

Smart Power Distribution Box with Power and Fault Monitoring using IoT

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Abstract

This paper describes the design, development, and deployment of a smart distribution box enabled by the Internet of Things (IoT) with the goal of improving defect detection, power monitoring, and overall energy management in single-phase residential power applications. The PZEM-004T100A module for measuring electrical parameters and the ZMPT101B voltage sensor for monitoring voltage levels are two examples of the advanced sensor technologies integrated into the project. This allows for comprehensive and real-time monitoring of electrical parameters like voltage, current, power consumption, and temperature. The Blynk platform allows the smart distribution box to be connected to smartphones, making it easy to use and accessible for users. With the use of this connectivity, customers may improve their energy management practices by having remote access to vital power usage data, receiving defect warnings instantly, and estimating bills accurately. Intelligent monitoring capabilities, precise problem detection, and user-friendly interfaces for web and smartphone applications that guarantee a smooth user experience are some of the system's key characteristics. The system's ability to dramatically improve energy management, increase safety, and decrease downtime in residential settings is highlighted by the thorough real-time data analysis and the precision of the fault detection techniques used to illustrate the system's effectiveness. This research demonstrates how smart technology may revolutionize power distribution networks by tackling typical problems including excessive power use, distribution board failures, and customer misunderstanding about energy consumption. According to the report's conclusion, the smart distribution box provides a full answer for contemporary energy management problems in residential applications thanks to its integrated IoT capabilities and cutting-edge sensor technologies.

1. Introduction

Distribution panels, also known as power distribution boards, have a lengthy history that dates back to the late 1800s. From primitive fuse boxes and knife switches to cutting-edge circuit breakers and smart meters, they have come a long way. In order to improve energy management, modern distribution boards increasingly include smart technology and renewable energy sources. Building an electrical panel that distributes power from the primary source to several circuits while maintaining load capacity, efficiency, and safety is the design of a distribution board. Three important factors to take into account are accessibility, electrical code compliance,

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and grounding. For improved energy management, modern boards may also include smart technology and surge protection. By providing power usage monitoring via an LCD, the design seeks to empower people, facilitating informed decision-making and cutting down on waste. Smartphone technology is employed for maintenance and troubleshooting, reducing downtime and guaranteeing customer and staff safety. In order to promote energy efficiency and enhance safety and overall electrical system operation, the creative design places a high priority on power consumption management, efficient issue location monitoring, and user-friendly bill estimation.

A comprehensive method is needed to solve distribution board failure detection, excessive power usage, and user ignorance. This entails combining cutting-edge technology, approachable user interfaces, and instructional programs to build distribution networks that are safer, more effective, and satisfy changing grid and customer needs. A thorough understanding of consumer behavior, effective load distribution techniques, and the use of smart technology—such as real-time data-producing smart meters that adhere to IEEE Standard 1691-2021—are all necessary for managing and lowering excessive power use. [1][2]. It is necessary to provide user-friendly interfaces and implement educational initiatives to combat consumer ignorance about power consumption. These strategies have been demonstrated to encourage responsible energy use and raise awareness [3]. For home systems to be safe, problems must be identified quickly; yet modern distribution boards don't include sophisticated sensors for this purpose. The integration of intelligent sensors and real-time monitoring systems according to standards such as IEC 61850 can significantly improve problem detection capabilities, hence reducing risks and downtime [4][5]. To create safer and more efficient distribution systems, a thorough plan incorporating state-of-the-art technology, user-friendly interfaces, and instructional initiatives is required.

The aim of this project is to use Internet of Things (IoT) to construct a smart distribution box with power and fault monitoring for single-phase power applications that are typical in residential settings. The first major objective of the project is to design and create an intelligent monitoring and fault detection system that is incorporated into the distribution box. In addition to advanced defect detection technologies, this system will make use of sensors to monitor electrical properties in real time, including voltage, current, power consumption, and temperature. Additionally, it will have smartphone connectivity through an intuitive app developed on the Blynk platform, which would enable homeowners to get trouble warnings, remotely view and evaluate data on their power use, and maybe even predict their monthly costs. In order to guarantee dependability and safety, the project also focuses on evaluating and improving the fault detection system's accuracy through simulated fault situations. The distribution board will be furnished with sensors such as the PZEM-004T100A module for accurate monitoring, as well as normal, residual-current, and micro circuit breakers. Particularly, the ZMPT101B voltage sensor will identify possible system flaws. The ultimate goals of this integrated strategy are to improve the monitoring of household power, enable early defect detection, and encourage effective energy management techniques.

