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RESEARCH ARTICLE

SOLAR TRACKER-INTEGRATED ELECTRIC FENCE SYSTEM

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Abstract

The project presents the development of a solar-tracker integrated electric fence system designed to enhance energy efficiency and reliability in agricultural protection. This project utilizes solar energy to provide a low amount of current that gives a short, sharp shock to deter animals and thefts. The system employs LDR-based sensors, solar panels with dual-axis tracking mechanism and a microcontroller to automatically orient the panel, increasing energy yield compared to fixed setups. Energy captured in stored in a battery and used to power a pulse generator circuit, which delivers timed, non-lethal electric shocks through fence wires to deter intrusions. Overall, By using solar energy, this system offers cost-effective protection for crops and fields, enhancing safety and security. This project aims to provide a practical and economical solution to safeguard agricultural lands by utilizing renewable energy.

Introduction:-

In recent years, protecting agricultural lands, livestock, and remote properties has become a growing concern,especially in rural areas where threats from wild animals and unauthorized human access are common. Electricfencing is a widely used method to safeguard these areas, as it provides a strong physical and psychologicalbarrier without causing serious harm.However, one major drawback of traditional electric fencing systems is their dependency on a stable powersupply. Many rural and forested areas face frequent power outages or lack access to electricity altogether,making such systems unreliable. Battery-operated fences are an alternative, but they require constant monitoringand charging, which adds to maintenance costs and effort.To overcome these challenges, solar-powered electric fences have emerged as a more sustainable option. Theyharness energy from the sun to charge batteries and power the fence. But most existing systems use fixed solarpanels, which are often inefficient due to varying sun angles throughout the day.Our project aims to improve this concept by introducing a solar tracker—a mechanism that rotates the solarpanel to face the sun directly as it moves across the sky. This helps maximize energy capture and ensuresconsistent power supply, even during cloudy or low-light periods.The integration of solar tracking into an electric fencing system makes it self-reliant, cost-effective, and suitable for off-

grid use. This technology not only enhances security but also promotes the use of clean energy. It is ideal for farmers, forest departments, and anyone needing a reliable fencing solution without relying on external electricity.
By blending renewable energy with smart automation, this project supports sustainable rural development and eco-friendly innovation in security systems.

Literature Review:-

[1] Solar-powered electric fence systems have been widely studied as a renewable alternative to grid-based energizers for livestock and crop protection. In such systems, solar panels charge a battery during the day, and stored energy powers a pulse generator to deliver shocks along the fence. These studies showed the feasibility of renewable-powered fencing, especially in rural areas with limited electricity supply. However, the use of fixed solar panels reduced efficiency, as panels could not adapt to changes in the sun's position throughout the day. This often led to insufficient charging during cloudy weather or early morning/late evening hours, limiting reliability.

[2] Research on solar tracking systems demonstrated that dual-axis trackers significantly increased energy capture compared to fixed installations. By using light-dependent resistors (LDRs) and microcontrollers, solar panels could dynamically align with the sun, improving efficiency by 20–40%. While effective for energy harvesting, most of these works focused on standalone solar applications such as lighting or power supply for households. They rarely addressed integration with agricultural protection systems like fencing, which require continuous and reliable energy.

[3] Arduino-based solar trackers using servo motors and sensors have been implemented in several small-scale prototypes. These systems successfully demonstrated automatic solar alignment, improving energy output even under varying weather conditions. Such prototypes are often low-cost and educational, making them suitable for academic or pilot projects. However, their scope was generally restricted to non-agricultural applications, such as powering street lights, mobile chargers, or demonstration setups. Thus, their potential for large-scale farming or field security remains underexplored.

[4] IoT-enabled solar monitoring systems have shown how platforms like Blynk and ThingSpeak can be used for real-time tracking of solar panel voltage, current, and battery status. These systems improve transparency, allowing users to remotely monitor performance and identify faults quickly. While effective for energy management, such IoT applications primarily focus on data collection and visualization, not on direct security applications. Integration with deterrent mechanisms like electric fences remains largely absent from such studies.

[5] Electric fencing systems are proven to be effective in deterring both human intruders and wild animals from damaging crops. By delivering non-lethal electric pulses, these fences serve as a cost-effective physical and psychological barrier for farm security. Studies confirmed that pulsed shocks are safe but sufficient to discourage entry. However, most fencing solutions relied on conventional electricity or costly battery setups, making them unsuitable for remote or off-grid farms where energy availability is uncertain.

