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Advance Solar Tracking and Automatic Sprinkler Irrigation System

Shweta Patil, Preeti Navale, Vaishnavi Suryawanshi, Prof. S. K. Godase
UG Students, Department of Electronics and Telecommunication Engineering,
Assistant Professor, Department of Electronics and Telecommunication Engineering
SKN Sinhgad College of Engineering, Pandharpur
shwetapatil51869@gmail.com, navale.preeti28@gmail.com
vaishnavisuryawanshi41@gmail.com, sonali.karche@sknscoe.ac.in

Abstract: *This project suggests an Advanced Solar Tracking and Automatic Sprinkler Irrigation System that is improved by next-generation sensor technologies and mobile message integration. In comparison to static panels, the system greatly increases power generation by optimising solar panel orientation throughout the day using a single-axis solar tracker. High-precision temperature and soil moisture sensors are combined with an automated irrigation system to track field conditions in real time. The technology autonomously regulates sprinkler water distribution based on sensor feedback, minimising water waste and preserving ideal soil moisture levels. Farmers can receive real-time SMS warnings about soil conditions, irrigation events, and solar power efficiency thanks to a GSM-based communication module. Without requiring physical presence, this mobile integration enables remote monitoring and decision-making. Using LDR+servo modules for precise solar tracking, DHT22 sensors for high-accuracy temperature and humidity data, and capacitive soil sensors for durability. This Internet of Things-enabled solution supports smart farming, lowers energy and water usage, and boosts agricultural productivity. The design is an important step towards sustainable agro-tech solutions because it is affordable, scalable, and flexible for both small and big farms.*

Keywords: Advanced Solar Tracking

I. INTRODUCTION

One possible way to deal with these issues is to combine smart automation technologies with renewable energy. An inventive method for improving solar energy generation performance and automating the irrigation process in agricultural fields is the Advanced Solar Tracking and Automatic Sprinkler Irrigation System. A solar tracking mechanism is used to maximise solar energy capture, and an intelligent, sensor-based irrigation system is used to conserve water. These are the two main goals of the system.

A microcontroller or microprocessor unit (such as an Arduino or PIC) controls a dual-axis or single-axis mechanism powered by servo motors in the sun tracking subsystem. The solar panel can dynamically shift its orientation towards the direction of greatest solar irradiance thanks to light-dependent resistors (LDRs), which measure the intensity of sunlight in different directions. By doing this, the energy harvesting efficiency is greatly increased in comparison to traditional fixed solar panels, which receive less sunlight for the most of the day.

Soil moisture sensors are used by the autonomous sprinkler irrigation subsystem to track the soil's water content in real time. The microprocessor automatically turns on the sprinkler system and water pump to irrigate the field when the moisture content drops below a certain threshold. To avoid over-irrigation and water waste, the system shuts off the pump as soon as the appropriate moisture level is reached. By ensuring that the crops receive enough water, this

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closed-loop control system improves yield and conserves resources. In order to improve the irrigation logic according to external circumstances, the system can also include temperature and humidity sensors.

Since this combination system runs solely on solar power, it is an environmentally responsible and self-sufficient option for isolated agricultural areas with restricted connection to the electrical grid. The tracking and watering systems are powered by renewable energy, which utilisation, and energy production via a web-based or mobile interface. Numerous benefits come with putting such a system in place, such as increased solar panel efficiency (up to 30–40%), significant water savings (up to 50%), and less manual involvement in agricultural activities. Small and medium-sized farmers would especially benefit from this initiative since it offers a dependable and reasonably priced automation solution that promotes sustainable agriculture.

Innovative systems that effectively manage natural resources while requiring the least amount of human labour are now required due to the growing emphasis on sustainable energy generation and intelligent agriculture techniques worldwide. Since agriculture is the foundation of many economies, it requires cutting-edge technologies that can solve the dual problems of water conservation and energy optimisation. In order to support sustainable farming, the Advanced Solar Tracking and Automatic Sprinkler Irrigation System with GSM Integration combines wireless communication, intelligent irrigation, and renewable energy harvesting into a unified, automated framework.

In conclusion, the Advanced Solar Tracking and Automatic Sprinkler Irrigation System with GSM Module is an economical, clever, and environmentally responsible precision farming solution. It greatly advances the goal of sustainable and intelligent agricultural growth by improving irrigation control and solar energy use while also giving farmers remote system access.

