SOLAR CELL MONITORING DESIGN IoT BASED 3 PHASE INVERTER USING POWER MONITOR SYSTEM APPLICATION

Della Ayu Prastika[1*], Slamet Hariyadi[2] , Dwiyanto[3]

[1,2,3)] Civil *Aviation Polytechnics of Surabaya*
**Corresponding Author. Email: dellayu06@gmail.com*

ABSTRACT
The sun is a very potential source of energy for humans, both through the heat that reaches the earth's surface and the light it receives. To utilize solar energy, technology has been developed such as Solar Cells, or Solar Power Plants (PLTS), which convert solar energy into electrical energy. Research regarding the development of an Internet of Things (IoT) based solar cell monitoring system with the Power Monitor System application aims to prevent waste of electrical energy, which can be detrimental to individuals and groups. With this monitoring tool, electrical energy consumption can be monitored more effectively. This research aims to increase the operational efficiency and reliability of solar cells through IoT-based control. The Power Monitor System application makes it easy for users to access information about current, power and voltage performance in real-time.

Keywords: *Solar Cell, Power Monitor System Application.*

1. INTRODUCTION

The sun is a very potential source of energy for humans, both through heat and light received by the earth. With solar cells, sunlight can be converted into useful electrical energy. Solar energy from sunlight reaching Earth has enormous potential, around 3 x 10^{24} Joules per year, or the equivalent of 10,000 times current global energy consumption. In Indonesia, with abundant sunlight throughout the year, solar energy is a very promising source of electricity. Considering the great potential of solar energy that can be converted into electricity and the importance of efficiency in energy use, especially in 3 phase electric power systems, solutions such as the Internet of Things (IoT) based Solar Cell Monitoring System become relevant. This system enables real-time monitoring and optimization of energy use, taking advantage of Indonesia's wealth of solar energy and increasing energy efficiency. With the application of the right technology, energy efficiency and the use of renewable resources such as the sun can contribute to a more sustainable and environmentally friendly future

2. LITERATURE REVIEW

Figure 1 Solar cell

Solar Cell is a technology that converts sunlight into electrical energy. This process is influenced by light intensity and weather conditions.

Figure 2 PZEM 004t.

The PZEM 004t sensor is a tool used to measure current, voltage and power, then display the results on the application or LCD.

Figure 3 Batteries

Batteries are an important component in off-grid solar cell systems. Its function is to store electrical energy produced from sunlight.

3. METHODOLOGY

3.1. Research Design

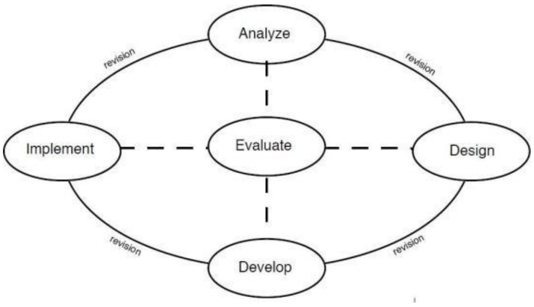

Figure 4 Research design

3.2. Tool Design

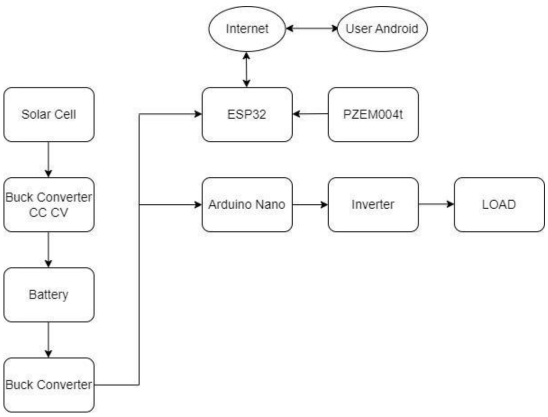

Figure 5 Block diagram

The design of the device shows that the electrical energy produced by the solar cell is stored in the battery. There are two microcontrollers, namely ESP32 and Arduino Nano, to fulfill the number of pins required by other components. The ESP32 receives data from the PZEM004t sensor, which monitors voltage, current, and power, and displays that information on the screen of an internet-connected smartphone. Meanwhile, Arduino Nano focuses more on load control.

