A Signals and Systems Approach to Automated Street Light Fault Detection

Mr. A. Balakumar[1], balakumar2712@gmail.com[1]
Faculty, Department of ECE, K. Ramakrishnan college of engineering
Abishek A[2], Gurubaran M[3], Jagadeeshkumar P[4], Jegan S[5]
abishekasai07@gmail.com[2], gurub8157@gmail.com[3], jagadeeshkumar45@gmail.com[4], jehanj641@gmail.com[5]
Student, Department of ECE, K. Ramakrishnan college of engineering

Abstract: - Street lighting plays a crucial role in ensuring public safety, urban aesthetics, and energy efficiency. However, manual monitoring and maintenance of street lights are time-consuming, inefficient, and prone to delays in fault detection. This paper presents an automated street light fault detection system designed to identify and report faults in real time. The proposed system utilizes sensors, microcontrollers, and wireless communication modules (such as IoT-based platforms) to monitor parameters like current, voltage, and illumination intensity. When an anomaly—such as lamp failure, wiring fault, or abnormal power consumption—is detected, the system automatically sends notifications to a centralized monitoring unit or maintenance personnel. The integration of machine learning algorithms or threshold-based decision models further enhances accuracy by distinguishing genuine faults from transient fluctuations. Experimental results demonstrate that the system significantly reduces maintenance time, operational costs, and energy wastage, while improving reliability and sustainability of street lighting infrastructure. This work contributes to the development of smart city initiatives by enabling autonomous, efficient, and cost-effective street light management.

Key Word: *Automated street lighting, Fault detection, IoT monitoring, Machine learning, Smart city infrastructure.*

I. INTRODUCTION

Street lighting is an essential component of urban infrastructure, contributing to public safety, traffic management, and the overall aesthetics of cities. Properly functioning street lights reduce accidents, deter criminal activity, and improve the quality of life for residents. However, the conventional approach of manually monitoring and maintaining street lights is inefficient, time-consuming, and often fails to detect faults promptly. Delays in identifying non-functional or malfunctioning lights can lead to increased maintenance costs, energy wastage, and safety hazards.

Recent advancements in technology, particularly in sensors, microcontrollers, wireless communication, and the Internet of Things (IoT), have enabled the development of automated systems capable of real-time monitoring and fault detection in street lighting networks. These systems can continuously monitor parameters such as voltage, current, and illumination intensity to detect anomalies such as lamp failures, wiring issues, or abnormal energy consumption. Furthermore, the integration of intelligent algorithms, including threshold-based models or machine learning techniques, enhances the system's ability to differentiate between genuine faults and transient fluctuations.

Automated street light fault detection systems offer multiple advantages, including reduced operational costs, improved energy efficiency, faster maintenance response, and overall reliability of the lighting infrastructure. By enabling real-time fault reporting to centralized monitoring units or maintenance personnel, such systems contribute to the broader vision of smart cities, where urban services are optimized through automation and data-driven decision-making.

II. LITERATURE REVIEW

The domain of street lighting fault detection has witnessed significant research driven by the need for enhanced reliability, efficiency, and smarter urban infrastructure. Existing literature can be broadly classified into three themes:

sensor and IoT-based monitoring systems, fault localisation and advanced analytics, and integration for smart-city deployment.

Early studies utilized basic sensors such as light-dependent resistors (LDRs) and ambient light sensors with microcontrollers to automate street light control and detect gross faults. For instance, Sangeetha et al. (2025) developed an Arduino-based system with LDR and IR sensors for fault detection and brightness adjustment, while other studies such as "IoT-based Street Light Auto Intensity Control and Fault Detection" (2022) and Kumar & Vadivel (2024) demonstrated IoT-enabled monitoring using Node MCU and platforms like Thing and Speak to track lamp status and ambient conditions in real time.

While these systems validated the feasibility of real-time monitoring, they often lacked granularity in fault classification and faced scalability challenges. Beyond monitoring, research has focused on fault localisation using machine learning and image-based approaches to identify specific lamps and fault types. Works like "Automated Fault Detection and Location Monitoring of Street Lights in Smart Cities" (2024) implemented sensor networks with GPS tracking, while computer vision and deep learning methods have been applied to analyse lamp conditions from nighttime imagery.

