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Monitoring System with Certified and Non-Certified Device Comparison

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Abstract

Despite the widespread adoption of Internet of Things (IoT) applications across various sectors such as transportation, healthcare, agriculture, and power systems, and the increasing use of electricity meters in EU and East Asian countries, a significant gap remains in consumer understanding of individual appliance energy consumption. This gap often results in inefficient energy use and higher energy costs. Energy efficiency labels, such as those used in Malaysia, provide a general idea of appliance efficiency but fail to deliver real-time data on actual energy consumption, which varies with usage patterns. This research addresses the critical need for a solution capable of measuring the real-time energy consumption of individual appliances and offering actionable insights to help consumers manage their energy use more effectively. The objectives of this project are to create a power usage model for electrical appliances in a typical room, contrasting appliances with a star rating from Suruhanjaya Tenaga against non-rated appliances, and to analyse the performance differences between models equipped with power-saving devices and those without. The scope includes creating models with certified and non-certified electrical devices and using power meters to measure and record their power usage. This project is significant as it enhances understanding of energy consumption, identifies more efficient appliances, and underscores the importance of energy certification. By promoting the use of energy-efficient devices, this project contributes to reducing overall energy consumption and greenhouse gas emissions, aligning with global efforts to combat climate change and promote sustainable living practices.

1. Introduction

The Internet of Things (IoT) is widely used in various sectors to simplify tasks and offer valuable applications. In the electric power sector, traditional electromechanical meters require manual readings, leading to inefficiencies [6]. Countries like Sweden, Denmark, and Finland use smart electricity meters that track energy consumption, inform users about costs, and help avoid high bills [7]. These meters also reduce the need for manual readings and can control household appliances via IoT, potentially lowering power consumption [8]. In Malaysia, an energy efficiency label rates appliances from 1 to 5 stars, encouraging the purchase of efficient appliances [9]. This research focuses on using smart power meters to provide precise consumption data, helping to evaluate the performance of appliances against energy-saving claims, promoting sustainability, and aiding consumers in making informed decisions.

1.1 Problem Statements and objective

Despite the widespread adoption of Internet of Things (IoT) applications across various sectors such as transportation, healthcare, agriculture, and power systems, and the increasing use of electricity meters in EU and East Asian countries, there remains a significant gap in consumer understanding of individual appliance energy consumption, often resulting in inefficient energy use and higher energy costs. While energy efficiency labels, like those used in Malaysia, provide a general idea of appliance efficiency, they fail to deliver real-time data on actual energy consumption, which varies with usage patterns. This research addresses the critical need for a solution capable of measuring the real-time energy consumption of individual appliances and offering actionable insights to help consumers manage their energy use more effectively. The project aims to develop a power usage model for electrical appliances in a typical room, contrasting appliances with a star rating from Suruhanjaya Tenaga against non-rated appliances, and to analyses the performance differences between models equipped with power-saving devices and those without. The scope includes creating models with certified and non-certified electrical devices and using power meters to measure and record their power usage. The project is significant as it enhances understanding of energy consumption, identifies more efficient appliances, and underscores the importance of energy certification. By promoting the use of energy-efficient devices, this project contributes to reducing overall energy consumption and greenhouse gas emissions, aligning with global efforts to combat climate change and promote sustainable living practices.

2. LITERATURE REVIEW

This chapter includes a comprehensive citation and discussion of previous research, an introduction to Suruhanjaya Tenaga, the Importance of Energy Efficiency Labels, Smart Power Meters, and IoT Integration, and a Comparative Analysis of Certified and Non-Certified Appliances.

2.1 Energy efficiency labels

Efficiency labels, introduced in the European Union (EU) in 1994, rate appliances from A (most efficient) to G (least efficient), helping consumers select energy-saving products [15]. Australia's energy labelling began in 1986 with a standardized star energy label, recognized by over 90% of buyers, leading to significant improvements in appliance energy efficiency [16]. These labels vary across countries; the EU uses a range from A+++ to D, considering annual electricity consumption and standby modes, while Australia uses a star rating system. China, Korea, India, and Malaysia have their own versions as well [17]. The primary objective of these labels is to help consumers consider operational energy costs, reducing overall life cycle costs [18]. They provide crucial information on energy consumption, showing annual kilowatt consumption, which can vary based on the appliance's capacity. Choosing appliances with lower energy consumption can significantly reduce electricity bills [19].

2.2 Development of Implementation Energy Label in Malaysia

Malaysia's Energy Commission (EC) awards energy labels to manufacturers who meet performance testing, regulations, and restrictions, fully implementing this system in 2013. The label rates appliances from 1-star (least efficient) to 5-stars (most efficient) and is required for seven household appliances, including refrigerators, televisions, and air conditioners, with plans to include more in the future [13] [20]. According to the Electricity Regulation 1994 (Amendments 2013), equipment meeting efficiency requirements must bear an efficiency rating label, enforcing the Minimum Energy Performance Standard (MEPS) for certain domestic electrical equipment [20].

Figure 2.1 *Comparative label*

The energy label system provides information on the appliance's energy rating, consumption, savings compared to lower-rated products, and testing standards. A Certificate of Approval (COA) from the EC is required, and manufacturers and importers must adhere to specific font and colour specifications for products rated between 2-star and 5-star.