II. LITERATURE REVIEW

In order to create automated and energy-efficient crop management systems, precision agriculture researchers have been actively studying the integration of solar energy with intelligent irrigation and communication technology. The development of sensor-based and solar-powered irrigation systems that are connected to GSM and IoT technologies has been greatly aided by a number of research.

An Arduino-based automatic irrigation system with SMS-based control for automation and monitoring was presented by H. M. Yasin et al. [1]. The system used soil moisture sensing. Their technique laid the groundwork for remotely controlled irrigation systems by demonstrating dependable GSM connectivity and efficient irrigation scheduling. Using a single-axis tracking technique, Pai et al. [2] created an automated water pumping and solar tracking system that greatly increased solar energy utilisation efficiency when compared to fixed systems. Using a dual-axis solar tracker, Gauri Bhosale et al. [3] created an intelligent irrigation system that maximised solar power generation for irrigation pumps. The need of integrating intelligent irrigation control with dual-axis solar tracking to optimise energy use. This research showed that solar-powered irrigation systems are advantageous for small-scale farmers both financially and environmentally.

The potential of dual-axis solar tracking systems in agricultural settings, which increase energy collecting efficiency and guarantee continuous irrigation operations, was also highlighted by Kanwal et al. [4]. In order to accomplish sustainable irrigation, especially in rural locations with restricted grid access, D. Ubharbande et al. [5] and Sri Tarun et al. [6] presented IoT-enabled dual-axis solar tracking irrigation systems that combine wireless control and renewable energy. Created an all-terrain irrigation system with real-time moisture control that runs on solar power, showcasing how automation and renewable energy can coexist.

In order to maximise photovoltaic power conversion through clever tracking algorithms, Gupta et al. [7] looked into solar radiation tracking for agricultural use. Centred on dual-axis solar tracking devices, which allow for elevation and azimuthal changes to maximise sun radiation. These systems showed an increase in power generating efficiency of up to 40%. By presenting IoT-enabled smart irrigation systems that combine solar energy, environmental sensing, and rainfall forecasting, Mannu et al. [8] and Balamurali et al. [9] expanded on this work and moved closer to adaptive and data-driven irrigation management.In order to increase irrigation precision, Ahmadi Pargo et al. [10] presented a hybrid agent-based Internet of Things irrigation system that uses dynamic system modelling to optimise water distribution.

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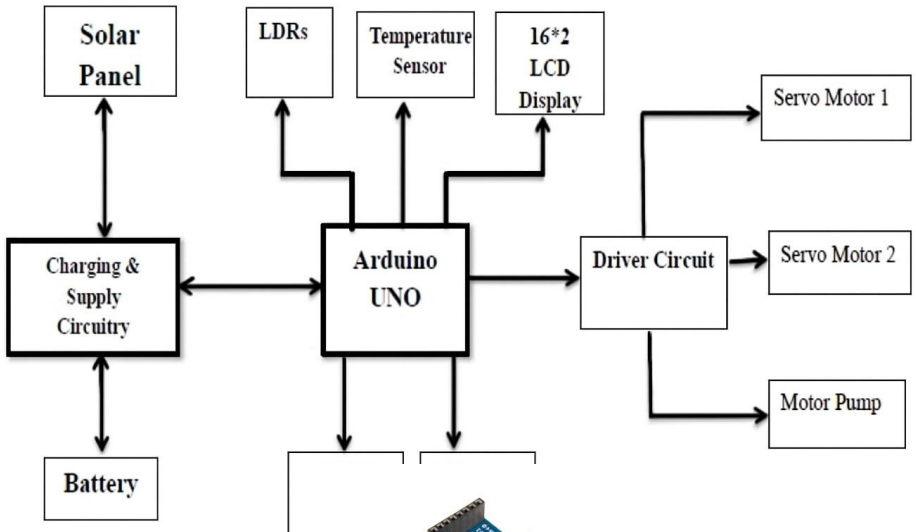
presented a hybrid agent-based Internet of Things irrigation model that made use of system dynamics and sensor networks to distribute water intelligently. In their demonstration of a solar-powered smart irrigation system for sustainable urban agriculture, Abdelhamid et al. [11] highlighted enhanced water conservation and less human involvement using automated control logic.

