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IoT Based Smart Home with Monitoring and Control System

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Abstract: The issue regarding the energy consumption that often heard is the waste of energy when electrical appliances are switched ON even it is unused. This is due to the human negligence where the user usually does not aware and forget to turn off unused electric appliances especially during morning when rushing for work. The overconsumption of energy will become a waste that might increases the electricity bills and also a possibility of short circuit and fire due to the overheating of electrical appliances. This project aims to develop a smart home system by integrating a hardware with IoT system consist of NodeMCU ESP32, relay, voltage and current sensors and the Blynk application to control electrical appliances wirelessly. The energy consumption from the tested electrical loads will be monitored and recorded in Blynk. The results show that the project was successful and have the ability to switch ON or OFF electrical appliances connected to the system wirelessly without having to be in the same places. The observed power consumption that is recorded will be calculated to acquire the electricity bill's information. This project will help in solving the energy wasted issue and monitoring of electrical appliances became easier.

Keywords: Smart Home System, Monitoring System, Control System, IoT, Blynk

1. Introduction

In this modern world, technologies exist to reduce the workload and also able to save time. Electrical energy is the root of technological advancement since the discovery made by Benjamin Franklin, the power consumption is increasing rapidly with more integration of electrical appliances for daily used [1]. However, the increasing of power consumption resulting to the increasing of power plant. Most power plant in Malaysia are based on coal power plant where the combustion process contribute to pollution such as the greenhouse gas emission.

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Due to those reasons, saving the environment is important and the easiest way is to ensure the electrical energy in home is used efficiently. In order to successfully achieved that objective, the current technology can be utilized where a communication system is used to control the electrical appliances efficiently. Electrical appliances can be controlled at home wirelessly from any location with the existence of a smartphone and the internet. Furthermore, time is very important especially to those who are working and will need a lot of time to commute to the workplace. Therefore, their morning routine will be very busy and often get to work hurriedly and might forget to switch off any unused electrical appliances such as the lamp around the house, fan and also the air-conditioning unit. Unfortunately, it will keep being on for hours or might take more than 8 hours according to common work hours to wait for the home owner to get back to their home and turn it off causing the overconsumption of energy that become a waste. Moreover, it will result to an increase of electricity bill and a possibility of short circuit and fire due to overheating of electrical appliances were on in a long period of time.

Based on previous studies, there is a development of a smart home system that uses NodeMCU ESP8266 as the microcontroller and also a Google Assistant as the IoT platform to manage electrical appliances. The advantage of this application is the capability to use human speech to switch ON or OFF the appliances. Moreover, a web-based service is the second interface for this project act as backup since the performance of a system that uses human speech can be reduced due to presence of heavy background noises [2]. There is also other method based on IoT platform which are by using Bluetooth, Global System for Mobile (GSM) and Zigbee [3].

The system proposed in this project will act as the solution to the stated problems which is a smart home system for home that applied the Internet of Things (IoT) to do a work without any direct communication and interaction between a human and machine [4]. This smart home system with IoT, various electrical appliances available at home such as lighting and switch will be connected to the microcontroller which is the NodeMCU ESP32 to form a hardware. A programmed or a software will be built to connect the control system which is the smartphone to the microcontroller by using the internet connection with the help of the Wi-Fi module. The integration of both hardware and software that uses IoT platform will be validated to acquire the information on power usage and to test it capability to conduct its operation anywhere with only the presence of smartphone and Wi-Fi connection.

2. Methodology

A block diagram is used to represent the structure of the hardware and systems involved in this project. The design of the project will be described. Figure 1 illustrates on the component used and the basic procedure on how this project will be operated. First, the electrical appliances will be supplied by AC supply with relay getting through it to the appliances to control it using IoT. The current sensor will measure the load current and the voltage sensor measure the supply voltage and both reading will be sent to the microcontroller NodeMCU ESP32. All information acquire will be received and sent to the Blynk server then appear in the application in the smartphone. The condition of the load will also be sent at the same time and saved in the Blynk server to be displayed in the smartphone.

