Arduino-Based System For Monitoring And Fault Detection In Street Lighting

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ABSTRACT

Managing urban infrastructure efficiently is essential for modern cities, particularly in maintaining public services like street lighting, which play a crucial role in safety and quality of life. Traditional approaches to street light maintenance can be labor-intensive and costly, leading to inefficiencies. To tackle this issue, a new system for Street Light Monitoring and Fault Detection using Arduino is proposed, which utilizes sensor technology along with visual displays.

This project focuses on developing a malfunction detection system for street lighting by incorporating an LCD screen and a Light Dependent Resistor (LDR) to monitor light levels. By tracking the ambient light, the system can automatically detect issues such as non-functioning bulbs or unstable power conditions and promptly display the relevant information on the LCD for quick maintenance intervention. This integration of sensor-based monitoring with visual output provides a practical approach to improving urban infrastructure management, enabling proactive maintenance efforts and ensuring consistent street lighting to enhance public safety.

Keywords: Urban infrastructure management, Street lighting, Maintenance,Fault detection, Arduino Sensor technology,Light Dependent Resistor (LDR),Malfunction detection, LCD display,Ambient light monitoring,Proactive maintenance,Public safety Smart cities,Automation, Energy efficiency,Fault localization,Visual input,Continuous illumination,Cost-effective solutions,Real-time monitoring.

I. INTRODUCTION

The study emphasizes the advantages of modern streetlight control systems over traditional setups, with LED lamps standing out due to their benefits such as lower heat output, reduced energy consumption, and longer lifespan. The aim is to improve system efficiency by reducing electricity waste during daylight or when lighting is unnecessary. By automating streetlights with LDR and PIR sensors integrated with an Arduino Uno, a cost-effective and secure alternative is achieved, overcoming the limitations of manual switching and facilitating cost savings and maintenance.Furthermore, applying a ZnO coating to streetlight housings enhances protection against dust and moisture, leading to more efficient lighting. The ZnO coating process includes sol-gel deposition on silica glass, followed by multiple dip coatings and annealing at 450°C to 600°C. The resulting uniform coatings are verified through SEM imaging, while transmission

https://doi.org/10.5281/zenodo.14540697

spectra indicate over 80% visible light penetration. Lower precursor concentrations improve light penetration for wavelengths below 300 nm [1].

The smart street lighting system, powered by IoT technology, brings a new level of efficiency and automation to urban lighting. By integrating various devices such as sensors and cameras, this system can dynamically adjust street lighting based on factors like traffic patterns and weather conditions, allowing for remote monitoring and control. The technology not only optimizes energy use but also enhances public safety and reduces the carbon footprint, contributing to more sustainable and eco-friendly cities. This IoT-based approach is transforming urban development, improving infrastructure, and promoting a higher quality of life for citizens [2].

The term "SMART" represents five key elements: specific, measurable, achievable, relevant, and time-based. In a world increasingly embracing automation, IoT technology is transforming urban infrastructure with billions of interconnected digital devices. As one of the world's fastest-growing economies, India is shifting towards smart solutions, such as the smart streetlight system. Traditional streetlights operate continuously from sunset to sunrise, consuming power at full intensity. By incorporating LDR sensors, this smart system can automatically adjust lighting based on ambient light levels, reducing energy waste. The power supply is managed via relays, while the IoT module enables real-time monitoring and control, making street lighting more efficient and automated. This shift to smart lighting not only conserves energy but also supports the broader trend towards automation and intelligent urban solutions [3].

The IoT-based street light controller and monitoring system offers a transformative approach to urban lighting by converting traditional setups into intelligent and energy-efficient networks. Utilizing advanced components like NodeMCU microcontrollers, relay modules, LDRs, motion, and environmental sensors, the system creates a dynamic lighting network that adjusts based on real-time data. This data includes ambient light, traffic, pedestrian activity, and environmental conditions, which inform adaptive lighting control algorithms to optimize energy use while ensuring safety.

The system supports remote monitoring for proactive maintenance, fault detection, and performance optimization, reducing both downtime and costs. Field trials and simulations confirm its effectiveness in lowering energy consumption, improving lighting efficiency, and enhancing maintenance operations. The system's adaptability to different environmental conditions and its ability to respond to changing needs highlight its versatility. Ultimately, this innovative solution sets the stage for smarter, safer, and more sustainable urban lighting management [4].