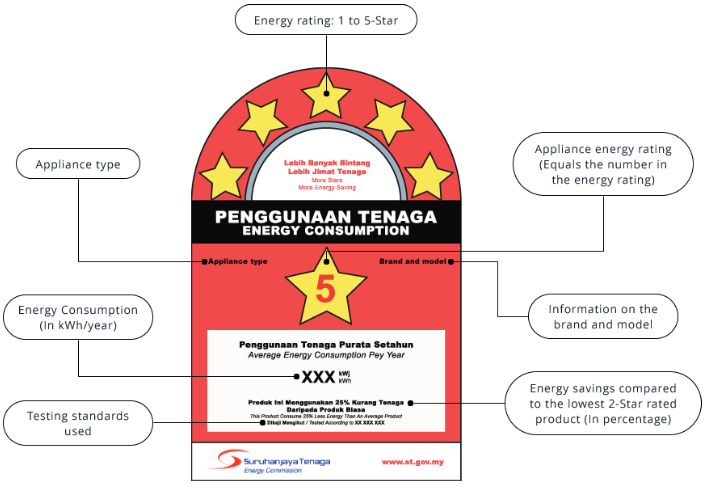


Figure 2.2: *Previous version of energy label in Malaysia*

Figure 2.2 showcases the former star rating energy label in Malaysia, which signifies that a product with a higher star rating is more energy-efficient over a year. This label is particularly useful for those who prefer to compare products side-by-side, as it emphasizes the energy consumption of a product based on the star rating system.

In 2020, the Energy Commission enhanced the energy label by incorporating additional information such as the Certificate of Approval (COA) number, the year of rating revision, and a QR code. This additional information aids consumers in obtaining accurate information, thereby facilitating informed purchasing decisions. The updated label is depicted in Figure 2.3.

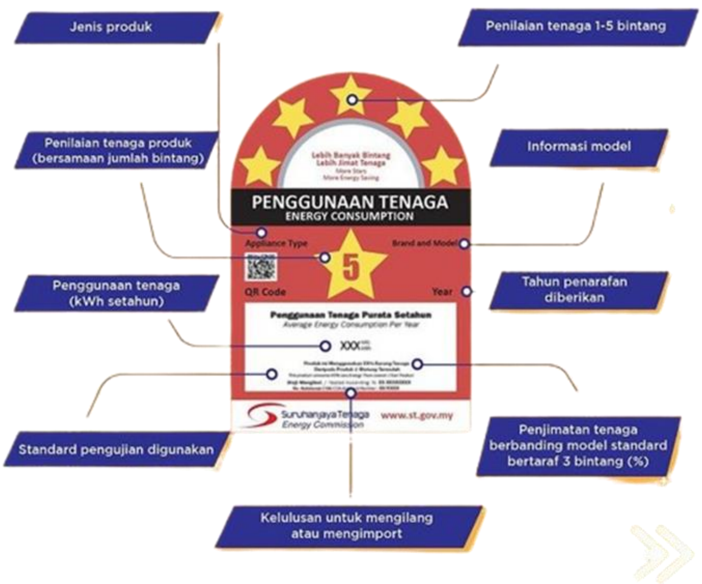


Figure 2.3: *New version of energy label in Malaysia*

3. METHODOLOGY

This chapter presents a methodology for developing a monitoring system that compares certified and non-certified devices. It addresses challenges related to inefficient energy usage and lack of real-time consumption data. Utilizing IoT technology and power meters, the system installs switches and a distribution box to manage power distribution and collect data on voltage, current, power consumption, and energy usage. Data is transmitted securely via Wi-Fi to the Life app for real-time analysis. The app serves as an interface for comparing energy consumption between certified and non-certified devices, aiming to empower consumers with insights for effective energy management and informed appliance choices.

3.1 Material and Methods

Hardware development and application development are the two categories of materials required to develop the project's prototype.

The following components are required for hardware development:

1. Main Switch
2. ii. Residual Current Circuit Breaker (RCCB)
3. iii. Miniature Circuit Breaker (MCB)
4. SMATRUL Wi-Fi Smart Switches for precise energy monitoring.

However, the tools required for the creation of the application are:

1. Smart Life Application for the reading display that is accessible from a smartphone.

3.2 Methods

The methods in developing the prototype of the Monitoring System with Certified and Non-Certified Device Comparison include a block diagram of the system, a flowchart of the system, and a circuit design of the hardware. Figure 1 shows the block diagram of the system.

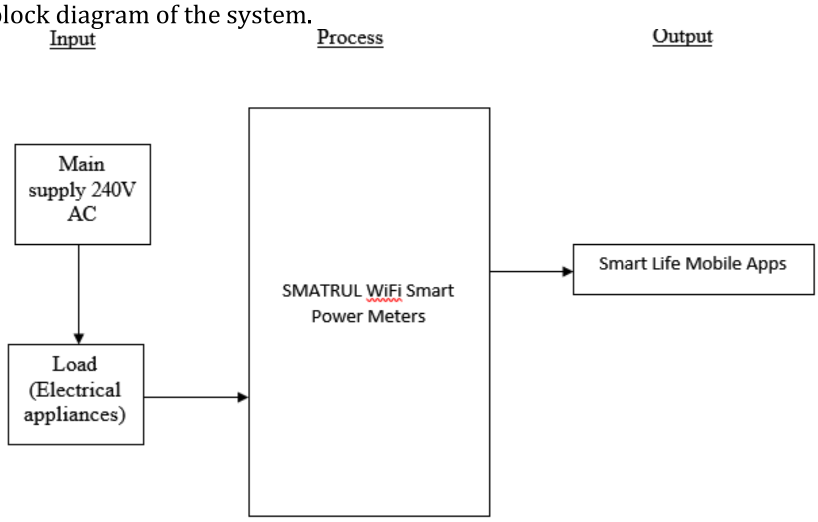


Figure Error! No text of specified style in document.**.1** *the block diagram of the system*

