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Solar Energy Powered Advanced Smart Streetlight For Remote Areas

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Abstract

This project is primarily designed for remote hilly areas, where smart streetlights equipped with fire detection sensors, vibration sensors, noise sensors, and an air quality monitoring module, provide critical safety and environmental monitoring. In the event of abnormal situations, the system instantly notifies government authorities, including police stations, fire stations, and the pollution control board, for swift responses. To ensure reliability in remote hilly regions, the system is powered by solar panels. This innovative solution enhances safety, security, and environmental vigilance in challenging terrains.

Keywords: *Smart Streetlight, Solar Panel.*

1. Introduction

1.1. Proposed Idea

The proposed idea is to implement a renewable energy-powered smart streetlight with fire detection, accident detection, and air quality monitoring in remote hilly areas, a comprehensive methodology is crucial. The process begins with a meticulous needs assessment, conducting surveys to identify suitable locations based on road density, accident-prone zones, and community input. Engaging residents and stakeholders in the planning phase is essential to understand their specific needs. Technology selection involves evaluating renewable energy sources like solar power, customized sensor networks for the terrain, and low-bandwidth communication protocols to ensure data transmission in areas with limited network coverage. Prototype development follows, with rigorous lab testing and field trials in select areas for real-world performance evaluation. Deployment and integration involve proper installation, configuration, and setting up a robust data management system. Continuous monitoring, maintenance, and evaluation are crucial, including remote monitoring systems and regular checks, while community training and engagement initiatives ensure local participation and long-term sustainability. Immediate alerts on emergency situations such as fires, unusual vibrations, excessive noise, or poor air quality in remote hilly areas. This enables swift responses and actions to address emergencies, ultimately improving safety and environmental management in challenging terrains. This proposed methodology prioritizes community involvement, adaptation to local conditions, and iterative improvements to create an effective and sustainable smart street light system in remote hilly areas.

1.2. Objectives

- Improve safety in remote areas by deploying smart streetlights equipped with fire detection capabilities to prevent and respond to fire accidents and natural calamities promptly.
- With the help of our system, we provide immediate alert to the government authorities (police, fire station) for further action.
- Utilize collected data for analysis and reporting on fire incidents, air quality trends, and energy consumption patterns to prevent

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further damage and alert the surrounding areas.

- Implement air quality sensors within the smart streetlights to continuously measure air pollution levels, providing valuable data for environmental monitoring and health assessments.

1.3. Existing Methodology

Method 1 – Traditional Street Lighting with Manual Monitoring:

In the traditional street lighting approach with manual monitoring, the deployment involves installing conventional street lights in remote hilly areas, devoid of advanced sensors or communication systems. Rather than relying on real-time data collection, safety and environmental monitoring hinge on periodic manual inspections conducted by local authorities. This method introduces inherent delays in identifying and addressing safety issues, such as fires, or environmental concerns. The absence of integrated sensors and communication systems means that abnormalities may go unnoticed until the next scheduled inspection, potentially compromising the effectiveness of the monitoring system. Without the ability to provide instant alerts or notifications, the traditional approach can lead to slower responses and increased risks in managing safety and environmental challenges in these remote terrains.

Method 2 – Solar-Powered Street Lights:

Solar-powered street lights are autonomous lighting systems featuring photovoltaic panels that harness sunlight to generate electrical energy. Positioned atop the streetlight, solar panels capture sunlight during the day, storing the energy in rechargeable batteries for nighttime use. Equipped with energy-efficient LED lamps, these lights automatically illuminate at dusk and turn off at dawn, offering a reliable and sustainable lighting solution. Operating independently of the main power grid, solar street lights are suitable for off-grid and remote locations, contributing to environmental sustainability by reducing reliance on traditional energy sources. With motion sensors for adaptive lighting and low maintenance requirements, they provide cost-effective and eco-friendly illumination for various settings. Block Diagram and models are shown in Figures 1 & 2.

