Intelligent Solar Power Monitoring System Using IoT and Tracking Mechanism

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Abstract
With the increasing demand for power, frequent power failures have become a common issue. This paper aims to address this problem by providing a solution to power loss. It utilizes components such as an LDR, amplifier, ADC, microcontroller, driver circuit, along with a motor and limit switches. The solar panel, made up of multiple silicon cells, generates voltage signals when sunlight falls on it. These signals are then passed to a conversion circuit. The amount of voltage generated depends on the size of the panel. Since the sun's position changes throughout the day, to maximize efficiency, the solar panel must adjust its position accordingly. Solar power plants need continuous monitoring to ensure optimal power output. This is essential for identifying faulty panels, poor connections, dust accumulation, and other factors that reduce performance. The paper also features an automated, Internet of Things (IoT) based solar power monitoring system, enabling remote monitoring of solar power from anywhere over the internet. Using an Arduino-based system, it monitors a 5-watt solar panel and transmits power output data to the IoT system for real-time tracking.

Keywords: IoT, Microcontroller, Solar Power Monitoring, Arduino.

1. Introduction

The Internet of Things (IoT) plays a significant and vital role in daily life by connecting a wide range of physical devices through the internet, allowing them to exchange data for monitoring and controlling these devices remotely. This connectivity makes devices smarter and more efficient. IoT data collection involves using sensors to monitor the conditions of physical objects. Devices connected through the IoT can track and measure data in real time, with the information being transmitted, stored, and accessible at any time.

Sunlight consists of two components: direct beam radiation, which accounts for about 90% of solar energy, and diffuse sunlight, which makes up the remainder. The diffuse portion is the blue sky on clear days and is a larger part of total sunlight on cloudy days. Since the majority of the energy is contained in the direct beam, optimizing energy collection requires the solar panels to be positioned to face the sun as much as possible. The energy from the direct beam decreases as the angle between the incoming light and the panel increases, following a cosine curve.