The rise of IoT is driving innovation in various sectors, with advancements in internet speed and bandwidth opening new possibilities. This project focuses on an IoT-based energy-efficient street light monitoring and control system, addressing the significant energy consumption of lighting and the need for quick fault detection. Two distinct model techniques are applied based on the application context: IEEE 802.11 wireless technology is used for smaller areas or confined spaces where appliances are cloud-connected, while a wired setup is employed for larger

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linear networks, such as street lamp poles, to avoid range limitations. When a fault is detected, the issue is promptly reported online, specifying the affected pole. This approach enhances efficiency and facilitates timely maintenance [5].

In today's rapidly urbanizing world, efficient energy management is crucial, with street lighting being a major energy consumer in cities. This paper introduces a Smart Street Light Fault Detection System leveraging IoT technology, using a Node MCU microcontroller, LDR sensor, street lights, and ThingSpeak. The system utilizes the microcontroller to monitor ambient light levels via the LDR, enabling automatic streetlight control for optimized energy use. It also incorporates fault detection to identify irregularities, such as unchanged light levels despite varying conditions, which could indicate malfunctions.

Real-time LDR data is transmitted to ThingSpeak, allowing users to monitor readings, receive fault notifications, and take prompt action. This system provides benefits like enhanced energy efficiency, automated control, and proactive fault detection, demonstrating an effective application of IoT for building smarter and more sustainable urban environments [6].

The Internet of Things (IoT) is transforming technology by enabling interconnected devices and automating processes. This paper focuses on developing a system for automatic detection and reporting of faulty street lights using IoT. The system's main objective is to automatically identify non-functioning street lights and notify the relevant electricity board substation. Poor street lighting contributes to increased incidents of theft and accidents, which this technology aims to prevent.

Sensors installed on the light poles detect malfunctioning lights and transmit details, including the area, street, and pole ID, to the substation. This allows maintenance personnel to quickly locate the faulty street light and take corrective actions, thereby enhancing public safety and improving infrastructure management [7].

II. METHODOLOGY

Existing Method

Modern streetlight control systems offer significant advantages over traditional setups, particularly when LED lamps are used. These lamps are favored for their lower heat production, energy efficiency, and extended service life. The main objective of upgrading street lighting systems is to enhance energy efficiency by minimizing unnecessary power consumption, especially during daylight hours or when lighting isn't required. Implementing automation with Light Dependent Resistors (LDR), Passive Infrared (PIR) sensors, and an Arduino Uno enables a practical and economical approach to streetlight management. This automation addresses the drawbacks associated with manual switching, making maintenance and cost management more streamlined.

Moreover, applying a zinc oxide (ZnO) coating to streetlight casings can improve resistance to dust and moisture, thus enhancing lighting performance. The coating process involves the sol-gel technique to deposit ZnO nanoparticles onto silica glass. Following this, a pre-annealing treatment and multiple dip-coating cycles are carried out to achieve the best results.

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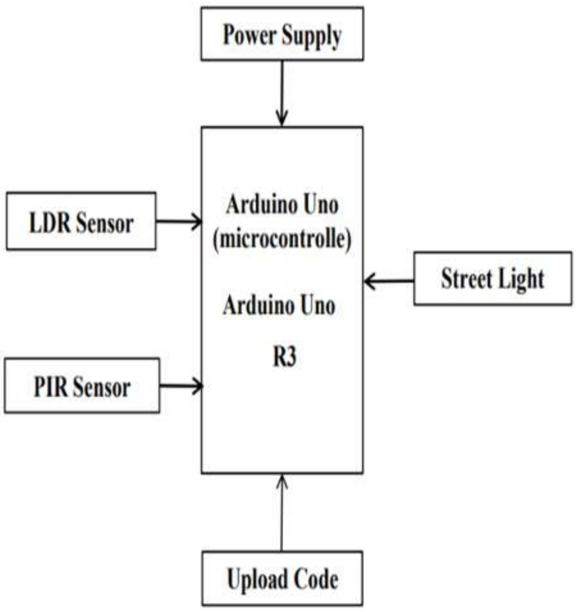

Fig.1.Existing Method Block Diagram

Proposed System

The proposed system employs an Arduino-based framework for the real-time monitoring and fault detection of street lights. It features Light Dependent Resistors (LDRs) designed to detect ambient light levels, along with LED indicators to alert users about any faults. Upon initialization, the system sets up the necessary pins for the LDRs and LEDs and prepares the LCD display for status updates. During the setup phase, an initial message is shown on the LCD, and the LED pins are designated as outputs. In the main loop, the system continuously reads analog data from the LDRs, comparing the readings against a set threshold to identify potential faults. The LCD display is updated to show the status of each LDR, while indicator LEDs visually signal any detected faults. This continuous monitoring ensures that street lights are regularly checked, allowing for quick identification of issues and enhancing safety and efficiency by enabling timely maintenance interventions.

