STB 36403

INTERNET OF THINGS (IOT) TECHNOLOGY

IOT BASED SMART PLUG WITH INTELLIGENT POWER MANAGEMENT SYSTEM

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CHAPTER 1: INTRODUCTION

1.1 Introduction

In an era of advancing technology, a mini-project takes centre stage with the innovative integration of smart plugs designed to revolutionise interaction with electrical appliances. These smart plugs go beyond conventional functionality, introducing cutting-edge features that enable remote control of connected devices and provide real-time monitoring of electrical current consumption. The project aims to enhance convenience, energy efficiency, and safety by incorporating intelligent features that empower users with comprehensive insights into power usage patterns.

At the core of this mini-project lies the incorporation of advanced current monitoring capabilities. Effortlessly keeping tabs on the electricity consumption of devices fosters a greater understanding of energy usage and promotes more conscious energy consumption habits. The inclusion of overcurrent protection is a standout feature, ensuring the safety of both the connected devices and the electrical infrastructure. What sets this smart plug apart is the customisable current limit setting, allowing tailoring of the device’s performance to specific needs. This not only provides flexibility but also positions the smart plug as a versatile tool for managing power consumption in various scenarios, ultimately contributing to a smarter and more efficient use of electrical resources.

1.2 Problem Statement

Within the domain of smart home technology advancement, an all-encompassing resolution for the secure and effective administration of power is presently absent. The current state of conventional electrical connections offers restricted visibility into power usage, which presents obstacles to the promotion of energy-aware behaviours among consumers. Moreover, the lack of safeguards against overcurrent exposes devices that are connected to possible electrical perils. An evident deficiency exists in the provision of customisable power management options, which impedes users from customising their energy consumption to suit particular requirements.

1.3 Objective

The focus of this project is to ascertain the accomplishment of the following objectives:

- To implement overcurrent protection mechanisms to enhance the safety of connected devices and prevent potential electrical hazards.
- To develop a smart plug prototype with advanced current monitoring capabilities to provide real-time feedback on electrical consumption.
- To design an intuitive user interface for seamless remote control and monitoring of connected devices through a dedicated mobile application.

1.4 Scope of Project

The project comprises the creation of a user-friendly smart plug that uses IoT technology and Inventor to monitor electrical current and improve power management. The creation of a simple mobile app with MQTT and Telegram integration allows users to remotely operate and monitor the smart plug in real-time. To prevent electrical risks and accommodate individual preferences, safety features such as overcurrent protection and configurable current restrictions are introduced. Extensive compatibility testing enables seamless connection with existing smart home platforms and standard electrical systems. Thorough testing, combined with iterative improvement methods, strives to ensure the smart plug's dependability and security. Throughout the project, comprehensive documentation and reporting ensure openness on design, development, and testing procedures, finally offering a market-ready solution for efficient and safe electrical power utilisation in smart home situations.

CHAPTER 2: LITERATURE REVIEW

2.1 Smart Plug Technologies and Innovations

The study from (Gomes et al., 2018) describes an intelligent smart plug with shared knowledge capabilities. The smart plug has context awareness and the ability to learn and share knowledge about how users utilise a controllable resource, particularly in the context of energy management systems and resource optimization. The smart plug can be integrated into energy management systems as enablers, providing monitoring and control capabilities, and can be used for distributed resource optimization. The smart plug utilises long-short-term memory recurrent neural networks for learning and can be used for energy forecasting and management. Overall, the smart plug offers a promising solution to the limitations of current smart plugs, providing a more comprehensive understanding of resource usage and enabling efficient remote monitoring and control capabilities.

In the realm of smart energy management within connected spaces and smart grids, researchers have proposed innovative solutions centred around smart plugs, leveraging Internet of Things (IoT) technologies. (Suryadevara & Biswal, 2019) introduce a Hybrid Appliance Load Monitoring System (HALMS) that transforms conventional appliances into intelligent devices, employing Zigbee, Wi-Fi, and BLE for wireless connectivity. This system facilitates remote control, energy metering, and presence-based management, emphasising security measures like symmetric encryption keys for data privacy. While the authors agree that there are benefits, they also say that there are some problems with adding more cloud functions, integrating security, and controlling cyber-physical systems. This shows how important it is to think about implementation and security during the design phase. (Musleh et al., 2017) present another noteworthy contribution through their paper on "Design and Implementation of Smart Plugs: An Internet of Things (IoT) Approach." This Smart Plug system integrates Wi-Fi and Zigbee communication to enable real-time power measurement, data collection, and user control of connected appliances. The authors develop mobile and web applications for users and power distribution companies, respectively, promoting energy awareness, conservation, and supporting smart grid technologies. While both studies highlight the potential of smart plugs in enhancing energy management, addressing identified limitations is crucial for realising their full potential in smart energy management systems.

