

Monitoring of solar panel simulator using Visual Studio

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ABSTRACT

The use of solar panels as an alternative energy source is increasingly widespread due to their environmentally friendly nature. However, their efficiency is highly influenced by external factors such as temperature and light intensity. Therefore, a monitoring system capable of observing panel performance in real-time is required. This study designs and develops a solar panel simulator monitoring system based on the Arduino Uno microcontroller and a Visual Basic interface, which displays sensor data in both graphical and tabular forms. The sensors used include DHT22 (temperature), BH1750 (light intensity and irradiation), ACS712 (current), and a voltage divider (voltage). The system is tested using four solar panel circuit configurations: series, parallel, series-parallel, and total cross tied (TCT). The test results show that each configuration is highly dependent on light intensity in relation to the current and voltage produced. The data visualization using Visual Basic functions optimally and is consistent with measurement results, indicating that this system is effective for monitoring and analyzing the performance of solar panels under simulated conditions.

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1. INTRODUCTION

Solar panels are increasingly being used as a source of solar power generation, both for commercial and personal needs, because this energy source is environmentally friendly [1]. However, solar panel performance is highly dependent on a number of external factors, such as light intensity and ambient temperature, which affect energy conversion efficiency [2]. Therefore, a monitoring system is needed that can directly monitor conditions to ensure optimal performance [3]. Solar panel monitoring systems are designed to support processes such as collecting, analyzing, and interpreting data to monitor progress toward predetermined goals [4]. Good monitoring allows users to know the condition of solar panels, detect early disturbances, and periodically evaluate system performance to enable decisions and improvements to solar panels [5]. However, monitoring practices in the field are still largely manual, with data collection on solar panels in the form of text files and difficult to access or analyze in real time [6].

In addition, an internet-based monitoring system must be stable because it greatly affects the performance of the monitoring system directly, and disruptions to the connection can cause delays or data loss [7]. Several studies have shown that the implementation of an automatic and network-based monitoring system is very necessary so that operators do not have to carry out physical inspections at the location, so that operational efficiency can be significantly increased [8]. To increase the effectiveness of the monitoring system, an interface is needed so that data can be accessed and analyzed easily [9]. Visual Studio is one platform that can design a monitoring interface, with the ability to simplify graphic creation and integration with databases [10]. Among the various programming languages in Visual Studio, this research uses the Visual Basic programming language because it is easy to design interfaces, and direct integration with Windows components [11].

As explained in other studies, visual basic can display data directly and save it in file format for further analysis purposes [12]. Visual basic can also visualize solar panel performance data dynamically and interactively in a desktop application [13]. To be able to produce accurate data, Arduino Uno is used as a microcontroller that will receive and send sensor data to visual basic. The data measures the characteristic values of solar panels with DHT22 sensors as temperature, BH1750 as light intensity and irradiation, ACS712 as current and voltage divider as voltage [14]-[15].

2. METHOD

Block diagram design is used to simplify the design of a comprehensive tool. The following block diagram of all components is shown in Figure 1.

