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Review Article

Iot Based Real Time Monitoring of Solar Power Plant

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I N F O

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A B S T R A C T

The Internet of Things is used in solar power generation to improve the functioning, monitoring, performance, and maintenance of solar power plants. The method is to monitor the dust in the solar panel to achieve maximum power. Using IoT technology, it monitors solar panel loads using data for remote users. The application can obtain data on current and past average matrices such as voltage, temperature, and current. The cost of renewable energy equipment is reducing globally due to technological advances, which are promoting solar plant installations on a large scale. The discussion in this paper focuses on a cost-effective solar power plant monitoring approach based on IoT. It also monitors voltage and current intensity and dust. In addition to tracking, it identifies faults and provides historical analysis of the area.

Keywords: PV, IOT, Thing Speak, Proteus, Solar Power Plant

Introduction

Solar power plant monitoring needs to achieve optimum generation power. When monitoring for connections, this efficient output power plant affects solar performance by minimizing the production monitoring system when dust or any other impurities accumulate in the solar panels, which allows solar monitoring on the cloud.[1] Check if there is a problem with the solar panel connection by reducing the output to be a problem with the solar panel. Controllers are used to monitor parameters in the solar panel. They track the output of the solar panel and send to IoT. Solar power parameters transmitted by Thing spec in the Think Pack app. The global shift towards sustainable energy sources has propelled the prominence of solar power generation, emphasizing the need for efficient monitoring and optimization. In this context, the integration of the Internet of Things (IoT) into solar power plants has emerged as a transformative solution.[2] This paper delves into the intricacies of an IoT-based real-time monitoring system for solar power plants, with a primary focus on enhancing functionality, performance, and maintenance. The fundamental objective is to overcome challenges posed by dust accumulation on solar panels, a factor that directly impacts the plant's overall efficiency.

As technological advances continue to drive down the costs of renewable energy equipment, solar power installations are witnessing unprecedented growth on a global scale. Leveraging these advancements, this paper explores a cost-effective approach to monitoring solar power plants through the lens of IoT. The proposed system not only tracks essential parameters such as voltage, temperature, and current intensity but also introduces a proactive strategy for dust detection and cleaning.[3] The integration of IoT technology facilitates remote monitoring, enabling data access for users situated at a distance.[4] Keywords such as PV (Photovoltaic), IoT, Thing Speak, Proteus, and Solar Power Plant encapsulate the core elements of this exploration. PV technology, vital for small to medium-sized solar applications, takes center stage in the discussion. The use of inverters, Arduino microcontrollers, and sensors becomes integral to the monitoring process, ensuring precise measurement of critical factors like temperature, wind speed, and solar radiation.[5] In essence, this paper seeks to unravel the intricate web of IoT applications in solar power plants. The discussion extends to the implementation of light-dependent resistors (LDRs) to control light input, Arduino-based systems for current and voltage monitoring, and dust sensors triggering automated cleaning mechanisms. A detailed simulation of the proposed system underscores its efficacy in mitigating power loss due to dust particles, emphasizing a self-sustainable model with rechargeable batteries directly fueled by solar panels.[6] The comprehensive exploration of the IoT-based solar power monitoring system presented here encompasses not only real-time data storage but also fault detection and historical analysis, paving the way for informed decision-making. As the paper concludes, it hints at future prospects, teasing the integration of reinforcement learning algorithms to forecast wind energy, thermal energy, and power generation. The plethora of references cited adds scholarly depth, grounding the discussion in a rich tapestry of prior research and insights. The journey through this paper unfolds the transformative potential of IoT in optimizing solar power plants for a sustainable and energy-efficient future.

