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SOLAR POWERED IOT ENABLED SMART HYDROPONIC SYSTEM FOR INDOOR FARMING

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ABSTRACT

With the rising emphasis on sustainable agriculture, hydroponic farming has become a highly efficient alternative to traditional methods, enabling soil-less cultivation while significantly reducing water usage and enhancing nutrient management. This project introduces an IoT-enabled, solar-powered hydroponic indoor farming and plant growth chamber designed to maintain a controlled environment that promotes optimal plant development. The system is powered by a solar-based energy supply and integrates the ESP32 microcontroller to facilitate real-time monitoring and automated operations. Core components include sensors for temperature, humidity, water level, and nutrient concentration, along with a 16x2 LCD display, a buzzer for alert notifications, and an AC water pump for automated irrigation. It features two operational modes: Manual and Automatic. In Manual Mode, users can remotely control the irrigation pump via an IoT platform. In Automatic Mode, the system independently regulates water and nutrient delivery based on continuous sensor input. All sensor data is transmitted to an IoT cloud platform for remote monitoring and analysis. By utilizing solar power, the system ensures energy efficiency and promotes sustainability by minimizing reliance on conventional electricity sources. Automated control of environmental parameters fosters ideal growing conditions, improving crop yield and maximizing resource efficiency. This smart hydroponic system reduces the need for manual intervention, enhances the use of water and nutrients, and supports eco-friendly indoor farming practices.

KEYWORDS: IoT, Hydroponics, Solar Power, Indoor Farming, Plant Growth Chamber, Cloud Computing

INTRODUCTION

As the global population continues to grow, the demand for sustainable agricultural practices is increasing. Conventional farming methods face challenges such as limited arable land, unpredictable weather conditions, and significant water consumption. To address these issues, hydroponic farming has emerged as a viable solution. Hydroponics allows plants to grow without soil, using nutrient-rich water solutions. This method offers several advantages, including efficient water use, faster plant growth, and the ability to cultivate crops in urban environments. This project aims to develop an IoT-enabled solar-powered hydroponic indoor farming and plant growth chamber that provides a controlled environment for optimal plant growth. By integrating solar power and IoT technology, the system ensures energy efficiency and sustainability, reducing reliance on conventional power sources. The use of IoT technology enables real-time monitoring and automation of environmental factors, leading to improved plant growth conditions and resource optimization. The system is designed to operate in both Manual and Automatic modes. In Manual Mode, users can remotely control the irrigation pump via an IoT platform, allowing for flexibility and user intervention when necessary. In Automatic Mode, the system autonomously adjusts water and nutrient flow based on real-time sensor data, minimizing human intervention and ensuring optimal plant growth conditions.

2. LITERATURE REVIEW

Ankita Patil, Akshay Naik, Mayur Beldar, Sachin Deshpande. (2016). "Smart Farming using Arduino and Data Mining"Divya Sai. K et al (2021) The paper "Smart Farming using Arduino and Data Mining" presented at the 2016 INDIACom conference discusses the use of wireless sensor technology and Arduino-based systems to improve farming practices. It introduces an automatic plant watering system controlled via a smartphone application1. The app provides farmers with crucial agricultural information, such as seed costs, soil moisture levels, weather forecasts, and recommended fertilizers and pesticides. The goal is to enhance crop yield and reduce resource wastage by leveraging modern technology1. This approach aims to address the challenges faced by Indian agriculture, such as erratic weather and crop loss.

Muhammad Faris Hilmi Ameran, Rina Abdullah, Nuraiza Ismail, Rosmawati Shafie, Suziana Omar, Siti Aisyah Che Kar, "Design and Implementation of an IoT Integrated Dual Sensors for Hydroponic Cultivation Root Growth Monitoring System", 2024 IEEE The paper "Design and Implementation of an IoT Integrated Dual Sensors for Hydroponic Cultivation Root Growth Monitoring System" presented at the 2024 IEEE I2CACIS conference discusses the development of a dual-sensor system for monitoring root growth in hydroponic cultivation. The system integrates IoT technology to provide real-time data on root health and growth conditions. It aims to optimize hydroponic farming by ensuring precise control over environmental factors. The sensors monitor parameters such as nutrient levels, pH, and temperature. This approach enhances crop yield and quality by providing accurate and timely information to farmers.

