SMART WATER SYSTEM WITH INTERNET OF THINGS (IOT)

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SMART WATER SYSTEM WITH INTERNET OF THINGS (IOT) WHICH HAS BEEN APPROVED BY THE FACULTY OF ELECTRONIC AND COMPUTER ENGINEERING

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DECLARATION

I declare that this report entitled "SMART WATER SYSTEM WITH INTERNET OF THINGS (IoT) " is the result of my own work except for quotes as cited in the references.

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Date : 6 JULY 2020

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Electronic Engineering with Honours.

Signature : ____________________________

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Date : 6 JULY 2020

DEDICATION

This thesis is dedicated to my parents, Professor Dr. Abdul Amir Bin H. Kadhum and Sardanah Binti Abdul Shukor, my brother, Abdul Aziz bin Abdul Amir for endless love and support. To my lecturers, Encik Mazran Bin Esro and Dr. Siva Kumar A/L Subramaniam and friends, thank you for the guidances and helps till this thesis is successfully done.

ABSTRACT

Malaysia is blessed with rain and sunlight every day in a year. The continuous supply of solar energy should be utilised efficiently to optimised free electrical energy. Water crises have led to water rationing and impacts on consumers' life and well-being. Therefore, this project aims to design and develop a Smart Water System with Internet of Things (IoT) and to implement renewable energy such as solar to the system. This project is a prototype covers the hardware part, software part and system integration. The hardware part consists of the ESP 32 microcontroller, solar panel, DHT 22, voltage sensor, ultrasonic sensor, smartphone, above ground pipeline and 10 L of water tank while the software part used are Arduino IDE which uses C++ language, Blynk app and java script for the Blynk local server. This project is conducted in Kajang, Selangor. As the result, the deep sleep mode in ESP 32 can save voltage consumption by 99.99%. Besides, real time monitoring Blynk app dashboard consists of graphs of rainwater level (cm, L and %) and energy monitoring (Vrms, Irms, W and kWh), display value of temperature (◦C), humidity (%) and water pump status (on/off). The comparison 10 L of rain water and 10 L of paid water resulted to the reduction of 84.4319 % monthly bills. Therefore, this project achieved its objectives and contributes in world Sustainable Development Goals (SDG).

ABSTRAK

Malaysia diberkati dengan hujan dan cahaya matahari setiap hari dalam setahun. Tenaga suria yang berterusan harus digunakan dengan cekap untuk mengoptimumkan tenaga elektrik yang percuma. Krisis air mengakibatkan catuan air dan memberi kesan kepada kehidupan dan kesejahteraan pengguna. Oleh itu, projek ini bertujuan untuk merancang dan membina Sistem Air Pintar dengan Internet of Things (IoT) dan menggunakan tenaga boleh diperbaharui seperti system solar dalam system tersebut. Projek ini adalah prototaip yang merangkumi bahagian perkakasan, bahagian perisian dan integrasi sistem. Bahagian perkakasan terdiri daripada mikrokontroler ESP 32, panel suria, DHT 22, sensor voltan, sensor ultrasonik, telefon pintar, saluran paip atas tanah dan tangki air 10 L sementara bahagian perisian yang digunakan adalah Arduino IDE yang menggunakan bahasa C ++, aplikasi Blynk dan java skrip untuk server tempatan Blynk. Projek ini dijalankan di Kajang, Selangor. Hasilnya, mod tidur dalam pada ESP 32 dapat menjimatkan penggunaan voltan sebanyak 99.99%. Selain itu, papan pemuka aplikasi Blynk pemantauan masa nyata terdiri daripada grafik paras air hujan (cm, L dan %) dan pemantauan tenaga (V, A, W dan kWh), paparan nilai suhu (◦C), kelembapan (%) dan pam air status (hidup / mati). Perbandingan 10 L air hujan dan 10 L air berbayar menghasilkan pengurangan 84.4319% bil bulanan. Oleh itu,

projek ini mencapai objektifnya dan menyumbang dalam Matlamat Pembangunan Lestari (SDG) dunia.

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May God shower the above cited personalities with success and honour in their life.

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Eqn.	:	equation

CHAPTER 1

INTRODUCTION

1.1 Introduction

Malaysia is a water-rich country. It recorded an annual rainfall of 907 million cubic meters (m^3) in 2016 [1]. The average annual precipitation ranges from 2,000 mm to 4,000 mm per year [1]. The availability of water resources makes it possible for us to sell water to neighboring Singapore [1]. 95 percent of the population have access to water when it comes to providing water to customers [1]. The water tariffs of the nation are also one of the lowest in the world [1]. There is no cap on water use as well. It seems unlikely for Malaysians to face water shortages with the abundance of water resources. The nation has faced a number of water crises since the 1970s — in 1977 and 1978 in Peninsular Malaysia's northwest; 1982 and 1991 in Kedah and Perlis (the Pedu and Muda Dam), 1998 in Kedah, Penang and Kuala Lumpur (as an impact of the El Nino) and drought impacting Perlis in 2002 and triggering water shortage[1].