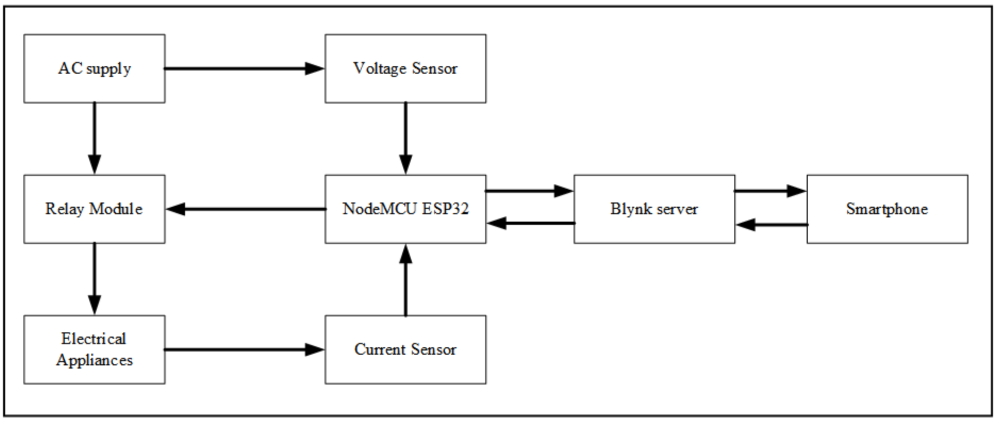

Figure 1: Block diagram of the systems

The flow chart in Figure 2 shows the operation on how the smart home with monitoring and control system operated. The flow of the system begins with initialization process, where the microcontroller NodeMCU ESP32 will connect to the designated Wi-Fi connection set in the coding programmed and then connect to the Blynk server. Then, a successful connection status will be displayed in the Blynk application. Furthermore, with a successful connection between ESP32 and Blynk will allow any information to be sent and received between them.

The condition of the load will be checked together with its control button in the widget interface in Blynk whether it is in ON or OFF. If the electrical load is already ON, the relay will be in energize state and displayed as ON in the widget control button in Blynk. At the same time current transformers clamp on each of the electrical load's live wire will read the current usage and the data is sent as a signal to ESP32. Then, the data is sent to the Blynk server to be displayed in the Blynk display. If the load is in OFF condition or the OFF button is pressed, the relay will de-energize and the condition of it will also be displayed in the application. Figure 2 shows the flowchart of the operating principle of this system.

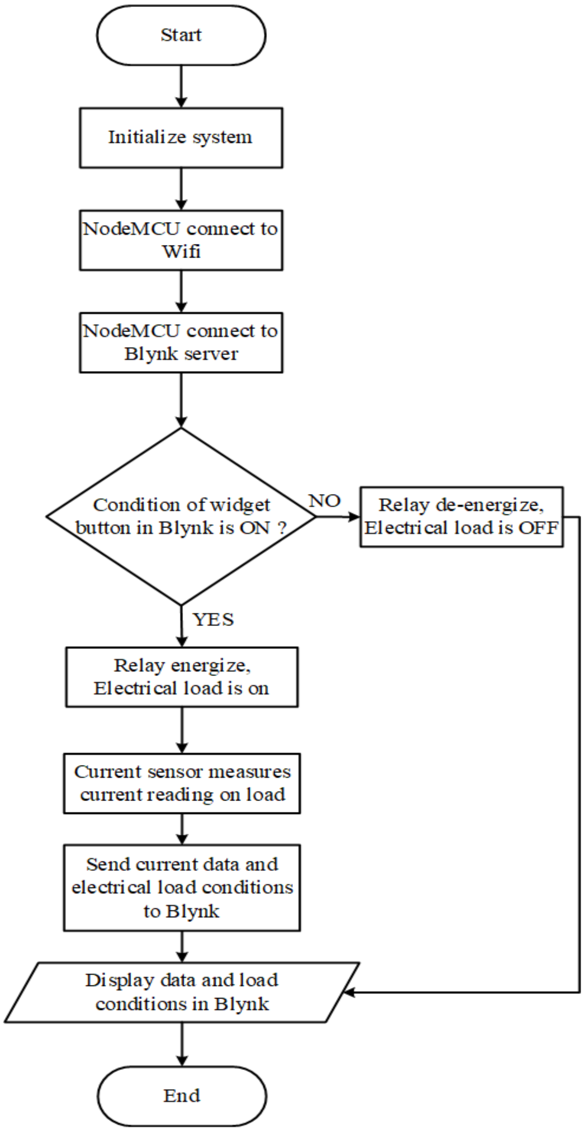

Figure 2: Flowchart of the systems

2.2 Hardware Development

The proposed system design for this smart home automation project can be separated into two sections which are for input and output where it also consists of components that will act as monitoring and control system shown in Table 1 and Figure 3. The input section for this design represents the voltage sensor that will read the value of supply voltage and the current transformers that will be clamped on each of the electrical load's live wires. The output section will be the relay module where it will be triggered after receiving signals from the Blynk application to turn ON or OFF any connected electrical loads.

