

## Lamp Malfunction Detection System

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### Abstract

In a hospital, reliable lighting is crucial. This study developed a lamp malfunction detection system using LDR and voltage sensors to monitor lamp conditions. An ESP32 microprocessor processed sensor inputs and communicated statuses to a Visual Basic (GUI) interface, which displayed lamp conditions and provided alerts for malfunctions. The ESP32's Wi-Fi module, integrated with the Blynk cloud platform, notified the person in charge (PIC) via phone messages. Testing confirmed the system accurately detected lamp statuses and alerted the PIC, enhancing maintenance efficiency and ensuring seamless operations in critical facilities.

## 1. Introduction

Efficient lamp monitoring and management have become crucial in technological advancement, marking a significant step in building automation. This innovation aims to streamline the control and supervision of essential daily components. As technology rapidly advances, integrated lamps in buildings have become ubiquitous, enhancing daily life. However, with increased reliance on these appliances, ensuring their safety and mitigating risks has become critical. Recognizing this, advanced systems have been developed to monitor lamp conditions, ensuring timely maintenance and preventing disruptions. These efforts enhance safety and reliability, underscoring the importance of efficient lamp management in our modern technological landscape.

Recent technological advancements have made lamps integral to modern living, enhancing convenience and efficiency. However, their increasing complexity raises the risk of malfunctions. This literature review examines Electrical Appliance Malfunction Detection Systems, highlighting current knowledge, identifying research gaps, and exploring innovative approaches to improve detection and reliability.

A Light-Dependent Resistor (LDR) sensor, also known as a photoresistor or photocell, changes resistance based on light intensity and is used in electronic circuits and light-sensing applications (Amin Marzuki et al., 2015). The ZMPT101B is a precision AC voltage sensor module for monitoring AC voltages up to 240V, commonly used in energy meters, power monitoring systems, and home automation. Its core component, the ZMPT101B voltage sensor, offers high accuracy, stability, and linearity, ensuring reliable voltage measurement. The sensor isolates high-voltage AC from low-voltage microcontrollers, enhancing user safety and protecting the electronics during the measurement process (Yan Xie, 2018).

The ESP32-WROOM, designed by Espressif Systems, is a powerful dual-core Wi-Fi and Bluetooth module. Ideal for IoT, smart home, and wearable devices, it supports 2.4 GHz Wi-Fi and BLE. Its high integration, including touch sensors, Ethernet MAC, and multiple interfaces, simplifies development and enhances versatility (Germano et al., 2008).

Visual Basic (VB) is a programming language and integrated development environment (IDE) developed by Microsoft. It is renowned for its user-friendly nature and versatility, catering to both novice and seasoned developers. VB excels in Rapid Application Development (RAD), enabling rapid creation of graphical user interface

(GUI) applications. VB operates on an event-driven programming paradigm, where actions or events initiate specific procedures or functions. Additionally, Visual Basic supports Object-Oriented Programming (OOP) principles, enhancing code organization and reusability within applications (Bryan Newsome, 2015).

The Arduino IDE (Integrated Development Environment) is a versatile open-source platform tailored for writing, compiling, and uploading code to Arduino-compatible boards. It features a user-friendly interface suitable for beginners and seasoned developers alike. The IDE includes a text editor for coding, a message area, a console, and a toolbar with essential functions like code verification and upload. It also offers a serial monitor for interacting with Arduino boards via serial communication. Programming is based on a simplified version of C/C++, supported by a range of libraries and examples that expedite project development and customization.

In conclusion, the advancements in lamp technology have significantly enhanced modern living by improving convenience and efficiency. However, the complexity of these devices has also increased the likelihood of malfunctions, underscoring the importance of robust Electrical Appliance Malfunction Detection Systems. This review has highlighted the pivotal role of technologies such as Light-Dependent Resistor (LDR) sensors and precision AC voltage sensors like the ZMPT101B in detecting and monitoring electrical faults effectively. The integration of advanced modules like the ESP32-WROOM and the versatility of development platforms such as Visual Basic (VB) and the Arduino IDE further enable the creation of sophisticated monitoring and control systems. Moving forward, continued research and innovation in these technologies will be crucial to enhancing detection accuracy, reliability, and user safety in electrical systems, ensuring seamless operation and longevity of essential appliances in diverse applications.