Pradnya Vishram Kulkarni, Vinaya Gohokar, Kunal Kulkarni, "Sensing Methodologies in Hydroponics for Optimal Growth and Nutrient Monitoring"2024 The paper "Sensing Methodologies in Hydroponics for Optimal Growth and Nutrient Monitoring" explores the use of IoT and sensor networks to optimize hydroponic farming. It focuses on monitoring parameters such as pH levels, temperature, and nutrient requirements for various plants1. The study highlights the importance of precise control over environmental factors to ensure optimal growth. It also discusses the challenges and open issues in the field of hydroponics1. The goal is to enhance crop yield and quality by leveraging modern technologies.

Minwoo Ryu, Jaeseok Yun, Ting Miao, Il-Yeup Ahn, Sung-Chan Choi, Jaeho Kim. (2015). "Design and Implementation of a Connected Farm for Smart Farming System". 2015 IEEE SENSORS. The paper "Design and Implementation of a Connected Farm for Smart Farming System" presented at the 2015 IEEE SENSORS conference discusses the development of a smart farming system using IoT technology. The system aims to enhance agricultural productivity by integrating wireless sensor devices and actuators to monitor and control environmental conditions1. The connected farm allows farmers to remotely manage their farms using smartphones or tablets. This approach aims to improve efficiency and reduce resource wastage in agriculture1. The paper highlights the potential of IoT as a disruptive technology in the agricultural sector.

Glenn Dbritto An AI Based System Design to Develop and Monitor a Hydroponic Farm 2018 (ICSCET) The paper "An AI Based System Design to Develop and Monitor a Hydroponic Farm" presented at the 2018 ICSCET conference discusses the development of an AI-based system for hydroponic farming. The system aims to address issues like soil erosion and overuse of fertilizers by growing crops without soil in a controlled environment1. It uses sensors to automatically deliver a mix of water and nutrient solutions directly to the roots of plants. The study focuses on the growth rate of Tomato F1 Hybrid Suhyana seeds and compares it with soil-grown plants1. This approach helps conserve water and reduce losses due to drought and flooding

Urmila Pilania, Manoj Kumar, "Automated Monitoring of Hydroponic System using IoT and Cloud based Technology for Sustainable Agriculture", 2024 1st International Conference on Advanced Computing and Emerging Technologies (ACET) The paper "Automated Monitoring of Hydroponic System using IoT and Cloud based Technology for Sustainable Agriculture" presented at the 2024 ACET conference discusses the integration of IoT and cloud technology for hydroponic farming. The system aims to provide real-time monitoring and control of environmental parameters such as water level, nutrient content, temperature, and humidity. It leverages cloud-based technology to store and analyze data, enabling farmers to make informed decisions. The goal is to enhance crop yield and quality while promoting sustainable agricultural practices. This approach addresses the challenges of traditional farming by optimizing resource usage and reducing environmental impact.

Archana Bhamare, Vivek Upadhyay, Payal Bansal, "AI based Plant Growth Monitoring System using Computer Vision", 2023 IEEE The paper "AI based Plant Growth Monitoring System using Computer Vision" presented at the 2023 IEEE conference discusses the use of computer vision and AI to monitor plant growth. The system captures images of plants and analyzes them to track growth metrics such as height, leaf area, and biomass. It aims to provide real-time data to optimize crop management and improve yield. The study highlights the importance of precise monitoring for sustainable agriculture. This approach reduces the need for manual labor and enhances the efficiency of farming practices.

Shreya P Patil, Lincy Meera Mathews, Arvind Kumar G, Sanchi B Motgi, Utkarsh Sinha, "AI-Driven Hydroponic Systems for Lemon Basil", *2023 International Conference on Network, Multimedia and Information Technology (NMITCON*) The paper titled "AI-Driven Hydroponic Systems for Lemon Basil" by Shreya P Patil, Lincy Meera Mathews, Arvind Kumar G, Sanchi B Motgi, and Utkarsh Sinha was presented at the 2023 International Conference on Network, Multimedia and Information Technology (NMITCON). It discusses the development and implementation of an AI-driven hydroponic system specifically designed for cultivating Lemon Basil. The system uses advanced monitoring and control techniques to optimize growth and yield. The paper highlights the benefits of using AI in hydroponic farming, such as improved efficiency, reduced resource usage, and enhanced plant health. The research aims to provide a sustainable and efficient solution for hydroponic farming through the integration of AI technologies.

