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Smart Solar PV Monitoring System Using IoT

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Abstract - In the era of modernization, the Internet of Things (IoT) emerges as a pivotal technology, particularly in enhancing the performance and monitoring of solar energy systems. By integrating IoT into solar plants, real-time supervision becomes feasible, allowing users to monitor crucial parameters such as current, voltage, and light intensity. This monitoring system addresses the challenges associated with remote location monitoring, making it especially relevant for off-grid solar home systems in remote areas, including coastal communities. The IoT-based monitoring system enables users to remotely track the performance of solar panels and receive alerts for abnormal conditions such as panel breakage or excessive dust accumulation. Through mobile connectivity, users can access real-time data and receive warning messages in case of anomalies, facilitating efficient fault detection and maintenance. The proposed solution aims to prototype this IoT-enabled monitoring system, offering a cost-effective and scalable approach to monitoring and maintaining solar plants in remote locations.

Key Words: Internet of Things (IoT), Solar Energy, light, Smart Solar, Temperature, Remote areas.

1.INTRODUCTION

Solar energy, generated by photovoltaic cells utilizing the photovoltaic effect, holds significant promise as a renewable energy source. However, conventional PV cells often suffer from low efficiency, primarily due to their dependency on light intensity, exacerbated by the sun's dynamic movement across the sky. This variability in light exposure reduces the absorption efficiency of stationary solar panels, especially when they are not aligned perpendicularly to the sun's rays.

The emergence of the Internet of Things (IoT) signifies a transformative technological development with extensive implications for various aspects of daily life. IoT devices facilitate connectivity between machinery and cloud-based platforms, enabling seamless data exchange within interconnected networks. This technology empowers users to remotely access and manage devices from anywhere globally, fostering a more interconnected environment. Given the dynamic nature of solar radiation, IoT offers a compelling solution for continuously monitoring solar panels, ensuring optimal performance regardless of geographical location or climatic conditions.

Significance of Solar Power Monitoring:

Solar power represents a sustainable and increasingly popular energy source due to its abundance and cost-effectiveness. By harnessing solar energy through the photovoltaic effect, light energy is converted into electrical energy, offering a clean and renewable alternative to traditional power generation methods. Effective monitoring of solar power systems facilitates energy forecasting, enhances productivity in households and communities, and contributes to pollution reduction efforts.

Proposed IoT-Based Solar Power Monitoring System:

The proposed system outlines an IoT-based approach to solar power monitoring, aiming to maximize energy efficiency and system performance. Solar cells within solar panels convert sunlight into electricity, with current and voltage parameters measured using sensors connected to an Arduino microcontroller. These measured values are displayed on an LCD screen for local monitoring, while an IoT device facilitates remote monitoring via network connectivity.

2. LITERATURE SURVEY

The literature review delves into the vital role of solar tracking systems in optimizing energy production from photovoltaic (PV) cells. Solar panels, comprising PV cells, are fundamental to solar energy systems. However, their efficiency depends on optimal alignment with the sun's position. Solar tracking systems, such as heliostats, dynamically adjust the orientation of panels to maximize sunlight exposure, thus enhancing energy efficiency.

Research has focused on refining solar panel technology to increase energy output, including innovations like double-sided panels and geometric integration. Advancements in monitoring techniques have addressed challenges posed by pulse width modulation (PWM) charge controllers in solar home systems, ensuring accurate measurement of photovoltaic power. Studies have explored low-cost silicon pyranometers coupled with microcontroller-based data acquisition systems for monitoring solar radiation. Additionally, the development of monitoring systems for PV solar plants, leveraging virtual instrumentation and high-precision field point devices, emphasizes the importance of real-time data collection and analysis for optimizing system performance and reliability. These efforts highlight the significance of integrating advanced tracking and monitoring technologies to enhance the efficiency and viability of solar energy systems.

3. WORKING METHODOLOGIES

The solar panel is fitted with various sensors, including those for rain, vibration, light, and temperature. These sensors are strategically placed to capture pertinent environmental data and panel performance metrics. Through a Wi-Fi module, the sensors transmit their data to the ThingSpeak server, a cloud-based IoT platform. Here, the data is aggregated and updated in real-time, providing a thorough overview of solar panel conditions and environmental factors. Additionally, voltage and current sensors are positioned between the solar panel, battery, and load, allowing for the monitoring of essential electrical parameters for system operation.

