Photovoltaic Power Plant Monitoring by Using Low-Cost Internet of Things (IoT): Design and Implementation

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Abstract. A study on the monitoring system of a photovoltaic (PV) power plant using low-cost Internet of Things (IoT) technology for monitoring electrical output (voltage and current) and environmental parameters (solar irradiance and cell temperature) to measure the performance of PV power plant has been realized. The prototype design of the monitoring system developed is the integration of several smart sensors, microcontrollers and algorithms that are able to read, send and process data in real-time. The monitoring system's implementation of IoT involves connecting sensors and devices from specialized systems to a public network using wired or wireless nodes. In general, IoT-based wireless systems are preferred to avoid the risks associated with wired systems. By continuing to focus on the requirements for the foreseeable future, when every gadget will be intelligent, autonomous, and connected to the internet.

1 Introduction

Energy is the ability to do work, one of the is electrical energy. Electrical energy is energy that comes from electric charges, the electrical energy that we commonly use is usually produced from power plants sourced from fossil fuels. With the development of the times and technology, of course the use of energy is also increasing, especially in electrical energy, this is one of the causes of energy demand continues to increase, With the increasing demand for energy, of course, it will be directly proportional to the consumption of fossil energy sources. According to the Minister of Energy and Mineral Resources quoted from an article made by the Public Relations of New Renewable Energy and Energy Conservation in 2020 "without the discovery of new energy reserves in Indonesia oil will run out in 9 years, natural gas will run out in 22 years, and coal will run out in 65 years". Based on these data, Indonesia is getting closer to an energy crisis. So that Indonesia needs a form of alternative energy that is more efficient according to Indonesia's natural potential.

Alternative energy that can be used is new renewable energy. Renewable energy is energy that comes from "sustainable natural processes" One of them is a photovoltaic

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power plants or what we know as solar power plants. A solar power plant is a power plant that converts solar radiation energy into electrical energy using solar cells or photovoltaic cells According to Ireneus Hasibuan in his paper, the solar panel is a semiconductor expanse that can absorb photons from sunlight and convert them into electricity or in simple terms, solar panels are solar cells or photovoltaic cells arranged into one module. According to (Dede Pramana et al., 2018) “at the equator the sun shines for 12 h every day with a high intensity of about 4.8 kWh/m^2”, thus making Indonesia a very strategic place for the utilization and construction of solar power plants. However, natural conditions are still very likely to affect the performance of solar power plants.

Even though the received sunlight has a large intensity every day, natural conditions are a factor that quite affects the performance of solar power plants. So it is very necessary to monitor. There are several conventional ways to monitor solar power plants, one of which is by conducting direct field monitoring every predetermined period of time. Of course, using this method has many drawbacks, some of which are costs and the second is data recording. Internet of things is a technology that utilizes internet connectivity that is connected continuously so that it is able to share data and control systems remotely. By utilizing this technology, a method can be developed that can reduce costs and record better data.

2 Methods

2.1 Research Location

The research was conducted at the Laboratory of Material Physics and Theory, Faculty of Mathematics and Natural Sciences, Mulawarman University, Barong Tongkok Street, Gunung Kelua, Samarinda Ulu District, Samarinda, East Kalimantan.

2.2 Research Procedures

2.2.1 Hardware Design

The experimental setup of the system hardware can be seen in Fig. 1.

The experimental prototype developed mainly consists of a PV panel, sensors and dual core ESP32 controller. In this experiment, the PV panel used has a maximum power specification of 60 W, an open circuit voltage of 22 V and a short circuit current of 3.9 A.

The NodeMCU ESP32 microcontroller, the ESP32 is a system on chip (SOC) microcontroller that supports low power and has integrated Wi-Fi and dual-mode Bluetooth. The excellent processing performance of this board was the deciding factor. The Tensilica 32-bit dual-core Xtensa CPU and LX6 Microcontroller are the foundation of the ESP32 board (Prastyo, 2019). One of its key features is that it can be coded using numerous opensource platforms and languages. In this work, code is created using the Arduino IDE and uploaded straight to the board.