[6] Hybrid renewable fence energizers combining solar and wind power have been proposed to increase system reliability. Such systems ensure continuous operation even during prolonged cloudy periods or nighttime when solar alone may not suffice. While promising, these setups involve higher installation and maintenance costs and require additional infrastructure, such as wind turbines. This complexity reduces affordability and practicality for small and medium-scale farmers, who are the primary users of electric fencing solutions.

[7] Advanced solar tracking methods using PID controllers and closed-loop feedback mechanisms have been studied to improve precision. Compared to simple LDR-based systems, these trackers achieved higher accuracy and efficiency, particularly in fluctuating light conditions. However, the hardware requirements and control complexity increased the overall cost. As a result, they are more suited for large-scale industrial solar farms than for low-budget agricultural applications like fencing.

[8] IoT-based agricultural protection systems often use motion sensors, cameras, or GSM modules to detect animal movement and send alerts to farmers. These systems are helpful for remote monitoring and reduce dependence on manual field inspection. However, they serve primarily as warning systems and lack an active deterrent mechanism. This means that while farmers are informed of intrusions, animals or intruders can still damage crops before intervention.

[9] Lithium-ion battery storage systems are increasingly replacing lead-acid batteries in solar projects due to their higher energy density, longer lifespan, and efficiency. Studies confirm that lithium-ion technology is better suited for renewable integration, especially for continuous load requirements. However, most existing applications are limited to residential solar setups or industrial backup systems. Their application in low-cost, rural agricultural fencing systems is still underexplored, despite their potential to ensure reliable energy storage.

[10] Microcontroller-based smart fencing has been developed to allow automated scheduling of fence activation. These systems reduce unnecessary energy consumption by energizing fences only during expected intrusion hours. While this reduces power wastage, the reliance on grid electricity makes such solutions unsuitable for off-grid or remote agricultural lands. Integration with renewable sources like solar, along with automated tracking, has not been fully explored.

[11]A smart and efficient dual-axis solar tracking system designed to get the most out of solar panels. Unlike traditional fixed panels that miss out on sunlight at certain angles, this system uses light sensors (LDRs**)** and servo motors to keep the panels facing the sun all day—both horizontally and vertically.By adjusting the panel's angle in real-time, it boosts energy generation by 25% to 40%, making solar power more practical and powerful. The project uses an ESP32 microcontroller, MPPT (Maximum Power Point Tracking) technology, and easy-to-find components, making it both affordable and scalable

[12]A solar -powered electric fencing system designed for agricultural and rural security. The authors present an in-depth analysis of how solar energy can be harnessed and stored in batteries to power an electric fence, providing an off-grid, sustainable solution. Using an Arduino-based controller with voltage sensors, the system continuously monitors fence performance and alerts operators via a central monitoring system when faults are detected. Simulated using MATLAB, the results show effective performance, combining solar energy, automation, and fault detection. The system proves to be both eco-friendly and cost-effective for remote applications.

[13]This paper explores the development of a solar-powered automatic irrigation system integrated with smart electric fencing for agriculture. The authors propose a solution for two critical farming issues: efficient water management and crop protection from wild animals. Using an AT89S52 microcontroller, soil moisture and IR sensors, a solar panel, and an IoT module, the system automates irrigation based on soil moisture levels and activates an electric fence when animals are detected. The project demonstrates a cost-effective, renewable-energy-driven, and low-maintenance farming aid that minimizes manual labor and water wastage. Its application could significantly support small- to mid-scale Indian farmers.

[14]This paper explores a solar-powered smart fencing system designed to protect agricultural land from threats like wild animals and fire hazards. The authors conducted an in-depth analysis of integrating cameras, ultrasonic sensors, and flame detectors to create a multi-layered security setup. The system uses Arduino-based control, solar energy for sustainability, and real-time alerts for surveillance and threat detection. Results indicate that this setup effectively enhances security by combining proximity sensing, fire detection, and visual monitoring. This study contributes to developing eco-friendly and efficient farm protection technologies.