Solar Power Plant

The solar power plant converts the sun's energy into electricity, either directly or indirectly, using photovoltaic (PV) or concentrated renewable energy (CSP). We use focused solar power systems with lenses, mirrors, and monitoring systems to focus a wide area of sunlight. Solar cells convert electricity into light using optical effects. The 354 MW Solar Energy Generating System (SEGS) CSP was the world's largest photovoltaic power plant in the Mojave Desert, California. A solar thermal plant generates heat and electricity from the concentration of the sun's heat energy.[7] It consumes 240 kWh of electricity per day, so 100 solar panels required to generate electricity per day. Solar power plants serve as vital installations in the renewable energy landscape, harnessing the inexhaustible energy from the sun to generate electricity. The primary objective of these plants is to convert solar radiation into electrical power through various technologies, each tailored to specific environmental conditions and energy requirements.[8] Photovoltaic (PV) technology represents one of the most widely adopted methods in solar power generation. PV cells, commonly known as solar cells, directly convert sunlight into electricity using semiconductor materials. The operation of PV cells involves absorbing photons from sunlight, facilitating the movement of charge carriers, and extracting electrical current for external use. These cells can be integrated into solar panels and arrays, forming the foundation of solar power generation systems.

Concentrated Solar Power (CSP) is another significant technology employed in solar power plants. Unlike PV cells, CSP systems use mirrors or lenses to focus sunlight onto a small area, generating intense heat. This concentrated solar energy is then utilized to produce steam that drives turbines connected to generators, ultimately producing electricity. CSP is particularly effective in large-scale power plants and can incorporate thermal storage systems to provide electricity even during periods without direct sunlight.[9] The 354 MW Solar Energy Generating System (SEGS) CSP plant, located in the Mojave Desert, California, stands out as one of the largest photovoltaic power plants globally. SEGS serves as a testament to the scalability and efficiency of solar power technology, contributing significantly to the clean energy landscape.[10] In addition to traditional solar power technologies, advancements in solar thermal plants have expanded the capabilities of solar power generation. These plants focus on harnessing the sun's heat energy to produce both electricity and heat for various applications. The integration of lenses, mirrors, and sophisticated monitoring systems allows solar thermal plants to concentrate sunlight over a wide area, optimizing energy production.

Solar power plants play a pivotal role in the global shift toward sustainable and renewable energy sources. The environmental benefits, including reduced greenhouse gas emissions and a lower carbon footprint, make solar power an attractive alternative to conventional fossil fuel-based energy generation. As technology continues to advance, solar power plants are becoming more cost-effective, making them increasingly accessible for widespread adoption.

In the context of the discussed IoT-based real-time monitoring system, the efficient functioning of solar power plants becomes even more critical. The integration of IoT devices enhances the monitoring, performance, and maintenance aspects of these plants, ensuring optimal power output, fault detection, and historical analysis. This synergy of solar power technology and IoT advancements reflects a promising future for clean and sustainable energy generation.

PV Cell

For small to medium-sized applications, photovoltaics is used as a source of electricity. A solar cell is an electrical system that converts light energy directly into electricity. The operation requires absorption spectra, the separation of charge carriers of opposite forms, and the extraction of those carriers for external vessels. Photovoltaic (PV) cells, also commonly known as solar cells, serve as the heart of solar power generation systems. These cells are fundamental in converting sunlight directly into electrical energy through the photovoltaic effect. The operation of PV cells involves a sophisticated interplay of materials and physical processes aimed at harnessing the sun's energy efficiently.

- **Working Principle:** PV cells operate based on the photovoltaic effect, a phenomenon in which certain materials generate an electric current when exposed to sunlight. The core of a PV cell typically consists of semiconductor materials, often made of crystalline silicon. When photons from sunlight strike these semiconductors, they impart energy to electrons, allowing them to move within the material.