## 2. Related Research

The Fault Monitoring System for Traffic Lights addresses delays in responding to malfunctions by automating the detection of power failures and malfunctioning LED bulbs. It promptly notifies maintenance personnel via SMS for immediate action and ensures operational integrity by testing traffic light sequences and power stability. Components include LEDs, IC 4017, Arduino Atmega, and current sensors. System functionality was validated through tests on light sequences, power stability, malfunction detection, and SMS notifications using a GSM modem.

Other than that, The Analog Signal Malfunction Detection System for Audio Distribution Frames, utilizing RFID/GPRS technology, automates the assessment of analog signal and cable status, which is traditionally reliant on manual inspections. It integrates the ADSP21060 processor and GPRS SIM300 module, with RFID and analog signal fault detectors. Current sensors ensure precise monitoring. The system remotely detects and processes faults, eliminating the need for on-site checks and maintenance costs effectively.

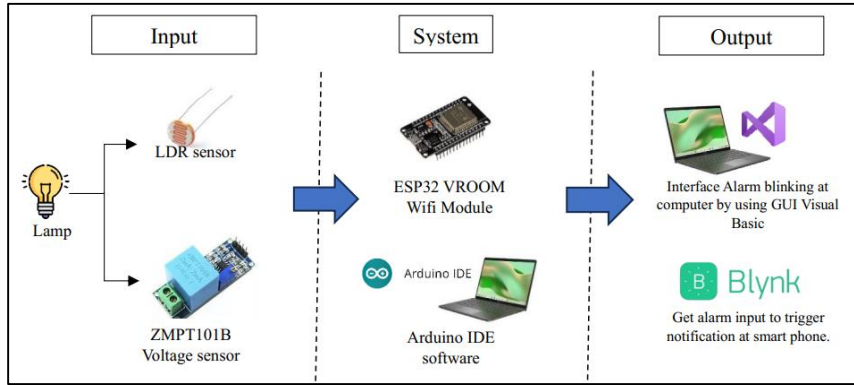
Next, The Blackbird Monitoring System addresses the complexities of diverse application environments, often lacking adequate monitoring systems. It aims to provide comprehensive monitoring capabilities across various applications, which is crucial for environments like Vodafone. This project develops in-house monitoring systems that deliver detailed metrics aligned with core application objectives. By executing specific tasks within applications and utilizing their interfaces, the system extracts essential operational parameters effectively. The results showcase its ability to offer detailed application-level monitoring with minimal setup, using a simplified model that standardizes application descriptions. Future enhancements focus on expanding interface modules to enrich monitoring capabilities further.