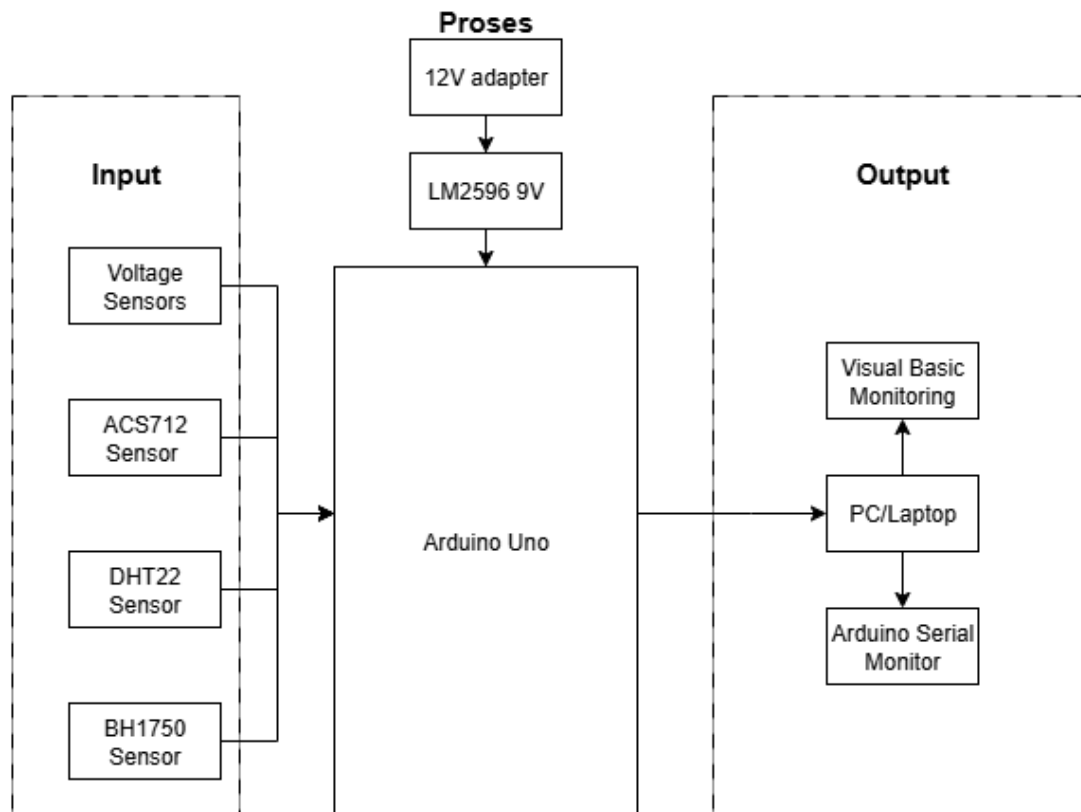


Figure 1. Block diagram

Referring to the structure in Figure 1, each block has a specific role that supports the overall performance of the system. The following is the function of each component. The voltage sensor is used to read the output voltage value from the solar panel module. The ACS712 sensor is used to measure the amount of current generated by the solar panel. The DHT22 sensor is used to measure the temperature on solar panels. The BH1750 sensor is used to measure the light intensity and irradiance produced by halogen lamps. LM2596 to produce a stable supply voltage. Arduino uno for the main controller that controls the entire system. Visual Basic is used to monitor the results of the captured sensor data.

The working principle of this tool is to monitor the output of the solar panel when the PV module is exposed to light, then the solar panel converts light energy into electrical energy. In this study we use a halogen lamp that functions as a light source on the solar panel, then a dimmer switch to regulate the lighting on the halogen lamp. Furthermore, several sensors such as the DHT11 sensor to measure humidity temperature, the ACS 712 sensor as a reader of the output current value, the voltage sensor to calculate the voltage value, and the BH1750 sensor to measure the intensity of light and irradiation working on the panel, then the output from the sensor is then sent serial data to the Arduino microcontroller, then the Arduino sends serial data to the PC or to the software, Visual Basic which is used as monitoring the output of the panel.