Water crises have led to water rationing and have had an impact on many users ' life and well-being. When an exceptionally dry season took place in 2014, the rationing of water lasted for months[1]. Due to low water levels in water treatment plants, 85,000 people are facing water rations in Johor in 2016[1]. Malaysia also faces the Non-Revenue Water (NRW) issue. This is one of the main causes of shortage of water. NRW's ratio was 35.2 percent in 2016[1]. Perlis reported the highest at 60.7%, while Sabah (52%), Kelantan (49.4%), Pahang (47.9%) and Kedah (46.7%) were the other states that registered more than 40%[1]. Compared to Japan (3%) or Singapore (5%), the rates are extremely high[1]. Mostly, as a result of tube leakage and water theft, water loss occurs. Household and commercial water users can and should be actively involved in reporting the matter to the authorities. When we mentioned the incidents, issues such as tube leakage or burst pipe could be solved sooner. Nevertheless, they are customers. Consumers have a direct impact on issues with heat. Excessive heat, for example, leads to waste. The average water consumption per person (water consumption per capita) in 2014 is 211 liters per day, based on the Malaysia Water Industry Guide (2015). Water consumption varies by state— Penang is the highest water intake per capita of 293 liters per day and Sabah is the lowest (114 litres). There is indeed a high consumption of water among Malaysians. Our job is to conserve water. Water is essential to all life forms; the loss of water resources would also destroy other life forms. Water must be protected to protect the lives of other animals. Water recycling is one aspect I find in the report to be sorely lacking. When water resources are exhausted and poisoned, the bleak prospect of water rationing, polluted water, and even no water for long spells during the dry season is faced by many communities. Therefore, more focus needs to be placed on the 3Rs–i.e. reuse, re-use and increasing the water available [2]. This is all the more relevant because the water supply is limited (the quantity is actually decreasing due to pollution, depletion of catchments, competing interests and other reasons), but the population is increasing. Water demand increases on average about every two decades or so, but the quantity of water for earth remains the same [2]. It is therefore clear that the amount of water per person available would decrease in the future. In other words, the same amount of water should be shared by more people. If water pollution is considered, there will be even less water available. Therefore, recycling would no longer be an option but a must in the near future [2]. Government plans must be accepted by the public in order to work. There is no improved use of water supply (supply management) by building dams and treatment plants if water is still being wasted and exploited by the public. Effective management of water resources requires government, industry and community cooperation [2]. Controlling demand, i.e. increasing and controlling one's water demand, is essential to effective water management [2]. It's bad enough when households and businesses suffer from dry spells from time to time, but what's worse is that water supply interruptions occur with little or no notice more often than not [3]. Unplanned water cuts in Peninsular Malaysia last year far outnumbered scheduled water cuts, according to figures from the National Water Services Commission (SPAN) [3]. Many states registered thousands of cases of unplanned water cuts [3]. SPAN said that such disturbances were caused by water source contamination, water shortage due to dry weather, and pipes that burst or leak [3]. This has sparked calls to do more to secure our sources of water and to maintain our water supply [3]. The commission said that large-scale water cuts usually have the most effects on densely populated areas [3].

Number of scheduled and unscheduled water cuts in years 2017 and 2018

	2017		2018	
	Scheduled	Unscheduled	Scheduled	Unscheduled
Johor	691	5,032	621	5,271
Kedah	262	4,355	162	3,003
Kelantan	136	384	137	472
Labuan	0	403	0	266
Melaka	21	117	21	23
Negri Sembilan	26	4,545	18	4,701
Penang	10	4,127	1	4,838
Pahang	281	2,342	325	2,311
Perak	186	13,131	149	26,289
Perlis	5	12	4	7
Selangor	798	19,061	767	11,781
Terengganu	26	1,019	5	663

Source: National Water Services Commission (SPAN)

