Sustainable Automatic Irrigation System with Dual Axis Tracker

Kunal, Parul Priya, Seema Arora, Nikhil Gupta

Department of Electrical Engineering
Greater Noida Institute of Technology, India
kunal_2100550@gniotgroup.edu.in, parul_2100890@gniotgroup.edu.in, seema.ee@gniot.net.in, hodee@gniot.net.in

ABSTRACT: This paper describes an innovative solution to improve the efficiency of solar panels in agricultural irrigation systems by incorporating a dual-axis tracker and light-dependent resistors. By using sensor-based irrigation control, and real-time weather monitoring technologies and further integrating these solutions, farmers can improve the efficiency, effectiveness, and sustainability of agricultural irrigation practices, ultimately enhancing crop yields and contributing to economic development in agricultural communities. By automating irrigation processes and utilizing renewable energy sources, such systems can contribute significantly to improving agricultural productivity while minimizing environmental impact.

Keywords: Solar Panel Installation, Dual-Axis Tracking, Agro-Based Automation, IoT Technology, Arduino Micro-controller.

1. INTRODUCTION

It's evident that the increasing global population and energy demands require a shift towards sustainable energy sources. Solar energy indeed stands out as a front runner due to its renewable nature and minimal environmental impact. Its versatility in powering various devices and systems, including DC loads like battery chargers and irrigation systems, makes it particularly attractive.

In terms of irrigation, traditional methods like Dhekli are being replaced by more efficient modern techniques such as sprinklers and tube wells. This transition is crucial given the heavy reliance on water in agriculture and the need to optimize water usage. Smart irrigation systems are a significant advancement in this regard, ensuring that water is supplied efficiently and without wastage. This becomes especially vital in agricultural settings where water resources are often limited.

Overall, the adoption of renewable energy sources like solar power and the implementation of smart irrigation systems represent important steps towards sustainability and resource conservation. The focus on utilizing solar power for various applications, including agriculture, reflects a crucial shift towards sustainable practices, particularly in regions like India where agriculture is a cornerstone of the economy. With a significant portion of the population engaged in agriculture, ensuring efficient water management becomes paramount, especially in the face of depleting groundwater resources and increasing water scarcity.

Implementing agro-based automation for irrigation can indeed be a game-changer in optimizing water usage in rural areas. By utilizing technology to coordinate irrigation efforts and minimize wastage, farmers can better cope with water scarcity challenges. Additionally, promoting rainwater harvesting and water conservation campaigns can further supplement water resources, reducing reliance on groundwater.

The integration of electronic equipment and instrumentation powered by solar energy can also revolutionize water management in areas lacking access to traditional power sources. This not only enhances the efficiency of water usage but also reduces the environmental impact associated with conventional energy sources.

Overall, these initiatives underscore the importance of sustainable practices and the role of technology, particularly solar power, in addressing pressing challenges such as water scarcity and agricultural sustainability. By harnessing renewable energy and adopting innovative approaches, we can pave the way for a more resilient and environmentally friendly future. Developing a comprehensive sensor-based irrigation system that leverages soil moisture sensors and water level detectors to optimize water usage in agricultural fields is the objective of our work. By continuously monitoring soil moisture levels and water levels, the system can efficiently regulate the operation of the pump motor, ensuring that water is only apply, when necessary, thus reducing wastage.

The integration of solar panels to power the system aligns with the sustainability goals of utilizing renewable energy sources. The inclusion of a dual-axis tracker for the solar panel further enhances its efficiency by ensuring optimal orientation towards the sun, maximizing energy output. Additionally, incorporating a weather forecast system provides valuable information to farmers, allowing them to make informed decision regarding irrigation scheduling based on predicted weather patterns.

Our work demonstrates a practical application of technology to address real-world challenges in agriculture, particularly in water management. By automating irrigation processes and utilizing renewable energy sources, such systems can contribute significantly to improving agricultural productivity while minimizing environmental impact.

2. LITERATURE REVIEW

The advancements in solar-powered irrigation systems and their potential to revolutionize agricultural practices, particularly in remote areas with limited access to stable electricity. The work carried out by the other authors highlight the importance of utilizing smart technology and renewable energy sources to enhance irrigation efficiency and optimize water usage [1].

