



Portable Solar Panel Using IoT for Monitoring Current and Voltage using ESP32

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Abstract

The development of solar power plant (SPP) technology presents an effective solution for providing electrical energy in remote or off-grid areas, particularly through the use of portable solar systems. This study discusses the design and implementation of a portable solar power generation system utilizing solar panels, a solar charge controller (SCC), a battery (accumulator), an inverter, and the integration of an ESP32 microcontroller with a PZEM-004T sensor module for real-time monitoring via the Blynk IoT platform. The system converts solar energy into electrical energy, stores it in a battery, and supplies it to AC loads through an inverter.

The test was conducted to evaluate the accuracy of voltage and current measurements using a multimeter as a standard. The voltage sensor showed a slight deviation from multimeter readings with error percentages ranging from -0.0013% to -0.0057%. The current measurements remained stable with a consistent error of -0.66%. These results indicate that the sensor modules provide reliable data for monitoring purposes, validating their application in portable and renewable energy systems. The integration of IoT-based monitoring enhances usability and system reliability, especially for outdoor or mobile applications such as camping or emergency backup power.

Keywords: Solar Power Plant, Portable Solar System, ESP32, PZEM-004T, IoT Monitoring.

1. Introduction

Solar energy is an unlimited energy source that will never run out, and it can also be used as an alternative energy source that can be converted into electrical energy using solar cells. Solar panels as an alternative source of electrical energy can be used by communities that need electrical energy but are constrained by the unavailability of electrical energy.[1]

Sunlight is heat energy produced by solar radiation, which can be used as renewable alternative energy for electricity needs if solar heat is available[2]. Photovoltaic solar energy is a technology used to harness solar energy into direct current using semiconductor devices commonly known as solar panels (solar cells).

Portable power generators are very easy and inexpensive to use, so they do not hinder productivity anywhere, and are often referred to as portable power generators. These solar cells are made from monocrystalline materials. They are the most efficient panels produced with the latest technology and generate the highest power per unit area[3].

The development of solar power plant (SPP) technology has become a highly effective solution for addressing the challenges of electricity supply during camping trips. Especially with the availability of portable solar panels, which make it easy for users to take them anywhere, particularly during camping trips.

2. Literature Review

2.1. Solar power plant

Solar power plants (PLTS) are devices that apply solar energy as renewable electrical energy, namely solar cell (photovoltaic) technology that is used to generate electrical energy[4]. This technology works by converting solar radiation into electricity through the photovoltaic effect that occurs in semiconductor materials within solar panels. Solar power plants are a sustainable alternative solution to meet energy needs, especially amid rising electricity consumption and limited availability of fossil fuels. The energy produced is clean, pollution-free, and does not produce carbon emissions, thus greatly supporting efforts to reduce the impact of climate change.

2.2. Accumulator

The use of batteries as an energy storage medium is expected to become a very important technology in the development of renewable energy. Accumulators are portable electrical energy storage components that can store electrical energy through chemical processes so that electrical energy can be used at other times[5]. This system is particularly useful for solar power plants, as it can store excess energy generated during the day for use at night or when weather conditions are unfavorable.

Additionally, the use of batteries enhances the reliability and continuity of energy supply, particularly in areas not connected to the main power grid. Modern batteries such as lithium-ion or VRLA (Valve Regulated Lead Acid) have high efficiency and a longer lifespan, making them suitable for use in long-term renewable energy systems.

2.3. Inverter

An inverter is an electronic device that converts direct current (DC) to alternating current (AC). The inverter is installed to convert the 12-volt DC voltage from the battery into a 220-volt AC voltage[6]. This process allows household electrical appliances that typically use AC current to continue operating even when their power source comes from a DC system such as solar panels or batteries.

Inverters play a crucial role in renewable energy systems, particularly in Solar Power Plants (SPP), as they connect the converted energy from solar panels to electrical loads or the national grid. Additionally, modern inverters are equipped with safety features such as protection against overcurrent, overvoltage, high temperature, and the ability to automatically shut down in the event of a system failure.

2.4. SCC (Solar Charge Controller)

SCC (Solar Charge Controller) is a device that regulates the flow of electricity from solar panels to batteries, with its main function being to prevent overcharging and overdischarging of batteries by regulating the voltage and current entering the battery. In other words, SCC helps extend the life of batteries and improve the overall efficiency of solar power systems.[7]

Additionally, the SCC acts as a safeguard against reverse current flow from the battery back to the solar panels, which can occur at night or when the panels are not generating voltage. If left unchecked, this reverse current can cause damage to the solar panels and waste energy from the battery. The SCC will automatically disconnect the connection if it detects an unfavorable condition.