2. Research Methodology

This section explains the project design for an IOT-enabled smart distribution box that monitors power and faults. For example, the project's block diagram, flowchart, and project circuit for the project.

2.1 Block Diagram

Referring to Fig. 1, the block diagram started with input power of 230V AC single phase supplied (TNB), Then go to the distribution box which manage the incoming power and providing protection and isolation for different components. Next it will go thought the AC to DC converter to power up the NodeMCU (ESP-WROOM-32). After that the NodeMCU will control 2 sensor which is ZMPT101B and PZEM-004T. Finally, it will send the data to smartphone through Blynk apps.

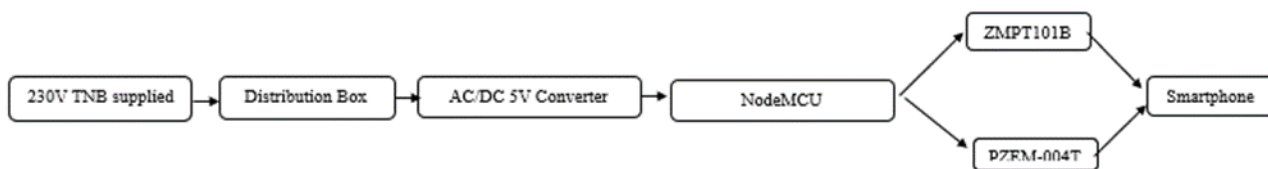


Fig. 1 Block diagram of the project

For further understanding, the flowchart of the project is being showed in Fig. 2. Where the system starts with RCCB, or main circuit breaker are being supplied with 230V AC single phase and connected with AC to DC converter which supplied 5V DC to ESP-WROOM-32. Then the systems are divided into 2 which are monitoring and fault detection. For monitoring, the main sensors are PZEM-004T and Temp sensor. Where the sensor will monitor data for voltage, current, power, power factor, temperature, energy and more. Then the data is being sent and stored in the Blynk cloud. On the Blynk website all the data can be accessed and monitored on the

phone or through a laptop. As for fault detection there are 2 ZMPT101B sensors which will detect voltage if the voltage is equal or lower than 0, the sensor will send signal and notification to the Blynk or smartphone. The bill calculations are being programmed in the ESP-WROOM-32 to use the information from the PZEM-004T.

