OUTSMART: A SMART OUTLET DEVICE FOR MONITORING AND CONTROLLING CONNECTED DEVICES TO OPTIMIZE ELECTRICITY CONSUMPTION

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In Partial Fulfilment
of the Requirements for the Degree
Bachelor of Science in Computer Engineering

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ABSTRACT

Title of research:	**OutSmart: A Smart Outlet Device for Monitoring and Controlling Connected Devices to Optimize Electricity Consumption**
Researchers:	**Daniel Ross B. Camara** **Chemical V. Valdehueza** **Michael James L. Velasco** **Jullie Ann L. Villas**
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Energy efficiency and electrical safety remain essential priorities as power consumption continues to increase and unattended devices pose potential hazards. This study presents OutSmart: IoT-Enabled Smart Outlet Monitor, a system developed to optimize energy usage and promote safety through intelligent outlet monitoring and control.

The prototype integrates a NodeMCU ESP8266 microcontroller, relay module, and sensors enclosed in a metal enclosure, enabling Wi-Fi–based real-time data monitoring via a web dashboard. The system was tested for one week using a 760 W Sony flat-screen television under controlled conditions. During idle-load testing, OutSmart recorded 0.0478–0.048 kWh consumption compared to 0.04 kWh from a standard outlet, yielding a mean difference of 16.53%, primarily due to submeter rounding limitations. The device maintained stable latency with an average of 78.8ms for device-to-cloud transmission and 79.6 ms for web response. Thermal readings remained consistent, averaging 37–38°C for both the relay and ESP8266, indicating safe operational temperatures.

Overall, the findings confirm that OutSmart can accurately monitor energy consumption while maintaining system stability, safety, and reliability—demonstrating its potential as a practical solution for smarter energy management.

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Symbol	**Description**
kWh	Kilowatt per hour
W	Watts
℃	Degree Celsius
ms	Milliseconds
V	Voltage (Volts)
A	Ampere

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INTRODUCTION

Fire stands among the most destructive forces known, with an alarming capacity to spread quickly and cause extensive harm—not only to property but also to human lives, livestock, and wildlife. Beyond immediate destruction, fires disrupt natural habitats, often decimating biodiversity and leaving a lasting environmental impact that may take years or even decades to recover from. In some cases, the damage is permanent, leaving a scar on ecosystems that were once rich and thriving (Joshi & Saini, 2023). Fires can arise from natural causes, such as lightning strikes, volcanic eruptions, or spontaneous sparks in dry conditions, but they are also triggered by human actions, whether accidental or intentional (The International Charter Space and Major Disasters, 2024). When fires encounter combustible materials, flammable liquids, gases, or electrical equipment, they can intensify rapidly, transforming a small spark into a large-scale disaster (Evans, 2021).

One common but often overlooked source of man-made fires is electrical equipment, specifically when appliances are left plugged in unattended. Although most modern electrical devices have built-in safety mechanisms, any appliance left plugged in poses a potential risk. Some appliances, like computers, enter a standby mode when unused, consuming small but continuous amounts of electricity, while others, if left on, continue to draw full power (Giroux Electrical Contractors, 2019). As the Scottish Fire and Rescue Service emphasized in 2023, "Any electrical appliance that is left plugged in to the mains could cause a fire." Even appliances designed for long-term use, such as refrigerators, can become hazardous if mishandled or malfunctioning. This continued energy draw isn't just wasteful; it can lead to increased voltage consumption and, in rare but dangerous cases, the conditions necessary for an electrical fire.

Given these potential hazards, this project seeks to address the safety risks and energy waste posed by unattended plugged-in devices. The goal is to explore the feasibility of creating a smart outlet monitor—a device that will enhance user control over electrical consumption by sending alerts when appliances are left plugged in. This monitor would allow users to remotely control their outlets, turning them off as needed to reduce energy waste and prevent potential fire hazards. By introducing this added layer of safety and convenience, the smart outlet monitor could help users safeguard their homes and reduce their environmental footprint, making their spaces both safer and more energy efficient.

Background of the problem

Electrical fires remain one of the most common yet preventable household hazards in the Philippines. According to the Bureau of Fire Protection (BFP, 2024), electrical-related incidents continue to account for a significant portion of reported fire cases nationwide. Faulty wiring, overloaded circuits, and the habit of leaving appliances plugged in even when not in use are among the leading causes. These unsafe practices not only pose fire risks but also contribute to unnecessary electricity consumption and higher utility costs.

A major contributor to this issue is standby power consumption, commonly referred to as phantom load. This occurs when appliances and devices continue to draw power despite being switched off. The Department of Energy (DOE, 2024) reports that standby power can make up 6–10% of total household electricity use—equivalent to hundreds of pesos wasted annually per home. Similarly, Tongol et al. (2022) found that appliances left plugged in consume between 0.1W to 3W of electricity, accounting for up to 3.34% of total household energy costs. This idle consumption, while seemingly small per device, becomes significant over time and across multiple outlets.

Beyond financial waste, phantom load also increases the likelihood of overheating and short circuits, which can lead to fire hazards. Despite ongoing awareness campaigns about energy efficiency and fire safety, most users still lack a practical system for monitoring and managing their electrical outlets in real time.

In light of these risks, this study seeks to address the problem of electricity waste and fire hazards caused by human negligence, particularly from devices left plugged into power outlets. The proponents aim to develop a smart outlet monitoring system that provides users with real-time data on their plugged-in devices, alerts them when appliances are left on unnecessarily, and promotes safe, efficient power management. By integrating Internet of

Things (IoT) technology, the system can contribute to reducing energy waste, preventing electrical fires, and encouraging responsible electricity use.

The potential beneficiaries of this study include homeowners, who will benefit from enhanced safety and reduced energy costs; businesses and commercial establishments, which can improve operational efficiency and fire prevention; and the elderly or persons with limited mobility, who will gain convenience and peace of mind through remote control of outlets. By addressing the gaps in existing fire safety and energy management practices, this study aims to provide an innovative, data-driven solution toward a safer and more sustainable electrical environment.

Overview of the current state of the technology

Electrical fires have been a persistent problem for many years, often caused by faulty wiring, equipment malfunctions, or human negligence. Various solutions have been implemented to reduce these risks, but despite technological advancements, the issue remains a concern in both residential and commercial spaces.

Faulty wiring is one of the leading causes of electrical fires. This can be due to poor installation, aging electrical systems, or physical damage to wires over time. In response, updated safety codes and regulations have been established to ensure buildings meet modern electrical safety standards. New technologies, such as thermal circuit breakers and residual current devices (RCDs), have also been introduced. These devices can detect abnormal electrical activity and shut off the power to prevent fires. While these solutions are effective for addressing structural issues, they do not fully eliminate risks caused by human error—like leaving appliances plugged in for extended periods.

Other solutions, such as surge protectors and smart plugs, have been developed to manage electrical loads and prevent the overuse of extension cords, which can overheat and cause fires. Surge protectors help safeguard devices against power surges, and smart plugs allow users to control appliances remotely. However, these devices have limitations. While they can reduce energy consumption and manage electrical loads, they do not always address the risk posed by people forgetting to unplug devices, which can still lead to overheating and fires.

Fire prevention tools, such as smoke detectors and fire alarms, have also become standard in most homes and buildings. These devices are helpful in detecting fires early and alerting occupants, but they only act as reactive solutions once a fire has started. They do not prevent fires from occurring in the first place, particularly those caused by human negligence around electrical appliances.

The key issue this study aims to tackle is the lack of a system that proactively alerts users when appliances are left plugged in and offers them control over their outlets. While technologies like smart plugs and surge protectors have made progress in managing electrical safety, there is still no comprehensive solution that can monitor appliances in real time, send alerts, and allow users to remotely shut off power to prevent potential hazards.

This research will focus on developing a smart outlet monitor that alerts users when appliances are unnecessarily plugged in and allows them to turn off the outlet remotely. By addressing this gap, the proposed solution aims to reduce electrical fire risks, improve energy efficiency, and enhance overall household safety.

Objectives of the study

The study aims to design and develop a smart outlet monitoring system, using IoT technology, to give users control over their plugged-in devices, helping reduce fire risks and energy waste. This system will send real-time alerts, provide remote control options, and ensure easy usage through the following detailed objectives:

1. To develop a precise sensor system that detects appliance power usage and communicates real-time data to a central system.

2. To design a user-friendly mobile application for monitoring, alerts, and appliance control.
3. To integrate a scheduling feature for automated appliance management.
4. To implement real-time alerts for idle devices to encourage energy-saving practices.
5. To ensure system compatibility and ease of installation across various appliances.

Scope and limitations of the study

Scope of the study

This study focuses on the development and evaluation of *OutSmart*, an IoT-enabled smart outlet monitor designed to improve energy efficiency, safety, and convenience in device management. Furthermore, the following are the scope of this study:

- Integration of real-time device monitoring
- Implementation of alert notification for presence of unused devices
- Implementation of control via mobile app
- Integration of automated scheduling
- Target audience involving households, business owners, and industrial users who rely on multiple electrical devices in their daily operations.

Limitations of the study

This study on OutSmart is bound by several limitations that affect both the scope of evaluation and the generalizability of findings. These include the amperage capacity of the OutSmart outlet and as well as to where the implementation for testing will focus on. Furthermore, the following are the limitation of this study:

- The system relies on a stable internet connection for real-time monitoring and remote access. Any interruptions in connectivity hinder the delivery of notifications and limit remote-control functions.
- The system depends on a continuous 220V power supply; during outages or electrical interruptions, OutSmart becomes inactive, restricting its usability. The outlet can also accept up to 10A, which is the typical range of household and business appliances/equipment. Thus; industrial equipment having 15A or above wattage may not be covered by the capacity of the outlet.

- The research is confined to devices connected directly to the OutSmart outlet prototype. Appliances plugged into other outlets or separate power sources are excluded from monitoring and control, thereby narrowing the scope of the study to selected test environments.

- The study does not encompass detailed energy analytics, predictive insights, or automated troubleshooting of appliances, as the prototype is limited to real-time monitoring, alerts, scheduling, and manual user input.

- The study does not cover adaptive learning features or personalized energy-saving recommendations, as OutSmart is designed only for fixed scheduling and manual control.

- The evaluation is also limited to short-term testing within controlled environments, and does not extend to long-term deployment, large-scale industrial applications, or integration with renewable energy systems.

By acknowledging these limitations, the study establishes the boundaries within which OutSmart's features are assessed, ensuring a focused evaluation of its intended objectives.

LITERATURE REVIEW

Review of Related Literature/Studies/Systems

The concept of utilizing smart plugs has been in rising popularity for the last years. As described by Meteor Electrical (2024), smart plugs are advanced electrical sockets that integrates the technology of one's home smart network by which the user can control any device plugged on it with the use of a prebuilt application via a device (i.e. smartphone or tablet) or a virtual home assistant (i.e. Alexa or Google Assistant). To make them work, these plugs need to connect on a home network or one's home Wi-Fi. With the wireless connection established, the users can be able to control and automate an appliance' electrical connection which makes it convenient. Key components of these plugs involve Wi-Fi module (that will send the data collected on the socket and will receive instructions from the app), Control Interface (an application or website where the users can interact and manage the plug), Power Monitoring Unit (that will detect the amount of power consumption connected to the plug), Relay Switch (to turn on/off the flow of electricity) and Compatibility Chip (that communicates with the virtual assistants, if it is the ones where it will base its instructions from). These promotes remote control even outside one's own house or buildings, voice control if linked with virtual assistants, setting timers to schedule it, monitor the energy consumption, promotes safety against potential electrical risks of leaving unplugged appliance for a long period of time and its versatile use. In itself, typical smart plugs only consume around 1 watt in standby mode up to 1 to 2 watts per day if connected to Wi-Fi. Utilizing this not only cuts off electrical connections remotely but as well as removes any presence of phantom load/vampire load which can further increase energy consumption.

As discussed further by GE Lighting in 2024, smart plugs remove the stress of attempting to go back on the house after forgetting a left plugged device after leaving on it which provides a peace of mind for its users. Smart outlets as well have their outdoor and indoor variants with the core difference being outdoor outlets have waterproof qualities and is able to withstand various weather conditions. If used accordingly on its purpose, these plugs can prove efficient in saving energy by utilizing its core features of tracking the devices/appliances currently plugged in and make the decision if notified so and prevents instances of energy wastage which is great for lessening the amount of electrical consumption to pay.

Experimentations of its feasibility has been already conducted and was proved to be useful. As Honeywell tried to implement these smart plugs on schools and universities, it was found out that even during the weekends where no people was present inside the building, energy can still be wasted. To resolve this, smart plugs were utilized in particular areas like music room, kitchen or gymnasium and set up with a timer of its use.

Later on, the said schools and universities noticed a drop in energy consumption, oftentimes going to zero energy wastage. Another type of implementation was with the help of adapters with the same mechanisms as to what smart outlets do, with the additional feature of temperature sensor to track any potential overheat risk and make actions about it. (Deslandes, 2023).

Huang (2024) further elaborated the list of preexisting in the market. Short to medium range smart plugs involves Bluetooth, Wi-Fi, Zigbee and Z-Wave smart plugs with long range smart plugs that involves LoRaWAN, NB-IOT, GSM, LTE and 5G, with Bluetooth having range of 100 meters, is easy to setup, lower cost and low power consumption at the cost of low transfer rates up to 3Mbps which is ideal for close spaces like small apartments or close rooms. Wi-Fi has varying range depending on the capability of the router to receive signals and the antenna used on it, has moderate to high power consumption, transfer rates ranging from hundreds of Mbps to few Gbps, costs around $15 or more than $50 depending on the model and is perfect for controlling devices anywhere. Zigbee can reach up to 300 meters in open space, transfer rates from 20-250kbps, price ranging from $20-50 and is ideal for mid-sized homes or buildings. Z- Wave has a range up to 100 meters, consumes little electricity, transfer rates from 9.6 to 100kbps, price ranging from $25 to 60 and is ideal for providing secure connection, commonly used in home automation systems. LoRaWAN can reach connectivity up to several kilometers in rural application and several hundred areas in urban areas which can further vary if another gateway or mesh network was used for it, has low power costs, data rates of kbps not reaching up to 1000, is moderately priced and used in industrial settings for remote monitoring and control. NB-IoT has range extending several kilometers, is low power, transfer rate from few kbps to tens of kbps, is affordable and is best used for monitoring other utility services. GSM's range varies depending on the area coverage, has moderate power consumption due to cellular network connection, transfer rate up to 9.6 kbps for circuit switched data and hundreds of Kbps for packet switched data, is moderately priced and is suitable for remote monitoring, security systems and automation as long as it is within the area coverage. LTE is similar on the range of GSM, moderate power consumption, higher cost, can send tens to hundred megabits per second and is ideal for reliable connectivity for smart home automation systems. 5G is similar on the range of GSM, has moderate power consumption, can send hundreds of Mbps to multiple Gbps, is higher in cost and is best for applications that demand real-time data transfer and automation.

Newton (2023) provides a review of how implementing these smart plugs can prove beneficial for office application. In a report made by Green Alliance, some office had larger amount of energy footprints like in London, around 1000 offices uses the same amount of energy as 65000 homes do. As a fix, a smart socket paired with machine learning software are utilized and tested if there would be any changes later on. It was later on found out that at least 20% of an office energy can be saved. As mentioned by measurable energy,100 sockets could save a business 5,000 GBP per year and reduce carbon emission by 3.4 tonnes. Another issue they face on is with security since the fact that it is connected to a network can lead to hijacking that can shut down the entire building's power supply, by which, hardware-enabled encryption and regular updates must be required to avoid these instances.

The integration of IoT in household electrical systems is increasingly recognized for its role in enhancing energy management, safety, and convenience. Smart plugs, which enable appliances to connect to the internet for monitoring and control, represent a significant step toward smarter homes and grids. According to Castro et al. (2020), IntelliPlugs, an IoT-based smart plug, showcases the potential of such devices in energy monitoring and control. By utilizing Wi-Fi and GSM connectivity, IntelliPlugs allow users to remotely manage appliances through a mobile application powered by Blynk Software. This system features energy monitoring graphs, safety sensors, and real-time control, which contribute to better demand-side management and energy conservation. The inclusion of fire, temperature, and humidity sensors further enhances the safety aspects, allowing users to take preventive measures remotely. The study highlights the ease of integration into residential settings and the capability of IntelliPlugs to address issues such as electrical fires and phantom loads. By allowing remote control and energy monitoring, IntelliPlugs reduce energy waste and improve user convenience, underscoring their role in facilitating the transition toward smarter grids. However, the researchers recommend the use of higher-accuracy sensors, a more compact design, and the addition of backup power supplies for further improvements.

Caldo et al. (2015) also developed a Wi-Fi-based switch control system utilizing an Arduino microcontroller and an Android application highlights the potential for seamless automation of up to seven home appliances. The system employs an Arduino Ethernet board as the main control unit, functioning as a web server to monitor and execute user commands, while an 8-channel relay module ensures efficient switching. Connectivity through both LAN and Internet enables local and remote control, with a mobile application providing features such as password protection and device renaming for enhanced user experience. Extensive testing showed a 95% success rate in system functionality, with 100% accuracy in real-time control via both LAN and Internet modes. While effective, the researchers recommend incorporating radio frequency (RF) connectivity to minimize wiring, expanding compatibility to iOS and Windows platforms, and integrating sensors to enhance automation capabilities. This study demonstrates the potential of IoT-enabled solutions to simplify home automation and pave the way for smarter household systems.

According to Monton et al. (2024), the IoT-based Energy Monitoring System developed for Caraga State University demonstrates the potential for advanced energy management in educational institutions. Utilizing the ACS712 current sensor for current detection and the ESP8266 Wi-Fi module for connectivity, the system captures real-time energy consumption data, transmitting it to a Firebase cloud database. This architecture supports remote monitoring and control via a web-based interface, enabling users to optimize energy usage and reduce costs effectively. The system achieved an accuracy margin of ±1.5% during tests, reflecting its reliability. Notably, it facilitated a significant reduction in energy consumption and associated costs across monitored university facilities. Despite its success, the study highlighted limitations, such as the absence of voltage sensors, which could enhance data precision, and a reliance on stable internet connectivity for seamless operation. Future improvements proposed include integrating voltage sensors, expanding monitoring to water and gas utilities, and leveraging machine learning for predictive energy management. These findings underscore the transformative impact of IoT on energy sustainability in resource-intensive settings like universities, offering a scalable model for broader application.

The study conducted by Simbulan, Navalta, and Ostia (2023) developed a system aimed at monitoring and managing power consumption with advanced features. The system incorporates functionalities such as per-user power monitoring, timer control, budget limits, and automatic shutdown of standby appliances. Additionally, it provides protection against overloading, overvoltage, and undervoltage. The innovative use of RFID cards and mobile applications for activation enables user identification and equitable electricity bill distribution among cohabitants based on actual usage. This system, employing the PZEM-004T for voltage and current measurement, achieves high accuracy, with 95.15%-99.94% for current readings and 99.30%-99.90% for voltage readings when benchmarked against standard tools. By generating reports for both users and landlords, the system enhances accountability and promotes energy efficiency, offering a reliable solution for managing electrical consumption in shared living environments. These features underscore the study's contribution to sustainable energy usage and equitable resource allocation.

