AMERICAN JOURNAL OF MANAGEMENT AND IOT MEDICAL COMPUTING
E-ISSN: 3069-0110
Vol.3, No. 4(2024)
www.ajmimc.com

A SMART AGRICULTURE FRAMEWORK USING AN IOT-BASED DUAL-AXIS SOLAR TRACKING SYSTEM

SATHULURI RAMARAO

Department of Electronics and Communication Engineering (ECE)
Chalapati Institute of Technology,AR Nagar, Mothadaka, Andhra Pradesh, India- 522016
Email-id: ramarao409@gmail.com.

ABSTRACT

This project presents an IoT-based dual-axis solar tracking system integrated with a smart agriculture framework to improve energy efficiency and agricultural sustainability. The dual-axis solar tracker maximizes solar energy generation by continuously adjusting the orientation of photovoltaic panels along both horizontal and vertical axes to follow the sun's movement, ensuring optimal exposure throughout the day. IoT-enabled sensors are used to monitor key environmental parameters such as solar irradiance, temperature, and humidity in real time. Based on the collected data, an automated irrigation system dynamically regulates water usage, reducing wastage and enhancing crop productivity. Utilizing solar energy to power agricultural operations minimizes dependence on conventional electricity sources, making the system environmentally friendly and cost-effective. By integrating renewable energy with intelligent monitoring and control mechanisms, the proposed system offers a sustainable and efficient solution for modern precision agriculture.

Index Terms: IoT, Dual-Axis Solar Tracking, Smart Agriculture, Renewable Energy, Automated Irrigation, Environmental Monitoring, Solar Energy Optimization, Sustainable Farming, Eco-Friendly Systems, Precision Agriculture.

1.INTRODUCTION

Agriculture plays a crucial role in India's economic development, with irrigation systems prioritized to ensure consistent crop productivity. However, farms are frequently exposed to threats such as wild animal intrusion, leading to significant crop losses. Effective protection and continuous monitoring are therefore essential to safeguard farmland. Solar-powered fencing systems offer a reliable, eco-friendly solution by detecting animal presence and reducing dependence on conventional power sources, especially in remote rural areas. Simultaneously, automation in agriculture has become increasingly vital to improve operational efficiency, minimize manual labor, and optimize resource utilization. The integration of solar energy and intelligent systems forms the backbone of smart agriculture, enabling real-time control and decision-making. A key component of this integration is the solar tracker. Solar tracking systems orient solar panels to follow the Sun's path across the sky, maximizing energy absorption. Dual-axis trackers, which adjust the panel's position both horizontally and vertically, can improve energy output by 20–30% compared to fixed PV systems, making them ideal for energy-intensive applications. This project proposes an IoT-based dual-axis solar tracking system integrated with smart agricultural functionalities. The prototype is developed using the Arduino Uno microcontroller—an open-source, user-friendly, and cost-effective platform. The tracker operates in both automatic and manual modes. In automatic mode, Light Dependent Resistor (LDR) sensors detect sunlight intensity and adjust the panel's orientation accordingly using two servo motors. In manual mode, a potentiometer allows user control. Push-buttons are included for easy switching between control modes. A key feature of the system is real-time data acquisition and visualization using Microsoft Excel, which displays voltage, current, and power readings of the solar panel. The hardware components used are compact, inexpensive, and easily accessible, making the system ideal for educational and agricultural use. Globally, solar energy is among the most abundant and sustainable resources. The Sun delivers over 120,000 terawatts (TW) of energy to Earth's surface. Even with a modest 10% conversion efficiency, it could generate around 20 TW—double the current global consumption. In India, solar energy costs have fallen from ₹17.25/kWh to approximately ₹7.5/kWh, supporting its rapid adoption. Despite this, most solar farms still use fixed PV systems due to the high cost of tracking systems. This project aims to overcome that limitation by introducing a low-cost, efficient dual-axis tracker integrated with smart agriculture, contributing to sustainable and energy-efficient farming practices.

1.1 SOLAR FENCE

Solar fencing uses security fencing sensors and Passive Infrared (PIR) sensors to detect wild animal intrusion along farm boundaries. The solar-powered system provides early warnings and activates alerts or deterrents to prevent crop damage. Operating on renewable energy, it is suitable for remote areas and offers an economical, energy-efficient, and sustainable solution for agricultural field protection.