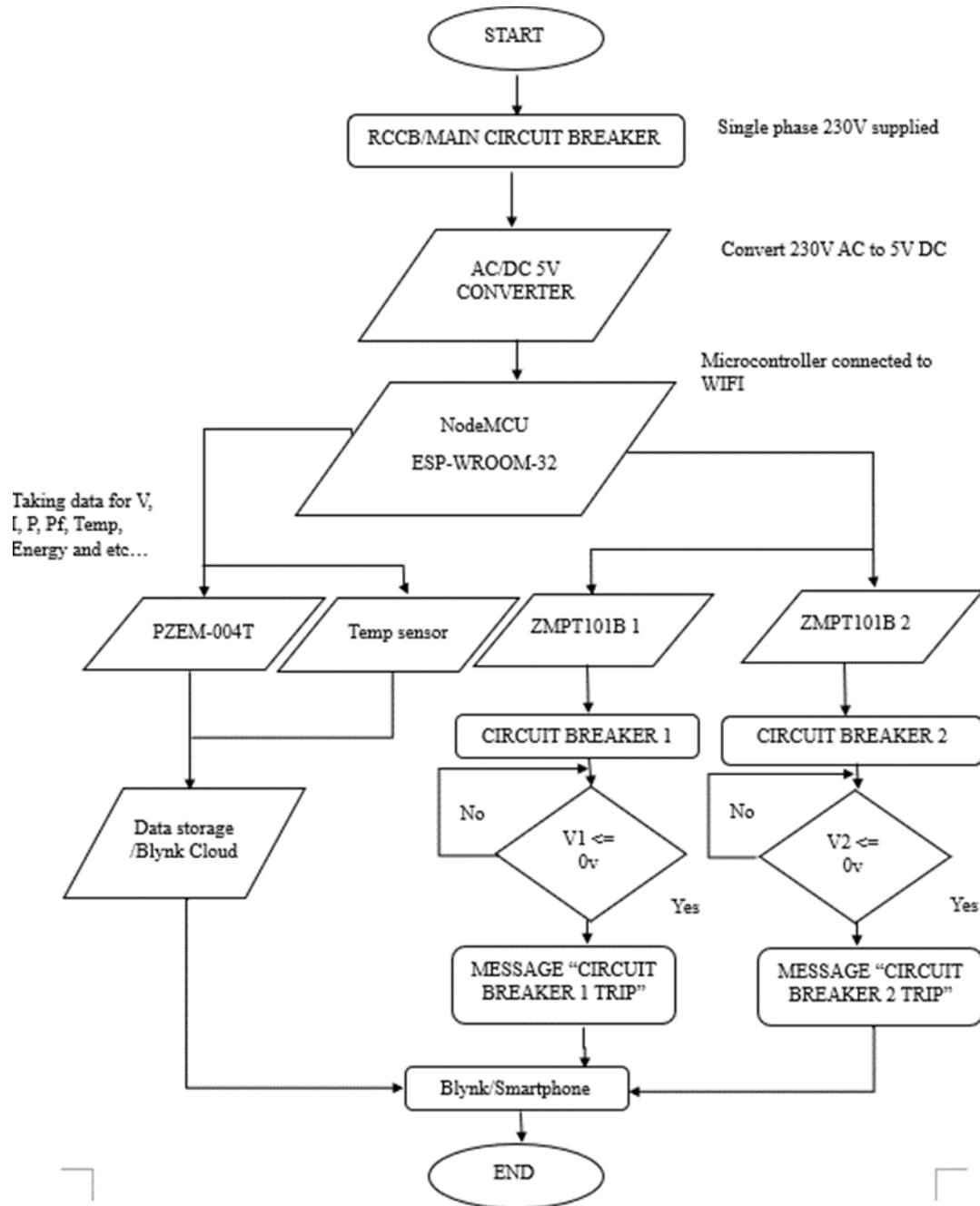


Fig. 2 Systems flowchart

2.2 Circuit Design

Referring to Fig. 3, the circuit design consists of ACDC 5V converter, ESP-Wroom-32, PZEM-004T, ZMPT101B, resistor 4.7k ohm, DS18820 temperature sensor, LCD display, residual-current circuit breaker and main circuit breaker. The circuits are connected as shown in Fig. 3.

