

# Renewable Energy Based Mppt Design In Smart Agriculture Monitoring System

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**Abstract:** The increasing demand for sustainable agricultural practices has led to the integration of renewable energy sources with smart monitoring systems. This paper presents the design and implementation of a renewable energy-based Maximum Power Point Tracking (MPPT) system for smart agriculture applications. The proposed system utilizes solar photovoltaic (PV) energy as the primary power source to ensure uninterrupted operation in remote farming areas. An efficient MPPT algorithm is employed to maximize energy extraction under varying environmental conditions such as irradiance and temperature fluctuations. The harvested energy is used to power a smart agriculture monitoring system equipped with sensors for soil moisture, temperature, humidity, and water level detection. Data collected from these sensors is transmitted through an IoT-based platform for real-time monitoring and decision-making. The integration of MPPT enhances system efficiency, reduces energy loss, and improves reliability. Additionally, the system supports automated irrigation control, thereby optimizing water usage and increasing crop productivity. The proposed model is cost-effective, energy-efficient, and environmentally friendly, making it suitable for modern precision agriculture. Experimental results demonstrate improved power utilization and stable system performance under dynamic conditions. This work contributes to the development of sustainable and intelligent farming solutions using renewable energy technologies.

## Introduction

Agriculture plays a vital role in economic development, yet traditional farming methods often rely on inconsistent power sources and manual monitoring. The adoption of smart agriculture technologies has significantly improved productivity by enabling real-time data collection and automated decision-making. However, powering these systems in remote and rural areas remains a major challenge due to limited grid accessibility. Renewable energy, particularly solar photovoltaic systems, offers a reliable and sustainable solution for such applications. Efficient utilization of solar energy is essential, as its output varies with environmental conditions like sunlight intensity and temperature. Maximum Power Point Tracking (MPPT)

techniques are widely used to optimize energy extraction from solar panels under these dynamic conditions. By integrating MPPT with smart agriculture systems, it becomes possible to ensure continuous and efficient power supply. The use of IoT-based sensors allows farmers to monitor key parameters such as soil moisture, temperature, and humidity with high accuracy. This combination of renewable energy and intelligent monitoring enhances resource management and reduces operational costs. Furthermore, automated irrigation systems driven by sensor data help in conserving water and improving crop yield. The proposed approach supports sustainable farming practices while minimizing environmental impact. Overall, this integration represents a significant advancement toward energy-efficient and technology-driven agriculture.

## Body of the Paper

The demand for efficient and sustainable agricultural practices has increased significantly due to the growing need for food production and resource conservation. In many rural and remote farming areas, the availability of reliable power supply remains a major challenge, which affects the operation of modern agricultural monitoring systems. Conventional energy sources are not only costly but also contribute to environmental pollution. These challenges emphasize the importance of adopting renewable energy-based solutions that can provide continuous and eco-friendly power for smart agriculture applications.

Solar photovoltaic energy is one of the most promising renewable sources for agricultural systems due to its wide availability and low operational cost. However, the efficiency of solar panels is highly dependent on environmental conditions such as solar irradiance and temperature. To overcome this limitation, Maximum Power Point Tracking (MPPT) techniques are used to extract the maximum possible power from the solar panels under varying conditions. The implementation of an efficient MPPT controller ensures optimal energy utilization and enhances the overall performance of the system.

In the proposed system, solar energy is harnessed and regulated using an MPPT-based power conditioning unit, which supplies energy to the smart agriculture monitoring system. Various sensors are deployed in the field to measure

important parameters such as soil moisture, temperature, humidity, and water level. These sensors are interfaced with a microcontroller that processes the collected data and transmits it to a cloud platform using IoT communication technologies like Wi-Fi or GSM. This enables real-time monitoring and remote access to agricultural data through mobile or web-based applications.

The system is designed to support intelligent decision-making by analysing sensor data and triggering appropriate actions. For instance, when the soil moisture level drops below a predefined threshold, the system can automatically activate the irrigation system to supply water. Similarly, environmental data can help farmers optimize crop conditions and improve productivity. The integration of renewable energy ensures uninterrupted operation of the system even in off-grid locations.

Furthermore, the use of cloud storage allows data logging and historical analysis, which can assist in predicting future trends and improving farm management strategies. The system reduces dependency on manual labour and enhances efficiency through automation. It also minimizes energy wastage by ensuring that the solar power generated is utilized effectively through MPPT control.