## 3. Methodology

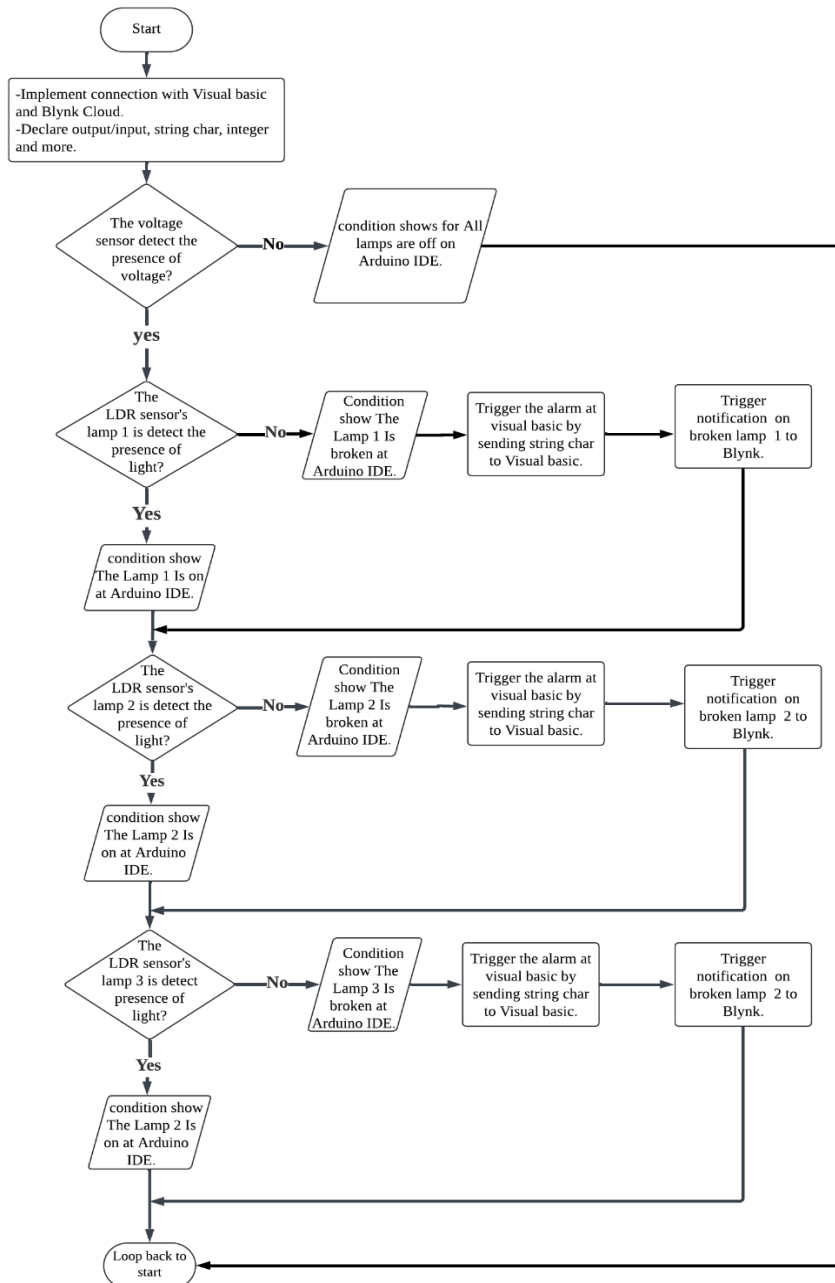
The electrical lamp malfunction detection and monitoring system, depicted in Fig. 1, employs LDR and voltage sensors to assess lamp conditions and detect faults. Sensor inputs, including current and voltage, are processed by an analog input processor. This data triggers alarms on the GUI interface. An ESP32 microprocessor analyzes sensor data and communicates it to a Visual Basic GUI, which displays device statuses as Fig. 1. The interface visually signals malfunctions, such as flashing indicators for faulty lamps. Using its Wi-Fi module and the Blynk cloud platform, the ESP32 sends notifications via phone messages to alert users about lamp malfunctions promptly. This integrated system ensures efficient monitoring and timely maintenance of electrical equipment, enhancing operational reliability in critical facilities.

The flowchart outline, based on Fig. 2, is a lamp detection system to assess the status of three lamps: on, off, or broken. Initially, the processor establishes a connection with the Graphic User Interface (GUI) via Microsoft Visual Basic and the Blynk platform. It then uses a voltage sensor to detect the presence of circuit voltage. If no voltage is detected, the lamps are marked as switched off. Conversely, if voltage is detected, the processor checks each lamp using its respective Light Dependent Resistor (LDR) sensor.

The LDR sensors are pivotal in identifying broken lamps; if the light is detected, the lamp is declared as on. Otherwise, it is marked as broken. Once all lamp statuses are determined, any broken lamps trigger an alarm and alert notification sent to the Microsoft Visual Basic GUI and Blynk platform through the processor.