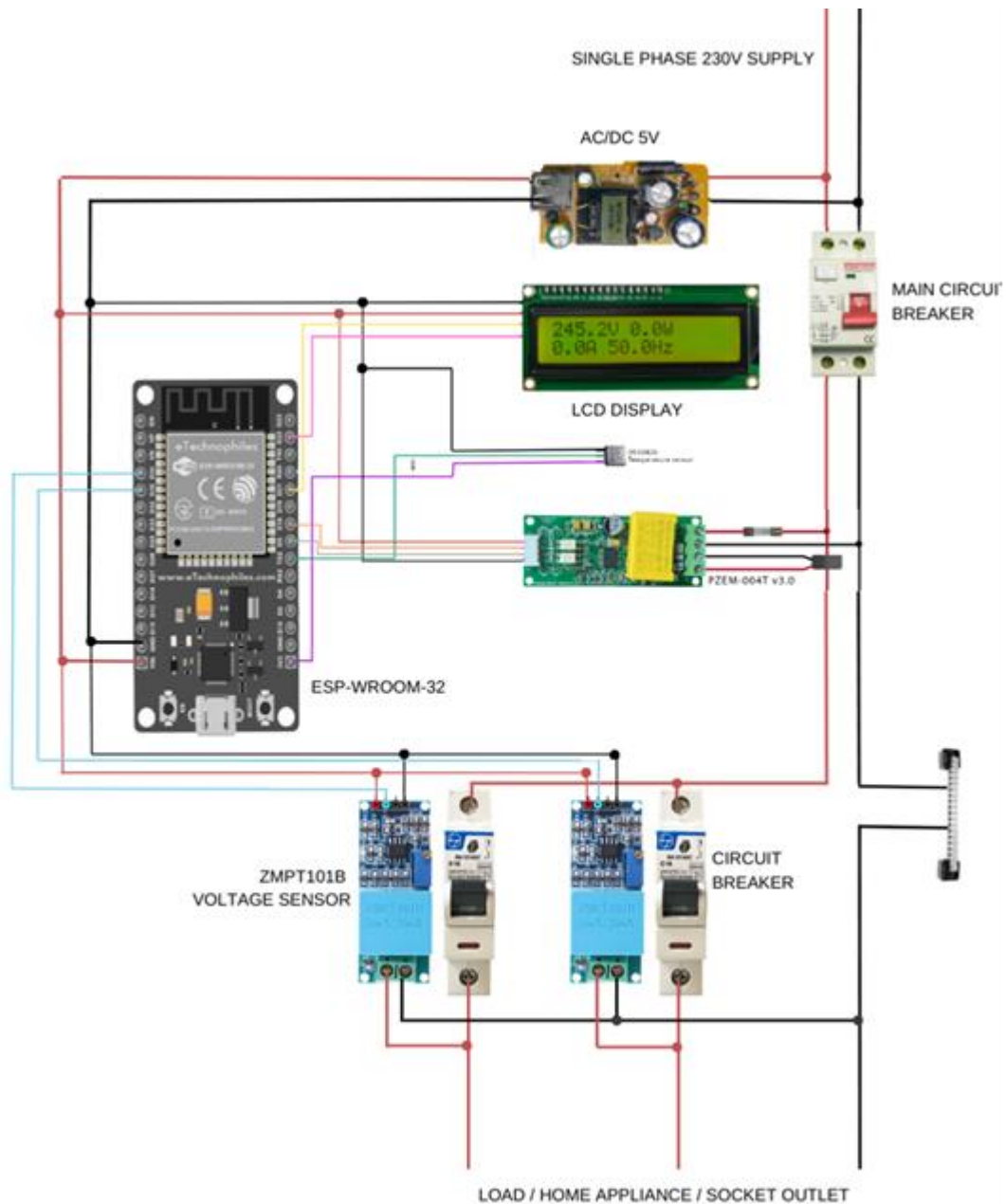


Fig. 3 Circuit design of the systems

3. Result and Discussion

This section presents the results of the smart distribution box that monitors power and faults with IOT are completely put together and all functions can be achieved. Functions that have been discussed are System monitoring with Blynk data, fault location detection and bill estimate charges. Fig. 4 shows a complete assembled and functional smart distribution box.

There is no need to physically engage with the distribution box itself because all of these features can be easily accessible through user-friendly websites or smartphone apps. Regardless of their level of technological expertise, this encourages simple access and monitoring for users. Additionally, platforms like Blynk are particularly made with user-friendly interfaces and clear visualizations, so even inexperienced users can easily grasp them. By focusing on the needs of the user, the smart distribution box's capabilities and insights are made accessible to everyone, enabling them to make knowledgeable decisions regarding their energy usage. Fig. 5 shows the interface for websites and smartphone

