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AUTOMATIC SOLAR-POWERED EMERGENCY LIGHTING AND POWER ISOLATION FOR FLOOD-AFFECTED HOMES

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Abstract:

Flood disasters are among the most frequent and disruptive natural hazards in Malaysia, often causing prolonged power outages that compromise the safety and visibility of residents in landed houses. Although emergency lighting and flood monitoring systems have been widely developed, few solutions integrate autonomous renewable power supply, automatic electrical isolation, and real-time IoT monitoring into a single household safety system for flood emergencies. This paper presents the development of Automatic Solar-Powered Emergency Lighting and Power Isolation for Flood-Affected Homes, an automated emergency backup lighting system designed to reduce electrical hazards and maintain emergency lighting during flood events. To ensure operational continuity during rising water levels, the system is intended for installation at elevated positions, such as rooftops or upper floors. The methodology involves an ESP32 microcontroller integrated with a suite of sensors, including water level, current, voltage, and temperature, to monitor environmental conditions and manage electrical safety. This project utilises a solar-harvesting mechanism to charge a 9V battery, ensuring a sustainable power supply for LED illumination in the event of a grid failure. System performance was validated through Wokwi simulation, where it successfully demonstrated real-time data visualisation via an LCD interface and the

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Blynk IoT platform. Results indicate that the system effectively triggers safety indicators, such as buzzers and emergency lighting, while automatically cutting off unsafe power lines to prevent electrical hazards. The proposed system offers a practical solution for improving household resilience by reducing electrical hazards and maintaining essential lighting during flood-induced power failures. Unlike existing flood monitoring systems that primarily provide notifications, the proposed system integrates solar-powered emergency lighting, automatic electrical power isolation, environmental sensing, and IoT-based monitoring within a single low-cost platform for residential flood protection.

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Keyword:

Blynk App, Emergency Backup System, ESP32, Flood Detection, IoT, Relay Module, Solar Energy, Voltage Monitoring, Water Level Sensor

Introduction

Flood disasters are one of the most frequent and economically damaging natural disasters in Malaysia, with their severity and frequency increasing significantly during the monsoon season. This can lead to power outages with severe consequences for the lives of the inhabitants and critical infrastructure. In rural residential buildings, a loss of electricity in the grid is both a hazard, as the visibility is low and the electrical outlets, devices, and wires are submerged. Recently, the use of IoT (Internet of Things) technology has enabled flood monitoring and early warning systems, where ultrasonic water level sensors and cloud-based notification systems are used. Although these systems can be used to provide early warnings, they are mostly passive and rely on user awareness and manual response.

When people are asleep, physically limited, and unable to move in a flooded and dark environment, human intervention can cause delays in electrical isolation and lead to secondary risks of electrical fire or electrocution. This problem highlights the need for an autonomous system that can integrate environmental sensing and prevent disaster in real time. This paper presents an intelligent emergency lighting and automated electrical safety system for home floods. It is based on an ESP32 microcontroller and has a multi-sensor architecture, which includes water level, voltage, current, and temperature sensors with real-time monitoring of the environment and electrical state. This project aims to implement automatic protective measures due to the limited availability of flood monitoring solutions. When flood levels are detected, a relay module automatically disconnects the main electrical supply to prevent electrocution, and a solar-powered LED backup lighting system is triggered to provide indoor visibility.

Following a successful simulation, a prototype of a hardware implementation was developed based on a split-power battery architecture to ensure the reliability of the system. This design also ensures emergency lighting even in the case of failure of the primary control system. The innovation of this work is that four safety functions are combined in one autonomous system: solar-powered emergency lighting, automatic power isolation, real-time environmental and electrical monitoring, and IoT-based remote notification. In comparison to earlier research that primarily concentrated on flood detection, emergency lighting, or the shutdown of appliances, this system plays a proactive role in environmental safety management and is not limited to merely activating emergency lighting during a power failure.