Table 1: List of components

Item	Component	Description
1	Microcontroller	NodeMCU ESP32 I/O pins: 30
2	Relay Module	Operating Voltage: 5V 4-Channel

3	Voltage Sensor	ZMPT101B Voltage rating: 250V AC
4	Current Transformer	SCT-013 Operating Voltage: 1V Current rating: 30A

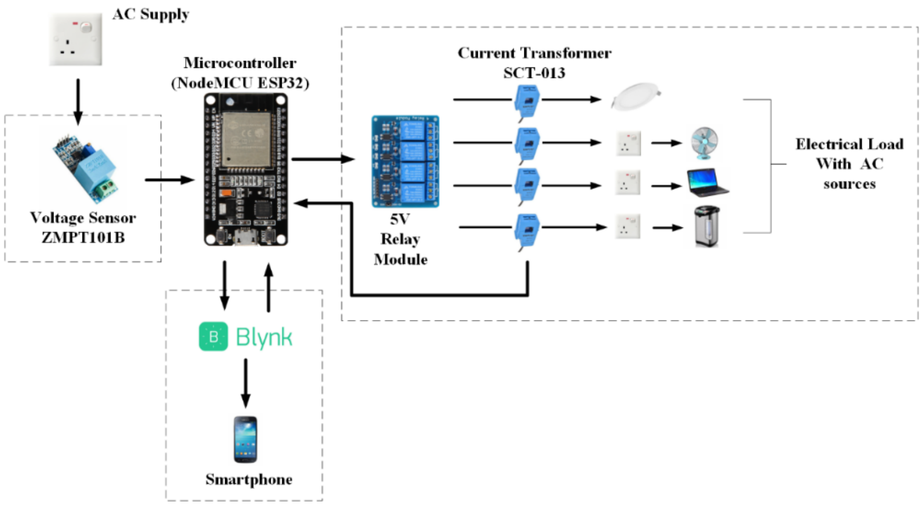

Figure 3: Proposed design of the systems

2.3 Software Development

A smart system must need a platform to interface between the microcontroller and an application that is programmed to conduct the control and monitoring function. Blynk is an IoT platform that can be installed inside a smartphone. The display interface inside it can be added with various functions according to how to operate the systems The display interface in the Blynk for this smart home system will consist of four buttons to control the relay module that will triggered to turn ON or OFF the electrical loads and also a display value function to show the current and voltage readings from the sensors. In addition, the value of the voltage and current of each load will be multiplied together stated in the coding programmed to get the reading of the total power usage from all electrical loads and will be displayed in Blynk. In addition, a graph or a chart can also be displayed inside the Blynk to record the reading value in a long period of time. The functions and the display interface in Blynk are shown on Figure 4.

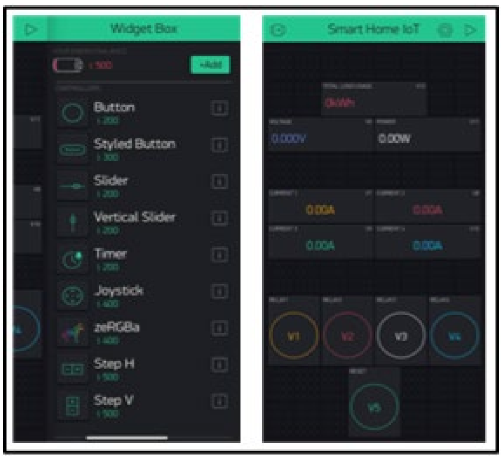

Figure 4: Functions and display interface in Blynk

3. Results and Discussion

3.1 Final Design

The wiring diagram designed as shown in Figure 5 is used to develop a complete hardware as shown on Figure 6 with a junction box that placed the components together in this system as shown in Figure 7. The electrical appliances are supplied by the AC voltage through the relay that act as triggers to control it. The voltage sensor that is also connected to the supply voltage and the current transformer clamped on the live wire of electrical appliances will read the value to be appeared and recorded in Blynk.

The completed hardware is tested its functionality with the electrical appliances connected to the built-in socket which are electrical thermoflask, laptop, fan and a downlight lamp to assure it works as planned. The location of where these appliances are connected into the socket outlet with its current transformer is shown on Table 2.