In their study, Castrodes, Funa, Lim, Angelia, and Linsang (2020) conducted an extensive study on IoT-enabled systems for home automation, focusing on methods to enhance convenience, energy efficiency, and control over electronic appliances. Among the various technologies explored, NodeMCU ESP8266-12E and Raspberry Pi emerged as vital microcontrollers due to their compatibility with Wi-Fi-based communication and real-time monitoring capabilities. These devices interfaced with Solid State Relays (SSRs) to enable seamless control of electrical appliances via mobile applications. The research also examined alternative methods for control, such as SMS-based automation and Zigbee-enabled systems, which further expanded the range of communication mediums. The inclusion of these diverse methods highlights the adaptability of IoT systems in addressing different user requirements. Moreover, integrating user-friendly interfaces, such as Android applications, enhanced accessibility, making it easier for individuals to manage their appliances. The study emphasized the importance of accurate energy tracking and device-specific control. By leveraging similar IoT components and techniques, it aims to provide users with precise monitoring, timer controls, and safety features like overload protection, ensuring efficient power management and enhanced safety.

Jing (2020) expanded previous concepts of implementation of smart power outlet while avoiding any possibilities of electrocution from the outlet by using an external solenoid locking cover alongside a remote controlling system away from the house where the smart plugs were connected. This was done by attaching RFID readers and ESP32 on a normal outlet by which the RFID (verified with MFRC522) will be used to open the wall outlet for potential modification, where the solenoid lock will lose its magnetic properties once the right card was inserted, alongside the ESP32 where the outlet can send data based on the sensors linked to it. The information received will then be received with a home server built in Raspberry Pi microcontroller with Hass.io operating system which will serve as the bridge from the outlet to the cloud servers. The main sensors used in this study is ACS712 for the detection of the number of currents. To cut on/off the supply, TRIAC BTA16-600b is utilized to serve as an AC switch for high power applications regulated by an opt isolator. ESP Home is utilized in order to regulate the ESP32 board via its programming similar to the syntax of Arduino C++. Data sent will be transported to Google Cloud for online viewing and if in any case internet shuts off, Firebase cloud will be used. The interface of the application, alongside its functions was then programmed in Android Studio. The application then shows the total energy consumed within a particular room of the house alongside its estimated electrical bill. When expanded in a particular area in a house, the application outlines per socket the system temperature, humidity, the RFID number last used to open the socket, its corresponding current and energy consumption, energy and bill sum and the decision to turn on/off the socket cover and the power switch. In an average, the power consumed by the home-controlled server unit ranges from 2.96 to 3.22W per day, the main outlet consuming 3.96 up to 6.04W depending on certain trigger scenarios on the outlet, temperature ranging from 38 to 43 degrees Celsius and 63 to 66% system humidity upon continuous usage within 90 hours. However, there are certain discrepancies on its reading due to the fact that live wires has its own magnetic field with error percentage spanning from 1.34 to 117.39% depending on how much the watt consumption of the appliance plugged inside the smart outlet. The study provides a promising advancement of creating a smart outlet controlled by an application even if the controller is outside the proximity of the house while avoiding any instance of electrocution of someone attempting to open the outlet or get close to it. The said study can be further improved if implementations of circuit protection would be introduced (i.e. to avoid short circuits or damage to power supply) and as well as to utilize improved hardware components so that the system will run optimally with minimal heat loss and power consumption. Factors like voltage and power factor measurement can be used in order to accurately monitor the power measurement within the outlet.

A similar approach was done by Bhagwatkar, Maskar and Lewarkar in 2022 for creating a smart power outlet with features primarily concerning basic switching and energy monitoring present in their proposed outlet. For this, they utilized Arduino UNO as a microcontroller, ESP8266 as the Wi-Fi Module for transmitting the collected electrical data of the outlets in the web, ZMPT101B AC Single Phase AC voltage sensor paired with ZCMCT102 Micro current transformer for measuring both voltage and current consumption, relay module for modulating the flow of electricity by either opening or closing the circuit connection and switch mode power supply as a temporary means to demonstrate electrical supply due to potential damage on the circuits on sudden electrical fluctuations. The data will then be sent to Thinger.io to be used as a web monitoring platform. This simple framework provides a basic mechanism of data analysis of the current, voltage and power consumption connected to the plug with demonstration of changes of this electrical information within a particular period of time. The said study can be improved if functions like device identification and electricity theft detection would be implemented. With wide range of platforms for IoT-based monitoring, majority among the users will not have issues regarding device compatibility and is expected to become more crucial in the future for creating smart cities.

An identical implementation was proposed by Alden, Han and Ionel in 2019 with the aim of making the system with minimal components yet the same functionalities. To do this, the researchers used LTS 25-NP current transformer and ZMPT101B voltage transducer as key sensors, 5V relay to make the circuit open/closed depending on the data sent on it, Arduino Uno microcontroller that will accept the data from the sensors and transmit it to Raspberry Pi 3B+ via serial connection and the Raspberry Pi 3B+ will be the communication bridge to transmit the data to the cloud which will then display the information on web and as well as to receive any instructions for turning on/off the circuit connection. For additional accuracy, power quality analysis was done in MATLAB by using fast Fourier transformation. By using coffee maker, vacuum cleaner and DC power as appliance to examine, it was found out that the hair dryer produced very low harmonic distortions and the voltage and current is aligned with each other and both the DC power and vacuum cleaner has distorted current waveforms which can track the energy consumption of every individual device from an aggregated data.

Another alternative was proposed by Jitket (2022) for the implementation of smart power outlets paired with machine learning for appliance detection aside from the usual control and monitoring mechanism. The researchers used PZEM-004T V.3 as the electrical power sensor which is used as a current transformer. This sensor is capable of detecting multiple electrical components like power (W) ranging from 0.4 to 23k, voltage (V) ranging from 80-260, current (A) ranging from 0.02 to 100, power factor (PF) ranging from 0.00 to 1.00, frequency (Hz) ranging from 45-65 and energy consumption ranging from 0 - 9999.99(Wh). These will then be regulated by ESPino32 which is a microcontroller with Wireless LAN and Bluetooth module to be stored in a cloud server which then will be transmitted to their software and as well as a direct display within the outlet for monitoring the electrical consumption of an outlet real-time. The proposed system can detect what appliance has been plugged in alongside its electrical consumption by implementing ExtraTree, Random Forest, Decision Tree, K-NearestNeighbors, Bagging Classidier, XGBoost and Gradient Boosting machine learning models. By doing so, the application is able to detect what appliance was plugged with accuracy ranging from 96.84 to 99.81%, precision ranging from 92.89 to 98.73%, recall ranging from 92.62 to 98.77% and F1 score ranging from 91.45 to 98.77% with the best algorithm being the ExtraTree. This research shows a promising approach on smart power outlets where an appliance can be detected precisely alongside its electrical information aside from basic electric consumption detection and monitoring.

Albraheem, Alajlan, Aljenedal, Alkhair and Gwead (2023) proposed the design of a smart power outlet with a comprehensive comparative analysis to determine which component will prove ideal to build the outlet given the same features. For this, Mokosmart Wi-Fi plugs are used for being cost-effective and as well as for the connections to be directly communicated with the modem, capable of connecting power devices up to 2.4kW, consumes little power and is compatible with IoT cloud platform supporting Message Queuing Telemetry Transport protocol. For the collection of data, Amazon Elastic Compute Cloud is used due to its compatibility with MQTT protocol to be analyzed by a Python code to be done in Jupyter Notebook which will be used for reading the sensor inputs and as well as to do the electrical computations. This will then be transmitted on Firebase as the primary database of the system and displayed on a mobile application designed on Android Studio 2020.3.1. By implementing this on actual residential buildings, it was found out that the power consumption readings fit within the power consumption range predefined on the label of the appliance and as well as to conduct predictive analysis on the potential monthly power consumption. For the software testing, it was found out that in a span of 30 minutes, only 1% was used for the CPU allocation for the system as its maximum and 32% as its minimum with an average of 395MB memory allocation and given a code that would test the stress capacity, within 7340 random user actions, the system is able to run without any unhandled exceptions running in the code. The research can be improved further by implementing AI models for anomaly detection and machine learning techniques for recognizing appliance consumption patterns to give smart suggestions about their utilization.

The evolution of home automation and appliance control has been significantly influenced by the integration of Internet of Things (IoT) technologies, as explored in multiple studies. Arispe et al. (2020) examined the integration of IoT into home automation by designing a smart electrical outlet system to enhance safety and convenience for household users. Utilizing the Rapid Application Development (RAD) methodology, the study featured a NodeMCU microcontroller programmed with Arduino IDE, enabling remote control via a mobile application built with MIT App Inventor and connected through the ThingSpeak IoT platform. The system achieved reliable functionality under high-speed internet conditions, with activation times consistently within a user latency standard of 10 seconds. While its capacity was limited to appliances drawing up to 10 amperes, the system effectively reduced fire risks caused by plugged-in appliances and improved energy efficiency. These findings underscore IoT's potential to provide practical solutions for common household safety challenges while promoting sustainability.

Expanding on appliance safety, Homeres (2020) designed an electrical outlet box with built-in high and low voltage cut-off and a power-on delay circuit to protect appliances from voltage fluctuations. This system automatically disconnects appliances when voltage exceeds 231 V or drops below 199 V, with a four-minute power-on delay ensuring stability upon power restoration. Testing with an industrial fan demonstrated the device's ability to maintain performance within the optimal voltage range of 201–229 V. Although this system proved effective in mitigating damage from voltage surges, the study highlighted the need for further testing with diverse appliances and larger-scale trials. By integrating overvoltage and undervoltage protection with a delay function, the device presents a significant innovation in safeguarding household appliances, emphasizing reliability and user convenience in environments with unstable power supplies.

Booc et al. (2020) focused on developing an IoT-Based Mobile Controlled Appliances with Online Monitoring System to address energy management and home automation challenges. The system incorporated the NodeMCU ESP8266 microcontroller for Wi-Fi connectivity and utilized the MQTT dashboard for seamless communication. It enabled users to control appliances remotely through manual commands or voice inputs while enhancing security through motion detection and notifications. Energy monitoring was supported by visual indicators and a buzzer for alerts. The system demonstrated strong connectivity with an average Wi-Fi response time of three seconds. While the study emphasized its potential for regions with emerging IoT adoption, such as the Philippines, it recommended broader implementation and testing to maximize its impact on energy efficiency and cost reduction.

According to Santos (2017) proposed replacing traditional wall sockets with smart sockets capable of wireless power monitoring and appliance control via an Android application. Their system, built around the ATmega328 microcontroller and Arduino Mega2560 board, allowed users to pre-set power consumption limits, monitor real-time usage, and schedule operations. Each socket handled up to 25A and could detect standby appliances, shutting them off to reduce energy waste. Testing revealed an accuracy rate exceeding 98% in power monitoring, with features tailored for multi-occupant households. By addressing energy awareness and automating standby power disconnection, the study demonstrated the environmental benefits of smart sockets in lowering household energy bills and reducing greenhouse gas emissions.

Mendoza et al., 2020 developed "ImHome," a system combining IoT modules for dust monitoring, gas detection, and lighting control. Using Arduino-based microcontrollers, sensors, and the Firebase cloud platform, the study enabled remote monitoring and automation through an Android mobile application. The dust sensor provided air quality data based on the AQI, while the gas detection system issued alerts for leaks, and the lighting module allowed scheduling and remote control. Employing iterative development, the researchers refined the system with timestamped data reporting and enhanced hardware protection. Compatibility testing confirmed responsiveness across multiple Android devices. Despite excluding iOS compatibility, the project illustrated IoT’s potential to optimize convenience and safety in smart homes, setting a foundation for future developments.

Synthesis

The reviewed foreign and local studies highlight the growing role of IoT-enabled devices in enhancing energy management, safety, and user convenience. While innovations such as IntelliPlugs (Castro et al., 2020), RFID-based energy monitoring (Simbulan, Navalta, & Ostia, 2023), and institutional monitoring systems (Monton et al., 2024) showcase the potential of IoT, their limitations include restricted automation, connectivity dependence, and limited applicability to households. Similarly, Homeres (2020) focused on appliance protection but did not incorporate predictive or behavioral features essential for efficient energy use.

To address these gaps, OutSmart: IoT-Enabled Smart Outlet Monitor integrates intelligent scheduling, real-time alerts, and manual bill estimation suited for residential settings. By combining the strengths of earlier systems while introducing advanced automation, OutSmart bridges manual control and full automation, providing a more efficient, safe, and sustainable solution for smart home energy management.

Resources

Hardware Components

The OutSmart: IoT-Enabled Smart Outlet Monitor integrates several hardware components that enable real-time monitoring, protection, and reliable system performance. Each component contributes to the functionality, safety, or structural integrity of the device:

- **NodeMCU ESP32S Microcontroller**
  Serves as the main processing unit with built-in Wi-Fi capability. It handles sensor data acquisition, energy monitoring, temperature reading, and wireless communication with the user interface.
- **PZEM-004T Energy Monitoring Module**
  Measures real-time electrical parameters, including voltage, current, power, and energy usage of the connected appliance. This module provides accurate consumption data essential for monitoring and analysis.
- **DS18B20 Temperature Sensor**
  Monitors internal system temperature to detect overheating conditions, particularly around the load-handling components inside the enclosure.
- **Solid State Relay (SSR 40DA)**
  Controls the switching of AC loads safely and efficiently. Its fast-switching capability and electrical isolation make it suitable for IoT-driven power control.
- **AC-DC Power Supply (ACE-6839)**
  Converts 240V AC input to a stable low-voltage DC output required to power the ESP32S and the supporting electronics.
- **TMOV 14D471 Metal Oxide Varistor (MOV)**
  Provides surge protection by clamping excessive voltage spikes. It helps protect sensitive electronics from transient overvoltage conditions.
- **Glass Fuse (10A)**
  Acts as a safety cutoff device that disconnects the circuit in cases of overload or short circuits, reducing fire and equipment-damage risks.

- **Metal Enclosure**
  Houses all internal components, providing mechanical protection, heat resistance, and electrical shielding. The metal casing enhances durability and improves safety during prolonged operation and stress testing.
- **Omni Surface Outlet**
  Serves as the AC output interface for connecting household appliances to the OutSmart system.
- **Electrical Wires (#12 Solid THW and #14/7 THHN)**
  Used for internal power distribution and signal wiring. These wires support high-current flow and ensure reliable connectivity between components.
- **Female Pin Headers (48-pin)**
  Provide modular and secure connections between sensors, modules, and the microcontroller for ease of assembly and maintenance.
- **Heat Shrink Tubing (Insulation Set)**
  Insulates exposed connections and enhances electrical safety inside the enclosure.
- **Double-Sided Foam Tape**
  Used for component mounting and vibration reduction within the metal enclosure.

Software Components

The software aspect of OutSmart was developed using the following technologies:

- **HTML, CSS, and JavaScript:** These programming languages were utilized to design and implement the user interface of the web application, allowing users to monitor and interact with the smart outlet.
- **Firebase:** Serves as the backend platform for real-time database management, user authentication, and cloud-based data storage. It enables seamless communication between the hardware device and the user interface.

METHODOLOGY

Requirements Analysis

The project is designed to provide a computing solution that addresses the need for efficient and safe management of electrical outlets through real-time monitoring and smart alerts. It targets homeowners, business owners, industrial users, and individuals who rely on electrical outlets in their daily routines. OutSmart responds to the demand for improved energy awareness and safety by enabling users to track plugged-in devices and receive notifications about unusual consumption or forgotten appliances. It is intended for use in various settings, including residential, commercial, and industrial environments. Operating continuously, the system ensures that users are always informed of outlet activity. Unlike traditional manual checks and basic circuit breakers, OutSmart leverages IoT sensors and a web application to automate the monitoring process, making electrical management more intelligent, responsive, and user-friendly.

Requirements Documentation

This table outlines the functional and non-functional requirements for the hardware components of the OutSmart system. Functional requirements focus on the system's ability to detect, transmit, and alert based on electrical usage, while non-functional requirements emphasize reliability, power efficiency, durability, and physical design. Each item is accompanied by its current development status.

Hardware	Status
Functional Requirements	
1. The device detects and measures the electrical current passing through connected appliances.	Completed
2. The device transmits usage data wirelessly to the ESP32 microcontroller.	Completed
3. The device controls the on/off state of the connected outlet through a relay module.	Completed
4. The device sends real-time consumption data to a cloud platform via Wi-Fi.	Completed
Non-Functional Requirements	
6. The device operates efficiently with low power consumption to ensure continuous monitoring.	Completed
7. The device is enclosed in a durable, heat-resistant Metal casing for safety and component protection.	Completed
8. The device fits standard electrical sockets without requiring modification.	Completed
9. The device includes built-in safety features like overheat protection and short-circuit prevention.	Completed

Table 1.0. Hardware requirements

Software	Status
Functional Requirements	
1. The web and mobile application display real-time outlet status and power consumption data per connected device.	Completed
2. The web and mobile application send browser-based notifications to users when the outlet is online or offline.	Completed
3. The web and mobile application allow users to remotely control the outlet (turn on/off) through the web interface.	Completed
4. The web and mobile application log the status and actions done by the outlet in the cloud.	Completed
5. The web and mobile application manage user authentication, accounts, and personalized settings.	Completed
6. The web and mobile application handle multiple connected outlets under a single user account without performance issues.	Completed
7. The web and mobile application syncs with the cloud for automatic backup and data recovery in case of errors or crashes.	Completed

Non-Functional Requirements	
8. The web and mobile application features a responsive and intuitive interface accessible on desktop and mobile browsers.	Completed
9. The web and mobile application uses secure communication protocols (e.g., HTTPS, TLS) for data exchange and device access.	Completed

Table 1.1. Software requirements

Design of Software, System, Product and/or Processes

The design of OutSmart integrates software, system, and product design elements that collectively support accurate energy monitoring, enhanced safety, and user convenience. These three design areas work together to ensure that the device functions reliably while following best practices for IoT development and safe prototype construction. Each design domain contributes to the iterative improvement of the system throughout the prototyping phases.

Software Design

The software design centers on the OutSmart mobile application and its communication with the hardware. The mobile app provides an intuitive interface that allows users to view real-time and historical energy consumption, monitor internal temperature, and remotely control the connected appliance. User authentication, device registration, and data handling are managed through a secure backend service, ensuring the privacy and integrity of transmitted information. Communication between the ESP32S and the app uses efficient wireless protocols to maintain real-time responsiveness. The design prioritizes ease of use, clear data visualization, and reliable connectivity during everyday operation.