**Fig 1** Block diagram for Lamp malfunction detection system



**Fig 2** Project flowchart

The hardware setup for the lamp detection system includes three lamps, each equipped with an LDR sensor to monitor their operational status. Additionally, a voltage sensor is integrated into the circuit, positioned across the

live and neutral wires of the lamp power supply. This sensor detects whether there is voltage present, indicating if the lamps are powered on or off.

In Fig. 3, all sensors—LDR and voltage—are connected to the ADC (Analog-to-Digital Converter) input pins of the ESP32 microcontroller. These connections enable the ESP32 to receive analog signals from the sensors, converting them into digital data for processing. Power for the sensors is supplied from the ESP32's stable 5V output, ensuring consistent operation. This setup allows the ESP32 to effectively monitor and manage the lamps in real-time. Through integration with the Blynk app, the system can provide remote updates and alerts, facilitating efficient fault detection and management in the lamp detection system.

### 3.1 Overview Hardware Setup

In a 240-volt circuit, ensuring safety and compliance with electrical standards is crucial when wiring three lamps. Typically, lamps are wired in either series or parallel configurations. Parallel wiring is preferred for its reliability and safety features. In a parallel setup, each lamp functions independently. This means if one lamp malfunctions or is turned off, the others remain operational. To wire three lamps in parallel, the live (brown) wire from the 240-volt power source connects to the live terminal of each lamp. Similarly, the neutral (blue) wire from the power source connects to the neutral terminal of each lamp. Ground (green) wires should also be connected to the grounding terminals of each lamp to ensure safety.

Based on Fig. 3, the LDR sensor system utilized in this setup employs resistive voltage dividers to regulate voltage levels based on the lamps' brightness levels. This configuration aids in promptly detecting any lamp malfunctions. The voltage divider circuit consists of a resistor connected between the positive supply voltage (Vcc) and one terminal of the LDR sensor. The other terminal of the LDR sensor connects to the ground (GND), completing the circuit. This arrangement allows the sensor to monitor changes in light intensity and provide corresponding voltage signals to the ESP32 microcontroller for analysis and monitoring.