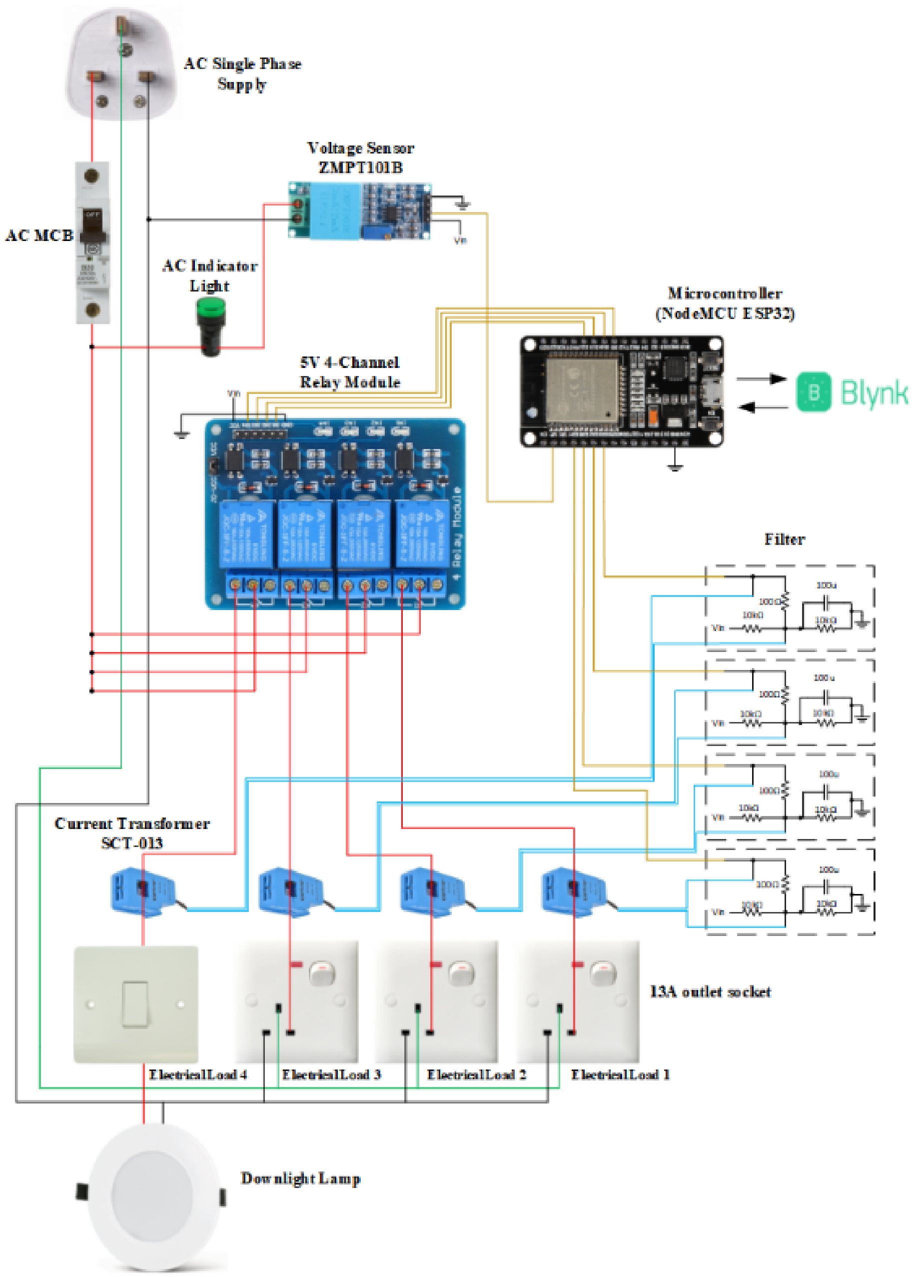

Figure 5: Functions and display interface in Blynk

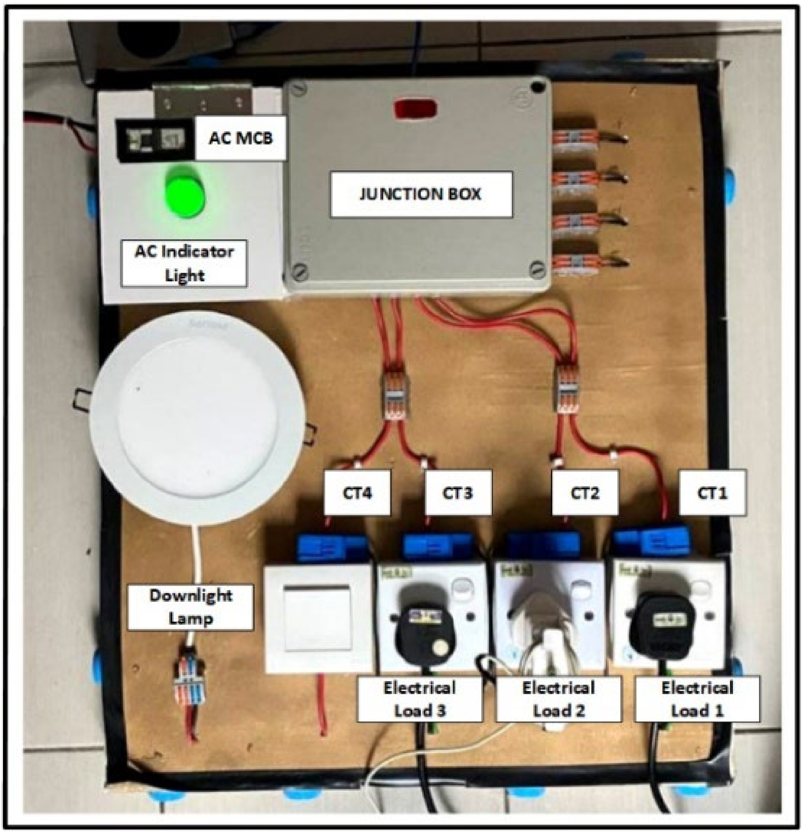

Figure 6: Functions and display interface in Blynk 1

Table 2: Connected electrical load

Item	Current Transformer	Electrical Load
1	CT1	Electrical Thermoflask
2	CT2	Laptop
3	CT3	Fan
4	CT4	Downlight lamp

