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A study of IoT based real-time monitoring of photovoltaic power plant

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ABSTRACT

Global electricity demand has increased in the last few years. This need is growing all the time as energy consumption increases using conventional energy, which will soon be phased out. So, we had to look at alternative energies, namely renewable energies. The largest and most efficient of these is solar energy, and to make the most of this energy with the greatest efficiency, the performance of these solar panels needs to be directly monitored. This study presents an independent monitoring system based on the internet of things (IoT) to measure essential factors (terminal voltage, load current, energy consumption, humidity, temperature, and light intensity). These values are realistic and accurate, based on the sensors used to measure the aforementioned factors and then using the Node MCU ESP8266 to transmit the analyzed data to the circuit. The Thingspeak platform was then employed to display, analyze, and store these results in real time.

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1. INTRODUCTION

The pollution of the earth's environment through carbon dioxide (CO^2) emissions, the rise of fossil fuel costs, climatic warming, and an energy emergency due to the finite nature of fossil fuels make using sustainable sources of power an absolute necessity [1]–[3]. One of the renewable energy sources that is being extensively used to try, and surmount these problems is solar energy based on photovoltaic technologies [4]. Compared with conventional sources of energy, solar power is abundant and cost-free. Apart from this, by using advanced monitoring and regulation systems, photovoltaic technology based on solar energy could be one of the most reliable and efficient sources available for renewable sources of power [5], [6].

The monitoring of the system is essential to guarantee the proper functioning of the photovoltaic system [7], [8]. A controlling system is used to collect information and forward it to the monitoring center, enabling operators to evaluate and monitor systems to reduce the cost of maintenance, visualize system performances, and detect faults in the photovoltaic system [9]. There are many purposes for monitoring a photovoltaic system, such as supplying data on potential energy, detecting faults, extracting energy, and losing energy [6], [10]. Not only isit necessary to include a detailed description of the system benefits, but it's also necessary to find out more about the period during which a photovoltaic system can operate efficiently over a day and other problems that could affect power generation [11]. Such surveillance measures also apply as solar radiation levels are constantly changing, depending on location, the time of the day, and weather factors [12].

Any surveillance data may be utilized to guide preventive and corrective measures and to provide warning of changes in the ambient conditions [13]. One way of carrying out surveillance in real time is using internet of things (IoTs) technologies [14]. The IoTs designates a network consisting of hardware devices and software components [15], [16]. Using the IoT within the system is new for the research, in which the switch system could also allow humans to control more easily electrical energy use on the charge, recover electrical energy in the solar cell, and check equipment damage remotely. Recommend an IoTs monitored via the device, consisting of an alternate-energy visualization widget that allows automatic alternate-energy use from any place over the internet [17], [18].

The IoTs methodology enables electronic communication between humans and monitoring unit devices [19], [20]. According to [21], [22], for this research titled design of IoT-based smart meters for solar power plant applications, having an IoT server available can facilitate remote monitoring of photovoltaic panels via an internet connection. Further, the research by Al-Ali *et al.* [21] on smart-powered IoT solar energy states that a remote surveillance website provides a highly accessible system that can be supervised using a computer or cell phone, and that, in the future, this concept could be enhanced to support the operation system with no human intervention required [23], [24]. These authors performed research utilizing real-time IoT technologies, which are a method of research to control the monitoring of photovoltaic solar parameters at the laboratory level [25].

With IoT technologies and internet connections, this data transmission solution can provide both distance and speed. In this article, we develop IoT technologies to send data on parameters via solar modules and send them directly through the Thingspeak platform. This data, which is transmitted directly to a web server, can be further analyzed and processed for identification purposes. Subsequently, these data can provide experience in determining the photovoltaic characteristics used in a photovoltaic system in the everyday cycle and affected by meteorological conditions. In addition, the suggested system can identify the amount of potential energy generated by a solar energy system.

2. METHOD

As part of this approach, the system takes measurements of solar panel characteristics, such as current, voltage, power, temperature, humidity, and irradiance. Aboard (ESP8266) will be used for collecting and transmitting data via the Thingspeak platform. Table 1 summarizes the components included in this article. This system's IoT provides an output to monitor the parameters produced by the sensors and identify the data in real time. This data is collected and transferred via the Thingspeak platform. After that, this parameter data may be edited for subsequent analysis. Figure 1 shows the system's schematic diagram. Figure 2 shows the flowchart dedicated to the operation of the algorithmic program created using Arduino IDE software. First, we define the libraries corresponding to the various devices (sensors and the ESP8266 board), as well as the values of the constants and variables used by the algorithm.

