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THE DEVELOPMENT OF IoT CONTROLLED HYBRID POWER SWITCHING

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ABSTRACT

This paper discusses the development system of IoT Controlled Hybrid Power Switching to provide consumer a system which allows them to manage their hybrid electricity sources. The generations of electricity can be produced by various of resources such as conventional and renewable resources. The existing method of generating electricity through renewable resources for instance a small scale of stand-alone solar photovoltaic system or pico-hydropower system gives consumers the ability to generate their own electricity source. In general, generated electricity from the resources is able to store in energy storage devices such as rechargeable lead-acid batteries. The main reason for generating electricity from renewable resources is that to reduce consumer dependence on depleting conventional resources at the same time they can experience monthly electricity bills saving. Without wasting the existed conventional resources, two different electricity generation can be combined thus creating a hybrid power system. The system is developed in order for consumers to consume both resources efficiently without producing any energy waste. The objectives development of IoT Controlled Hybrid Power Switching could help the consumer to manage both their electricity generation and consumption more effectively thus able to reduce their monthly electricity bills with more savings. This system provides flexibility for consumer to choose their options on how to consume electricity consumption. The available options are Auto-Mode and Manual-Mode. Both options using different methods consuming generated electricity. The Auto-Mode implementing an IoT element that provides consumers the ability to control electricity consumption through the Blynk application on smartphones. The switching between two sources is based on the percentage level of battery voltage capacity. For the Manual-Mode, the option gives the consumer the capability to control switching between two sources based on the time set by the consumer. Both options are able to deliver advantages to consumers in order to manage their electricity consumption dynamically.

Keywords: IoT, hybrid power, electric.

INTRODUCTION

Nowadays, there are two elements of electrical sources that had been consuming by the majority of people around the globe. It can be categories into two categories which are the conventional power source and renewable energy source. The conventional power source which basically the main supply comes from power distribution grid line a generation from coal or hydropower plant. As a renewable energy resource, electrical energy comes from the harvesting of solar energy, wind energy, hydropower, and biomass.

These two power sources have been a huge dependency for humans on electricity consumption. As decades have passed, the conventional electrical power source as in Tenaga Nasional Berhad (TNB) already had an organization that was able to manage or organize the activity for the electric generation and consumption. However, the management is not applicable for electricity generated by renewable energy resources. The system is standalone, only fully controlled by the user itself. These proven that the usage of conventional electrical power and standalone renewable energy electric generator are not connected or communicate with each other. Hence, an appropriate system is needed to able a switching activity between these 2 power sources efficiently controlled. The consumption of renewable energy resources as an alternative electric power generation is meant to reduce the consumer electric bill monthly. As follows, a device is needed for any household or building that consumes both conventional electricity and electricity generation from renewable energy resources. The device could able deliver a system that able the consumer to monitor and switching between these 2 sources directly or indirectly. In other words, without using an impropriate device or any system implementation to manage the consumption flow of 2 electricity sources, it might be a result of the inefficiency consumption of these sources. Particularly, the utilization of a switching device would tackle the waste of energy problem that happened day by day of these sources. Thus, creation of the device or system would lead to able of reducing the monthly electricity billing and waste of renewable energy electricity generation.

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HYBRID POWER SOURCE

A hybrid can be defined as a composition of different elements. A hybrid system is referred to a term of reactive structures, which incorporate with discrete and continuous components (Maler, Manna, & Pnueli, 2005). Hybrid power source is specified to a system that powered up by two or more power sources which either generated from conventional energy or renewable energy resources. Implementation of two or more power sources to supply for a system can be seen at buildings or residential area. They are designed to suit the needs of electric power generation and utilization. The purpose of combining two or more power supply sources is intended for consumer be undependable on electricity generated by conventional resources since it is limited and decreasing days by days. Besides that, also to be considered that electricity generated by conventional resources can't immediately rid off and need to be fully utilize since the resources are still can be take advantage of it.