2. Literature Survey

[1] An accident prevention road safety system for a hill station was created with the Arduino Uno serving as the primary design component. The main goal of this project was to use IR sensors and an Arduino Uno to develop a safety road control. The Arduino Uno (ATMEGA328) is used in the operation, and it integrates with various circuits including the power supply, solar panel, infrared sensor, signal light, buzzer, and streetlight. [2] This work has put into practice smart street lighting, which is an affordable urban solution that combines low-cost LED lights, sophisticated wireless communication technologies, and extra sensors to regulate light intensity. This essay provides a case study of a smart lighting system installed in Nagpur Smart City, where one of the objectives was to lower energy usage and hence the carbon footprint. This was accomplished by adding 63 more LED lights with motion detection smart lighting system and replacing the antiquated 320 roadway lamps. [3] A carbon monoxide detecting system that can track and monitor CO levels and quantify values was attempted to be developed by the above authors. By serving as a bridge connector to the existing Internet infrastructure, the Internet of Things (IoT) links things—physical devices like lights, phones, and cars—to the Internet. Gathering, viewing, and analyzing real-time data streams is possible with Blynk, an IoT analytics platform that runs on the cloud. The usage of a MQ7 Gas sensor to stop carbon monoxide-related automobile accidents is the main topic of this article. [4] A study consisting of a wireless sensor network and LED-based remote streetlight monitoring and controlling system has been proposed by the above researcher. If the system is used in automatic mode, streetlight levels will be adjusted based on seasonal fluctuations. Additionally, the system has an indication feature that uses a wireless network medium to show how damaged the streetlights are. [5] The above work proposed a range of sensors, including as accelerometers, vibration sensors, can be used by accident detection systems to identify

incidents. This work ascertains whether an accident has happened, accident detection systems can analyze sensor data using a range of techniques. Real-time notifications from accident detection systems can be utilized in this work to notify emergency services, speeding up response times and potentially saving lives. [6] This work discussed about soil moisture and vibration levels are important markers of landslip danger, and they can be measured in real time by IoT-based landslip detection systems. This paper introduced an early warning system that notifies people of the possibility of a landslip before it happens can be developed using the data gathered by Internet of Things-based landslip detection systems. They concluded that compared to conventional landslip monitoring systems, IoT-based landslip detection systems may be more effective and economical. [7] Real-time data on air quality in smart cities can be obtained by IoT-based air quality monitoring equipment. An identification system and reducing the sources of pollution, this data can be utilized to assess the effects of air quality on city inhabitants. By making IoT-based air quality monitoring devices available to the public via mobile applications, people would be able to make more informed decisions regarding their health and wellbeing.

3. Methods and Materials

3.1. Project Working

The project's functionality begins with solar panels capturing sunlight and a charge controller optimizing energy storage in a battery. The accident and fire detection circuits use sound and vibration sensors, responding to specific events by detecting sudden impacts or abnormal noise levels indicative of accidents and fires. An air quality monitoring system, equipped with gas sensors, continually assesses the surrounding air. In response to sensor inputs, the smart lighting system, integrated with LED streetlights, dynamically adjusts brightness to improve visibility during emergencies. This cohesive system, utilizing sound and vibration sensors alongside other components, enhances safety and environmental monitoring in remote hilly areas by efficiently utilizing solar energy and enabling real-time responses to diverse events. The integration of these sensors provides a robust and adaptive solution for comprehensive monitoring in challenging terrains.