Table 1. Components of research

Name components	Function
NodeMCU ESP8266	Principal controller
Sensor C11A063	Voltage sensor
ACS712 sensor	Current sensor
DHT22 sensor photo resistance	Temperature sensor light-dependent resistor sensor
ADS1115	16-bit ADC player
Solar panel	Power generator
CJMCU-219I2CINA21	Sensor module bidirectional power supply current monitoring

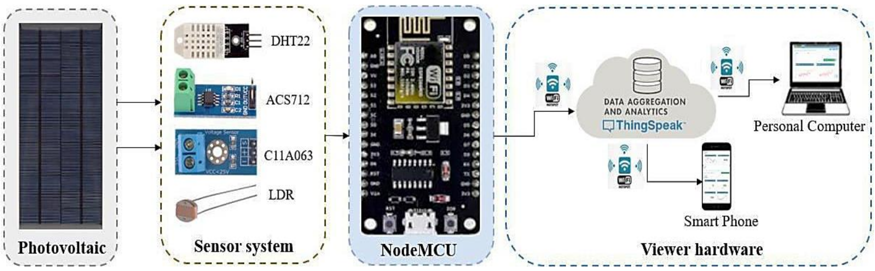


Figure 1. Configuration of photovoltaic system parameter measurement

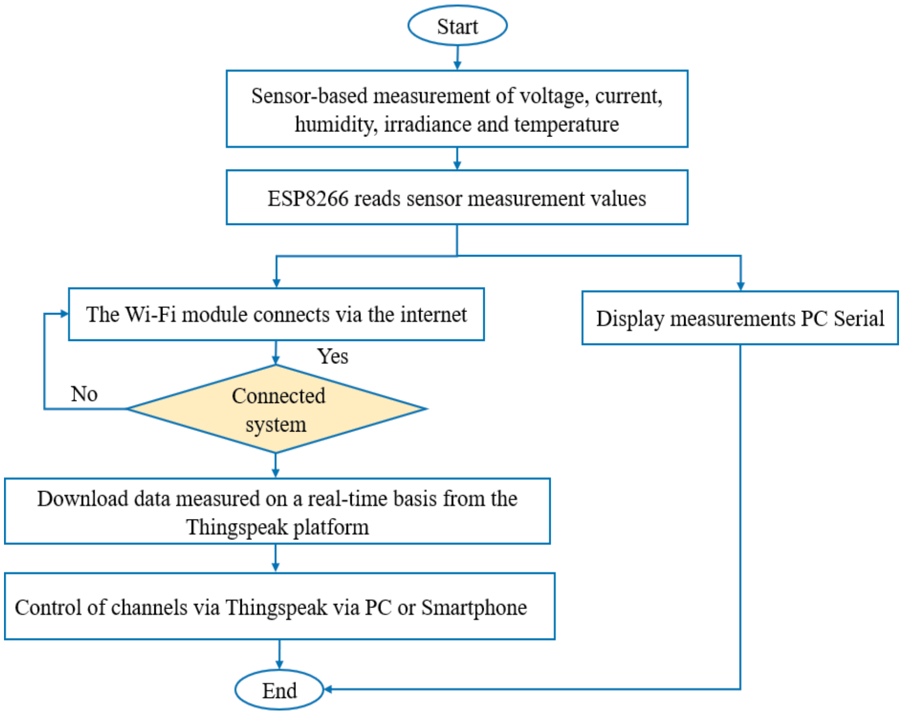


Figure 2. Proposed system flowchart

2.1. Photovoltaic

A photovoltaic module uses the light of the sun to produce up to 3 W of power. Its compact, eco-friendly design provides a flexible solution for a variety of renewable and energy-self-sufficient applications. Its effective construction enables it to power small appliances, grid-independent systems as well as portable consumer electronics, thus contributing to a more sustainable energy future through reduced dependence on traditional power supplies.

2.2. Sensor system

This device is used to measure important parameters of the photovoltaic system. A current sensor depends on the field effect. This sensor is used to measure alternating or direct current. It is equipped as standard with operational amplifier circuits to enhance the sensitivity of current sensing and measure extremely small changes in current. The voltage transducer is employed for measuring both AC and DC voltages. The operating principle of the voltage sensor module uses the principle of resistance suppression and can reduce the original voltage input by up to five times.