The report makes it abundantly evident that solar-powered irrigation systems have evolved into clever, independent, and multifunctional farming solutions. Dual-axis solar tracking maximises the usage of solar energy, as has been shown time and time again. By combining IoT and environmental monitoring, these systems have been transformed into data-driven precision agricultural frameworks that ensure improved crop yield, sustainable energy management, and water use optimisation. Solar-powered irrigation systems will become crucial for ecologically friendly farming as future research likely focusses on cloud integration, AI-based prediction, and fully autonomous agricultural equipment.

The overall trend indicates a move towards data-driven, self-sufficient, and environmentally responsible solar irrigation systems that maximise the use of renewable energy sources while simultaneously resolving the issues related to agricultural water scarcity. These advancements pave the way for the development of next-generation smart farms, which integrate artificial intelligence, the Internet of Things, and solar energy to ensure efficient and sustainable farming practices. Their experiments demonstrated that the system could consistently detect alcohol within seconds, offering immediate feedback and control. However, the study also highlighted some limitations related to environmental influences. Factors such as humidity, temperature, and the presence of other volatile gases could affect sensor readings, leading to possible false positives or reduced accuracy over time. These challenges necessitated periodic calibration of the sensor to maintain reliability, particularly in diverse driving environments. The researchers suggested

III. METHODOLOGY



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Arduino UNO:

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Fig2.Arduino UNO

The Arduino UNO serves as the system's central processing unit. In charge of processing control algorithms, reading sensor data, and powering output parts such the GSM module, servo motor, and water pump. Allows for simple interface with sensors and modules by offering a number of digital and analogue I/O pins. It is based on the ATmega328P microcontroller, which handles lecting, and control tasks required for system automation. The Arduino UNO serve linating the entire operation sequence effectively by interacting with all input and , actuators, communication units, and display modules.

Solar Panel:

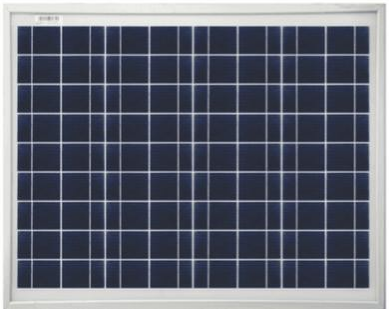

Fig3.Solar Panel

The suggested Advanced Solar Tracking and Automatic Sprinkler Irrigation System is primarily powered by the solar panel. It captures solar energy by means of the photovoltaic (PV) effect, in which sunlight is absorbed by semiconductor materials in the panel (usually silicon-based) and transformed into direct current (DC) electricity. With the removal of reliance on traditional grid power, this renewable energy source makes the system ideal for off-grid and isolated agricultural regions with inconsistent or non-existent electrical supplies. Temperature, shade, and sunlight intensity all affect the solar panel's output voltage and current. The charge controller optimises these settings, guaranteeing maximum power point functioning and steady voltage regulation for effective energy use. By lowering carbon emissions and reliance on fossil fuels, solar power integration not only guarantees sustainability but also aids in environmental preservation.

Soil Moisture Sensor :

Fig4. Soil Moisture Sensor

The Soil Moisture Sensor is used because it continuously measures the amount of water in the soil, the soil moisture sensor is essential to irrigation automation. As the main feedback component of the system, it makes sure that water is only given to the crops when it is needed, reducing water waste and improving irrigation effectiveness. The dielectric

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permittivity or conductivity of the soil, which changes depending on the amount of water present, is what the sensor measures. The autonomous sprinkler system's decis the soil moisture sensor, allows for intelligent irrigation management and maximises the connection ut, water availability, and soil health.

Light Dependent Register:

Fig5.LDR

LDR is the one of the most important sensing elements in the proposed project's sun tracking subsystem is the Light Dependent Resistor (LDR), sometimes referred to as a photo resistor. Its main job is to sense the strength and direction of the sun's rays so that the solar panel ca h the area with the highest irradiance. According to the photoconductivity principl ce changes in direct proportion to the intensity of the incident light. In comparison DR-based tracking system's continuous feedback mechanism guarantees ideal solar pa / harvesting efficiency by 25–30%. The overall independence, dependability, and ener ed irrigation system are enhanced by this clever light-sensing technique.

GPS Module:

Fig6.GPS Module

Real-time remote monitoring and control of agricultural activities is made possible by the Global System for Mobile Communication (GSM) module, which acts as a communication interface between the user and the irrigation system. Farmers may send control orders and receive system updates even from remote regions without an internet connection thanks to its bidirectional communication capabilities via Short Message Service (SMS).Because it allows for real-time feedback, remote system control, and improved user convenience, the GSM module is essential to accomplishing the project's main goals of converting conventional irrigation systems into intelligent, networked, and energy-efficient solutions.