- **Absorption Spectra and Charge Carrier Separation:** The efficiency of a PV cell is closely tied to its ability to absorb a broad spectrum of sunlight. Different materials exhibit unique absorption spectra, influencing the range of light they can convert into electricity. Once photons are absorbed, they create electron-hole pairs within the semiconductor material through a process known as charge carrier separation.
- **Electricity Generation:** The separated charge carriers (electrons and holes) create an electric potential, leading to the generation of a direct current (DC) within the PV cell. This DC electricity is then harnessed for various applications, including powering homes, businesses, or being fed into the grid.
- **Inverter Integration:** In practical solar power systems, the DC electricity generated by PV cells undergoes conversion through inverters. Inverters transform the DC power into alternating current (AC), which is the standard form of electricity used in homes and businesses. This transformation enables seamless integration with existing electrical grids.
- **Monitoring and Control:** For efficient operation, PV cells are often equipped with monitoring systems that track key parameters such as voltage, current, and temperature. These monitoring devices contribute to the overall health and performance of the solar power plant, ensuring that the PV cells operate within optimal conditions.
- **Advancements and Types:** Ongoing research and technological advancements continue to improve the efficiency and affordability of PV cells. There are different types of PV cells, including monocrystalline, polycrystalline, and thin-film solar cells, each with its unique characteristics and applications.
- **Environmental Impact:** PV cells are recognized for their environmentally friendly nature, as they produce electricity without emitting greenhouse gases. However, the manufacturing process of PV cells involves various materials, and their disposal at the end of life requires careful consideration to minimize environmental impact.
- **Integration with IoT:** In the context of the discussed IoT-based solar power monitoring system, PV cells play a pivotal role as the primary energy conversion units. The integration of sensors, microcontrollers, and IoT devices enhances the monitoring capabilities of PV cells, contributing to the overall efficiency and reliability of the solar power plant.

As the global push towards renewable energy intensifies, PV cell technology continues to evolve, promising even greater efficiency and sustainability in the future of solar power generation.

Inverter

The Arduino is connected to a microcontroller sensor that monitors temperature, wind speed, and solar radiation. In the daisy chain, all the inverters of the plant are connected. The Daisy chain is used to collect the data of all inverters using the Modbus protocol. Every five minutes, the Daisy chain is used to obtain the total power output, grid fault, PV over, temperature, overcurrent, and short circuit. In the context of solar power plants, an inverter plays a crucial role in the conversion of direct current (DC) generated by photovoltaic cells into alternating current (AC), which is the standard form of electricity used in homes and businesses. The Arduino microcontroller is connected to a sensor that monitors key parameters such as temperature, wind speed, and solar radiation. The inverter, being an integral component of the solar power plant, is crucial for the efficient functioning of the entire system. The inverter serves as a bridge between the solar panels and the power grid, ensuring that the electricity generated by the solar panels is compatible with the electrical infrastructure. In the proposed system, a daisy chain configuration is employed, connecting all the inverters in the solar power plant using the Modbus protocol. This configuration allows for the collective gathering of data from all inverters at regular intervals, typically every five minutes.

The daisy chain setup enables the acquisition of essential information, including total power output, grid faults, PV overvoltage, temperature, overcurrent, and short circuits. By continuously monitoring these parameters, the system can promptly detect irregularities or faults in the solar power generation process. This real-time data collection is instrumental in maintaining optimal performance, identifying potential issues, and preventing downtime.

Liquid Crystal Display (LCD)

The items shown on LCD screens are used for displaying voltage, current and intensity. When the current intensity increased, the sunlight energy falling on the panel also increased. The intensity and current vary, and the voltage is fixed at 12 volts. The simulation results are displayed on the LCD screen. The data obtained from the inverters and various sensors are visually presented through a Liquid Crystal Display (LCD). The LCD screen serves as an interface to showcase critical metrics such as voltage, current, and intensity. As sunlight intensity on the solar panel fluctuates throughout the day, the displayed values on the LCD provide a real-time representation of the system's performance.

The LCD serves as a user-friendly display, allowing operators and maintenance personnel to quickly assess the current status of the solar power plant. Any anomalies or deviations from the expected values can be easily identified, enabling timely intervention and maintenance. This visual representation on the LCD screen enhances the accessibility of information, making it a valuable tool for on-site monitoring and troubleshooting.

IOT Module

The IOT-based solar power plant stores the necessary data in real-time and reduces labor. The system can track the fast transmission of data and update information. IoT can access the location, store the data, and save it as a record. IoT-based remote monitoring of solar panels will save energy and reduce manpower. We use the Arduino microcontroller connected to the sensor for current and voltage information. The Internet of Things (IoT) module is a key component in the proposed solar power monitoring system. It facilitates the storage of real-time data, reducing the need for manual labor in data collection and analysis. The IoT module enables rapid data transmission and information updates, ensuring that stakeholders have access to the most recent and relevant information about the solar power plant's performance.

