



## IOT Based Remoting and Monitoring of Solar Power

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### ABSTRACT

This paper presents an IoT-based system for remote monitoring and control of solar panel operations, aimed at harnessing renewable energy to conserve electricity. The system incorporates a solar panel equipped with an ESP32 controller and an MPPT charge controller to optimize power generation and storage. Voltage and current sensors, connected to an Arduino Uno controller, facilitate real-time monitoring of solar panel performance. The system utilizes a web interface to display essential parameters such as current, power, and voltage, enabling users to remotely observe and manage solar panel activities. Moreover, an RTC module enables automated tilting of the solar panel to maximize power absorption, while integration with IoT cloud technology facilitates seamless data transmission and visualization. By leveraging HTML, CSS, and Javascript, a user-friendly webpage is created to present the collected data. This project signifies a significant advancement in IoT-based solutions for renewable energy sources, offering a sustainable approach to electricity generation and consumption.

**Keywords** - IoT (Internet of Things), Solar Panel, Motors, ESP32, voltage sensor, current sensor, RTC module, IoT Cloud, Solar Power, Renewable energy resources, Remote Monitoring, webpage, MPPT charge controller, Real-time, Smart Technologies.

### I. Introduction

In recent times, the global focus on renewable energy sources has boosted, with solar power arising as one of the most promising alternatives to traditional fossil energies. Solar energy offers multitudinous benefits, including sustainability, cost-effectiveness, and scalability. Still, maximizing the effectiveness and trustability of solar power systems requires effective monitoring and control mechanisms. This is where the Internet of Effects (IoT) technology comes into play. Our design aims to make this task easier by incorporating an Internet of Effects (IoT) controlled operation. This design we make use of solar power to induce power. So when the current is off it works as an inverter. Then the main element that we're using is MPPT charge regulator where it checks from which direction the maximum power is absorbed and makes the solar panel to remain in that position. And then the solar panel tilts according to the maximum power consumption. Then we used ESP32 regulator to control all the factors. And voltage detectors and current detector is used to smell the current, power, voltage, which is displayed in IOT webpage. Our design substantially focuses on making use of renewable energy like solar power. The advantage and benefit of this design is to make use of renewable energy and then the information that's gathered from the voltage and current detectors is given to the Arduino uno regulator which will be automatically diverted to the web runner where the complete information is stored. And it helps us to know how important current is stored, employed etc. And we use RTC module to make the solar panel cock according to real-time. And solar panel tilts 45 degrees in both directions. So we get the complete information in the webpage which will produce an interest to make use of solar energy

### II. Literature Review

The integration of Internet of Things (IoT) technology into solar energy management systems marks a paradigm shift in the way we harness renewable energy. By leveraging a network of interconnected devices and sensors, IoT enables real-time monitoring, intelligent control, and data-driven optimization, thereby revolutionizing the efficiency, sustainability, and accessibility of solar energy [1].

At the forefront of IoT's impact on solar energy management is its ability to enhance efficiency and precision in energy capture. Automated tracking systems equipped with IoT sensors dynamically adjust solar panel angles in response to real-time sunlight data, ensuring optimal positioning for maximum energy yield. Moreover, sophisticated algorithms powered by IoT, such as Maximum Power Point Tracking (MPPT), fine-tune energy conversion processes to extract the highest possible output from solar panels under varying environmental conditions. This precision not only maximizes energy production but also improves the reliability and consistency of solar power generation [2].

Predictive maintenance algorithms, fueled by IoT-collected data, preemptively identify potential equipment failures or performance degradation, enabling proactive interventions to prevent costly downtime and repairs. Furthermore, IoT-based diagnostics facilitate the early detection of underperforming components, optimizing maintenance efforts and prolonging the lifespan of solar infrastructure [3].

The deployment of IoT in solar energy management extends beyond technical optimization to address broader environmental concerns. IoT-powered environmental monitoring systems enable real-time tracking and management of resources, such as water bodies, contributing to sustainable practices in water conservation and pollution mitigation. Moreover, by enhancing the efficiency and accessibility of solar energy, IoT-enabled systems play a crucial role in reducing reliance on fossil fuels and mitigating greenhouse gas emissions, thereby fostering a cleaner and greener energy ecosystem [4].