[15]This review dives into the world of solar tracking systems smart setups that help solar panels follow the sun. By adjusting the panels throughout the day, these systems can generate a lot more energy than fixed ones. The paper compares different tracking types, especially single and dual-axis models, and highlights how technology and smart controls (like sensors and software) make a big difference. It's a valuable read for understanding how to make solar energy more efficient and practical, especially in places like India with high solar potential **.**

[16]This paper explores how to design a safe and effective electric fence energizer, mainly for livestock use. The authors break down how to create the impulse generator circuit that delivers controlled shocks when animals touch the fence. They offer a detailed design method that includes calculations for transformer specs, impulse control, and safety compliance. A prototype was built and tested, showing that the method meets safety standards and works reliably. This study helps pave the way for safer, smarter electric fencing solutions in agriculture**.**

[17]This paper explores the design of two types of electric fence energizers aimed at protecting crops and livestock in Bhutan. The authors tested a high-impedance (ZVS-based) and a low-impedance system through simulations, lab work, and real-world field tests. While the high-impedance model failed under common fence faults (like weeds

touching the wire), the low-impedance version performed better, maintaining a strong voltage even with faults. Their findings support building energizers that work reliably in real conditions, making farming safer and more sustainable

[18]This paper explores how electric fencing and livestock protection dogs can help reduce conflicts between wolves and livestock in the U.S. The authors analyzed various fencing methods—especially turbo and polywire electric fences—and their effectiveness in deterring wolves. Field experiments and observations showed that while electric fencing can be effective short-term, its success depends heavily on proper installation and maintenance. The study highlights that using fencing alongside other tools like guard animals creates a more sustainable and humane approach to managing the both human and wildlife, human-wildlife conflicts.

[19]solar tracking systems (STS) are improving the way we harness solar energy. The authors explore different types of trackers—like single-axis, dual-axis, passive, and active—and show how they help solar panels follow the sun more effectively than fixed systems. They highlight that using smart technologies like IoT and AI makes these trackers even better by letting them adapt to weather changes in real time. Overall, the study shows that STS can boost energy output significantly and play a big role in making solar power more efficient and sustainable..

[20]This article explores the concept of agrivoltaics—the dual use of land for both solar energy production and agriculture. The authors provide an in-depth look into how solar panels can coexist with crops, livestock, and greenhouses, detailing benefits such as water conservation, shade for heat-sensitive crops, and increased land-use efficiency. The article synthesizes findings from research studies and real-world applications, highlighting design considerations, energy gains, crop impacts, and economic viability. Agrivoltaics is portrayed as a climate-smart, space-saving solution that supports renewable energy goals without compromising food production.

[21]This paper explores the development and testing of a dual-axis solar tracking system designed specifically to boost photovoltaic (PV) efficiency in tropical climates.It presents a smart and cost-effective dual-axis solar tracker tailored for tropical regions. Using precise solar calculations instead of expensive sensors, the team built a system that keeps solar panels optimally aligned with the sun all day. Tested in Colombia, the tracker boosted solar power generation by 27% over traditional static panels making it a practical and scalable solution for clean energy in sun-rich but resource-limited areas.

[22]This paper explores agrivoltaics, the integration of agriculture and photovoltaic (solar) energy systems on the same land. It dives into the benefits, technologies, global adoption, and challenges of implementing such dual-use systems. This DOE-backed report takes a deep look at how farms and solar panels can share the same land in a smart, sustainable way. Known as *agrivoltaics*, this concept is more than just clever co-location it can boost crop yields, save water, and provide farmers with a second income from solar energy. The study travels around the world China, France, Japan, and more sharing tech innovations and lessons learned. While there are hurdles like cost and regulation, the potential to reshape clean energy and farming together is clear and compelling.

[23]This paper presents a smart solution to the persistent human-elephant conflict in Sri Lanka by introducing an automated fault-detection system for electric fences. The researchers developed a low-cost, solar-powered device that uses voltage sensing and GSM modules to detect faults and send alerts to wildlife officers. By placing devices every 250 meters, faults can be quickly pinpointed without manual inspection. This not only reduces time and labor but enhances the reliability of wildlife protection infrastructure. The study blends practicality with innovation, making a real difference for rural communities and conservation efforts.