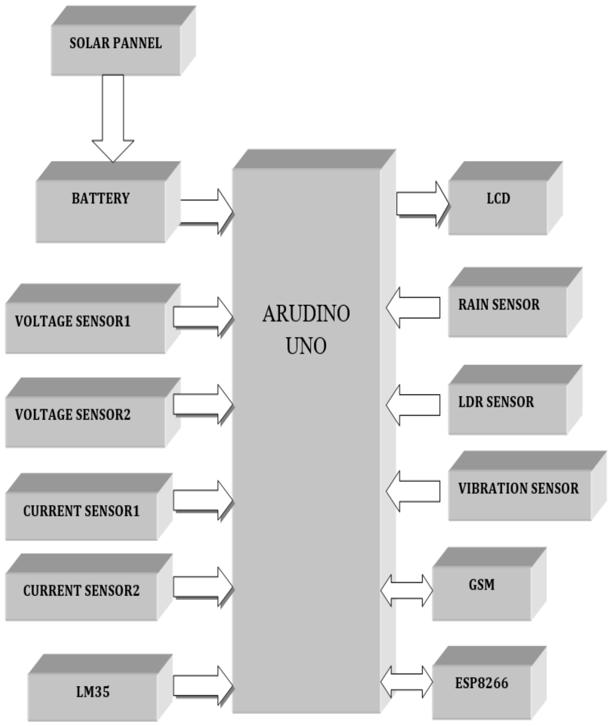
Mobile Application Interface:

Using the ThingSpeak cloud application, users can access real-time data and track various parameters related to solar panel performance and environmental conditions. The application offers a user-friendly interface displaying essential metrics such as light intensity, temperature, vibration status, rain status, source voltage and current, as well as battery voltage and current. This information is also mirrored on a dedicated LCD display for convenient onsite monitoring.

Alert Mechanisms:

In case of abnormal conditions like low panel voltage or significant vibrations caused by external factors, a GSM module is activated to send alert messages to the user's registered mobile number. This proactive alerting mechanism ensures timely notification of potential issues, enabling users to take prompt action to address emerging problems and prevent system downtime. This description outlines the systematic integration of sensors, data transmission, mobile application interface, and alerting mechanisms within the solar panel system, highlighting the role of IoT technology in enhancing monitoring, user accessibility, and fault detection.

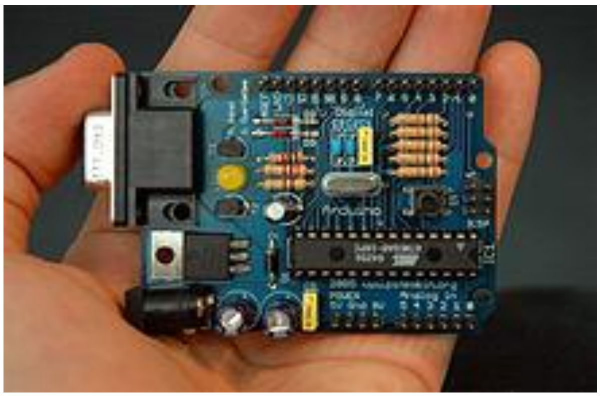
4.BLOCK DIAGRAM



5. SYSTEM DESIGN

Arduino UNO:

The Arduino UNO is a widely used open-source microcontroller board developed by Arduino.cc, based on the Microchip ATmega328P microcontroller. It features 14 digital pins and 6 analog pins, facilitating interfacing with various expansion boards and circuits. Programmable via the Arduino IDE, it can be powered by USB or an external 9-volt battery, accepting voltages between 7 and 20 volts. The hardware design is distributed under a Creative Commons Attribution Share-Alike 2.5 license, with layout and production files available on the Arduino website. Named "Uno" to coincide with the release of Arduino Software (IDE) 1.0, it serves as the reference model for the Arduino platform. The ATmega328 comes preprogrammed with a bootloader, enabling code uploading without an external hardware programmer and communicates using the STK500 protocol. Notably, it utilizes the Atmega16U2 (Atmega8U2 up to version R2) as a USB-to-serial converter, distinguishing it from previous boards. Originating from the Interaction Design Institute Ivrea, the Arduino aimed to provide affordable tools for digital methods. Initially based on the Wiring platform, it evolved independently, incorporating the ATmega328P microcontroller and ATmega16U2 for USB-to-serial conversion.