Federated learning has also been explored for decentralized fault detection. These approaches improve detection accuracy but introduce challenges such as high cost, computational overhead, and practical deployment constraints in large-scale networks. Additionally, integrating fault detection with smart-city and energy-efficiency goals has gained attention.

Systems like the IoT-based framework in Bangladeshi cities (2022) and "Intelligent Street Lighting: An IoT-based System for Adaptive Brightness and Fault Management" (2024) combined adaptive brightness control with real-time fault monitoring, achieving energy savings while enhancing infrastructure reliability. Despite these advances, several gaps remain, including limited detection of subtle faults (e.g., wiring degradation, sensor drift), inconsistent location tracking, experimental nature of ML/vision methods, high deployment costs, network reliability issues, and underexplored trade-offs between energy efficiency and fault detection.

III. MATERIALS AND METHODS

The proposed automated street light fault detection system utilizes a combination of hardware and software components to enable real-time monitoring and fault reporting. The hardware consists of a microcontroller, such as Arduino Uno or Node MCU, which processes sensor data and controls communication, along with sensors including Light Dependent Resistors (LDR) for measuring illumination, current sensors (ACS712) for detecting power anomalies, and voltage sensors to monitor electrical irregularities. Optional IR motion sensors can be incorporated for adaptive brightness control based on pedestrian or vehicle movement. Data collected by the sensors is processed by the microcontroller using either threshold-based methods, where predefined limits identify anomalies, or machine learning algorithms such as decision trees or support vector machines to classify faults including lamp failures, wiring.

Upon detecting a fault, the system sends real-time notifications via Wi-Fi or GSM modules to a centralized monitoring unit or maintenance personnel, specifying the fault type and location. All sensor readings and detected faults are logged on an IoT platform or cloud database to enable trend analysis, predictive maintenance, and efficient scheduling. The system architecture follows a modular design, with sensor nodes at each lamp post transmitting data to the microcontroller, which either processes the data locally or forwards it to a cloud server. The prototype can be deployed on a small-scale street-light network or laboratory setup to evaluate performance, and fault scenarios such as lamp burnout, power loss, and wiring failures are simulated to assess detection accuracy, response time.

At the same time, a light detector checked how bright it was outside to know if it was dark or nighttime - when lights should turn on. The small computer kept checking data from both sensors, measuring against set limits. When little power flowed but only while the light ought to be running - and electricity supply showed normal - it marked that bulb as broken. That alert got sent off through wireless signals via Wi-Fi, cellular networks, Lora WAN, or narrowband IoT, based on which hardware piece was installed. The setup kept sending regular check-ins on its condition - this made sure distant tracking worked well. In total ongoing info checks meant spotting broken streetlights fast while hardly.

STREET LIGHT FAULT DECTECTION

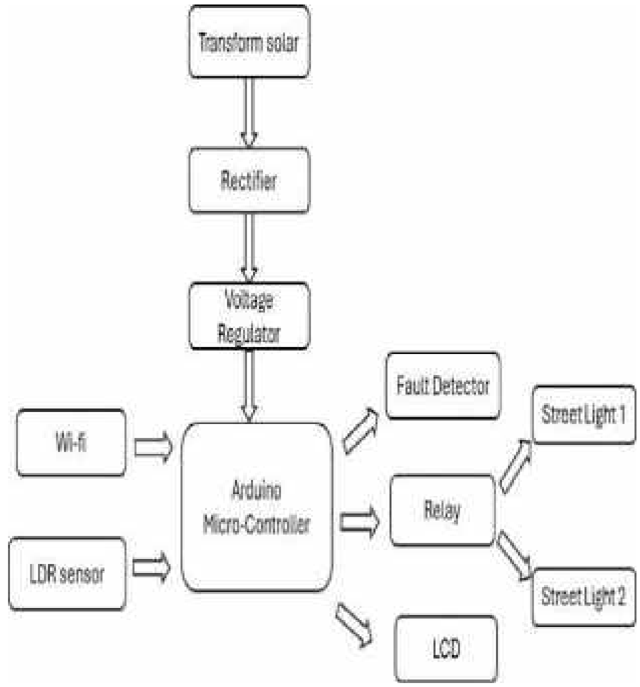

Fig 1: Block Diagram

VI. RESULT AND DISCUSSION

The proposed automated street light fault detection system demonstrates significant improvements in reliability, efficiency, and maintenance responsiveness compared to traditional manual monitoring approaches. By integrating sensors, microcontrollers, and wireless communication modules, the system provides real-time detection and reporting of various fault types, including lamp failures, wiring issues, and abnormal power consumption. The use of current, voltage, and illumination sensors ensures comprehensive monitoring of each street light, while threshold-based or machine learning algorithms enhance fault classification accuracy, distinguishing genuine faults from transient fluctuations.