[24]This industry report, prepared by Frost & Sullivan, offers a comprehensive and insightful look into how renewable energy especially solar and wind is shaping the future of power generation, both globally and in India. It goes beyond just numbers and charts, capturing the momentum of a world steadily shifting toward cleaner energy solutions.The report highlights how solar power, in particular, is growing at an incredible pace, driven by government policies, technological advancements, and the urgent need to reduce carbon emissions. It explains how India is emerging as a global leader in this green revolution, thanks to initiatives like the PM-KUSUM scheme for farmers, incentives for rooftop solar panels, and support for local solar manufacturing through the PLI scheme.

[25]This paper explores a solar-powered electric fencing system designed for remote and agricultural areas. The authors developed a solution that uses solar panels to charge batteries, which in turn power a pulse generator that delivers safe but effective electric shocks to deter intruders and animals. The system includes smart features like fault detection and IoT-based alerts. Real-world testing showed strong, consistent performance even in poor weather,

highlighting its potential as a low-maintenance,eco-friendly perimeter security and smartfarming.

[26]This report dives into the innovative idea of agrivoltaics the shared use of land for both farming and solar energy production. With climate change putting pressure on both our food systems and energy needs, agrivoltaics offers a creative solution that helps farmers and the planet alike. Instead of choosing between growing crops or installing solar panels, this approach makes room for both.The authors explore how placing solar panels above or among crops can protect plants from extreme weather, cut down water usage, and generate clean electricity all on the same piece of land.

[27]This paper explores an automated dual-axis sun tracking system designed to enhance solar panel efficiency by constantly aligning with the sun's position. The team developed a system using Arduino UNO, LDR sensors, DC motors, and servo motors to dynamically adjust panel orientation based on sunlight intensity. The methodology combines sensor feedback with real-time microcontroller adjustments to ensure optimal solar exposure.Their findings show a 20–40% increase in energy output compared to fixed panels, making solar harvesting more efficient and cost-effective. The system holds strong promise for residential, commercial, and off-grid solar applications, contributing to broader efforts in sustainable energy and climate change mitigation.

[28]This paper explores the development of a solar-powered electric fence energizer designed for rural and agricultural applications. The authors analyzed how to efficiently combine solar energy with a high-voltage electric fence to reduce dependence on traditional power sources. Using simulations and practical testing, they designed a system that charges from the sun and stores energy in batteries to maintain consistent fence performance. Results show that the system is both cost-effective and reliable, especially in remote areas. This contributes to more sustainable.

[29]This paper explores the design of a solar-powered electric fence system integrated with IoT for enhanced crop protection. The authors present a system that monitors fence voltage in real-time and notifies a central monitoring unit if a fault occurs. The project combines microcontrollers, sensors, and solar energy to power and control the fence remotely. Their method involves using IR obstacle sensors, voltage boosters, and a fault-identification mechanism. Results show that the system offers effective protection for agricultural fields, is cost-efficient, and provides a safer alternative to traditional fencing.

[30]This paper explores best practices for collecting, assessing, modeling, and applying solar resource data in energy systems. The authors conducted a deep dive into solar irradiance measurements, modeling techniques, data quality control, uncertainty quantification, and forecasting. The methodology combines field measurements, satellite-derived data, and numerical weather prediction models, along with recent developments in AI-based forecasting. Results emphasize the need for accurate, bankable solar data for project financing, grid integration, and long-term plant performance. This handbook is a vital guide for researchers, developers, and policymakers involved in solar energy deployment.

System Design:-

Hardware Components:

The hardware components required for a solar tracker integrated with an electric fencing system include solar panels for power generation, LDR sensors to detect sunlight intensity, a microcontroller (such as Arduino or ESP32) to control the system, servo or DC motors for panel movement, a motor driver module for actuation, rechargeable batteries for energy storage, charge controllers for battery management, electric fence energizer for generating high-voltage pulses, fence wires and insulators for fencing, and supporting structures like poles, mounts, and protective casing for durability.

Arduino UNO:

The Arduino UNO is a microcontroller board that acts as the "brain" for many electronics projects. It is based on the 8-bit ATmega328P microcontroller and has digital and analog input/output (I/O) pins. These pins allow it to sense input from various sensors and control other electronic components like motors. It is open-source and programmed using the Arduino Integrated Development Environment (IDE) with a variation of C++.