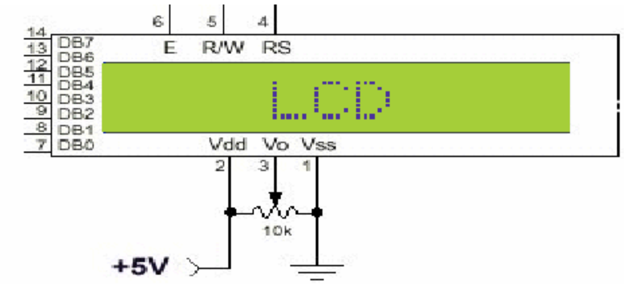


Power Supply:

A power supply unit (PSU) plays a crucial role in converting AC voltage to DC voltage and adjusting its amplitude. It usually receives an input signal from the mains at 230V/50Hz as AC voltage and transforms it into a desired output with specific amplitudes of +5V and +12V for various applications. Typically, the power supply section consists of a Transformer, Bridge rectifier, and voltage regulators (like the 7805 and 7812) connected in series. Capacitors (typically 1000µF) are connected in parallel with the regulators to stabilize the output. Additionally, each regulator output is further connected in parallel with capacitors of different values (such as 100µF, 10µF, 1 µF, 0.1 µF) to ensure smooth and consistent output voltages (+5V or +12V).

LCD (Liquid Crystal Display):

A liquid crystal display (LCD) is a flat, thin display device consisting of numerous color or monochrome pixels arranged in front of a light source or reflector. Each pixel contains liquid crystal molecules suspended between transparent electrodes and polarizing filters oriented perpendicularly to each other. The liquid crystal twists the polarization of light, enabling it to pass through both filters. LCD displays are commonly used as output devices for programs to interact with users. Variants such as 16x1, 16x2, and 20x2 displays are often connected to controllers, indicating the number of characters per line and available lines. Many microcontroller devices utilize 'smart LCD' displays, such as the LCD NT-C1611 module, which are affordable, user-friendly, and capable of displaying ASCII characters and mathematical symbols. Key features of such LCD modules include compatibility with 4-bit or 8-bit microprocessors, an 80x8-bit display data RAM, a character generator ROM offering 160 different 5x7 dot-matrix character patterns, and user-programmable character generator RAM with eight distinct 5x7 dot-matrix patterns. These displays can be controlled using various instructions such as Clear Display, Cursor Home, Display ON/OFF, Cursor ON/OFF, Blink Character, Cursor Shift, and Display Shift.



ESP 8266:

The ESP8266, developed by the Chinese company Espressif Systems, is designed for applications in the Internet of Things (IoT) systems. It serves as a comprehensive Wi-fi system-on-chip, integrating a 32-bit processor, RAM, and flash memory ranging from 512KB to 4MB, depending on the vendor. This chip can function either as a Wi-fi adapter to enhance other systems' connectivity or as a standalone unit capable of executing basic applications. With variants ranging from ESP-1 to ESP-12, the module offers between 0 and 7 General Purpose Input/Output (GPIO) pins, along with UART Rx and Tx pins, making it highly suitable for IoT applications. Espressif Systems provides a Software Development Kit (SDK) featuring a lightweight implementation of a TCP/IP control stack (lwIP) for Wi-fi communication. Additionally, the SDK includes libraries for optional services like Dynamic Host Configuration Protocol (DHCP), Domain Name System (DNS), JavaScript Object Notation (JSON), and Secure Socket Layer (SSL) for application-level programming. The chip incorporates 802.11 MAC extensions to manage signal transmission, encapsulation, encryption, collision management, and roaming functionality. Typically, the chip is housed within a module soldered onto a Printed Circuit Board (PCB). However, standalone chips are also available for custom module creation. Module variants on the market may feature PCB or ceramic antennas, a U.FL connector, hardware components for serial communication.

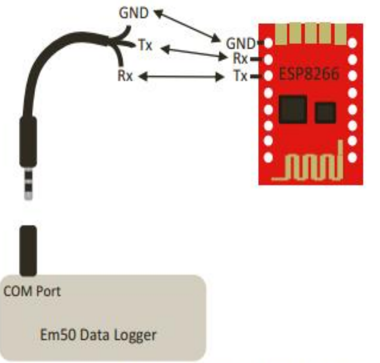


Figure 3.9 Serial communication was conducted over a 3.5mm AUX cable attaching ESP8266s Rx, Tx and GND to sensors Tx, Rx and GND respectively

6. RESULTS AND DISCUSSIONS

The results will include real-time generated values from the solar panel, sensors, and the battery. The result images are retrieved from the ThingSpeak cloud application, which is fed by the ThingSpeak server through the ESP8266 Wi-Fi module. Additionally, alert messages from the user's registered mobile number are sent via the GSM Module.