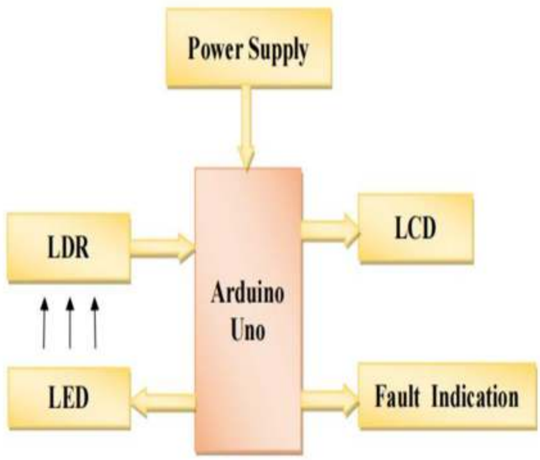

Fig.2.Proposed System Block Diagram

III. PROPOSED SYSTEM DESCRIPTION

Power Supply: This component provides the electrical energy needed for the entire circuit. It is the source that powers all other components in the system.

Rectifier: Converts alternating current (AC) to direct current (DC), which is necessary because the circuit and the Arduino board require DC power to operate.

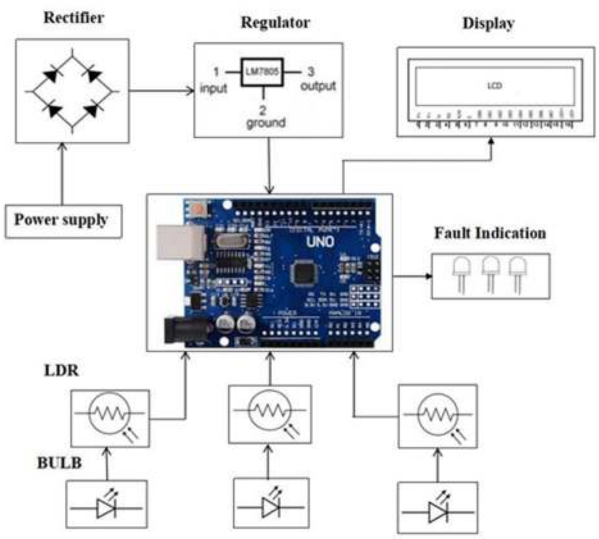

Fig.3.Hardware Circuit Diagram

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Voltage Regulator (LM7805): This device ensures a consistent 5V output is delivered to the Arduino and other components, regardless of fluctuations in the input voltage, thereby protecting the circuit from voltage variations shown in Fig 3.

Arduino UNO: A microcontroller board that serves as the brain of the system. It reads data from the sensors (LDRs), processes the information, and then controls the outputs, such as turning the bulbs on or off shown in Fig 3.

LDR (Light Dependent Resistor) Sensors: These sensors detect the intensity of ambient light. Their resistance changes with light levels, allowing the Arduino to measure light variations and make decisions based on the readings shown in Fig 3.

Bulbs: Act as the output devices in this setup. Their state (on or off) is controlled by the Arduino based on the data received from the LDR sensors, adjusting lighting automatically shown in Fig 3.

Display (LCD): An output device used to show information such as light levels, system status, or any errors detected. It helps in monitoring the system's operation.

Fault Indication LEDs: These LEDs indicate the presence of any faults or issues within the system, providing a visual alert to the user for maintenance or troubleshooting.

IV. RESULT AND DESCRIPTION

The system operates by automatically controlling lighting based on the ambient light detected by the Light Dependent Resistors (LDRs). The power supply initially provides the necessary electrical energy, which is converted from AC to DC by the rectifier. The voltage regulator (LM7805) then ensures a stable 5V output to power the components.

The central control is managed by the Arduino UNO, which processes signals received from the LDRs. As the light intensity changes, the resistance of the LDRs varies, sending corresponding data to the Arduino. Based on these readings, the Arduino decides whether to turn the connected bulbs on or off, effectively regulating lighting according to the environment.