At the input, the main power connection is sourced from the distribution box (DB), which includes all necessary safety measures. This 240V AC supply from the DB powers the entire setup. The power is split into two sections, each connected to a separate SMATRUL Wi-Fi Smart Power Meter. These sections are distinguished by the type of devices they monitor: one section for certified appliances and the other for non-certified appliances. The certified section includes non-certified devices such as LED lamps (2 fluorescent type and 2 bulb type). The non-certified section comprises non certified devices like a TLD fluorescent lamp and a non-LED bulb. Each SMATRUL smart power meter is connected to wall plugs that supply power to their respective devices. The live and neutral wires from the switch sockets are connected to the SMATRUL Wi-Fi Smart Power Meters to measure voltage, current, power consumption, energy usage, frequency, and power factor. The data collected from the meters is then transmitted via Wi-Fi to the Smart Life app, facilitated by the smart meters' built-in Wi-Fi modules. During the process, data from the smart meters, including energy, power, voltage, current, frequency, and power factor, is continuously sent to the Smart Life app. This allows real-time monitoring and analysis of the power usage of both certified and non-certified devices. The Smart Life app serves as the interface for displaying the collected data, enabling detailed comparisons and analyses to be conducted. This setup and data transmission process ensures secure and reliable communication between the smart meters and the app, providing users with actionable insights to manage their energy usage effectively.

3.3 Project Operational Flowchart

The project begins by setting objectives to develop an Energy Monitoring System for effective energy usage monitoring and comparison of certified versus non-certified devices. Components like SMATRUL Wi-Fi Switches are procured, supplemented by UTHM lab components if required. Installation involves placing switches between the distribution box and devices, configuring for efficient power distribution, and ensuring stable Wi-Fi connectivity. The switches are then initialized to monitor voltage, current, power consumption, and energy usage accurately, calibrated for precise data collection. Data is securely transmitted to the Life app for real-time monitoring and analysis, with continuous collection for insights into consumption patterns. The app compares energy usage between certified and non-certified devices, evaluating data accuracy, transmission consistency, and app usability, addressing challenges as they arise. The project concludes with findings on energy label effectiveness, recommendations for enhancements, and strategies for improved energy management..

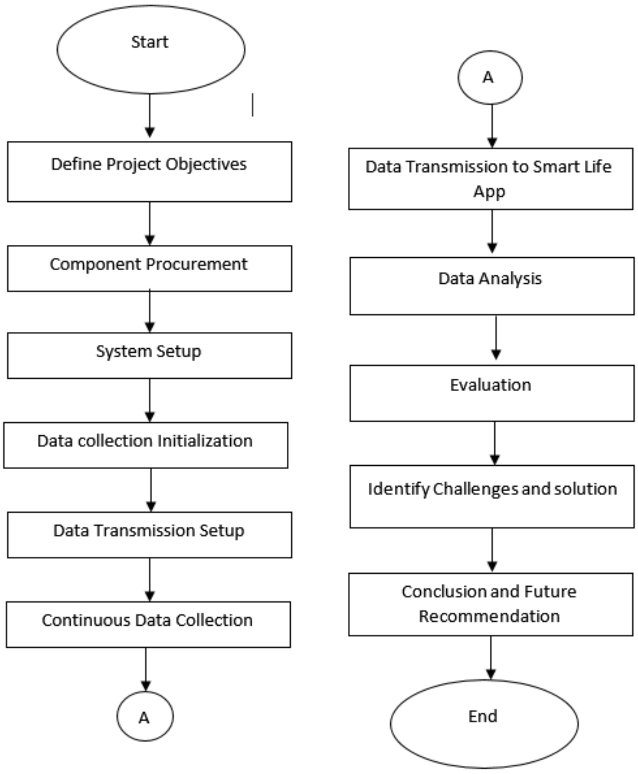


Figure Error! No text of specified style in document.**.2** *Project Operational Flowchart*

3.4 Project Flowchart

The model consists of two sections, each representing a different scenario of energy usage. In the first section, devices equipped with power-saving technology certified by Suruhanjaya Tenaga are employed, while the second section comprises devices without such certification. The main power source is connected to a distribution box (DB), which then splits the power and distributes it to SMATRUL Wi-Fi Smart Power Meters, with each section having its dedicated meter. From the SMATRUL meters, wall plugs are connected to power the respective devices.

In the power-saving section, energy-efficient LED lamps are used, with two pendarflour-type LED lamps and two bulb-type LED lamps. Conversely, the non-power-saving section employs less efficient lighting options, such as one TLD pendarflour lamp and one non-LED bulb. Additionally, there is a free slot on the wall plug, allowing for the connection of an additional electrical appliance to simulate the energy usage of a typical room. Both have initial 43-45 total watts power usage.

Data on power usage from both sections is transmitted to a smartphone application, Smart Life, enabling real-time monitoring and analysis. This setup allows for the comparison of energy consumption patterns between certified and non-certified devices, providing valuable insights into the effectiveness of energy-saving technologies and the impact of energy efficiency labels on consumer choices.