Fig -1: Temperature

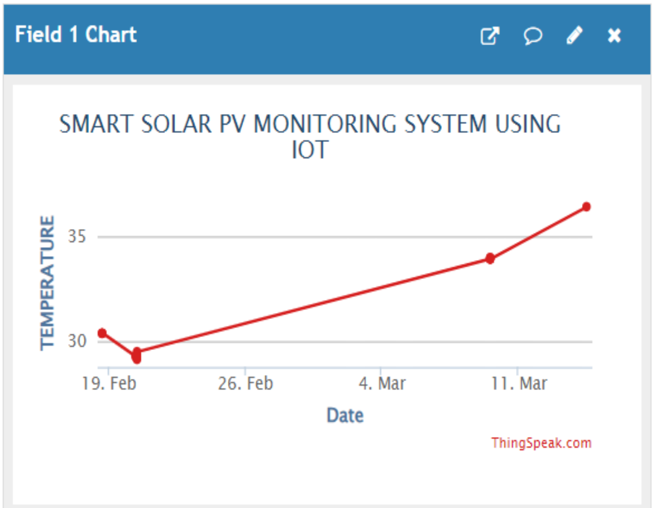


Fig -2: Light Intensity

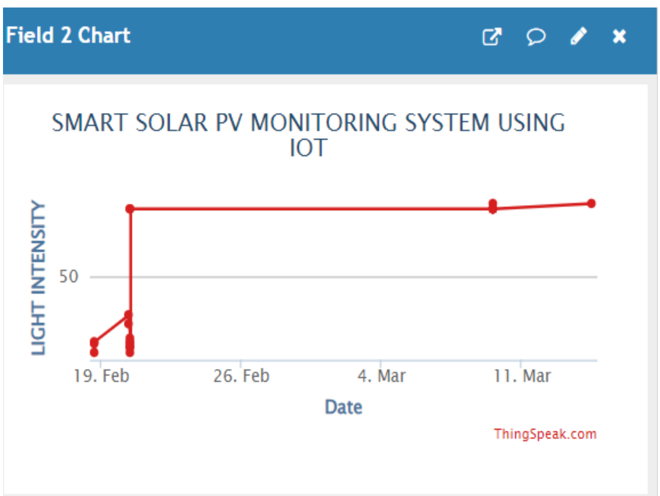


Fig -3: Rain Status

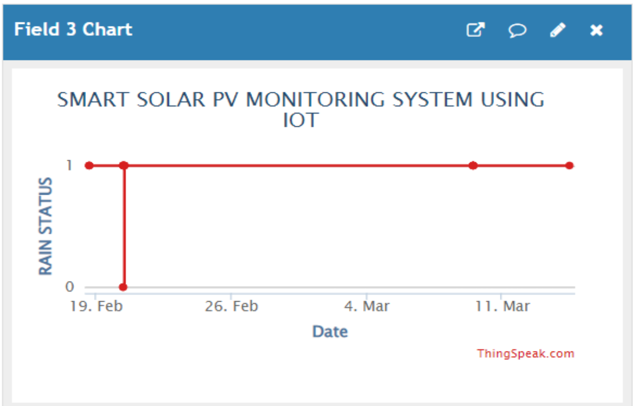


Fig -4: Vibration Status

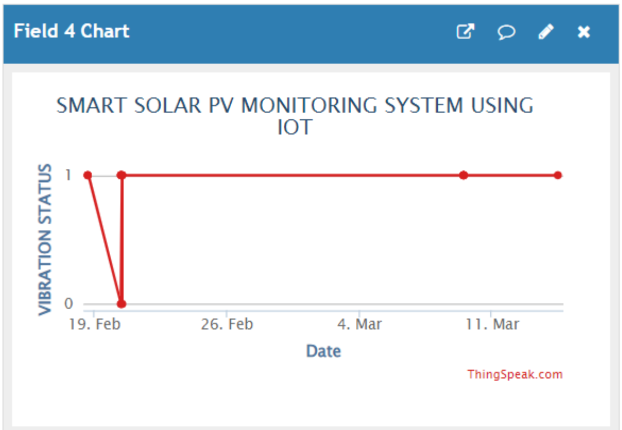


Fig -5: Panel Voltage

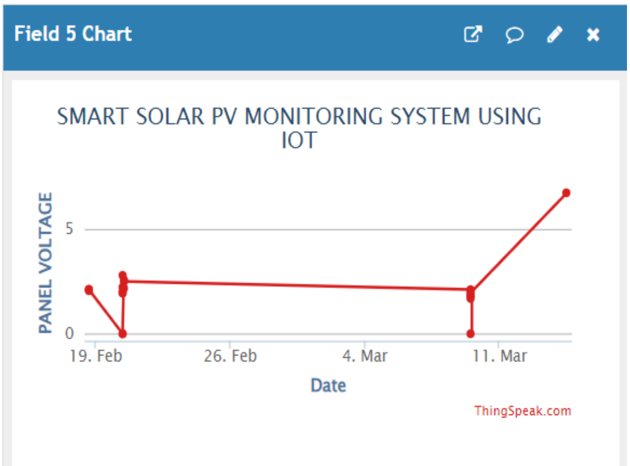


Fig -6: LCD Display

Fig -7: Battery Voltage

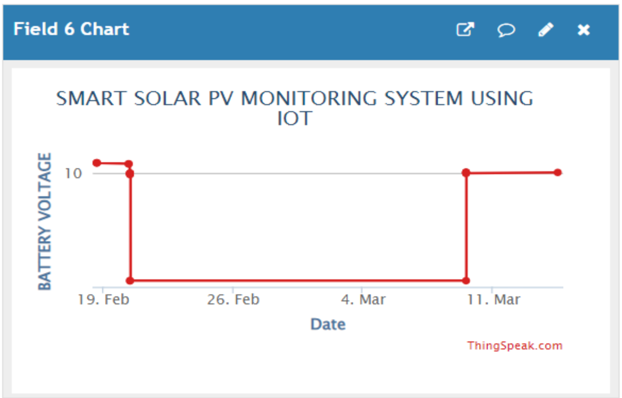


Fig -8: Panel Current

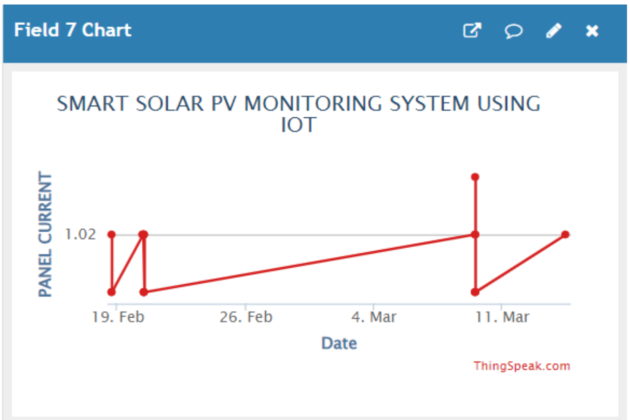


Fig -9: Battery Current

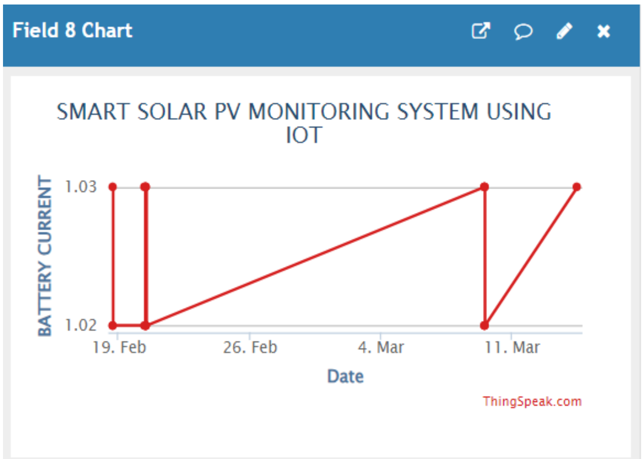


Fig -10: LCD Display

Fig -11: Rain alert message

Fig -12: Vibration alert message

Fig -13: Low voltage alert message

7.CONCLUSIONS

The integration of renewable energies into the electricity distribution network has become a necessity, prompting the search for new and effective solutions for remote monitoring and control. In this proposed method, an IoT-based solar panel remote monitoring system is introduced to gather data on crucial parameters of solar panels. Continuous recording of performance data and failure data is enabled by IoT, allowing for analytics to predict and forecast future power generation possibilities and income production, while also preventing frequent maintenance of photovoltaic systems. IoT will play a significant role in accessing control over photovoltaic systems installed at remote locations or far from the control center. IoT-based monitoring will enhance the energy efficiency of the system, reduce intervention and supervision time, and facilitate network management. Following the examination of the remote monitoring architecture for solar panels, the next step will involve implementing, testing, and achieving this IoT-based system to establish a reliable and secure system capable of real-time data collection.

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