An LCD display shows the system's current status, such as the detected light level or other useful information, while the fault indication LEDs provide alerts if any issues are detected in the system, assisting in troubleshooting. This automated setup enhances energy efficiency by adjusting lighting only when necessary and supports fault detection for maintenance purposes.

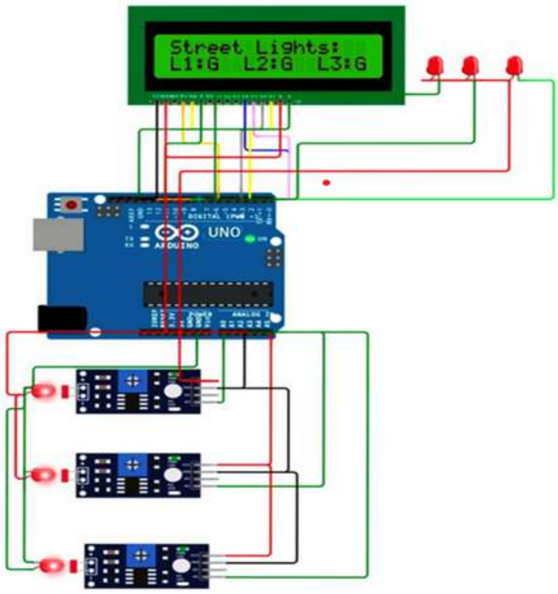

Fig .4.Street Light Monitoring And Condition Of The Street Light

The status of street lights L1, L2, and L3 is shown on an LCD, indicating that there are no issues detected. Additionally, an LED display provides a visual confirmation that everything is functioning normally shown in fig 4.

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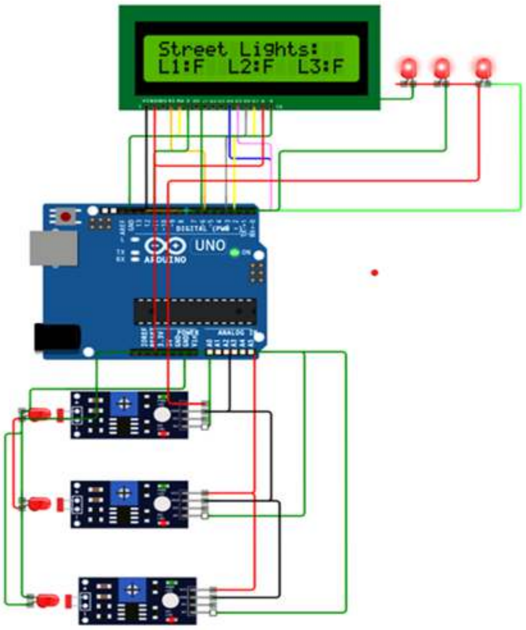

Fig.5.Street Light Monitoring And Fault Identification Display

The LCD shows any issues detected with street lights L1, L2, and L3, while an LED display provides a visual alert to indicate the presence of a problem shown in fig 5.

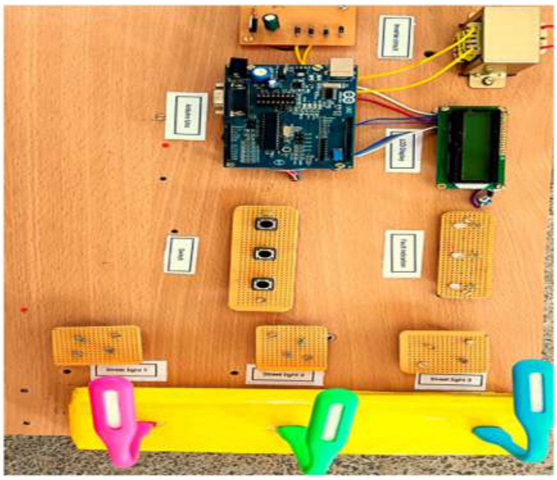

Fig.6.Hardware Kit

V. CONCLUSION

An Arduino-based street light monitoring and fault detection system provides a proactive solution for managing urban lighting. Utilizing real-time data and visual feedback, it improves safety, boosts efficiency, and supports sustainable practices in city environments. The system's continuous monitoring and prompt response capabilities help create safer and more livable urban areas, enhancing the overall quality of life for both residents and visitors. As urban areas grow, investing in such innovative technologies is crucial to tackling the challenges of urbanization and promoting sustainable city development.

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