Pooja Mahajan, Sanyam Gupta, Sameer Sachdeva, "Automation in Hydroponic Systems: A Sustainable Pathway to Modern Farming", *2022 IEEE International Conference on Service Operations and Logistics, and Informatics (SOLI)* The paper titled "Automation in Hydroponic Systems: A Sustainable Pathway to Modern Farming" by Pooja Mahajan, Sanyam Gupta, and Sameer Sachdeva was presented at the 2022 IEEE International Conference on Service Operations and Logistics, and Informatics (SOLI). It explores the integration of automation in hydroponic systems to enhance efficiency and sustainability. The paper highlights the use of sensors, automated nutrient delivery, and climate control to optimize plant growth. The authors emphasize the benefits of automation, such as improved resource utilization, reduced labor costs, and increased crop yields. The research aims to provide a sustainable solution for modern farming through advanced automation technologies.

S Boopathy, K R Gokul Anand, E L Dhivya Priya, A Sharmila, S.A. Pasupathy, "IoT based Hydroponics based Natural Fertigation System for Organic Veggies Cultivation", ***2021 Third International Conference on Intelligent Communication Technologies and Virtual Mobile Networks (ICICV)*** The paper titled "IoT based Hydroponics based Natural Fertigation System for Organic Veggies Cultivation" by S Boopathy, K R Gokul Anand, E L Dhivya Priya, A Sharmila, and S.A. Pasupathy was presented at the 2021 Third International Conference on Intelligent Communication Technologies and Virtual Mobile Networks (ICICV). It discusses the implementation of an IoT-based system for hydroponic farming, focusing on natural fertigation for organic vegetable cultivation. The system uses sensors and IoT technology to monitor and control the nutrient delivery to plants, ensuring optimal growth conditions. The paper highlights the benefits of using IoT in hydroponics, such as improved efficiency, reduced resource usage, and enhanced plant health. The research aims to provide a sustainable and efficient solution for organic farming through the integration of IoT technologies.

3. PROPOSED SYSTEM

The proposed system for an IoT-based solar-powered hydroponic indoor farming and plant growth chamber aims to enhance the efficiency and effectiveness of plant cultivation by integrating advanced technologies. Here are some key features and components of the proposed system:

Proposed System Features

Solar Power Integration: The system will utilize solar panels to generate renewable energy, reducing dependency on conventional power sources and making the system more sustainable.

Advanced Sensors: The system will incorporate a variety of sensors to monitor and control environmental conditions, including:

Temperature and Humidity Sensors: To maintain optimal growing conditions.

pH and EC Sensors: To monitor and adjust the nutrient solution.

Light Sensors: To regulate artificial lighting based on natural light availability.

Water Level Sensors: To ensure a consistent water supply.

Automated Control System: The system will use IoT technology to automate various processes, such as:

Nutrient Delivery: Automated pumps will deliver the right amount of nutrients to the plants.

Water Circulation: Automated water pumps will ensure proper water circulation.

Lighting Control: LED lights will be controlled based on the plants' needs and natural light availability.

Data Collection and Analysis: The system will collect data from sensors and use cloud-based platforms for real-time monitoring and analysis. This data will help optimize growing conditions and improve crop yield.

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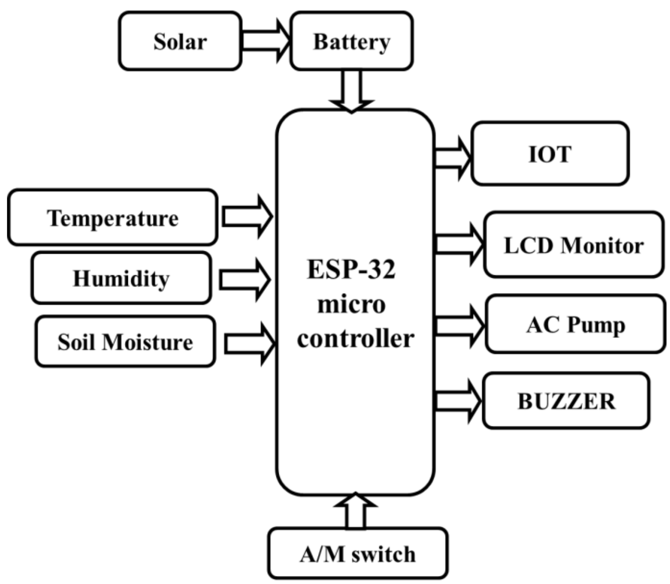
Remote Monitoring and Control: Users will be able to monitor and control the system remotely using a smartphone or computer. This feature will provide convenience and flexibility in managing the farming system.