Relay Module:

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Fig7.Relay

The Arduino microcontroller-driven low-power control circuitry can run high-power electrical components like the water pump thanks to the relay module's electromechanical switching capability. It ensures electrical isolation and the irrigation system operates safely by acting as an interface between the high-voltage load devices and the low-voltage control system. The relay module serves as the primary switching interface that permits the safe and effective direct control of high-power irrigation components using Arduino-based control logic. For the suggested solar-powered irrigation system to achieve automation, dependability, and control flexibility, its integration is essential.

Servo Motor:

Fig 8. Servo Motor

The suggested project's solar tracking subsystem relies heavily on the servo motor, which allows the solar panel to move precisely and controllably in order to stay aligned with the direction of the most sunshine. This electromechanical actuator is perfect for applications that need precision rotation within a given range since it offers exact angular position control. The mechanical actuator in charge of the solar panel's automated alignment, which permits ongoing solar energy optimisation, is the servo motor. The project's objective of developing an intelligent, self-sustaining solar-powered irrigation system is ideally aligned with its incorporation, which guarantees accuracy, efficiency, and automation.

Temperature Sensor:

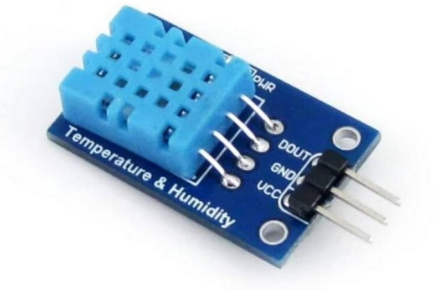

Fig 9. Temperature Sensor

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The DHT11 sensor is a low-cost, digital temperature and humidity sensing device that plays a vital role in monitoring environmental conditions within the proposed Advanced Solar Tracking and Automatic Sprinkler Irrigation System. Its primary function is to provide accurate real-time measurements of ambient temperature and relative humidity, enabling intelligent decision-making for automated irrigation control.

DHT11 sensor serves as a key environmental monitoring component that provides accurate, real-time data on temperature and humidity. This information enables the irrigation system to make intelligent decisions, ensuring optimal soil moisture levels, reducing water wastage, and supporting sustainable agricultural practices.

IV. RESULT

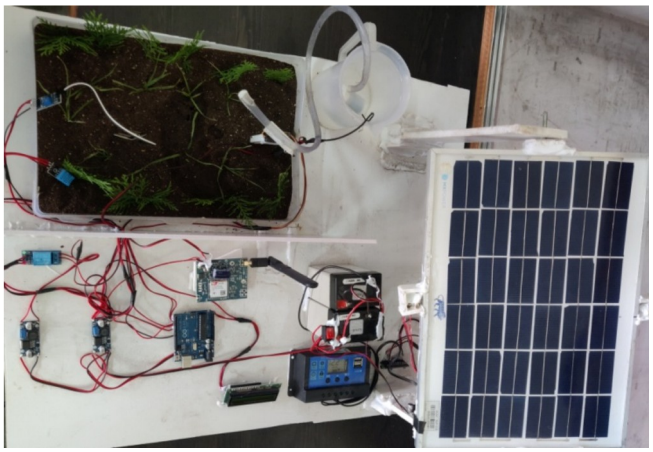

Fig 10. Advance Solar Tracking and Automatic Sprinkler Irrigation System

The Advanced Solar Tracking and Automatic Sprinkler Irrigation System integrates solar energy harvesting, environmental sensing, and GSM-based communication to enable intelligent, energy-efficient, and remotely controlled irrigation. The system automatically aligns the solar panel for maximum power generation and regulates water supply based on real-time soil moisture and temperature data.

Fig 11. LCD Displays Functioning of System

The LCD display presents real-time system information such as temperature, humidity, and motor status, allowing local monitoring of field conditions. It provides instant visual feedback on sensor readings and operational states, ensuring transparency and ease of system control.

