• Portable measuring device	5	5	5	
		• The measuring device can display data in a minimalist way.	4	5	4,5	
2	Practical	• Tools and materials in a simple measurement system.	4	4	4	Indicator Average: 4,5 = 4 “Eligible”
		• The tools and materials used are easily available in the market.	5	5	5	
3	Quality	• The measuring instrument has long-term durability.	3	4	3,5	Indicator Average 3,75 ~ 4 “Eligible”
		• The measuring instrument has the capability to read data very quickly (within seconds).	4	4	4	

Overall, the results of the media expert validation in Table 3 indicate that the developed tool is deemed suitable for use. However, there are still indicators with an average rating of 3.75 regarding quality. Recommendations for improvement include addressing the tool's resistance to heat and water, as it will be placed outdoors. Additionally, there is a suggestion to incorporate power consumption measurements for the logger, as well as to implement calibration procedures for the data logger's storage. The intensity of sunlight refers to the amount of solar energy that reaches the surface of solar panels over a period of time, typically expressed in watts per square meter (W/m^2) [23]. The voltage produced by solar panels is a result of the photovoltaic effect [5], [11], In this process, photons from sunlight strike a semiconductor material (usually silicon), releasing electrons and creating an electric potential difference (voltage). The ATMega328 microcontroller can be used for data control and management. Generally, the voltage generated by solar panels depends on several factors: (i) Sunlight intensity—higher intensity means more photons hitting the solar panel, resulting in more free electrons and increased voltage, (ii) Panel temperature—higher temperatures will reduce the output voltage of the solar panel, and (iii) Panel efficiency—solar panels with higher efficiency will produce more voltage for the same light intensity. [15], [23]. Analysis of the data provides a better understanding of the performance of solar panels in generating electricity and how effectively the panels capture solar radiation.

Conclusion

A system for measuring solar light intensity and electrical voltage on solar panels has been successfully developed using the BH1750 sensor, ATmega 328 microcontroller, INA219 sensor, and data logger module. The assessment of the developed tool has received a qualified rating from media experts. The tool has demonstrated good performance when compared to the solar power meter SM-26, with an average percentage error of 0.8%. The intensity of sunlight detected by the tool depends on the time of testing, location, and current weather conditions. The measurement of the solar panel voltage and irradiance is a crucial aspect in evaluating the performance and efficiency of solar panels and can provide valuable insights for future improvements or enhancements in solar panel efficiency. Further studies are still needed for the developed tool's output from the solar panel, as no load has been connected yet, resulting in power data that only reflects a value of 0. It is hoped that future researchers can develop and expand the output from the solar panel.

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