System Design

The system architecture integrates sensing, control, and protection mechanisms to ensure safe and stable operation. The ESP32S microcontroller handles data acquisition from the PZEM-004T energy monitoring module and the DS18B20 temperature sensor while executing switching commands through the SSR 40DA. The AC-DC power supply provides stable low-voltage power to the electronics, while protective components such as the TMOV 14D471 varistor and 10A fuse help manage abnormal voltage or overcurrent conditions. Internal circuitry is designed to minimize electrical noise, ensure accurate measurements, and maintain reliable wireless communication. System logic prioritizes safety responses such as automatic shutdown during detected overheating or abnormal readings.

Product Design

The physical design of OutSmart emphasizes durability, heat resistance, and safe internal layout. Earlier prototypes utilized a wooden enclosure to allow rapid access during development, while the final prototype now uses a metal enclosure, providing improved structural integrity and better heat management. Internal components are arranged to optimize airflow, maintain safe wire clearances, and support secure mounting. Proper insulation, heat-shrink protection, and organized wiring reduce risks related to short circuits during operation. The design incorporates a standard Omni surface outlet for appliance connection and provides a clean, compact form factor suitable for real-world testing environments.

Development and Testing

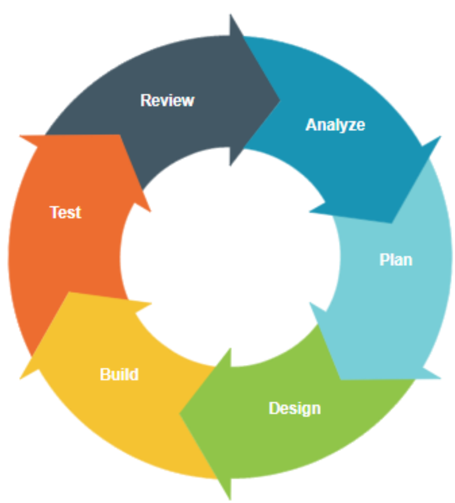

Figure 1.0. Iterative prototyping model

OutSmart follows the Iterative Prototyping Model, a development approach that emphasizes repeated cycles of building, testing, evaluating, and refining hardware and software components. Instead of completing the system in one linear pass, the project undergoes three major prototype iterations—Concept Prototype, Functional Prototype, and Final Prototype. Each cycle produces an improved version of the system based on test results and feedback, ensuring that OutSmart becomes progressively more accurate, reliable, and aligned with user needs.

Prototype Cycle Activities

Each iteration follows the same structured sequence:

1. Analyze

Identify issues in outlet safety, temperature rise, and household energy monitoring. Define system requirements based on research, user pain points, and previous iteration results.

2. Plan

Determine which features or hardware improvements will be included in the current prototype. Prioritize tasks such as sensor integration, microcontroller programming, enclosure revision, or user-interface adjustments.

3. Design

Develop or refine the hardware layout, wiring configuration, and enclosure structure. Update software design for microcontroller logic, data processing, and user interface improvements.

4. Build

Assemble the prototype using the required components, including the ESP32S microcontroller, PZEM-004T energy monitor, DS18B20 temperature sensor, SSR 40DA, TMOV 14D471 varistor, metal enclosure, fuse protection, and wiring. Implement firmware updates and improve the interface or communication logic.

5. Test

Evaluate the prototype through structured testing to determine accuracy, stability, and safety. Issues found during testing become inputs for the next iteration.

6. Review

Assess the test results, identify weaknesses (e.g., inaccurate readings, poor enclosure heat management, unstable communication), and use findings to refine the next prototype cycle.

OutSmart uses a range of testing methods across all prototype iterations to ensure performance, reliability, and safety.

Unit Testing

Individual components—such as the ESP32S microcontroller, PZEM-004T, DS18B20, SSR 40DA, and backend firmware—are tested independently to verify correct operation before integration.

Integration Testing

Hardware modules and firmware logic are tested together to confirm smooth communication between the ESP32S, sensors, and data processing functions. This includes verifying load switching, temperature monitoring, and real-time energy reporting.

Stress Testing

Simulated heavy electrical load and prolonged operation are performed to evaluate system stability. This includes checking whether the metal enclosure safely dissipates heat and whether the TMOV and fuse respond properly to abnormal conditions.

Performance Testing

Measurements are compared under normal and high-demand appliance usage to verify the accuracy of wattage readings, temperature sensing, and operational responsiveness.

Field Testing

The prototype is deployed in real household or small-office environments. Tests focus on real appliance usage, temperature and energy monitoring accuracy, ESP32S reliability, and user interaction with the system. Field results guide adjustments in firmware logic, enclosure improvements, and hardware layout.

Description of Prototype

The OutSmart prototype consists of two core components:
(1) the smart outlet hardware, which performs energy monitoring, temperature sensing, and load control; and
(2) the mobile application, which provides users with real-time data visualization and remote switching capabilities.

The smart outlet hardware integrates the ESP32S microcontroller, PZEM-004T energy monitoring module, DS18B20 temperature sensor, Solid State Relay (SSR 40DA), TMOV 14D471 surge protection component, and a 10A fuse housed in a metal enclosure. This hardware measures voltage, current, power, and internal temperature, while enabling safe remote on/off control of connected appliances.

The mobile application communicates wirelessly with the smart outlet, allowing users to monitor energy usage, check internal temperature, view historical data, and remotely control the outlet. The app ensures quick access to data through real-time synchronization and secure communication.

System Requirements:

- The OutSmart smart outlet must be plugged into a standard 220V AC power source and connected to a stable Wi-Fi network.
- The mobile device must have an active internet connection (Wi-Fi or mobile data) to receive real-time updates and send control commands.