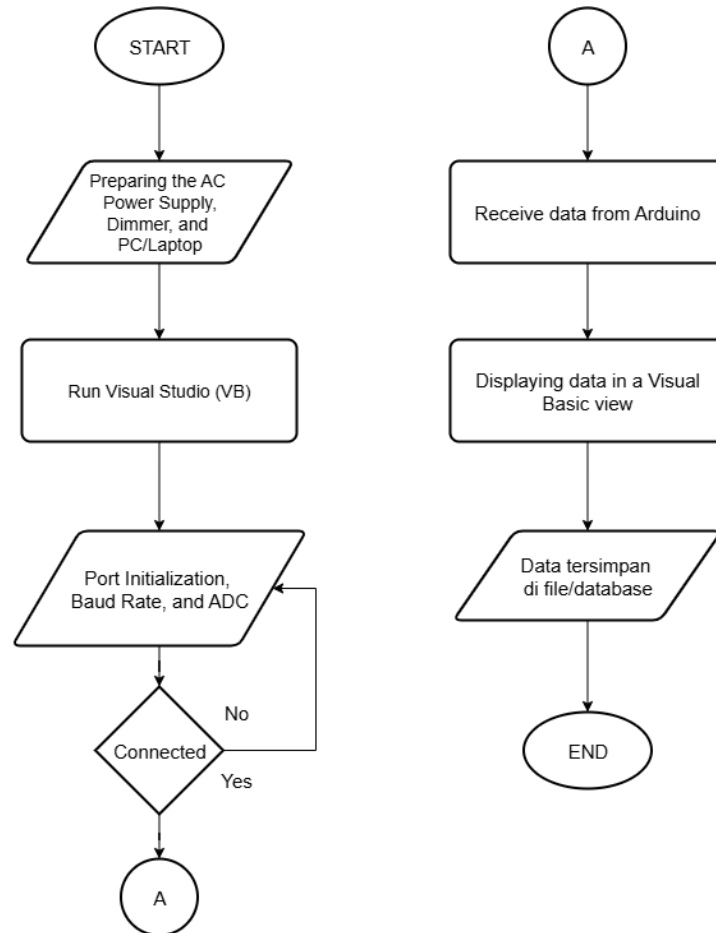


Figure 2. Flowchart

The components used in this system consist of 1 Arduino Uno unit as a microcontroller, 1 voltage sensor unit (Voltage Divider), 1 ACS712 current sensor unit, 1 DHT22 temperature sensor unit, 1 BH1750 light sensor unit, and 1 LM2596 buck converter unit. To make the overall electrical design scheme of the tool clearer, it can be seen in Figure 3.

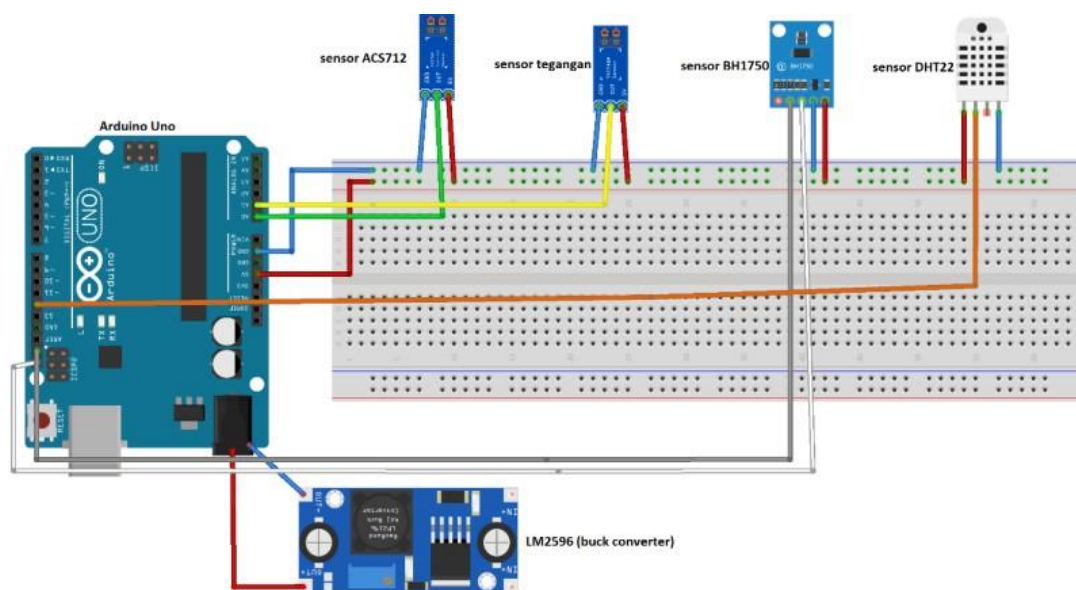


Figure 3. Microcontroller components



Figure 4. Visual Basic Design View

The simulator used can be seen in Figure 5, which contains several important components to simulate lighting to obtain output from solar panels, these components consist of 3 dimmers to regulate variations in light intensity on halogen lamps, 54 halogen lamps that produce artificial light intensity for solar panels, and 6 solar panels used to produce solar panel output.



Figure 5. Solar Panel Simulator

3. RESULTS AND DISCUSSION

In this experiment, data monitoring will be carried out in the form of values from each sensor that has been programmed and the sensor can send data that has been taken by the sensor and then it will be sent to visual basic in the form of a graph of its output and also in the form of a table so that it can be directly displayed in visual studio software. In this experiment, several circuit simulations will be carried out consisting of 4 circuits, namely series circuits, parallel circuits, series parallel circuits, and total cross- tied (TCT) circuits. The following is the data from the monitoring results after testing using a 5 Watt 4.5 Ohm resistor load, including testing on series circuits, testing on parallel circuits, testing on series parallel circuits and testing on Total Cross Tied (TCT) circuit.