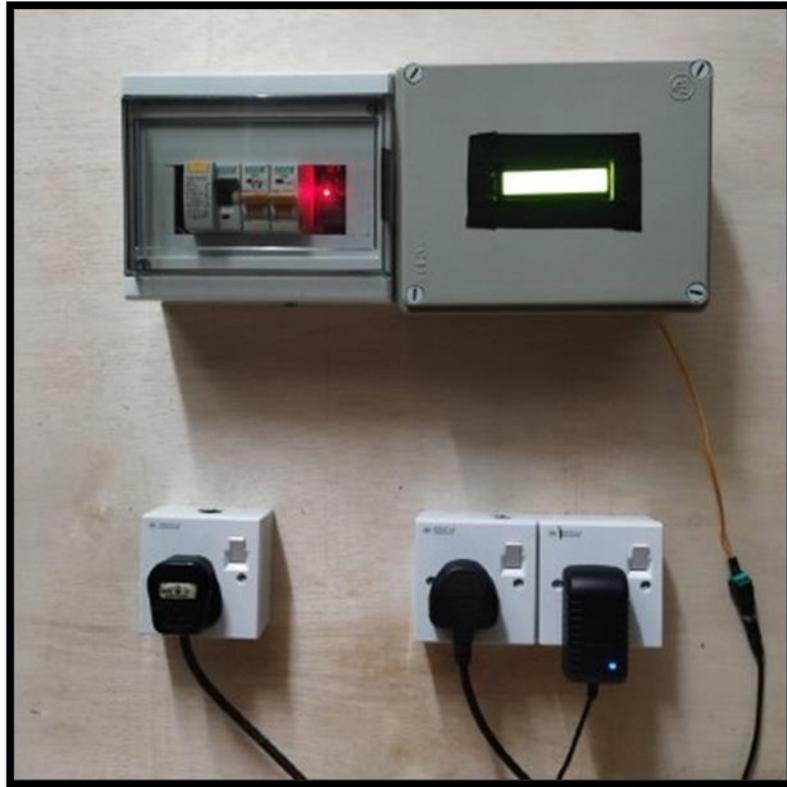


Fig. 4 Complete assembled and functional smart distribution box

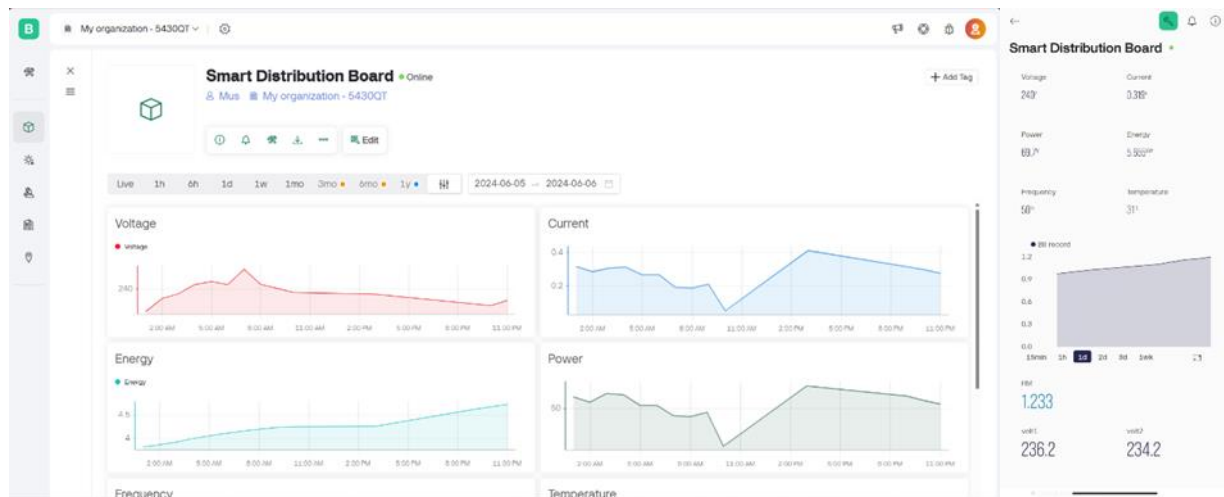


Fig. 5 Interface for websites and smartphone

3.1 System Analysis based on Blynk data

The systems analysis is being tested in the bedroom and the electric appliances commonly used are laptop chargers, phone chargers, earphone chargers and stand fan. The supplied for smart distribution box are being taken from the socket which is 230V AC voltage supplied. Thus, the system can be analyzed through the smartphone and websites for voltage, current, power, power factor and other more. The data are taken 1 hour, where at the time, customer usually at home which is 9.05PM until 10.05PM. Fig. 6 shows the graph for voltage and current at 10.05 PM.