3.2. Block Diagram

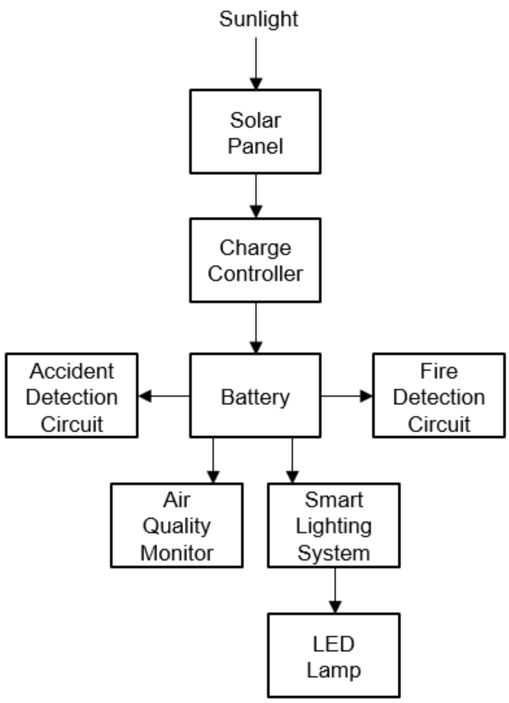

Figure 1 Block Diagram

3.3. Project Model

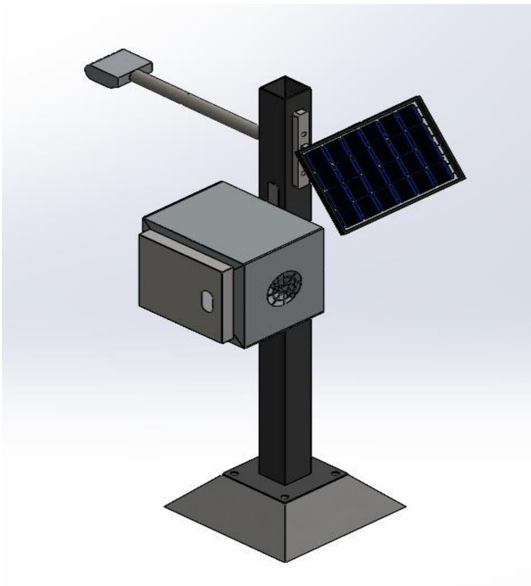

Figure 2 Project Model

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3.4. Components Required

1. Solar Panel 12V(40W)
2. Charge Controller 10A
3. Battery 40Ah
4. LED Streetlight
5. Arduino Uno
6. GSM Module (SIM900A)
7. Vibration Sensor (SW-420)
8. Flame Sensor (KY-026)
9. LDR (QRE1113)
10. Sound Sensor (LM393)
11. AQ Monitoring Sensor (BME680)

4. Circuit Design

4.1. Source and Battery

The project incorporates solar panels to harness renewable solar energy, providing a sustainable power source for the street lighting system during sunny weather, reducing dependence on grid electricity. A charge controller is a crucial component in a solar power system. Its primary function is to regulate the voltage and current coming from the solar panels to ensure that the battery is charged optimally without overcharging or damaging the battery. Charge controllers prevent overcharging, which can reduce the lifespan of batteries. Battery is incorporated to store surplus energy from solar panels, enabling a consistent power supply and serving as a backup during energy fluctuations. Source and Battery image is shown in Figure 3.