The measurement sensor network in the presented application involves four average sensors that sense four physical signals: Current, Voltage, irradiation, and temperature.

a. ACS712 is a packaged IC which is useful as a current sensor replacing a current transformer which is relatively large in terms of size. In principle, ACS712 is the

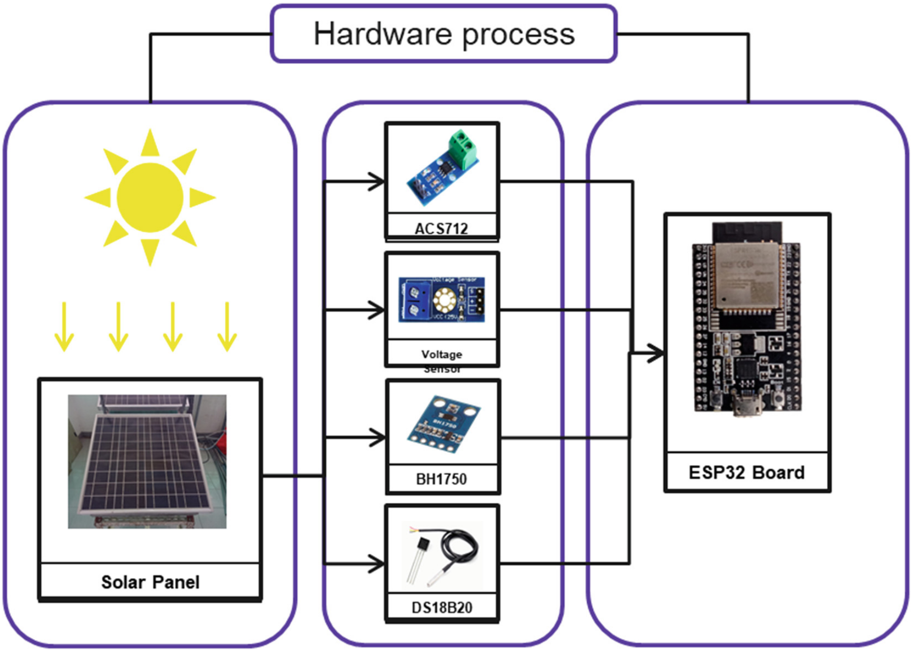

Fig. 1. The experimental setup of the system hardware.

same as other hall effect sensors, namely by utilizing the magnetic field around the current and then converting it to a linear voltage with changes in current. (Taif dkk., 2019)

b. The voltage sensor used is a voltage sensor module that uses the principle of a voltage divider. Voltage Divider is a simple circuit that converts a large voltage into a smaller voltage.
c. The BH1750 light sensor is a piece of electronic equipment that converts physical quantities—for example, light—into electrical values (Dwinata et al., 2019). This study made use of a BH1750 kind of light sensor. This sensor generates a sensor output value in the form of an intensity value in lux units based on the amount of light intensity it receives as input. The irradiance of the solar panel is measured in this study using a sensor that is a light sensor.
d. DS18B20 Temperature Sensor, DS18B20 temperature sensor serves to change the amount of heat captured into a voltage scale. The type of temperature sensor used in this system is IC DS18B20, this sensor has high precision. This sensor is very simple with only 3 feet. The first leg of the DS18B20 IC is connected to a power source, the second leg is an output and the second leg is connected to the ground (Akbar, 2017).

2.2.2 Software Design

Grafana is an open source platform for data monitoring, analysis, and visualization that also includes an internet server to enable access from anywhere. It is free software available under the Apache 2.02 license that enables users to sometimes build graphs and dashboards. It is also a crucial tool for raising awareness because of its cross platform impartiality. Grafana is particularly effective due to offers a full HTTP API. It enables the creation of dashboards and graphs using many repositories, including MySQL, Graphite, Influx DBs, and time collecting databases.

The records transmitted from the ESP32 controller is saved withinside the cloud; in our case set up domestically in "MySQL" database. "Grafana" gives a platform for researchers and engineers to obtain, examine and visualize beneficial statistics graphically. In addition, Grafana may be related to numerous neighborhood databases and net servers, and MySQL is certainly considered one among them. Moreover, it consists of a real-time dashboard and might percentage records thru public links. The records saved withinside the cloud may be used for similarly specific evaluation.