Fig. 6 The graph for voltage and current at 10.05 PM

As the analysis is going both voltage and current graph are fluctuating base on the figure 6. There are fluctuations in the voltage because, nominal voltage of a single-phase AC supply varies from +10% to -6%. Considering this, the systems appear normal and Voltage fluctuations in a home's electrical system can be caused by a number of things, including high-power appliances, overloaded circuits, and broken wiring. While high-power appliances can cause sudden drops in voltage, variable power demand can lead to mild variations in voltage. Resistance from overloaded circuits affects other appliances. Bad wiring might also be the source of voltage dips. These variances may affect the way appliances perform and may possibly damage sensitive devices. Therefore, by using a Smart Distribution Box Monitor, this might be prevented. Next for current, the number of electric appliances utilized at any given moment determines the current use. Three items are utilized, for instance, a laptop charger, a phone charger, and a stand fan, when the data is being collected. Whether the smartphone is already fully charged or unplugged, there is a rapid dip in the graph. Therefore, in order to prevent overcharging, the smartphone automatically reduces the current. To make sure that the data calculated from the sensors are accurate, comparison between manual and smart distribution box are made for real powers. Table 1 shows comparison between manual and smart distribution boxes.

Table 1 Comparison between manual and smart distribution boxes

No	Time Taken	Voltage, V	Current, A	Power Factor	Manual Calculation, Watt	Real Power Smart Distribution Box, Watt	Error (%)
1	9.07 pm	235.7	0332	0.91	71.21	71.25	0.056
2	9.30 pm	236.5	0.35	0.911	75.41	75.45	0.053
3	10.06 pm	237.5	0.32	0.905	68.78	69.5	1.000

For real power and power factor analysis from the system. The real powers are dependent on the value of voltage, current and power factor. After obtaining all of this data, then use the formula, $Real\ Power = VI\ Cos\ \theta$ to obtain the real power of the systems and for percentage error use, $Error\% = \frac{V_{observed} - V_{true}}{V_{true}} \times 100$. The results indicate that there is little error percentage between the true power numbers from the manual and smart distribution boxes. Because there is little inaccuracy between the Smart Distribution Box and the manual, the true power number that the Smart Distribution Box displays is dependable and suitable for examination.

3.2 Fault Location Detection

The Smart Distribution Box has several characteristics, one of which is fault location detection. When a system is set up to detect, it will identify the circuit breakers that are linked to the lighting circuit or socket outlet. In this project, just socket outlets are being utilized for testing, and two circuit breakers are being employed. Fig. 7 shows Circuit breakers 1 tripped and Blynk send notifications.

3.3 Bills Estimate Charges

These Smart Distribution Boxes have the ability to calculate how many charges will be imposed on the customer based on how much energy they use. Why is the user benefiting from this feature? This is because by knowing how much they would be charged at the end of the month; consumers can manage their budget for other necessities and anticipate their power payment at the end of the month. The TNB bill calculator is being used to demonstrate the accuracy of the bill estimations. Simply visit the TNB official website and look for the TNB bill calculator option to utilize the TNB calculator. After that, enter the energy usage amount in the box for total consumption and hit calculate. There are no variations in bill consumption when all the bills from the Smart Distribution Box and TNB calculator are combined. The TNB calculator differs from others in that it computes

the ICPT. In reaction to changes in fuel and producing costs, TNB's Imbalance Cost Pass-Through (ICPT) mechanism adjusts electricity tariffs in Malaysia. In reaction to fluctuations in the price of fuel on a worldwide scale, it adjusts the true cost of power generation, which might lead to a bill surcharge or refund. The final charge is calculated by multiplying a client's monthly power use by the ICPT rate, which is expressed in Sen per kWh. By being aware of the ICPT, customers may have a better understanding of how fuel prices and production costs affect their power rates. Table 2 shows the comparison with TNB calculator and Fig. 8 shows the interface of TNB and smart distribution box.