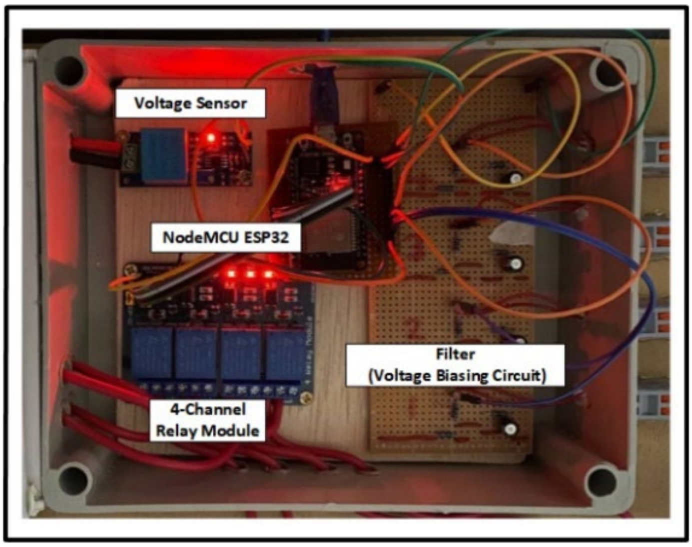

Figure 7: Functions and display interface in Blynk

3.2 Results on Control System

The integration between the hardware and the IoT system developed will test the capability of the relay component to be energized to turn ON the connected electrical appliances. Whenever the button designated for each load in the Blynk interface is pressed, a signal from the application will be sent to the microcontroller and the action required will be done by the relay module. The test is conducted on electrical appliances which are electrical thermoflask, laptop, fan and a downlight lamp. Figure 8 shows the situation where all the electrical appliances are switched ON after button in Blynk are all in ON condition.

Figure 8: All electrical appliances turned ON

3.3 Results on Monitoring System

The monitoring system will be tested by using two conditions. The first condition is by turning ON all the electrical loads from the Blynk application continuously for 24 hours starting on 07.00 AM, 27th December 2021 until 07.00 AM, 28th December 2021. The second condition is by turning ON some of the electrical loads continuously starting 07.00 PM, 31st December 2021 until 07.00 PM, 1st January 2022 for 24 hours.

This test will allow this system to acquire the information needed from the connected electrical appliances and display it in Blynk continuously during the 24 hours**.** Moreover, this continuous operation can determine whether the smart home system that utilized NodeMCU ESP32 and Blynk is robust enough for home application. The display interface for monitoring will include the graphs for current on each load and the total power usage as shown on Figure 4.18. In addition, these graphs are able to record the reading value needed and the data can be transferred into the Excel file and comparison can be made between the two conditions. Table 3 shows the current reading conducted for these two conditions.

Table 3: Current reading for first and second condition

Current, A					
First Condition			Second Condition		
CT1	**CT2**	**CT4**	**CT1**	**CT2**	**CT4**
3.37	0.17	0.05	1.45	0.07	0.04
3.3	0.16	0.05	1.69	0.10	0.03
3.28	0.17	0.05	1.36	0.07	0.03
3.3	0.18	0.05	1.55	0.06	0.05
3.19	0.17	0.05	1.47	0.07	0.03
3.21	0.17	0.05	1.55	0.09	0.03
3.2	0.16	0.05	1.32	0.06	0.03
3.46	0.17	0.04	1.32	0.06	0.03
3.31	0.17	0.05	1.27	0.07	0.03
3.75	0.18	0.05	1.66	0.08	0.03
3.68	0.19	0.05	1.27	0.07	0.03
3.36	0.18	0.05	1.97	0.09	0.08
3.54	0.18	0.07	1.36	0.06	0.04
4.54	0.23	0.12	1.14	0.07	0.04
3.64	0.18	0.07	1.71	0.10	0.04
3.55	0.18	0.04	1.61	0.09	0.03
3.6	0.19	0.06	1.43	0.07	0.03
3.63	0.19	0.06	3.37	0.16	0.06
3.48	0.18	0.05	1.87	0.08	0.06
3.43	0.18	0.05	1.65	0.08	0.03
3.62	0.18	0.06	1.70	0.08	0.04
3.59	0.17	0.04	1.47	0.07	0.04
3.62	0.18	0.05	1.43	0.07	0.03
3.54	0.18	0.05	1.32	0.09	0.03
3.74	0.17	0.05	1.19	0.06	0.03