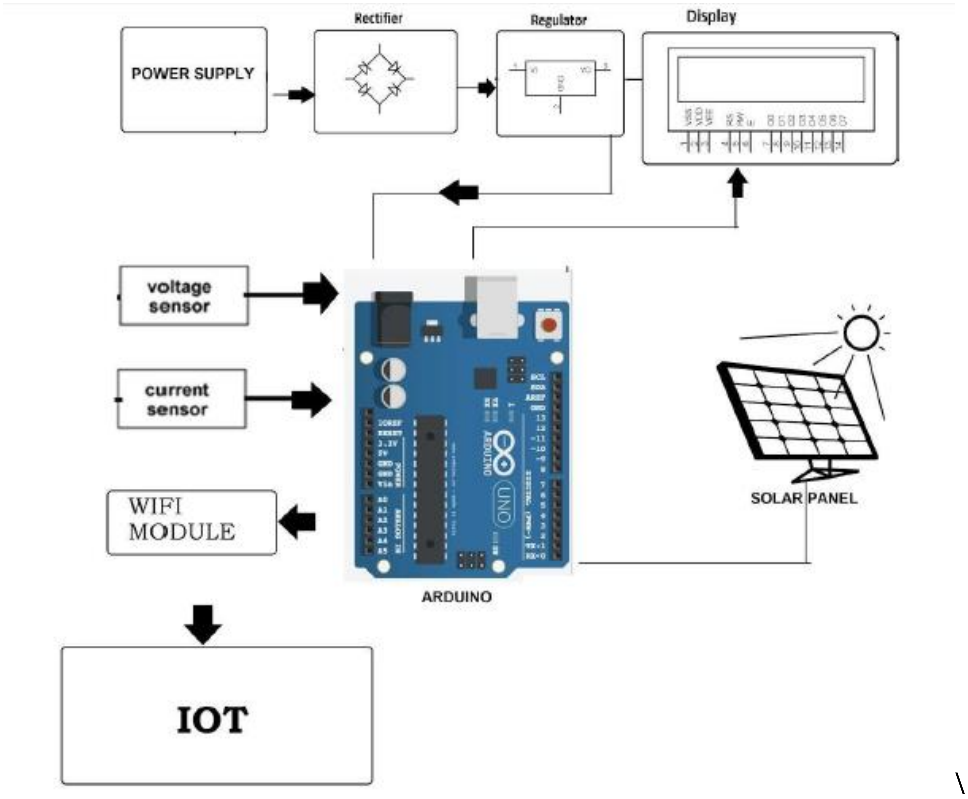

Figure 1: Proposed Block Diagram

2. Literature Review

The Internet of Things (IoT) is one of the most important technologies of everyday life, which helps users to lead a smarter life, and the IoT plays a significant role in this transformation. IoT refers to devices that enable the connection between machines and the cloud [9]. This technology facilitates data exchange between connected devices over a network [7]. Through the internet, users can access data and control devices from anywhere in the world [8], [10]. IoT is an ecosystem consisting of web-enabled devices that use processors, sensors, and communication hardware to collect and transmit data. It allows for machine-to-machine or device-to-device communication without the need for human intervention. Additionally, it leverages computing resources and software systems for information processing. The integration of IoT technology in solar power monitoring systems is essential because solar radiation is not constant and varies with location, time, and weather conditions. Therefore, solar panels, which are constantly exposed to the sun, must be continuously monitored. IoT technology enables remote monitoring of solar panels from any location [1], [6].

In today's world, electricity is a fundamental necessity for daily life. It is required for heating, lighting, refrigeration, transportation systems, and all home appliances [2], [12]. Energy consumption is increasing rapidly, while energy resources are depleting at a similar rate. To address the shortage of electricity, various sources are used for its generation. These sources can be classified into two categories: renewable and non-renewable. Non-renewable sources include coal, natural gas, and fossil fuels, while renewable sources can be replenished and used repeatedly sources such as solar, wind, and tidal energy [3], [5], [11] are considered renewable, making solar power an inexhaustible energy source. To address the challenges of electricity scarcity, an IoT-based solar power monitoring system is being proposed.

Solar power has gained significant popularity due to its abundance and the affordability of solar energy conversion technologies. The process of converting light energy into electrical energy is known as the photovoltaic effect, and this is what powers solar energy. Using solar power helps reduce pollution, and by monitoring it, energy forecasting and productivity in households and communities can be improved [4], [2]. Monitoring the system also allows us to check its status and quickly identify any issues, which is highly beneficial.

3. Problem Definition

This approach addresses the challenges that arise when faults occur in a solar energy system, which impact its output and reduce its efficiency. Identifying the source of errors is often difficult, making it necessary to monitor and properly maintain the solar power system. The paper also tackles the issue of the varying angle of sunlight throughout the day, which can prevent the system from harnessing maximum solar energy. This highlights the need to control the solar panel's position, adjusting it to face the direction of optimal sunlight in order to achieve maximum output.

4. Objectives

1. To monitor the power generated by a solar panel by measuring the current and voltage values obtained from sensors.
2. To track environmental factors, such as temperature, that influence energy production.
3. To track the direction of solar radiation.
4. To adjust the angle of the solar panel based on the direction of solar radiation using LDR sensors and a motor.
5. To enable real-time monitoring of all collected data via a mobile application using IoT.
6. To enhance the overall efficiency of the solar energy system.

5. Proposed System

The proposed system outlines an IoT-based solar power monitoring system. In this system, sunlight is converted into electricity by solar cells embedded in solar panels. The system utilizes an Arduino, with sensors to measure current and voltage parameters. These values are displayed on an LCD screen. Additionally, an IoT device is connected to the sensors, enabling remote monitoring of these parameters from anywhere using the available network.

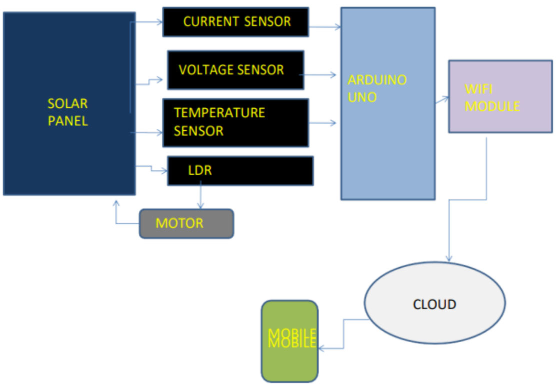

Figure 2: Proposed Data Flow Process

6. Methodology

Solar Panel

Solar energy refers to the electricity generated by capturing sunlight, which can be used for both business and home purposes. The sun acts as a natural nuclear reactor, releasing energy in tiny packets called photons. When photons strike the solar cells, they cause atoms to lose electrons. A solar panel is made up of multiple interconnected cells, and the more panels there are, the more electricity is produced. Solar panels generate Direct Current (DC) electricity.

