SMART FAULT DETECTION AND MAINTENANCE FOR IOT BASED STREET LIGHTING SYSTEMS

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Abstract-This project delves into the creation of an advanced Smart Fault Detection and Maintenance system tailored for IoT-based street lighting networks. It leverages an array of sensors including current and voltage sensors, along with LDR (Light Dependent Resistor) sensors, in conjunction with a relay module, Arduino Uno microcontroller, GSM module, and power adaptor. The core objective is to detect and rectify faulty bulbs within the street lighting infrastructure.The system operates by strategically deploying a reference LDR sensor exposed to sunlight to establish a baseline reading. Simultaneously, other LDR sensors are deployed at individual streetlight locations, functioning inversely in response to ambient light levels. When the reference LDR detects low light conditions, indicating darkness, the relay module is activated to illuminate all street lights until the reference LDR reverts to sunlight conditions. During this period, the LDR sensors at streetlights record low values due to the artificial lighting. The identification of faulty bulbs is achieved through a comparison of the LDR values of street lights with the reference LDR. Additionally, the system incorporates current and voltage sensors to gather data on power consumption, aiding in the detection of faulty bulbs. The data collected from all sensors is then processed by the Arduino Uno microcontroller and transmitted via the GSM module to the ThingSpeak server for comprehensive monitoring.This project's primary aim is to significantly enhance fault detection efficiency while fostering energy-efficient street lighting systems by harnessing advanced sensor technology and IoT connectivity.

Keywords: Smart Fault Detection, IoT-based Street Lighting Systems, Current Sensor, Voltage Sensor, LDR Sensor, Relay Module, GSM Module

1.INTRODUCTION

In modern urban environments, street lighting plays a pivotal role in ensuring safety and security for pedestrians and motorists alike. However, ensuring the continuous and efficient operation of streetlights poses significant challenges, particularly in large-scale installations spread across vast urban areas. To address this issue, the development of a smart fault detection and maintenance system for IoT-based street lighting systems is paramount.In the modern urban landscape, the integration of Internet of Things (IoT) technology is reshaping traditional systems, and one area experiencing significant transformation is street lighting infrastructure. Our project endeavors to harness the power of IoT to develop a sophisticated yet user-friendly system for fault detection and maintenance in street lighting networks. The advent of the Internet of Things (IoT) has ushered in a new era of innovation, particularly evident in the realm of urban infrastructure. Among the many areas experiencing transformation, street lighting systems stand out as a focal point of development and optimization. With the rise of smart cities globally, there is an increasing emphasis on leveraging IoT solutions to enhance the functionality, efficiency, and sustainability of urban infrastructure. In this context, the current project is dedicated to the development and implementation of a sophisticated Smart Fault Detection and Maintenance system tailored specifically for IoT-integrated street lighting networks. At the heart of this endeavor lies a fusion of cutting-edge technologies, including current sensors, voltage sensors, Light Dependent Resistor (LDR) sensors, relay modules, GSM (Global System for Mobile Communications) modules, Arduino Uno microcontrollers, and power adaptors. These advanced components collectively form the backbone of a system designed to autonomously detect and identify faulty bulbs within street lighting infrastructure. The primary objective is to facilitate rapid and targeted maintenance interventions, thereby minimizing downtime and ensuring optimal performance of street lighting networks.The motivation behind this project stems from several critical challenges prevalent in traditional street lighting setups. These challenges include inefficient fault detection mechanisms, delayed maintenance responses, and excessive energy consumption due to inefficient lighting operations. By integrating real-time monitoring capabilities and intelligent sensor technology, the project seeks to address thesechallenges comprehensively, paving the way for a more efficient, sustainable, and resilient urban lighting ecosystem.One of the key features of the proposed system is its ability to leverage sensor data and IoT connectivity to proactively detect faults in street lighting infrastructure. The utilization of current sensors and voltage sensors enables the system to monitor the electrical parameters of individual bulbs, detecting anomalies such as power surges or failures. Additionally, the incorporation of LDR sensors facilitates environmental sensing, allowing the system to adjust lighting levels based on ambient light conditions and optimize energy usage.The integration of relay modules and GSM modules further enhances the system's capabilities by enabling remote control and monitoring. The Arduino Uno microcontroller serves as the central processing unit, orchestrating data collection, analysis, and communication between various system components. This centralized control mechanism streamlines operations and enhances the overall efficiency of the system.In summary, the Smart Fault Detection and Maintenance system for IoT-based street lighting represents a significant step forward in urban infrastructure management. By harnessing the power of IoT, advanced sensors, and intelligent data analytics, the system promises to revolutionize the way street lighting networks are monitored, maintained, and optimized. Ultimately, the project aims to contribute to the creation of smarter, more sustainable, and resilient cities that prioritize efficient resource utilization and enhanced quality of life for residents.Byintegrating advanced sensor technology, cloud communication, and user-friendly interfaces, this project aims to revolutionize the maintenance and management of IoT-based street lighting systems. Through proactive fault detection and streamlined maintenance processes, we endeavor to create safer, more efficient, and sustainable urban environments for communities worldwide.