An alternative renewable energy resource is a preferable choice for consumers not depend much only on one resource. In addition, hybrid energy solutions are a very effective alternative power supply option for stand-alone renewable energy system applications (Kaldellis, 2010). An article was published by a Solar Technologies Company, SUNPOWER about Advantages and Disadvantages of Hybrid Solar Energy Systems mention that hybrid power source could allow effective use of the renewable energy sources such that batteries are linked to the energy storage network hence there is no wasting of excess energy produced on sunny days (Resources, 2018). Besides that, when renewable energy technology becomes more developed, interest in the advantages of integrating two or more energy sources is growing linearly thus creating hybrid electricity.

Apart from focusing on hybrid power sources in the urbanization areas, there is research has been conducted in 2005 title Optimized Model for Community-Based hybrid energy system. The case study of the research conducts an evaluation of installing a hybrid energy system consisting of micro-hydro, solar photovoltaic and wind energy near the rural areas of Western Ghats in Kerala, India. The research also mentions that a various combination of renewable energy resources merges together to create a hybrid energy system could minimize the life cycle cost in a rural community area (Ashok, 2006). Based on the research paper it shows that the demand for a hybrid power sources is needed all over the premises category. The hybrid power source is not bound with a combination of electricity from the utility grid networks and renewable energy systems, however it can be both supplies are generated from renewable energy sources. For example, a combination of wind energy from a turbine and solar energy from a solar photovoltaic panel would be sufficient enough in a certain rural area. For this project, other than combining power supply from utility grid network and electricity generated from renewable energy system to establish the term of hybrid power system, it can both such that consumption of electricity depending on renewable energy system only.

METHODOLOGY

A flowchart showing the overall methodology of the project process. In this project, the process is divided into 2 sections which installing the stand-alone PV system and configuring the switching system. In analysis section has a set-up of the project and results achieved with the project.

Figure-1 and Figure-2 below show the overall flow of the methodology for this project.

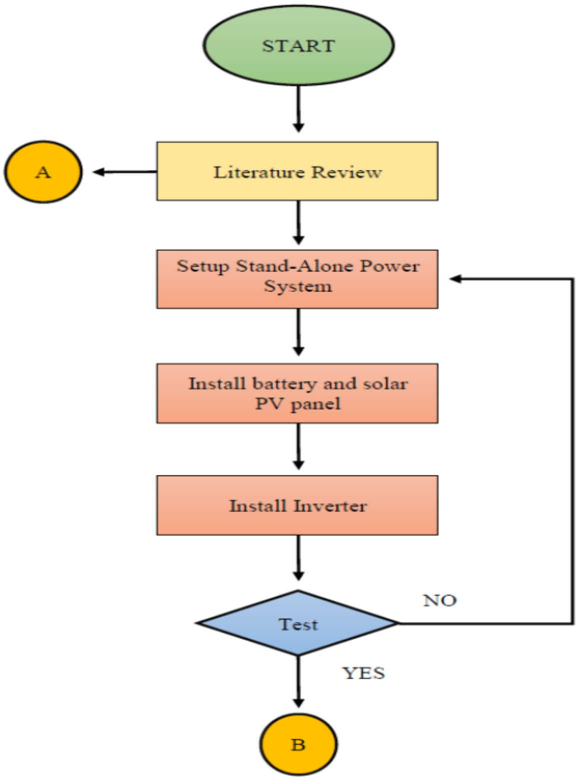

Figure-1. Flow chart for installing the stand-alone PV system.