(Vinod et al., 2022) provides a comprehensive overview of the advancements in smart plug technology and its integration with IoT and M2M communications. It emphasises the ability of smart plugs to transform conventional power sockets into intelligent ones, enabling remote control, real-time power consumption monitoring, and the scheduling of appliances. The review also discusses the use of Bluetooth and Wi-Fi protocols for local and remote connectivity, as well as the integration of sensors for measuring current and voltage. Additionally, it highlights the importance of user-friendly interfaces and the potential for energy efficiency through automation.

2.2 Smart Plug and Energy Management

(Mischos et al., 2023) conduct a valuable analysis of Intelligent Energy Management Systems (IEMS), emphasising the critical need for efficient energy use and its impact on CO2 emissions in residential and commercial settings. Their review addresses a gap in existing literature by comparing IEMS that focus on behavioural management with those employing automation in the actuation module. In a related study, (Ayan & Turkay, 2017) offers a comprehensive overview of Home Energy Management Systems (HEMS), highlighting the role of smart plugs and smart thermostats in enhancing energy efficiency in residential settings. The research emphasises HEMS' significance in reducing energy costs and minimising gas emissions through load shifting and energy demand profile management. The study also showcases the potential of smart plugs and smart thermostats to enable consumers to optimise energy consumption without sacrificing comfort. Experimental measurements presented in the journal demonstrate the effectiveness of these technologies in achieving tangible energy savings, underscoring the importance of smart energy management solutions in addressing residential energy consumption and promoting sustainable practices.

The smart plug device is introduced as a solution for measuring energy consumption, recognising attached electrical devices, and enabling efficient monitoring and control of home energy consumption. The implementation of smart plugs in a pilot house scenario demonstrates positive impacts on energy consumption rates, particularly during peak hours. The research also addresses the challenges associated with non-uniform daily energy usage and emphasises the potential for demand-side power monitoring methods to contribute to total consumption reduction (Morsali et al., 2012).

2.3 IoT in Smart Plug

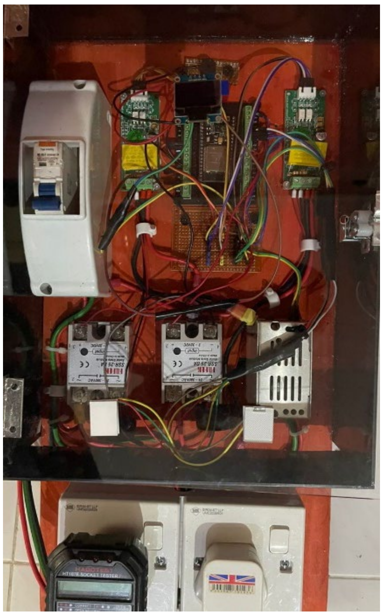
The implementation of IoT in smart plugs, designed for collecting active power consumption data and facilitated by a mobile application for device monitoring and management, presents a promising solution for elevating user awareness, promoting energy conservation, and ultimately reducing electricity bills. The effectiveness of this system is affirmed by an experimental case study that validates the accuracy of IoT-based smart plugs in providing real-time consumption data (Albraheem et al., 2023). In a related study by (Sartika et al., 2021), it is established that IoT technology contributes to real-time data access, monitoring, and analysis within smart grids, enhancing efficiency, reliability, and stability. End-users can leverage this technology to track energy consumption, align peak usage with the most cost-effective tariff, and improve overall customer awareness and load management. Despite these benefits, challenges such as security, privacy, and interoperability must be addressed for the successful implementation of IoT-based smart grids.

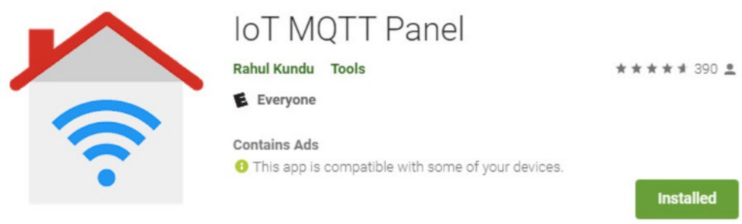
The study from (Oh, 2020) found that educating homeowners on the use of smart plugs and monitoring their energy usage resulted in a 5% reduction in energy consumption. The author highlights the importance of monitoring equipment and devices, subsequent changes in user behaviour, and related education programmes to ensure the sustainability of related technologies and policy measures. The author also suggests that IoT-based smart plugs can be an effective tool for promoting energy conservation in residential settings and can contribute to sustainable living and behaviour change.