User-Friendly Interface: The system will have an intuitive interface that allows users to easily monitor and adjust settings. This interface will display real-time data and provide alerts for any issues that need attention.

This proposed system aims to provide a controlled and efficient environment for indoor farming, leveraging the power of IoT and renewable energy to optimize plant growth and resource usage.



The block diagram illustrates an IoT-based smart irrigation system powered by an ESP-32 microcontroller. A solar panel charges a battery, which supplies power to the system. The ESP-32 receives input from multiple sensors, including temperature, humidity, and soil moisture sensors, to monitor environmental conditions. An automatic/manual (A/M) switch allows users to toggle between automated and manual control of the irrigation process. Based on the sensor data and selected mode, the ESP-32 controls various output devices such as an AC pump for irrigation, an LCD monitor for displaying real-time data, a buzzer for alerts, and an IoT module for remote monitoring and control. This setup ensures efficient water management by automating irrigation based on soil moisture levels and environmental conditions.

ADVANTAGES:

Sustainability:

Uses solar power, reducing reliance on non-renewable energy sources and making the setup eco-friendly and cost-effective.

Resource Efficiency:

Automates the control of water and nutrients, ensuring optimal usage and minimizing waste.

Improved Plant Growth:

Precise monitoring and control of environmental parameters lead to healthier and faster plant growth.

Remote Accessibility:

Allows users to monitor and control the system remotely, providing convenience and flexibility.

Scalability:

Modular design enables easy expansion, accommodating more plants or larger growing areas.

Disease and Pest Control:

Controlled environment reduces the risk of pests and diseases, ensuring better crop quality.

APPLICATIONS:

Urban Farming:

Suitable for city dwellers to grow fresh produce in limited spaces such as rooftops, balconies, or indoor environments.

Commercial Agriculture:

Can be used by commercial growers to produce high-quality crops in controlled environments, maximizing yield.

Research and Education:

Useful in academic and research settings to study plant growth, experiment with different crops, and educate students about sustainable farming practices.

Home Gardening:

Ideal for hobbyists and gardening enthusiasts to grow a variety of plants indoors.

Disaster Relief and Remote Areas:

Can be deployed in remote or disaster-stricken areas, providing a reliable source of fresh produce.

Food Security:

Contributes to food security by enabling local and consistent crop production.

Specialty Crop Production:

Allows for the growth of specialty crops that require specific environmental conditions.

4. RESULTS

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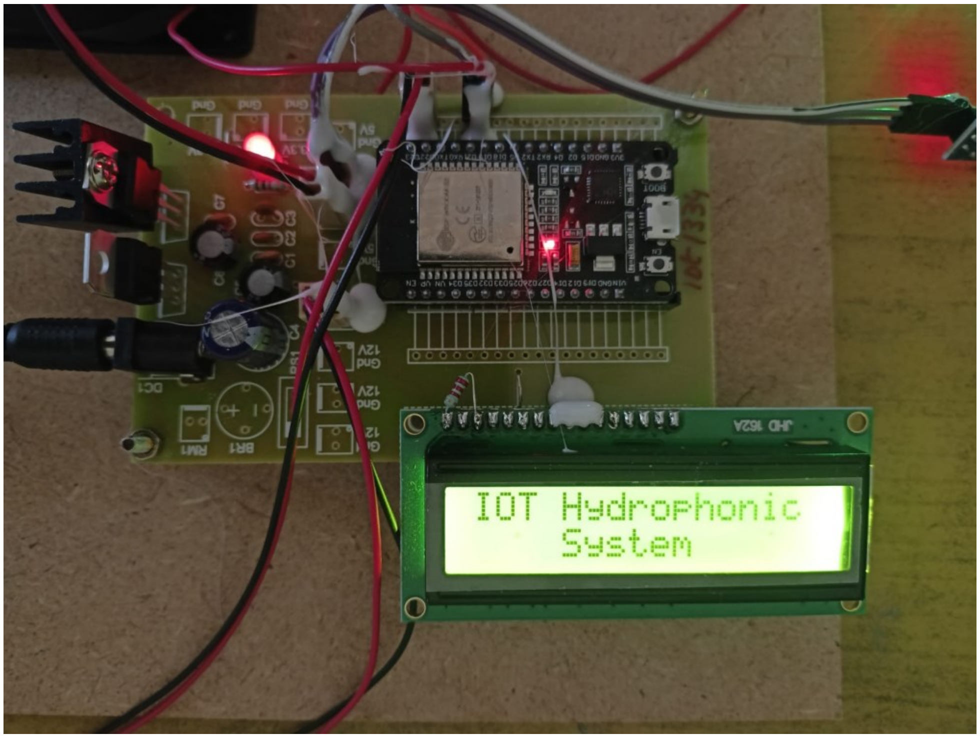