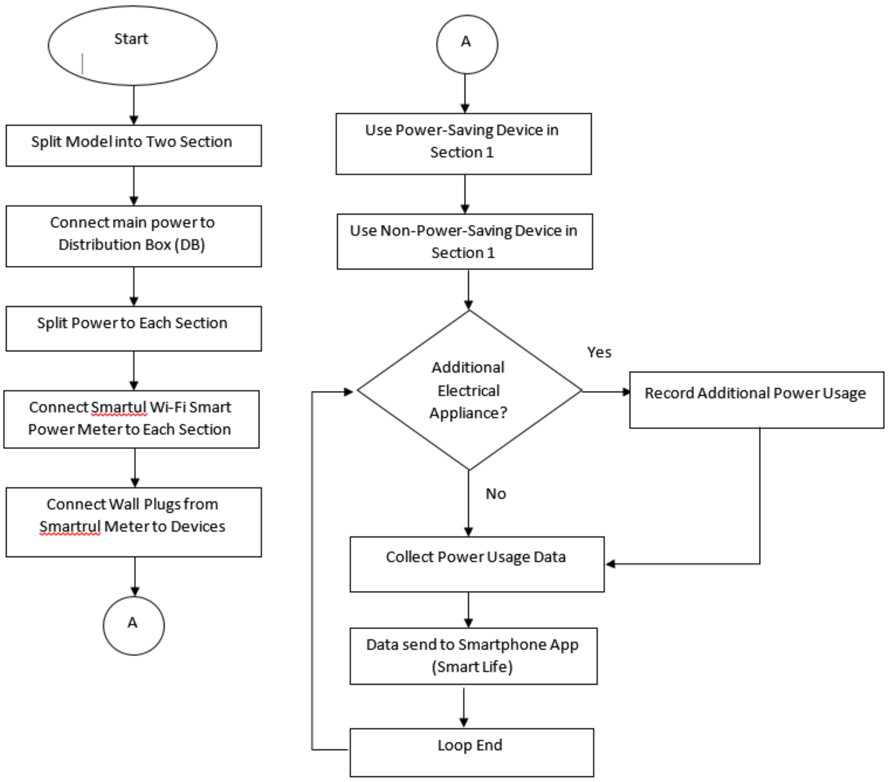


Figure Error! No text of specified style in document..**3:** *Flowchart of the Project*

3.5 Schematic Circuit

Figure 3.3 shows the project is divided into two sections, each representing a different scenario of energy usage. The main power source is connected to a distribution box (DB), which splits the power and distributes it to each section of the model. Each section has its dedicated SMATRUL Wi-Fi Smart Power Meter connected to the DB. These meters measure the power consumption of the devices in their respective sections. From the SMATRUL meters, wall plugs are connected to power the respective devices. Energy-efficient LED lamps are used in the certified device section, with two fluorescent-type LED lamps and two bulb-type LED lamps. Conversely, the non-certified device section employs less efficient lighting options, such as one TLD fluorescent lamp and one non-LED bulb. Additionally, there is a free slot on the wall plug in each section, allowing for the connection of an additional electrical appliance to simulate the energy usage of a typical room. Both sections have an initial total power usage of 43-45 watts.

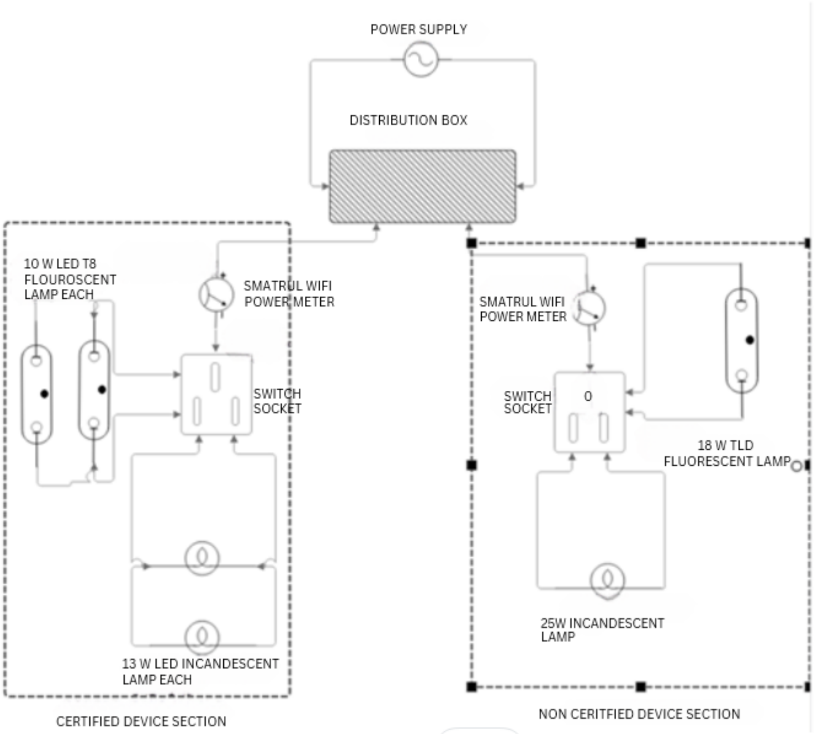
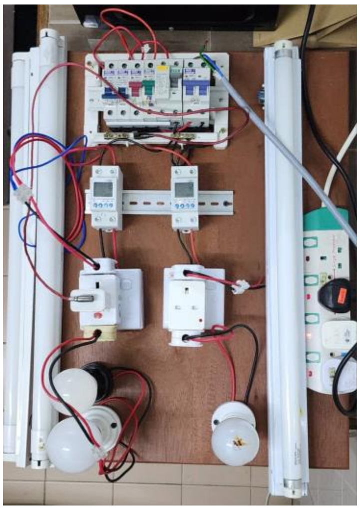


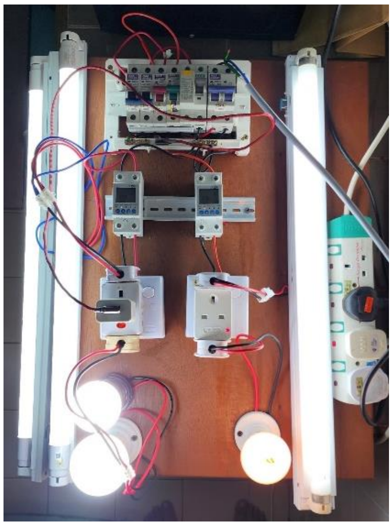
Figure 3.3: *Schematic Circuit of model*

3.6 Prototype of Complete Model Development

Figure 3.4 shows the complete model where all the components are placed on the wiring board. Placing it on the wiring board will make observing the model more organized and easier. The power supply from the wall is connected to the distribution box to supply power for the whole model. It will supply consistent power to both sections. The distribution box also protects the model from any voltage spike. Both have around 42 to 45 total watts. Figure 3.4 (a) and (b) shows the model before and after it turns on, and it can start to measure and record the power usage of the model.