The method for connecting the gadget to the database (MySQL) and the Grafana cloud follows the subsequent steps:

- Connect to get right of entry to factor the usage of ssid and password thru your phone, tablet or non-public computer.
- Configure database with Grafana (Fig. 2)

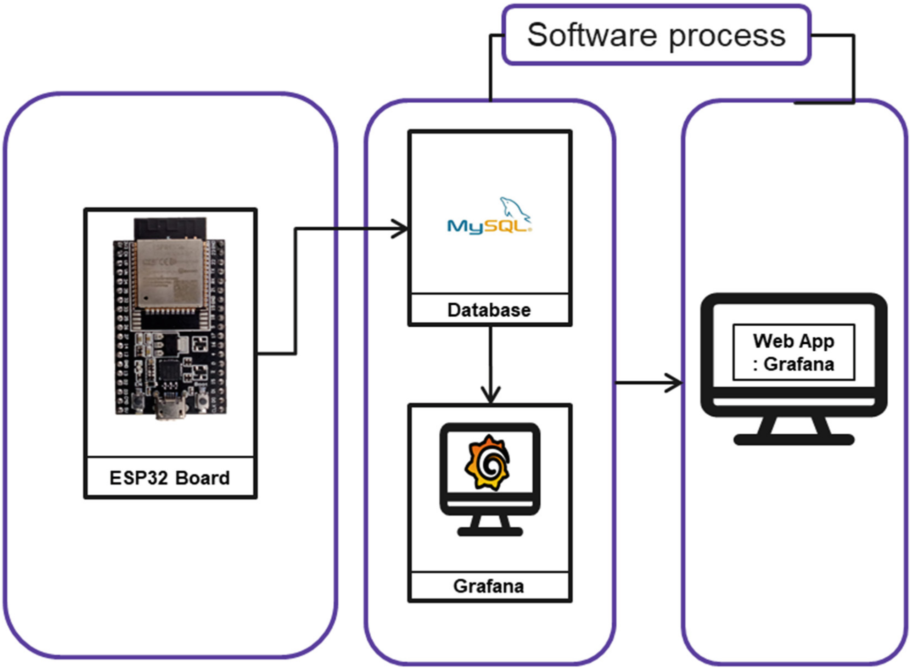

Fig. 2. The experimental setup of the system software.

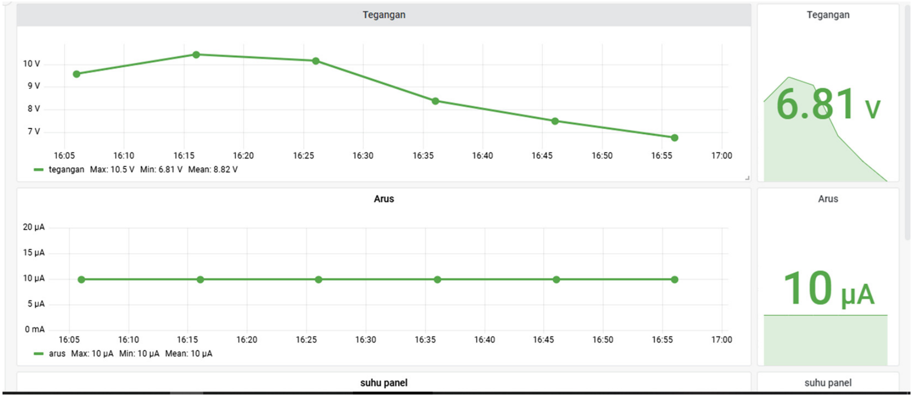

Fig. 3. A caption of the Solar panel Current and Voltage

3 Result and Discussion

3.1 Results

This ESP32 monitoring tool was used to detect current, voltage, temperature, and a solar power meter. It was wirelessly connected to the mySQL database and displayed using the Grafana platform. Electrical measurements, such as current and voltage, taken in real time and shown on the Grafana dashboard with precise time and date stamps are shown in Fig. 3. In order to maximize the amount of electricity generated by the panel, the system does not incorporate any MPPT algorithm. However, It does demonstrate the measuring station being watched in real-time.