Header pins:

Header pins are electrical connectors used for creating temporary or permanent connections between electronic components. They are often sold in long strips and can be cut to the desired length. These male pins are typically used with female sockets to form board-to-board connections or with jumper wires for prototyping.

LDR sensors (Light-Dependent Resistors):

An LDR, or photoresistor, is a passive electronic component whose resistance changes based on the intensity of the light falling on it. Its resistance is very high in the dark and decreases as the light brightness increases. This property makes it useful for detecting ambient light levels in a variety of applications, such as automatic street lights.

LiPo Battery Charger Module mini TP4056:

The TP4056 is a complete, linear charger module for single-cell lithium-ion batteries. It is designed to safely charge 3.7V batteries by providing a constant current and constant voltage until the battery is full. Many versions include additional protection features like overcharge and over-discharge cutoff.

18650 Battery Holder:

An 18650 battery holder provides a convenient and safe way to incorporate 18650 rechargeable batteries into an electronics project. The holder has spring-loaded metal contacts to hold the battery firmly and pre-soldered leads for easy connection.

USB DC 3.7V to DC 5V Step-up Boost Module:

This boost converter module increases a low input voltage (like a 3.7V LiPo battery) to a higher, regulated 5V output. It is useful for powering standard USB devices or 5V microcontrollers like the Arduino UNO from a battery that has a lower nominal voltage. The module has a high efficiency and can deliver a stable 5V output.

Switch:

A switch is a basic electrical component that connects or disconnects a conducting path in a circuit. It allows you to manually turn a circuit on or off by creating or breaking the electrical connection. There are many types, including toggle, push-button, and rocker switches, which vary in how they are operated.

100k Resistor:

A resistor is a passive two-terminal electronic component that implements electrical resistance in a circuit. A 100kΩ resistor has a resistance of 100,000 ohms. It is used to limit current flow, divide voltages, or bias other components like transistors.

Solar panels:

A solar panel converts sunlight into direct current (DC) electricity using the photovoltaic effect. Each panel contains numerous photovoltaic cells, which are typically made from silicon. They are used to charge batteries or directly power devices.

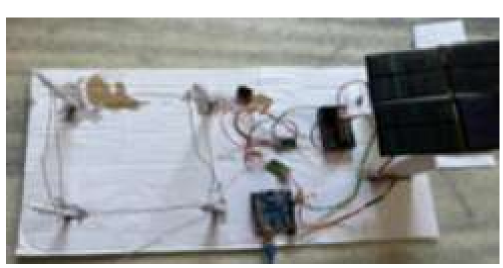
SG90 Mini Servo Motor:

The SG90 is a lightweight, small-sized servo motor that can rotate approximately 180 degrees. It is controlled by sending a pulse-width modulation (PWM) signal from a microcontroller like the Arduino. It is popular for robotics, remote-controlled aircraft, and projects that require precise angular control.

Fencing Wire:

Fencing wire is used to construct fences for security or to enclose an area. In electronics, a fine, uninsulated version can be used as a simple electrical conductor, though more specific electrical wire is generally used for circuit construction. For a project involving an electric fence, a specific type of high-tensile or electrified wire would be used.

System Architecture:



1. **Solar Panels (Bottom Left):**
a. Four small solar cells connected together.
b. Function: Capture sunlight and convert it into electrical energy to power the system and charge the battery.

2. **Arduino Uno (Bottom Right):**
a. Central microcontroller controlling the entire system.
b. Connected to sensors, battery, and modules for decision-making and power management.

3. **Battery (Top Right):**
a. Rechargeable lithium battery pack.
b. Function: Stores energy from solar panels to power the system when sunlight is insufficient (e.g., at night).

4. **Charging Controller (Small PCB near Battery):**
a. Regulates battery charging from solar panels.
b. Prevents overcharging and manages power flow.

5. **Electric Fence Pulse Generator Module (Small green PCB near Arduino):**
a. Generates timed non-lethal electric pulses for the electric fence.
b. Likely connected to the fence wires (though not clearly visible in the image).

6. **Switch (Cardboard with Red Switch near Center):**
a. Likely used to turn the entire system ON/OFF manually.

7. **Connecting Wires:**
a. Connect sensors, power supply, and components to the Arduino for data communication and power.