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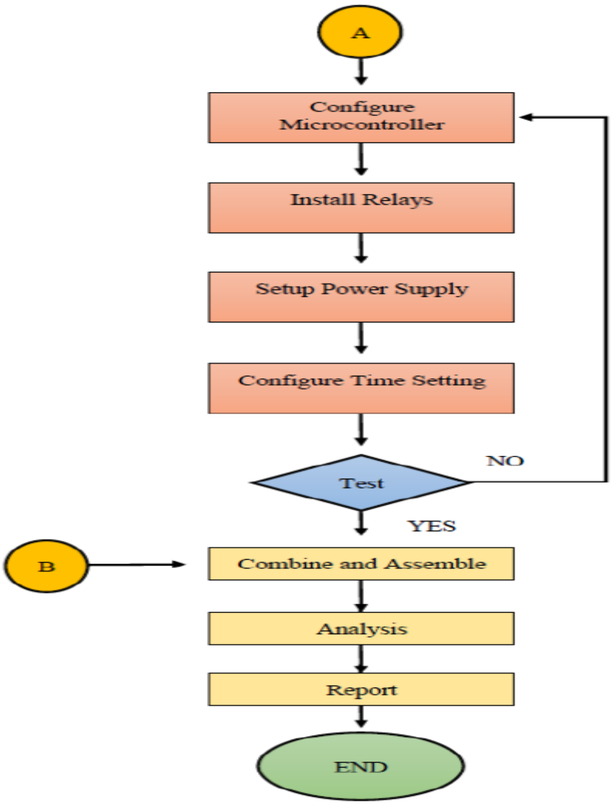

Figure-2. Flow chart for configuring the switching system.

Equipment and Component Selection

The system of this project is controlled by the Arduino Mega 2560 R3 microcontroller. The microcontroller had enough required input and output pin terminals. Figure-3 below shown the microcontroller board.

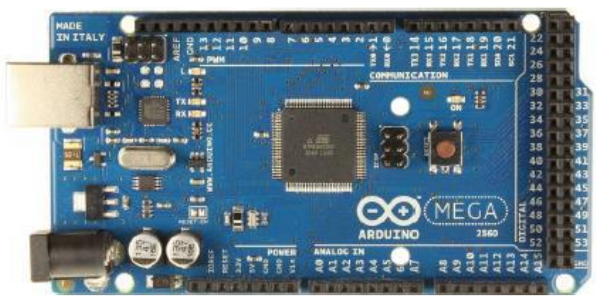

Figure-3. Arduino mega 2560 R3 board.

Modules such as i2C 16x2 LCD and 4x3 Membrane Keypad are used for consumer to interact with the system. Both these modules will ease consumer to navigate and controlling desired setting of the system. Figure-4 below shown both implemented modules.

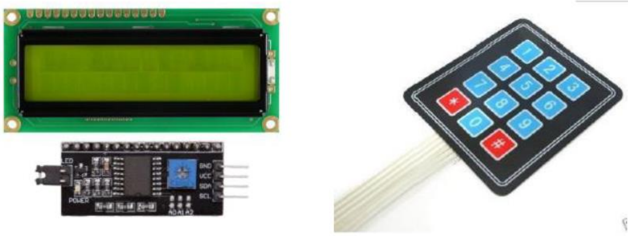

Figure-4. i2C 16x2 LCD and 4x3 membrane keypad modules.

Real-Time Clock 1307 (RTC) Module is used in this project which gives consumer access to control switching process based on time setting. This module is implemented in Manual Mode of this project. Figure-5 shows the module used.

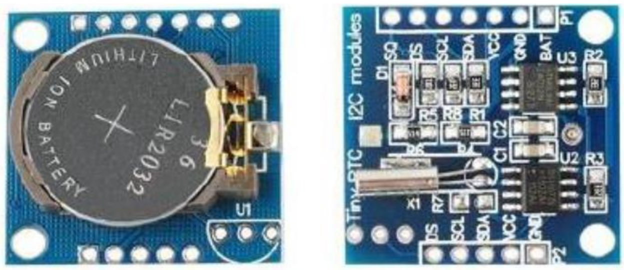

Figure-5. Real-Time Clock (RTC) 1307 module.

Voltage Sensor Module and ESP8266-01 WiFi module are used in this project system which enable consumer to control switching process based on battery voltage percentage. The process is fully controlled via Blynk application through consumer smartphone. Figure-6 below shows all the components used for this Auto Mode.