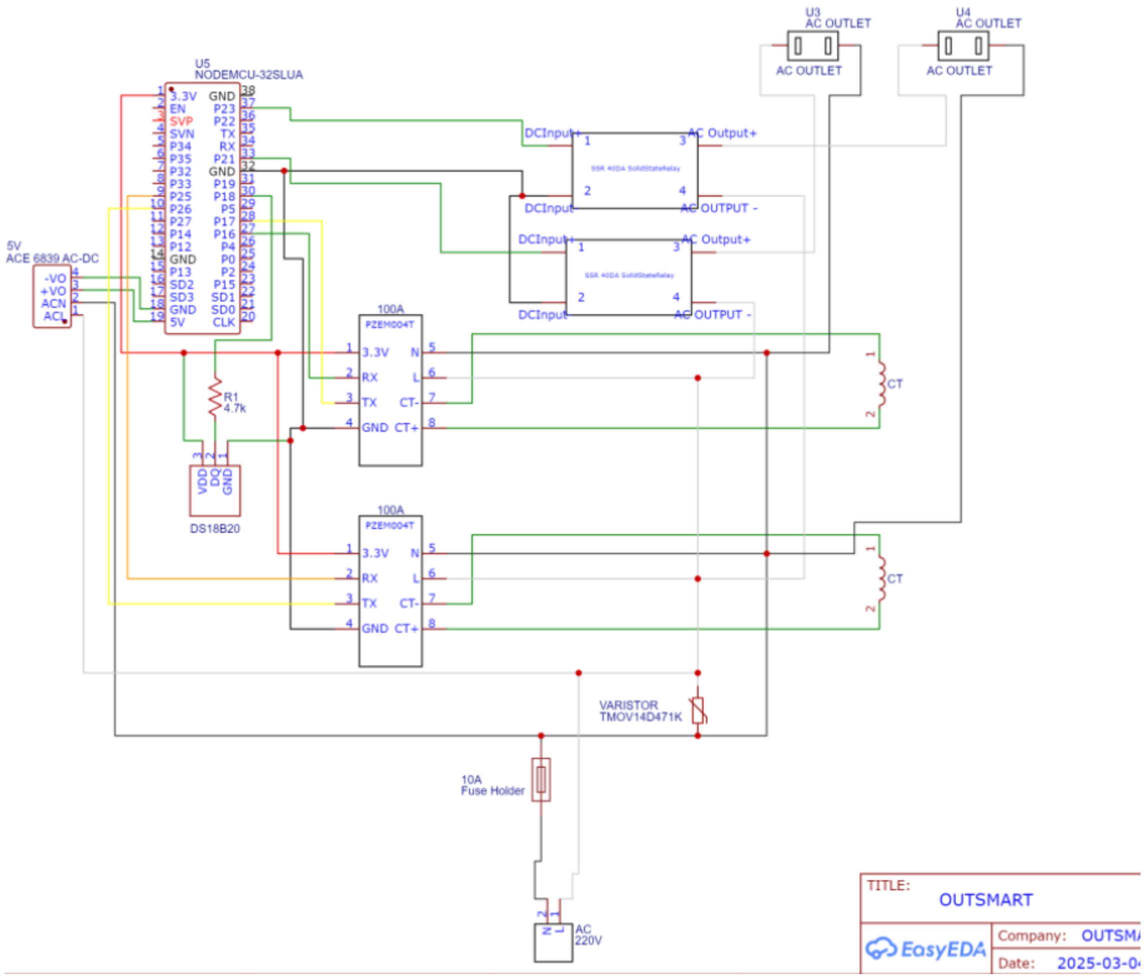

Figure 1.1. Schematic diagram of outsmart

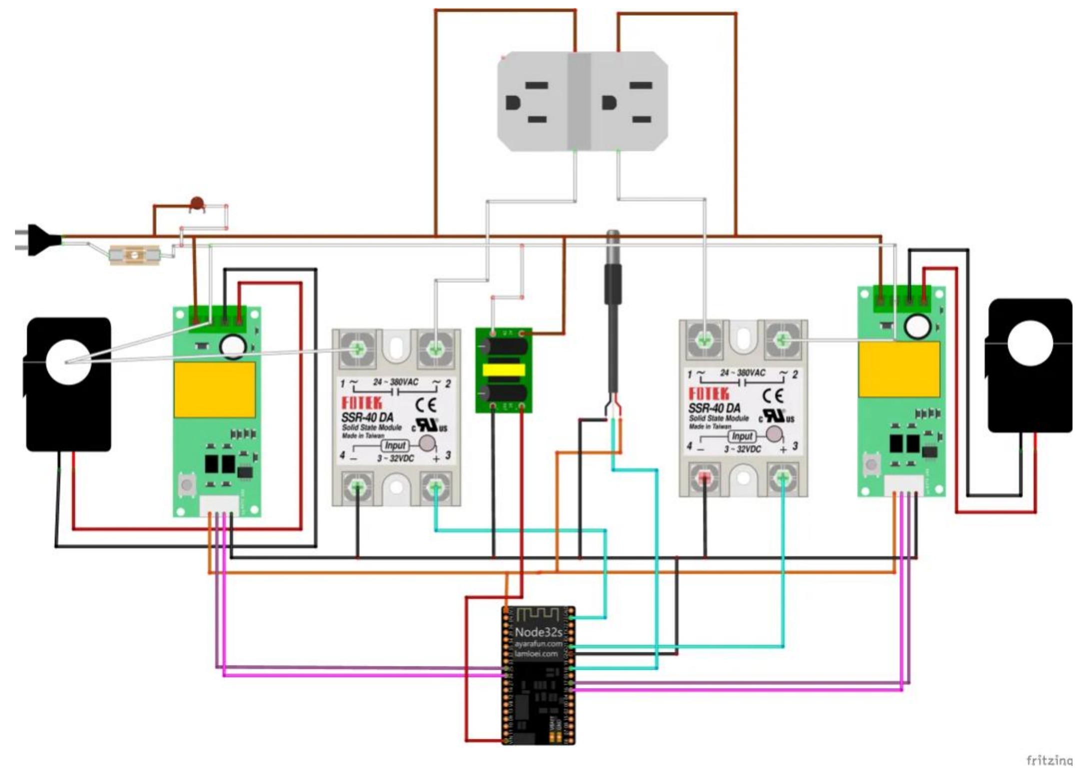

Figure 1.2. Wiring diagram of outsmart

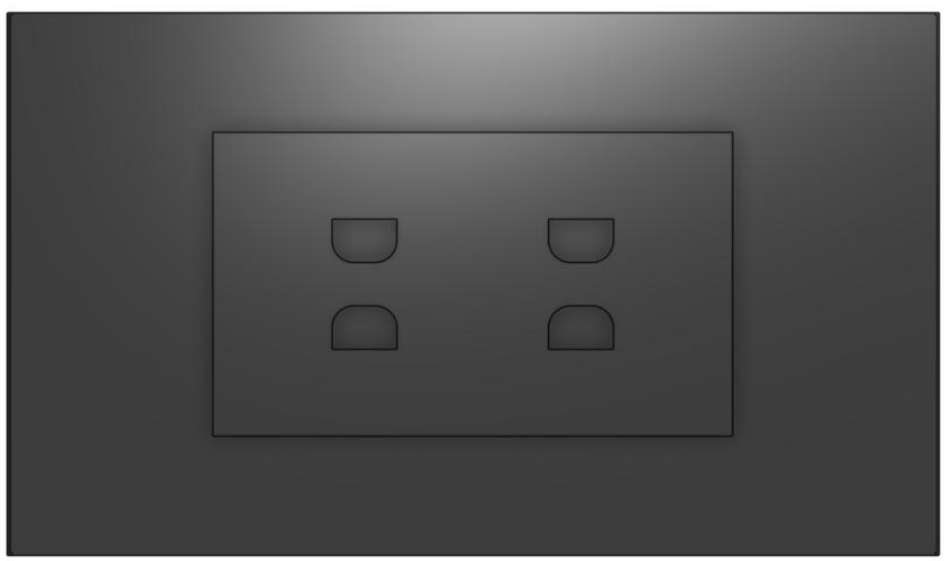

Figure 1.3. 3d model of outsmart in top-view

Figure 1.4. 3d model of outsmart in front-view

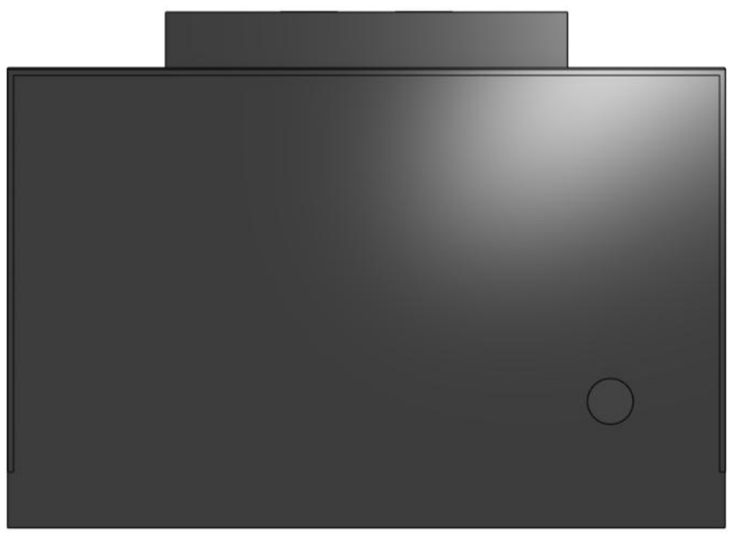

Figure 1.5. 3d model of outsmart in left-view

Figure 1.6. 3d model of outsmart in right-view

Figure 1.7. 3d model of outsmart in back-view

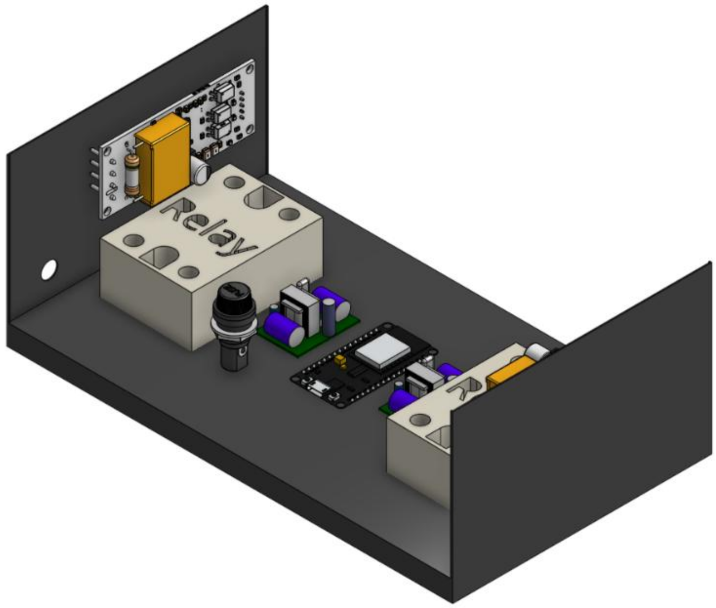

Figure 1.8. 3d model of outsmart's components in isometric-view

Figure 1.9. Actual prototype of outsmart in top-view

Figure 2.0. Actual prototype of outsmart in front-view

Figure 2.1. Actual prototype of outsmart in bottom-view

Figure 2.2. Actual prototype of outsmart in side-vie

Figure 2.3. User interface of outsmart's mobile application

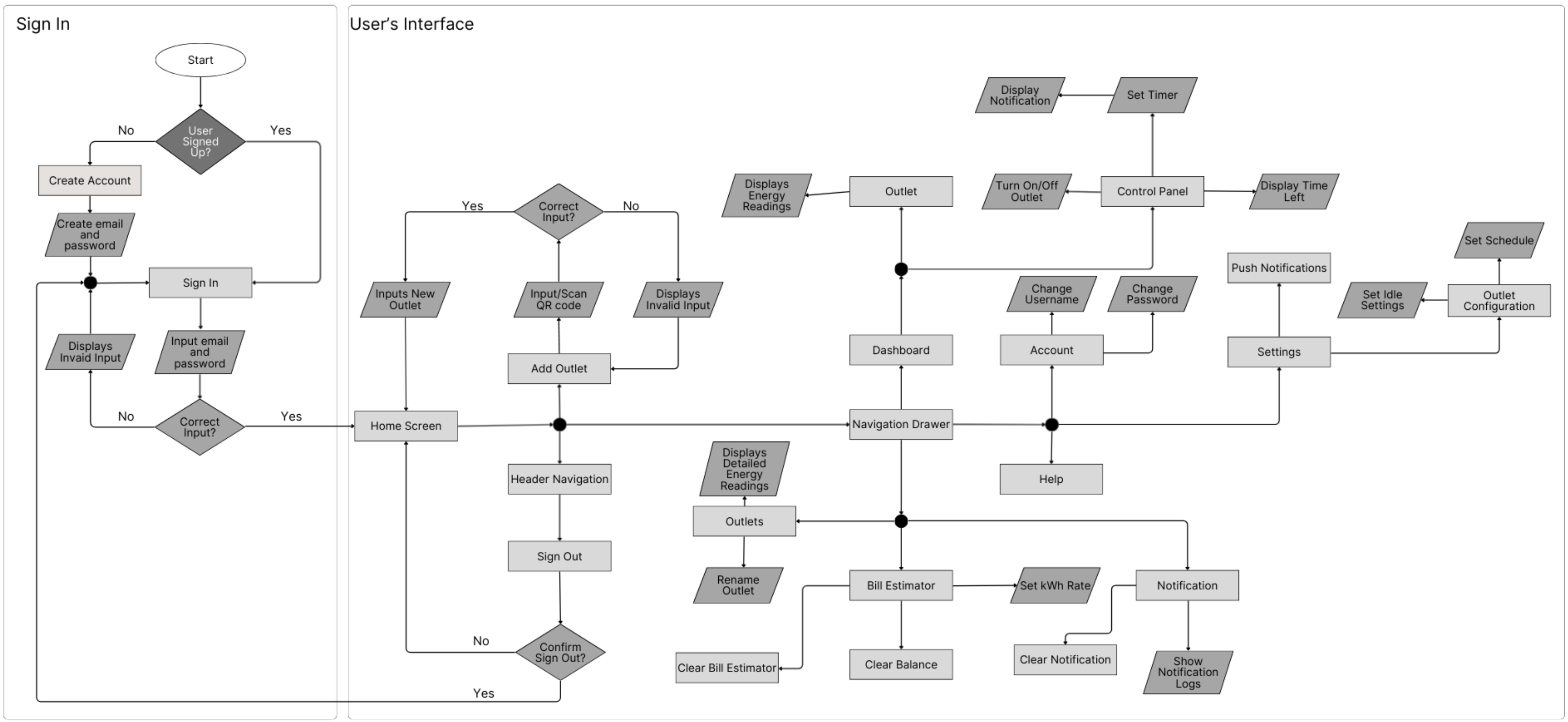

Figure 2.4. User flowchart

Implementation Plan

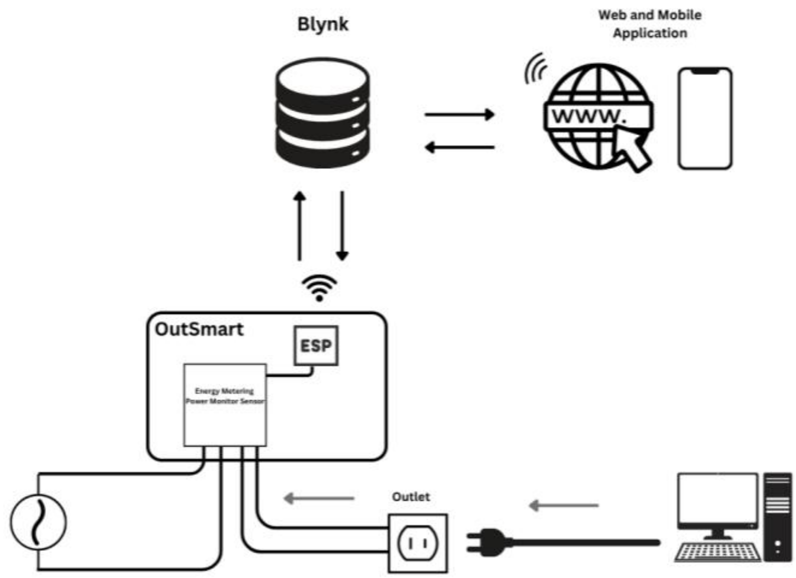

Figure 2.5. Outsmart implementation plan

The diagram above illustrates how the OutSmart system will be implemented for testing and evaluation. The OutSmart hardware unit is plugged into a standard 230V AC power source. An Omni surface outlet is integrated into the device, allowing household appliances—such as lamps, fans, rice cookers, or chargers—to be connected as test loads. The energy consumed by the connected appliance is measured in real time by the PZEM-004T energy monitoring module inside the hardware unit.

The ESP32S microcontroller collects measurements including voltage, current, power, and accumulated energy, along with temperature readings from the DS18B20 sensor. This data is processed and transmitted via Wi-Fi to the Firebase backend, where values are logged and stored for real-time and historical tracking.

The OutSmart mobile application retrieves this data from the cloud, providing users with an interface to view real-time consumption, track historical trends, and monitor internal temperature. The app also sends remote control commands—such as turning the connected appliance ON or OFF—which the ESP32S executes through the SSR 40DA relay inside the hardware.

This implementation setup allows the team to assess key aspects of system performance:

- accuracy and stability of the energy and temperature measurements,
- reliability of wireless transmission and cloud synchronization,
- responsiveness of remote load control, and
- usability and functionality of the mobile application.

The configuration supports iterative refinement of the hardware, software, and overall user experience.

RESULTS

User Testing

Within this testing, the researchers selected random respondents that will use the system for 30 minutes which will be followed by their review in regards to the software/hardware parts of the system as well as their feedback about it. Convenience sampling is used by the researchers in order to gain easy access to the respondents and as well as to acquire relevant and in-depth detail about their review about the prototype model, given the fact that they can represent an entirety of a household that is accessible to the researchers.

To evaluate the hardware and software aspects of the OutSmart project, survey questionnaires were distributed to the identified respondents. The survey aimed to gather feedback on the usability, functionality, and effectiveness of the prototype, as well as to collect suggestions for further improvement. The responses obtained serve as the basis for validating the system's design, identifying areas for enhancement, and assessing the overall acceptance and potential impact of OutSmart.

Summary of the Survey Results

Demographic	No. of Respondents	Percentage
18-25 years old	9	60%
26-35 years old	5	33.33%
36-45 years old	0	0%
46+ years old	1	6.7%
Total	15	100%

Table 1.2. Demographic profile

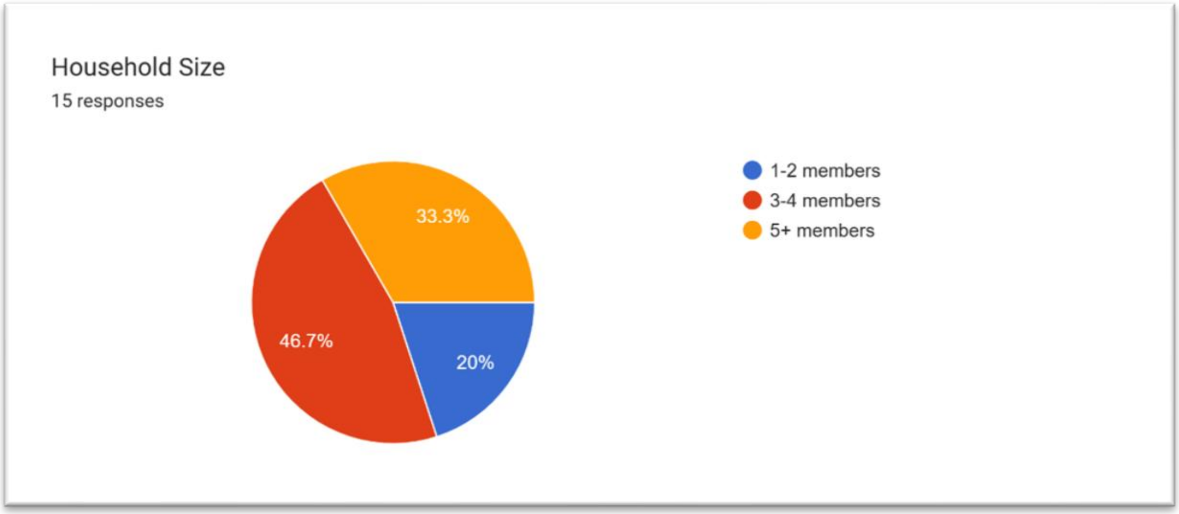

Figure 2.6. Household size of survey respondents

The survey results indicate that the majority of respondents (46.7%) live in households with 3–4 members. Meanwhile, 20% come from smaller households with only 1–2 members, and 33.3% belong to larger households with 5 or more members. This distribution suggests different electricity consumption patterns, which may influence the applicability and effectiveness of OutSmart in managing energy use across varying household sizes.

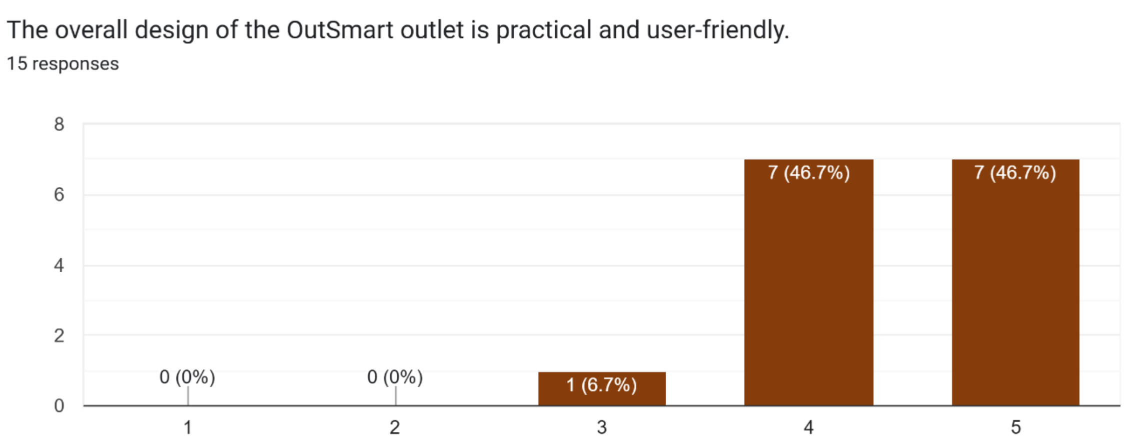

Figure 2.7. Respondents' ratings on the design of OutSmart outlet

The majority of respondents rated the overall design of the OutSmart outlet as practical and user-friendly, with 46.7% giving a rating of 4 and another 46.7% giving the highest rating of 5. Only a small portion, 6.7%, provided a rating of 3, and no respondents strongly disagreed with the statement. These results suggest that the outlet's design is generally perceived as effective and user-friendly.

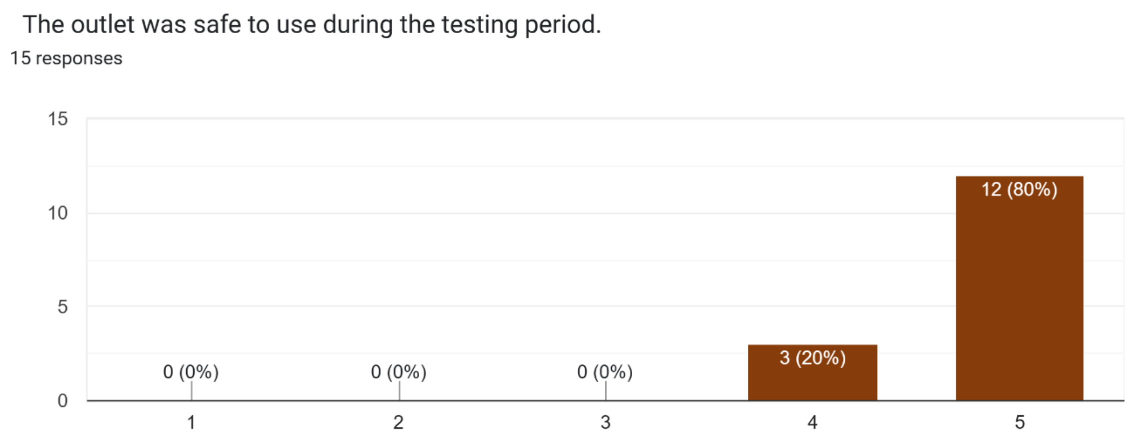

Figure 2.8. Respondents' ratings on the safety of OutSmart outlet

All respondents agreed that the OutSmart outlet was safe to use during the testing period. A majority of 80% rated it with the highest score of 5, while the remaining 20% gave a rating of 4. These results indicate a strong level of confidence in the safety and reliability of the outlet.

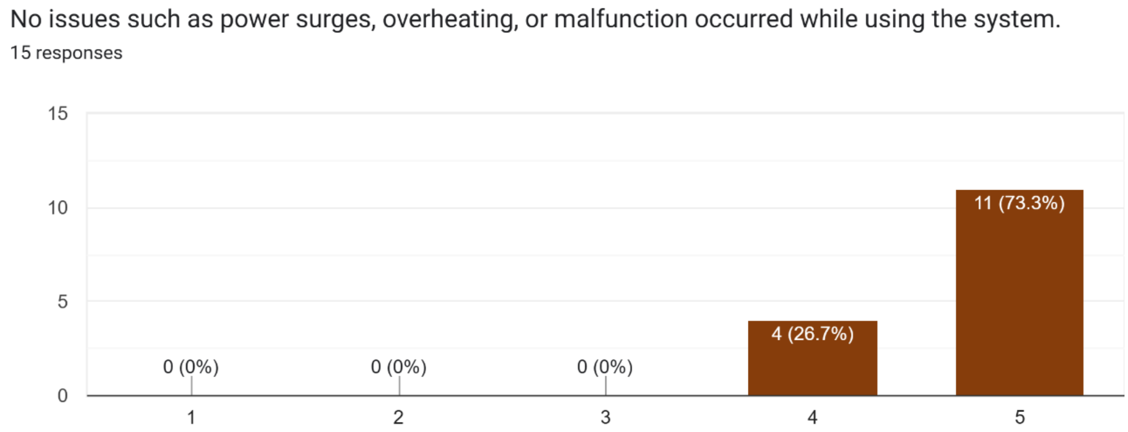

Figure 2.9. Respondents' ratings on the reliability of OutSmart system

The respondents confirmed that no issues such as power surges, overheating, or malfunctions occurred while using the OutSmart system. A majority of 73.3% strongly agreed with this statement by giving a rating of 5, while 26.7% provided a rating of 4. These findings highlight the system's stability and reliability during operation.

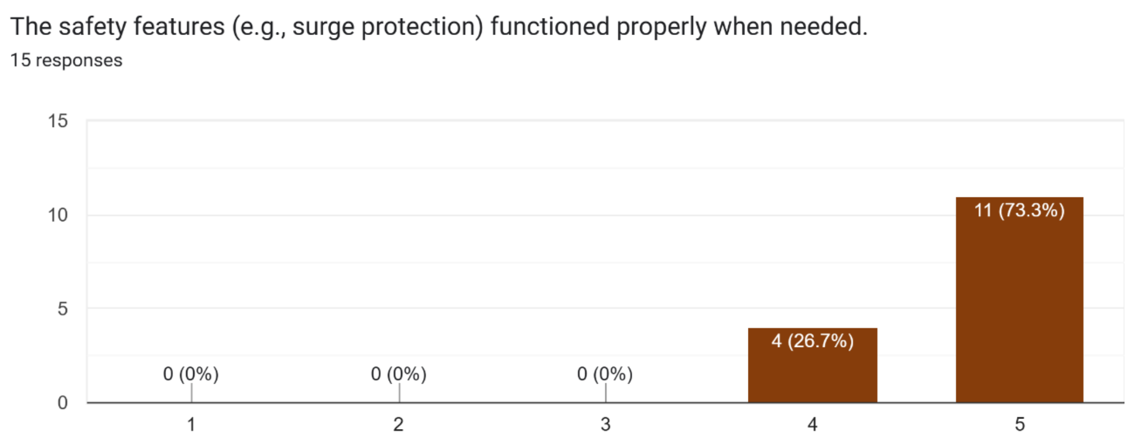

Figure 3.0. Respondents' ratings on OutSmart safety features

The majority of respondents agreed that the safety features of the OutSmart outlet, such as surge protection, functioned properly when needed. A total of 73.3% strongly agreed by giving a rating of 5, while 26.7% provided a rating of 4. These results demonstrate the effectiveness of the system's built-in safety mechanisms.

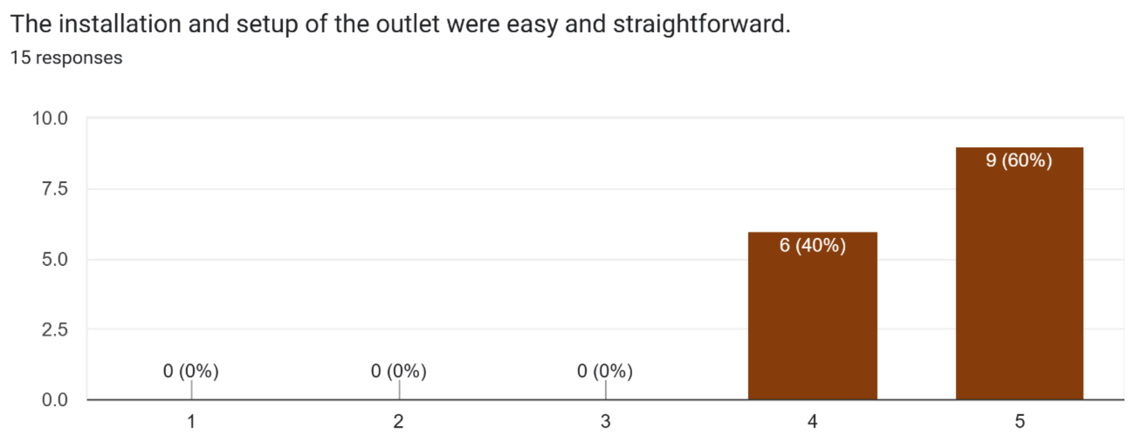

Figure 3.1. Respondents' ratings on installation and setup

Respondents found the installation and setup of the OutSmart outlet easy and straightforward. A majority of 60% strongly agreed by rating it a 5, while the remaining 40% gave a rating of 4. These results indicate that the system is generally user-friendly and accessible even for first-time users.

Respondents' Suggestions on Hardware Design and Safety

Comments/Suggestions	Percentage Value
None	8.33%
I would like the outlet to be more smaller	8.33%
Nothing	8.33%
Nothing in particular	8.33%

Improve to minimize the size of the device while keepings all of its functionality.	8.33%
Brilliant idea, it will definitely be beneficial especially for safety concerns, I believe this device would be competitive in market around the world.	8.33%
Maybe make it more compact and space-saving	8.33%
LCD screen displaying essentials	8.33%
N/A	8.33%
I think no improvements are needed here because the hardware system is highly optimized and user friendly	8.33%
The wiring and its cover, you should input more protective especially to the component	8.33%
The casing could've been smaller	8.33%

Table 1.3. Respondents' suggestions on hardware design and safety

Aside from rating the hardware design and safety features of OutSmart, respondents also provided specific suggestions for improvement. A recurring recommendation was to minimize the overall size of the outlet to make it more compact and space-saving, while retaining its full functionality. Some respondents also proposed integrating an LCD screen to display essential information for easier monitoring. In terms of safety, it was suggested that additional protective measures be applied to the wiring and its cover, along with improvements to the casing, which could be made smaller yet durable. These insights highlight opportunities to further refine OutSmart's design for both practicality and safety.