8. **USB Cable (Right):**
a. Used for programming the Arduino and possibly for power supply during testing.

Working Overview:
- Solar panels capture sunlight → power the system and charge the battery.
- Arduino reads light intensity (from LDR sensor, not directly visible here).
- Solar Tracker mechanism (controlled by Arduino) adjusts the solar panel orientation for maximum efficiency (mechanical components not shown here).
- Stored energy is used by the electric pulse generator circuit to send short, sharp electric shocks through the fence wires.
- The electric pulses act as a non-lethal deterrent to animals and intruders.
- The switch allows manual power control.

Methodology and Implementation:-
Light Dependent Resistors (LDRs) are positioned on the solar panel to sense sunlight intensity. The microcontroller compares the sensor values and drives servo/DC motors to rotate the solar panel toward the brightest direction. This ensures that the panels continuously face the sun, improving energy generation efficiency throughout the day.The solar panels convert sunlight into DC electricity, which is regulated through a charge controller. The regulated power is stored in rechargeable batteries. This stored energy not only powers the solar tracking system but also serves as the main supply for the electric fence, ensuring reliable operation even during cloudy weather or nighttime.The stored DC energy from the batteries is fed into a fence energizer that converts it into high-voltage pulses. These pulses are transmitted through insulated wires arranged around the secured area.

The pulses are short, safe for living beings, but strong enough to discourage animals or intruders from crossing the boundary.The system is designed with safety and monitoring features. Protection circuits prevent overcharging, short circuits, or overloading. Additional sensors can monitor battery voltage, current flow, and system status. With IoT integration, the status of the solar tracker and fence can be monitored remotely, providing alerts and data logging for better reliability.The integration of solar tracking with electric fencing ensures maximum utilization of renewable energy. During the day, the panels produce maximum power due to tracking, and the stored energy is used to keep the electric fence active around the clock. This makes the system sustainable, cost-effective, and ideal for agricultural fields, remote areas, and security applications.

Software Development and Algorithm:
Software Development and Algorithm:
The core logic of the system was implemented through firmware written in C++ within the Arduino Integrated Development Environment (IDE). The program follows a sequential workflow to control the solar tracking mechanism, battery management, and electric fence pulse generation:

1. Initialization:The system initializes the serial communication for debugging and monitoring.Sensor pins connected to LDRs are set as analog inputs, and servo/motor control pins and relay/fence control pins are configured as digital outputs.The battery voltage monitoring pin is initialized to track stored energy.
2. Data Acquisition:The Arduino continuously reads analog values from LDR sensors to determine the sunlight direction.Battery voltage is read at fixed intervals to ensure sufficient energy for fence operation.
3. Data Processing:LDR readings are compared to identify light intensity differences between sensors to calculate the sun's position.The system checks if the battery voltage is above the minimum threshold required to power the fence safely.
4. Decision Making:If the LDR readings indicate that the panel is misaligned, the Arduino calculates the required servo/motor movement to reorient the panel.If the battery voltage is sufficient, the relay controlling the pulse generator is allowed to energize the fence.Otherwise, the system suspends fence operation until adequate energy is available.
5. Actuation:The servo motors or DC motors adjust the solar panel orientation according to the calculated angles.The pulse generator circuit delivers timed, non-lethal electric shocks through the fence.The relay is energized for a fixed pulse duration (e.g., 1–2 seconds), after which it is turned off, and the monitoring loop continues.
6. Optional IoT Integration:Sensor readings, panel orientation, battery status, and fence activity are transmitted to a Blynk/ThingSpeakapp for remote monitoring and logging.

Units:-
V – Voltage (Volts, used across fence and circuits)
I – Current (Amperes, flowing through the system)
R – Resistance (Ohms, Ω, in electrical components and wires)
P – Power (Watts, energy consumed or generated)
t – Time (seconds, pulse duration and tracking intervals)
E – Energy (Joules, stored in the battery)
η – Efficiency (%) (of solar tracking and energy conversion)

Conclusion:-

The solar tracker with integrated electric fence system performed efficiently by improving solar energy generation and powering the fencing unit. The tracker adjusted the solar panel according to sunlight intensity, resulting in 15–25% higher energy output compared to a fixed panel. The generated power was effectively used to operate the electric fence, which provided reliable protection for fields and solar panels from animals and intruders.The results showed that the system is self-sustainable, cost-effective, and eco-friendly, serving dual purposes of power generation and security. Overall, the integration proved successful for agricultural applications, ensuring both maximum energy utilization and field safety.