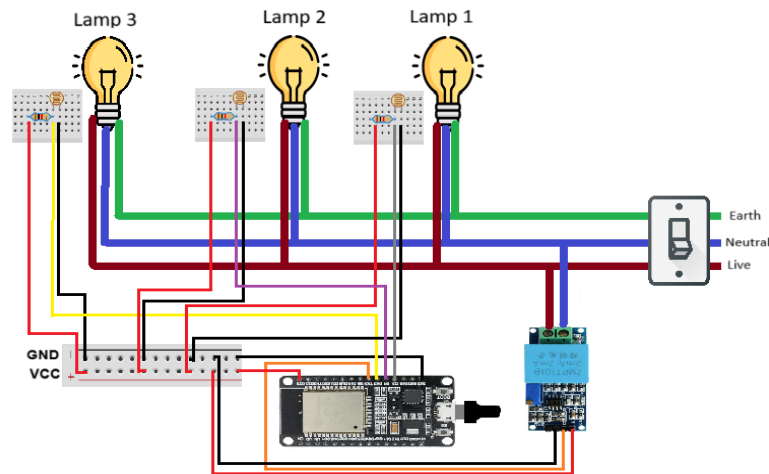


Fig 3 fully connected to ESP32

## 4. Result and Analysis

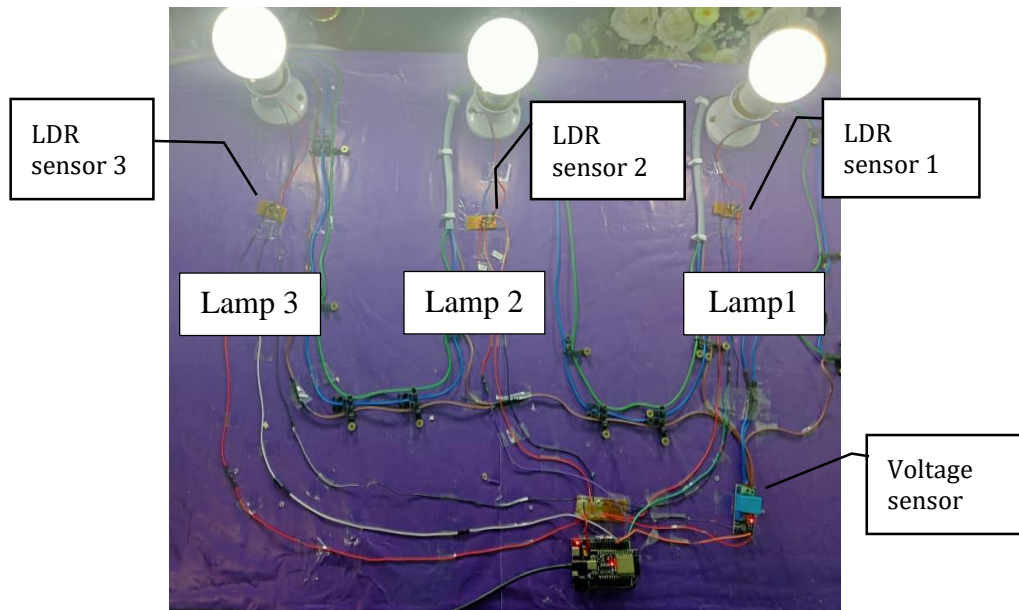
This section presents the results and analysis of the lamp fault detection system using Light Dependent Resistor (LDR) sensors and voltage sensors. The system uses three LDR sensors to measure light intensity from each lamp and a voltage sensor to monitor the electrical supply, providing insights into the lamps' operational conditions. We begin by detailing the experimental setup, sensor configuration, and data collection methodology. The data shows the system's response to different lamp statuses—on, off, and broken.

The project conducted tests in controlled environments to simulate various fault conditions, analyzing the data to assess the system's accuracy and reliability. Threshold values for detecting lamp statuses were optimized based on these observations. This section discusses any limitations encountered during testing and suggests improvements for future iterations. By analyzing the results, we aim to demonstrate the effectiveness of the LDR and voltage sensor-based approach in real-world applications, providing valuable insights for refining and enhancing the fault detection system in various lighting management scenarios.

### 4.1 Experimental Result

Fig. 4 illustrates the circuit simulation setup, which utilizes LDR sensors for each lamp and a single voltage sensor. Specifically, LDR sensor 1 is assigned to lamp 1, LDR sensor 2 to lamp 2, and LDR sensor 3 to lamp 3. These LDR sensors detect the condition of their respective lamps, providing input signals to the ESP32 microcontroller via

its 30-pin configuration. This setup allows for precise monitoring and control, enabling the ESP32 to determine whether each lamp is on, off, or broken based on the LDR sensor readings.



**Fig 4** the full hardware prototype

In the experimental setup, lamps are initially set to a broken bulb condition to determine the optimal threshold for the LDR sensor. Thresholds range from 500 to 1700 in 200-step increments, with voltage readings taken at each level. This detailed analysis examines how varying thresholds affect detection accuracy, aiming to identify the best threshold for reliably indicating a broken lamp. This methodical approach ensures maximum detection reliability and minimizes false positives or negatives, enhancing the lamp detection system's efficiency and accuracy.

**Table 1** LDR sensor testing

Threshold	Lamp1		Lamp2		Lamp3	
	Voltage (V)	Condition of detection by IDE	Voltage (V)	Condition of detection by IDE	Voltage (V)	Condition of detection by IDE
500	4.06	broken	4.11	broken	2.88	broken
700	4.07	broken	4.01	broken	3.71	On
900	4.05	broken	4.01	broken	3.80	On
1100	4.05	broken	4.14	broken	3.80	On
1300	4.06	broken	4.20	broken	3.90	On
1500	4.06	broken	4.06	broken	3.98	On
1700	4.67	On	4.56	On	3.92	On

Table 1 presents data outlining the conditions of three lamps (Lamp 1, Lamp 2, and Lamp 3) as detected by IDE software at various threshold voltage levels. The threshold is the manipulated variable, while the voltages and conditions (on, off, broken) of the lamps are the dependent variables. This analysis examines how changes in the threshold affect voltage readings and each lamp's operational status. By studying these patterns, we can assess the responsiveness and functionality of each lamp under different conditions.