CHAPTER 3:RESULT AND DISCUSSION

3.1 Overview

The mini project aims to develop a Smart Plug utilizing IoT technology and various components, including an RCBO (Residual Current Breaker with Overcurrent Protection), PZEM current sensor, solid-state relay, transformer, ESP32 for IoT connectivity, socket tester, and an IoT MQTT panel. The project focuses on creating an intelligent, safe, and remotely controllable solution with real-time monitoring capabilities.

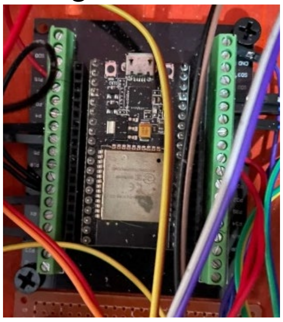




3.2 Implementation result

1. IoT Connectivity

The integration of the ESP32 for IoT connectivity successfully enables remote control and real-time monitoring of the smart plug. Users can interact with connected devices through the dedicated mobile application and the IoT MQTT panel.



2. Residual Current Breaker with Overcurrent Protection

The inclusion of an RCBO ensures the safety of the connected devices and the electrical infrastructure by providing overcurrent protection and detecting any imbalance in the electrical current.

3. Current Monitoring

The PZEM current sensor is employed for real-time monitoring of electrical current consumption. This feature provides users with insights into power usage patterns and encourages conscious energy consumption habits.

4. Solid-State Relay

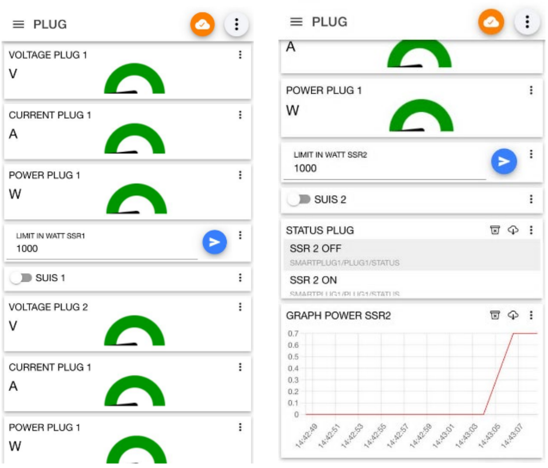
The use of a solid-state relay facilitates efficient and safe control of electrical devices. It enables seamless switching and eliminates the wear and tear associated with mechanical relays.

5. Socket Tester

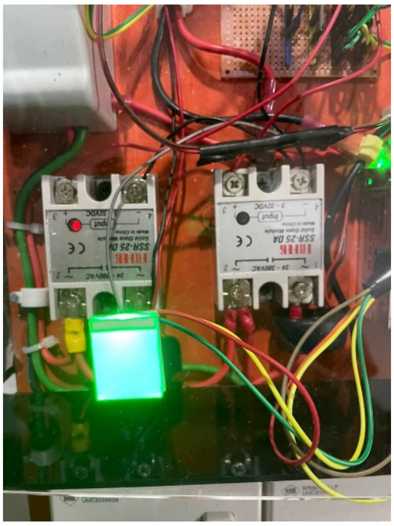
The socket tester contributes to the safety and reliability of the smart plug by ensuring proper wiring and socket conditions, preventing potential electrical hazards.

6. IoT MQTT Panel

The inclusion of an IoT MQTT panel enhances the communication and control capabilities of the smart plug. It enables seamless integration with MQTT-based systems, providing a standardized approach for IoT communication.