Literature Review

There have been several studies on the use of Internet of Things (IoT) technologies in flood detection, early warning and emergency response. Tamilarasi and Janani (2020) developed an IoT-based flood detection and alert system that sends early warnings to users when water levels are above a danger threshold. Arduino Uno that is equipped with an ultrasonic sensor to monitor water levels, and the notifications were sent to the user via a GSM module, and a sound-activated warning system was used to send local alerts.

Similarly, Mohammed Siddique, Tasneem Ahmed, and Mohammad Shahid Husain (2023) presented an IoT-oriented perspective on flood monitoring and early warning mechanisms. The work emphasised the use of Arduino-based microcontrollers and ultrasonic sensors to continuously track rising water levels. The system communicates warnings based on GSM technology, ensuring that residents receive updates before critical flood conditions occur.

In addition to detection and notification, some researchers have tried to mitigate the impact of power interruption by considering mitigation strategies. Lee and Chia (2021) proposed a smart emergency lighting system that automatically turns on the lights when a blackout is detected. The system based on Arduino Nano, an LDR sensor, LEDs, and relay circuits was designed and implemented. However, no flood detection or water-level monitoring technology was implemented in the study.

In addition, Rizwan et al. (2020) proposed an IoT-based solar-powered flood alert system. The approach highlighted the importance of renewable energy integration to maintain operation during utility power failures. The system, built around an ESP32, an ultrasonic sensor, GSM communication, and solar panels, successfully delivered flood notifications but did not include electrical load management or appliance protection.

Lim and Yong (2022) turned the attention to household safety by presenting a home automation system with an automatic safety cut-off during flooding. Connecting to the NodeMCU, water sensors, relays, and indicators, the system disconnects electrical appliances that are leaking water, thereby reducing the chance of equipment damage and electrocution. However, this system is mainly targeted at indoor smart home protection, not flood forecasting or emergency lighting.

Overall, previous works show significant progress in IoT-enabled flood detection, alert dissemination, backup lighting, and electrical safety mechanisms. Many systems tend to deal with these aspects independently. The integration of flood monitoring, renewable backup power, automatic lighting, and load isolation within a unified framework still needs to be integrated into a unified framework. However, there are still a few obvious limitations, even with the success of IoT technology in flood monitoring and emergency response studies. These systems do not provide a complete safety picture; instead, they are primarily limited to flood monitoring, alarm notification, emergency illumination, or appliance shutdown. In previous studies with ultrasonic sensors, for instance, Arduino or ESP-based systems that use GSM technology to give alerts have been used effectively to communicate early alerts. These systems could not do it more proactively and do not support adaptive lighting or automatic electrical separation in case of a power outage. By contrast, intelligent emergency lighting systems can deal with blackout situations but are not truly sensitive to their surroundings, especially if a high-water level in the room will lead to electrical damage.

Moreover, solar-powered systems offer reliability in case of grid outages, but these systems typically have no smart load management systems to keep household devices safe in the event of grid outages and are less robust. Although they are usually only in indoor spaces and not able to deliver real-time or predictive flood alerts, home automation techniques to shut off appliances when water is detected improve electrical safety. Therefore, a complete, integrated system that integrates automatic emergency lighting, safe load disconnection, renewable energy backup, early warning systems, and real-time flood monitoring is required. This gap will help in the safety of occupants in the event of flooding and reduce disaster risk and enhance the resilience of homes.

Methodology

The prototype is based on an ESP32 microcontroller that integrates water level, voltage, current and temperature sensors to monitor flood conditions and electrical safety. A solar-powered charging circuit charges a dedicated 9 V backup battery, which provides emergency LED lighting during grid outages. The ESP32 hosts a relay module to automatically protect the system and displays the status of the system on a 20×4 I²C LCD, transmitting real-time notifications through the Blynk IoT platform.