Figure 1.1: Water cuts in 2017 and 2018

This can be readily attested to by customers and entrepreneurs in Selangor, Kuala Lumpur, Johor, Perak and Penang [3]. Selangor went through 767 expected water cuts in 2018. Nevertheless, there were more than 15 times more unplanned disturbances in the water supply–11, 781 incidents. This is a fresh problem in people's minds in Selangor because in Sungai Selangor, four water treatment plants in the state had to be closed last month due to diesel pollution [3]. Other states last year were Negeri Sembilan and Perak, with alarmingly high numbers of unplanned water cuts. Negeri Sembilan had only 18 planned water cuts but a total of 4, 701 unplanned cuts. Perak had 26, 289 unplanned water cuts compared to 149 scheduled [3]. The fact that data from SPAN for 2013 to 2018 indicates a diminishing number of unplanned water cuts in some states is some help. Cases of unplanned water cuts in Selangor fell from 85, 481 in 2013 to 11, 781 in 2018, by about 86 percent [3]. In Pahang, where the number of unplanned water cuts fell from 8, 379 in 2013 to 2, 311 last year, a similar trend can be seen. Last year, Kedah's amount of unplanned water cuts was half the figure for 2013. Unplanned water cuts by Perak had decreased steadily between 2013 and 2017, but the number of such incidences increased to 26, 289 last year [3]. Johor recorded an increase from 4, 889 unplanned water cuts in 2013 to 5, 271 in 2018 [3]. Certain commercial products such as cleaning fluids, paints or pesticides discarded by commercial establishments or individuals can be defined as hazardous waste similar to the Sungai Kim Kim and Sungai Rui incidents. Failure to protect water supply will be costly to Malaysians [3]. Johor recorded an increase from 4,889 unplanned cuts to 5,271 in 2018 in 2013 [3]. Some industrial items such as cleaning fluids, paints or pesticides discarded by commercial establishments or individuals may be classified as hazardous waste similar to incidents involving Sungai Kim Kim and Sungai Rui. Malaysians would find it costly to fail to secure water supply [3].

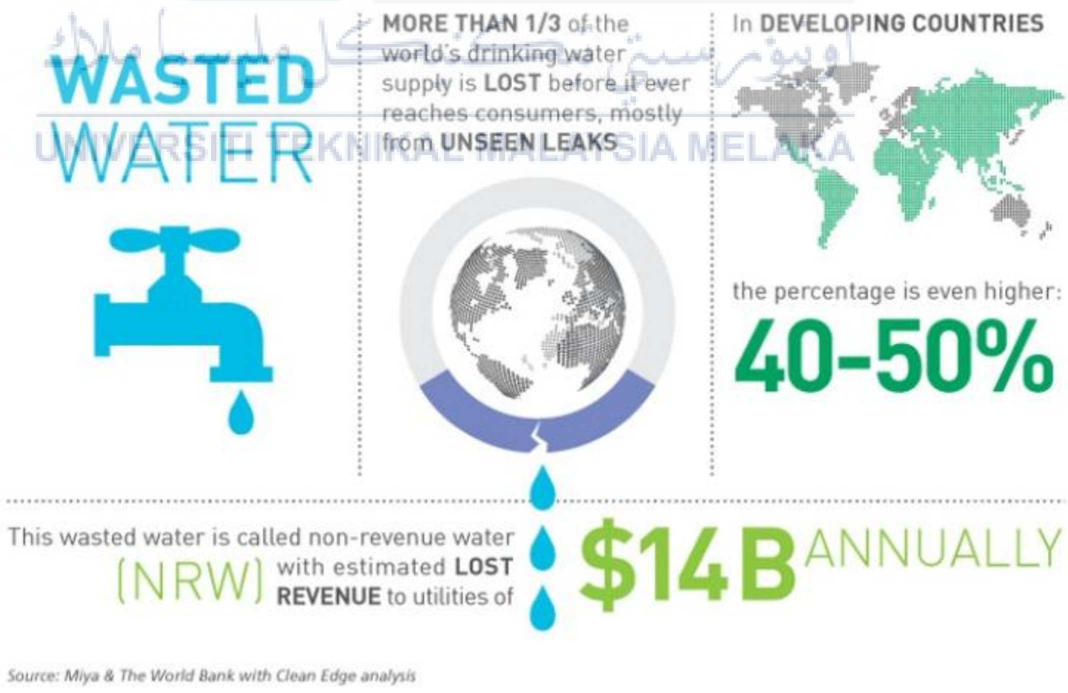


Figure 1.2: World facts on water

Management of water loss is becoming more and more important as resources are strained by population growth or water scarcity. There are historic droughts in many countries, and others are depleting aquifers faster than they are being replenished.

1.2 Background

The state is primarily responsible for the country's water resource project planning, growth and management. State governments and their departments perform the primary role in water resource management. There are a range of departments and agencies in government that are responsible for a particular water resource aspect or purpose. Table 1.1 offers a rundown of the responsibilities and duties of the various water-related departments and agencies.