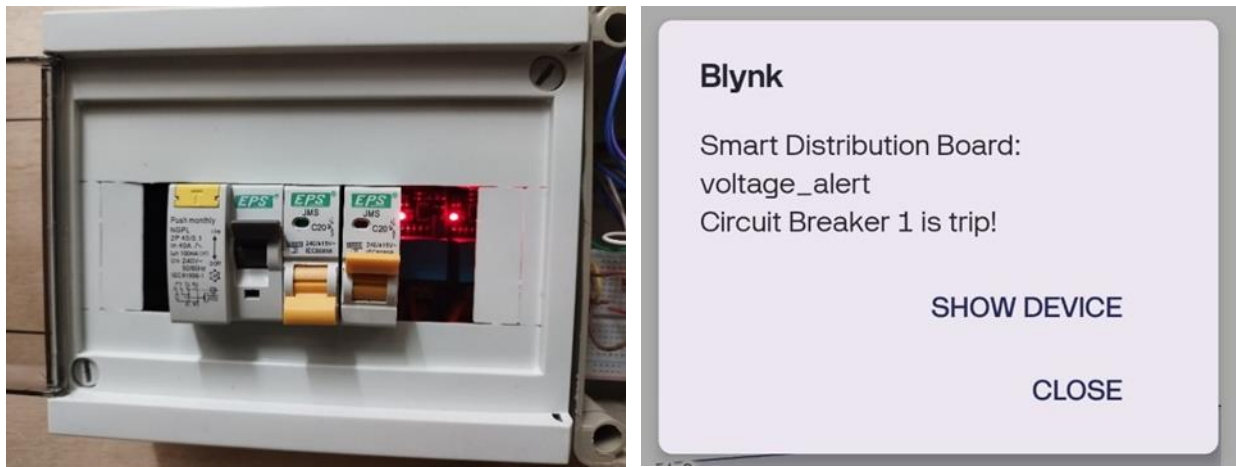


Fig. 7 Circuit breakers 1 tripped and Blynk send notifications

Table 2 The comparison with TNB calculator

No	Energy, kWh	TNB Calculator, RM		Smart Distribution Box, RM
		With ICPT	Without ICPT	
1	0.718	RM 0.16	RM 0.16	RM 0.16
2	2.124	RM 0.42	RM 0.46	RM 0.46
3	6.08	RM 1.21	RM 1.33	RM 1.33
4	7.53	RM 1.49	RM 1.64	RM 1.64