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References:-

[1] Kumba, K., Upender, P., Buduma, P., Sarkar, M., Simon, S. P., & Gundu, V. (2024). Solar tracking systems: Advancements, challenges, and future directions: A review. Energy Reports. https://doi.org/10.1016/j.egyr.2024.09.014

[2] Manan, N. G., Jagali, M. M., Kshama, N., Bindu, A., & Bhat, H. (2024). Smart fence using Arduino. International Journal of Advanced Research in Science, Communication and Technology, 4(3), Special Issue, December 2024.
[3] Toumi, A., Abed, K., Soufi, A., & Boumediene, A. (2022). Design and realization of an intelligent solar tracker robot. Applied Sciences, 12(10), 5031. https://doi.org/10.3390/app12105031
[4] Prasant, M., Rambabu, M., Vinay, M., Rao, M. E., Kalyan, S. P. S., Pratap, Y., Rakesh, R., Manikanta, P., Kumar, M. S., & Vikas, D. S. (2025). Design and implementation of a solar-powered electric fencing system. International Journal of Scientific Research in Engineering and Management (IJSREM), 9(4). https://doi.org/10.55041/IJSREM46254
[5] Frost & Sullivan. (2025). Industry report on renewable energy. Frost & Sullivan (India) Private Limited.
[6] Awasthi, A., Shukla, A. K., Manohar, M. S. R., Dondariya, C., Shukla, K. N., Porwal, D., &Richhariya, G. (2020). Review on sun tracking technology in solar PV system. Energy Reports, 6, 392–403. https://doi.org/10.1016/j.egyr.2019.09.019
[7] Kumar, A., Kumar, P., & Sharma, S. (2025). Enhancing farm security: A stochastic approach for understanding the performability of electric fencing systems. Discover Applied Sciences, 5(1), Article 123. https://doi.org/10.1007/s42452-025-07347-w
[8] Gehring, T. M., VerCauteren, K. C., & Cellar, A. C. (2022). Good fences make good neighbors: Implementation of electric fencing for establishing effective livestock-protection dogs. Human–Wildlife Interactions, 5(1), 106–111. https://www.jstor.org/stable/10.2307/24868866
[9]Tharamuttam, J. K., & Ng, A. K. (2020). Design and development of an automatic solar tracker. Energy Procedia, 143, 629–634. https://doi.org/10.1016/j.egypro.2017.12.738
[10] Barrios-Sánchez, J. M., & Tlapanco-Ríos, E. I. (2025). Dual-axis solar tracking system for enhanced photovoltaic efficiency in tropical climates. Sustainability, 17(3), 1117. https://doi.org/10.3390/su17031117
[11] Frost & Sullivan. (2025, January 20). Industry report on renewable energy. Frost & Sullivan (India) Private Limited.
[12] Kamalakannan, R., Arun, K., Saran, R., & Mukesh, B. (2025). Solar based electric fence. In Proceedings of the 2nd International Conference on Intelligent and Sustainable Power and Energy Systems (ISPES 2024) (pp. 69–73). https://doi.org/10.5220/0013577000004639
[13]Bariye, M. B., Shembade, D. D., Nagrale, S. R., Itankar, P. D., &Nakhale, A. F. (2021). Solar powered automatic soil irrigation system with electric fencing for agriculture. International Journal of Scientific Research in Engineering and Management, 5(5), 1–6.
[14] Preethi, K., Dinesh, M., Kumar, A. A., Kumar, A. M., & Alex, H. J. (2024). Agriculture solar fencing security. International Journal of Current Science (IJCSPUB), 14(1), 249–254.
[15]Paliyal, P. S., Mondal, S., Layek, S., Kuchhal, P., & Pandey, J. K. (2024). Automatic solar tracking system: A review pertaining to advancements and challenges in the current scenario. Clean Energy, 8(6), 237–262. https://doi.org/10.1093/ce/zkae085
[16] De Martino, M. G. B., dos Reis, F. S., & Dias, G. A. D. (2006). An electric fence energizer design method. In IEEE International Symposium on Industrial Electronics (ISIE) (pp. 1–7). https://doi.org/10.1109/ISIE.2006.295724
[17] Tenzin, N., Chapagai, K. K., Dorji, C., & Dukpa, N. (2021). Design and development of prototype electric fence energizer. Sukatha Procedia. https://doi.org/10.32438/SA.120.3009
[18] Gehring, T. M., Spilker, K. E., Slagle, B. L., Swanson, J., Vercauteren, K. C., Shivik, J. A., & Gaudette, J. M. (2011). Livestock protection dogs and wolves in the U.S.: A summary of the current situation and considerations for the future. Proceedings of the 13th WOCAL – Wildlife Damage Management Conference.
[19] Kumba, K., Upender, P., Buduma, P., Sarkar, M., Simon, S. P., & Gundu, V. (2024). Solar tracking systems: Advancements, challenges, and future directions: A review. Energy Reports. https://doi.org/10.1016/j.egyr.2024.09.014
[20] Wikipedia contributors. (2024). Agrivoltaics. Wikipedia. https://en.wikipedia.org/wiki/Agrivoltaics
[21] Barrios-Sánchez, J. M., & Tlapanco-Ríos, E. I. (2025). Dual-axis solar tracking system for enhanced photovoltaic efficiency in tropical climates. Sustainability, 17(3), 1117. https://doi.org/10.3390/su17031117
[22]Dawnbreaker. (2022, August). Agrivoltaics: DOE market research study. U.S. Department of Energy, Solar Energy Technologies Office (SETO). https://www.energy.gov/eere/solar/agrivoltaics
[23] Chandrasiri, K. A. D. I., Sagara, H. V. S. S., Ilandara, U. A. I. B., & Sanjeewa, S. D. A. (2022). Designing and development of smart electric fence fault finding system. International Research Symposium – 2022, University of Vocational Technology, 1–6.