Current Sensor

The ACS712 current sensor is a device used to measure the amount of current flowing through a wire. It operates based on the Hall Effect and is a linear sensor capable of detecting both AC and DC currents.

Light Dependent Resistor (LDR)

An LDR, or light-dependent resistor, is a component that operates based on the principle of photoconductivity. When light or photons strike the semiconductor material of the resistor, the electrons in the valence band become excited. As a result, the resistance of the LDR decreases when exposed to light and increases in darkness, which is referred to as dark resistance.

LDR Sensor Module

The LDR sensor module is an affordable sensor that functions as both a digital and analog sensor, capable of measuring and detecting light intensity. Also known as the Photoresistor sensor, it features an onboard Light Dependent Resistor (LDR) that enables it to detect light. The module has four terminals, where the "DO" pin is for digital output and the "AO" pin is for analog output. The module's output goes high in the absence of light and low when light is present. The sensitivity of the sensor can be adjusted using the onboard potentiometer.

Arduino UNO

The Arduino Uno is a microcontroller board based on the ATmega328P. It is an open-source electronics platform that features easy-to-use hardware and software. Arduino boards can read inputs and convert them into outputs. It includes 14 digital input/output pins (6 of which can be used for PWM output), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button.

LCD Display

A Liquid Crystal Display (LCD) is a flat-panel display that uses the light-modulating properties of liquid crystals combined with polarizers. It is used to present information or data, which is received from the Arduino for display.

Motor

A simple DC motor consists of a stator, an armature, a rotor, and a commutator with brushes. The interaction between the opposite magnetic fields inside the motor causes it to rotate. In this system, the motor is used to rotate the solar panel.

Limit Switch

A mechanical limit switch is used to link mechanical motion or position with an electrical circuit. When choosing a limit switch, the contact arrangement is an important factor. The most common type is a single-pole contact block with one normally open (NO) and one normally closed (NC) set of contacts. However, limit switches can come with up to four poles. Some limit switches also feature time-delayed contact transfer, which is useful for detecting jams that cause the switch to remain engaged for a predetermined period.

Thermistor

A thermistor is a temperature-sensitive resistor whose resistance changes with temperature. As the temperature increases, the resistance increases, and as the temperature decreases, the resistance decreases. The NTC 103 thermistor is a 5mm epoxy-coated disc with an operating temperature range of -20°C to +125°C.

WIFI Module

The ESP8266 is an affordable, Arduino-compatible Wi-Fi module with full TCP/IP capabilities. A standout feature of this small board is the integrated Microcontroller Unit (MCU), allowing control of I/O digital pins through simple, almost pseudo-code-like programming.

Spur Gear Arrangement:

Spur gears are the simplest form of gears, consisting of a cylinder or disk with teeth extending radially. While the teeth aren't straight-sided, the edge of each tooth is straight and aligned parallel to the axis of rotation. These gears mesh properly only when mounted on parallel shafts, and they don't generate axial thrust due to the tooth loads. Spur gears perform well at moderate speeds but can be noisy at higher speeds.

Driver Circuit

The L298N Motor Driver Module is a high-power driver module used to control DC and stepper motors. It includes an L298 motor driver IC and a 78M05 5V regulator. The L298N module can control up to 4 DC motors or 2 DC motors with both directional and speed control.

Mobile Application

Blynk is an open-source, hardware-agnostic IoT platform that offers white-label mobile apps, private cloud services, device management, data analytics, and machine learning capabilities.

Solar Power Monitoring System Using IoT

1. A 12V solar panel is connected to an ACS712 current sensor, which measures the current generated by the solar panel.
2. The current sensor is linked to the Arduino UNO, which reads the data from the sensor.
3. The voltage from the solar panel is measured by the Arduino using a voltage divider circuit.
4. An NTC 103 thermistor is connected to the Arduino to monitor the temperature.
5. The Arduino is interfaced with an LCD display.
6. Using the current and voltage values, the Arduino calculates the power output.
7. The current, voltage, power, and temperature values are displayed on the LCD.
8. At the same time, these values are uploaded to the cloud via a Wi-Fi module (ESP8266) connected to the Arduino.
9. The data from the cloud is then shown in the Blynk mobile application.

