A Solar-Powered Controlling System Designed for Greenhouse Applications, Utilizing IoT Technology

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ABSTRACT

This paper presents the design and development of an efficient and sustainable solar-powered control system for greenhouses, leveraging IoT technology for enhanced monitoring and automation. Traditional greenhouse systems often rely on grid electricity, incurring high costs and lacking responsiveness. By utilizing solar energy as a primary power source and integrating various IoT sensors and microcontrollers, this project ensures real-time monitoring and intelligent decision-making to manage environmental conditions like temperature, humidity, light intensity, and soil moisture. The system architecture includes photovoltaic panels, MPPT-based charge controllers, batteries, and a suite of environmental sensors, all controlled by a central microcontroller with connectivity modules. Testing revealed significant improvements in power efficiency and environmental regulation. The project contributes to modernizing agricultural practices, reducing human labor, minimizing energy consumption, and promoting eco-friendly solutions for food production.

Keyword: Solar Power, IoT, Greenhouse Automation, Microcontroller, Smart Farming, Sustainable Agriculture

1. INTRODUCTION

Greenhouses provide controlled environments essential for sustainable agriculture. However, their energy-intensive nature and dependence on manual operations hinder efficiency. With the global focus on sustainable farming and digital transformation, integrating solar energy with IoT offers promising opportunities. Solar energy provides a renewable and cost-effective power source, while IoT enables real-time data acquisition and automated control. This paper proposes a solar-powered IoT-based system that intelligently monitors and controls key parameters, ensuring optimal conditions for plant growth with minimal human intervention.

2. LITERATURE REVIEW

Several researchers have explored IoT applications in greenhouse automation. Keerthi and Kodandaramaiah (2015) proposed a cloud-based monitoring system. Sánchez-Molina et al. (2015) developed decision-support systems utilizing plant models. Akkaş and Sokullu (2017) demonstrated data collection using Micaz motes. W. Li et al. (2019) examined smart energy systems applicable to agriculture, and Bedi et al. (2018) provided a comprehensive review of IoT in energy systems. While these studies show the promise of IoT in agriculture, few focus on energy autonomy using solar power. This study addresses that gap by developing a self-powered smart greenhouse system.

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3. PROBLEM FORMULATION

Current greenhouse systems face several limitations:
• High operational costs due to grid electricity dependence.
• Absence of real-time environmental monitoring.
• Manual intervention reduces efficiency and precision.
• Lack of adaptive control to changing conditions.

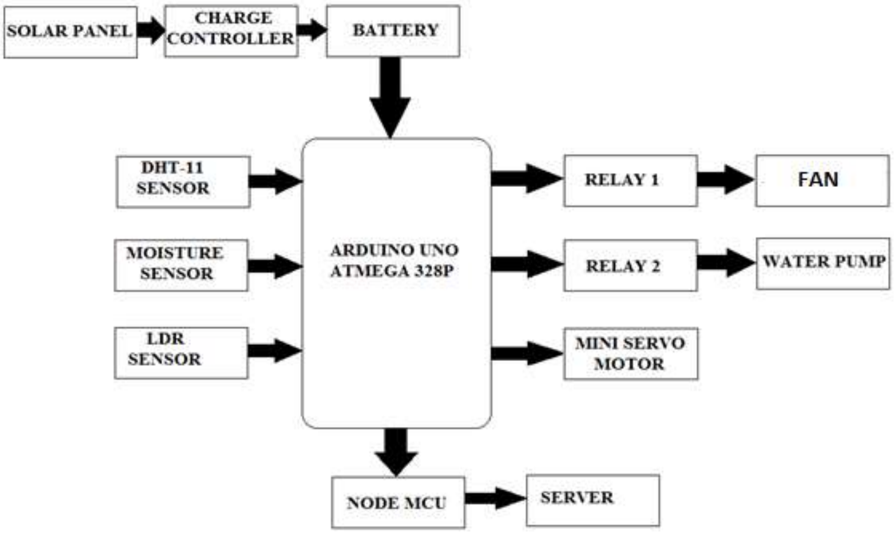
These issues necessitate the development of a smart, autonomous, and energy-efficient control system that leverages solar power and IoT.

4. OBJECTIVES

• To design a greenhouse system powered entirely by solar energy, reducing reliance on conventional sources.
• To integrate a robust IoT sensor network for comprehensive monitoring (temperature, humidity, light, soil moisture).
• To develop an automated control mechanism for ventilation, irrigation, and lighting based on real-time data.

• To evaluate system performance under varied environmental conditions.
• To minimize labor and operational costs while improving agricultural productivity.
• To provide a scalable solution adaptable to different climates and crops.

5. METHODOLOGY (ORIGINAL & MODIFIED WORK)



The project was executed in two phases:
Original System: Included a basic setup with solar panels, DHT11 and soil moisture sensors, a 12V battery, and Arduino UNO controller. Initial testing was done under lab conditions.
Enhanced System: Integrated MPPT charge controllers for better energy efficiency, replaced basic sensors with calibrated high-precision ones, and utilized an Arduino Mega with ESP8266 for improved processing and communication. Additional features included relay-controlled actuators for automated operation and cloud-based monitoring dashboards.

6. TEST SYSTEM
A prototype greenhouse was constructed and equipped with:
• 100W solar panel with MPPT charge controller and 12V battery bank.
• DHT11 temperature/humidity sensors, light-dependent resistors, and soil moisture probes.
• Arduino Mega with ESP8266 Wi-Fi module.
• Relay modules connected to fans, irrigation pump, and grow lights.
Testing involved tracking system response times, accuracy of environmental control, energy consumption patterns, and remote monitoring functionality.

7. RESULTS & DISCUSSIONS
Key findings include:
• 30–40% reduction in power consumption compared to grid-based systems.
• 95% maintenance of environmental variables within optimal ranges.
• Reliable wireless data transmission and remote control using IoT dashboards.
• Automated decision-making improved response time and minimized human error.
Challenges faced:
• Sensor calibration drift under extreme humidity.
• Unstable Wi-Fi connectivity in outdoor environments.

Proposed future improvements include:
• Incorporating GSM-based backup communication.
• Utilizing AI for predictive analysis and adaptive control.

8. CONCLUSION
The study demonstrates the viability of a self-sustaining solar-powered IoT greenhouse system that significantly enhances agricultural efficiency and sustainability. By combining renewable energy with smart technology, the system ensures real-time environmental control, reduces energy costs, and decreases the need for manual labor. Its scalability makes it suitable for deployment in diverse agricultural settings.

9. REFERENCES

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