II. LITERATURE REVIEW

S. Fotios et al., proposed a system that explores the impact of road lighting on pedestrian reassurance, particularly in enhancing confidence during nighttime walks. Emphasizing an unfocused approach to avoid bias towards lighting or fear, findings suggest an optimal illuminance of 10 lux with high S/P ratio, aimed at pedestrians and natural surroundings. Further research is warranted to validate these parameters[1].

M.N.Bhairi et al., proposed a system that paper presents a novel approach to energy-efficient street lighting using a low-cost microcontroller-based Arduino system. Targeting rural, urban, and smart city environments, the system integrates LED luminaires, a PV panel, charge controller, light and motion sensors, and Arduino. The system dynamically adjusts lighting based on traffic, daylight, and weather conditions, aiming to minimize energy wastage and promote sustainability in street lighting infrastructure [2].

J.W. Baek et al., proposed that the dynamic lighting control system for smart streetlights employing an edge camera equipped with a lightweight deep neural network for object detection. The system dynamically adjusts brightness based on pedestrian presence, maintaining low illumination in absence and switching to high illumination upon detection. Protocol design ensures real-time processing and high detection accuracy, enhancing efficiency and safety in urban environments [3].

A.Jha et al., proposedthe proliferation of IoT technology has revolutionized connectivity, transitioning from human-device interactions to device-device connections. Automatic detection of faulty streetlights emerges as a critical application of this technology. This project aims to automate the identification and control of damaged street lights, ensuring energy efficiency and timely fault response. Utilizing sensors, the system captures the status of street lights without manual intervention, reducing manual effort and response time. Notifications are sent to authorized personnel regarding malfunctioning streetlights, along with location details. IoT facilitates automatic ON/OFF control of street lights, further enhancing efficiency based on weather conditions[4].

Y.S.Yang et al., proposed an efficient system for configuring, deploying, and managing smart street lights, integrating sensors for data collection. Through container-based management,enablesfast deployment and scalability. Secure data transmission is ensured via asymmetric key encryption, meeting the demands of smart cities for data throughput and low-latency[5].

G. Gagliardi et al., proposed this paper presents the outcomes of the SCALS (Smart Cities Adaptive Lighting System) project, focusing on developing hardware and software components for an adaptive urban smart lighting framework. The system autonomously adjusts street lamp brightness based on vehicle and pedestrian presence to minimize energy consumption. It contributes by designing a cost-effective smart lighting system and an IoT infrastructure for networked lighting poles. This infrastructure supports scalability for broader technological architectures aimed at sustainable cities. The smart system integrates subsystems like local controllers, motion sensors, video cameras, and weather sensors for various operations. These include remote street lamp management, individual lamp brightness control, vehicle motion detection and classification, and data exchange for power consumption analysis and traffic evaluation. Pilot sites were established for real-world testing and validation. Results demonstrate energy savings of up to 80% compared to traditional systems[6].