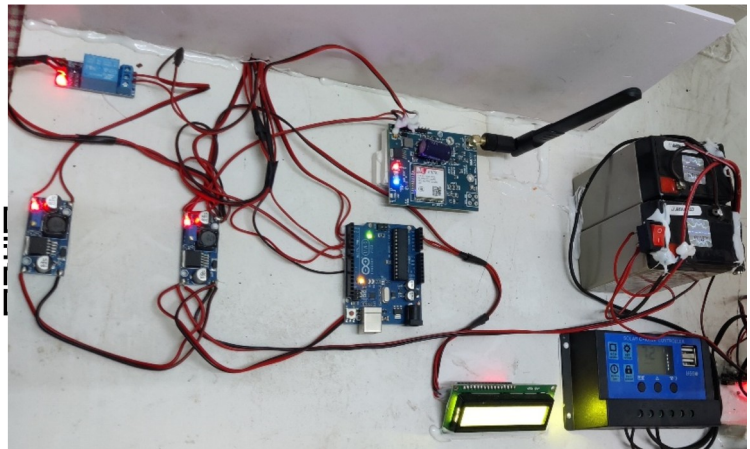

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Fig 12. System in ON State

When the system is ON and operational, all sensors actively monitor environmental parameters while the solar panel tracks sunlight for maximum energy generation. Based on sensor data, the irrigation motor and GSM communication function automatically, ensuring efficient and intelligent watering control.

Discussions:

To assess the Advanced Solar Tracking and Automatic Sprinkler Irrigation System with GSM Module's performance in terms of energy efficiency, irrigation precision, and communication dependability, real-time environmental testing was conducted. When compared to a fixed solar panel, the power generation from the single-axis solar tracking system consistently improved. The tracking system maintained superior alignment with the sun throughout the day, producing an average 25–30% higher voltage production, according to measurements made between 8:00 AM and 5:00 PM. The irrigation and communication subsystems were able to function continuously thanks to this extra energy, demonstrating that single-axis tracking provides an economical and effective solar energy improvement for rural application.

Using sensor feedback, the autonomous irrigation subsystem effectively controlled soil moisture. The pump automatically turned on when the soil moisture fell below the threshold (about 30%), and it turned off when the moisture level surpassed 45%. When compared to manual watering, this dynamic management reduced over-irrigation and water waste by almost 40% by keeping the soil in an ideal moisture range of 35–50%. In order to ensure that crops received the proper amount of water based on current weather conditions, the temperature sensor further improved the irrigation process by modifying the watering cycle based on ambient temperature.

The SIM800L GSM module operated effectively, enabling dependable two-way communication between the user's mobile device and the system. Automatic SMS messages on temperature, motor status, and soil moisture were provided by the system. Examples of these announcements were "Soil Dry: 27% – Motor ON" and "Soil Moist: 48% – Motor OFF." Users could also send SMS messages like "MOTOR ON" or "MOTOR OFF" to remotely operate the watering system. The typical GSM response time was 4–6 seconds, making it appropriate for remote agricultural monitoring in real time. Furthermore, the LCD monitor continuously displayed real-time measurements of temperature, motor condition, solar voltage, and soil moisture, enabling local visibility and prompt on-site examination.

All things considered, the system showed a good balance between sustainability, energy efficiency, and automation. Power generation was enhanced by the incorporation of solar tracking, and efficient water management was guaranteed by the intelligent irrigation module. Long-distance monitoring made possible by GSM connectivity reduced manual labour by about 80%. The combined findings demonstrate that the suggested design is a workable, environmentally responsible, and self-sustaining precision agricultural solution that offers major advantages in power optimisation, water conservation, and remote accessibility.

V. CONCLUSION

The proposed Advance Solar Tracking and Automatic Sprinkler Irrigation System for contemporary agricultural applications, the suggested Advanced Solar Tracking and Automatic Sprinkler Irrigation System effectively combines intelligent irrigation control with renewable energy. In comparison to traditional fixed panels, the efficiency of solar energy harvesting is greatly increased by the use of a single-axis solar tracking mechanism that makes use of servo

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motors and LDR sensors. The system efficiently makes use of temperature and moisture sensors in the soil to track external conditions and control the water pump, guaranteeing accurate irrigation based on the soil's current requirements.

By integrating the GSM module, users may remotely monitor and operate the irrigation system, reducing the requirement for physical presence. They can remotely turn the pump ON or OFF and receive SMS notifications about temperature, motor status, and soil moisture. An LCD monitor improves the system's usability for on-field control by offering local real-time feedback on crucial parameters.

The system's complete solar power ensures sustainable operation with little reliance on outside power sources, making it appropriate for off-grid and rural locations. All things considered, the experiment shows a notable decrease in water waste and human involvement, encouraging effective resource use and encouraging the use of intelligent farming techniques.

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