3.1 Testing on Series Circuits

This test confirms that the series circuit is effective in increasing the total voltage of the solar panel system. However, its performance is highly dependent on uniform irradiation across all modules. A difference is observed between the increase in lux and irradiation. At the highest lux and irradiation conditions, the series circuit produces the highest voltage and current, namely 1.02V and 0.22A using a measuring instrument. Conversely, at low lux and irradiation conditions, namely 0.22V and 0.05A, confirming that the performance of the series circuit is highly dependent on the amount of light received by the solar panel surface. Therefore, in designing a system with a series circuit, it is crucial to ensure environmental conditions with minimal shading and all modules receive relatively uniform light and irradiation to achieve optimal performance and maximum efficiency.

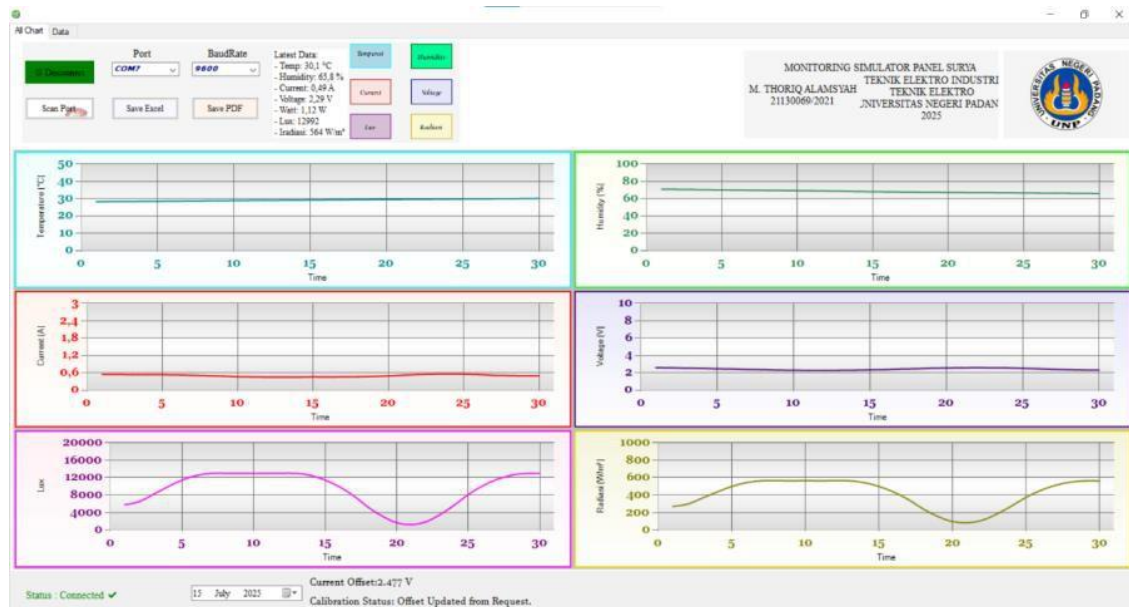


Figure 6. Series Circuit Monitoring Display

Table 1. Testing of Series Circuits

No	Dimmer Configuration	Test Position 5W 4.5Ω Load with Series Circuit									
		Measuring instrument					Monitoring Results				
		A	V	L	W/m2	°C	A	V	L	W/m2	°C
1	130, 130, 130V	0.05	0.22	1280	80	30.3	0.03	0.21	1282	76	29.6
2	140, 150, 160V	0.07	0.36	2590	125	36.0	0.06	0.34	2527	120	34.9
3	100, 150, 200V	0.11	0.52	4190	151	33.9	0.09	0.50	4138	159	34.9
4	200, 150, 100V	0.10	0.47	2800	139	32.0	0.09	0.47	2733	135	32.6
5	220, 220, 220V	0.22	1.02	11300	440	38.4	0.19	1.01	11558	443	39.7

3.2 Testing on Parallel Circuits

Testing the parallel circuit under lux and irradiation conditions resulted in peak output current and voltage of 1.03A and 4.95V using a measuring instrument. The resulting output power at this point was approximately 5.1W, indicating that the system was capable of meeting or even slightly exceeding the power requirements of a 5W load under optimal conditions. Conversely, under the lowest lux and irradiation conditions, the current and voltage dropped dramatically to 0.23A and 1.09V, resulting in a much lower output power of approximately 0.25W. This indicates that the lower the lux and irradiation, the lower the ability of the parallel circuit to generate significant power.