Summarizing the observations of the current readings for the first condition recorded by CT1, CT2 and CT4 as shown in Figure 9. Most of the time during the 24 hours duration, the currents were slightly deviated compared to the actual currents reading taken from clamp meter. The presence of noises in the electronic components and current transformer can be a factor for this deviation. Furthermore, a 5 second loops in the system set in the coding for CT to update the reading in Blynk may interrupt the data accuracy preventing to acquire a fix data. However, a long period of time taken for the loops will cause more discrepancy on the recorded data. From the graph in Figure 10 it can be seen that the current reading is higher during 8PM due to the sudden slow Wi-Fi connection causing lag on data transmission between Blynk and ESP32.

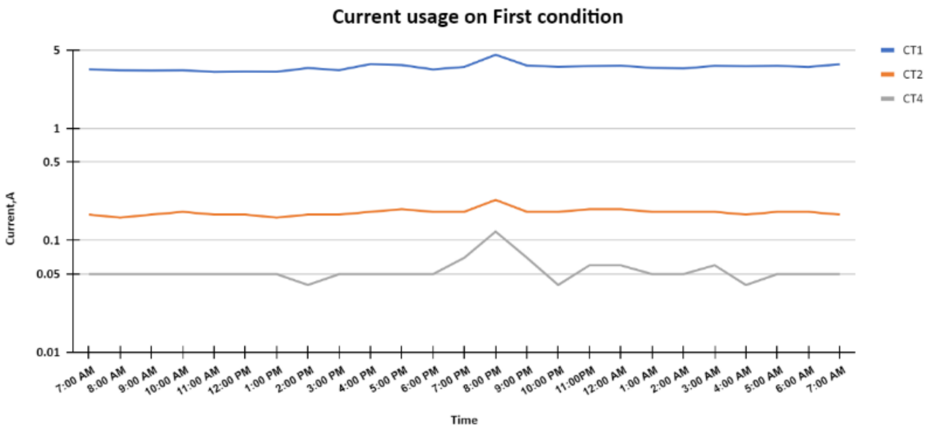

Figure 9: Current reading on first condition

To conclude the observations made for the current reading on the second condition recorded by CT1, CT2 and CT4, the graph on Figure 10 shows higher discrepancy compared to the first condition. Current reading from CT1 is also recorded here even the electrical appliance connected with this current transformer not switched ON because of the sensitivity of this component. Moreover, there is an existing library for this type of sensor in the coding programmed even when there is no current detected by the CT, it will keep produce random values for it to be calculated and measured.

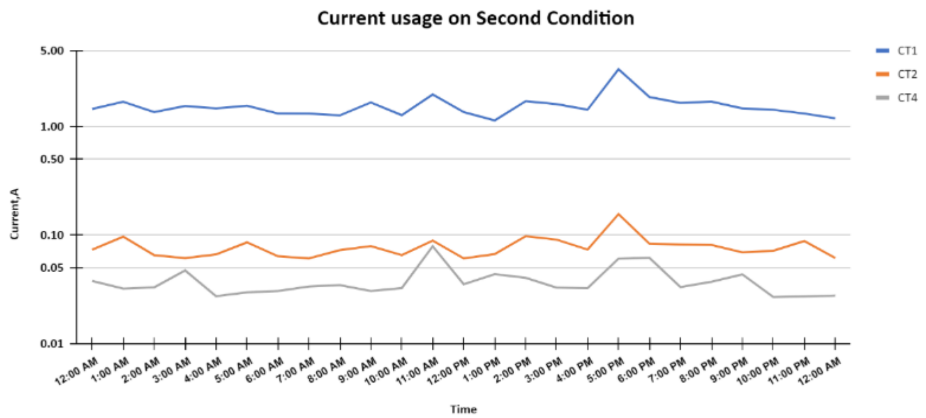

Figure 10: Current reading on second condition

The total power consumption of all three loads that are switched ON for the first condition are the 750 W electric thermoflask, laptop with 85 W AC adapter and a 15 W downlight lamp while for the second condition only laptop and downlight lamp are ON. Since the current and voltage reading already gathered in the system, it will be multiplied to acquire the reading of power consumption. It will then be displayed in the Blynk interface and updated every 5 seconds on how much the usage of power during that time. Table 4 shows the reading on power consumption for both conditions.