The sensor voltage uses a voltage divider circuit that converts a reference potential (V_{ref}) from the microcontroller. A voltage divider resistor on this sensor $(R_1$ and $R_2)$ is dependent on the amplitude in voltage input voltage mode. In this case, photovoltaic voltage (V_{pv}) can be measured. The voltage divider circuit equation is given by (1) [26].

$$V_{ref} = \frac{R_2}{R_1+R_2} V_{pv} \tag{1}$$

On the sensor side, the output current generated matches the sensor's oscillation. As a result, the signal converter requires a signal conditioning system that includes a subtractor and an inverter. A subtract or circuit utilizes an op-amp with a voltage output of (2). When the inverter is inverted, it uses an $u2$ op-amp with an output voltage of (3).

$$V_{u1} = \frac{R_3}{R_1+R_3} V_{R_1} - \frac{R_4}{R_1} V_i = (V_{RV_2} - V_i) \tag{2}$$

$$V_{u2} = -(\frac{R_{v2}}{R_5}) V_{u1} \tag{3}$$

In this article, a DHT22 sensor module is utilized to detect the temperature and humidity of objects, providing a voltage analog output that can be subsequently evaluated using a microcontroller. A light-dependent resistance (LDR) sensor is employed as the light detector. It detects the luminosity and intensity of the ambient sunlight.

2.3. NodeMCU

To operate an IoT device, a microcontroller is needed on the Wi-Fi module. The microcontroller transmits data to the Wi-Fi connection of a predefined sacrificial network server. Node MCU represents a board development that combines both the practical functionality of each input/output port and that of a microcontroller connection board. This depends on the Wi-Fi module. The microcontroller is capable of performing all the calculations that require all the computations, but it also provides the necessary communications to the Wi-Fi.

2.4. Viewer hardware

The principal viewer in this article is a web server. The web server works as a receiver of browser messages and answers the request as a web page. This article discusses a web server powered by the ThingSpeak IoT platform and application programming interface (API), which facilitates real-time data storage from monitored sensors. It's a backup solution for your data in the event of a problem on your internet connection.

3. RESULTS AND DISCUSSION

Figure 3 shows the electrical connection of the prototype, comprising a solar panel and several sensors: a voltage divider to measure voltage, an LDR sensor for light, an ACS712 current sensor, and a DHT22 sensor for humidity and temperature. Measured data is sent via the ESP8266 Wi-Fi module for remote system monitoring. This allows for real-time performance and environmental monitoring.

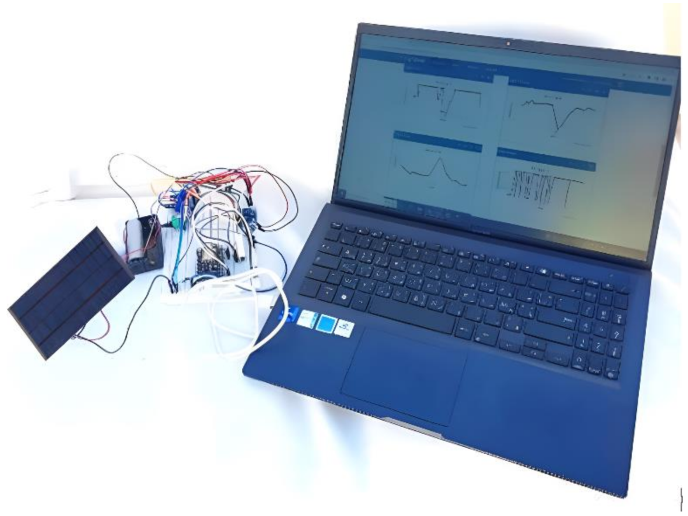
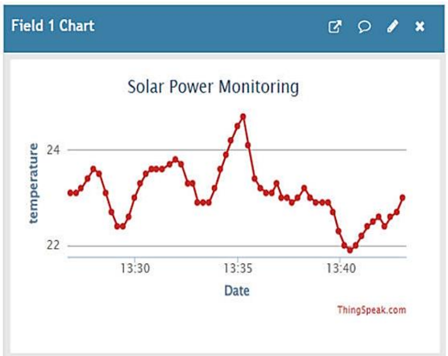


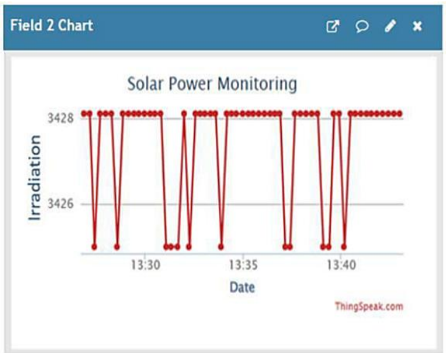
Figure 3. Practical diagram of the proposed system

Photovoltaic system measuring results components shown in graphic representation using a Thingspeak platform are presented in Figures 4 and 5. The more frequently used variables in the optimization algorithm for photovoltaic system parameters were the temperature, the irradiance, and the humidity. Figures 4(a) to (c) illustrate the various parameters for temperature, irradiance, and humidity for the period from 13:20 to 13:43 (GMT). That is due to environmental factors like clouds, buildings, and trees blocking the view.