Block Diagram

Figure 1 shows the overall system architecture where the ESP32 is the master controller that handles the input from sensors, controls the relay for automatic power isolation, activates emergency lighting, and sends monitoring data to Blynk. An LCD screen indicates local status and provides audio-visual alerts in case of an emergency. All elements are connected to the breadboard for the purposes of power distribution and signal management. This arrangement enables automatic flood detection, timely power isolation, and simultaneous alerts to the user, thereby enhancing safety in emergencies.

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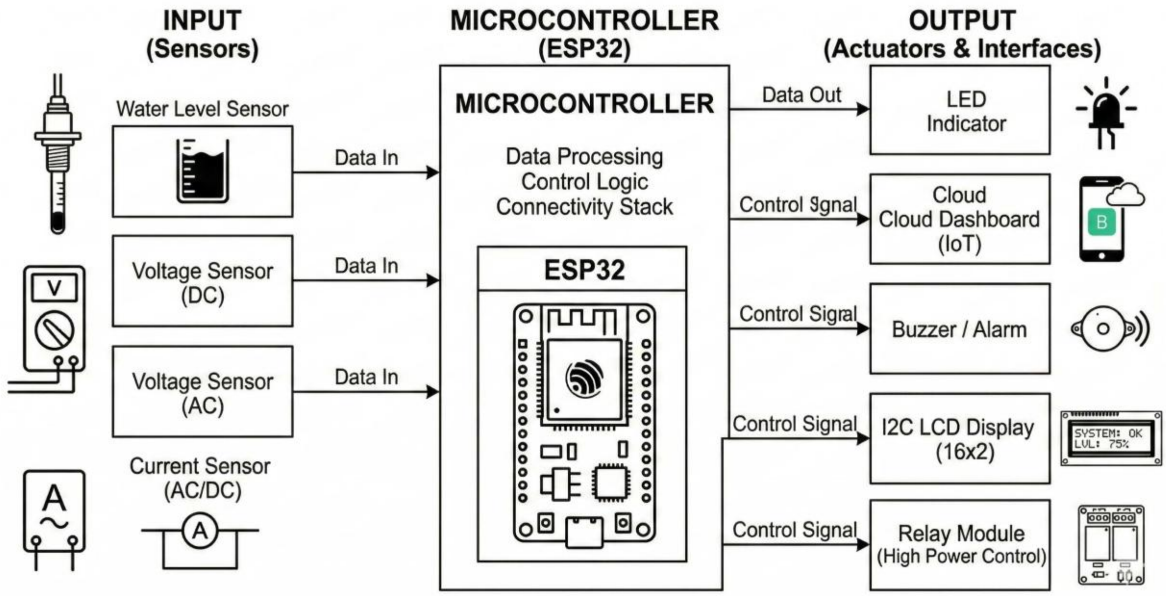

Figure 1: Block Diagram

Flow Chart

Figure 2 demonstrates the flowchart of the system, which illustrates its operation and decision-making process. The flowchart displays how the ESP32 microcontroller processes the sensor information and the control actions that are performed based on the input and output conditions. It also shows the system's autonomous response to the fluctuation of water and electrical state. The system starts by initialising all sensors. The system continuously reads the data from the water level sensor to monitor the possibility of flooding. If the detected water level is still in the low to medium range (0-1800 units), the system continues the monitoring. If the ESP32 detects a high-water level (≥1800 units), the relay module will be activated to disconnect the electrical supply and turn off the LED that indicates the power availability.

To ensure safety, voltage and current sensors are used to check if the electricity is isolated. After power isolation, the system activates emergency mechanisms such as emergency lighting. At the same time, the system is emitting audible and visual alerts through a buzzer and LED, and the status and water level are displayed on the LCD. An alert notification is also sent to the user via the Blynk IoT application. The system will keep monitoring and maintaining the status until the water level is at a safe level.