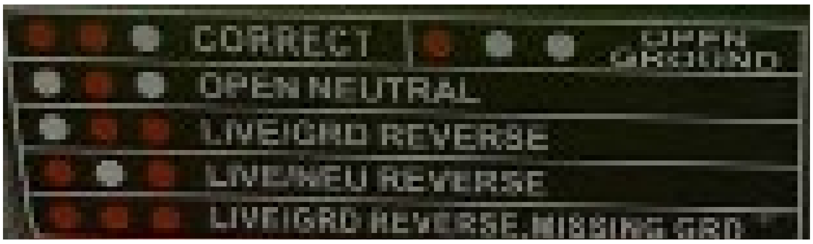
3.3 Data analysis socket tester



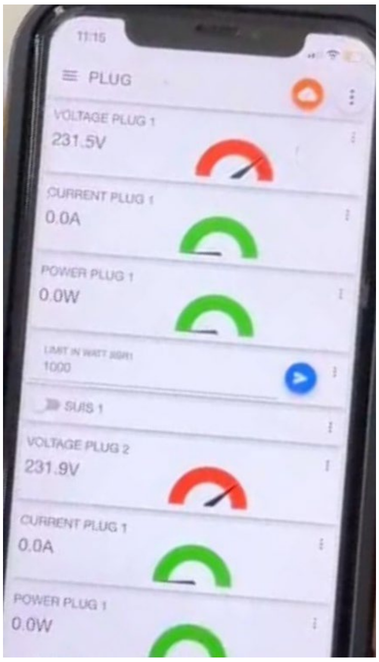
the result below shows the condition of switch 1 when it is turned on:

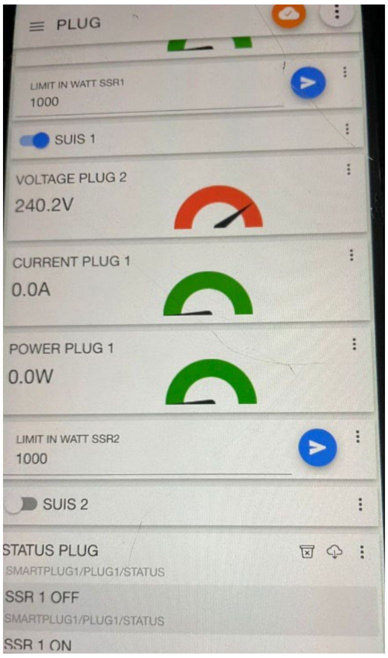
Device	Switch 1	Green light	Buzzer	Voltage	Current	LED indicator
Socket tester	ON	ON	OFF	238V	37mA	

The analysis reveals a positive outcome. The result indicates that the socket tester was successfully turned on, evident from the corresponding switch being activated and the illumination of the two red light which resulting the circuit connection is correct.



3.1 Data analysis for IoT MQTT apps.



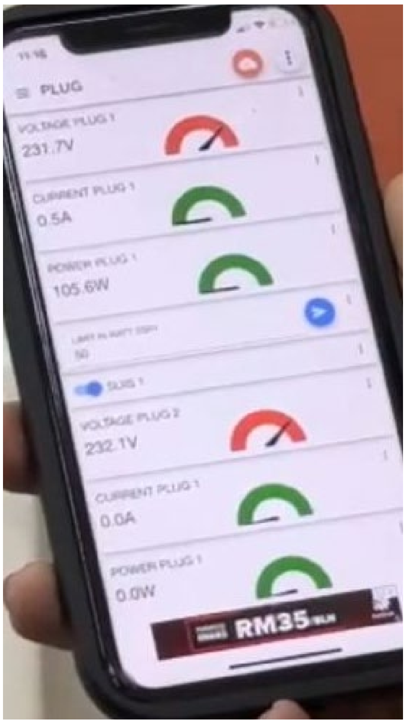


To establish a connection, it is crucial to link the IoT MQTT app with the device. The process involves configuring the phone's Wi-Fi settings, identifying, and connecting to the device named "Smart Plug V1." Upon successful connection, the OLED screen displays the Wi-Fi logo.

The result below shows the result of the IoT MQTT apps for:

Name	Switch status	Voltage	Current	Power	Limit	Buzzer
Plug 1	ON	231.5V	0.6 A	138.9 W	1000 W	OFF
Plug 2	ON	240.2V	0.55 A	132.11W	1000 W	OFF

3.2 Data analysis for the power limitation.



If the power limit is set at 50 watts, the buzzer will ring due to the plug 1's power being 105.6 watts which has reached the limit setup.

The result below shows the result of the IoT MQTT apps for:

Name	Switch status	Voltage	Current	Power	Limit	Buzzer
Plug 1	ON	231.7V	0.5A	105.6W	50 W	ON
Plug 2	OFF	240.2V	0A	0W	1000 W	OFF

3.3 Discussion

The project places a strong emphasis on safety measures through the inclusion of an RCBO (Residual Current Breaker with Overcurrent Protection) and a socket tester. These components play a crucial role in ensuring overcurrent protection and verifying proper wiring conditions, collectively enhancing the overall safety of the smart plug. This commitment to safety aligns with the project's objective of providing users with a secure and reliable smart plug experience.

