

“Research Paper on Solar Tracker With Fire Alarm”

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Abstract— This paper presents the design and implementation of an IoT-enabled Solar Tracking and Fire Detection System based on the Arduino Nano platform. The proposed system integrates renewable energy optimization, safety monitoring, and real-time data visualization into a compact and cost-effective solution. A dual Light Dependent Resistor (LDR)-based sensing mechanism continuously detects the direction of maximum solar irradiance and automatically aligns a 6 V photovoltaic panel using an SG90 servo motor (180°), thereby improving solar energy harvesting throughout the day.

To enhance operational safety, an infrared (IR) flame sensor is incorporated for continuous fire detection. Upon detecting the presence of a flame, the Arduino Nano activates an audible buzzer and a visual LED indicator to provide an immediate local alert. Additionally, a relay module is included to enable automatic control of external electrical loads or safety devices when required.

The system also incorporates a voltage sensor module (0–25 V) to monitor the real-time output voltage of the solar panel. A Wemos D1 Mini (ESP8266) module is interfaced with the Arduino Nano to transmit sensor data to an IoT dashboard, allowing users to remotely monitor the solar panel performance and system status over the internet. Power is supplied by a 12 V battery, while an LM2596 buck converter provides a regulated 5 V supply for the microcontroller and peripheral modules. The complete hardware prototype is assembled on a PCB/zero board to achieve a compact, reliable, and portable design.

Experimental evaluation demonstrates that the proposed system effectively tracks solar movement, increases solar energy utilization, provides timely fire detection, and enables remote performance monitoring through IoT connectivity. Owing to its low cost, simplicity, and scalability, the proposed solution is well suited for residential, agricultural, educational, and small-scale renewable energy applications.

Keywords— Arduino Nano, Solar Tracking System, Internet of Things (IoT), Light Dependent Resistor (LDR), Fire Detection, Infrared Flame Sensor, ESP8266, Wemos D1 Mini, Renewable Energy, Servo Motor, Voltage Monitoring, Smart Energy Management.

1. INTRODUCTION

The increasing demand for sustainable energy solutions and intelligent safety systems has encouraged the development of smart automated technologies. Solar energy is one of the most abundant renewable energy sources; however, the efficiency of conventional fixed photovoltaic (PV) panels is limited because they cannot continuously align with the changing position of the sun. As a result, a considerable amount of potential solar energy remains unutilized. Additionally, fire hazards in residential, agricultural, and industrial environments require rapid detection and timely alerts to minimize damage and ensure safety.

This paper presents an IoT-enabled Solar Tracking and Fire Detection System that integrates renewable energy optimization with real-time safety monitoring. The proposed system is built around an Arduino Nano microcontroller, which serves as the central controller for sensor data acquisition, processing, and actuator control. Two Light Dependent Resistor (LDR) sensors are employed to detect the direction of maximum sunlight, while an SG90 servo motor automatically adjusts the orientation of a 6 V solar panel to maximize energy harvesting throughout the day.

To enhance safety, an infrared (IR) flame sensor continuously monitors the surroundings for the presence of fire. When a flame is detected, the Arduino Nano immediately activates a buzzer and an LED indicator to provide an early warning. A relay module is also incorporated to enable automatic switching of external safety devices or electrical loads whenever required.

The system further includes a voltage sensor module to measure the real-time output voltage of the solar panel. A Wemos D1 Mini (ESP8266) provides IoT connectivity by transmitting the measured data to an online dashboard, allowing users to remotely monitor solar panel performance and system status. The hardware is powered by a 12 V battery, while an LM2596 buck converter provides a regulated 5 V supply for reliable operation of all electronic components. The complete prototype is assembled on a compact PCB to improve system reliability and portability.

The proposed system offers a low-cost, efficient, and scalable solution by integrating solar tracking, fire detection, and IoT-based monitoring into a single platform. It is well

suited for residential, agricultural, educational, and small-scale industrial applications, demonstrating an effective approach to improving renewable energy utilization while ensuring operational safety.

2. LITERATURE REVIEW

Recent advancements in renewable energy and smart automation have led to significant research on solar tracking and fire detection systems. Solar tracking systems are designed to improve the efficiency of photovoltaic (PV) panels by continuously aligning them with the sun, thereby maximizing energy generation. Most existing systems employ Light Dependent Resistor (LDR) sensors and microcontrollers such as Arduino or Raspberry Pi to detect sunlight intensity and automatically adjust the panel position using servo or DC motors. Compared with fixed solar panels, these systems provide higher energy output by maintaining an optimal angle of incidence throughout the day.

Among various tracking mechanisms, single-axis solar trackers are widely preferred for small-scale and educational applications due to their simple design, low cost, and reduced power consumption. Although dual-axis trackers offer greater tracking accuracy, their higher complexity and maintenance requirements limit their practical implementation in low-cost systems.

Fire detection has also received considerable attention in recent years. Conventional fire alarm systems commonly use infrared (IR) flame sensors or smoke sensors to detect fire at an early stage and activate warning devices such as buzzers and LED indicators. Modern systems further incorporate wireless communication technologies, including Wi-Fi and IoT platforms, enabling users to receive real-time alerts and monitor system status remotely. However, many existing fire detection solutions operate independently and lack integration with renewable energy systems.

Recent research has focused on developing intelligent systems that combine multiple functionalities, such as renewable energy monitoring, automation, and safety features, into a single platform. IoT-enabled monitoring has become increasingly popular, allowing real-time visualization of system performance and remote access to operational data. Nevertheless, many of these integrated solutions are intended for industrial-scale applications and often involve high implementation costs and complex hardware architectures.