AGENCY \ FUNCTION	Water supply	Water sanitation	Irrigation	Hydropower	Flood control	Water quantity regulation	Water quality regulation	Watershed management	Integrated area development	Data collection	Research	Cloud seeding	Ports and navigation	Fisheries	Recreation
Department of Chemistry							■								
Department of Environment							■	■		■					
Department of Fisheries														■	
Department of Forestry								■							
Department of Irrigation and Drainage			■		■			■		■					■
Department of Mineral and Geoscience										■					
Department of Sewerage Services		■													
Department of Town and Country Planning								■	■						■
Local Authorities		■			■			■	■						■
Malaysian Meteorological Services										■		■			
Ministry of Health (Engineering Division)	■	■					■			■					
Ministry of Transport													■		
National Hydraulic Research Institute Malaysia											■				
National Water Resources Council	■							■							
Royal Malaysian Air Force												■			
State Water Resources Management Authority						■	■	■	■	■					
Tenaga National Berhad				■											
Waterworks Department	■					■									

Table 1.1: Water agencies ' operational obligations

The overall responsibility for comprehensive planning and water management in the country is not assigned to a single agency. Conflicts in water resource management such as water rights distribution, flood management, pollution control, protection of the environment, etc. are currently being resolved by cooperation and consultation between agencies. It has been taken for granted in the National Five-Year and Perspective Plans that portable water will be made available in urban areas and to a significant extent in rural areas. Nevertheless, due to the rapid rate of urbanization and industrialization, both in terms of quantity and quality, the availability of raw water has been adversely affected. In view of this problem, water supply policy objectives need to meet the growing demand for water and the protection of water resources from potential sources of pollution. Water use is also influenced by the national hydropower policy. While non-consumptive in nature, hydroelectric generation requires water to be kept behind dams to provide the power generation potential. Although non-consumptive in nature, hydroelectric generation requires water to be stored behind dams to provide the potential energy for generating electricity. The importance of this would be felt when less water is made available to downstream water users during periods of low flow.