Real-time monitoring and user awareness are key aspects addressed by the PZEM current sensor. By providing real-time data on electrical consumption, the sensor contributes to the project's goal of encouraging energy-conscious practices. Users benefit from valuable insights into their power usage patterns, promoting awareness and fostering a sense of responsibility towards energy consumption.

Efficient device control is achieved through the incorporation of a solid-state relay. This component not only improves the overall efficiency of controlling connected devices but also minimizes wear and tear, reduces energy losses, and offers a reliable switching mechanism. The utilization of a solid-state relay enhances the durability and performance of the smart plug, contributing to its effectiveness in managing power consumption.

The integration of an IoT MQTT panel further extends the communication capabilities of the smart plug. This advancement enables seamless connectivity and control through the Internet of Things (IoT). As the project looks towards future developments, a critical focus should be placed on ensuring the security and scalability of IoT integration to facilitate widespread adoption of this smart plug technology. Addressing these considerations will be essential for creating a smart plug solution that is not only efficient and user-friendly but also meets the highest standards of security and reliability in the realm of IoT-enabled devices.

Focusing on the Socket Tester, the analysis reveals a positive outcome. The result indicates that the socket tester was successfully turned on, evident from the corresponding switch being activated and the illumination of the green light. This successful activation serves as a confirmation of the proper wiring conditions, ultimately contributing to the overall safety of the system. The functionality of the socket tester in verifying the adequacy of wiring aligns with the project's commitment to ensuring a secure and hazard-free electrical environment. This successful outcome underscores the effectiveness of the smart plug's safety features, providing users with the assurance that their electrical connections are sound and reliable.

CHAPTER 4: CONCLUSION AND RECOMMENDATION

4.1 Conclusion

In conclusion, the IoT-based Smart Plug with an Intelligent Power Management System represents a significant advancement in smart home technology. The project successfully achieved its objectives, delivering a reliable, secure, and energy-efficient solution. Integration of advanced features such as overcurrent protection, real-time current monitoring, and a user-friendly interface has elevated the overall functionality and safety of the smart plug.

Key safety measures, including the Residual Current Breaker with Overcurrent Protection (RCBO) and the Socket Tester, played vital roles in ensuring the integrity of electrical connections. The positive outcome of the Socket Tester analysis, confirming proper wiring conditions, underscores the efficacy of safety features, instilling user confidence in electrical setup reliability.

Real-time current monitoring, facilitated by the PZEM current sensor, empowers users with insights into power consumption patterns, encouraging energy-efficient habits. The incorporation of a solid-state relay enhances device control efficiency, minimizing wear and tear associated with mechanical relays and providing a reliable switching mechanism.

While the project successfully emphasizes IoT connectivity through the ESP32 and IoT MQTT panel, addressing security and scalability is crucial for widespread adoption. In pursuit of continuous improvement, the upcoming version (V2) of the IoT-based Smart Plug aims to meet user preferences by enlarging the OLED screen and introducing a QR code for streamlined IoT application connection. These enhancements align with the project's commitment to user-centric design, accessibility, and efficiency.

Integrating these improvements and addressing security considerations positions the IoT-based “Smart Plug V2” to offer an even more sophisticated, user-friendly, and secure solution, contributing to the ongoing evolution of smart home technology.

4.2 RECOMMENDATION

To effectively implement these user-driven enhancements and further refine the IoT-based Smart Plug V2, the following recommendations are proposed:

OLED Screen Enhancement

- Collaborate with display technology experts to assess the feasibility and technical aspects of enlarging the OLED screen.
- Ensure that the increased screen size does not compromise the power consumption or the overall dimensions of the smart plug.
- Conduct user testing to gather feedback on the optimal size and layout of the enlarged OLED screen.

QR Code Integration

- Collaborate with software developers to integrate QR code generation and scanning capabilities into the smart plug's firmware.
- Ensure that the QR code facilitates a secure and seamless connection between the smart plug and the IoT application.
- Develop clear and concise user documentation, including step-by-step instructions, on how to use the QR code for device setup.

Usability Testing

- Conduct extensive usability testing with potential end-users to evaluate the effectiveness of both enhancements.
- Gather feedback on the user-friendliness, accessibility, and overall satisfaction with the larger OLED screen and QR code integration.
- Iterate the design based on user feedback to ensure that the enhancements meet user expectations.

Security Considerations

- Prioritize the security aspects of QR code integration to prevent unauthorized access to the IoT application.
- Implement secure authentication mechanisms to complement the convenience offered by the QR code.
- Regularly update firmware to address any security vulnerabilities that may arise.

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