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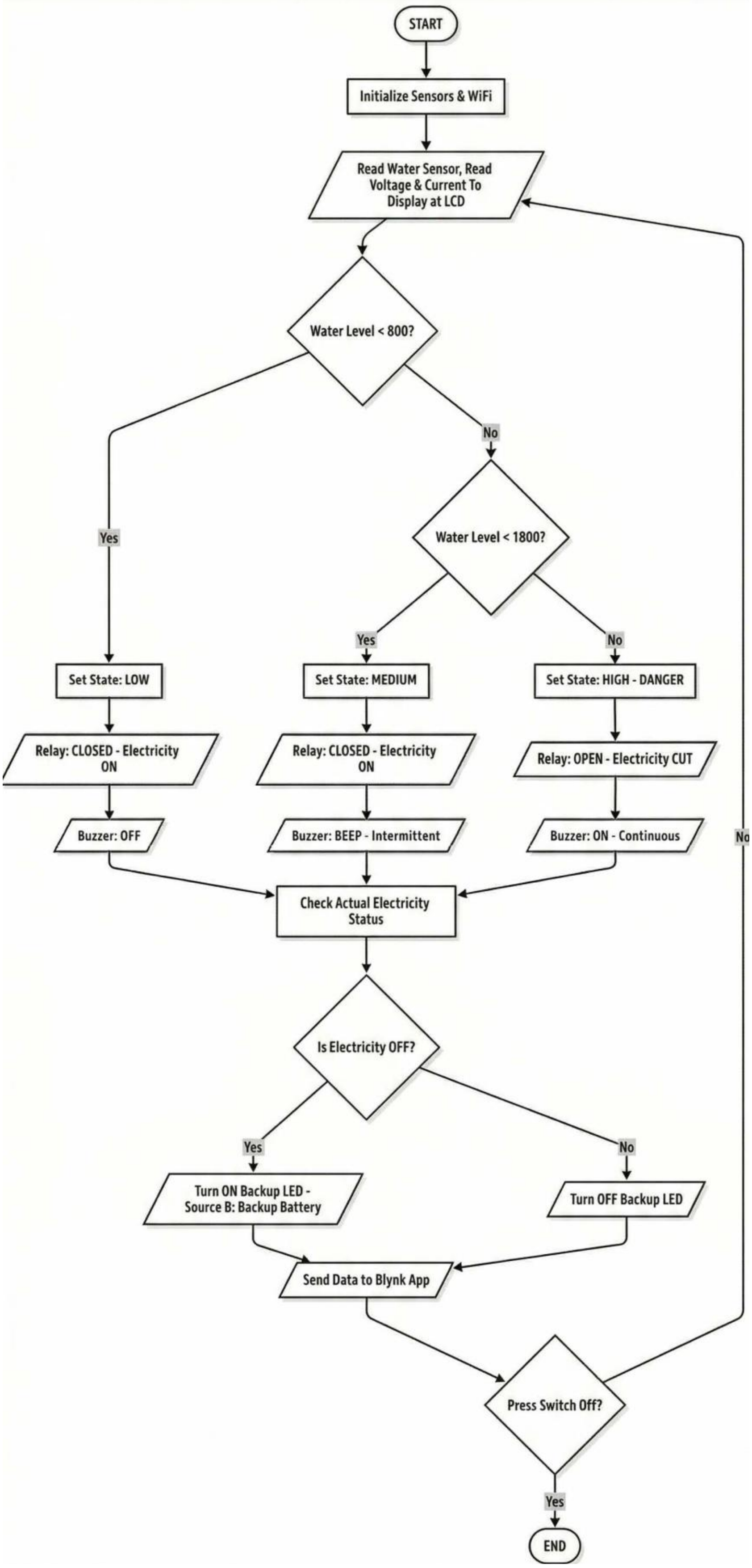

Figure 2: Project Flowchart

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Schematic Diagram

Figure 3 shows the connections in the system. The main testing platform for the logic of the project before hardware assembly was Wokwi Simulation, which is a web-based simulator that allows testing the system logic in a secure and virtual space and connected systems like ESP32 and relays without physical damage. It was a great tool to validate the software code for flood detection and safety cutoffs. This validation process ensured that the digital design was seamless and error-free in the physical prototype.