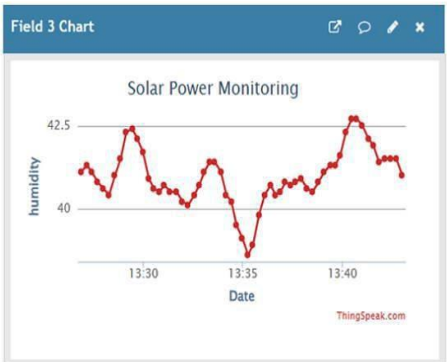
The fluctuations observed in the temperature, irradiance, and humidity variables will cause a modification in the photovoltaic power generation value. As illustrated by Figures 5(a) and (b), photovoltaic production appears as a changing voltage and current. This is due to temperature and irradiance influencing the photovoltaic voltage and current values. Consequently, the variable photovoltaic power generation represented in Figure 5(c) is variable.



(a)

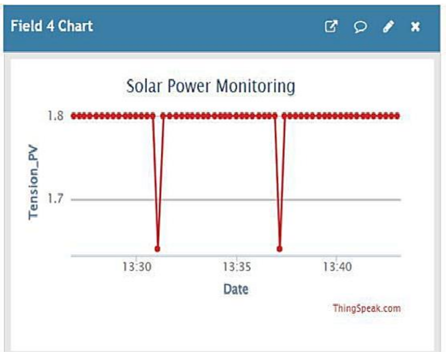


(b)

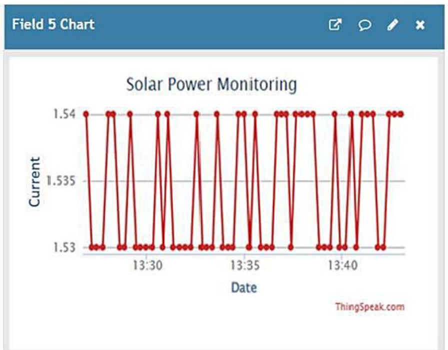


(c)

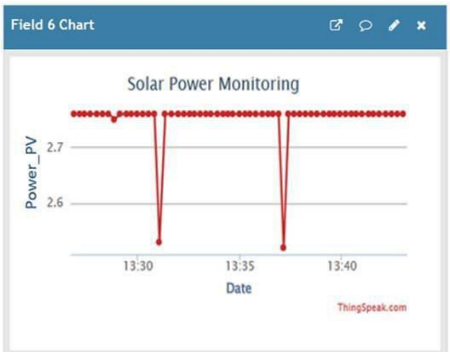
Figure 4. Results of (a) temperature, (b) irradiance, and (c) humidity measurements via the thingspeak



(a)



(b)



(c)

Figure 5. Results of (a) voltage, (b) current, and (c) power photovoltaic

Thingspeak software can assist operators in prevention and maintenance activities while supplying alerts to enable early warning and evaluation of any changes in the environmental situation. As well as providing an interactive display of data, the Thingspeak-based surveillance systems employed in this study provide an open-source, low-cost platform. The objective will be to decrease dependence on high-cost proprietary hardware, licensed software packages, and cloud solutions. Based on the results of the tests, our system can be used in a wider system for more simple, real-time, open-source control of the parameters of a solar power system.

4. CONCLUSION

In this study, the parameters of an integrated photovoltaic system based on an IoT system were measured for the community. This IoT system is based on a platform called Thingspeak, which can be accessed rapidly for both real-time analyses and general applications. The developed system includes the Node MCU ESP8266 for the microcontroller, ACS712 for current measurement, C11A063 to measure output photovoltaic voltage, the LDR sensor to measure irradiance incident at photovoltaic panels, and DHT22 to measure environmental temperature and humidity. An ADS1115 is used as the 16-bit ADC drive with a photovoltaic bloc. Overall, this system successfully measures photovoltaic system parameters in various weather situations and correctly transmits data using the Thingspeak platform.

We can use this study as a model for training photovoltaic systems. A further development application is energy load management for solar photovoltaic power plants to maximize energy use and conserve energy for the consumer. The management systems track photovoltaic energy generation facing global warming.

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