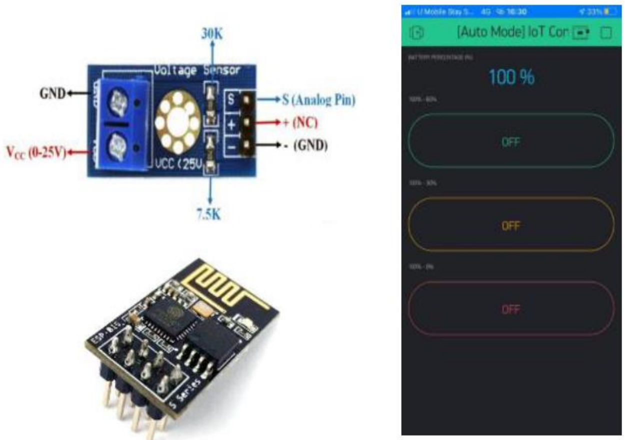

Figure-6. Voltage sensor, ESP8266 Wi-Fi module.

The switching process would be performed by the 4-Channel 5V Relay Module. Figure-7 below shows the module used in this project.

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Figure-7. 4-Channel 5V relay module.

Data Collection

The data power consumption for both loads of the prototype project is taken by assuming both loads powered for 24 hours and having loads power of 0.1kW. Hence, the rates of consumer electricity bill in Ringgit Malaysia can be obtain by referring to calculations shown in Table-1below.

Table-1. Consumer electric bill without implement IoTCHPS system.

Consumer Monthly Electric Bill (without IoTCHPS System)
• Total Loads Power (kW) = 0.1kW • Hours of loads operation (per month) = 720 hrs/month
• Total kWh loads per month (kWh/month) = (0.1kW) x (720h/month) = 72kWh/month • Total price consumer electricity bill per month (RM/month) = (72kWh/month) x (RM0.218/kWh) = RM15.70/month

RESULT AND DISCUSSIONS

Figure-8 below shows the fully hardware development of IoT Controlled Hybrid Power Switching

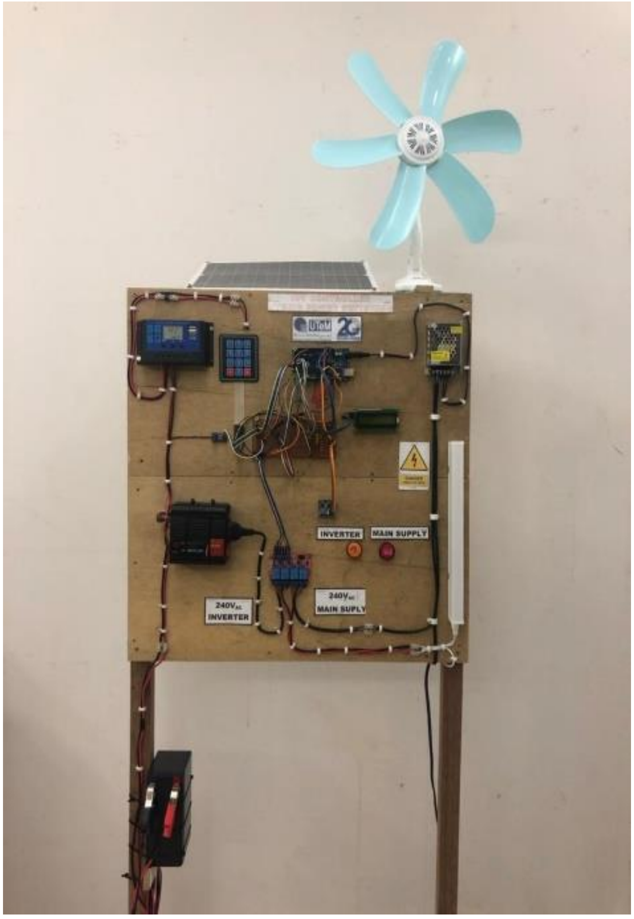

Figure-8. Hardware development of IoT controlled hybrid power switching.

Performance of Manual Mode

Figure-9 shows consumers can control the switching process between two different sources based on desired time setting. The “ON” value would be indicating of time to power up the loads using the inverter source, while the “OFF” value would be the cut-off time powering the loads using the inverter source.

Figure-9. Configuring “ON” and “OFF” value of manual mode.