(a) Off

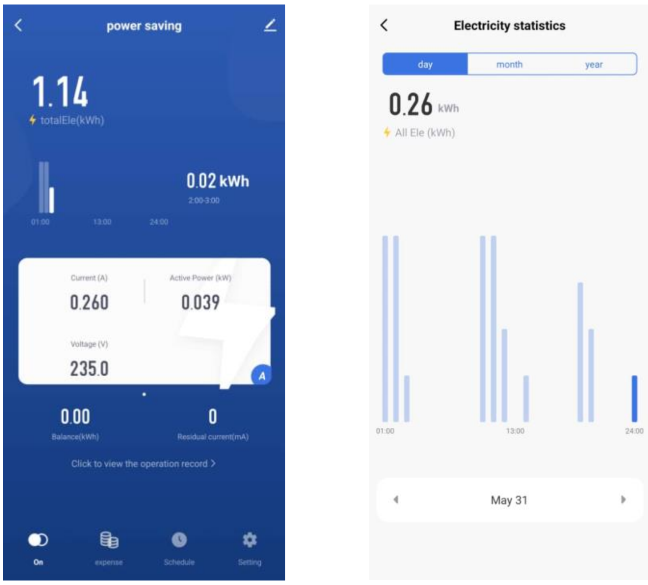


(b) On

Figure 3.4: *Complete Model*

3.7 Monitoring System Smart Life Mobile Application

The Smart Life application is an innovative, comprehensive platform designed to enhance the management and automation of smart home devices. This application facilitates seamless integration and control of various Internet of Things (IoT) devices, such as smart lights, thermostats, cameras, and appliances through a unified interface. Users can remotely monitor and manage their connected devices, schedule automation routines, and receive real-time notifications about their home's status. The Smart Life app also supports voice commands and is compatible with major virtual assistants like Amazon Alexa and Google Assistant, providing hands-free control and enhancing user convenience. The app's robust functionality is further complemented by its user-friendly design, enabling both tech-savvy individuals and novices to navigate and utilize its features efficiently.



(a) **(b)**

Figure Error! No text of specified style in document.**.4** *the main page interface (a), the power usage graph (b)*

3.8 Measuring Procedure

The measuring procedure for the Smart Energy Monitoring System involves several key tasks. First, the setup and configuration of the system include installing the SMATRUL Wi-Fi Smart Power Meters between the main power source and the appliances, connecting the smart switches to the distribution box (DB box) to manage power distribution, and ensuring all connections are secure and compliant with safety standards. The smart switches are then configured to measure voltage, current, power consumption, and energy usage, with protection settings set for under voltage at 100V, overvoltage at 270V, overcurrent at 63A, and electrical leakage at 30mA. Additionally, the smart switches are connected to a stable Wi-Fi network and paired with the Smart Life app on a smartphone.

Following the initial setup, the data collection process is initialized with calibration of the smart power meters to ensure accurate measurements and an initial test run to verify system functionality. During continuous monitoring, power usage data is recorded at regular intervals, and transmitted to the Smart Life app for real-time monitoring. Observations and recordings of power usage are made for whole days.

For data analysis, the Smart Life app is used to monitor power consumption in real-time, with a focus on comparing the power usage of certified versus non-certified appliances. This analysis helps identify patterns and differences in energy efficiency. The collected data is then evaluated for accuracy and reliability, ensuring consistent data transmission via Wi-Fi. Documentation of challenges, solutions, and overall findings is essential, compiling the data and analysis into a comprehensive report. Finally, feedback on the usability of the Smart Life app and the overall system is gathered, identifying areas for improvement and making necessary adjustments. This detailed process aims to provide valuable insights into energy usage and efficiency, helping to make informed decisions for better energy management.

4. RESULT AND DISCUSSION

This chapter presents the results of the Energy Monitoring System project. It covers both the hardware and software components in detail. The Smart Life mobile application will be described as the software component, while the hardware aspects, including the SMATRUL Wi-Fi Smart Power Meters and the distribution box configuration, will be discussed as part of the embedded system. Utilizing the Smart Life app for real-time monitoring and data analysis ensures that the system delivers precise and actionable insights into energy consumption. From the project's initiation to the completion of the prototype, all safety measures were meticulously followed to prevent any unintended accidents.

4.1 software implementation

4.1.1 The Smart Life mobile application

On an energy monitoring system project, the smart life application has been used, it provide so many feature that helping for this project. One of its primary advantages is real-time monitoring. The app provides instantaneous data on power consumption, allowing users to observe the energy usage of various devices immediately. Additionally, the app sends instant notifications about anomalies or when specific thresholds are reached, enabling prompt action and ensuring efficient energy management.

Figure 4.1 show the main interface for individual smart power meter. Here it show the total electric use at the top of interface, how much power use in one hour in kWh. It also show the currently use current (A), Voltage (V), and active power (kWh). User also can set a limit of power usage to fully control it.

Figure Error! No text of specified style in document.**.5** *list data shown on main interface*

In terms of data collection and analysis, the Smart Life app is invaluable. It logs historical data, making it easy to review past power usage trends and compare the performance of certified and non-certified devices over time. The app generates detailed reports and visualizations, such as graphs and charts, which help in understanding energy consumption patterns and identifying inefficiencies.