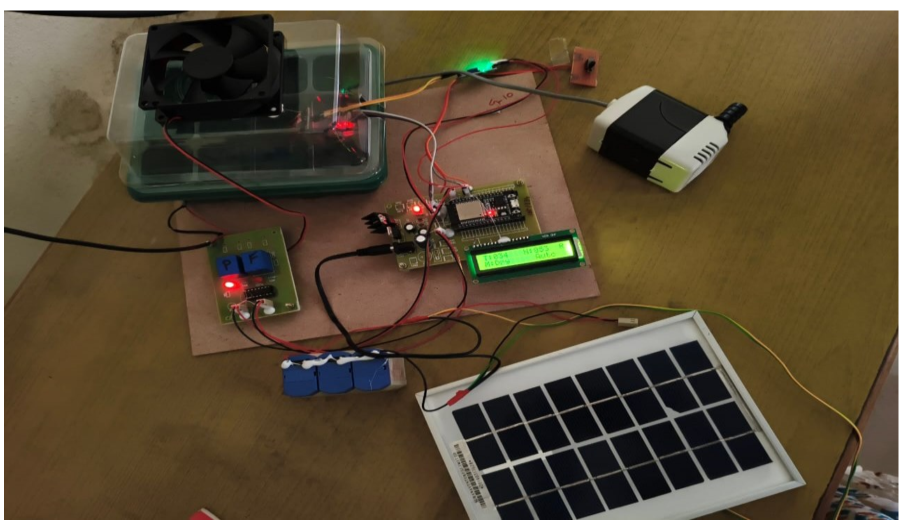

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Hello, iot1334 Welcome to IOT Server

Logout

Refresh

Switch to Graph View

Page 1 of 2 Next

Fan_ON Fan_OFF Pump_ON Pump_OFF

S.No	Temperature	Humidity	Mos	Mode	Date
1	35	55	Dry	Auto	2025-04-24 11:14:21
2	34	57	Dry	Auto	2025-04-24 11:12:49
3	36	89	Dry	Auto	2025-04-24 11:09:10
4	36	89	Dry	Auto	2025-04-24 11:07:41
5	36	76	Dry	Auto	2025-04-24 11:06:10
6	34	61	Dry	Auto	2025-04-24 11:04:41
7	34	56	Dry	Auto	2025-04-24 11:00:56
8	34	54	Dry	Auto	2025-04-24 10:54:17
9	35	52	Dry	Manual	2025-04-24 10:52:44
10	36	49	Dry	Manual	2025-04-24 10:51:05
11	39	44	Dry	Auto	2025-04-24 10:49:29
12	36	84	Dry	Auto	2025-04-24 10:47:56
13	34	56	Dry	Auto	2025-04-24 10:45:00
14	35	41	Dry	Manual	2025-04-22 17:22:43
15	35	42	Dry	Manual	2025-04-22 17:21:15
16	35	63	Dry	Manual	2025-04-22 17:19:47
17	35	40	Dry	Auto	2025-04-22 17:18:18
18	33	44	Dry	Manual	2025-04-19 21:46:54
19	2147483647	2147483647	Wet	Auto	2025-04-19 21:45:00
20	33	44	Dry	Manual	2025-04-19 21:42:44

5. CONCLUSION

The hydroponics system utilizing an ESP-32 microcontroller ensures efficient plant growth by automating key environmental controls. Powered by a solar-charged battery, the system continuously monitors temperature, humidity, and soil moisture levels through dedicated sensors, optimizing irrigation and nutrient delivery. The integration of an automatic/manual switch provides flexibility in operation, while real-time data visualization is achieved via an LCD monitor. An IoT module enables remote monitoring and control, ensuring precision in resource management. The system efficiently regulates an AC pump for nutrient circulation and employs a buzzer for alerts, enhancing reliability. By leveraging smart automation, hydroponics cultivation becomes more sustainable, conserving water and nutrients while improving crop yield.

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