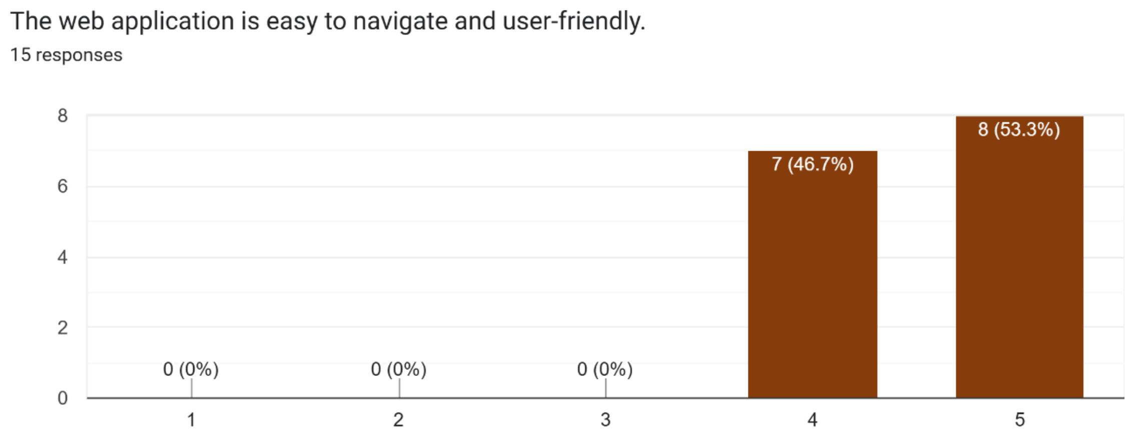

Figure 3.2. Respondents' ratings on the OutSmart web application

Respondents evaluated the web application as easy to navigate and user-friendly. A majority of 53.3% strongly agreed by rating it a 5, while 46.7% gave a rating of 4. These results indicate that the application provides a smooth and accessible user experience, requiring minimal effort to operate.

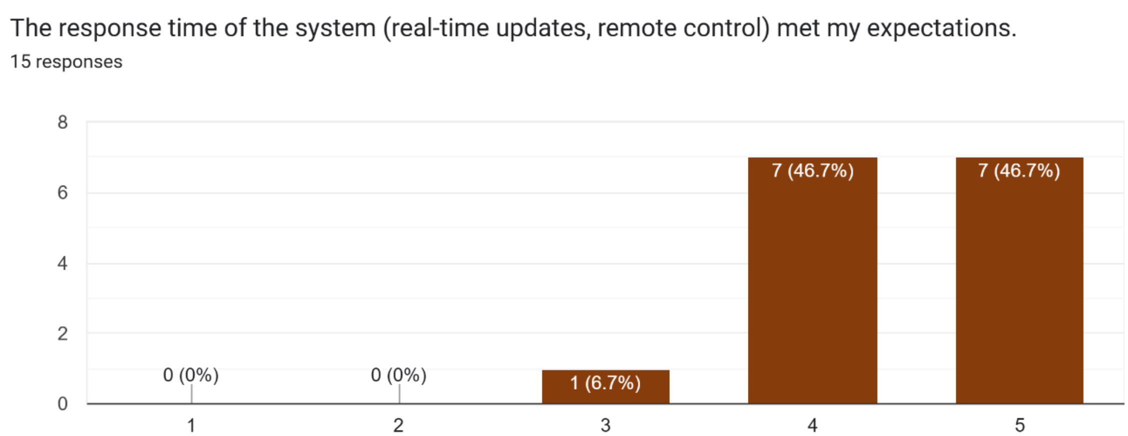

Figure 3.3. Respondents' ratings on the response time

Respondents indicated that the response time of the OutSmart system, particularly in terms of real-time updates and remote control, met their expectations. A total of 46.7% rated it a 4, while another 46.7% gave the highest rating of 5. Only 6.7% rated it a 3, indicating minor reservations. Overall, these findings suggest that the system performs reliably in providing timely updates and remote-control functions.

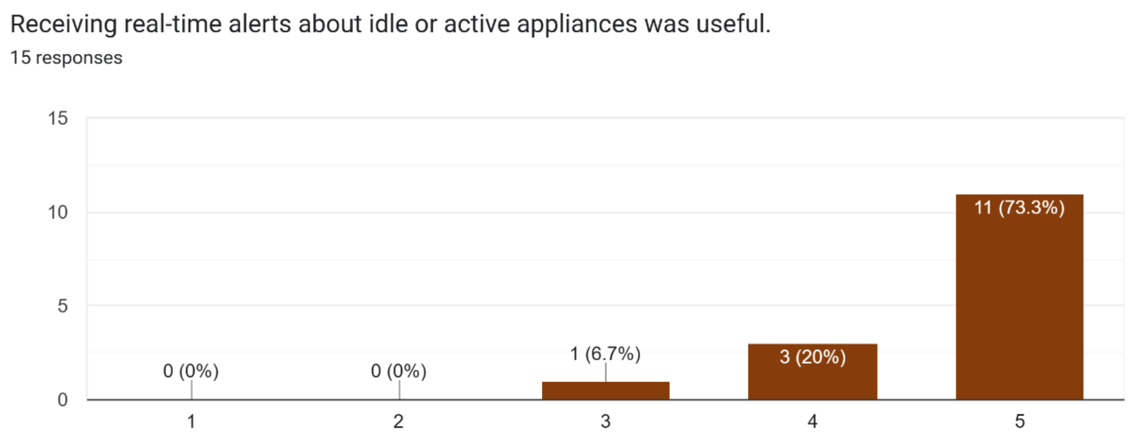

Figure 3.4. Respondents' ratings on real-time alerts

Respondents agreed that receiving real-time alerts about idle or active appliances was useful in managing their electricity consumption. A total of 46.7% rated it a 4, while another 46.7% gave the highest rating of 5. Only 6.7% rated it a 3, reflecting minor reservations. These results suggest that the alert system of OutSmart is a valuable feature that supports users in monitoring and controlling their appliances effectively.

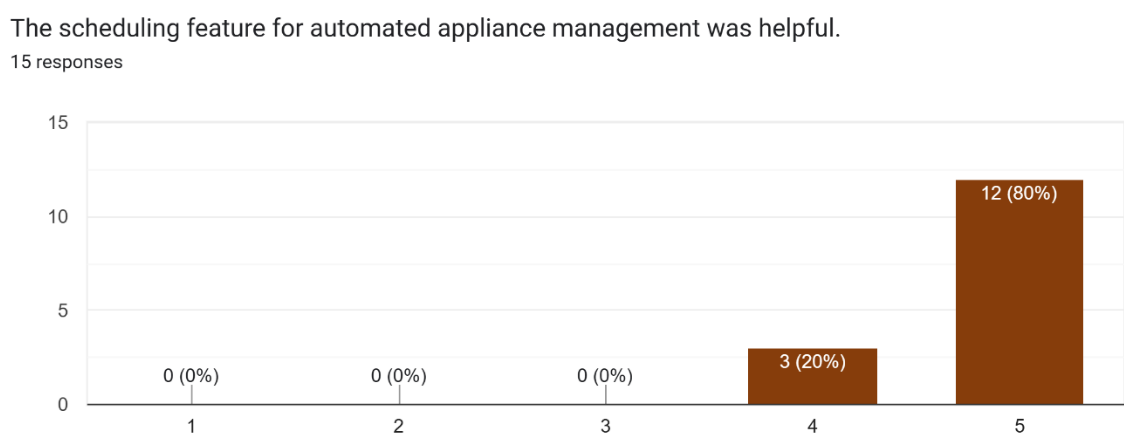

Figure 3.5. Respondents' ratings on scheduling feature

Respondents found the scheduling feature for automated appliance management to be helpful. A majority of 80% strongly agreed by giving it a rating of 5, while the remaining 20% rated it a 4. These results indicate that the scheduling functionality is highly valued by users, as it provides convenience and supports efficient energy management.

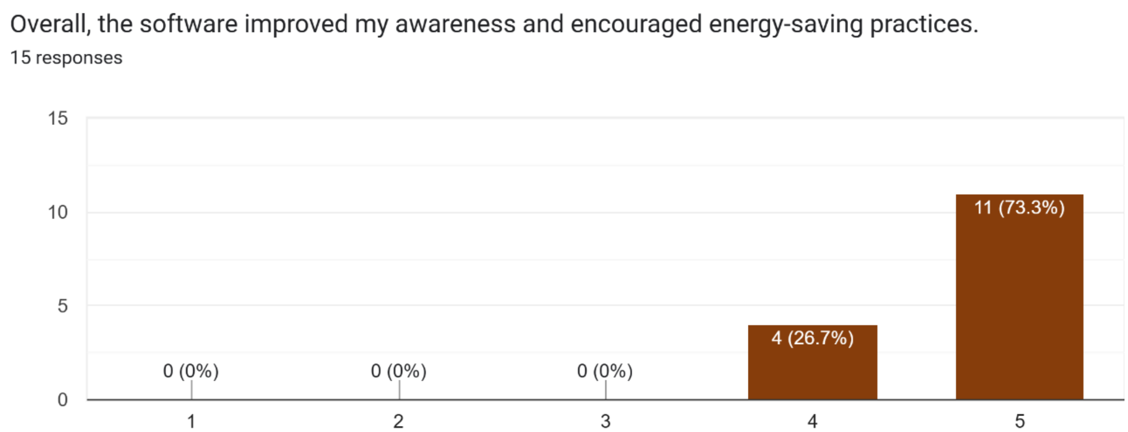

Figure 3.6. Respondents' ratings on energy awareness and savings

Respondents agreed that the OutSmart software improved their awareness of electricity usage and encouraged energy-saving practices. A majority of 73.3% strongly agreed by rating it a 5, while 26.7% gave it a 4. These results highlight the system's effectiveness in promoting energy-conscious behavior among users.

Respondents' Suggestions on Software Design, Alerts, and Features

Comments/Suggestions	Percentage Value
None	8.33%
I would recommend to add a feature where I can choose a custom notification sound so I can determine much more easier that the notification is from OutSmart.	8.33%
Not much	8.33%

Nothing in particular	8.33%
Improve on the accuracy of the readings of the system	8.33%
Features were designed and planned properly	8.33%
No suggestion	8.33%
Cross compatibility for mac os linux and ios	8.33%
n/a	8.33%
I don't think any improvements are needed here, the software design is neat, UI is clean and the features are easy to understand.	8.33%
none for now	8.33%
The UI is great	8.33%

Table 1.4. Respondent's suggestions on software design, alerts, and features

Along with evaluating the software features of OutSmart, respondents also shared recommendations for further improvement. A common suggestion was to enhance the notification system by allowing users to set a custom notification sound, making alerts more distinguishable and easier to identify as coming from OutSmart. Some respondents also emphasized the need to improve the accuracy of the system's readings to ensure more reliable monitoring of electricity usage. Additionally, suggestions were made to expand cross-platform compatibility, specifically for macOS, Linux, and iOS devices, to make the software accessible to a wider range of users. These insights provide valuable input for enhancing the overall functionality, accuracy, and usability of OutSmart's software component.

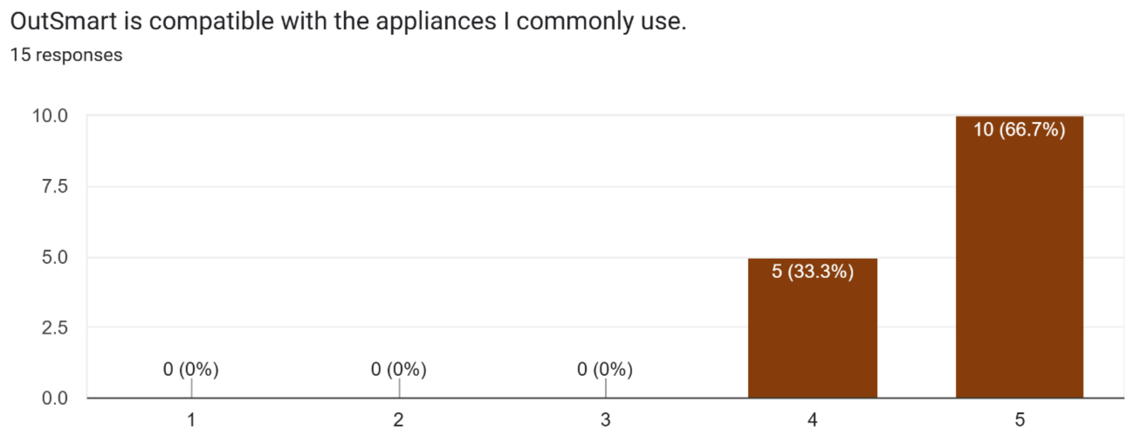

Figure 3.7 Respondents' ratings on appliance compatibility

Respondents agreed that OutSmart is compatible with the appliances they commonly use. A majority of 66.7% strongly agreed by giving a rating of 5, while 33.3% rated it a 4. These results indicate that the system is generally adaptable to typical household appliances, making it practical and convenient for everyday use.

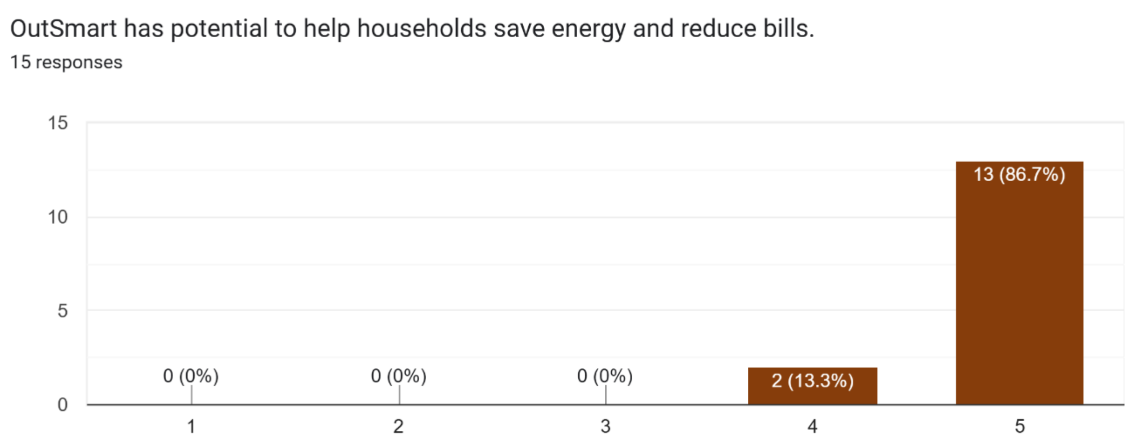

Figure 3.8. Respondents' ratings on energy-saving potential

Respondents strongly recognized the potential of OutSmart to help households save energy and reduce electricity bills. A significant majority of 86.7% rated it a 5, while 13.3% rated it a 4. These results emphasize the system's perceived value in promoting energy efficiency and cost reduction, aligning directly with the objectives of the study.

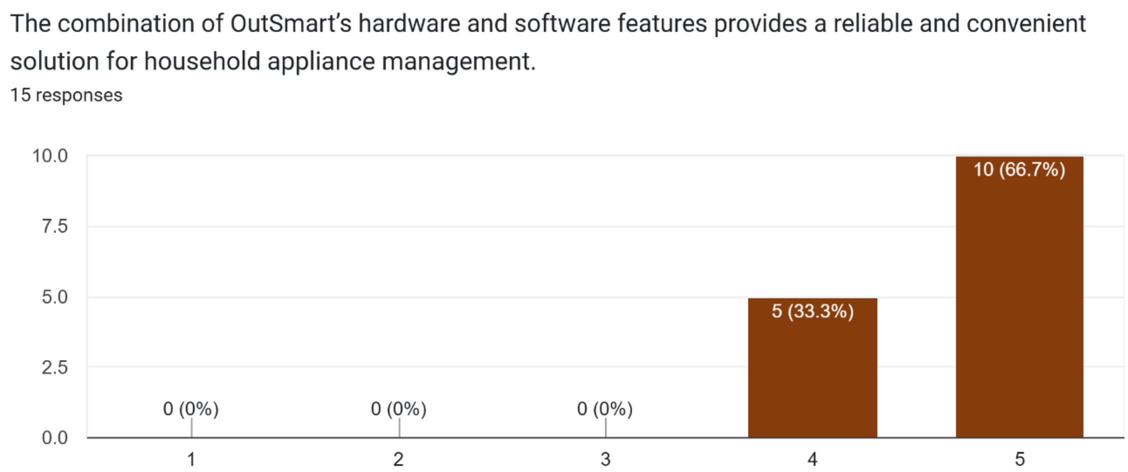

Figure 3.9. Respondents' ratings on integrated hardware and software

Respondents agreed that the combination of OutSmart's hardware and software features provides a reliable and convenient solution for household appliance management. A total of 66.7% strongly agreed by rating it a 5, while 33.3% gave a rating of 4. These results indicate that OutSmart's integrated design successfully delivers both functionality and ease of use for household energy management.

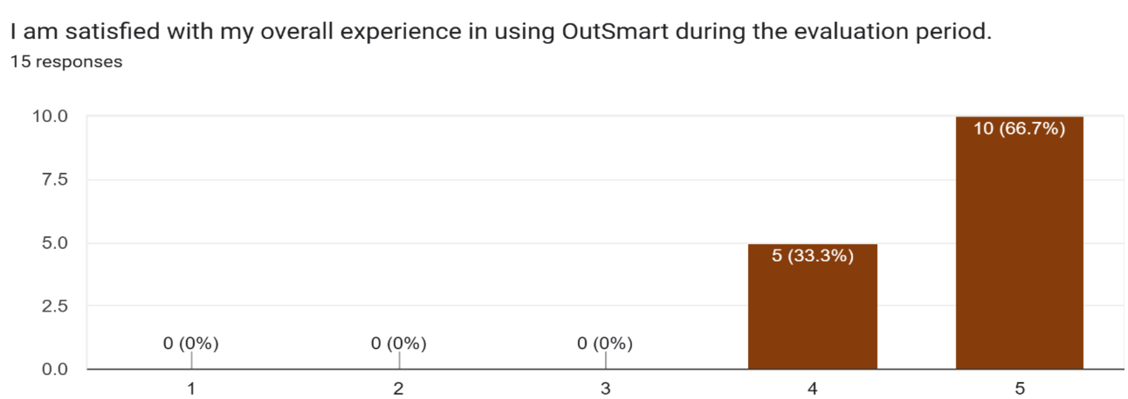

Figure 4.0. Respondents' overall satisfaction with OutSmart

Respondents expressed satisfaction with their overall experience in using OutSmart during the evaluation period. A majority of 66.7% strongly agreed by rating it a 5, while 33.3% gave a rating of 4. These results indicate that users had a positive overall impression of the system, reflecting its usability, effectiveness, and potential for real-world application.