Figure 4.2 show electricity statistics of power meter. It has a selection of by day, month or year. It also show the total power use for each hour to display a total usage.

Figure 4.2 *electricity statistics interface*

The app's remote control capabilities further enhance the project's efficiency. Users can control devices from anywhere, which includes turning devices on or off, adjusting settings, and scheduling operations. The app also supports convenient scheduling, allowing devices to operate only when necessary, and thereby conserving energy. These features ensure that the Energy Monitoring System is not only effective but also user-friendly and adaptable to various needs.

Figure 4.3 show the confirmation to turn off the power just from the phone.

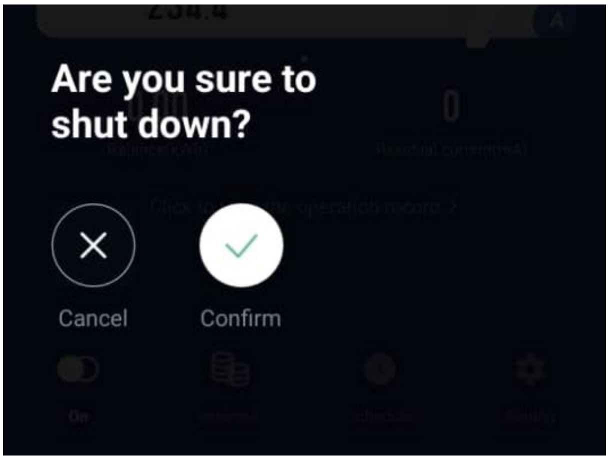


Figure Error! No text of specified style in document.**.6** *confirmation to turn off the power*

Automation features within the Smart Life app add another layer of convenience. Users can create scenes that automate multiple devices simultaneously or develop custom automations based on conditions such as time of day, device status, or other sensor inputs.

Figure 4.4 show schedule that user can use to specify the time to turn off and on the device. Here it show that it will turn off every day at 2:00am and the other one is to turn it on every day at 20:41pm.

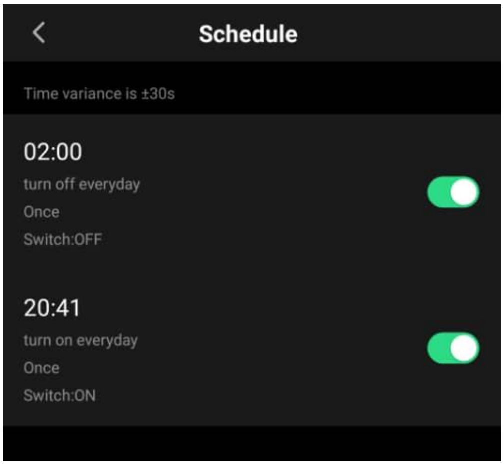


Figure Error! No text of specified style in document.**.7** *schedule of operation time*

Integration with other systems is seamless with the Smart Life app. It is compatible with popular voice assistants like Amazon Alexa and Google Assistant, facilitating hands-free control. The app also supports a wide range of devices and brands, ensuring compatibility with existing smart home setups. Secure connections and user permission management further enhance the app's reliability and security.

Figure 4.5 show the selection of the voice service that can be connected to smart life apps.

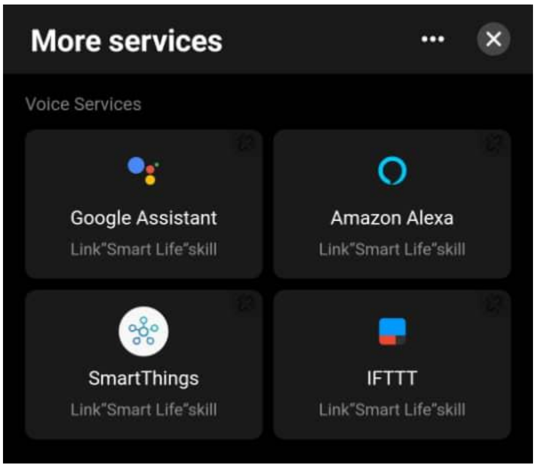


Figure Error! No text of specified style in document.**.8** *the selection of the voice service*

In practical terms, the Smart Life app facilitates experimentation and testing by allowing users to easily switch between different devices and settings during various phases of the project. It streamlines the documentation and reporting process by providing detailed data logs and reports, essential for documenting findings and generating comprehensive project reports.

4.2 hardware implementation

4.2.1 SMATRUL Wi-Fi Smart Power Meter

The SMATRUL Wi-Fi Smart Power Meter is an advanced smart switch and energy meter that allows users to measure and control the electricity consumption of connected devices. It integrates seamlessly with the Smart Life app, providing real-time data and control via a smartphone or other smart devices.

In the implementation of the Energy Monitoring System project, specific protective settings were configured on the SMATRUL Wi-Fi Smart Power Meters to ensure the safety and reliability of the electrical appliances being monitored. The under-voltage protection was set at 100 V, safeguarding the devices from damage caused by insufficient voltage supply. To prevent potential harm from excessive voltage, the over-voltage protection was configured at 270 V. additionally, the over-current protection was set to 63 A, ensuring that any current exceeding this threshold would trigger protective measures. For enhanced safety against electrical faults, the electrical leakage protection was established at 30 mA.

Figure 4.6 show the interface of smart life application when showing a power outage warning because of receiving an overvoltage when thunderstorm occur. It show that the built-in protection work and can protect the model.