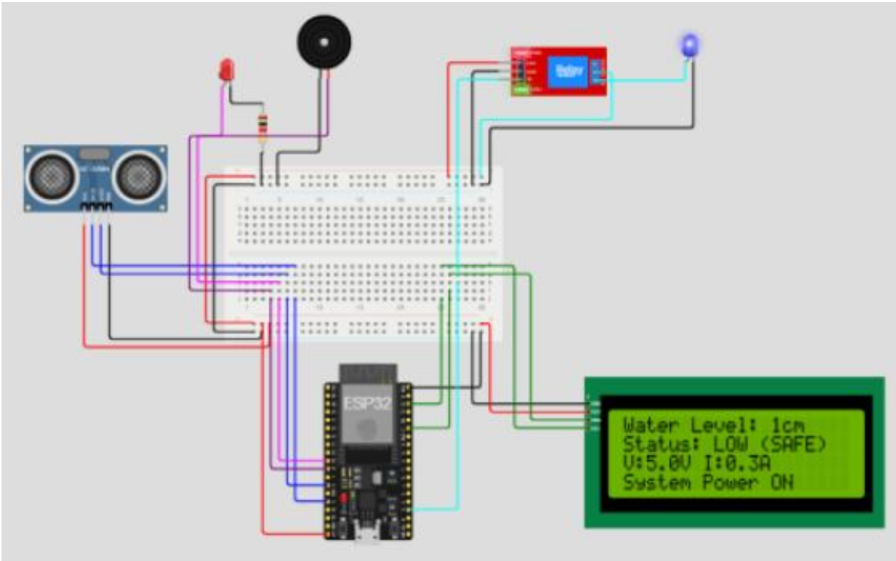

Figure 3: Schematic Diagram

Prototype Development

Figure 4 shows the finalized hardware prototype, which is designed to accurately replicate a residential setting. The LCD is positioned on the front panel to offer a clear indication of the system's status.

Figure 4: Fully Completed Hardware Prototype

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Figure 5 shows the first test scenario of the water sensor being placed in a water cup that has no water. This is a typical dry day without any floods. "LOW" is the status on the LCD to check that the home is safe. The LED is on to show that the main household electrical source is still working and providing power to the house. The figure then shows that the backup LED is off on the second floor. The backup LED will only be activated in case of a flood. Also, the system runs in silence, and homeowners can use the electricity they normally have without disturbance to their electricity.

To replicate the early stages of rising water that would lead to flooding, the medium condition is applied, in which the sensor is partially submerged in the water cup. The system instantly detects the water level, which is between 50 and more than 800, as shown in Figure 6. The LCD status shifts from "LOW" to "MEDIUM." The LED is on, but the system is now in "Warning Mode." The buzzer will beep often in this case to let the occupants of the house know. Early warning is important, as it allows you to realize if you have to evacuate and you are ready to leave before the situation is so bad you can’t even take your belongings to safety.

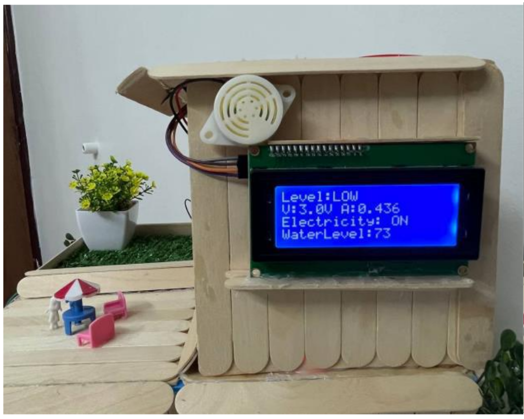

Figure 5: LOW Condition Scenario **Figure 6: MEDIUM Condition Scenario**

The efficiency of the system is illustrated in Figure 7 when the room's lighting is turned off to indicate that the LED is off. This indirectly means that the main electrical load (the LED) is being interrupted by the relay, which is crucial for preventing electrocution. As shown in Figure 7, the Backup LED is activated when the Electricity LED is turned off. This backup light operates on its own dedicated battery. The results show that although the room is totally dark, the occupants are able to move out safely. The Backup LED is also illuminated when dark and will be an indicator for the rescuers to find the location.