Solar Tracking System

1. Two LDR sensor modules are mounted on either side of the solar panels.
2. The analog output signals from both LDR modules are connected to the analog inputs of the Arduino.
3. The Arduino compares the signals from both modules.
4. These signals change based on the amount of sunlight.
5. The Arduino then activates the driver circuit to rotate the motor.
6. The motor is connected to the solar panel via a spur gear mechanism.
7. This setup allows the solar panel to adjust its orientation according to the sun's position.

8. As a result, the solar panel's direction is optimized for maximum efficiency, allowing it to generate more power by following the sun.

7. Results

The "IoT-Based Solar Panel Monitoring System Using Arduino & ESP8266" was successfully implemented to monitor the performance and condition of a solar panel system. The system utilizes a range of sensors and components, including a current sensor (ACS712), LDR sensor module, thermistor, and an LCD display to monitor the solar panel's output, light intensity, temperature, and other key parameters. The system is also capable of transmitting the collected data to a cloud platform for remote monitoring via the Blynk mobile application.

- **Current Sensor (ACS712):** The current generated by the solar panel was accurately measured and transmitted to the Arduino for processing. The ACS712 provided real-time data on the current, which was then used to calculate the power output of the solar panel.
- **LDR Sensor Module:** The LDR sensor module detected changes in light intensity, helping the system track the sunlight exposure and adjust the solar panel's orientation accordingly. The LDR also played a key role in determining the efficiency of the panel, as the output is influenced by the sunlight intensity.
- **Thermistor (NTC 103):** The thermistor continuously monitored the temperature of the solar panel, ensuring that it operates within a safe temperature range. This data was also displayed on the LCD and uploaded to the cloud.
- **LCD Display:** All the monitored parameters, including current, voltage, power, and temperature, were displayed on the LCD for immediate viewing. This allowed for local real-time monitoring without needing a connected device.
- **Wi-Fi Module (ESP8266):** The ESP8266 Wi-Fi module enabled seamless data transfer from the Arduino to the cloud. It facilitated remote monitoring of the solar panel's performance through the Blynk mobile application, making the system easily accessible from anywhere with an internet connection.

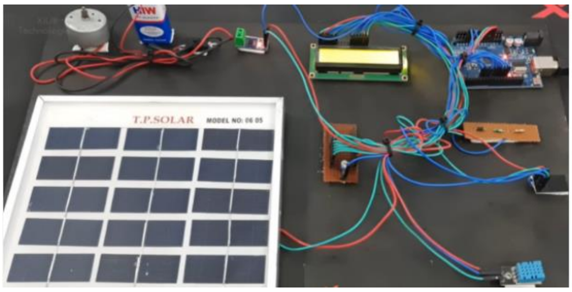

Figure 3: Proposed Model

8. Conclusion

The system has been successfully designed and tested. Current, voltage, power, and temperature values are monitored via an LCD display and the Blynk mobile application. The solar panel adjusts to the side with higher solar radiation using a motor. The system continuously tracks the solar panel, making daily, weekly, and monthly analysis both easier and more efficient. This analysis also helps detect any faults in the power plant, as inconsistencies in the generated power data may indicate issues. The system enhances the power plant’s efficiency through solar tracking.

The IoT-based Solar Panel Monitoring System using Arduino and ESP8266 successfully demonstrated the integration of hardware and software for efficient solar panel monitoring. By using a combination of sensors and communication modules, the system was able to monitor key parameters such as current, voltage, temperature, and light intensity. The data was processed and displayed locally through the LCD and remotely through the Blynk mobile application.

This system offers several advantages, including:

- **Real-time monitoring:** Immediate access to solar panel performance data for users to take necessary actions if required.
- **Remote accessibility:** Data can be accessed remotely through the Blynk mobile application, making it more convenient for users to monitor their solar systems from anywhere.
- **Energy efficiency:** By tracking parameters such as sunlight intensity and temperature, the system helps optimize the solar panel's performance, ensuring better energy generation.

9. Future Work

A web application can be developed for user interaction, allowing users to predict future events. In the future, features for controlling the solar panel's voltage, current, and power could be added to the system. Based on the customer's consumption, once the maximum power consumption is reached, the control unit will generate a signal, triggering the necessary actions. Additionally, the system could be improved by implementing time-based control to disconnect the load when needed.

Future improvements could include integrating additional sensors for more detailed environmental monitoring, enhancing the mobile app interface, and adding a battery backup to ensure continuous operation even in the event of power failure. This paper serves as a solid foundation for creating more advanced solar monitoring systems and could be expanded to support multiple solar panel arrays, further optimizing solar energy production.

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