Overall, the proposed renewable energy-based smart agriculture monitoring system provides a cost-effective, reliable, and environmentally sustainable solution. By combining solar energy, MPPT techniques, and IoT technology, the system supports precision agriculture and contributes to improved crop yield, efficient resource utilization, and long-term agricultural sustainability.

## Related Work

Several research works have been carried out in the field of smart agriculture by integrating renewable energy and IoT technologies. A solar-powered smart irrigation system has been widely studied, where solar photovoltaic panels are used along with soil moisture sensors and microcontrollers to automate irrigation processes, thereby reducing dependency on grid electricity and ensuring efficient water management. In addition, MPPT-based solar energy systems have been developed to improve power extraction from photovoltaic panels using algorithms such as Perturb and Observe and Incremental Conductance, which enhance system efficiency under varying environmental conditions.

IoT-based smart agriculture monitoring systems have also gained significant attention, enabling real-time monitoring of parameters such as soil moisture, temperature, and humidity, with remote access through mobile or web applications. These systems support precision farming and reduce manual intervention.

Furthermore, Wireless Sensor Networks have been implemented in agricultural fields to provide large-area coverage using distributed sensor nodes and low-power communication technologies like Zigbee and LoRa, improving scalability and efficiency.

Cloud-based smart farming systems have also been explored, where platforms such as IoT Cloud, Thing Speak, and AWS IoT are used for centralized data storage, visualization, and analysis, aiding better decision-making. Moreover, the integration of renewable energy sources with precision agriculture has been proposed to ensure continuous system operation in remote areas while promoting environmentally sustainable farming practices. These existing works highlight the importance of combining renewable energy, MPPT techniques, and IoT to develop efficient and intelligent agricultural systems.

## Problem Statement

Agricultural fields, especially in rural and remote areas, often face challenges related to unreliable power supply, inefficient resource utilization, and lack of continuous monitoring. Traditional farming methods depend heavily on manual observation and conventional irrigation practices, which can lead to water wastage, reduced crop yield, and increased labour effort. Additionally, the use of grid electricity or diesel-powered systems increases operational costs and contributes to environmental pollution.

There is a lack of an integrated system that can efficiently utilize renewable energy while simultaneously monitoring important agricultural parameters in real time. Solar energy, though widely available, suffers from fluctuating output due to changing weather conditions, resulting in inefficient power utilization. Moreover, existing systems often do not incorporate intelligent control mechanisms for irrigation and environmental monitoring.

In large agricultural lands, it becomes difficult to continuously track soil conditions and respond promptly to variations such as low moisture levels or unfavourable climatic changes. This highlights the need for a smart, energy-efficient system that combines renewable energy with advanced monitoring and control techniques. An optimized solution using MPPT and IoT can address these limitations by ensuring maximum energy extraction, real-time data monitoring, and automated decision-making for improved agricultural productivity.

## Existing System

In traditional agriculture systems, farming activities are primarily based on manual observation and conventional irrigation methods. Farmers rely on their experience to

decide irrigation schedules, often using diesel pumps or grid electricity as the main power source. These methods do not support real-time monitoring of soil or environmental conditions and are highly dependent on seasonal rainfall. As a result, they lead to excessive water usage, increased labour requirements, and reduced crop productivity due to the lack of accurate data and automation.

With the advancement of technology, IoT-based smart agriculture systems have been introduced to make farming more efficient and data-driven. These systems utilize sensors such as soil moisture, temperature, and humidity sensors, along with microcontrollers like Arduino or Node MCU, to collect real-time data from the field. The collected data is transmitted through wireless communication technologies such as Wi-Fi or GSM to cloud platforms, where it can be monitored remotely through mobile or web applications. This enables farmers to make informed decisions and automate irrigation processes, thereby reducing manual effort and improving crop management.

The working of these systems involves continuous data collection from field sensors, processing through a microcontroller, and transmission to cloud platforms for storage and visualization. Based on predefined threshold values, alerts are generated or actions such as irrigation are triggered automatically. Although these systems improve monitoring and automation, they still face several limitations, particularly in terms of energy management. Most existing systems depend on grid electricity or battery power, and even when solar energy is used, it is often not optimized due to the absence of MPPT techniques. This results in inefficient energy utilization, power fluctuations, and limited operation in remote or off-grid areas.