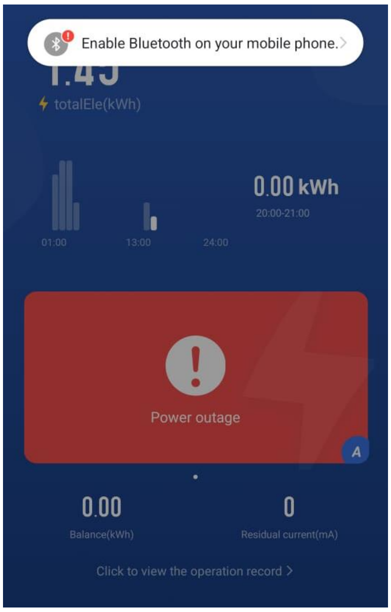


Figure Error! No text of specified style in document.**.9** *power outage warning*

4.3 Online Certification Verification for electrical appliance.

This section outlines the procedure for verifying the certification of electrical appliances through the Suruhanjaya Tenaga (Energy Commission) website, ensuring compliance with required energy efficiency standards for the Energy Monitoring System project. The LED bulb model E27 13W by Philips was verified in 2023 and is certified under approval number 13183/23, with an efficacy value of 113.6 lm/W. The LED tubes model T8-10W by Fighter were also verified in 2023 and are certified under approval number 13532/23. Additionally, the power adapter model EP-T1510 by Samsung was verified in 2022, certified under approval number 2280/22. A screenshot of the certification page is included in the appendix.

Table Error! No text of specified style in document.**.1:** *show the power usage of each device use and confirmation of certification form Suruhanjaya Tenaga.*

certified electrical appliance			Non certified electrical appliance		
Name of electrical appliance	Power (W)	Total use	Name of electrical appliance	Power (W)	Total use
And another entry	10	2	Generic TLD penda fleur lamp	18	1
E27 13W by Phillips	13	2	Generic non-LED bulb	25	1

4.4 Analysis of Testing Results

This section outlines the procedure for verifying the certification of electrical appliances through the Suruhanjaya Tenaga (Energy Commission) website, ensuring compliance with required energy efficiency standards for the Energy Monitoring System project. The LED bulb model E27 13W by Philips was verified in 2023 and is certified under approval number 13183/23, with an efficacy value of 113.6 lm/W. The LED tubes model T8-10W by Fighter were also verified in 2023 and are certified under approval number 13532/23. Additionally, the power adapter model EP-T1510 by Samsung was verified in 2022, certified under approval number 2280/22.

4.4.1 Analysis of Power Saving and Non-Power Saving Sections:

Figure 4.7 illustrates the power-saving/certified section, while Figure 4.8 shows the non-power-saving/non-certified section. These figures present overall statistics from one week of testing.

In the power-saving section, the total power usage is 1.80 kWh. The average current is 0.210 A, with an average voltage of 233.7 V. The average true power is 0.030 kWh. In contrast, the non-power-saving section shows a total power usage of 2.18 kWh, with an average current of 0.290A and an average voltage of 234.6 V. The average true power in this section is 0.045 kWh.

Figure Error! No text of specified style in document..**10:** *the power-saving/certified section (a), the non-power-saving/non-certified section (b)*

4.4.2 Analysis of True Power Usage:

These results reveal that in the power-saving section, the true power usage is only 0.030 kWh, despite the total power usage of electrical appliances being 0.046 kW. This suggests that certified electrical appliances can operate with lower power consumption than the suggested power usage. Conversely, in the non-power-saving section, the true power usage is 0.045 kWh, even though the total power usage of electrical appliances is 0.043 kW. This indicates that non-certified electrical appliances may consume more power than expected.

4.5 Analysis of Daily Power Usage Data

The power usage data collected over a full day on 5th June 2024 was analysed to compare the energy consumption patterns of certified and non-certified light bulbs and tubes. This analysis is presented in Figures 4.8 and 4.9.

4.5.1 Certified Light Bulbs (Figure 4.8)

The power usage for certified light bulbs was recorded consistently throughout the day, predominantly showing a usage of 0.04 kWh. However, a significant spike to 0.09 kWh was observed at one point during the day, likely due to a temporary loss of Wi-Fi connection. Despite this anomaly, the overall data indicates that certified light bulbs, which have received energy efficiency certification from Suruhanjaya Tenaga, generally operate with a predictable and steady energy consumption rate. The total power usage for the certified light bulbs throughout the day was 0.93 kWh.

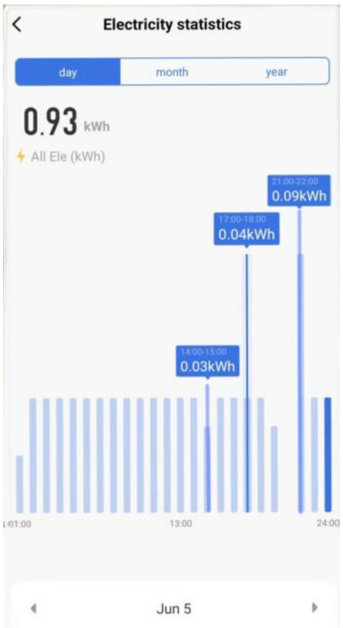


Figure 4.8 *electricity statistics of certified light bulb*

4.5.2 Non-Certified Light Bulbs and Tubes (Figure 4.8(b)

In contrast, the power usage data for non-certified light bulbs and tubes shows greater variability. The recorded usage fluctuates between 0.04 kWh and 0.05 kWh at different times throughout the day, indicating less stable power consumption. Additionally, the total power usage for the day sums to 1.11 kWh, which is higher than that of the certified bulbs. Similar to the certified bulbs, a significant spike to 0.10 kWh was observed, also due to a temporary loss of Wi-Fi connection. Even without this spike, the non-certified bulbs and tubes show a trend of higher and more variable energy consumption compared to the certified ones.