The literature indicates a need for a compact, affordable, and user-friendly system that integrates solar tracking, fire detection, and IoT-based monitoring. The proposed work addresses this gap by combining an Arduino Nano, dual LDR sensors, an SG90 servo motor, an IR flame sensor, a voltage sensor, and a Wemos D1 Mini (ESP8266) into a unified platform. The system optimizes solar energy harvesting, provides early fire detection with immediate alerts, and enables remote monitoring through an IoT dashboard, making it suitable for residential, agricultural, educational, and small-scale industrial applications. Development goals.

3. PROBLEM STATEMENT

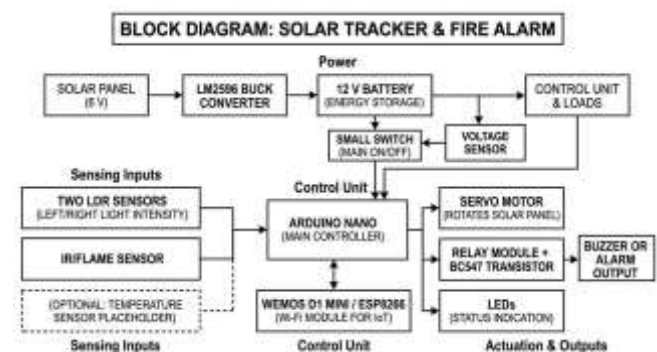
In earlier versions of the system, the fire detection mechanism was limited to only generating an alarm when fire was detected. The system could not automatically disconnect the power supply or shut down connected

devices during hazardous situations, which reduced overall safety and required manual intervention to stop the system. Additionally, the previous model did not provide real-time monitoring of the generated solar panel voltage, making it difficult for users to analyze system performance and energy generation effectively.

To overcome these limitations, the updated “Solar Tracker with Fire Alarm” system introduces automatic relay-based power disconnection during fire detection, improving safety by preventing further electrical damage and reducing the need for manual shutdown. The system also integrates real-time voltage monitoring and IoT-based display functionality using ESP8266 and a dashboard interface, allowing users to monitor the generated solar voltage directly on a laptop or online platform.

The main objective of the updated system is to develop a smart, cost-effective, and automated solution that combines solar tracking, real-time voltage monitoring, automatic fire safety control, and remote monitoring into a single integrated platform. This enhancement improves system reliability, safety, efficiency, and usability for residential, agricultural, and small-scale industrial applications.

4. System Design:



The proposed system integrates a solar tracking mechanism, fire detection and alerting, and solar output monitoring with IoT support. The system is controlled primarily by an Arduino Nano microcontroller, which processes sensor inputs and generates control outputs.

1. Solar Tracking Mechanism

The system uses two LDR sensors placed on the left and right side to detect the intensity and direction of sunlight. When sunlight falls unevenly on the sensors, a difference in analog readings is generated. The Arduino compares the LDR values and generates PWM control signals. Based on the difference, the SG90 servo motor rotates the solar panel toward the direction of maximum sunlight (up to 180°). This continuous adjustment helps maximize solar energy absorption throughout the day.

2. Fire Detection and Alert System

An IR flame sensor module continuously monitors the surroundings. When flame/fire is detected, the sensor output changes and is read by the Arduino. The Arduino activates a buzzer and a status LED to provide immediate alert. A relay module is also interfaced as an optional output for switching an external load/safety device when required. Solar Output Monitoring and IoT Dashboard To monitor the electrical output of the solar panel: A voltage sensor module (0–25V) measures the solar panel voltage and provides a scaled analog signal to the Arduino. The measured values are transmitted to a Wemos D1 Mini

(ESP8266) module. The Wemos displays/uploads the output on a dashboard interface, enabling monitoring during testing and demonstration.

3. Power Supply and Regulation

The system is powered using a 12V battery and an ON/OFF switch. An LM2596 buck converter steps down 12V to a stable 5V rail. The regulated 5V supply powers the Arduino Nano, sensors, and other modules.

4. Circuit Design and Assembly

All components are connected as per the circuit diagram and mounted on PCB/zero board. Proper wiring and soldering ensure stability and compactness. Common ground is maintained across all modules for reliable operation.

4. Results and Discussion



4.1 System Performance

The proposed IoT-enabled Solar Tracker and Fire Detection System was successfully designed, implemented, and tested. The Arduino Nano served as the central controller, integrating solar tracking, fire detection, and real-time monitoring into a single platform.

The solar tracking mechanism effectively utilized dual LDR sensors to detect the direction of maximum sunlight. Based on the sensor inputs, the SG90 servo motor

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continuously adjusted the orientation of the solar panel, ensuring optimal alignment with the sun and improving energy harvesting compared to a fixed panel system. The output voltage of the solar panel was measured using a voltage sensor module and successfully transmitted to an online dashboard through the Wemos D1 Mini (ESP8266), enabling real-time remote monitoring.

The fire detection subsystem accurately identified flame conditions using an IR flame sensor. Upon detection, the Arduino Nano immediately activated a buzzer and LED indicator to provide an early warning. The integrated relay module also demonstrated the capability to control external safety devices or electrical loads during emergency conditions.

Experimental results confirmed that the proposed prototype performed reliably under different operating conditions. The integration of automatic solar tracking, fire detection, voltage monitoring, and IoT connectivity provides an efficient, low-cost, and intelligent solution suitable for residential, agricultural, educational, and small-scale industrial applications.

5. INPUT SCREENS



A1: Complete Hardware Setup of Solar Tracking System with Solar Panel, LDR Sensors, Servo Mechanism, Battery Module, Relay Circuit, and Microcontroller

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