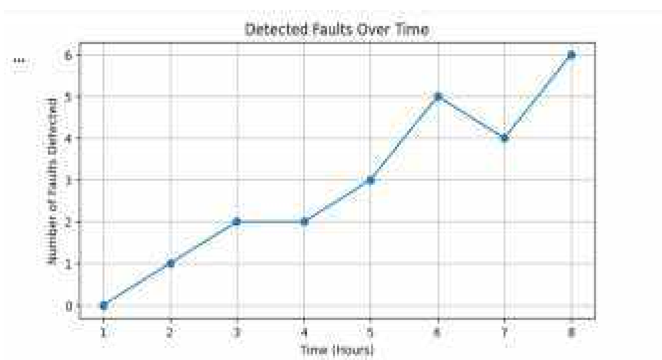

Fig2: Detected Fault Over Time

Fig 2: The number of faults increases during an 8-hour period. On the x-axis, time is shown in hours from 1 to 8, and on the y-axis, the number of faults detected ranges from 0 to 6. The graph starts with 0 faults in the first hour, then gradually rises to 1, 2, and 2 faults in the next few hours. As time continues, the faults increase to 3, 5, and 4, and finally reach the highest value of 6 faults in the eighth hour. Overall, the image tells that faults were detected more frequently as time passed, with some small fluctuations, showing a general upward trend in system fault detection**.**

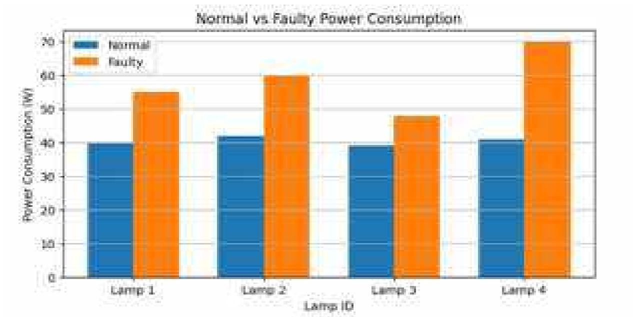

Fig 3: Normal vs Faulty Power Consumption

Fig 3: A bar graph comparing power consumption of four lamps under normal and faulty conditions. Each lamp (Lamp 1 to Lamp 4) has two bars: a blue bar for *normal* power use and an orange bar for *faulty* power use. In all cases, the faulty power consumption is higher than the normal one. Lamp 1 increases from about 40W to 55W, Lamp 2 from about 42W to 60W, Lamp 3 from 40W to 48W, and Lamp 4 from 41W to 70W. Overall, the graph tells that faulty lamps consume significantly more power, indicating abnormal operation and energy wastage.

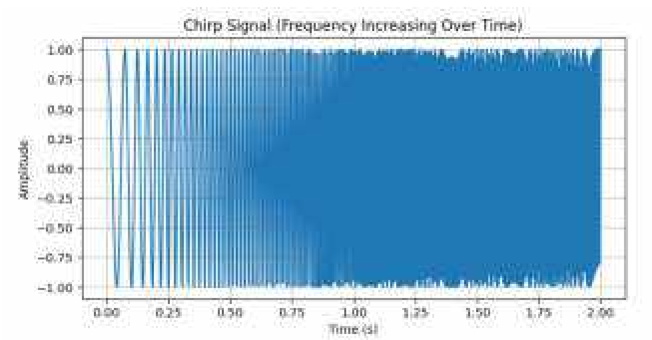

Fig 4: Chirp Signal (Frequency Increasing Over)

Fig 4: which is a type of waveform whose frequency increases over time. At the left side of the graph (near time = 0 seconds), the signal oscillates slowly, meaning the frequency is low. As time moves forward toward 2 seconds, the oscillations become much faster and closer together, showing that the frequency becomes very high. The amplitude stays between +1 and –1, but the spacing between the wave changes, indicating the frequency sweep. Overall, the graph tells that this is a signal whose pitch or frequency continuously rises from low to high over a period of 2 seconds.