For Lamp 1 and Lamp 2, the data shows a consistent pattern where both lamps are detected as "broken" at threshold values from 500 to 1500. In this range, Lamp 1's voltage remains around 4.06V, while Lamp 2's voltage slightly varies between 4.01V and 4.20V. These voltages, combined with the threshold levels, are insufficient to trigger an "on" condition for these lamps. However, at a threshold of 1700, there is a significant voltage increase to 4.67V for Lamp 1 and 4.56V for Lamp 2, indicating an "on" condition. This suggests a higher sensitivity threshold is needed for these lamps to transition from "broken" to "on."

The experiment assesses bulb conditions under different switch states using a 240V wiring voltage, as shown in Table 2. When the lamp switch is on, and the wiring voltage is 240V, a functioning bulb shows a voltage input of 2.06V and is detected as "on" by the IDE, indicating proper operation. When the switch is off, the wiring voltage drops to 0V, and the voltage input slightly increases to 2.40V, with the bulb detected as "off," reflecting the

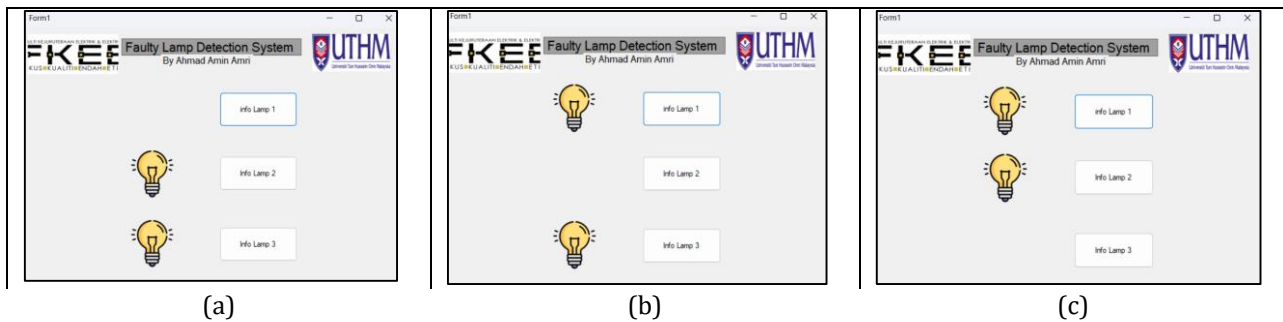
expected behavior when power is cut. In contrast, when the lamp switch is on with a 240V wiring voltage, a faulty bulb shows a voltage input of 2.09V and is identified as "broken" by the IDE. This data suggests that while good bulbs maintain consistent voltage inputs and are accurately detected based on switch positions, faulty bulbs can be identified by their slightly higher voltage input even when the switch is on, allowing the system to effectively distinguish between functional and defective bulbs.

**Table 2** Voltage Sensor testing

Lamp Switch is ON/OFF	Wiring Voltage, V	Voltage input, V	Bulb condition	Condition to IDE
On	240	2.06	Good	On
Off	0	2.40	Good	Off
On	240	2.09	Faulty	Broken