Table 4: Power Consumption for first and second condition

Power Consumption, W	
First Condition	**Second Condition**
804.48	376.99
773.55	441.15
785.37	352.08
793.32	401.7
762.41	381.88

779.69	411.44
788.64	346.51
827.24	347.82
785.68	337.34
874.36	429.39
874.33	328.09
803.10	531.67
837.47	358.23
1336.88	308.62
849.02	446.46
814.04	416.99
834.70	367.47
851.26	852.67
805.49	482.31
803.30	421.84
841.42	430.11
835.97	386.97
846.87	365.76
830.19	343.01
867.65	310.8

The total power consumption recorded from Blynk for the first condition is around 700 W and 900 W and when compared with the total power calculated as shown in Table 5, the power calculated is 850 W. The result shows that the reading of the power consumption is still within the acceptable range without any large deviation. Meanwhile the power consumption for second condition is around 400 W, higher than the total power calculated on Table 6 which is 100 W. The reason for huge differences for second condition is the reading recorded includes the reading from CT1 even the appliance didn't even switch ON due to the presence of noises in the electronic equipment.

Table 5: Load calculation for first condition

First Condition					
No.	**Description**	**Power, W**	**Max Current, A**	**Diversity factor**	**Estimated Current, A**
1.	Electric Thermoflask	750	3	100%	3
2.	Laptop with AC adapter	85	0.14	100%	0.14
3.	Downlight Lamp	15	0.07	66%	0.0462
	Total	850	3.21		3.19

Table 6: Load calculation for second condition

Second Condition					
No.	**Description**	**Power, W**	**Max Current, A**	**Diversity factor**	**Estimated Current, A**
1.	Laptop with AC adapter	85	0.14	100%	0.14
2.	Downlight Lamp	15	0.07	66%	0.0462
	Total	100	0.21		0.19

The last parameters that need to be observed in this system is the total energy consumption which will indicate the potential of energy saving. This will be calculated in the system by utilizing the values of power consumption that is already recorded. Both readings of the energy consumption for the first and second condition will be compared. The differences between the two conditions can be seen whereas the energy consumption during the first condition is much higher due to all electrical appliances are switched ON while on the second condition where only two are switched ON. The comparison is shown on graph on Table 7 and Figure 11.

Table 7: Energy Consumption for condition 1 and 2

Total Energy Consumption, kWh					
Condition 1			Condition 2		
Energy, kWh	Time	Date	Energy, kWh	Time	Date
1.43	7:00 AM	27/12/2021	0.01	12:00 AM	1/1/2022
2.22	8:00 AM	27/12/2021	0.51	1:00 AM	1/1/2022
3.00	9:00 AM	27/12/2021	0.92	2:00 AM	1/1/2022
3.79	10:00 AM	27/12/2021	1.3	3:00 AM	1/1/2022
4.58	11:00 AM	27/12/2021	1.66	4:00 AM	1/1/2022
5.37	12:00 PM	27/12/2021	2.03	5:00 AM	1/1/2022
6.16	1:00 PM	27/12/2021	2.45	6:00 AM	1/1/2022
6.96	2:00 PM	27/12/2021	2.86	7:00 AM	1/1/2022
7.75	3:00 PM	27/12/2021	3.23	8:00 AM	1/1/2022
8.55	4:00 PM	27/12/2021	3.58	9:00 AM	1/1/2022
9.41	5:00 PM	27/12/2021	3.94	10:00 AM	1/1/2022
10.27	6:00 PM	27/12/2021	4.46	11:00 AM	1/1/2022
11.13	7:00 PM	27/12/2021	4.87	12:00 PM	1/1/2022
12.13	8:00 PM	27/12/2021	5.22	1:00 PM	1/1/2022
13.02	9:00 PM	27/12/2021	5.55	2:00 PM	1/1/2022
13.86	10:00 PM	27/12/2021	5.96	3:00 PM	1/1/2022
14.7	11:00PM	27/12/2021	6.35	4:00 PM	1/1/2022
15.56	12:00 AM	28/12/2021	6.96	5:00 PM	1/1/2022
16.41	1:00 AM	28/12/2021	7.41	6:00 PM	1/1/2022
17.22	2:00 AM	28/12/2021	7.9	7:00 PM	1/1/2022
18.04	3:00 AM	28/12/2021	8.33	8:00 PM	1/1/2022
18.85	4:00 AM	28/12/2021	8.79	9:00 PM	1/1/2022
19.70	5:00 AM	28/12/2021	9.15	10:00 PM	1/1/2022
20.55	6:00 AM	28/12/2021	9.49	11:00 PM	1/1/2022
21.4	7:00 AM	28/12/2021	9.82	12:00 AM	2/1/2022