The operation of Manual Mode gives user an independent experience to fully control switching between two difference electricity sources to power the loads by setting the ON and OFF value correspond with current time. Ideally, this mode is focusing on charging the 12V lead-acid battery that installed on the stand-alone solar PV

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system during the peak-sun hour (PSH) occurs. Figure-10 below shows timeline to guide user in controlling the switching timing for the Manual Mode.

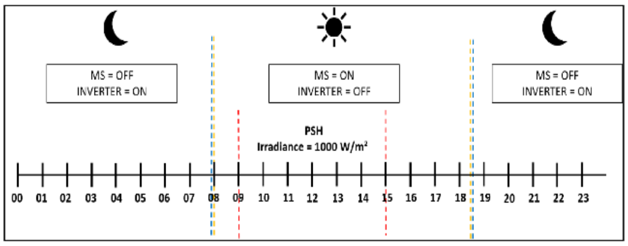

Figure-10. Timeline to guide user in controlling the switching timing for manual mode.

Based on the Solar Panel MALAYSIA website, the occurrence of PSH in Malaysia region are approximately 4 hours a day starting from 11am until 3pm per day. When PSH occurs, it is ideal for user to power on the loads using electricity from the main supply while the 12V lead-acid battery is being charge by the solar PV system. Hence, the Manual Mode feature gives an advantage for user to fully utilize occurrence of peak-sun hour to charge 12V lead-acid battery to the fullest as for uninterruptible power supply (UPS) or as for to save monthly electricity consumption bills.

Performance of Auto Mode

In Auto Mode, consumer able to control the switching process based on 12V lead acid battery percentage level using Blynk application through their smartphone. Figure-11 below shows the interface provided in Blynk application for user to control the switching process.

Figure-11. Result of trimming area vs time for string method.

Figure-12 below shows the depletion of the battery voltage capacity against it discharge time in hours. The graph shown that the maximum voltage capacity of the battery able to achieve approximately 12.4V while the maximum discharging value of the battery is approximately at 11.3V. The 12V 7Ah rated lead acid battery required about 5 hours to be fully discharge.

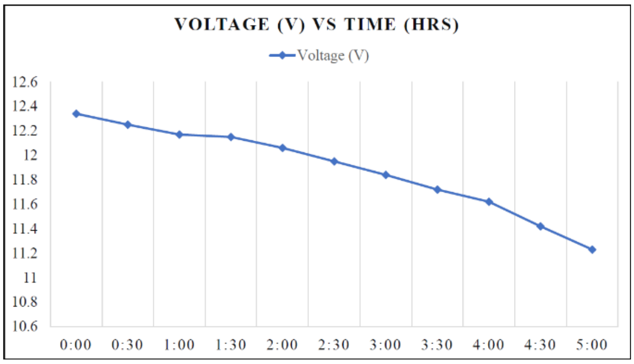

Figure-12. Depletion of battery voltage capacity against discharge time in hours.

Figure-13 below shows the result of switching process if the consumer selects V1 button for their percentage consumption of using battery to power the loads. The Blynk widget display showing the current battery level percentage at 100% and 58%. When the battery level percentage is still at 100%, the loads are consuming electricity from the lead acid battery. And when the battery level percentage is reach to below 60%, the loads are consuming electricity coming from the main supply. The switching method is the same when user choose V2 and V3 as their options.

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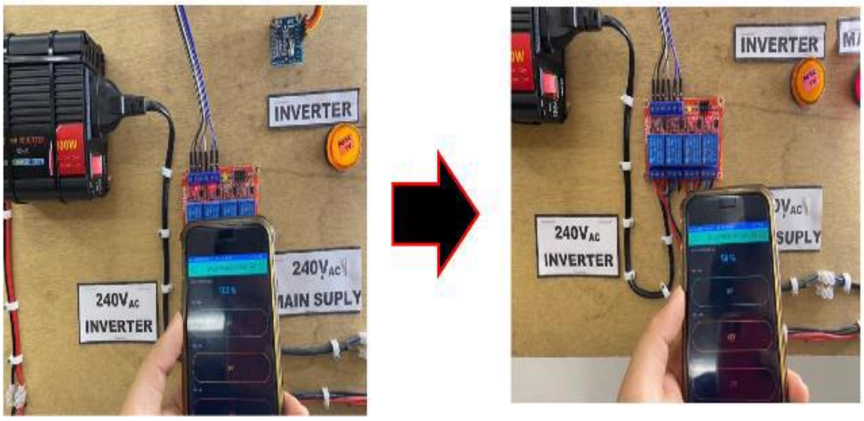

Figure-13. Result of trimming area vs time for two blade method.