Table 2. Testing of Parallel Circuits

No	Dimmer Configuration	Test Position 5W 4.5Ω Load with Series Circuit									
		Measuring instrument					Monitoring Results				
		A	V	L	W/m2	°C	A	V	L	W/m2	°C
1	130, 130, 130V	0.23	1.09	1390	91	27.3	0.20	1.07	1388	88	27.2
2	140, 150, 160V	0.37	1.73	2580	131	30.7	0.33	1.70	2555	128	31.7
3	100, 150, 200V	0.41	1.93	3760	152	33.5	0.37	1.91	3707	147	33.0
4	200, 150, 100V	0.42	1.95	2380	118	34.9	0.37	1.92	2366	115	34.7
5	220, 220, 220V	1.03	4.95	11760	447	42.2	1.01	4.96	11662	448	42.7

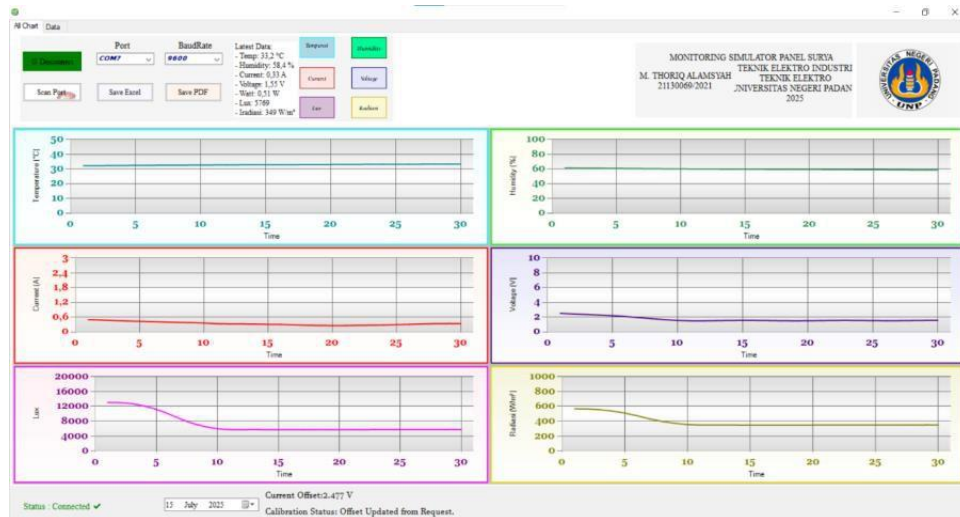


Figure 7. Parallel Circuit Monitoring Display

3. 3 Testing on Series Parallel Circuits

In the series-parallel circuit test, the highest lux and irradiance produced peak current and voltage of 0.56A and 2.58V using the measuring instrument. The output power generated at this point was approximately 1.44W. Although this is the highest power achieved, it is still far from the 5W load requirement. Conversely, under low lux and irradiance conditions, the current and voltage dropped drastically to approximately 0.13A and 0.59V, resulting in a minimum output power of approximately 0.076W. This shows that despite offering flexibility, this circuit remains highly dependent on the availability of adequate light energy