Therefore, there is a need for an improved system that integrates renewable energy with efficient energy management techniques such as MPPT, along with continuous monitoring and automation. Such a system can ensure reliable operation, optimal energy utilization, and minimal human intervention, thereby enhancing the overall efficiency and sustainability of smart agriculture.

### Proposed System

The proposed system integrates renewable energy with IoT technology to provide an efficient and automated solution for smart agriculture monitoring. It utilizes solar photovoltaic energy as the primary power source, which is optimized using a Maximum Power Point Tracking (MPPT) controller to ensure maximum energy extraction under varying environmental conditions. This approach improves energy efficiency and enables reliable system operation even in remote or off-grid agricultural areas. The system continuously monitors field conditions and supports

automated irrigation, thereby enhancing crop productivity and reducing resource wastage.

The overall system architecture consists of multiple interconnected components that work together to ensure smooth operation. Solar panels convert sunlight into electrical energy, which is regulated by the MPPT controller and stored in a battery to provide uninterrupted power supply. Various sensors, including soil moisture, temperature, humidity, and water level sensors, are deployed in the agricultural field to collect real-time data. This data is processed by a microcontroller such as Arduino, Node MCU, or ESP32, which also controls the irrigation system based on predefined conditions.

The processed data is transmitted to a cloud platform through communication modules such as Wi-Fi or GSM, enabling remote monitoring and data analysis. The cloud platform stores and visualizes the data, allowing farmers to access real-time information through mobile or web-based applications. Additionally, the system can generate alerts and automatically control irrigation when required, ensuring efficient water usage and timely response to environmental changes. Overall, the proposed system offers a reliable, energy-efficient, and scalable solution for modern smart agriculture applications.

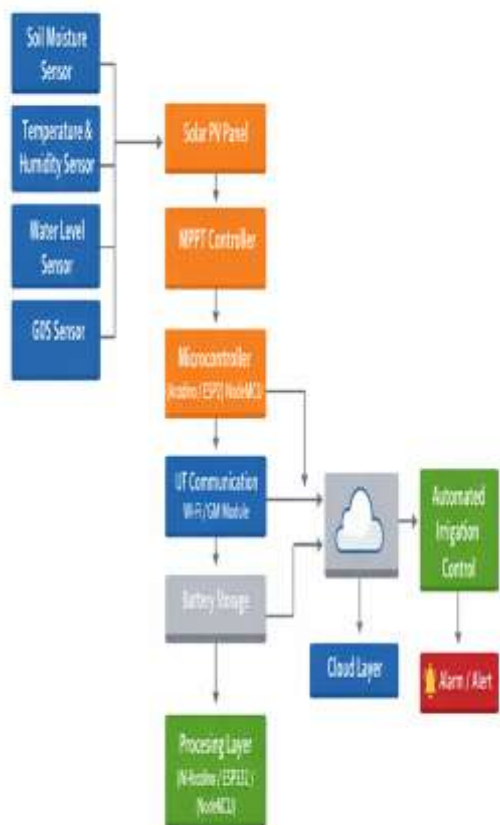
### System Architecture

The proposed system is designed using a layered architecture that ensures efficient operation, reliable communication, and optimal energy utilization. The sensing layer consists of soil moisture, temperature, humidity, and water level sensors that continuously collect real-time data from the agricultural field. To support uninterrupted operation, an energy layer is incorporated, which includes a solar photovoltaic panel integrated with an MPPT controller and battery storage system to provide efficient and continuous power supply. The collected sensor data is processed in the processing layer using a microcontroller such as Arduino, ESP32, or Node MCU, which also controls system operations like irrigation.

The communication layer enables data transmission to the cloud using technologies such as Wi-Fi or GSM, ensuring remote accessibility. The cloud layer is responsible for storing, analyzing, and visualizing the data, allowing better monitoring and decision-making. Finally, the application layer provides a user-friendly interface through mobile or web-based dashboards, where farmers can monitor real-time conditions and control irrigation automatically. This layered architecture ensures smooth data flow from sensors to end users while maintaining energy efficiency and system reliability, thereby supporting smart and sustainable agriculture.