A dashboard to illustrate and visualize the outcomes of data gathered in the database is shown in Fig. 4. This graphic displays temperature and sun power measurements along with precise time and date derived from sensing data. Figure 5 shows the application of the tool to solar panels as well as testing, for a joint note on this test the value that appears has not been calibrated, so the uncertainty value of the resulting measurement has not been traced.

3.2 Discussion

This article proposes a low-cost IoT system for collecting and monitoring real-time environmental and power data from solar power plants. The low cost of this solution is the result of careful selection of controls and equipment used. Two inexpensive sensors are used to measure changes in the environment. For temperature monitoring, utilize the DS18B20. The illuminometer and a calibrated pyranometer are used to generate precise data-driven estimates for the BH1170 light sensor, a lux meter, to measure solar radiation. This solution leads to lower overall system costs. For electrical parameters, the ACS712 sensor is for current sensors and the voltage divider for voltage sensors is generated by the PV panel.

ESP32 controller was selected to acquire, process and transmit the collected data in real time due to its high computing power, easy programming and low cost. In addition

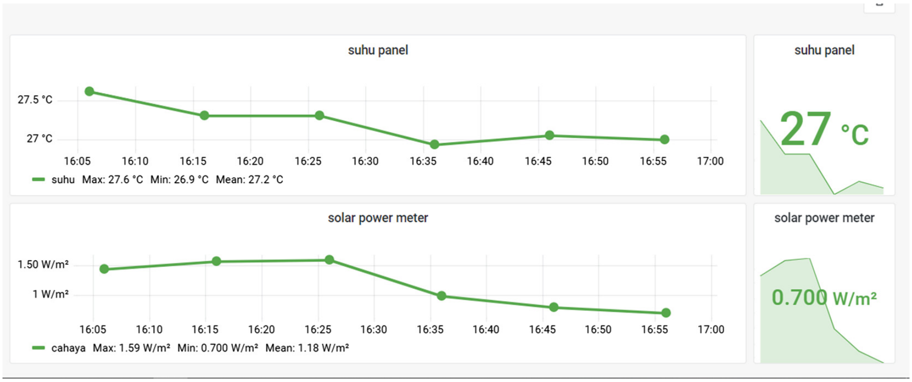

Fig. 4. A caption of the Solar panel Temperature and solar power meter

Fig. 5. Application of tools to solar panels

to high computing power, this controller has built-in WiFi technology, therefore your application does not need additional Ethernet or WiFi protection to ensure connectivity to the internet and data transfer to the cloud. The proposed system may update measurement data on the Grafana dashboard every second. On the other hand, due to the higher range of current/voltage needs in a sizable solar power plant, the necessary electrical sensors will be significantly more expensive and potent than those utilized in this prototype. However, there are many high performance current and voltage sensors on the market known for their accuracy and low power requirements. B. Hall effect current transformers (HCT0036) that can detect up to 500A, etc. Briefly stated, the suggested IoT application is intended to continually monitor the solar power plant, maintain it safely with high operating performance, monitor the station's weather, and control the impact in the event of a power loss. You can warn the user. The feature is a cost-effective method that works well for monitoring large solar farms with only minor modifications to the electrical sensors used.

4 Conclusion

This paper investigates the look at of equipment and strategies utilized in current sun electricity plant tracking structures. Furthermore, a low-fee shrewd IoT answer for tracking the electric and environmental parameters of photovoltaic structures is proposed. A laboratory prototype implementation became created to illustrate the overall performance of the advanced answer. Several clever sensors, latest controllers and algorithms for sun array tracking are defined on these paintings to offer real-time information to stakeholders. In addition, a low-fee oblique dimension approach is proposed to lower the charge of the measuring gadget. Indicators for anomaly detection at PV stations were included, improving the experimental check bench. Lastly, the proposed solution's cost-effectiveness is mostly determined by the utilization of low-cost facet sensing technology, free software, and processing time. This analysis is supported by a financial analysis of the suggested acquisition and tracking system.

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