Despite the immense potential of IoT in solar energy management, several challenges remain to be addressed. Data security and privacy concerns pose significant hurdles, necessitating robust encryption protocols and stringent access controls to safeguard sensitive information collected by IoT devices. Moreover, interoperability issues and the need for standardized communication protocols present barriers to seamless integration and scalability of IoT solutions in solar energy systems. Future research and development efforts should focus on overcoming these challenges while exploring innovative applications and advancements in IoT technology to unlock the full potential of solar energy management [5].

The global impact of IoT-enabled solar energy systems is far-reaching, offering transformative opportunities for sustainable development and energy access worldwide. Policymakers and stakeholders have a pivotal role to play in incentivizing the adoption of IoT-based renewable energy solutions through supportive policies, financial incentives, and international collaborations. By fostering innovation, promoting research and development, and investing in infrastructure, governments can accelerate the transition to a more sustainable and resilient energy future powered by IoT-enabled solar energy systems [6].

The integration of IoT technology into solar energy management systems holds immense promise for revolutionizing the way we generate, distribute, and utilize renewable energy. Through enhanced efficiency, cost-effective operations, and sustainable practices, IoT-enabled solar energy systems offer a pathway towards a cleaner, greener, and more equitable energy future for generations to come. With continued innovation, collaboration, and policy support, IoT stands poised to unleash the full potential of solar energy, driving positive environmental, social, and economic outcomes on a global scale [7].

In addition to efficiency gains, IoT introduces cost-effective solutions for operations and maintenance in solar energy systems. Remote monitoring capabilities enabled by IoT sensors allow for continuous surveillance of solar installations, minimizing the need for physical inspections and reducing operational overheads, particularly in remote or inaccessible locations [8].

### III. Methodology

Building on this idea, the Solar panel is Connected with MPPT charge controllers, RTC module, motor with relay, which are used to sense from which direction the power is more, and motor makes it to tilt in that direction. And RTC module makes the solar panel tilt at which maximum power is observed. And the power is given to battery to work to charge and this UPS connection is given to the room/load. Now to know how much current, voltage, power we use voltage and current sensors to get all this information which is connected to Arduino uno and it is connected to ESP32 to send the information which displays in the webpage created.