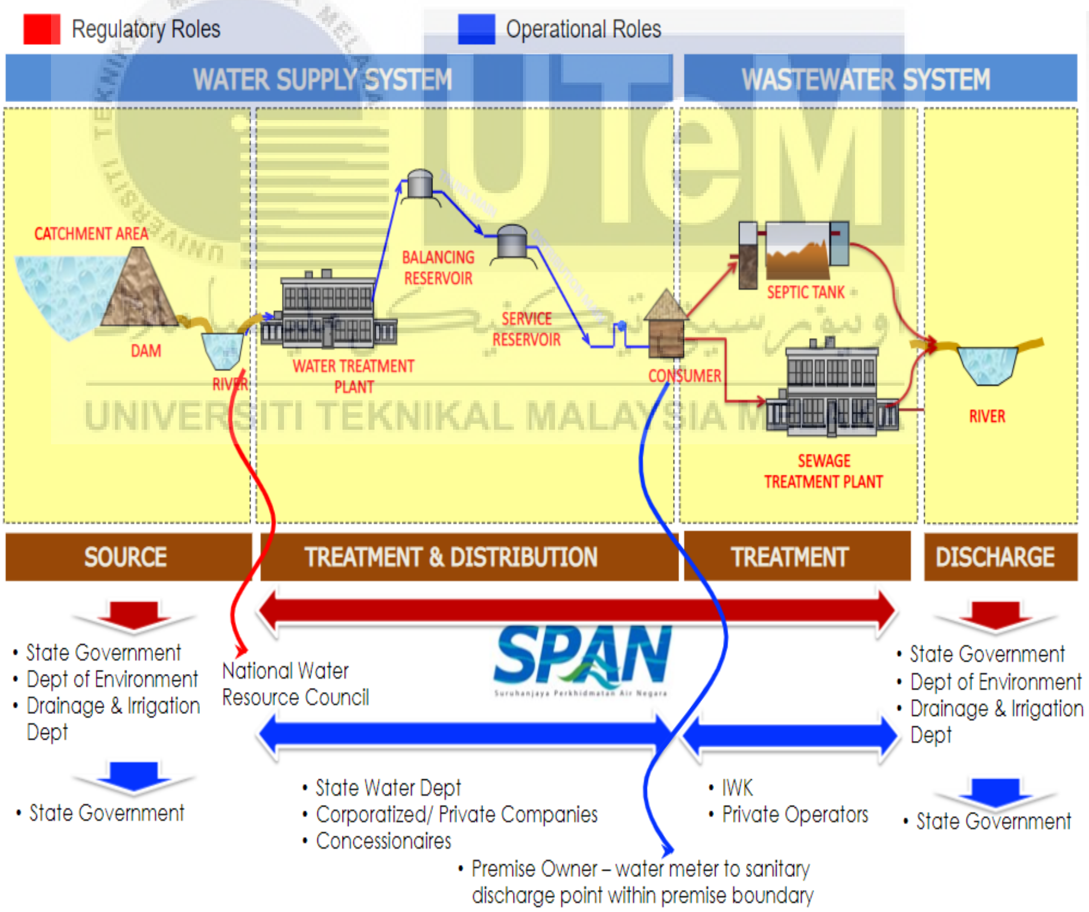


Figure 1.3: Water management in Malaysia

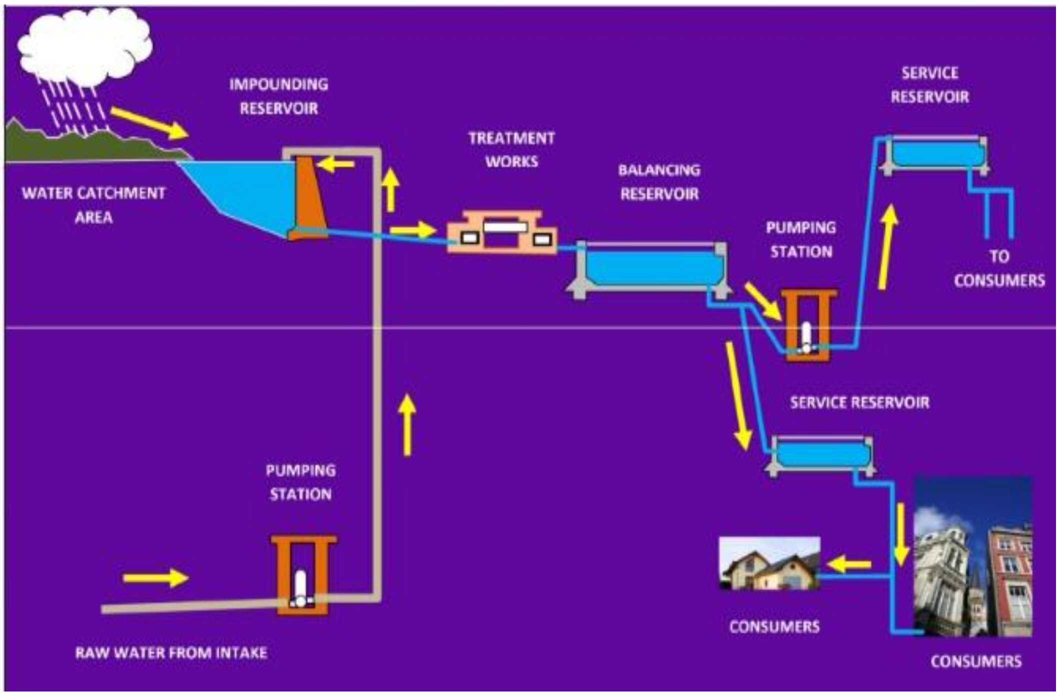


Figure 1.4: Water flow system

Internet of Things (IoT) is the advanced technology that is used to describe as a modern wireless network of telecommunications and a smart and interoperability node interconnected in a complex global network of infrastructure as well as trying to incorporate the idea of connectivity from anywhere at any time [4]. IoT is extended to a wide variety of uses in a variety of different industries, companies, consumers and public sectors and will have a profound impact on the development of markets [4]. One such area is the Water Management System, which is strongly influenced by the Internet of Things. Although ensuring the correct use of water is certainly difficult, proper implementation of IoT technology in Water Management Systems would surely make our lives easier and conserve our valuable resources.

Figure 1.5: Benefits of Internet of Things (IoT) in water system

In terms of water conservation, for dams and overhead water tanks, it is essential to have sensors and equipment specifically designed to view the water level in it. The water level in the reservoir or the overhead tank can be sent to the database at regular intervals with the aid of these sensors to measure the average amount of water used. This whole process of determining the water level in the dam and then comparing it to the main server would certainly help with water conservation. Besides, for smart irrigation, we are seeing a large amount of water being lost during the irrigation process right now. This is because the irrigation cycle is planned automatically, regardless of the weather and moisture present in the soil, at a particular time. With the use of IoT, this water waste issue can be solved. IoT sensors will assess the environment and soil moisture conditions that will help to get the right amount of water to the desired location at the right time. Next, for smart sater sanagement, water conservation is one of the key aspects of water management, especially in urban areas, where it is extremely challenging to keep a record of water consumption. To determine the amount of water consumed by the people in a particular area, we can evaluate the data and weather conditions of that day. This will certainly help water authorities to manage water flow much more effectively. Furthermore, for water waste management, Water management's biggest challenge is controlling water levels, pollution, water quality, and water flow through various channels. In all of these places, IoT will come to our rescue. Sensors mounted at different locations in the water system can detect changes in temperature, water leakage, chemical leakage and pressure. Then the data will be gathered by these sensors and sent to the main server. This will ensure rapid solving of the problems by service engineers. The benefit of IoT in water (waste water management) is that the amount of chemical residue present in water can be detected and measured. For water quality testing and analysis, to calculate and track the data collected and draw real-time analysis of water testing in industries such as manufacturing, electricity etc., the internet of things can be used. IoT can also be used in the sector of public utilities. Using water test meters and sensor tools, the readings are given to end users. Users can obtain information such as Total Dissolved Solids (TDS), Bacteria, Chlorine, Electrical Conductivity, etc. This will help to view the results in real-time, precise quantification and will also provide the ability to identify the areas of concern.