P.T. Delay et al., proposed the integration of sensors and ZigBee-based wireless modules enables innovative LED street lighting crucial for smart cities. Correlated color temperature (CCT)-based illumination enhances energy efficiency and safety. This paper proposes an integration of public weather data, ZigBee-based communication, and web-based management for smart LED streetlights, ensuring optimal transmission and reception parameters[7].

III. METHODOLGY

The research paper focuses on leveraging the IoT technologies to enhance the monitoring and maintenance of street lighting systems. By integrating various sensors and communication modules, the system aims to detect and address faults in streetlight bulbs promptly. Key components utilized in the project include current sensors, voltage sensors, relay modules, GSM modules, Arduino Uno microcontrollers, LDR sensors, and power adaptors.The heart of the system lies in its ability to detect faults within streetlight bulbs efficiently. This is achieved through the utilization of current and voltage sensors, which continuously monitor the electrical parameters of each streetlight. A predefined cutoff threshold is established for both current and voltage values. If the measured values deviate from these thresholds, indicating abnormal behavior, it signifies a potential fault in the corresponding streetlight bulb.Additionally, the system incorporates LDR sensors to assess the ambient light conditions surrounding each streetlight. In areas with ample natural light, such as open spaces or locations exposed to sunlight, the LDR sensor registers high values. Conversely, in areas with minimal ambient light, the LDR sensor readings are lower. This information is crucial in determining the operational status of streetlight bulbs, especially during daylight hours.Once sensor data is collected by the Arduino Uno microcontroller, it is transmitted via GPRS using the SIM800L GSM module. The data is then relayed to the ThingSpeak platform, a cloud-based IoT analytics platform. Here, a read API key is utilized to extract and process the updated sensor values in JSON format. The ThingSpeak platform serves as a central hub for monitoring and analyzing streetlight data in real-time. By aggregating sensor readings from across the city, authorities gain valuable insights into the health and performance of the street lighting infrastructure. Any deviations from normal operating parameters trigger alerts, allowing maintenance teams to respond promptly to potential faults.To provide stakeholders with a comprehensive overview of streetlight status, a user-friendly interface is developed. This interface takes the form of a simple webpage, accessible through any internet-enabled device. Using JSON data retrieved from ThingSpeak, the interface visually represents the operational status of streetlight bulbs. Functional bulbs are depicted in green, signifying normal operation, while faulty bulbs are highlighted in red, indicating the need for maintenance or replacement. This intuitive visualization allows city officials and maintenance crews to quickly identify areas requiring attention and prioritize their efforts accordingly. Overall,the development of a smart fault detection and maintenance system for IoT-based street lighting systems represents a significant advancement in urban infrastructure management. By leveraging IoT technologies, sensor data analytics, and cloud-based communication platforms, the system enables proactive maintenance and efficient utilization of resources. Ultimately, it enhances public safety, reduces downtime, and ensures the continuous operation of street lighting systems in urban environments.

IV. PROPOSED MODEL

A) Block Diagram of our work

The block diagram depicts the Smart Fault Detection and Maintenance system for IoT-based Street Lighting and Monitoring. It includes current, voltage, and LDR sensors linked to the Arduino Uno microcontroller. These sensors monitor streetlight parameters and ambient light. The Arduino processes data and communicates with the relay module to control streetlights. The project aims to detect and rectify faults efficiently by analyzing sensor data to identify faulty bulbs based on predefined thresholds. The LDR sensor distinguishes between high and low ambientlightareas.