1.2 AUTOMATIC IRRIGATION SYSTEM

In agriculture, farmers often face difficulties in maintaining timely and adequate irrigation, which can lead to poor crop quality and reduced yields. Continuous monitoring of soil moisture is essential to determine whether the soil is dry or sufficiently wet. With advancements in automation, irrigation processes can be efficiently controlled to reduce manual labor and time consumption. The proposed automatic irrigation system uses soil moisture sensors to monitor field conditions in real time and automatically supply water when required. This ensures optimal soil moisture levels without human intervention. As a result, farmers are not required to visit the farm frequently, while water usage is optimized and crop productivity is improved.

2.LITERATURE SURVEY

Several researchers have investigated the design and implementation of solar-powered electric fencing systems for livestock control and agricultural field protection using diverse methodologies. Suraj Dilip Chinchole and Sampada Milind Jadhav presented a detailed study that begins with fundamental concepts of electric fencing technology. They proposed an improved design methodology for livestock electric fence energizer circuits and impulse transformers, utilizing transmission line theory and propagation wave analysis. Their work emphasizes adherence to safety standards and includes a validated circuit model supported by real-time fence measurement results. In a different approach, Mr. Chandolu Sai Deepak and Mohammed Arbaz Ali developed a solar-based electric fencing system that employs operational amplifier circuits for detecting animal intrusion and generating early warning signals. Their system integrates key components such as energy storage units, a shocking circuit, and an ON/OFF control mechanism regulated by a Passive Infrared (PIR) sensor. This design offers an efficient and energy-conscious alternative to conventional fencing solutions. Similarly, S. Firdosh Parveen and Sabeeha Atahar proposed a microcontroller-based solar electric fence system incorporating a solar panel, ULN2003 driver IC, controller circuitry, and an alert buzzer. In their approach, a 12 V rechargeable battery is charged using solar energy, with voltage regulation handled by the controller circuit. The driver circuit manages current flow, while the buzzer provides audible alerts during fence interruptions. The system is designed to deliver a short-duration, low-intensity electric shock, ensuring safety while effectively deterring both animals and humans.

Received: 03-10-2024 | Accepted: 08-11-2024 | Published: 16-11-2024 |

3.SYSTEM ANALYSIS

3.1 EXISTING SYSTEM

Conventional agricultural systems largely depend on manual monitoring and control, leading to inefficient utilization of resources and delayed decision-making. Farmers are required to physically assess environmental conditions and manually operate irrigation equipment, which often results in untimely responses to variations in weather and crop requirements. Additionally, most traditional farming practices rely heavily on grid-based electricity, increasing operational costs and limiting sustainability. These systems also lack adequate automation in critical areas such as energy management, farm security, and environmental monitoring, thereby reducing overall efficiency, productivity, and effective resource conservation.

3.2 PROPOSED SYSTEM

The proposed system provides a smart and energy-efficient solution for modern agriculture by integrating a dual-axis solar tracking mechanism with IoT-based automation. An Arduino Nano, along with four LDR sensors, controls two servo motors to continuously adjust the solar panel orientation for maximum solar energy capture. An ESP32 microcontroller is used for real-time monitoring by interfacing with sensors such as DHT11 for temperature and humidity, LDR for light intensity, and PIR for motion detection. Sensor data is transmitted to the Blynk IoT platform, allowing remote monitoring and control. PIR sensors also enhance farm security by detecting movement and generating alerts.

4.IMPLEMENTATION

4.1 BLOCK DIAGRAM OF THE PROJECT:

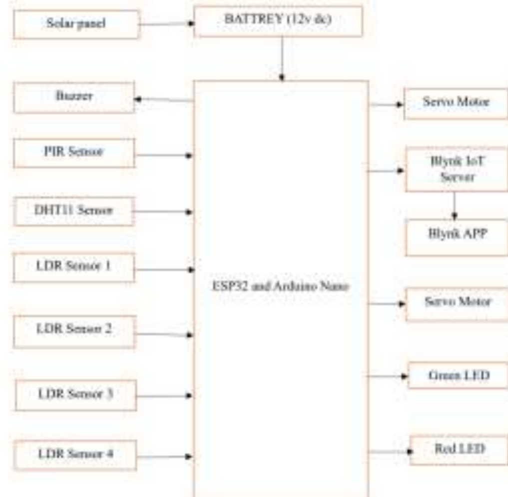

Fig 4.1 Block Diagram

4.2 WORKING PRINCIPLE

The proposed system detects the entry of animals or humans into the farm using PIR sensors and fencing sensors. Upon detection, the system activates voice announcements through a speaker to deter intruders and simultaneously sends real-time alerts to the farmer via an IoT platform. The primary objective is to prevent crop damage and reduce losses caused by animal intrusion, thereby improving crop yield. In addition, soil moisture levels are continuously monitored, and irrigation is automated using IoT-based control. When dry conditions are detected, the water pump is automatically turned ON. Notification alerts are generated whenever abnormal conditions occur.