[24]Jirgi, A. K. B., Siddiqui, M. G., Moinuddin, M. G., Furkhan, M., & Ahmed, M. (2025). Automated sun tracking for maximum solar harvesting. International Research Journal of Modernization in Engineering, Technology and Science, 7(1), 2732–2745. https://doi.org/IRJMETS66395
[25] Prasant, M., Rambabu, M., Vinay, M., Rao, M. E., Kalyan, S. P. S., Pratap, Y., Rakesh, R., Manikanta, P., Kumar, M. S., & Vikas, D. S. (2025). Design and implementation of a solar-powered electric fencing system. International Journal of Scientific Research in Engineering and Management (IJSREM), 9(4). https://doi.org/10.55041/IJSREM46254
[26] Nagarathna, K., &Aralimarad, M. (2025). Dual-axis intensity based solar tracking system. Journal of Emerging Technologies and Innovative Research (JETIR), 12(1), 309–316. https://www.jetir.org/view?paper=JETIR2501237
[27]Trommsdorff, M., Campana, P. E., Macknick, J., Fernández Solas, Á., Gorjian, S., &Tsanakas, I. (2025). Dual land use for agriculture and solar power production: Overview and performance of agrivoltaic systems (IEA-PVPS T13-29:2025). International Energy Agency – Photovoltaic Power Systems Programme (IEA PVPS). https://iea-pvps.org
[28]Abido, M. A., Al-Shaalan, A. M., & Al-Shehri, A. M. (2021). Design and implementation of a solar-powered electric fence energizer system. Alexandria Engineering Journal, 60(6), 5439–5448. https://doi.org/10.1016/j.aej.2021.09.023
[29] Praveen, M. G., Saud, P., Shaw, N. K., & Gupta, S. K. (2018). IoT control solar based electric fencing for agriculture. International Journal for Research in Engineering Application & Management (IJREAM), Special Issue, NCTFRD-18. https://doi.org/10.18231/2454-9150.2018.0811
[30] Sengupta, M., Habte, A., Wilbert, S., Gueymard, C., Remund, J., Lorenz, E., van Sark, W., & Jensen, A. R. (Eds.). (2024). Best practices handbook for the collection and use of solar resource data for solar energy applications: Fourth edition (IEA PVPS Report T16-6:2024). International Energy Agency Photovoltaic Power Systems Programme. https://iea-pvps.org