2.5. Microcontroller ESP32

The ESP32 is a microcontroller introduced by Espressif Systems as the successor to the ESP8266 microcontroller. This microcontroller features an integrated WiFi module, making it highly suitable for developing Internet of Things (IoT) applications.[8]

In addition to the WiFi module, the ESP32 also features Bluetooth modules (BLE and Classic), enabling short-range wireless communication with various other devices. This microcontroller offers high performance thanks to its dual-core 32-bit Xtensa LX6 processor operating at up to 240 MHz, along with ample RAM and flash memory to run complex applications.

2.6. Pzem-004T

The PZEM-004T is a sensor that can be used to measure RMS voltage, RMS current, and active power, and can be connected via Arduino or other open-source platforms. The physical dimensions of the PZEM-004T board are 3.1×7.4 cm. The PZEM-004T module is bundled with a 3mm diameter current transformer coil that can be used to measure a maximum current of 100A.[9]

This sensor operates on the principle of indirect measurement using a current transformer (CT) to measure current and a voltage divider to measure voltage, making it safe to use without directly connecting high-voltage loads to the microcontroller. The PZEM-004T can also calculate active power (watts), energy (kWh), frequency, and power factor, which are highly beneficial for real-time monitoring of electrical loads.

2.7. IOT (Internet of Things)

IoT is an integrated system designed to continuously expand internet connectivity. This technology connects various devices or objects through the internet. The Internet of Things (IoT) is a technology that enables control, communication, and collaboration with various hardware devices.[10]

Devices connected within an IoT system are typically equipped with sensors, actuators, and wireless communication modules such as WiFi, Bluetooth, or LoRa, enabling these devices to automatically exchange data without direct human intervention. This technology is widely applied across various fields such as agriculture, industry, transportation, smart homes, and environmental monitoring systems.

2.8. Blynk

Blynk is a platform for mobile OS applications (iOS and Android) used to control Arduino, Raspberry Pi, ESP8266, and similar modules via an internet connection. Since its launch in 2014, this application has become widely used because it offers ease of use and provides users with the opportunity to create graphical user interfaces using the drag-and-drop widgets provided.[11]

Blynk enables users to quickly create custom user interfaces (UI) for Internet of Things (IoT) projects without having to develop mobile app code from scratch. With a variety of widgets such as buttons, sliders, graphs, terminals, and displays, users can monitor sensor data, control devices, and receive real-time notifications directly from their smartphones.

In addition, Blynk also provides Blynk.Cloud, a cloud service that acts as a bridge between mobile applications and hardware. This platform supports authentication via auth tokens, which maintain security and connectivity between devices. Blynk can also be used in local mode with Blynk Local Server for users who want to manage the system independently without relying on internet services.

3. System Design

3.1. Block Diagram

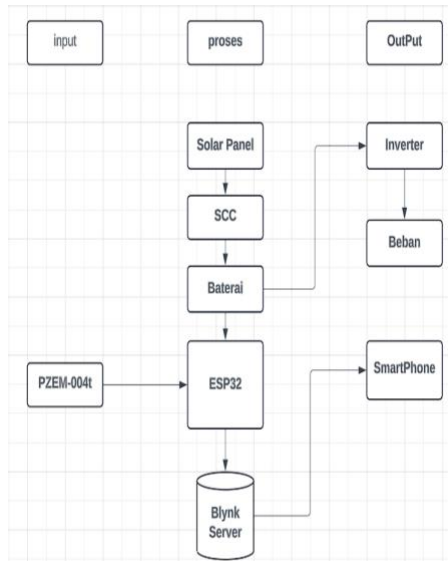


Fig. 1: Block diagram

A system block diagram aims to show the flow of each component used for implementation. A system block diagram has three main elements, namely input, process, and output.

Figure 1 illustrates the pzem-004t module as an input that functions to measure AC voltage and current. The data is then sent and processed by the ESP32 as a controller. After that, the ESP32 sends the data to the Blynk server, which is displayed on a PC or mobile phone.

The solar panel serves as the primary energy source for the system, which is then routed to the SCC (Solar Charge Controller) to prevent overcharging of the battery by regulating the voltage and current entering the battery. The battery then stores the energy. The inverter converts DC current into AC current, which is then used by AC loads such as lights.