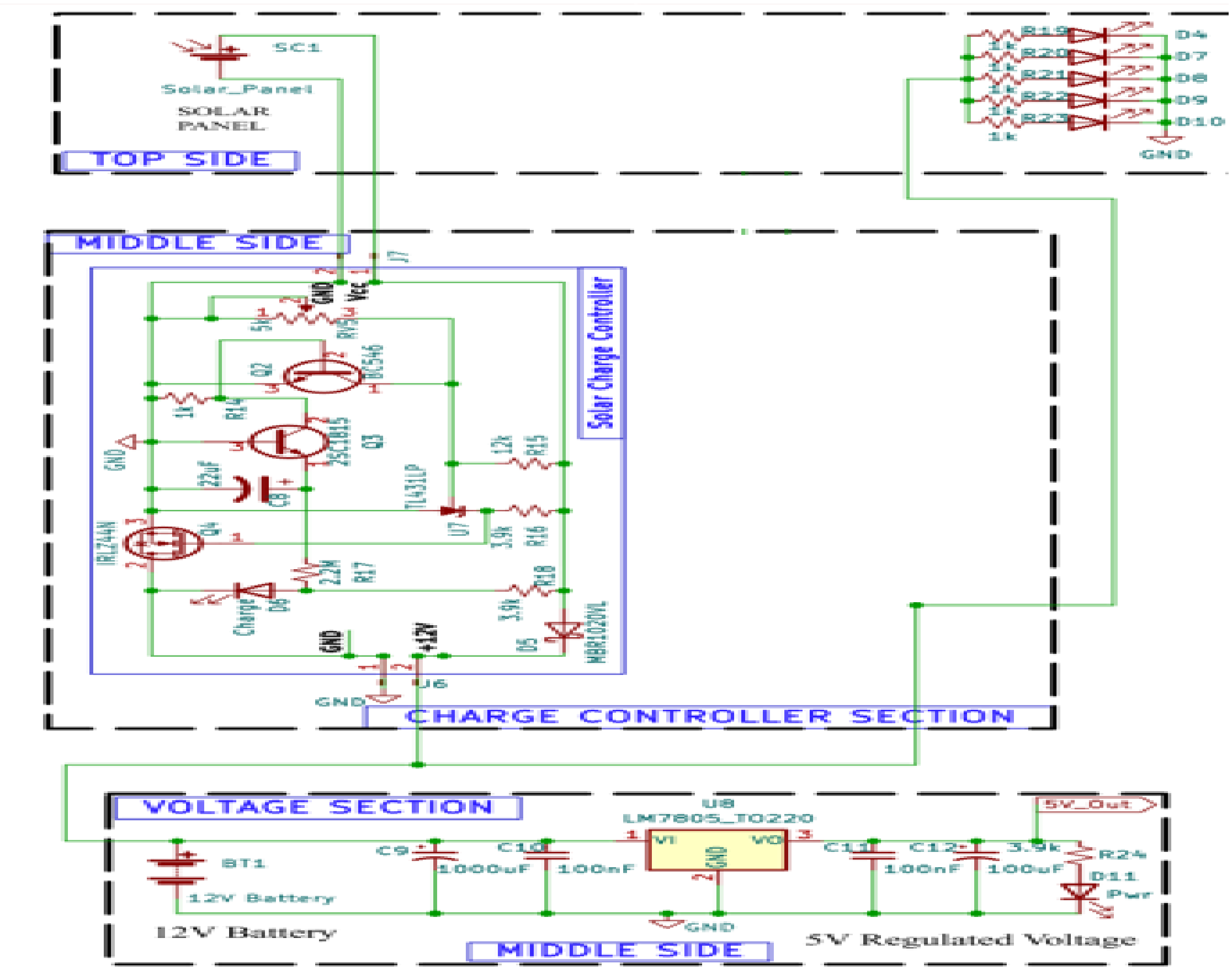

Figure 3 Source and Battery

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4.2. Accident, Fire Detection and Communication

IoT is used to create a forest fire detection system and accident detection system that can identify fires, accidents and use the same technology to notify authorities of an emergency. Since network bandwidth is typically very limited or nonexistent in forest settings, a GSM/GPRS module is employed here to communicate with the IoT server. Therefore, to communicate with the server, a 2G network is preferred. The main parts of the project are the SIM800L GSM/GPRS, Flame sensor, sound sensor, vibration sensor, and buzzer. The flame sensor, which provides the Arduino with a digital output corresponding to the fire condition, can detect fires. Since the SIM800L operates on 3.3-volt logic, it is connected to the Arduino via logic shifting resistors. With the use of vibration and sound sensors, the system continuously scans the ambient sound characteristics. An accident detected message is sent to the central server via the GSM module when a sound signature exceeds the threshold specified on devices mounted on street poles. Concurrently, a buzzer is set off at the scene of the accident to alert other cars to an impending collision. Each pole has a manual switch to turn off the buzzer. Accident and Fire Detection Circuit and Smart Lighting Systems are shown in Figures 4 & 5.