V. CONCLUSION

This paper presents an automated street light fault detection system that enhances the efficiency, reliability, and sustainability of urban lighting infrastructure. By integrating sensors to monitor current, voltage, and illumination, along with microcontrollers and wireless communication modules, the system enables real-time detection and reporting of faults such as lamp failures, wiring issues, and abnormal power consumption. The incorporation of threshold-based or machine learning algorithms further improves fault classification accuracy and reduces false alarms caused by transient anomalies. Experimental evaluation demonstrates that the proposed system significantly reduces maintenance time, operational costs, and energy wastage, while providing actionable insights for maintenance personnel through centralized monitoring platforms. The modular and IoT-enabled architecture supports scalability, smart-city integration, and future enhancements such as predictive maintenance and adaptive energy management. Overall, this work contributes to the development of intelligent, autonomous, and cost-effective street lighting management systems, paving the way for safer, energy-efficient, and sustainable urban environment.

REFERENCE

[1] Sampath Kumar Pappula, Lakshmi Lavanya Eemani, Pavan Sita Ram Galaba, Pranathi Karra, Sai Prasanna Katta & Trisha Indagate. *"IoT based Street Light Auto Intensity Control and Fault Detection."* International Journal of Engineering Research & Technology (IJERT), Vol. 11, Issue 05, May 2022.

[2] R.P. Sharan Kumar & R. Vadivel. *"IoT based smart street light fault detection management system."* World Journal of Advanced Research and Reviews, 2024, 21(03), 1659-1666.

[3] Pradeep R, Sobiya S, Nukala Kavya, Vuddanti Keshuvardhan. *"Automated Fault Detection and Location Monitoring of Street Lights in Smart Cities."* International Research Journal on Advanced Engineering Hub (IRJAEH), Vol. 2 No. 05 (May 2024), DOI: 10.47392/IRJAEH.2024.0198.

[4] Sasidevi S., Vasanthi M., Ganeshkumar J., Kamalesh V., Naveenkumar G., Ajithkumar S. *"Intelligent Street Lighting: An IoT-based System for Adaptive Brightness and Fault Management."* Journal of IoT in Social, Mobile, Analytics, and Cloud, 2024; 6(3):227-239. DOI: 10.36548/jismac.2024.3.003.

[5] A. T. M. Mustafa Masud Chowdhury, Jeenat Sultana, Md Sakib Ullah Sourav. *"IoT-based Efficient Streetlight Controlling, Monitoring and Real-time Error Detection System in Major Bangladeshi Cities."* arXiv preprint, 2022.

[6] Sangeetha S, Ganesh G, Jeeva R, Kavin K, Suriya S. "Street Light Automation and Fault Detection". International Journal of Electronics Automation, 2025; 03(01):123-130.

[7] Sharan Kumar R. P. and Vadivel R. "IoT based fault detection in smart street light management system. World Journal of Advanced Research and Reviews, 2024; 21(03):1659-1666. DOI: 10.30574/wjarr. 2024. 21. 3. 0685.

[8] Resmara S. "Smart street light system with fault detection." Manipal Journal of Science and Technology, Vol. 7, Issue 1, 2022.

[9] S., Sasidevi; Vasanthi M.; Ganeshkumar J.; Kamalesh V.; Naveenkumar G.; Ajithkumar S.

[10] Intelligent streetlighting: an IOT based system for the adaptive brightness and fault management. Journal of IoT in Social, Mobile, Analytics, and Cloud (JISMAC), 6(3), 2024 pp.227-239. DOI: 10.36548/jismac. 2024. 3. 003

[11] Pradeep R., Sobiya S., Nukala Kavya, Vuddanti Keshuvardhan. "Automated Fault Detection and Locating of Street Lighting in the Smart Cities. International Journal of Advanced Engineering Research and Science (IJAERS) [Vol-5, Issue-7, July-2018] 398 NATIONAL INSTITUTE OF TECHNOLOGY warangal.Copy right@2016 ISSN : 2349 - 6495(Print) ISSN : 2454 - 9333(Online),343. 2, P. 1441-1446 05 Su M.. Niu H.: Empty gelcoat for composite material[J]. DOI: 10.47392/IRJAEH. 2024. 0198