3.2. Wiring

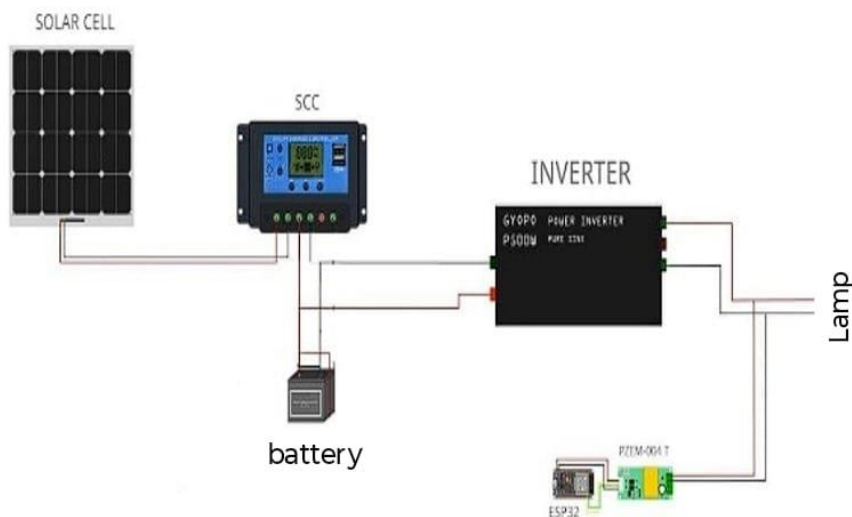


Fig. 2: Wiring

Electrical design serves as the initial planning for the design and wiring of electrical components, which functions as a guide for the circuit when in the field.

3.3. Flowchart

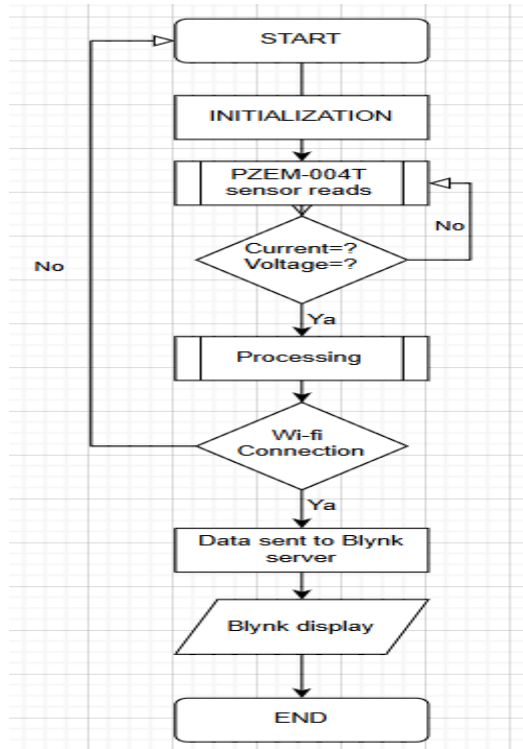


Fig. 3: Flowchart

4. Results and Discussion

4.1 Voltage and current test.

The voltage and current test aims to test how accurate the current and voltage sensors are table 1 below shows the voltage measurement testing using multimeter and pzem sensor.

Table 1: Voltage Testing

No	Time	Vm (V)	Vs (V)	Error (%)
1	14.00	227	227.3	-0,0013
2	14.05	226	227.2	-0,0053
3	14.10	226	227.3	-0,0057
4	14.15	226	227.2	-0,0053
5	14.20	226	227.3	-0,0057
6	14.25	226	227.3	-0,0057
7	14.30	226	227.2	-0,0053
8	14.35	226	227.1	-0,0048
9	14.40	226	227.1	-0,0048
10	14.45	226	227	-0,0044

Desc:

Vm : Multimeter Voltage (Volt)

Vs : Sensor Voltage (Volt)

Error : Presentase Error (%)