### 4.2 Graphic User Interface

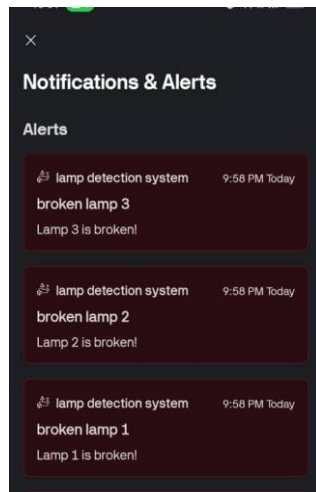
Fig. 5 illustrates the lamps with bulb symbols representing each lamp. The upper line shows the blinking info button for Lamp 1, the second line for Lamp 2, and the lower line for Lamp 3. This dataset provides insights into the temporal dynamics and interplay between the physical condition of the lamps and their visual representation through blinking symbols. By analyzing patterns over time, including the duration and frequency of state transitions, we can gain a deeper understanding of lamp behaviours and how these behaviours are reflected in their corresponding visual conditions.



**Fig. 5** Blinking features (a) blinking for Lamp 1; (b) blinking for Lamp 2 (c) blinking for Lamp 3

### 4.3 Notification through Blynk Platform

This condition triggers notifications through the Blynk Application. When a broken lamp is detected, the input is sent to the Blynk cloud, triggering a notification through the Blynk App and recording it in Fig. 6. Each lamp transitions between on, off, and broken states, prompting corresponding notification changes. For example, at 11:39 pm, Lamp 1 is on, triggering a notification ("Yes"), while Lamp 2 and Lamp 3 do not trigger notifications as they are off. Throughout subsequent time intervals, the lamps' dynamic behaviour leads to changes in their condition, resulting in notifications being triggered accordingly.



**Fig. 6** Notification through the Blynk application

## 5. Conclusion and Recommendations

The project's goal was to develop a reliable system using ESP32 and LDR sensors to monitor and identify faulty lamps. Various configurations and thresholds were tested to determine the most accurate setup. Analyzing sensor data, response times, and environmental factors provided valuable information on the system's performance and limitations. The project demonstrates the feasibility and efficiency of automated lamp monitoring, offering a practical solution for maintaining lighting systems. This project synthesizes the project's accomplishments, challenges, and recommendations for future improvements, aiming to contribute significantly to the field of automated fault detection and maintenance in electrical systems.

This project needs some improvements to develop better technology for the future. It can be expanded in the following ways:

To improve reliability and ease of integration, it is recommended to use LDR sensor modules as it directly provides Boolean outputs. These modules can simplify detection logic by eliminating the need for analog-to-digital conversion and complex threshold calculations. Boolean input sensors offer straightforward 'true' or 'false' signals, indicating the presence or absence of light. This simplification reduces processing overhead on the ESP32 microcontroller and enhances the system's response time.

Additionally, proper insulation of all wiring is crucial to prevent electrical interference and ensure the reliable operation of the lamp detection system. It is recommended to use high-quality insulated wires and employ techniques such as heat shrinking, cable management, and secure connections. Ensuring all connections are robust and insulated minimizes the risk of short circuits, signal degradation, and electromagnetic interference. This practice enhances the system's safety and contributes to consistent sensor readings and accurate lamp condition detection, ultimately improving system reliability and lifespan.

Finally, implementing a Visual Basic (VB) interface to display the system's status can significantly enhance user interaction and monitoring capabilities. The GUI should provide clear indicators for different lamp states, including 'on,' 'off,' 'broken,' and 'power trip' conditions. This visual representation allows users to quickly assess the system's status and respond to issues. Additionally, the interface can include features like historical data logging, real-time updates, and actionable alerts. A user-friendly and intuitive GUI improves the overall efficiency and effectiveness of the monitoring system, ensuring timely maintenance and operational continuity.

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## Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

## Author Contribution

*The authors confirm contribution to the paper as follows: **study conception and design:** Ahmad Amin Amri Azra'i, Nurulhuda Ismail; **data collection:** Ahmad Amin Amri Azra'i; **analysis and interpretation of results:** Ahmad Amin Amri Azra'i, Nurulhuda Ismail; **draft manuscript preparation:** Ahmad Amin Amri Azra'i. All authors reviewed the results and approved the final version of the manuscript.*

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