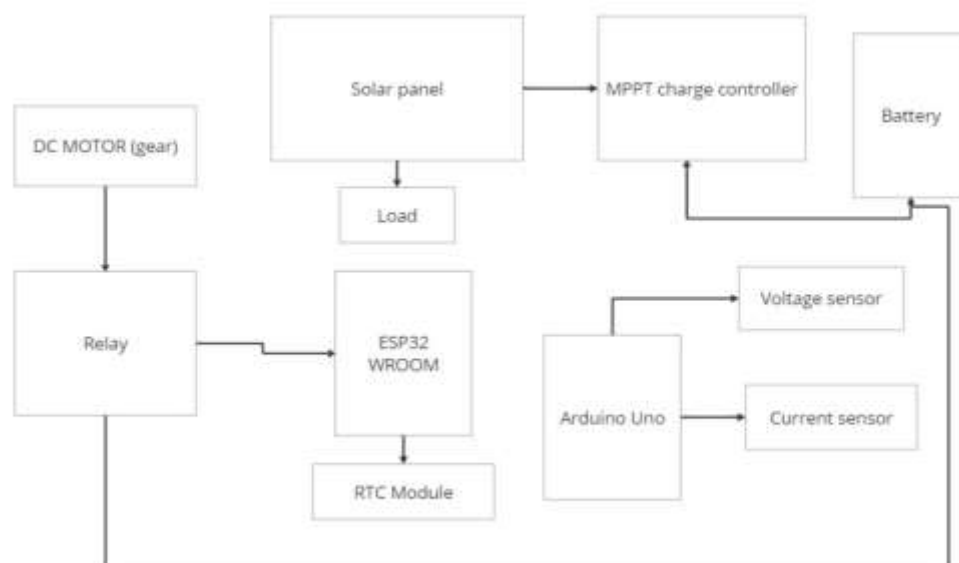
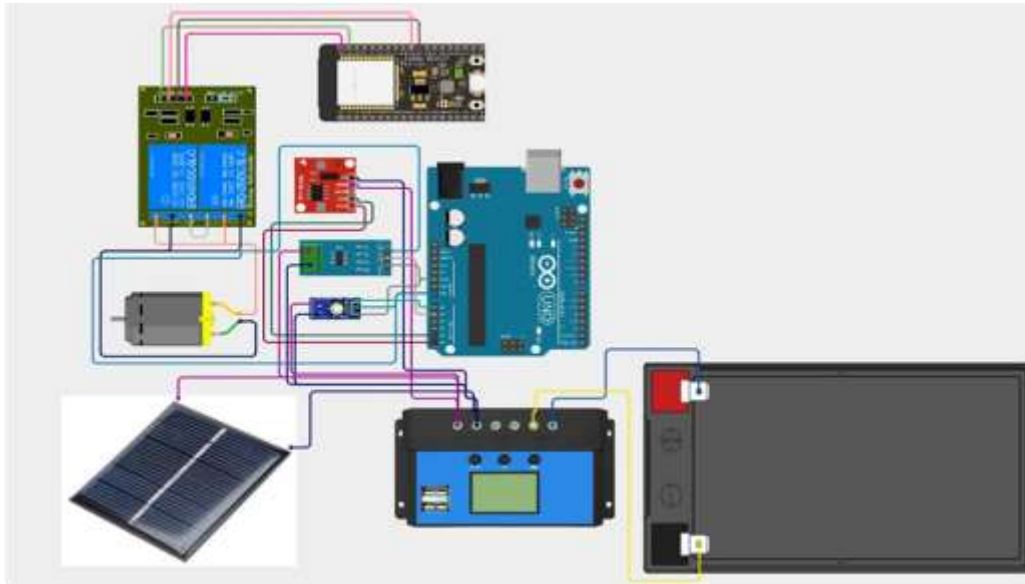