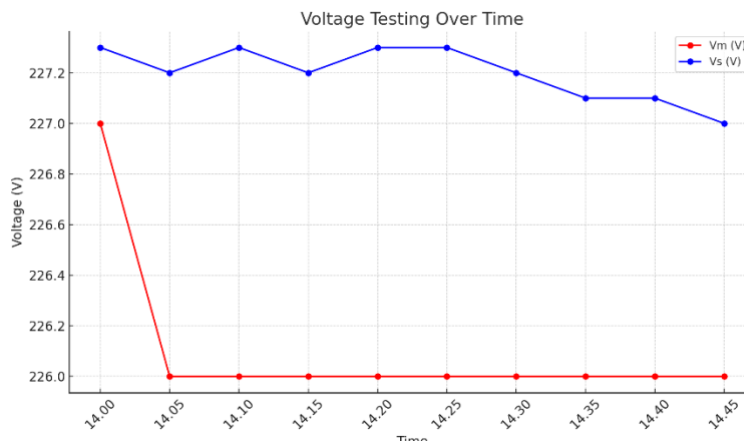


Fig. 4: Grafik Volatge

The purpose of this test was to compare the multimeter voltage and the sensor voltage. As shown in Figure 4, at 14:00, the multimeter voltage was 227 volts, and from 14:05 to 14:45, the voltage measured using the multimeter was stable at 226 volts. The voltage measured using the sensor at 2:00 PM was 227.2 volts, and by 2:45 PM, the voltage had dropped to 227 volts. The error was calculated using the following formula: $\% \text{ Error} = \frac{\text{Measurement data} - \text{Sensor data}}{\text{Measurement data}} \times 100$ Table 2 below shows the current measurement testing using amp meter and Pzem sensor:

Table 2: Current Testing

No	Time	Im (A)	Is (A)	Error (%)
1	14.00	0.03	0.05	-0.66
2	14.05	0.03	0.05	-0.66
3	14.10	0.03	0.05	-0.66
4	14.15	0.03	0.05	-0.66
5	14.20	0.03	0.05	-0.66
6	14.25	0.03	0.05	-0.66
7	14.30	0.03	0.05	-0.66
8	14.35	0.03	0.05	-0.66
9	14.40	0.03	0.05	-0.66
10	14.45	0.03	0.05	-0.66

Desc:

Im : Multimeter Current (A)

Is : Sensor Current (A)

Error : Presentase Error (%)

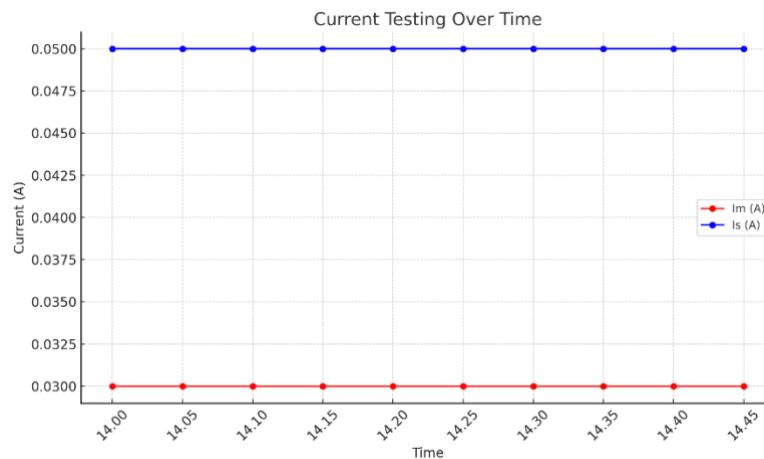


Fig. 5: Grafik Current

The current test at 14:00 using an ammeter showed a value of 0.03A, and at 14:45 the current was still at 0.03. A test using a current sensor was also conducted from 14:00 to 14:45, showing a stable value of 0.05A. The error value resulted in -0.66 using the formula $\% \text{ Error} = \frac{\text{Measurement data} - \text{Sensor data}}{\text{Measurement data}} \times 100$.

5. Conclusion

Based on the results of the voltage and current tests, it can be concluded that the system is functioning properly in measuring electrical parameters, although there are slight discrepancies between the sensor readings and multimeter values.

From the voltage test, it was observed that the sensor readings were slightly higher than the multimeter readings, with an error percentage ranging from -0.0013% to -0.0057%. These differences are very minimal and still fall within an acceptable margin of error, indicating that the voltage sensor provides reliable data for monitoring purposes.

In the current test, both the multimeter and sensor showed stable values throughout the measurement period. The multimeter consistently recorded 0.03 A, while the sensor measured 0.05 A, resulting in a constant error of -0.66%. Although this indicates a slightly higher reading from the sensor, the value remains consistent, which is useful for identifying trends and system performance.

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