3.3. Tool Component

In making this tool, several components are needed which are designed to produce the tool as desired. These components include:

Do not italicize subscripts unless they are variables. Equations should be either display (with a number in parentheses) or inline. Use the built-in Equation Editor or MathType to insert complex equations.

3.3.1. Hardware

1. Solar Panels

In designing this tool, a 20 WP capacity solar panel was used with a maximum current of 1.16 A and a maximum voltage of 17.2 V.

2. Arduino Nano

Arduino Nano is a small component that is equipped with a microcontroller to control devices according to commands. The design of this tool uses the Arduino Nano microcontroller as the basis for programming. This device will later be connected to the MOSFET driver before being connected to the load. Even though its size is very small, this board offers quite complete features.

3. ESP32

ESP32 is a module that allows sending data via WiFi, making it easier for users to develop Internet of Things (IoT) based application systems.

4. Battery

A battery is a component that converts chemical energy into electrical energy through chemical reactions, which is then used to operate electronic devices. The electrical energy produced acts as a power source for electronic equipment. The battery used is a 12V VRLA, which stores electrical energy from solar panels and is connected to a buck converter.

5. LM2596

Stepdown Module The LM2596 Stepdown Module is a converter circuit that lowers the voltage from 12 Vdc to 5 Vdc to supply Arduino and ESP32. This module uses Surface Mount Device (SMD) components and is equipped with a potentiometer to regulate the input voltage from 4V to 24V DC with a working frequency of 150 kHz, allowing voltage adjustments as needed.

6. XL4016

Stepdown Module The XL4016 Stepdown Module is a buck converter that has high efficiency up to 95%. This module is used to reduce the output DC voltage to be lower than the input voltage. Apart from that, this module is also equipped with an output voltage display which makes it easier for users to adjust the voltage drop.

7. PZEM 004t sensor

The PZEM 004t sensor is a sensor used to measure parameters such as current, voltage and power, especially electrical parameters for AC current.

3.3.2. Software

1. Arduino IDE

Arduino IDE is software used to program Arduino microcontrollers. Users can write code using the Arduino programming language, access hardware connected to the Arduino, and monitor the performance of running programs.

Figure 6 Arduino IDE

2. Power Monitor application

The Power Monitor Supply application aims to monitor solar cells. This application displays data such as current, voltage, power and energy. To design this tool, a wifi connection is needed to connect the ESP32 with the application.

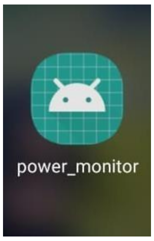

Figure 7 Power monitor application

3.3.3. Testing Techniques

1. Solar Panel Testing

This test functions to find out whether the solar panels are functioning properly. This is determined by the output of the solar panel itself based on the intensity of light or weather which will be measured using a measuring instrument in the form of an avometer. Testing is carried out by placing it in a location exposed to sunlight.

2. Buck Converter Testing

This test functions to find out whether this component can regulate a stable voltage. This test is carried out by connecting negative and positive probes to the input and output with an avometer. After that, the results obtained will be recorded.

3. Battery Testing

This test serves to find out whether the battery can work well to store energy converted from solar panels. The test is carried out using a measuring instrument, namely an avometer, by connecting the positive and negative probes.

4. PZEM004t Sensor Testing

This test functions to determine whether this sensor can read current, voltage and power from the solar panel. This test is carried out by activating the switch so that there is a red indicator light on the sensor, which means the sensor is functioning properly.

3.3.4. Data Analysis

Techniques Based on the explanation above, the author will design a tool to find solutions to the problems that have been determined. The following are the analysis techniques that will be used.