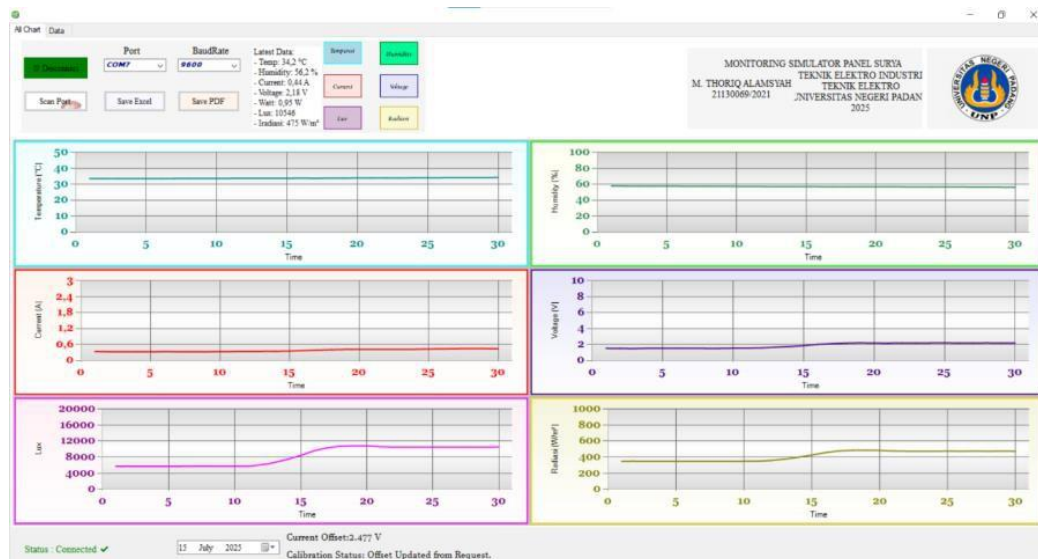


Figure 8. Series Parallel Circuit Monitoring Display

Table 3. Testing of Series Parallel Circuits

No	Dimmer Configuration	Test Position 5W 4.5Ω Load with Series Circuit									
		Measuring instrument					Monitoring Results				
		A	V	L	W/m2	°C	A	V	L	W/m2	°C
1	130, 130, 130V	0.13	0.59	1420	86	30.1	0.12	0.59	1409	84	29.7
2	140, 150, 160V	0.20	0.93	2520	132	32.2	0.19	0.92	2524	128	31.7
3	100, 150, 200V	0.22	1.01	4190	130	33.3	0.19	1.01	4088	131	34.3
4	200, 150, 100V	0.22	1.02	2230	163	35.8	0.19	1.02	2340	160	35.8
5	220, 220, 220V	0.56	2.58	11800	476	38.0	0.44	2.57	11808	471	39.0

3. 4 Testing on Total Cross Tied (TCT) Circuit

In the TCT test at the highest lux and irradiance conditions, the TCT circuit produced peak current and voltage of 0.55A and 2.65V using a measuring instrument. The output power generated at this point was approximately 1.46W. Although this power is the highest in the TCT test, it is still below the 5W load requirement, indicating the need for scaling or module number adjustments. Decreasing irradiance consistently causes a decrease in output current and voltage. At low irradiance, the power generated is very minimal at around 0.068W. This confirms the dependence of TCT performance on the availability of adequate light energy, just like other configurations.



Figure 9. TCT Circuit Monitoring Display

Table 4. Testing of the TCT Circuit

No	Dimmer Configuration	Test Position 5W 4.5Ω Load with Series Circuit									
		Measuring instrument					Monitoring Results				
		A	V	L	W/m2	°C	A	V	L	W/m2	°C
1	130, 130, 130V	0.12	0.57	1320	61	28.5	0.10	0.57	1328	59	27.6
2	140, 150, 160V	0.20	0.90	2590	114	31.2	0.18	0.89	2588	110	30.2
3	100, 150, 200V	0.23	1.20	4480	116	34.2	0.21	1.20	4482	113	34.0
4	200, 150, 100V	0.21	1.12	2270	161	35.6	0.19	1.10	2271	157	35.4
5	220, 220, 220V	0.55	2.65	11880	460	37.3	0.54	2.63	11820	455	37.8

4. CONCLUSION

Based on the results of testing and discussion of the visual basic monitoring system for series circuits, parallel circuits, series-parallel circuits, and TCT circuits, it can be concluded that all solar panel circuit configurations exhibit a strong dependence on irradiance and light intensity. The higher the irradiance, the higher the current, voltage, and power output produced by all circuit types. This is consistent with the working principle of photovoltaics, where electricity production is directly proportional to the absorbed light energy. The display in Visual Basic runs according to the data generated by all sensors, and the comparison with the measuring instrument is not much different from the values on all sensors.

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