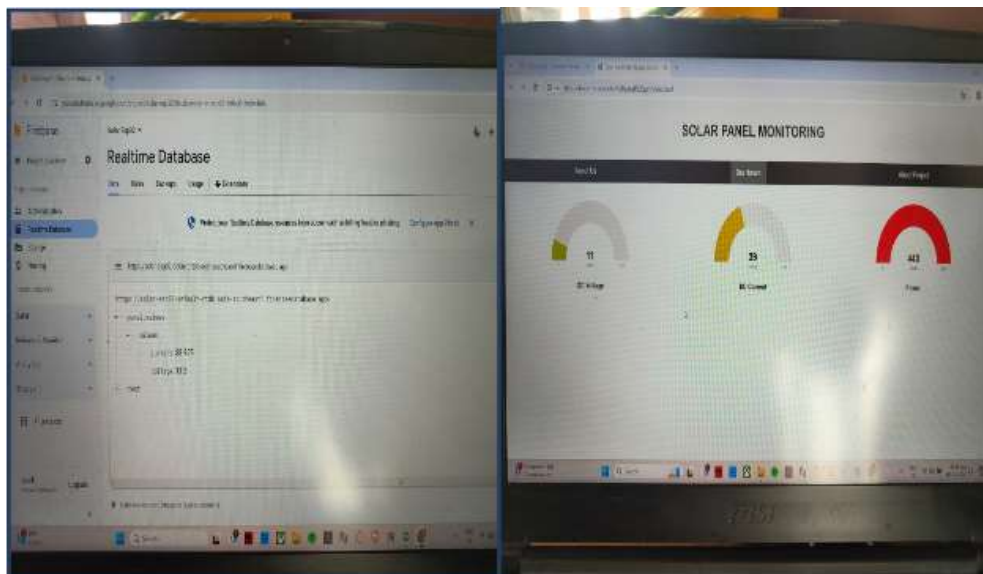
Figure: Block Diagram

The solar panel project integrates an RTC module and MPPT charge controller to optimize solar energy capture and usage. The RTC module aligns the solar panel accurately towardsthe sun, leveraging real-time clock data to maximize exposure throughout the day. This alignment ensures that the panel absorbs maximum sunlight and converts it into electrical energy efficiently. The generated DC electricity is then fed into the MPPT charge controller, which optimizes the voltage and current to extract the most power from the solar panel, enhancing overall efficiency. This optimized power is used to charge a battery and power DC loads, such as a DC fan, either simultaneously or separately based on the energy availability and requirements. The system is designed to maximize the direct use of solar energy during peak sunlight hours to power the fan, reducing reliance on the battery and extending its life. At times of insufficient sunlight, the stored energy in the battery provides a continuous power supply, ensuring reliable operation. Overall, the project exemplifies a smart use of solar technology by combining effective sun tracking, power optimization, and efficient energy management to deliver a sustainable and reliable power source for DC loads. This not only makes the system efficient but also environmentally friendly, reducing the dependency on non-renewable energy sources.



**Figure: Circuit diagram for Solar panel Remoting and Monitoring**

The IoT-enabled project involves the integration of Arduino and ESP32 by using Firebase to create a webpage dashboard for monitoring the Voltage, Current and Power. On the software side, an webpage is created using HTML,CSS, REACTJS, and the data is given to firebase, from firebase it is given to the webpage. So we can see the values of voltage, current, power using the webpage.



**Figure: Web Dash Board.**

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## IV. Hardware Components

1. **POLYCRYSTALLINE SOLAR PANEL:** A type of photovoltaic panel composed of multiple silicon crystals, converting sunlight into electricity. The 12V, 100-watt panel referenced here indicates its voltage and power output.
2. **DC MOTOR:** A device that converts electrical energy into mechanical motion. The motor specified operates on direct current (DC) at 12V, with a rotational speed of 10 revolutions per minute (rpm) and a torque capacity suitable for handling loads up to 15 kilograms (kgs).
3. **REAL-TIME CLOCK (RTC) MODULE:** An electronic device that keeps track of current time with high accuracy and precision. The module mentioned operates within a voltage range of 3.3V to 5.5V, ensuring consistent timekeeping functionality.
4. **ESP32 WROOM DEV KIT MODULE:** A microcontroller module based on the ESP32 chip, offering Wi-Fi and Bluetooth connectivity along with processing capabilities. It operates at 3.3V and serves as the central control unit in the system.
5. **CURRENT SENSOR:** A sensor that measures the electric current flowing through a circuit. The current sensor mentioned is calibrated for 12V applications, providing real-time data on energy consumption and flow.
6. **BATTERY:** A device used for storing electrical energy for later use. The specified battery has a voltage rating of 12V and a capacity of 18 ampere-hours (Ah), serving as an energy storage unit for the system.
7. **JUMPER CABLES AND WIRES:** Electrical cables used for making temporary connections between components or providing power and data transmission pathways. Wires are essential for interconnecting various components within the system, ensuring proper functionality and communication.

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## V. SOFTWARE TOOLS

1. **Arduino IDE:**
  - Software for programming Arduino microcontroller boards, ESP32 Boards.
  - Includes text editor, compiler, and uploader.
  - Supports C and C++ languages.
  - Provides libraries for hardware integration.
  - Features serial monitor for debugging.
2. **HTML (HYPERTEXT MARKUP LANGUAGE):**
  - Language for creating web pages.
  - Uses tags to structure content.
  - Supports multimedia and forms.
  - Includes semantic elements for accessibility.
  - Often combined with CSS and JavaScript.
3. **CSS (CASCADING STYLE SHEETS):**
  - Styles HTML elements.
  - Defines presentation and layout.
  - Controls text, colors, spacing.
  - Supports animations and transitions.
  - Enhances user experience.
4. **JAVASCRIPT:**
  - Adds interactivity to web pages.
  - Runs in web browsers.
  - Handles user actions and events.
  - Manipulates HTML elements.

- Supports asynchronous programming.