The system effectively integrates solar panels with soil moisture sensors and microcontrollers to automate the irrigation process. By utilizing GSM technology, real-time updates about pump status are sent to the farmer's mobile phone, ensuring efficient water management even in remote locations. Additionally, the versatility of the system allows for various applications beyond irrigation, such as mobile phone charging and weather monitoring, enhancing its utility and cost-effectiveness.

Similarly, authors research [2] emphasize the role of smart technology in irrigation systems, leveraging solar energy and IoT technology to automate irrigation based on soil moisture levels and weather forecasts. This intelligent system provides real-time updates to users and ensures optimal water usage, contributing to sustainable agricultural practices.

Both projects showcase innovative approaches to address water scarcity challenges and improve agricultural productivity through the integration of solar power and smart technology. By harnessing renewable energy sources and leveraging modern advancements, these systems offer promising solutions for sustainable irrigation practices.
A moisture sensor is used to collect the soil moisture data, enabling the pump to shut off once irrigation requirements are met and activate again when the soil dries out. The entire system is controlled by an Arduino Micro-controller. This project emphasizes sustainable power generation by harnessing two renewable energy sources, resulting in affordable and eco-friendly electricity production.

The authors research [3] showcases a sophisticated approach to maximizing solar energy utilization for irrigation purposes through the integration of a single-axis solar tracking system with intelligent irrigation control modes. By dynamically adjusting the orientation of the photovoltaic panel based on real-time Light Dependent Resistor (LDR) sensor values, the system optimizes solar energy absorption throughout the day. The irrigation system features two distinct operating modes: an automatic mode, which activates the water pump based on soil moisture readings, and a GSM module mode, which enables remote control of the pump via GSM technology. This combination of solar tracking technology and intelligent irrigation control not only enhances energy efficiency but also improves agricultural productivity by ensuring optimal water management.

The authors research [4] introduces an innovative IoT-based solar-powered smart irrigation system with monitoring and control features. By incorporating sensors for precise environmental monitoring and an Android application for user interface, the system enables real-time monitoring and control of irrigation processes. This empowers farmers to make informed decisions, optimizing water usage and energy efficiency. The integration of IoT technology and solar power represents a significant advancement in addressing the challenges of water and power scarcity in agriculture, promising a more sustainable and technologically advanced future for farming practices.

Both studies demonstrate the potential of advanced technologies, such as solar tracking, GSM, and IoT, to revolutionize irrigation systems, improving efficiency, productivity, and sustainability in agriculture. By harnessing renewable energy sources and leveraging intelligent control mechanisms, these systems offer practical solutions to the pressing challenges faced by farmers worldwide. The innovative approaches in [5] utilizing renewable energy sources and smart technology to enhance irrigation systems in agriculture.

The authors research highlights the benefits of solar-powered water pumping systems in agriculture, which reduce dependency on conventional energy sources and mitigate manpower requirements through automation using humidity sensors and GSM modules. This approach not only enhances efficiency but also contributes to sustainable agricultural practices.

The authors work addresses the challenges associated with traditional pressurized irrigation systems, such as over-irrigation and under-irrigation, by introducing a solar-powered smart irrigation system (SIS) equipped with soil moisture sensors. By leveraging real-time data from these sensors, the system autonomously adjusts irrigation levels, optimizing water usage and crop yield while reducing manpower dependency and energy consumption.

The integration of PV panels with an automatic irrigation system, incorporating sensors to monitor soil humidity and air temperature for precise irrigation control is demonstrated [6] and the use of two-axis solar tracking ensures optimal solar energy absorption, further enhancing the efficiency and effectiveness of the system is discussed.

Overall, the studies done by the researchers [8,10] showcase the potential of renewable energy sources, smart technology, and sensor-based monitoring systems to revolutionize irrigation practices in agriculture, leading to improved productivity, resource efficiency, and sustainability.

3. PROBLEM STATEMENT

The problem statement highlighted by the authors of the research work underscores several challenges faced by farmers in agricultural irrigation, particularly in the absence of efficient solar tracking systems and real-time weather information.

1. Inadequate Solar Efficiency: Without solar tracking systems, the efficiency of solar panels may not be optimized, leading to suboptimal energy production. This inefficiency can impact the overall effectiveness and reliability of solar-powered irrigation systems.