The daily power usage data reveals that both certified and non-certified light bulbs experience occasional spikes in power usage due to connectivity issues. However, certified light bulbs maintain a generally stable and efficient energy consumption pattern, aligning with their certification standards. Non-certified light bulbs and tubes, on the other hand, show more variability and higher overall consumption. This variability can lead to less efficient energy usage and higher electricity costs over time.

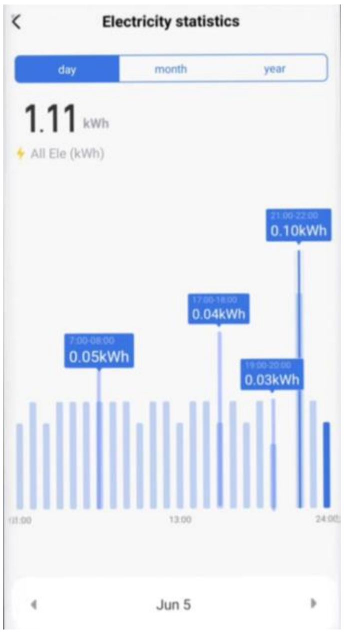


Figure Error! No text of specified style in document.**.11** *electricity statistics of non-certified light bulb*

4.5.3 Summary of Power Usage Data for Certified and Non-Certified Light Bulbs

Table Error! No text of specified style in document.**.2:** *the summary of result of the testing*

Parameter	Certified Light Bulbs	Non-Certified Light Bulbs and Tubes
Total Power Usage on 5/6 (kWh)	0.93	1.11
Typical Daily Power Usage (kWh)	0.04	0.04 - 0.05
Maximum Power Spike on 5/6 (kWh)	0.09	0.10
Total Power Usage (29/5 - 6/6) (kWh)	2.81	3.40
Variability in Power Usage	Low	High

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Consistency in Energy Consumption	High	Low

4.6 Explanation of Results

4.6.1 Daily Power Usage Data

On 5th June 2024, power usage data was collected to compare the energy consumption of certified and non-certified light bulbs and tubes. The data showed the following:

1. Total Power Usage on 5/6: Certified light bulbs consumed 0.93 kWh, while non-certified bulbs and tubes used 1.11 kWh. This indicates that non-certified devices have a higher daily power consumption.
2. **Typical Daily Power Usage**: Certified bulbs consistently used 0.04 kWh, whereas non-certified bulbs and tubes showed more variability, fluctuating between 0.04 kWh and 0.05 kWh.
3. **Maximum Power Spike on 5/6**: Both certified and non-certified devices experienced significant spikes due to temporary Wi-Fi connection losses, with peaks of 0.09 kWh and 0.10 kWh, respectively.
4. **Variability in Power Usage**: Certified light bulbs exhibited low variability, maintaining a consistent usage pattern. Non-certified bulbs and tubes demonstrated higher variability, suggesting less stable energy usage.
5. **Consistency in Energy Consumption**: Certified light bulbs showed a high level of consistency in energy consumption, in line with their energy efficiency certifications. Non-certified devices showed less consistency, leading to potential inefficiencies and higher energy costs.

4.7 Extended Period Power Usage Data (29/5 - 6/6)

The total power usage over the entire experiment period, from 29th May to 6th June 2024, provides additional insights:

1. Total Power Usage (29/5 - 6/6): Certified light bulbs consumed a total of 2.81 kWh over this period, while non-certified bulbs and tubes used 3.40 kWh. This further emphasizes the higher overall consumption of non-certified devices.
2. Implications of Extended Usage Data: The data from the extended period confirms the trend observed in the daily data. Non-certified light bulbs and tubes not only consume more power on a daily basis but also result in higher cumulative energy consumption over time. This supports the conclusion that certified light bulbs are more efficient and consistent in their power usage.

4.8 Conclusion

The analysis of both daily and extended period power usage data highlights the clear advantages of using certified energy-efficient appliances. Certified light bulbs consistently demonstrate lower and more stable energy consumption compared to non-certified light bulbs and tubes. The higher variability and overall consumption of non-certified devices can lead to increased energy costs and inefficiencies. This data underscores the importance of energy efficiency certifications and their role in promoting sustainable and cost-effective energy usage practices.

5. Conclusion

This section covers the summary and recommendations that can be used for upcoming projects.

5.1 Conclusion

The project achieved its objectives by successfully creating two models of power usage: one using certified energy-efficient appliances and the other using non-certified appliances. Through detailed data analysis, it was evident that certified appliances consistently consumed less energy and exhibited more stable power usage patterns compared to non-certified appliances. This underscores the importance of using certified energy-efficient devices to reduce energy consumption and costs.

The reliability of the system was demonstrated through accurate data collection and real-time monitoring. Despite a few instances of Wi-Fi connection loss, the SMATRUL Wi-Fi Smart Power Meter provided precise measurements of voltage, current, power consumption, and energy usage. The Smart Life mobile application facilitated real-time monitoring, making it easy to track and compare energy usage effectively.

While the system performed well, there are opportunities for improvement. Enhancing Wi-Fi connectivity would improve data transmission reliability and reduce instances of data spikes due to connection losses. Additionally, extending the monitoring period and including a wider variety of appliances would provide more comprehensive data and insights.

5.2 Future Recommendations

For future research, integrating the smart power meter with other IoT devices and systems could create a more holistic smart home energy management system. Implementing advanced data analytics and machine learning algorithms could provide deeper insights into energy usage patterns and help predict future energy consumption. Enhancing the user interface of the monitoring application with more detailed analytics and user-friendly features would improve user experience and engagement. Furthermore, developing a system that provides personalized energy-saving recommendations based on usage patterns could further help in reducing energy consumption and costs. These recommendations can enhance the capabilities and effectiveness of smart energy monitoring systems, contributing to more efficient and sustainable energy usage practices.

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Conflict of Interest

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

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