5.RESULT

The proposed system was successfully designed and implemented in accordance with the specified hardware and software requirements. Experimental results demonstrate that all system components operate as intended, validating the effectiveness of the dual-axis solar tracking mechanism, IoT-based monitoring, automated irrigation, and intrusion detection features. The system responds accurately to environmental changes and intrusion events, providing timely alerts and automated control actions. Owing to its innovative design and practical applicability, the proposed solution shows significant potential for real-world agricultural deployment. The experimental setup and implementation of the developed prototype are illustrated in the corresponding hardware demonstration.

Fig.5.1 Practical Representation of kit

Fig.5.2 Practical Representation of Result

6.CONCLUSION

The proposed system offers a low-cost, energy-efficient, and smart embedded solution for farmland protection and management. It effectively prevents crop loss by detecting intruders and wild animals, thereby safeguarding agricultural areas. The system assists farmers by reducing financial losses and improving field security. Additionally, real-time weather monitoring and automated motor pump control enhance irrigation efficiency, minimize manual intervention, and support sustainable agricultural practices, making the system highly beneficial for modern farming applications.

7.FUTURE SCOPE

Agriculture is the backbone of every nation, and advancements in agricultural technologies are crucial for enhancing crop yield and quality. The design and development of smart crop protection systems, as well as the implementation of wireless sensor platforms, represent important initial steps in this field. Future work can focus on expanding these systems for large-scale deployment, integrating advanced IoT and AI-based decision-making, and improving energy efficiency. Collaborative efforts involving research teams, government support, and industry participation can further enhance sustainable and technology-driven agriculture.

8.REFERENCES

1. Kulkarni, A. H., & Patil, R. K. A. (2012). Applying image processing technique to detect plant diseases. International Journal of Modern Engineering Research, 2(5), 3661–3664.
2. Revathi, P., & Hemalatha, M. (1990). Classification of cotton leaf spot diseases using image processing edge detection techniques.
3. Khmag, A. Recognition system for leaf image based on its leaf contour and centroid.
4. Taware, T. H., Badgujar, R. D., & Patil, P. G. (2012). Crop disease detection using image segmentation. National Conference on Advances in Communication and Computing, World Journal of Science and Technology, 190–194, Dhule, Maharashtra, India.
5. Sankar Das, S. (2024). Transforming Data: Role of Data catalog in Effective Data Management. International Journal for Research Trends and Innovation, 9(12). https://doi.org/10.56975/ijrti.v9i12.207245
6. Dhaygude, S. B., & Khumbar, N. P. (2013). Agricultural plant leaf disease

detection using image processing. International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, 2(1), 599–602.

7. Tarawneh, M. S. (2013). An empirical investigation of olive leaf spot disease using auto-cropping segmentation and Fuzzy c-means classification. World Applied Sciences Journal, 23(9), 1207–1211.
8. Prodduturi, S.M.K. (2024). ‘Legal challenges in regulating AI-powered cybersecurity tools’, International Journal of Engineering & Science Research, 14(4), pp. 316–323
9. Ramesh, S. M., & Shanmugan, A. (2011). A new technique for enhancement of color images by scaling the discrete cosine transform coefficients. International Journal of Electronics and Communication Technology (IJECT), 2(1), March.
10. Naga Charan Nandigama, “Data-Driven Cyber-Physical Customer Experience Management In Iort-Enabled Banking Infrastructures,” International Journal of Data Science and IoT Management System, vol. 2, no. 3, pp. 22–27, Aug. 2023, doi: 10.64751/ijdim.2023.v2.n3.pp22-27.
11. Wang, H., Li, G., Ma, Z., & Li, X. (2012). Image recognition of plant diseases based on back propagation networks. 5th International Conference on Image and Signal Processing, 894–900, Chongqing, China.
12. Menukaewjinda, A., Kumsawat, P., Attakitmongcol, K., & Srikaew, A. (2008). Grape leaf disease detection from color image using hybrid intelligent system. Proceedings of Electrical Engineering/Electronics, Computer, Telecommunication and Information Technology (ECTI-CON), 1, 513–516, Krabi, Thailand.