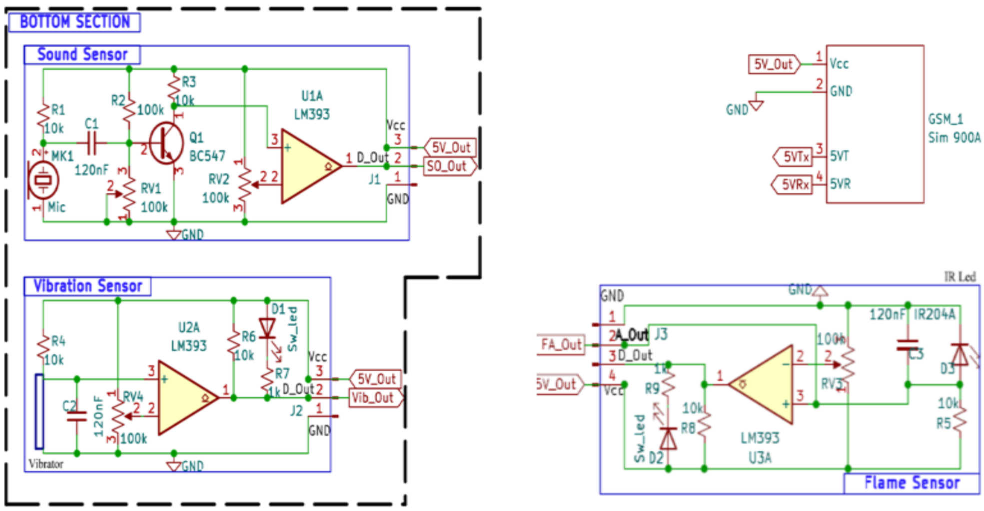

Figure 4 Accident and Fire Detection Circuit

4.3. Smart Lighting System

The Arduino's analog pin is linked to an LDR. It senses if sunlight is present or not, to control the LEDs. The LDR provides high resistance and functions as an insulator when there is enough sunlight present in the environment. In this instance, the Arduino automatically turned down all LEDs (streetlights) after reading high analog output values from the LDR. The LDR senses darkness in the absence of sunlight, provides low resistance, and functions as a conductor. In this instance, the Arduino automatically turns on the LEDs (streetlights) by reading Low analog input signals from the LDR.

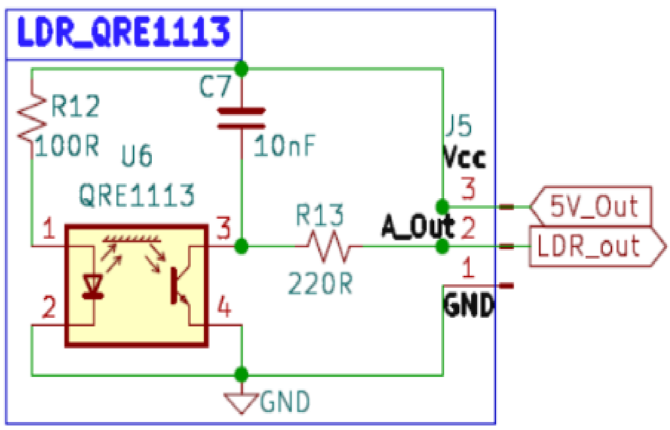

Figure 5 Smart Lighting System

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4.4. Air Quality Monitoring

Air quality monitoring (Figure 6) circuits typically include various sensors to detect and measure key air pollutants such as particulate matter (PM), carbon monoxide (CO), nitrogen dioxide (NO2), sulfur dioxide (SO2), and volatile organic compounds (VOCs). To facilitate real-time monitoring and remote access, air quality monitoring circuits often include communication interfaces. This enables users to access air quality data remotely or receive alerts when pollutant levels exceed predefined thresholds.