1. Literature study method

The literature study method is carried out by exploring and analyzing relevant theories to support solving the problem being studied, through searching and studying previously existing written sources. (Indrawan, 2014).

2. Library method

The library method involves the use of various reference books, information from lecturers, as well as data from internet sites and colleagues. Library research is a type of qualitative research that does not require direct data collection in the field, but relies entirely on written works, both published and unpublished. (Ramadan, 2021).

3. Observation Method

The observation method is carried out by going directly into the field to make observations to look for supporting data or information as a first step in collecting information about how to monitor solar cells in the power monitor system application.

4. Experimental method

The experimental method involves carrying out trials to obtain data from experiments created by simulation, with the aim of helping solve existing problems.

5. Discuss

The Discuss method involves consultation with supervisors and lecturers. It is hoped that discussions with the supervisor will ensure the smoothness and accuracy of the research process according to the ideal plan.

4. RESEARCH RESULT

This chapter will discuss testing the system designed in the previous chapter. The purpose of this testing is to evaluate the performance of the tool, both from each component and the entire system, and ensure that the system functions according to plan. This test also aims to check the condition of the system so that the application can run normally and optimally.

1. Analysis Results

This research begins with analyzing potential problems, identifying the tools needed, and planning tool development. In the process of making the device, researchers identified the great potential of solar energy which can be converted into electricity through solar cells and the importance of efficiency in the use of electrical energy. Especially in 3-phase electric power systems, solutions such as Solar Cell Monitoring Systems based on the Internet of Things (IoT) are becoming increasingly relevant.

2. Design

After the analysis stage is complete, the next step is the planning stage (Design) for the tool to be created.

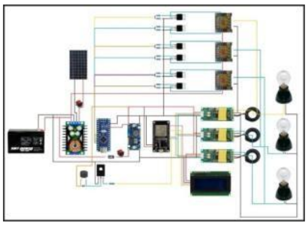

Figure 8 Tool design

3. Development

At the development stage, the system design that has been previously designed will be realized into the final product. At this stage, the plans that have been made in the design stage will begin to be realized into the tools that are expected.

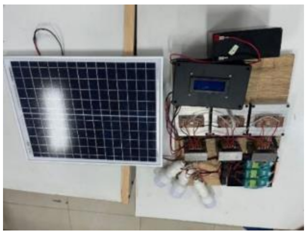

Figure 9 Overall tool

5. DISCUSSION

5.1. Research Design

On a 20 WP solar panel, measurements were taken from 08.00 am to 16.00 pm with data collection intervals every hour. The following are the results of solar panel measurements. Testing was carried out in sunny to cloudy conditions, where the weather greatly affects the solar panel output.

Table 1. Solar panel output testing

Waktu	$V_{(output)}$
09.00	11,80
10.00	11,95
11.00	12,10
12.00	12,25
13.00	12,10
14.00	11,98
15.00	11,90
16.00	11,80

Analysis results: Based on this data, solar panel output measurements are carried out every hour from 09.00 to 16.00 using an Avometer. The measurement results obtained show different voltage variations, so it can be concluded that the output of solar panels is influenced by weather and light intensity.

Table 2. Stress testing

	TEGANGAN (Voltage)								
Waktu	LCD			APK			AVOMETER		
	R	S	T	R	S	T	R	S	T
09.00	184,4	185,1	185,2	184,4	185,1	185,2	183,4	184,0	184,2
10.00	185,8	186,3	186,6	185,8	186,2	186,6	185,3	186	186,1
11.00	187,2	186,9	187,5	187,2	186,4	187,5	187	186,1	187,2
12.00	188,5	188,6	188,7	188,3	188,6	188,7	186,3	186,6	187,7
13.00	186,8	187,4	187,6	186,8	187,1	187,6	185	186,1	186,5
14.00	182,5	183,4	184	182,5	183,4	184	180,1	181,4	182
15.00	176,0	176,8	177,4	176,0	176,8	177,4	176,3	177	177,7
16.00	171,6	172	172,3	171,6	172	172,3	172,1	172,4	172,5