Respondents' Suggestions for Future Features of OutSmart

Comments/Suggestions	Percentage Value
I would like OutSmart to have a widget feature that I can add to my phone or computer.	8.33%
Additional Socket	8.33%
Add safety features for pet	8.33%
An app connection instead of website	8.33%
Cannot think of anything for now, but we know how technology advancement time to time, more likely AI features in the future	8.33%
I can't think any for now, it is a great device!	8.33%
International compatibility	8.33%
n/a	8.33%
I cannot think of any features that can be added in future versions of OutSmart because the existing functions very useful and cover a wide range of usage.	8.33%
Put a solar for more energy-efficient	8.33%
No comment	8.33%
Partnerships with electric providers to tailor made my bill estimation accurately	8.33%

Table 1.5. Respondent's suggestions for future features of outsmart

In addition to evaluating the current hardware and software, respondents also suggested several features that could be integrated into future versions of OutSmart. Some respondents recommended practical enhancements such as adding an extra socket, including pet-related safety features, and providing a mobile or desktop widget for quicker access. Others highlighted improvements in connectivity, suggesting the development of a dedicated mobile application instead of relying solely on the web platform. Forward-looking ideas were also raised, such as integrating solar power for energy efficiency, incorporating AI-driven functions, and forming partnerships with electric providers to deliver more accurate, tailored bill estimations. These suggestions emphasize both immediate usability improvements and long-term innovations that could expand OutSmart's functionality and impact.

Recommendation of OutSmart to Other Households

All respondents expressed a strong willingness to recommend OutSmart to other households, reflecting a high level of satisfaction and trust in the system. The most common reasons centered on safety, with participants noting that the device provides assurance against electrical risks such as overheating or forgetting to unplug appliances. This highlights OutSmart's effectiveness in addressing practical concerns that are often overlooked in day-to-day household routines.

Aside from safety, respondents emphasized the system's convenience and ease of use. The ability to control appliances remotely, combined with its straightforward installation and user-friendly interface, was seen as highly beneficial—particularly for those who are not technically inclined. Respondents also noted OutSmart's potential to promote energy efficiency and cost savings, recognizing that it could help lower electricity bills while encouraging more responsible energy consumption at home. Beyond its practical benefits, participants viewed OutSmart as an innovative and modern solution suited to the needs of today's households. Many considered it a unique and forward-looking device that could improve daily living by making household management safer, smarter, and more efficient.

This unanimous willingness to recommend OutSmart validates its design, impact, and potential to become a household necessity.

Professional Consultation

2. ISO 50001:2011 – Energy Management System Compliance Checklist

(For Electrical Engineer Review – OutSmart: IoT-Enabled Smart Outlet Monitor)

Clause	Requirement Summary	OutSmart Description	Electrical Engineer Remarks / Level
4.1 General Requirements	Establish, implement, maintain, and improve an Energy Management System (EnMS).	OutSmart applies a structured process for monitoring energy data and improving efficiency through IoT-based control.	☑ Passed ☐ Needs Improvement ☐ Not Met
4.2.1 Top Management Commitment	Demonstrate management support and continuous improvement of energy performance.	Project team ensures proper testing, documentation, and energy-efficiency awareness.	☑ Passed ☐ Needs Improvement ☐ Not Met
4.2.2 Energy Policy	Establish and maintain an energy policy appropriate to operations.	Energy policy: "Promote efficient, safe, and responsible use of electrical energy through real-time	☑ Passed ☐ Needs Improvement ☐ Not Met

		monitoring and control.".	
4.2.3 Energy Management Representative (EMR)	Assign a person responsible for EnMS coordination.	System Analyst or Project Manager acts as EnMS Representative for documentation and reporting.	☑ Passed □ Needs Improvement □ Not Met
4.3.1 General Energy Planning	Define a structured energy-planning process.	OutSmart identifies standby power as a major energy-loss factor; planning focuses on measurement and reduction.	☑ Passed □ Needs Improvement □ Not Met
4.3.2 Legal and Other Requirements	Identify and comply with applicable electrical and energy laws.	References PEC 2017, DOE Energy Efficiency Act, and DOST guidelines.	☑ Passed □ Needs Improvement □ Not Met
4.3.3 Energy Review	Analyze energy use and consumption to identify Significant Energy Uses (SEUs).	Data collected from current and voltage sensors determines high-consumption or idle loads.	☑ Passed □ Needs Improvement □ Not Met
4.3.4 Energy Baseline (EnB)	Establish baseline(s) for comparison of energy performance.	Baseline = average kWh consumption before installation; used for comparison after OutSmart monitoring.	☑ Passed □ Needs Improvement □ Not Met
4.3.5 Energy Performance Indicators (EnPIs)	Define measurable indicators for monitoring performance.	EnPIs: kWh per outlet, standby power (W), % idle-power reduction, peak temperature (°C).	☑ Passed □ Needs Improvement □ Not Met
4.3.6 Objectives, Targets & Action Plans	Set measurable objectives and plans for energy improvement.	Objective: Reduce idle energy 10–15%; Action Plan: IoT control + temperature monitoring.	☑ Passed □ Needs Improvement □ Not Met
4.4.1 Competence, Training & Awareness	Ensure personnel involved are competent and aware of EnMS roles.	Team trained in safe electrical testing, data analysis, and sensor calibration.	☑ Passed □ Needs Improvement □ Not Met
4.4.2 Communication	Establish internal/external communication procedures regarding energy performance.	Results and updates documented and shared among project members; user alerts via app.	☑ Passed □ Needs Improvement □ Not Met
4.4.3 Documentation	Maintain documentation describing EnMS scope and procedures.	Technical documentation includes energy policy, wiring diagram, and testing records.	☑ Passed □ Needs Improvement □ Not Met

4.4.4 Control of Documents	Ensure documents are updated, approved, and traceable.	All test records version-controlled and timestamped in project folder.	☑Passed □ Needs Improvement □ Not Met
4.5.1 Operational Control	Identify operations affecting energy performance and control them.	IoT system controls each socket individually and monitors temperature for safety.	☑Passed □ Needs Improvement □ Not Met
4.5.2 Design Considerations	Ensure new designs enhance energy performance.	OutSmart's design integrates sensors and controls to optimize power usage per socket.	☑Passed □ Needs Improvement □ Not Met
4.5.3 Procurement of Energy Services and Equipment	Procure components that support energy efficiency.	Components selected based on rated efficiency and electrical safety standards.	☑Passed □ Needs Improvement □ Not Met
4.6.1 Monitoring, Measurement & Analysis	Monitor, measure, and analyze energy performance at planned intervals.	Sensor data continuously logged and analyzed through ESP32 module and Blynk app.	☑Passed □ Needs Improvement □ Not Met
4.6.2 Evaluation of Compliance	Periodically evaluate compliance with legal and other requirements.	Results checked against PEC ratings and DOLE/DOE energy guidelines.	☑Passed □ Needs Improvement □ Not Met
4.6.3 Internal Audit of the EnMS	Conduct audits at planned intervals to ensure EnMS conformance.	Team performs internal tests and verifies data accuracy after each iteration.	☑Passed □ Needs Improvement □ Not Met
4.6.4 Nonconformities, Correction & Preventive Action	Identify and correct non-conformities and implement preventive actions.	Any inaccurate sensor or overload incident logged and corrected through firmware update.	☑Passed □ Needs Improvement □ Not Met
4.6.5 Control of Records	Maintain evidence of EnMS implementation and results.	Energy logs and test reports stored in digital records for traceability.	☑Passed □ Needs Improvement □ Not Met
4.7 Management Review	Periodically review EnMS for suitability and effectiveness.	Energy data and performance reports reviewed to determine further design improvement.	☑Passed □ Needs Improvement □ Not Met

Table 1.6. ISO50001 compliance checklist

3. Philippine Electrical Code (PEC) Part 1 – 2017 Edition Compliance Checklist

(For Electrical Engineer Review – OutSmart: IoT-Enabled Smart Outlet Monitor)

Chapter/Article	Provision Summary	OutSmart Description	Electrical Engineer Remarks / Level
Chapter 1 – General			
Art. 1.0 – Scope and Definitions	Establishes code coverage for all electrical installations ≤ 600 V AC.	OutSmart operates at 220–230 V, 10 A, under low-voltage residential/commercial classification.	✓Passed ☐ Needs Improvement ☐ Not Met
Art. 1.1 – Purpose	Ensures practical safeguarding of persons and property from electrical hazards.	OutSmart aims to reduce overheating, short-circuit risks, and energy waste through monitoring.	✓Passed ☐ Needs Improvement ☐ Not Met
Art. 1.2 – Enforcement	Electrical installations must conform to approved engineering practices and inspections.	OutSmart's compliance to be validated by licensed Electrical Engineer through test and review.	✓Passed ☐ Needs Improvement ☐ Not Met
Art. 1.3 – Examination, Identification, Installation, and Use of Equipment	Equipment must be identified, properly installed, and suitable for intended use.	Outlet modified under controlled test; components properly rated and labeled.	✓Passed ☐ Needs Improvement ☐ Not Met
Art. 1.4 – Access to Electrical Equipment	Electrical devices shall have sufficient access and working space.	Design allows adequate spacing for socket access and maintenance.	✓Passed ☐ Needs Improvement ☐ Not Met
Art. 1.5 – Grounding and Bonding	All exposed conductive parts must be grounded.	Ground terminal provided; bonding connection to earth system included.	☐ Passed ✓ Needs Improvement ☐ Not Met
Art. 1.6 – Protection from Physical Damage	Cables and enclosures must protect conductors from mechanical injury.	Internal wiring enclosed within protective casing (wood prototype; PETG planned).	✓Passed ☐ Needs Improvement ☐ Not Met
Art. 1.7 – Overcurrent Protection	Conductors and equipment must have proper overcurrent protection.	10A fuse and TMOV used to prevent overload and transient damage.	✓Passed ☐ Needs Improvement ☐ Not Met
Art. 1.8 – Interrupting Rating	Equipment must have adequate interrupting capacity.	Fuse and TMOV rated for 250V, 10A interrupting current.	✓Passed ☐ Needs Improvement ☐ Not Met
Art. 1.9 – Ground-Fault Protection	Ground-fault protection must be installed in certain circuits.	GFCI not integrated; to be externally provided if installed in damp areas.	✓Passed ☐ Needs Improvement ☐ Not Met

Art. 1.10 – Circuit Identification	Each circuit and component must be clearly identified.	Labels provided for each socket, fuse, and wiring path.	☑ Passed ☐ Needs Improvement ☐ Not Met

Chapter 2 – Wiring and Protection			
Art. 2.0 – Branch Circuits	Outlets must be on properly rated branch circuits.	Uses 2.0 mm² copper conductor suitable for 10 A load.	☑ Passed ☐ Needs Improvement ☐ Not Met
Art. 2.1 – Feeders	Feeders must be protected and adequately sized.	Prototype powered through standard 15 A breaker-protected branch line.	☑ Passed ☐ Needs Improvement ☐ Not Met
Art. 2.2 – Services	Electrical service conductors must meet capacity and protection requirements.	Operates downstream of household service panel (not service-rated equipment).	☑ Passed ☐ Needs Improvement ☐ Not Met
Art. 2.3 – Outside Branch Circuits and Feeders	Requires additional protection for outdoor circuits.	Device intended for indoor use only; no outdoor wiring exposed.	☑ Passed ☐ Needs Improvement ☐ Not Met
Art. 2.4 – Overcurrent Protection	Conductors and devices must be protected from overload current.	Fuse interrupts overcurrent before conductor overheating.	☑ Passed ☐ Needs Improvement ☐ Not Met
Art. 2.5 – Ground-Fault and Arc-Fault Protection	GFCI and AFCI required in specific circuits to prevent fire/shock.	Not integrated but may be installed upstream for compliance.	☑ Passed ☐ Needs Improvement ☐ Not Met
Art. 2.6 – Surge Protection Devices (SPD)	SPD required for transient voltage surges.	TMOV component integrated for surge absorption.	☑ Passed ☐ Needs Improvement ☐ Not Met

Chapter 3 – Wiring Methods and Materials			
Art. 3.0 – Wiring Methods	Conductors shall be properly enclosed and supported.	Internal wiring fixed within casing and insulated.	☑ Passed ☐ Needs Improvement ☐ Not Met
Art. 3.1 – Cables: Types and Uses	Only approved cable types (THHN, TW, etc.) shall be used.	THHN/Equivalent wire used in branch and internal connections.	☑ Passed ☐ Needs Improvement ☐ Not Met
Art. 3.2 – Raceways and Conduits	Conductors in metallic/nonmetallic conduits must be secured.	Internal wiring routed through insulated paths; no exposed conductors.	☐ Passed ☑ Needs Improvement ☐ Not Met
Art. 3.3 – Conductors for General Wiring	Wire size and ampacity must match load rating.	2.0 mm² copper ensures $\leq$ 3% voltage drop at 10 A, 220 V.	☑ Passed ☐ Needs Improvement ☐ Not Met
Art. 3.4 – Cable Connectors and Fittings	Must be mechanically secure and prevent damage.	Screw terminals with heat-shrink insulation used.	☑ Passed ☐ Needs Improvement ☐ Not Met

Art. 3.5 – Pull and Junction Boxes	Boxes must be accessible and enclosed.	All wiring terminations inside enclosed outlet box.	✓Passed ☐ Needs Improvement ☐ Not Met

Chapter 4 – Equipment for General Use			
Art. 4.0 – Switches and Receptacles	Receptacles must match voltage/current rating and spacing.	Dual 10 A sockets spaced per PEC minimum.	✓Passed ☐ Needs Improvement ☐ Not Met
Art. 4.1 – Lighting Fixtures and Appliances	Appliances must include a disconnecting means.	IoT control provides remote disconnection via app.	✓Passed ☐ Needs Improvement ☐ Not Met
Art. 4.2 – Protection of Equipment	Equipment must be protected against overload, short circuit, and heat.	Fuse, TMOV, and temperature sensor integrated for safety.	✓Passed ☐ Needs Improvement ☐ Not Met
Art. 4.3 – Flexible Cords and Cables	Flexible cords must be rated and strain-relieved.	Plug cord rated for 10 A, 250 V with proper strain relief.	✓Passed ☐ Needs Improvement ☐ Not Met
Art. 4.4 – Heating and Cooling Equipment	Thermal devices must not exceed temperature limits.	Temperature sensor monitors overheating, triggers alert when high.	✓Passed ☐ Needs Improvement ☐ Not Met

Chapter 5 – Special Occupancies			
Art. 5.0 – Hazardous Locations	Equipment must be approved for explosive or flammable environments.	Not applicable; device designed for standard indoor environments.	✓Passed ☐ Needs Improvement ☐ Not Met
Art. 5.1 – Damp or Wet Locations	Not applicable; device designed for standard indoor environments.	Not waterproof; indoor dry use only.	✓Passed ☐ Needs Improvement ☐ Not Met

Chapter 6 – Special Equipment			
Art. 6.0 – Control Systems and Panels	Control systems must comply with design and protection standards.	ESP32 based control enclosed within protective housing.	✓Passed ☐ Needs Improvement ☐ Not Met
Art. 6.1 – Transformers and Power Supplies	Must be rated and protected from overcurrent.	DC power supply isolated and fused; low-voltage side < 5 V.	✓Passed ☐ Needs Improvement ☐ Not Met
Art. 6.2 – Electronic Equipment	Shall comply with grounding, insulation, and isolation requirements.	Circuit isolation maintained; microcontroller power separated from mains.	✓Passed ☐ Needs Improvement ☐ Not Met

Chapter 7 - Special Conditions

Art. 7.0 – Emergency Systems	Circuits for emergency use must be independent.	Not applicable; non-emergency system.	☑Passed □ Needs Improvement □ Not Met
Art. 7.1 – Communication Systems	Communication lines shall not introduce electrical hazards.	Wi-Fi-based IoT control isolated from mains circuit.	☑Passed □ Needs Improvement □ Not Met
Chapter 8 – Communication Systems	Covers data transmission systems for safety and interoperability.	IoT communication complies with low-voltage isolation.	☑Passed □ Needs Improvement □ Not Met
Chapter 9 – Tables (Conductor Ampacity, Voltage Drop, Conduit Fill)	Used as reference for sizing and current capacity.	Wire selection follows Table 9.1 for ampacity and 3% voltage drop rule.	☑Passed □ Needs Improvement □ Not Met

Table 1.7. PEC compliance checklist

Summary of Findings:

☑ Fully Compliant ☐ Partially Compliant ☐ Non-Compliant ☐ For Re-Evaluation

Electrical Engineer's Verification and Certification

I hereby certify that I have reviewed, inspected, and evaluated the **OutSmart: A Smart Outlet Device for Monitoring and Controlling Connected Devices to Optimize Electricity Consumption** in accordance with the provisions and requirements of the **Philippine Electrical Code (PEC) Part 1 – 2017 Edition** and the **ISO 50001:2011 – Energy Management Systems** standard.

The verification covered electrical safety, grounding, overcurrent protection, wiring conformity, and energy-management alignment based on available documentation and physical inspection results.

This certification does **not constitute full product approval or code compliance** but reflects the findings based on inspection and technical evaluation at the time of review. Final conformity shall depend on continued adherence to the applicable standards and subsequent re-assessment if design modifications occur.

Electrical Engineer's Name: FRANK MARC JM. SALSPOT
PRC License No.: 00 a5a 22
Designation / Position: Quality inspector Engineer
Date of Evaluation: November 06, 2025
Signature:

6. Electrical Engineer's Overall Remarks

(To be filled out by the reviewing Electrical Engineer after evaluation of the entire document.)

Remarks:

Needs partial cable management and wire upsize
Replace Metal Casing with proper grounding.

Based on the conducted assessment of the *OutSmart: IoT-Enabled Smart Outlet Monitor* in accordance with the ISO 50001:2011 Energy Management Systems standard and the Philippine Electrical Code (PEC) Part 1 – 2017 Edition, the device demonstrated substantial alignment with the required technical and safety provisions. The majority of checklist items under both standards were evaluated as Passed, indicating that the system generally conforms to established guidelines for energy monitoring, operational safety, and electrical installation practices.

However, two specific provisions under the PEC were identified as Needs Improvement, namely Article 1.5: Grounding and Bonding and Article 3.2: Raceways and Conduits. These findings indicate that, while the grounding terminal and internal wiring pathways are present, they do not yet fully satisfy the safety and structural requirements mandated by the code. The reviewing Electrical Engineer also noted several corrective measures necessary to achieve full compliance.

These include implementing partial cable management, upsizing the internal wiring to meet appropriate conductor ratings, and replacing the existing casing with a metal enclosure equipped with proper grounding.

In summary, the evaluation results classify the device as partially compliant, with only minor but essential modifications required. Upon completion of the recommended improvements and subsequent reassessment, the device is expected to meet full compliance with applicable standards.

User Testing Interpretation

For a more comprehensive analysis, mean will be used as statistical treatment in order to determine the average score of the questions given in the form as well as its according mean score interpretation (via Likert scale).