Connected to Arduino microcontrollers and sensors, the IoT module enhances the system's capabilities by providing remote access to critical data. This remote monitoring capability is particularly advantageous for large-scale solar power plants spread across vast geographical areas. The system's ability to transmit data to the cloud and store it in a centralized database further streamlines the monitoring process.

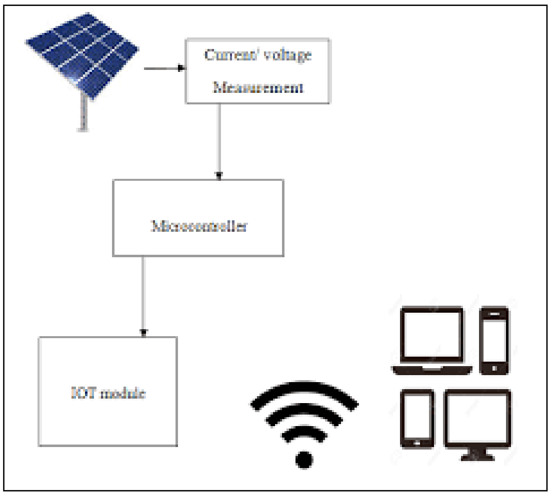

Figure 1. IOT Module

In conclusion, the integration of inverters, LCD displays, and IoT modules in the solar power monitoring system ensures efficient data collection, real-time visualization, and remote access. These components collectively contribute to the overall effectiveness and sustainability of the solar power plant, enabling optimal power generation and proactive maintenance.

LDR (Light Dependent Resistor)

A light-dependent resistor (LDR), also known as a photoresistor or LDR, is a device that controls the amount of light entering a solar panel. They are manufactured from high-resistance semiconductor materials. A picture blocker, also known as an LDR, is defined by various symbols. The light is falling on the LDR, as shown by the arrow. The most popular form of LDR is resistance that decreases with increasing temperature. As the light intensity in the solar panel improves, so does the sunlight in the solar panel.

LDR intensity graph

The most basic feature of LDR is a resistance that decreases as the amount of light falling in the system (as seen in the image).

The following resistances are common in resistance to LDR:

5000

20000000 = Dark

As a result, you can see that the figures vary a lot. If you mark this variation on a graph, it will look like the above.

Current and Voltage Sensor with Arduino

Arduino UNO is a microcontroller used to read current and voltage values in the system. The current and voltage sensors are connected to the Arduino Uno for measurement of read values in the solar panel. Arduino Uno reduces programming complexity.

Dust Sensor

The voltage here is fixed at 12 volts in the solar panel system. When the dust percentage increases, the motor starts running, and the sprayer cleans up the dust in the solar panel. The dust percentage increased above 60 percent, the DC motor started rotating, and the sprayer automatically cleansed the dust.