Analysis results: Data collection was carried out for two days, Saturday and Sunday, with transformer output measurements every hour. From these data, it can be concluded that the intensity of light affects the voltage produced. Data collection was carried out in sunny, cloudy weather conditions, which caused the incoming voltage to be less than optimal. The experimental results show that a 20 WP solar panel produces a voltage of around 185 VAC a day, with a difference between test equipment of no more than 2 VAC, and the amount of voltage depends on the solar heat radiation received.

Table 3. Flow testing

	ARUS (Ampere)								
Waktu	LCD			APK			AVOMETER		
	R	S	T	R	S	T	R	S	T
09.00	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02
10.00	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02
11.00	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02
12.00	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02
13.00	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02
14.00	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02
15.00	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02
16.00	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02

Analysis results: From this data, it can be concluded that the current flowing to the load remains constant at 0.02 A, because the load used is a 5 watt lamp in each phase. Current is affected by load; The higher the load power, the greater the current flowing. So the conclusion from the data taken is that the current produced is very small, namely 0.02 A. From 09.00 to 16.00, it can be seen that the current remains constant.

Table 4. Power testing

Waktu	POWER					
	LCD			APK		
	R	S	T	R	S	T
09.00	0,6	0,7	0,7	0,6	0,7	0,7
10.00	0,8	0,8	1,0	0,8	0,8	1,0
11.00	1,1	1,2	1,2	1,1	1,2	1,2
12.00	1,1	1,2	1,3	1,1	1,2	1,2
13.00	1,0	1,1	1,1	1,0	1,1	1,3
14.00	0,9	1,1	1,2	0,9	1,1	1,2
15.00	0,8	1,0	1,0	0,8	1,0	1,0
16.00	0,6	0,8	0,8	0,6	0,7	0,7

Analysis results : Based on this data, measurements are carried out every hour. With this measurement frequency, the power in each phase can be known. From the power test results, it can be concluded that power is influenced by voltage.

5.2. Buck Converter Testing

This Buck Converter test aims to check the input and output voltage, where the output voltage will be used to supply the Arduino Nano.

Table 5. Buck converter testing

Percobaan	Vinput	Voutput
1.	11,02	5,04
2.	11,01	5,03
3.	10,95	5,03
4.	10,96	5,03
5.	10,91	5,03

Analysis results : Based on these tests, it can be seen that the output voltage from the buck converter remains constant at 5 V to supply the Arduino Nano, while the average input voltage is 11 V.

6. CONCLUSIONS AND RECOMMENDATION

Based on experiments and discussions, it is concluded that:

This tool functions to monitor solar cells using the Internet of Things (IoT) based Power Monitor application which is only available for Android. Data read by the PZEM 004t sensor will appear in the application and can be seen by the user. Based on experiments, this tool functions well and the application can read data from the sensor. This tool uses three PZEM 004t sensors because this solar cell is a 3 phase type, as well as an XL4016 module to charge the battery. Data was collected between 09.00 and 16.00, with the highest output voltage from the solar panels reaching 12.25 V, influenced by weather and near shading. The resulting current is 0.02 A because the lamp load remains 5 watts per phase. This experiment uses a 20 WP solar panel, and this tool shows a square wave that is not completely precise at 120,° so the load used involves devices other than windings such as lights and switching PSU.

This application was created using the MQTT protocol and can only be accessed by Android users. This app displays the current, voltage and power delivered by the ESP32. This data will appear if connected to the registered WiFi.

AUTHORS' CONTRIBUTIONS

For further research, it is hoped that it can increase the capacity of solar panels to increase the energy produced from sunlight, as well as expand the application so that it can be accessed by users other than Android to make it easier to use.

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