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## VI. Results

The developed system effectively integrates a range of components including a 100-watt polycrystalline solar panel, a 12V DC motor, an RTC module, an ESP32 WROOM Dev Kit, an MPPT charge controller, an Arduino Uno, voltage and current sensors, a 12V, 18Ah battery, and jumper cables/wires. This integration facilitates precise solar panel control, optimal power generation, and remote monitoring capabilities through IoT cloud technology. The system offers a robust solution for renewable energy utilization and represents a significant advancement in IoT-based solar energy management.



Figure: Iot Based Remoting and Monitoring of Solar Power

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## VII. Advantages

1. **Renewable Energy Utilization:** The system harnesses renewable solar energy, offering a sustainable alternative to traditional electricity sources and reducing reliance on non-renewable resources like fossil fuels.
2. **Effective Power Generation:** By utilizing an MPPT charge controller and precise solar panel control mechanisms, the system maximizes power generation efficiency, ensuring optimal utilization of available sunlight and enhancing overall energy output.
3. **Remote Monitoring and Control:** Integration with IoT cloud technology enables remote monitoring and control of solar panel operations, providing users with real-time data on energy production and enabling proactive management for improved performance.
4. **Energy Storage and Distribution:** The inclusion of a battery storage unit ensures uninterrupted power supply, even during periods of limited sunlight, enhancing reliability and enabling the system to function independently of external power sources.
5. **Adaptability and Versatility:** The system's flexibility in installation and adaptability to seasonal changes ensure optimal performance across diverse environmental conditions, making it suitable for a wide range of applications and locations.
6. **Technological Integration:** Integration of advanced components such as ESP32, Arduino Uno, voltage and current sensors, and RTC module demonstrates the system's utilization of cutting-edge technology for efficient energy management and monitoring.
7. **User-Friendly Interface:** The creation of a web interface using HTML, CSS, and JavaScript provides users with an intuitive platform for accessing and visualizing energy data, enhancing user experience and facilitating ease of operation.
8. **Cost-Effectiveness:** The system's efficient energy production, remote monitoring capabilities, and reliance on renewable energy sources contribute to long-term cost savings, making it a financially viable and sustainable energy solution.

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## VIII. Applications

The proposed IoT based Remoting and Monitoring of Solar Power is suitable for a wide range of operations, including :

1. **Residential Solar Power:** Provides renewable energy for homes, reducing electricity costs and environmental impact.
2. **Commercial & Industrial Facilities:** Optimizes energy usage and costs for businesses and industries.
3. **Off-Grid Installations:** Supplies reliable power in remote areas without access to traditional grids.
4. **Mobile & Portable Power:** Enables portable energy solutions for RVs, boats, and outdoor events.
5. **Energy-Efficient Buildings:** Integrates into green building designs for sustainable energy solutions.
6. **Microgrids & Community Projects:** Supports localized energy generation and distribution for communities.
7. **Education & Research:** Facilitates hands-on learning and experimentation in renewable energy technologies.
8. **Humanitarian Aid & Disaster Relief:** Provides essential electricity in emergency situations and for temporary shelters.

These applications showcase the usage of renewable energy in various applications which will help in many situations.

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## IX. Impact of Solar Power Usage in Society

The impact of Solar Power Usage on society is wide-ranging and significant:

1. **Environmental Benefits:** Solar power usage reduces greenhouse gas emissions and reliance on fossil fuels, contributing to cleaner air, water, and land, and mitigating climate change effects.
2. **Energy Independence:** By harnessing solar energy, societies can reduce dependence on imported fossil fuels and volatile energy markets, enhancing energy security and stability.
3. **Economic Growth:** Solar power deployment stimulates job creation in manufacturing, installation, maintenance, and research sectors, fostering economic growth and local development.
4. **Affordable Energy:** Solar power offers a cost-effective energy solution, reducing electricity bills for households, businesses, and communities, especially in regions with abundant sunlight.
5. **Improved Health:** By reducing air pollution associated with fossil fuel combustion, solar power usage helps improve public health outcomes, reducing respiratory illnesses and related healthcare costs.
6. **Rural Electrification:** Solar power enables electrification in remote and off-grid areas, providing access to modern amenities like lighting, communication, healthcare, and education, thereby improving quality of life and opportunities for development.
7. **Resilience to Disasters:** Solar power systems enhance resilience to natural disasters and grid failures by providing reliable, decentralized energy sources that can operate independently of centralized grids.
8. **Technological Innovation:** Solar power usage drives innovation in renewable energy technologies, energy storage solutions, and smart grid systems, accelerating the transition to a sustainable energy future.