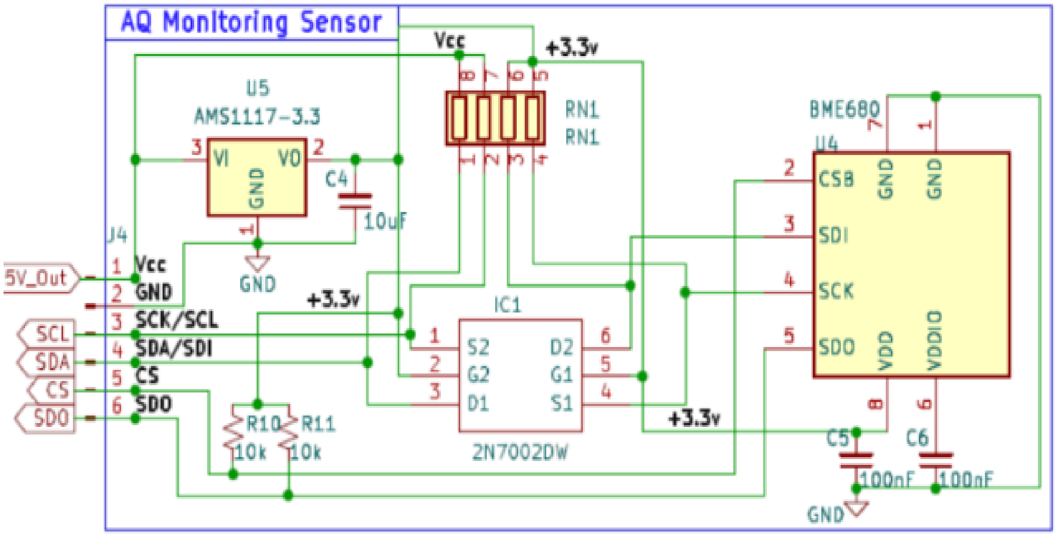

Figure 6 Air Quality Monitoring

4.5. Controller – Arduino Uno R3

All the sensor output is connected to the respective controller pins (Figure 7), where the controller is further programmed to perform various control actions like communication through GSM and turning the buzzer ON.

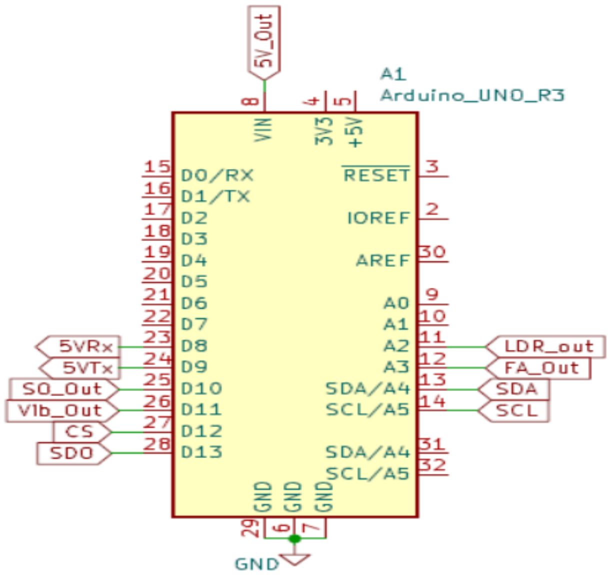

Figure 7 Arduino Uno

5. Results and Discussion

5.1. Advantages

- Enhanced Safety and Security through integrated sensors.
- Environmental Monitoring for pollution control and resident well-being.
- Swift Emergency Response with instant notifications to authorities.
- Off-Grid Power Solution using solar panels and battery storage.
- Community Empowerment by providing critical information for decision-making.

5.2. Disadvantages

- Initial Cost may be significant for comprehensive system implementation.
- Maintenance Challenges in remote hilly areas may affect regular upkeep.

5.3. Result

Solar system ensures sustainable street lighting in remote areas, optimizing energy production for reliability. High-sensitivity Forest fire and accident detection mechanisms trigger swift alerts through GSM, enabling rapid response and risk mitigation.

Robust GSM communication system ensures timely transmission of critical alerts for both forest fires and accidents in remote locations. Smart streetlights adapt to ambient light levels, optimizing energy usage by adjusting intensity based on prevailing natural light conditions. Real-time air quality monitoring provides crucial data on pollutants, contributing to environmental awareness and enabling appropriate interventions. Project enhances environmental sustainability with renewable energy sources, addressing safety concerns through fire detection, accident response, and air quality monitoring.

5.4. Future Scope

- Smart City Integration for urban development.
- AI and Machine Learning Integration for improved predictive capabilities.
- IoT Expansion for additional functionalities and interconnected infrastructure.
- Collaboration with Emergency Services to enhance response times.
- Energy Efficiency Optimization for enhanced sustainability.
- Customization for Varied Terrains to extend applicability.

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