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Figure 7: HIGH Condition Scenario

Result and Discussion

The flood emergency safety system was successfully tested by Wokwi simulations and hardware prototype tests in three operating conditions: Low, Medium and High-water levels. In normal situations, the system was constantly monitoring the environment and kept the main electrical supply running. When the water level was at medium, the LCD indicated MEDIUM and an early warning was issued by the buzzer. Once the water level reached High, the ESP32 automatically shut off the electrical supply via a relay and activated backup emergency lighting, which is a great example of what is possible with the autonomous protection system.

The IoT monitoring platform also demonstrated reliable communication between the ESP32 and the Blynk cloud server. The water level displayed on the local LCD was consistent with the values observed on the Blynk web dashboard and mobile application, indicating stable data transmission throughout the testing process. When the water level exceeded the danger threshold, push notifications were successfully delivered to the user, providing immediate awareness even when the mobile application was not actively opened. This synchronized operation between local alarms and cloud notifications improves the effectiveness of emergency response by allowing occupants to receive real-time warnings regardless of their location. The IoT monitoring interfaces and notification mechanism are illustrated in Figures 8–10.

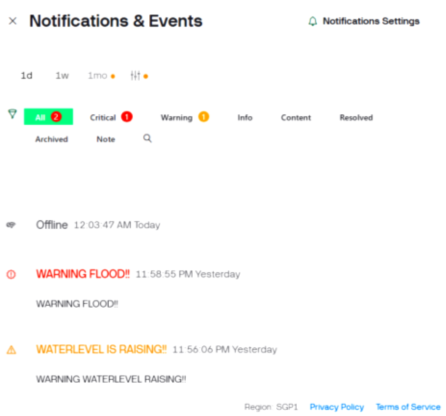
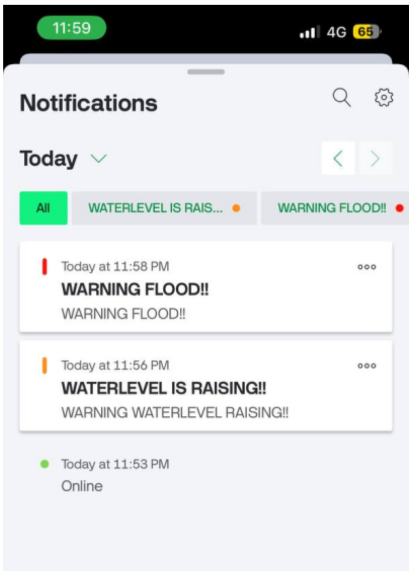


Figure 8: Blynk Notifications on Laptop

The evaluation of the prototype also validated the effectiveness of the split-power battery architecture. The dedicated backup battery ensured that emergency lighting functioned even after the main electrical supply was severed, while monitoring voltage and current confirmed successful power isolation. In contrast to many existing IoT flood monitoring solutions that primarily focus on warning notifications, the proposed system combines flood detection, automatic power disconnection, emergency lighting, and remote monitoring into a unified autonomous platform, thereby improving electrical safety in households during flood incidents.