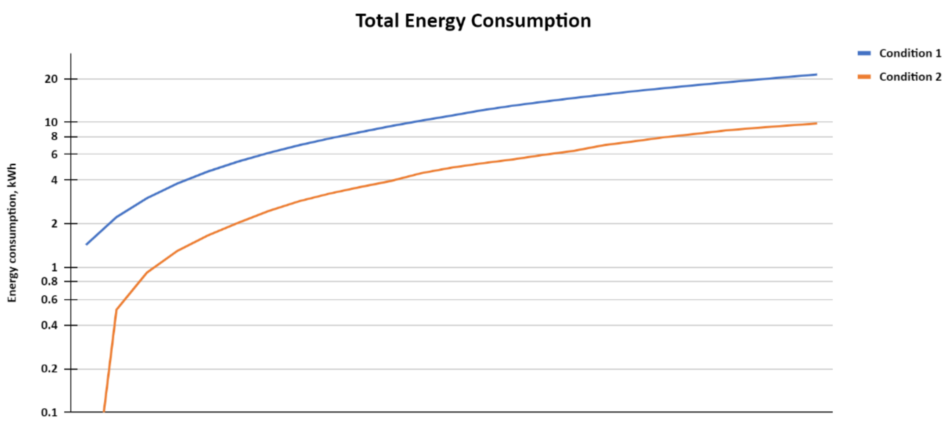

Figure 11: Total energy consumption on Condition 1 and 2

In 24 hours of testing, the first condition resulted in an increment of energy consumption where the electrical appliances that in ON are electrical thermoflask, laptop and a downlight lamp. Additionally, the final reading of the energy consumption on first condition after the 24 hours period of testing is 21.4 kWh. Meanwhile, 9.82 kWh is recorded for second condition where only a laptop and fan are switched ON.

Table 8 shows an average billing information for first and second condition with the tariff rate is considered as 21.8 sen/kWh for the first 200 kWh. On the first condition, with all the electrical appliances are ON for about 24 hours recorded is 21.4 kWh will have the total electricity bill of 466.52 sen or RM 4.67. Meanwhile, for second condition with only laptop and downlight lamp are ON, the final energy consumption is 9.82 kWh that contribute to the electricity bill of 214.076 sen or RM 2.14. It can be seen that the electricity bill on first condition is higher than the second condition due to more electrical appliances used during that time.

Table 8: Billing Information for condition 1 and 2

Condition	Energy Consumption, kWh	Tariff Rate, sen/kWh	Electricity Bill, sen
1	21.4	27/12/2021	466.52
2	9.82	27/12/2021	214.076

From the electricity bill compared for both the first and second condition, it can be concluded that in a day there is a saving of 252.44 sen. A calculation can be made to find out the total saving in a month when comparing both the first and second conditions. Assuming that the appliances are operating continuously 24 hours a day in a month, the total energy consumption shown in Table 9 for the first condition is 642 kWh while for second condition is 294.6 kWh.

Based from the standard tariff rate by TNB, the total estimated bill in a month for the first condition is RM 254.73. The second condition without having to switch ON the electrical thermoflask resulted in RM 75.20 for the total estimated bill in a month. Comparing these two conditions, the total saving in a month is RM 179.53. The value is quite high for residential used and shows the importance on saving the energy in the future.

Table 9: Total estimated bill for a month

Condition	First Condition	Second Condition
Energy consumed per day, kWh/day	21.4	9.82
Energy consumed per month, kWh/month	642	294.6
First 200kWh (1-200kWh) per month Tariff rate: 21.8sen	RM 43.60	RM 43.60
Next 100kWh (201-300kWh) per month Tariff rate: 33.4sen	RM 33.40	RM 31.60
Next 300kWh (301-600kWh) per month Tariff rate: 51.6sen	RM 154.80	-
Next 300kWh (601-900kWh) per month Tariff rate: 54.6sen	RM 22.93	-
Total Estimated Bill	RM 254.73	RM 75.20
Estimated saving	RM 179.53	

4. Conclusion

It can be concluded that IoT Based Smart Home with Monitoring and Control System project has been completed successfully despite some technical issues faced during the development. This project is a solution to the energy consumption problem where the amount of energy used can be monitored and minimize its usage by implementing the ability to control electrical appliances from a smartphone. This able to increase the user awareness on how important in saving the energy for the future.

The first objective achieved for this project is the hardware development to build a wiring circuit for the electrical appliances used for this system testing phase. The second objective is the development of smart system based on IoT which uses the Blynk application as platform to control the electrical appliances and also monitor the current usage with the power consumptions. With the successful development of a programmed code, the utilization of Blynk is a success since the Blynk interface developed are smoothly operated.

The third objective achieved is the integration between the hardware with the developed smart system using IoT platform into a single system is successfully tested. The result shows that the system is robust and compatible enough for home appliances with the power consumption details can be displayed and acquired.

Acknowledgement

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