1.3: Problem Statement

Water is essential to human lives. Source of groundwater are increasingly being strained in many areas throughout the world where it is depleting from time to time. This phenomenon has become a global problem and the government spends billions to address it immediately and sustainably and the supply of clean water has depleted Malaysian have to face a crisis such as no water supply from water service providers often in every year. This crisis becomes more serious when it happens at critical hours with no backup source. In addition, it is time-consuming to wait for the water to be distributed from the area to area or even until the problem is recovered. Digging deeper wells is not only expensive but can cause environmental damage such as collapsing of soil where the water used to be. Industries nowadays dispose of various chemical wastes into river which leads to pollution. To solve this solution, since Malayia is blessed with high yearly rainfall, the idea of storing rainwater is triggered as it can use for individual purposes until industries whenever possible. This back up water source safes the unpredictable water distribution from the water service company due to decreasing of water level. Hence, the automated rainwater level can be implemented. However, in this Fourth Industrial Revolution (4IR) era, the enhancement of this project can be done from the ordinary automated water level to smart water system with Internet of Things (IoT) with the implementation of the solar panel as the solar energy harvesting. This smart water system with Internet of Things (IoT) ables to assist human or consumer with the real data monitoring of their own rainwater level storage so they can alert or notified faster. Besides, high save of monthly water bill from water service provider can be guaranteed if the paid water is used for important purposes only that requires hygiene water such as food and bathing. Since, the daily rainfall is different from the other state, the project is done in Selangor area particularly in Kajang.

1.4 Objectives

The objectives of completing this project are as follows:

1.4.1: To design and develop the smart water system with Internet of Things (IoT).

1.4.2: To implement renewable energy such as solar to the system.

1.5 Scope of work

This project is a prototype covers the hardware part, software part and system integration. The hardware part consists of the ESP 32 microcontroller, solar panel, DHT 22, voltage sensor, ultrasonic sensor, smartphone, above ground pipeline and 10 L of water tank while for the software used in this project are Arduino IDE which is using C++ language, Blynk app and java script used for the Blynk local server. This project is conducted in Selangor area particularly in Kajang. The project does not cover filtration of the water sources (rainwater), water quality and pH of water. The integration of the hardware and software build a system named Smart Water System with Internet of Things (IoT).

1.6 Report Structure

This report aims on designing and develop Smart Water System with IoT. This report is classified into five major chapters which are introduction, background study, methodology, results and discussion, also, conclusion and future work. Chapter 1 reviews the background of the project, problem statement, objectives of the project, scope of work and the report structure. Next, Chapter 2 reviews on the literature review which contain the introduction and other studies that relates to this project from different researcher. Furthermore, Chapter 3 reviews the methodology used to achieve the objectives and the scope of work while Chapter 4 is the results and analysis of the data. Lastly, Chapter 5 reviews the conclusion of the system and suggestion for the future enhancement.

CHAPTER 2

BACKGROUND STUDY

We studied out various existing system developed by researchers to design the improving system. Different researchers have proposed variant models to monitor water quality, water leakage by examining the parameters such as pH, temperature and electrical conductivity, pressure and so on. Smart water monitoring system will be developed that can perform some of these monitoring functions by considering all of these criteria.

According to Naram Mhaisen, Omron Abazeed, Youssef Al Hariri, Abdullah Alsalemi and Osama Halabi (2018), the system consists of an IoT module that can be mounted at any source of water, a cloud software for receiving data from devices, and a mobile app for monitoring water consumption at any source monitored. The device allows the user to identify the location and time of inappropriate mobile phone use and leaks and this system allows the user to identify the location and time of excessive mobile phone use and leaks. The results of the experiment support the solution's self-powered concept.