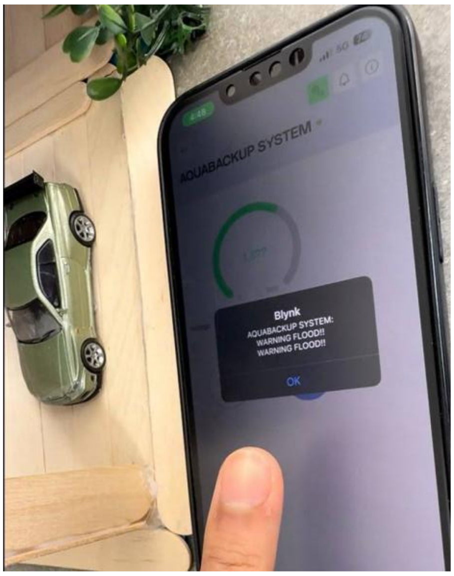


Figure 9: Blynk Notifications **Figure 10: Notifications Pop-Up**

While the prototype exhibited stable performance in laboratory settings, the assessment was confined to a controlled indoor environment. Subsequent efforts should involve field deployment in genuine flood-prone residential areas, quantitative evaluations of system response time and sensor accuracy, and long-term assessments of battery performance and communication reliability across varying environmental conditions.

Table 1: Performance Evaluation of the System

Performance Parameter	Result	Remarks
Water level detection threshold	140 cm	High flood condition
System response time	< 2 s	From detection to emergency activation
Relay switching	100% successful	Main power disconnected automatically
Emergency LED activation	100% successful	Activated immediately after power isolation
LCD update	Real-time	Local status displayed correctly
Blynk notification	100% successful	Remote alert received on smartphone
Voltage isolation verification	Verified	Main supply successfully isolated
Backup lighting operation	Continuous	Powered by a dedicated battery

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Table 1 summarizes the performance of the system. The water level threshold was set at 140 cm to detect hazardous flood conditions. Once the threshold was reached, the system automatically disconnected the electrical supply, activated the emergency LED, updated the LCD, and sent a Blynk notification in less than 2 seconds, demonstrating a fast emergency response. The relay successfully isolated the main electrical supply, reducing the risk of electrical shock during flooding. At the same time, the backup LED remained operational using the dedicated backup battery, providing continuous lighting for safer evacuation. The LCD and Blynk platform also functioned reliably by displaying real-time system status and delivering remote notifications to users. Overall, the results confirm that the proposed system effectively integrates flood detection, automatic power isolation, emergency lighting, and IoT monitoring into a single autonomous platform. This integrated operation improves household safety and provides timely alerts during flood emergencies.

Compared with conventional IoT flood monitoring systems that primarily provide warning notifications, this system integrates flood detection, automatic electrical isolation, solar-powered emergency lighting, and real-time cloud monitoring within a single autonomous platform. This integrated functionality significantly enhances household electrical safety and disaster preparedness while maintaining a low-cost implementation suitable for residential deployment.

Conclusion

Overall, this project addresses the challenges of power outages and electrical hazards during Malaysian flood disasters with a solar-powered emergency lighting solution. By integrating an ESP32 microcontroller and a multi-sensor array, the system has demonstrated a sustainable ability to monitor environmental conditions, execute autonomous power isolation via relay modules, and provide real-time safety alerts using the Blynk IoT platform. We validate the logic of the system with Wokwi simulation and prototype testing and show that it is functional so that even in off-grid scenarios, critical illumination and safety indicators can be maintained in the system. It is currently focused on a single-house simulation, and the low-cost, IoT-based method is proven to enhance disaster resilience and thus provides a scalable solution to build smart-safe homes in flood-prone areas.

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Author Contribution Statement: All authors contributed significantly to the development of this manuscript. Shakira Azeehan Azli was responsible for the conceptualization, methodology, and overall supervision of the study. Siti Musliha Ajmal Mokhtar and Nur Asfahani Ismail handled data collection, analysis, and interpretation of results. Zahari Abu Bakar and Affida M Zin contributed to the literature review, drafting, and critical revision of the manuscript. All authors read and approved the final version of the manuscript before submission.

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