To prove that IoT Controlled Hybrid Power Switching able to save consumer monthly electricity bills, Table-2 and Figure-14 below shown the comparison of the billing cost per month if the system implemented to power the loads and without the system to power the loads. The table calculation is based on Tenaga Nasional Berhad (TNB) electricity bill tariff rates calculation updated on 1st January 2014. The tariff rate would be focus on Tariff A for domestic consumption. It shown that for the first 200kWh (1-200kWh) per month, the updated tariff rate is 21.80 sen/kWh with a condition of minimum charge RM3.00.

Table-2. Comparison of the billing cost per month between system implemented to power the loads and without the system to power the loads.

Assume
• Total loads used (kW) = 0.1kW • Hours of loads operation (per month) = 720 hours/month
Without Manual Mode IoT Controlled Hybrid Power Switching
• Total kWh loads per month (kWh/month) = (0.1kW) x (720h/month) = 72kWh/month • Total price consumer electricity bill per month (RM/month) = (72kWh/month) x (RM0.218/kWh) = RM15.70/month
With Manual Mode Iot Controlled Hybrid Power Switching
• Total price consumer electricity bill per month without system (RM/month) = RM15.70/month • Total price consumer electricity bill per month generated by stand-alone PV system (RM/month) = (0.1kW) x (405h/month) x (RM0.218/kWh) = RM8.83/month • Total price consumer electricity per month with system (RM/month) = (RM15.70/month) - (RM8.83/month) = RM6.85/month

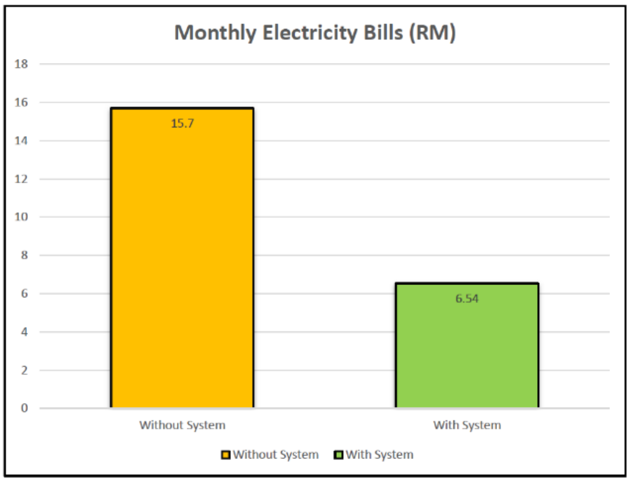

Figure-14. Comparison between monthly electricity bills without the system and with the system.

CONCLUSIONS

The developed system then is tested based on their functionality and efficiency in a real situation. This to make sure that the system is able to deliver the desired output to the user without causing any error or short circuit. Based on the results and data included in this paper, it is proven that the switching process able to perform smoothly without causing any error to the system. This is because there is a timing delay implement between the switching process to avoid any short circuit happened. Plus, the system able to power the loads according to the settings set by the user. From this, I have achieved my second objective that is to test the developed system functionality and efficiency with a real situation.

The main purpose developing this system is to save user's monthly electricity bill without discarding the existing electricity sources. The system also help user to manage the consumption of electricity supply more efficiently and effectively without causing any electricity waste. After able to test capability of the system, user can experience up to 44% of their monthly electricity bill. The system also capable to monitor percentage value of battery voltage capacity through the implemented displays and smartphone Blynk application. Thus, I have achieved my third objective which is analyse the capability of the system to tackle the stated problem efficiently.

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