These impacts highlight the transformative role of solar power usage in society, addressing environmental, economic, social, and technological challenges while advancing sustainability and resilience goals.

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## X. Implicit Limitations

While water surface cleaning bots offer numerous advantages, they also possess implicit limitations:

1. **Initial Cost:** The initial setup cost of integrating advanced components such as ESP32, MPPT charge controller, and IoT cloud technology might be relatively high, potentially limiting accessibility to users with budget constraints.
2. **Technical Complexity:** The complexity of configuring and programming the system, particularly with multiple interconnected components and IoT integration, may pose a challenge for users with limited technical expertise, requiring specialized knowledge for installation and troubleshooting.
3. **Maintenance Requirements:** Regular maintenance and calibration of sensors, controllers, and monitoring systems may be necessary to ensure optimal performance and accuracy, adding to the overall operational overhead and potential downtime.

4. **Scalability:** The scalability of the system to accommodate larger installations or varying energy demands may be limited by the capacity of the components, requiring additional investments in infrastructure or system redesign for expansion.
5. **Environmental Factors:** The system's performance may be affected by environmental factors such as inclement weather, shading, or geographical location, potentially reducing energy production efficiency and reliability in certain conditions.
6. **Compatibility Issues:** Compatibility issues between different hardware and software components, particularly when using third-party or custom-built solutions, may arise, requiring thorough testing and compatibility checks to ensure seamless integration and functionality.

Addressing these limitations through careful planning, system design, and ongoing maintenance can help mitigate potential challenges and enhance the overall effectiveness and reliability of the described system.

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## XI. Future Enhancements

Future enhancements in IoT based Remoting and Monitoring of Solar power may include:

1. **Enhanced Energy Storage:** Incorporate lithium-ion or flow batteries to boost storage capacity, efficiency, and lifespan, enhancing energy management flexibility.
2. **Smart Grid Integration:** Integrate smart grid tech to optimize solar power integration, improving grid stability, reliability, and efficiency, enabling bidirectional energy flows and demand response.
3. **AI and Predictive Analytics:** Utilize AI and predictive analytics to optimize solar panel performance, enabling proactive maintenance and fault detection based on real-time data.
4. **Modular Scalable Design:** Design the system with modular architecture for easy expansion and upgrades, allowing seamless integration of additional components and adaptability to evolving energy needs.
5. **Advanced Monitoring Systems:** Develop advanced monitoring systems with enhanced sensors and user interfaces for real-time insights and remote management, empowering users to optimize system performance efficiently.
6. **Energy Trading:** Explore blockchain tech for energy trading and peer-to-peer networks, enabling direct exchange of solar energy among consumers and promoting decentralized energy markets.
7. **Innovative Materials:** Research and develop innovative materials and manufacturing techniques for solar panels to improve efficiency, durability, and sustainability, reducing production costs and environmental impacts.

By implementing these enhancements, the system can achieve higher efficiency, reliability, and sustainability, paving the way for a more resilient and decentralized energy future.

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## XII. Conclusion

In summary, the IoT-based solar panel system described in the abstract represents a significant advancement in renewable energy utilization. By integrating technologies such as ESP32, MPPT charge controller, and IoT cloud, the system enables precise control, remote monitoring, and efficient utilization of solar power. Future enhancements, including advanced energy storage, smart grid integration, and AI-driven optimization, promise to further enhance the system's performance and scalability. With ongoing research and innovation, solar energy continues to emerge as a cornerstone of sustainable energy solutions, offering a pathway towards a greener and more resilient future.

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