2. Manual Monitoring of Water Levels: Farmers often rely on manual methods to monitor water levels during irrigation, which can be time-consuming and prone to errors. This manual approach may result in over-irrigation or under-irrigation, leading to water wastage or crop damage.

3. Lack of Weather Forecasting: Many farmers lack access to real-time weather information, which hinders their ability to plan irrigation activities effectively. Without knowledge of upcoming weather conditions, farmers may struggle to make informed decisions regarding irrigation scheduling and water management.

Addressing these challenges requires the development and implementation of innovative solutions, such as advanced solar tracking systems, sensor-based irrigation control, and real-time weather monitoring technologies. By integrating these solutions, farmers can improve the efficiency, effectiveness, and sustainability of agricultural irrigation practices, ultimately enhancing crop yields and contributing to economic development in agricultural communities.

4. DEPLOYMENT METHODOLOGY ON AUTOMATIC IRRIGATION THROUGH DUAL AXIS TRACKER

The methodology for implementing automatic irrigation with a dual-axis tracker typically involves several key steps:

1. System Design and Component Selection: Begin by designing the automatic irrigation system, considering the factors such as the size of the agricultural area, water requirements of the crops, and available solar resources. Select appropriate components such as solar panels, water pumps, sensors (e.g., soil moisture sensors, temperature sensors), microcontrollers, and communication modules (e.g., GSM module).

2. Solar Panel Installation and Dual-Axis Tracking: Install the solar panels in the agricultural field and implement the dual-axis tracking mechanism. The dual-axis tracker adjusts the orientation of the solar panels to maximize solar energy absorption by continuously tracking the sun's position in both azimuth and elevation angles.

3. Sensor Integration: Integrate sensors into the irrigation system to monitor relevant parameters such as soil moisture levels, ambient temperature, and light intensity. Soil moisture sensors are particularly important for determining when irrigation is required based on the moisture content of the soil.

4. Microcontroller Programming: Program the microcontroller (e.g., Arduino, Raspberry Pi) to interface with the sensors, control the water pump, and manage the irrigation schedule. The microcontroller should implement algorithms for analyzing sensor data and determining when to activate the water pump based on predefined thresholds.

5. Communication Setup: Configure communication modules such as GSM or Wi-Fi to enable remote monitoring and control of the irrigation system. This allows farmers to receive real-time updates on system status and adjust irrigation settings as needed using their mobile phones or other devices.

6. Simulation and Testing: Use simulation software to model the behavior of the irrigation system and validate the control algorithms before deploying the system in the field. Conduct thorough testing of the hardware and software components to ensure proper functionality and reliability.

7. Field Deployment and Optimization: Install the automatic irrigation system in the agricultural field and fine-tune the system parameters based on field observations and feedback also the monitor system performance over time and make adjustments as necessary to optimize irrigation efficiency and crop yields.

By following this methodology, farmers can implement an effective automatic irrigation system with a dual-axis tracker, leveraging solar energy to efficiently manage water resources and enhance agricultural productivity. The authors have proposed an innovative solution to improve the efficiency of solar panels in agricultural irrigation systems by incorporating a dual-axis tracker and light-dependent resistors (LDRs).

The breakdown of the components and their functions is discussed for execution:

1. Solar Panel with Dual Axis Tracker: The solar panel is equipped with a dual-axis tracker, which allows it to adjust its orientation both azimuthally and elevation ally to track the movement of the sun throughout the day. This ensures that the solar panel receives maximum sunlight exposure, thereby maximizing energy production.

2. Light-Dependent Resistors (LDRs): LDRs are mounted on the solar panel to detect the intensity and direction of sunlight. By continuously monitoring sunlight levels, the LDRs provide feedback to the system, enabling it to accurately track the sun's position and adjust the orientation of the solar panel accordingly.

3. Servo Motor: The servo motor is used to rotate the solar panels based on the input received from the LDRs. It precisely adjusts the orientation of the solar panel to ensure optimal alignment with the sun's position.