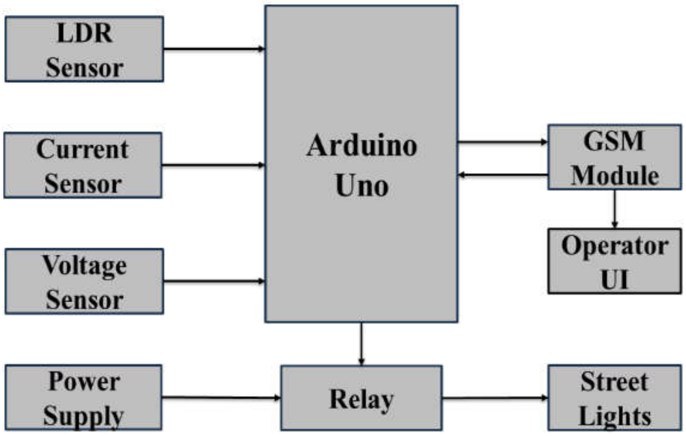

Fig1: Block Diagram of Smart Street Light Fault Detection Using IoT

Sensor data processed by the Arduino Uno is transmitted via GPRS using the SIM800L GSM module. It's sent to the ThingSpeak platform, using a read API key to extract updated values in JSON format. This cloud-based platform acts as a central repository for real-time monitoring. A user interface visualizes streetlight status on a simple webpage, with green indicating functional bulbs and red indicating faulty ones, aiding stakeholders in identifying maintenance areas.

LDR Sensor: This sensor measures the ambient light level to determine if the street lights need to be turned on or off, which is a fundamental part of automating street lighting based on day and night cycles.

Current Sensor:

By measuring the current, this sensor helps in fault detection by identifying unusual current draws that could indicate a malfunctioning light or wiring issue.

Voltage Sensor:

This sensor ensures that the voltage levels are within acceptable limits. Abnormal voltage readings can signal potential faults in the lighting system that may require maintenance.

Power Supply:

It provides the necessary power to the sensors and the Arduino Uno. Since it's part of a fault detection system, it might also include features to monitor power quality and interruptions.

Arduino Uno:

Acts as the central controller that processes the sensor data to manage the operation of the street lights and fault detection logic. It would also run the code that determines when maintenance is required based on sensor inputs.

Relay:

Serves as a switch controlled by the Arduino to turn the street lights on and off, and it could also be used to isolate parts of the system if a fault is detected.

GSM Module:

This module allows the system to communicate with a remote server or maintenance crew via cellular networks, sending alerts or reports when faults are detected or maintenance is needed.

Mobile Operator& Street Lights:

Represents the cellular service provider that the GSM module uses to send and receive data. This is crucial for the remote monitoring and alerting capabilities of the system.The Street lights are actual lighting fixtures that are controlled and monitored by the system.

B) Software Design

Flowchart of the working procedure of hardware:

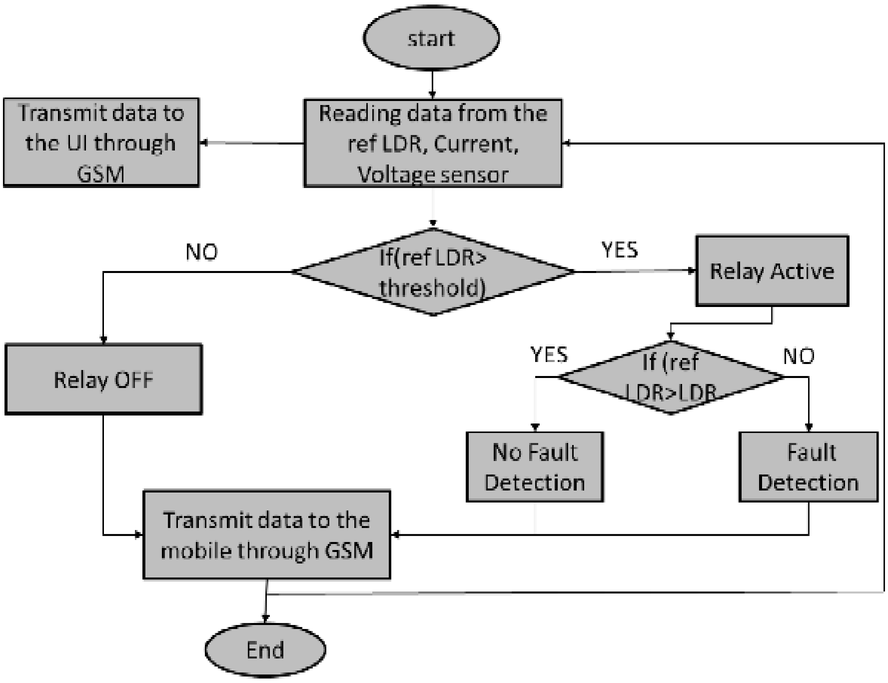

Fig.2: Flowchart of FaultDetection and monitoring system using IoT

The provided description outlines the operational sequence of a Fault Detection and monitoring system utilizing IoT technology. The process begins with the system that collects readings from the light-dependent resistor (LDR), current sensor, and voltage sensor.The data collected by the sensors of thesystem checks if the LDR value is greater than a predefined cutoff value OR if the current reading is outside the set high and low limits. If either condition is true, the system proceeds to the fault detected state.If neither condition is true, the system proceeds to read the data from the sensors.If no fault is detected, the system likely operates normally and this state might not be explicitly shown in the flowchart.This decision point where the data is collected from the sensors might be included to check the voltage reading against an actual value. If the voltage is higher than the expected value, the system transmits data to the operator via GSM. This might indicate an overvoltage condition. GSM stands for Global System for Mobile Communications, a standard for mobile network communication. If the voltage is within the expected range, the system likely operates normally and this state might not be explicitly shown in the flowchart. The system transmits the sensor readings to the operator through a GSM network, likely for further analysis or corrective actions.Overall, this system describes a basic fault detection system for monitoring light, current, and voltage levels. By setting appropriate thresholds for the LDR, current, and voltage readings, the system can identify potential issues and notify the operator for intervention.

RESULT AND DISCUSSION:

Fig.3: When the light intensity of the surroundings is low, then relay goes high and finally light is ON

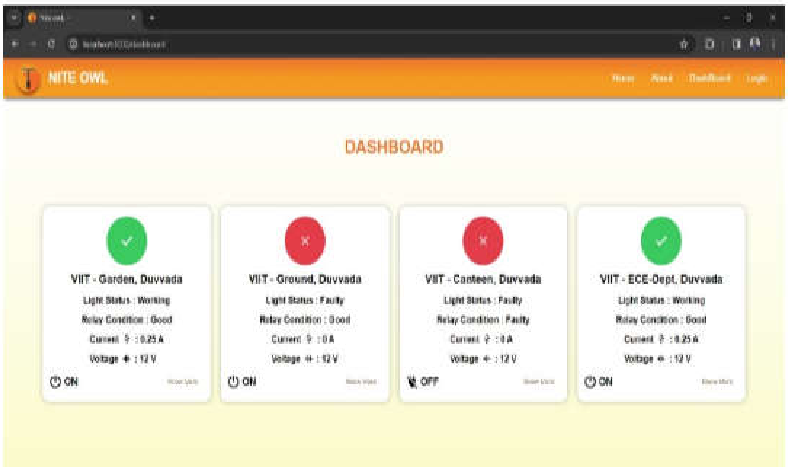

Fig. 4:Data on ThingSpeak Application

The Smart Fault Detection and Maintenance system is like a superhero for city lights. It uses special sensors and smart technology to keep an eye on the streetlights and any faults can be monitored quickly. With this system, it's easier to find damaged lights and make sure they get fixed faster, which helps in saving energy and makes the streets safer. It gives real-time updates which are easy-to-understand information, by helping cities run better and makes sure the streets stay bright and safe for everyone.

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