Figure 2. Dust Sensor

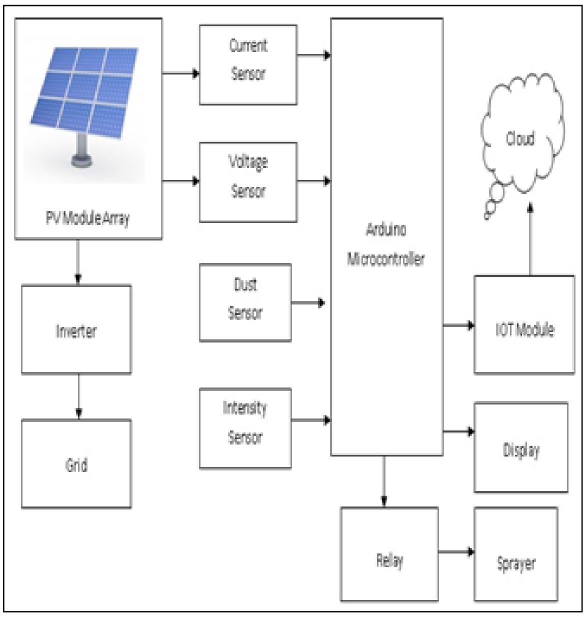

Figure 3.Solar Panel Monitoring demonstration

Solar Panel Monitoring Demonstration

The above diagram represents the block diagram of the proposed system. Data and knowledge from various solar panels is gathered by IOT technology, which then shares it to meet unique needs. IoT platforms, such as Thing spec, and cloud platforms can separate useful data from irrelevant information. Before using the information, we can detect faults and minimize problems. Data from paired sensors, such as voltage sensors and a current sensor, is used to make the right decisions based on real-time data, saving money and time. Solar monitoring systems are powered by inverters in our solar system. Solar-grid integration is a feature that allows large-scale solar power generation from PV or CSP systems that converts AC current to DC current. This technique is used in remote sensing applications, but its efficiency requires careful consideration and attention in such areas. Solar inverters are used in home appliances to convert AC power to DC supplies. Solar power plants must be monitored for optimal power generation, and this monitoring aids in the recovery of productive power generation from power plants. So, we implemented an IoT-based solar power monitoring system that allows automated solar power monitoring from anywhere using wireless modules on the Internet. We use an Arduino-based microcontroller system to track the parameters and variables of a 10-watt solar panel. Our control system tracks the performance of the solar panel and sends it over the Internet to the IOT system.

Simulation of Proposed System

The above diagram shows the simulation of the proposed system. The causes of power loss are the dirt particles present in the panel. Dry cleaning is another technique that cannot completely remove all dirt and other dust particles from the solar panel; it only removes the upper layer of the panel. Since this system does not require any external power, it uses a rechargeable battery, and the battery gets recharged directly from the solar panel. When the dust percentage rises above 60%, the DC motor starts running and automatically cleans up the dust present in the panel system.

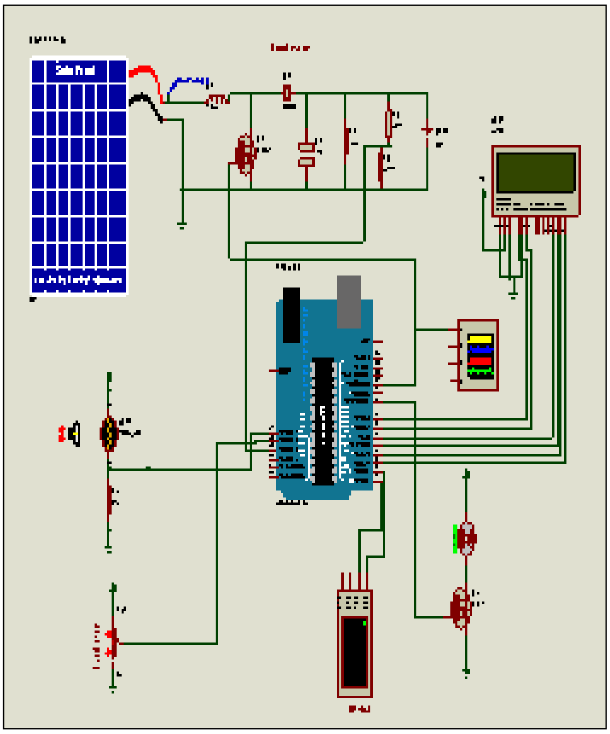

Figure 4.Simulation of Proposed System

Simulation Results and Discussion

The above diagram represents the voltage, current monitoring in LCD in virtual terminal and its displays the metrics. Simulation results shown when the dust increases above 60% the motor starts running and the sprayer clean the dust particles in the panel. When the light Intensity increases the sunlight current also increases as shown in the LCD.

Conclusion and Future Scope

With updated records stored in the cloud database, the Internet of Things was designed to get the most current and power. In addition, the solar panel is a monitoring device that will appear on the monitor in the event of failure, and we will get accurate information about whether it is connected to solar or battery power. The Internet of Things is changing human life in every aspect of their lives during the development of technology. Solar panels are not your specific source of power, but they can help you meet your energy needs. This paper discusses an IoT-based approach to tracking solar energy consumption, along with prototype Proteus software to simulate the effect. This method uses sensors to record solar panel metrics such as current, voltage, and temperature, which are then sent to the cloud via the Arduino. The results are shown on the board, on an LCD, and also through a smartphone application. We will use future reinforcement learning algorithm techniques to forecast wind energy, thermal energy, and power generation in the future.

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