Besides, from Varsha Radhakrishnan and Wenyan Wu (2018), they claimed that IoT enables information to be sent between various electronic devices embedded in new technology. Energy management is possible using mechanisms for energy harvesting, which is a way to collect energy from natural sources such as light, vibration, pressure, etc. Water distribution system(WDS) is important area of research that impacts our country's economic development. WDS mainly has two main problems: first, water loss due to leakage, and second, contamination-prone. This affects people's health and security. The water management system could benefit from the new energy harvesting methods and their desirable properties such as low cost, efficiency, availability and high robustness. The water management system could benefit from the new energy harvesting methods and their desirable properties such as low cost, efficiency, availability and high robustness. The implementation of solar cells seems to be difficult to transfer energy to underground water pipes, while slow process will happen if chemical reaction to generate power is used by the fuel cell. The other three approaches that are commonly used to track water pipes are piezoelectric, electrical and thermoelectric. There are many parameters for detecting water quality, but monitoring all parameters will affect the increase in workload and thus affect analytical quality. For a smart water network to provide water quality data based on an emergency situation and to make a quick decision, intelligent station choice, data fusion and forecasting is important.

Furthermore, M.B.Kawarkhe and Sanjay Agrawal have proposed that the smart water monitoring system using IoT at home will automatically track water quality and is cost-effective and does not require human workforce. To avoid wasting the tremendous amount of water due to unregulated use of home / offices, this method is used. Therefore, testing water quality is likely to be more cost-effective, convenient and quick. This smart water system designed can be generally applied to homes, offices, and schools, and wherever water tanks are used. Residents' water usage trends can be collected and analyzed and save a lot of water from waste by implementing this system in an intelligent building.

According to Prof. Savita Lade, Prathamesh Vyas, Vikrant Walavalkar, Bhaiyasab Wankar and Pranjal Yadav (2018), they proposed a smart water management system for controlling water wastage. The automated level detection method by using ultrasonic sensor is based on the minimum and maximum water level height in the tank that allows the motor's automatic ON / OFF switching. The motor is turned on once the minimum input level is reached and water is filled in the water tank until it reached maximum.

J.Vinoj and Dr.S. Gavaskar (2018) stated that before raining down to ground level to collect it, rainwater harvesting is stored in the tank. Besides irrigation, drink water and livestock, rainforest also is used to store rocks in the ground. From the building roofs, the rainwater is harvested.

Furthermore, S. Harishankar , R. Sathish Kumar , Sudharsan K.P, U. Vignesh and T.Viveknath claimed that the use of water can be optimized by reducing waste and human involvement for farmers by using automatic irrigation system. the excess electricity generated by solar panels can be transferred to the grid with slight changes in the system circuit that can be a source of farmer' income which encouraging farming in India and, at the same time, providing an energy crisis solution. Solar pumps also provide clean solutions without the risk of contamination from the borehole. As they power up on their own, the system requires minimal attention and maintenance.

From Mduduzi John Mudumbe and Adnan M. Abu-Mahfouz (2015), they stated that a smart water management system will make users aware of their use of water and help them reduce their use of water. At the same time, to reduce water loss, users will be notified to abnormal water use. This paper introduces a wireless sensor network (WSN)-based water management system.

The research done by Thinagaran Perumal , Md Nasir Sulaiman and Leong.C.Y (2015) is the IoT-based water monitoring data were analyzed to calculate the reliability and response time of their performance metric. To complete one cycle of sensor feed, the maximum time response is 126ms. In this work, a total of 500 readings have been sampled. The distance between water and ultrasonic is transformed into centimeters (cm) during the experimental design. The results show a linear correlation between the measured distance (i.e. water level) and the time taken to indicate the water level which clearly indicates the accuracy in generating consistent reading for the sampling period.

According to Roshni Gannoju, Nabiha Hasan, Nabeeha Sayeed, Ms. P R Anisha, Dr. B V Ramana Murthy and Mr. C Kishor Kumar Reddy (2019), they claim that as a result of rapid growth in population, there has been an increase in demand for food, housing space, consumer products, etc., which resulted in increased industrialization, urbanization, and agricultural demands leading to contamination of both river and groundwater. To sum up, the current rapid shortage of water is more urgent than ever before.

According to Seung Cheol Kee (2012), through the inlet portion built at the periphery of the solar cell module and stored in the water tank, water such as rainwater can be fed into the water tank, and water stored in the water tank can be used as required. The solar cell panel is mounted on top of the water tank and therefore does not occupy space, thereby avoiding the question of land occupancy and reducing the overall costs associated with it.

The research done by D.V.Ravikumar, R.K.Sudesh, J.Chanthini Mahaboob John, K.Dinesh Kumar and P.Vinupal, they claimed that farming in India, this self-starting irrigation system is economical in a long run. Besides, excess energy able to supply to the grid with small modifications in the system circuit where it can source of farmer revenue.