### Working Principle

The system operates by harnessing solar energy through photovoltaic panels, which is optimized using an MPPT controller to extract maximum power under varying environmental conditions. The generated energy is stored in a battery and supplied to the entire system for continuous operation. Sensors deployed in the agricultural field continuously collect data such as soil moisture, temperature, humidity, and water level. The microcontroller processes this data and compares it with predefined threshold values. Based on the analysis, appropriate actions such as automatic irrigation are triggered when required. The collected data is transmitted through IoT communication networks like Wi-Fi or GSM to a cloud platform for storage and monitoring. Farmers can access real-time information through mobile or web applications, and alerts are generated when abnormal conditions are detected, ensuring timely decision-making and efficient farm management.



## Applications

The renewable energy-based smart agriculture system has wide applications in modern farming by improving efficiency, sustainability, and productivity. In agricultural applications, the system enables smart irrigation by automatically controlling water supply based on real-time soil moisture levels, thereby reducing water wastage. It also

supports crop monitoring by continuously tracking parameters such as temperature, humidity, and soil conditions, which helps farmers make informed decisions. Additionally, it enhances water management practices and can be applied in greenhouse automation to maintain optimal environmental conditions for plant growth. These capabilities contribute to precision farming, where accurate data and automation lead to improved crop yield.

In terms of renewable energy applications, the system utilizes solar energy to power irrigation and monitoring units, making it suitable for solar-powered farming. It is highly beneficial for off-grid agriculture, as it ensures continuous operation in remote areas without relying on conventional electricity sources. The integration of MPPT technology enables efficient energy optimization by maximizing solar power utilization under varying weather conditions. Furthermore, the inclusion of battery storage systems allows excess energy to be stored and used during nighttime or low sunlight periods, ensuring uninterrupted functionality.

The system also plays a significant role in rural and environmental applications by promoting sustainable farming practices and reducing dependency on fossil fuels. It supports smart water resource management, especially in drought-prone areas, by ensuring efficient utilization of available water resources. Additionally, it enables environmental monitoring, helping farmers plan agricultural activities based on climatic conditions. Its cost-effective nature makes it accessible to small-scale farmers, providing an affordable solution for implementing advanced agricultural technologies and improving overall farm management.

## Conclusion

The renewable energy-based smart agriculture monitoring system provides an efficient and sustainable solution for modern farming challenges. By integrating solar photovoltaic energy with an MPPT controller, the system ensures maximum power extraction and reliable operation under varying environmental conditions. The use of sensors such as soil moisture, temperature, humidity, and water level enables continuous real-time monitoring of agricultural parameters. This allows timely decision-making and supports automated irrigation, reducing water wastage and improving crop productivity.

The incorporation of IoT technology ensures seamless data transmission to cloud platforms, enabling remote monitoring and control through mobile or web applications. The system is especially beneficial for rural and remote areas where power availability is limited, as it operates independently using renewable energy sources. Overall, the proposed system enhances energy efficiency, reduces operational

costs, and promotes sustainable farming practices. It is a scalable and cost-effective solution that can be widely adopted to achieve smart and precision agriculture.

#### Future Scope

The future scope of the renewable energy-based smart agriculture system lies in the integration of advanced technologies to further enhance efficiency and productivity. The combination of IoT with Artificial Intelligence can enable predictive analysis for crop diseases, growth patterns, and smart irrigation, allowing data-driven decision-making to achieve higher yields. Advanced communication technologies such as 5G and LoRa can be incorporated to provide faster, more reliable data transmission with low latency, ensuring seamless real-time monitoring even in remote agricultural fields.

Further improvements can be achieved in energy management by implementing intelligent MPPT algorithms and integrating hybrid renewable energy systems such as solar and wind to ensure consistent power supply. Enhanced battery management systems can also be developed to improve energy storage efficiency and reduce power losses. In addition, smart farming automation can be expanded through fully automated irrigation and fertilization systems, along with the integration of drones and robotics for precision agriculture, thereby minimizing human intervention.

Moreover, the use of cloud computing and big data analytics can play a crucial role in analyzing large volumes of agricultural data to predict crop performance and support strategic planning. Historical data-based insights, combined with advanced visualization through smart dashboards, can significantly improve farm management practices. Overall, these advancements will lead to a more intelligent, efficient, and sustainable agricultural system in the future.

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