The formula for mean is:

$\bar{x} = (\sum X_n)/n$

Where:

$\bar{x}$ = the overall mean of all the gathered data

$\sum X_n$ = the summation of all the gathered data

n = the overall number of data collected in the study

The formula for range score is

R = (HV – LV)/NC

Where:

R = range to interpret the data presented in mean

HV – highest value/score the respondents can give (5 = Strongly Agree)

LV – lowest value/score the respondents can give (1 = Strongly Disagree)

NC – number of choices in the specific question (5 choices from 1 to 5)

R = (5-1)/5 = 4/5 or 0.8

Starting from 1, these will be the mean interpretation of the results:

1.0 – 1.8 = Strongly Disagree

1.81 – 2.60 = Disagree

2.61 – 3.40 = Neutral

3.41 – 4.20 = Agree

4.20 – 5.00 = Strongly Agree

Hardware Evaluation

Question	Mean	Interpretation
The overall design of the OutSmart outlet is practical and user-friendly	4.4	Strongly Agree
The outlet was safe during the testing period	4.8	Strongly Agree
No issues such as power surges, overheating or malfunction occurred while using the system	4.73	Strongly Agree
The safety features (e.g. surge protection) functioned properly when needed	4.73	Strongly Agree
The installation and setup of the outlet were easy and straightforward	4.6	Strongly Agree

Table 1.8. Hardware evaluation results of outsmart

Overall, the respondents were mostly satisfied with the system, with some feedbacks includes making the casing more compact, potentially adding LCD display and adding protection in the case.

Software Evaluation/Web Application and Alerts

Question	Mean	Interpretation
The web application is easy to navigate and user-friendly	4.53	Strongly Agree
The response time of the system (real-time updates, remote control) met my expectations	4.4	Strongly Agree
Receiving real-time alerts about idle or active appliances was useful	4.67	Strongly Agree
The scheduling feature for automated appliance management was helpful	4.8	Strongly Agree
Overall, the software improved my awareness and encouraged energy-saving practice	4.73	Strongly Agree

Table *1.9. Software evaluation results of outsmart*

Given the said data, the respondents were mostly satisfied with the user interface of the system with some recommendations like adding custom notification sound, cross compatibility of the system and improving the accuracy of the system.

Overall Evaluation

Question	Mean	Interpretation
OutSmart is compatible with the appliances I commonly use	4.67	Strongly Agree
OutSmart has potential to help households save energy and reduce bills	4.87	Strongly Agree
The combination of OutSmart’s hardware and software features provides a reliable and convenient solution for household appliance management.	4.67	Strongly Agree
I am satisfied with my overall experience in using OutSmart during the evaluation period.	4.67	Strongly Agree

Table 2.0. Overall evaluation results of outsmart

In general, the respondents were satisfied with the overall functionality of the system with some recommended features to include like adding widget feature to their phone/computer, an application counterpart of the website, additional socket, AI features and partnership with local electric providers for tailor made bill estimation of their households.

Stress Testing

Appliance	Specifications	Duration of Test	Socket Used	Result/Observation
Standard Electric Fan	~<100W (Typical), 220V, 60Hz	5 minutes	1	Passed — No issues observed; stable power.
Mitsushi Impact Drill (MIT-13B)	750W, 220V, 60Hz, 3.86A	3 minutes	1	Passed — Initial power insufficiency was resolved after relay replacement; drill operated normally.
Dowell Flat Iron (DI-741NS)	1000W, 220V, 60Hz, 4.35A	3 minutes	1	Passed — Functioned normally; no overheating or drops.
NOVA Electric Kettle (NK-180S)	1500W, 220V, 60Hz, 6.52A	3 minutes (until boiled)	1	Passed — Stable operation; no abnormalities.
Imarflex Induction Cooker (IDX-1650S)	1500W, 220V, 60Hz, 6.52A	3 minutes (until water boiled)	1	Passed — Normal performance; continuous heating without issues.
LG Washing Machine (T2108VSPM)	450W (Wash Motor), 220V, 50–60Hz, 2.05A	50 minutes	1	Passed — Entire wash cycle completed with stable monitoring.
	Rated Input: 5.4 KVA, 220V,			Failed — Fuse repeatedly blew due

Yamato Inverter IGBT Welder (VS-300A)	50/60Hz, IGBT, Current Range 20–300A, Duty Cycle 60%	2 minutes per test × 8 tests	1	to high surge current far beyond outlet capacity.
Condura 6S 1HP Window Type Air Conditioner	208-230 V (single phase), 802-909W	20 minutes	1	First Attempt: Failed — Instantaneous surge due to turning on at max thermostat value caused the socket to blow out. Second Attempt (6A, 8A, 10A): Passed — Operated normally for 20 minutes with no blowout. Thermostat Stress Test (Rapid Value Change): • Sudden decrease: Passed — No abnormal response. • Sudden increase: Minor — Instantaneous current spike reached 9.7A, nearly tripping the

				fuse but stabilized without failure.

Table 2.1. Socket 1 stress test

The stress testing on Socket 1 demonstrated that the OutSmart prototype is capable of handling a wide range of household appliances with varying power demands. Low to medium wattage devices—such as the fan, flat iron, kettle, induction cooker, and washing machine—operated without any functional issues, confirming stable energy monitoring, proper data transmission, and reliable relay operation under normal conditions.

However, two critical observations emerged from the high-load tests. The impact drill exhibited a brief loss of sufficient power, indicating that sudden surge loads or high inrush currents may exceed the relay or wiring's momentary capacity. More notably, the welder test resulted in a blown fuse, highlighting that the current draw of industrial-grade equipment substantially exceeds the safe operating limits of the OutSmart prototype.

Overall, the system performs reliably for typical household appliances but requires upgraded protection components (relay, wiring gauge, fuse rating) if future iterations aim to support heavy-duty or high-surge devices.

Appliance	**Specifications**	**Duration of Test**	**Socket Used**	**Result/Observation**
Standard Electric Fan	~<100W (Typical), 220V, 60Hz	5 minutes	2	Passed — Operated smoothly; no fluctuations observed.

Mitsushi Impact Drill (MIT-13B)	750W, 220V, 60Hz, 3.86A	1 minute	2	Passed — No overcurrent detected, has run smoothly in the span of 1 min without no overheating and no delay
Dowell Flat Iron (DI-741NS)	1000W, 220V, 60Hz, 4.35A	1 minute	2	Passed — no overcurrent exceeding 10A, even with instantaneous maximum capacity, no overheating on the components.
NOVA Electric Kettle (NK-180S)	1500W, 220V, 60Hz, 6.52A	2 minutes and 30 seconds	2	Passed — No overcurrent exceeding 10A, no overheating on the components up to the auto shutoff of the kettle upon reaching its maximum boiling point temperature.
Imarflex Induction Cooker (IDX-1650S)	1500W, 220V, 60Hz, 6.52A	2 minutes and 30 seconds	2	Passed — no overcurrent exceeding 10A (reading is 6.22A 1.47kW), no overheating within

				the span of 2 mins 30 secs.
LG Washing Machine (T2108VSPM)	450W (Wash Motor), 220V, 50–60Hz, 2.05A	50 minutes	2	Passed — Stable load; no irregular behavior.
Yamato Inverter IGBT Welder (VS-300A)	Rated Input: 5.4 KVA, 220V, 50/60Hz, IGBT, Current Range 20–300A, Duty Cycle 60%	2 minutes per test × 8 tests	2	Within 150A and below, there is no overcurrent present during the operation. Within 200A and above, the fuse tripped in a span of 5 seconds of simultaneous use
Condura 6S 1HP Window Type Air Conditioner	208-230 V (single phase), 802-909W	20 minutes	2	First Attempt (6A, 8A, 10A): Passed — Operated under thermostat-controlled load for 20 minutes with no failure, including a trial at maximum capacity. Extended Run with Max Thermostat Value: Passed — Maintained stable performance for 2 hours and 30 minutes with no issues.

Table 2.2. Socket 2 stress test

Stress testing was also conducted to evaluate the operational reliability and protective response mechanisms of the OutSmart device under simulated overload ("octopus") and short-circuit conditions.

During the octopus' simulation, Socket 1 was loaded with an electric drill and a blade cutter, while Socket 2 simultaneously powered an electric stove and an electric kettle (wattage/amperage of the devices are the same as the appliance used in per individual appliance testing per socket). The device successfully operated under this combined load for a duration of two minutes. Minor wire overheating was observed; however, the system continued to function as intended, indicating acceptable short-term load capacity but highlighting the need for improved conductor sizing to ensure long-term safety.

In the short-circuit simulation, a deliberate fault was introduced by tapping the live and neutral conductors together. The device's protective mechanism responded immediately, with the fuse tripping as designed. This confirmed the effectiveness of the overcurrent protection in preventing further electrical damage or hazard.

Overall, the stress-testing results demonstrate that the device is capable of sustaining elevated load conditions for short periods and that its protective components activate appropriately during fault scenarios. Improvements in wire gauge and thermal protection are recommended to further enhance system safety and performance.

Performance Testing

The OutSmart system was tested over one week under controlled conditions, with results compared against a normal outlet. For the testing, a Sony flat screen TV with input of 100-240V 1.5A AC and output of 19.5V 3.5A DC was used (760W), within 24 hours of being used idle in order to determine if the device can automatically turn off the outlet and comparatively; save energy. Additionally, the temperature was recorded using a thermal scanner to determine if the case and ESP32 microcontroller is not overheating. Several key parameters were evaluated: energy consumption, sensor accuracy, latency, and internal

Day/s of Observation	Watts Consumed (OutSmart)	Watts Consumed (Submeter, Normal Outlet)	Watts Recorded with Submeter (OutSmart)	Percentage Error of Watts for OutSmart (vs Submeter)	Device Latency	Web Latency	Percent Difference of OutSmart vs Normal
Day 1	0.0479kWh	0.04kWh	0.04kWh	16.49%	69ms	73ms	19.75%
Day 2	0.0478kWh	0.04kWh	0.04kWh	16.32%	75ms	71ms	19.50%
Day 3	0.0479kWh	0.04kWh	0.04kWh	16.49%	85ms	76ms	19.75%
Day 4	0.048kWh	0.04kWh	0.04kWh	16.67%	70ms	79ms	20%
Day 5	0.048kWh	0.04kWh	0.04kWh	16.67%	95ms	99ms	20%
Day 6	0.048kWh	0.04kWh	0.04kWh	16.67%	74ms	78ms	20%
Day 7	0.048kWh	0.04kWh	0.04kWh	16.67%	67ms	80ms	20%

temperature stability.

Table 2.3. Comparative performance of outsmart and normal outlet

Day/s of Observation	Initial Temp (Relay)	Initial Temp (ESP32)	Temp After 24 hours (Relay)	Temp After 24 hours (ESP32)	Temp Increase (Relay)	Temp Increase (ESP32)
Day 1	33.6°C	33.5°C	37.4°C	37.6°C	3.8°C	4.1°C
Day 2	33.5°C	33.4°C	37.6°C	37.4°C	4.1°C	4°C
Day 3	33.4°C	33.7°C	37.7°C	37.1°C	4.3°C	3.4°C
Day 4	33.8°C	33.4°C	37.9°C	37.5°C	4.1°C	4.1°C
Day 5	33.4°C	33.2°C	37.1°C	37.4°C	4.7°C	4.2°C
Day 6	33.2°C	33.1°C	36.7°C	36.5°C	3.5°C	3.4°C
Day 7	33.3°C	33.1°C	37.1°C	36.8°C	3.8°C	3.7°C

Table 2.4. Daily temperature observation of relay and ESP32 in outsmart

During the multiple days of idle-load testing, OutSmart recorded a range of 0.0478kWh to 0.048kWh consumption after 24 hours compared to the normal outlet's 0.04 kWh, showing a 20% addition but is not the absolute value due to the fact that the submeter the researchers used are rounded up to the nearest hundredths value so it may be slightly lower. Accuracy against the submeter showed a small percentage difference (with a mean of 16.53%) which can decrease even further because the submeter used are only capable of reaching hundredths value, with the said trend being consistent within the span of the testing period.

Latency measurements revealed stable device-to-cloud transmission mean time of 78.8ms for the ESP32, while web application latency has a mean time of 79.6ms, influenced by network speed and code optimization. Internal temperature readings remained steady throughout the tests, averaging almost 37–38 °C for both the ESP32 and relay case, indicating safe operation with no overheating issues.

Overall, results confirm that the OutSmart system can accurately monitor consumption while maintaining stability in temperature and reliability in data transmission. Some discrepancies in readings were observed, but these were largely due to external electrical fluctuations rather than hardware limitations as well as the fact that the submeter can only record wattage up to the nearest hundredths value so the accuracy can be lower or closer to the readings of the OutSmart system itself.

Discussion

Given these said results from the survey, stress test, performance testing and as how the system was implemented, there are certain gaps and/or features that complements with those mentioned by previous researches included in the literature/related study review of this research. Monton et al (2024) and Jing (2020) highlighted the importance of adding a voltage reading in their systems, which was incorporated in OutSmart outlet with the help of PZEM-004T Energy Monitoring Module whose functions can include voltage reading; which was incorporated as well by Simbulan et al (2023) and Jitket (2022) in their prototypes. Castrodes et al (2020) also incorporated SSR relay, which is observed on SSR-40 DA relay implemented in the system. The maximum capacity of 2.4kW and incorporating 10A fuse was also observed in the systems made by Arispe et al (2020) and Albraheem et al (2023), which is the same for OutSmart outlet. Another optimization suggested by Jing (2020) in their prototype is to minimize the heat present in the device during its runtime, which had an average of 38 to 43 degrees Celsius. In OutSmart, the temperature reading for the components ranges from 33.1 to 37.6 degrees Celsius, which proves that the outlet made by the researchers have a slightly optimized heat consumption. Homeres (2020) recommended testing in diverse appliances, which was done by the researchers, namely: Standard Electric Fan, Mitsushi Impact Drill (MIT-13B), Dowell Flat Iron (DI-741NS), NOVA Electric Kettle (NK-180S), Imarflex Induction Cooker (IDX-1650S), LG Washing Machine (T2108VSPM), Yamato Inverter IGBT Welder (VS-300A) and Condura 6S 1HP Window Type Air Conditioner as well as testing the capacity of the outlet in octopus connection and short circuit simulation, by which the outlet works as intended by the researchers.

CONCLUSION AND RECOMMENDATIONS

Conclusion

The testing and evaluation of the OutSmart system demonstrated its effectiveness as an energy monitoring and control device. OutSmart consistently recorded lower power consumption compared to a standard outlet, with an overall performance difference of approximately 20%. Although the device showed a minor additional kWh consumption of 0.0017–0.0018 kWh over a 24-hour period, this is negligible and does not significantly affect its efficiency. The system maintained stable operating temperatures (34–36 °C), ensuring hardware safety and durability. Device latency remained within acceptable limits, while web latency, though slightly higher, was attributed to external network factors beyond the system's control.User feedback from the survey, conducted at 30-minute intervals, indicated high satisfaction among household residents. Respondents expressed interest in additional functionalities due to OutSmart's proven capability to save electricity and increase awareness of energy consumption.

Furthermore, the engineer's evaluation highlighted areas for improvement to optimize performance and safety. Recommendations included implementing partial cable management, upsizing wires, replacing the casing with a metal casing with proper grounding, and ensuring overall compliance with electrical safety standards.

In connection to all these, OutSmart outlet tend to meet the objectives this research wants for the prototype to met – the system use PZEM-004T as sensor to detect the power consumption of the appliance plugged in the outlet connected to Firebase to transmit/receive data real-time, the mobile app that is made with Ubidots as back end and Blynk as front end, scheduling feature that can be set either on a particular date or time or a timer to when it will be powered off, real-time alerts reflecting from the mobile app and the system being compatible to Android and iOS as well as being compatible on the test appliances being used by the researchers.

In summary, OutSmart reliably monitors electricity usage, provides real-time feedback via its web application, and operates safely under continuous use. Minor variations in accuracy were primarily due to external electrical fluctuations and network conditions, rather than inherent device limitations. With the recommended adjustments, OutSmart's performance and safety can be further enhanced, confirming its potential as a practical and innovative solution for energy management.

Recommendations

To enhance the performance and applicability of the OutSmart system, several recommendations are proposed for future development. Extended testing using multiple appliances with varying power ratings is suggested to better simulate real household scenarios. Conducting experiments in environments with stable power supply will help minimize the impact of sudden voltage fluctuations that may cause discrepancies in readings.

Hardware improvements, such as adding a snubber circuit to the CT coil, can absorb voltage spikes from the relay and protect the system's components from electrical stress. Using a submeter capable of measuring kilowatt-hour consumption up to the ten-thousandths digit will allow for more precise comparisons and validation of system accuracy.

Optimizing firmware and backend processes is recommended to reduce transmission delays and improve real-time responsiveness. Scalability testing, particularly when managing multiple OutSmart units simultaneously, will help validate the system's suitability for larger households or small business applications.

Finally, incorporating user-centered features—such as predictive analytics, energy cost estimation, and mobile application support—can increase practicality, usability, and value for everyday users, further strengthening OutSmart as an innovative solution for energy monitoring and management.