5. BLOCK DIAGRAM REPRESENTATION

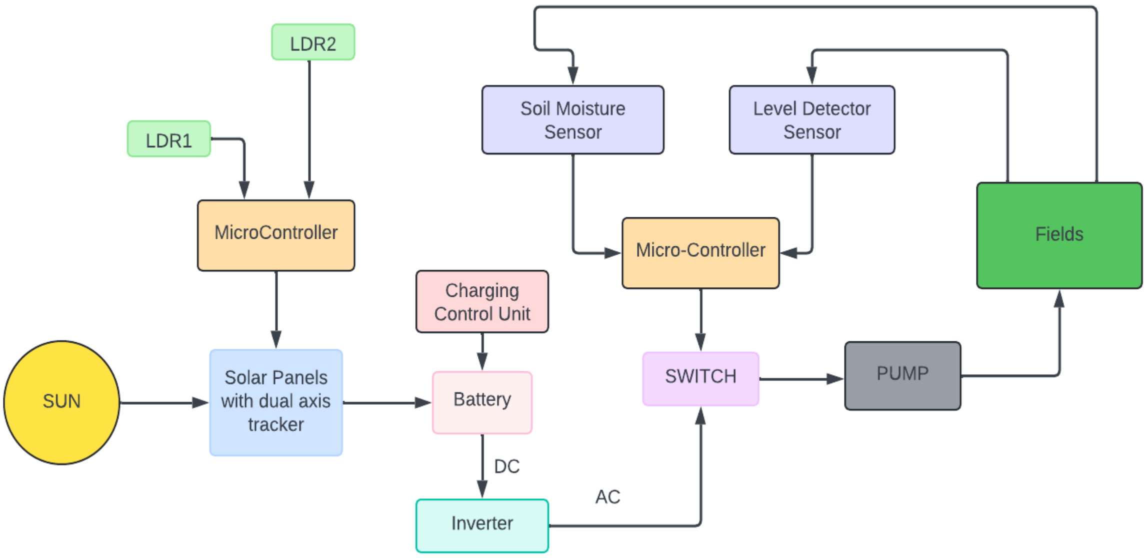

Fig.1. Block Diagram for effective dual-axis tracker system

This breakdown provides a clear overview of the components involved in the solar-powered irrigation system:

Solar Panels: These panels absorb sunlight and convert it into electricity, providing a clean and renewable energy source for the system.

Dual Axis Tracker Mechanism: The tracker ensures that the solar panels are always oriented optimally to maximize sunlight absorption, thereby improving the overall efficiency of the system.

Light Dependent Resistor (LDR): LDRs track sunlight intensity and provide data to the microcontroller, enabling it to adjust the orientation of the solar panels to face the sun.

Battery: Rechargeable batteries store excess energy generated by the solar panels for later use, ensuring continuous operation of the system even when sunlight is unavailable.

Charging Control Unit: This unit manages the charging process of the batteries, preventing overcharging or undercharging to prolong battery lifespan and ensure reliable performance.

Switch: The switch controls the flow of electricity within the system, allowing users to turn the system on or off as needed.

Soil Moisture Sensor: These sensors measure the moisture content in the soil, enabling precise irrigation control to prevent overwatering or underwatering of crops.

Level Detector Sensor: Used to detect the water level in the fields, ensuring that crops receive the appropriate amount of water for optimal growth.

Inverter: Converts the DC power generated by the solar panels into AC power, which is required to operate the water pump.

Pump: The pump is responsible for moving water from its source (e.g., well or reservoir) to the fields for irrigation, ensuring consistent water supply to the crops.

Each component plays a crucial role in the functionality and efficiency of the solar-powered irrigation system, contributing to improved agricultural productivity and sustainability.

6. CONCLUSIONS

We propose a solution of integrating a dual-axis tracker and light-dependent resistors (LDRs) into agricultural irrigation systems. This will represent an innovative approach to enhancing the efficiency of solar panels. By continuously adjusting the orientation of the solar panels to track the sun's movement and maximize sunlight absorption, the dual-axis tracker will ensure an optimal energy generation throughout the day.

Additionally, the incorporation of LDRs will enable precise tracking of sunlight intensity, providing real-time feedback to the system for accurate solar panel alignment. This combined approach will not only improve the overall efficiency of solar energy utilization but will also enhance the performance and effectiveness of the irrigation system.

By leveraging solar energy and advanced tracking technology, farmers can effectively manage water resources, optimize crop growth conditions, and ultimately enhance agricultural productivity in a sustainable manner.

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