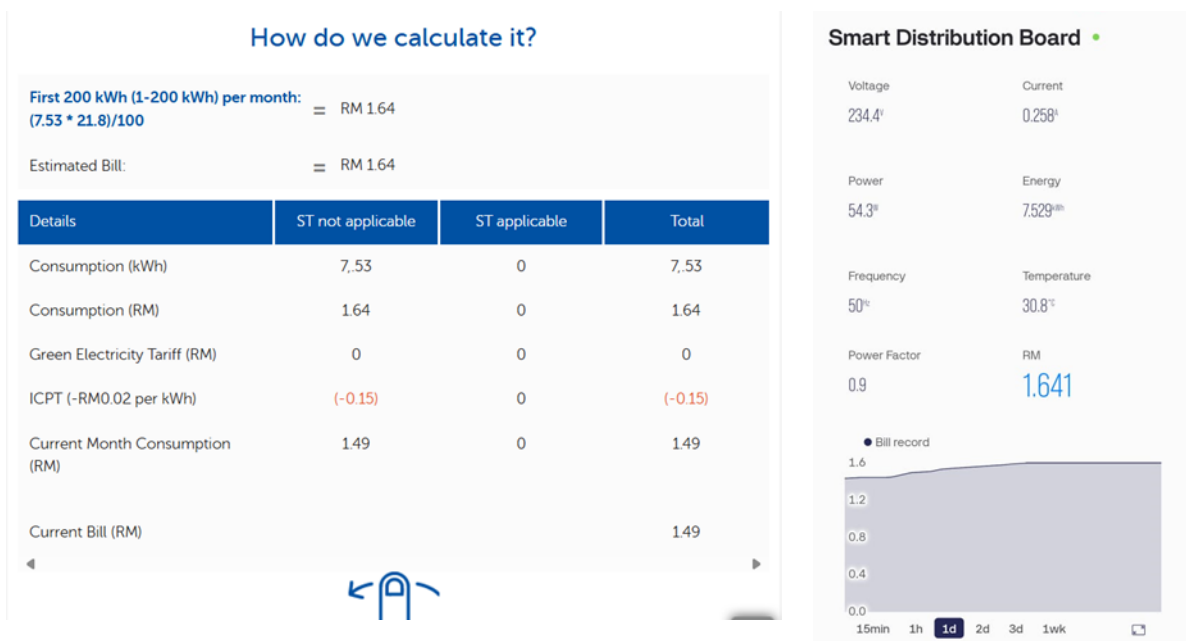


Fig. 8 The interface of TNB and smart distribution box

4. Discussion and Analysis

After several months of monitoring the smart distribution box operating, the functionality is all able to achieve the objectives stated and the smart distribution box seems to be a useful instrument for controlling and keeping an eye on domestic energy use. It is a useful addition to contemporary houses because of its intuitive interface, precise real-time data collecting, defect detection, and bill prediction functions. Technology gives consumers the ability to minimize their energy use and guarantee electrical safety by offering easily accessible insights and notifications. Although the prototypes are great, it cannot be denied that there is still a lack in certain areas, which can be upgraded or improved for future work. Divided into 3 functions, the first is system analysis. Where the systems still need a human or consumer to manually analysis if the systems operating in normal conditions or not. Thus, it tells that the user needs understanding in electrical to be able to analyze or understand the systems. To mitigate this, the systems can be built in with AI where it can automatically analyze the systems. Besides that, the system also needs to be improved, so that it can handle three-phase electrical applications for larger residential and commercial installations. As for aspects of renewable energy, the systems that can be integrated are battery storage monitoring and renewable energy source for comprehensive energy management.

For fault location detection, the systems only detect if the circuit breaker is in tripped condition or not by measuring the voltage. To improve the fault detection function, in the future the system may be able to type of fault happen on the circuit breaker. For example, it can detect if the fault happens on the circuit breaker is overloading, short circuit and ground fault with the help of ZMPT101B voltage sensors installed for each circuit breaker.

Finally, the bill estimation, based on the result obtained from the bill, are reliable and accurate. But it can only calculate the bill without resetting it for next month. In other words, the bill will continue calculate the bill using previous month energy consumption and add the new month consumption. Thus, the improvement area are the systems, or the bill estimates needs to be programmed that it will calculate for each month and stores the data on cloud for future reference. Other than that, collaboration with TNB are also good. Where the systems can access to latest energy consumption tariffs and ICPT of the energy generated at the moment. Thus, this will make the systems more efficient and reliable.

5. Conclusion

In conclusion, all project objectives are effectively met by the construction of a smart distribution box with power and fault monitoring using IOT. Advanced fault detection, real-time tracking of electrical characteristics, smartphone connectivity, and smart monitoring and fault detection systems have all been conceived and built. The intelligent distribution box and the easy-to-use Blynk app work together to give consumers real-time data, notifications, and estimations of their electricity bills. This allows users to take control of their energy usage and take prompt action in the event of a problem. The precision of the system's fault detection was carefully examined and improved, guaranteeing accurate problem localization and identification and boosting home safety. Furthermore, the project's scope, which concentrated on single-phase power applications, effectively combined hardware and software elements, such as the ZMPT101B voltage sensor for fault detection and the PZEM-004T100A module for monitoring, to create a comprehensive home monitoring system. Future developments could use artificial intelligence (AI) for automated system analysis and enhance fault detection to pinpoint certain kinds of electrical issues. Its usefulness might be further improved by adding renewable energy sources and expanding to accommodate three-phase electrical applications. All things considered, the smart distribution box is a major improvement in home safety and energy management.

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Conflict of Interest

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

Author Contribution

*The authors confirm their contribution to the paper as follows: **study conception and design:** Mohamad Anis Mustaqim Mohd Shuhaimi, Muhammad Saufi Kamarudin; **data collection:** Mohamad Anis Mustaqim Mohd Shuhaimi; **analysis and interpretation of results:** Mohamad Anis Mustaqim Mohd Shuhaimi, Muhammad Saufi Kamarudin, Nor Akmal Mohd Jamail, Mohd Fairouz Mohd Yousof; **draft manuscript preparation:** Mohamad Anis Mustaqim Mohd Shuhaimi, Muhammad Saufi Kamarudin; All authors reviewed the results and approved the final version of the manuscript.*

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