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APPENDICES

APPENDIX A. CALENDAR OF ACTIVITIES

Gantt Chart of Activities (Capstone Design 1 & Capstone Design 2)

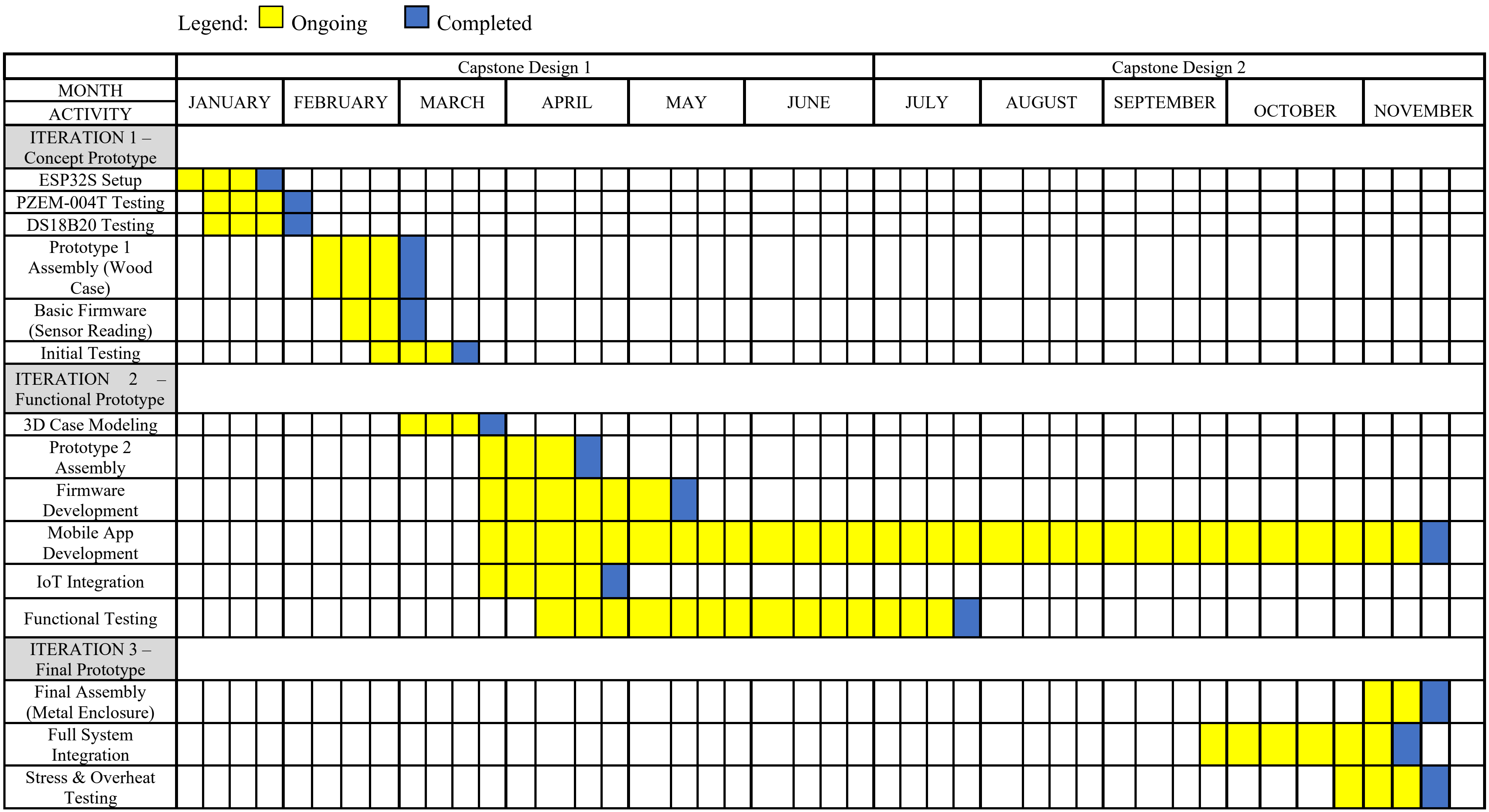

Table 2.5. Gantt chart of activities during capstone design 1 and 2

APPENDIX B. ACTUAL THESIS EXPENSES

THESIS EXPENSES

Quantity	Specifics	Actual Cost
1	TMOV 14D471 (Metal Oxide Varistor)	₱9.10
1	Metal Enclosure	₱400.00
2	PZEM-004T (Energy Monitoring Module)	₱1,100.00
1	NodeMCU ESP32S Microcontroller	₱350.00
2	Solid State Relay (SSR 40DA)	₱420.00
1	AC-DC Power Supply (ACE-6839)	₱100.00
1	Glass Fuse (10A)	₱5.00
1	Electrical Wire (#12 Solid Wire THW)	₱30.00
1	Omni Surface Outlet	₱75.00
1	Electrical Wire (#14/7 Electrical Wire THHN)	₱25.00
2	Female Pin Header (48 pins)	₱35.00
1	Double Sided Foam Type	₱30.00
1	Heat Shrink Tubing (Insulation) Set	₱137.00
1	DS18B20 Temperature Sensor	₱101.00
Total Cost		₱2,817.10

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APPENDIX C. USER'S MANUAL

User Guide

This guide is designed to help you monitor, manage, and optimize your electricity consumption through OutSmart outlets. This guide will walk you through how to navigate and use the key features of the OutSmart platform.

1. Getting Started

1.1. Creating an Account

1. Visit the OutSmart website.
2. Click on the “Register” or “Create account” button.
3. Fill out the required fields: username, email address, and password.
4. Click “Create account”.

1.2. Logging In

1. After account creation, enter your registered email and password on the sign-in page.
2. Click “Sign in”.

1.3. Adding an Outlet

Before you can monitor a device, you must add your OutSmart outlet to your account.

1. Click the plus (+) button located at the bottom-right corner of the screen.
2. This will open the QR Code Scanner. You may need to grant camera permissions to your browser.
3. Point your device's camera at the QR code provided with your OutSmart outlet.
4. Once scanned, the outlet will be automatically added to your account and will appear on your Dashboard.

2. The Dashboard

The Dashboard is your main hub for a real-time overview and control of all your connected outlets.

2.1. Outlet Table

This panel provides a live summary of each outlet's performance.

- Outlets: The name of your outlet and its current status (e.g., "Running" or "Stopped").
- Watts: The current power consumption in Watts (W).
- Current: The electrical current being drawn in Amperes (A).
- Voltage: The real-time voltage reading in Volts (V).
- Time Left: If a timer is set, this shows the remaining time until the outlet's state changes.

2.2. Control Panel

This panel allows you to interact with and manage your outlets.

- Status Toggle: A simple switch to manually turn each outlet ON or OFF.
- Set Timer: Click this to open a modal where you can set a timer. The outlet will automatically turn ON or OFF at the specified time.
- Turn on all / Turn off all: These buttons allow you to control all connected outlets at once.

3. Outlet Management

For more detailed information and management options, navigate to the Outlets tab from the sidebar.

This page displays a comprehensive table with additional data points like Power Factor, Read Latency, and Send Latency.

- Rename: Click the pencil icon in the "Rename" column to give your outlet a custom, easy-to-remember name.
- Status: You can also view and toggle the On/Off status of each outlet from this screen.

4. Bill Estimator

The Bill Estimator page helps you track your consumption and estimate your electricity costs.

4.1. Consumption Overview

The main table provides a breakdown of each outlet's consumption:

- kWh Consumed (Est.): Estimated energy consumed in the current billing cycle.
- Total kWh Consumed (Est.): The total lifetime energy consumed by the outlet.
- Highest/Lowest Watts: The peak and minimum power draw recorded.
- Rate: Your configured cost per kWh.
- Total Cost: The estimated cost for the current billing cycle.

4.2. Managing Your Billing

- Set kWh Rate: Enter your local electricity rate per kWh and click "Set" to ensure accurate cost estimations.
- Clear Bill Estimator: Ends the current billing cycle. The consumption from this cycle is added to the total, and the current cycle is reset to zero.
- Clear Highest/Lowest Watts: Resets the peak and minimum watt records for all outlets.
- Clear Balance: (Warning) This will permanently reset all accumulated cost and kWh history for all outlets to zero.

5. Notifications

5.1. Notification History

Navigate to the Notification tab to view a historical log of all important events, such as when an outlet was turned on/off, became idle, or was shut down due to inactivity.

6. Settings

6.1 Outlet Configuration

Navigate to the Settings tab to configure advanced features for each outlet.

- Schedule: Set up recurring schedules to automatically turn outlets on or off on specific days and at specific times.
- Idle Settings: Configure automatic power-off for devices that are left on but are idle (drawing very little power), helping you save energy.

6.2 Push Notification

Enables notification of the device that you are using.

7. Account Management

Navigate to the Account tab to manage your profile and security settings.

7.1. Updating Your Profile

- You can view your registered email address.
- You can update your display Username and click "Save Username".

7.2. Changing Your Password

1. Enter your current password.
2. Enter your new password and confirm it.
3. Click “Change Password”.

8. Help & Support

The Help section in the sidebar contains guides and frequently asked questions to assist you with common issues and features.

9. Logging Out

To securely log out of your account:

- Click on the Log Out button at the bottom of the left sidebar.

APPENDIX D. RESOURCE PERSON

Mr. Mark Alvin Malenab

Capstone Project Adviser

Mr. Mark Alvin is the academic adviser of the OutSmart Project. As a faculty member of STI College Novaliches, Mr. Mark Alvin provided valuable guidance in shaping the system's framework, particularly in the validation of its energy monitoring functions and research methodology. His academic expertise and constructive feedback ensured that the project met scholarly standards while remaining practical and innovative. By serving as the resource person, Mr. Mark Alvin helped the research team refine OutSmart into a reliable solution for monitoring and managing household energy consumption.

Mr. Frank Marc DM. Salipot

Electrical Engineer Consultant

As a licensed electrical engineer and a practitioner of electrical engineering in the field as a quality inspector engineer, Mr. Frank gave an insightful opinions and suggestions on the things that are needed to be improved in the prototype especially with the implementation of the system in its wirings and as well as to how grounding can be achieved without too much need of modification in the system. With his guidance despite limited time frame, the researchers had a clearer view of how should OutSmart outlet comply with ISO and PEC standards that are to be observed in case the outlet will be deployed on the industry.

APPENDIX E. RELEVANT SOURCE CODES

```
#if defined(ESP32) || defined(ARDUINO_RASPBERRY_PI_PICO_W)
#include <WiFi.h>
#elif defined(ESP8266)
#include <ESP8266WiFi.h>
#elif __has_include(<WiFiNINA.h>)
#include <WiFiNINA.h>
#elif __has_include(<WiFi101.h>)
#include <WiFi101.h>
#elif __has_include(<WiFiS3.h>)
#include <WiFiS3.h>
#endif
#include <Firebase_ESP_Client.h>
#include <PZEM004Tv30.h>
#include <SoftwareSerial.h>

#if !defined(PZEM_RX_PIN) && !defined(PZEM_TX_PIN)
#define PZEM_RX_PIN 13 //13 dati
#define PZEM_TX_PIN 12 //12 dati
#endif



SoftwareSerial pzemSWSerial(PZEM_RX_PIN, PZEM_TX_PIN);
PZEM004Tv30 pzem(pzemSWSerial);

/* 1. Define the WiFi credentials */
#define WIFI_SSID "(^_^)_Guest"
#define WIFI_PASSWORD "1234asdf"
```

```
/* 2. Define the API Key */
#define API_KEY "AIzaSyDtG6AiTwmJSRI3utIEexF3dmXwH1RqOPw"

/* 3. Define the user Email and password */
#define USER_EMAIL "xdzak68@gmail.com"
#define USER_PASSWORD "asdf1234"

/* 4. Define the RTDB URL */
#define DATABASE_URL "https://outsmart-f1174-default-rtdb.asia-southeast1.firebasedatabase.app/"

/* 5. Define the Target Path in your Database */
#define FIREBASE_PATH "/Outlets/outlet1"

#define RELAY_PIN 4

String relayState = "HIGH"; // Default state

unsigned long lastSendLatency = 0; // <-- ADD THIS LINE
unsigned long lastReadLatency = 0; // <-- ADD THIS LINE

// Define Firebase Data object
FirebaseData fbdo;
FirebaseAuth auth;
FirebaseConfig config;

unsigned long sendDataPrevMillis = 0;

void setup()
```

```
{
  pinMode(RELAY_PIN, OUTPUT);
  digitalWrite(RELAY_PIN, HIGH); // Set default relay state on boot
pinMode(LED_BUILTIN, OUTPUT);

  Serial.begin(9600);
  WiFi.begin(WIFI_SSID, WIFI_PASSWORD);

  Serial.print("Connecting to Wi-Fi");
  while (WiFi.status() != WL_CONNECTED)
  {
    Serial.print(".");
    delay(300);
  }
  Serial.println();
  Serial.print("Connected with IP: ");
  Serial.println(WiFi.localIP());
  Serial.println();
  digitalWrite(LED_BUILTIN, HIGH);
  /* Assign the api key (required) */
  config.api_key = API_KEY;

  /* Assign the user sign in credentials */
  auth.user.email = USER_EMAIL;
  auth.user.password = USER_PASSWORD;

  /* Assign the RTDB URL (required) */
  config.database_url = DATABASE_URL;
```

```
  Firebase.reconnectNetwork(true);

  fbdo.setBSSLBufferSize(4096, 1024);
  fbdo.setResponseSize(2048);

  Firebase.begin(&config, &auth);
  Firebase.setDoubleDigits(5);
  config.timeout.serverResponse = 10 * 1000;
}

void loop()
{
   // Check if Firebase is ready and if it's time to send data (every 1 second)
   if (Firebase.ready() && (millis() - sendDataPrevMillis > 1000 || sendDataPrevMillis ==
0))
   {
      sendDataPrevMillis = millis();

      float voltage = pzem.voltage();
      float current = pzem.current();
      float power = pzem.power();
      float energy = pzem.energy();
      float frequency = pzem.frequency();
      float pf = pzem.pf();

      if (isnan(voltage) || isnan(current) || isnan(power) || isnan(energy) || isnan(frequency)
|| isnan(pf))
      {
```

```
    Serial.println("Error reading from PZEM sensor. Skipping Firebase update.");
  }
  else
  {
    // --- BUNDLE ALL DATA INTO A SINGLE JSON OBJECT ---
    FirebaseJson json;
    json.set("voltage", voltage);
    json.set("current", current);
    json.set("watts", power);
    json.set("energy", energy);
    json.set("frequency", frequency);
    json.set("powerfactor", pf);
    // Add the server-side timestamp
    json.set("lastUpdatedTimestamp/.sv", "timestamp");
    // Include the latency values from the PREVIOUS cycle
    json.set("sendLatencyMs", lastSendLatency);
    json.set("readLatencyMs", lastReadLatency);

    // --- SEND THE ENTIRE JSON OBJECT AND MEASURE LATENCY FOR
NEXT TIME ---
    Serial.println("Sending bundled JSON data to Firebase...");
    unsigned long sendStartTime = millis();
    bool sendSuccess = Firebase.RTDB.updateNode(&fbdo, FIREBASE_PATH,
&json);
    lastSendLatency = millis() - sendStartTime; // Store latency for the next loop

    if (sendSuccess)
    {
      Serial.print("JSON data sent successfully. Latency for this send: ");
```

```
    Serial.println(lastSendLatency); // <-- FIXED: Print the variable directly
  }
  else
  {
    Serial.println("Failed to send JSON data: " + fbdo.errorReason());
  }

  // --- READ THE RELAY STATUS AND MEASURE LATENCY FOR NEXT
TIME ---
  unsigned long readStartTime = millis();
  bool readSuccess = Firebase.RTDB.getString(&fbdo, String(FIREBASE_PATH)
+ "/status");
  lastReadLatency = millis() - readStartTime; // Store latency for the next loop

  if (readSuccess)
  {
    relayState = fbdo.to<const char *>();
    if(relayState.equalsIgnoreCase("HIGH")) {
      digitalWrite(RELAY_PIN, HIGH);
    } else {
      digitalWrite(RELAY_PIN, LOW);
    }
    Serial.print("Relay status read successfully. Latency for this read: ");
    Serial.println(lastReadLatency); // <-- FIXED: Print the variable directly
  }
  else
  {
    Serial.println("Failed to get relay status: " + fbdo.errorReason());
  }
```

```
        }
    }
    delay(500);
}
```

APPENDIX F. CURRICULUM VITAE OF RESEARCHERS

DANIEL ROSS B. CAMARA

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EDUCATIONAL BACKGROUND

Tertiary, Bachelor of Science in Computer Engineering — September 2022 - Present
STI College Novaliches

Senior High School — June 2020 – June 2022
STI College Novaliches

High School
Springfield School of Novaliches — June 2018 – June 2022
San Bartolome High School — June 2016 – June 2018

Elementary
Placido del Mundo Elementary School — June 2015 – March 2016

PROFESSIONAL OR VOLUNTEER EXPERIENCE

Inclusive Dates	Nature of Experience/ Job Title	Name and Address of Company or Organization
2017	Volunteer	Camara Taxation and Management Services

AFFILIATIONS

Inclusive Dates	Name of Organization	Position
2023	Association of Computer Engineering Students (ACES)	4th Year Representative

SKILLS

- Software Installation
- Programming Languages (Java, C#, Javascript, Python)

TRAININGS, SEMINARS OR WORKSHOP ATTENDED

- AMA with Launchgarage Founders — 2025
- Pitch Deck 101 with Plug and Play Center — 2025
- Blockchain is not just Crypto — 2025
- The Future of Development: Will Vibe Coding Replace — 2025

CHEMICAL V. VALDEHUEZA

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(+63)995-2623-647

EDUCATIONAL BACKGROUND

Tertiary, Bachelor of Science in Computer Engineering September 2022 - Present
STI College Novaliches

TechVoc
Electron College of the Philippines November 2019 – December 2019

Senior High School June 2020 – June 2022
STI College Novaliches

High School
Sauyo High School June 2016 – March 2022

Elementary
Sauyo Elementary School June 2009 – March 2016

PROFESSIONAL OR VOLUNTEER EXPERIENCE

Inclusive Dates	Nature of Experience/ Job Title	Name and Address of Company or Organization
2015	Part Time Mixologist	Con Vista

AFFILIATIONS

Inclusive Dates	Name of Organization	Position
2024 – Present	PowerHaven Tech.	Hardware Specialist
2023 – Present	Association of Computer Engineering Students (ACES)	Member

SKILLS

- Shielded Metal Arc Welding (SMAW)
- Computer Operations
- Computer Troubleshooting

TRAININGS, SEMINARS OR WORKSHOP ATTENDED

10 Hours BOSH Course for SO1 with 2 hours Training of Trainer June 202

MICHAEL JAMES L. VELASCO

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EDUCATIONAL BACKGROUND

Tertiary, Bachelor of Science in Computer Engineering 2022 – Present
STI College Novaliches

High School
School of Our Lady of La Salette 2016 – 2022

Elementary
FSS Patulo Elementary School 2010 – 2016

PROFESSIONAL OR VOLUNTEER EXPERIENCE

Inclusive Dates	Nature of Experience/ Job Title	Name and Address of Company or Organization
N/A	N/A	N/A

AFFILIATIONS

Inclusive Dates	Name of Organization	Position
2025 – Present	MFC Singles	Member
2024 – Present	PowerHaven Tech	Quality Assurance
2024 – 2025	Association of Computer Engineering Students (ACES)	Auditor

SKILLS

- 3d Modelling (Onshape)
- Basic Computer Troubleshooting
- Basic Programming (Java, Python, JavaScript)
- Basic Proofreading

TRAININGS, SEMINARS OR WORKSHOP ATTENDED

- Cisco Networking Academy: JavaScript Essentials 101 — September 2025
- 10 Hours BOSH Course for SO1 with 2 hours Training of Trainer — July 2025
- Next-Gen NLP on a Budget: The Art of Small Language Modeling — July 2025
- Networking Career Path: Cisco Technologies — June 2025

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(+63) 969-0680-151

EDUCATIONAL BACKGROUND

Tertiary, Bachelor of Science in Computer Engineering September 2022 - Present
STI College Novaliches

Senior High School June 2020 – June 2022
STI College Novaliches

High School
Doña Rosario High School June 2016 – March 2020

Elementary
San Agustin Elementary School June 2009 – March 2016

PROFESSIONAL OR VOLUNTEER EXPERIENCE

Inclusive Dates	Nature of Experience/ Job Title	Name and Address of Company or Organization
N/A	N/A	N/A

AFFILIATIONS

Inclusive Dates	Name of Organization	Position
September 2025 – Present	Association of Computer Engineering Students (ACES)	President

SKILLS

- Project Management
- Documentation
- Project Management Tools – Trello, Asana & Monday.com
- Microsoft Word

TRAININGS, SEMINARS OR WORKSHOP ATTENDED

- Next-Gen Tech Talks: IoT Applications and Data-Driven Governance August 2025
- Next-Gen Computer Engineers: ICT Development Plan ` July 2025
- 10 Hours BOSH Course for SO1 with 2 hours Training of Trainer June 2025