From Hideyuki Tadokoro and Kazunori Uemura, they stated that optical fibre multi sensing system for sewage pipes. In addition, it also used to deliver electric power to the sensors via an optical power feeding technology. They also claimed that the images and audio data can be used as new sensing media.

Furthermore, according to Kodathala Sai Varun, Kandagadla Ashok KoKumar, Vunnam Rakesh Chowdary and C. S. K. Raju, their research is water level management using ultrasonic sensor (automation). For DC 12V pump with two conditions which are as Figure 1.1 shown.

SI. NO	Input Voltage	Time taken
1.	6V	13 minutes 28 seconds
2.	10V	3 minutes 22 seconds

Table 2.1: Two cases of DC 12V pump

Water level is inversely proportional to the distance measured by ultrasonic. Time duration is directly proportional to the distance and lesser time duration results in higher water level.

Based on Kandagadla Ashok KoKumar, Vunnam Rakesh Chowdary and C. S. K. Raju, IoT is important as it can show the data at centralized location. The data also can be stored for permanent which may useful for further research. The also did put the flood indication nearby people. But, the disadvantage of the system is that the system is not waterproof.

Besides, Duc Canh Nguyen, Anh Dung Dao, Tschung-il Kim and Mooyoung Han had done a research about the sustainability assessment of the rainwater harvesting system for drinking water supply in Cukhe Village, Hanoi, Vietnam. They claimed that groundwater has a very high concentration of heavy metals (arsenic) and NO_2. Besides, rainwater is far less polluted than that listed in the WHO drinking water guideline. Rainwater harvesting (RWH) is relatively inexpensive, effective and sustainable method of supplying clean water. If it is exposed to the sun, the stored water would produce a foul odour. Thus, the storage tank must be covered.

CHAPTER 3

METHODOLOGY

3.1 Overview

This chapter will explain methods that were used to complete this project and achieve project objective. This part will reveal the flow of the project from the beginning until the end of the project. The project will be divided into three parts which are hardware development, software development and project development. The first part involves the connection of sensors and ESP 32 microcontroller. For the software development part, it comprises the uses of Multisim and Proteus software for circuit design and simulation and Arduino IDE for programming language. Lastly, in project development, it will cover website development using Blynk app, blynk local server and PCB layout design using Proteus software.

3.2 Project planning

There are three major parts that require to complete this project, which are planning, implementation and analysis. Project planning is done at the earliest stage of the project. In order to select hardware and software that meet with the requirement, project planning becomes the most vital part of the project. There are several methods being done to complete the project. Based on block diagram in Figure 3.1, the first step includes creating a project schedule that using Gant chart to list out activities need to be done within a time period. Next step is by doing research from previous work to obtain more knowledge regarding this project. Then, hardware and software are integrated to complete circuit that meet project requirements. After that, the project will be created based on the findings and tested with code programmed using dedicated software. Furthermore, the completed circuit will be measured and record using a suitable method in obtaining the project result. Lastly, after the project circuit is working and completed, analysis on its performance and accuracy will be done on the last part.

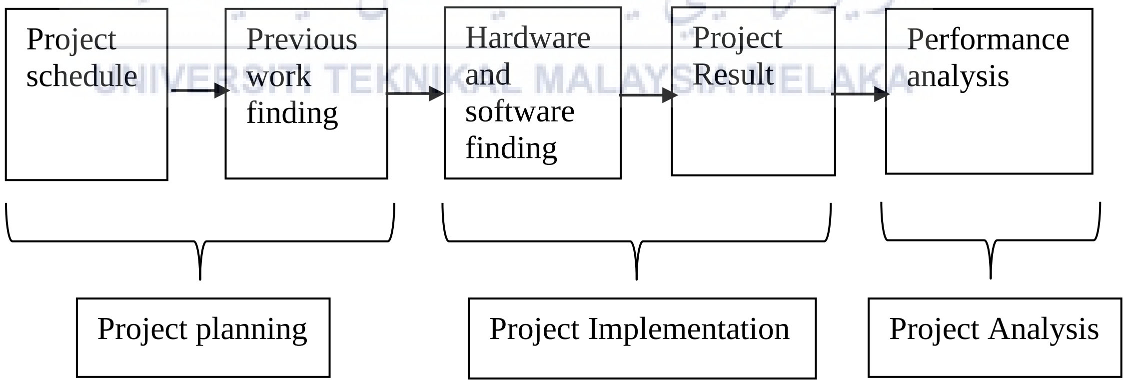


Figure 3.1: Methodology steps

3.2.1 Research methodology flowchart

In order to complete this project, it consists of three parts which are software development, hardware development and project development as shown in Figure 3.2. The flowchart below describes step by step from starting to end of the project. Hardware and software were completed simultaneously at the same time. For project development, it can only be done after getting the first two parts are completed.

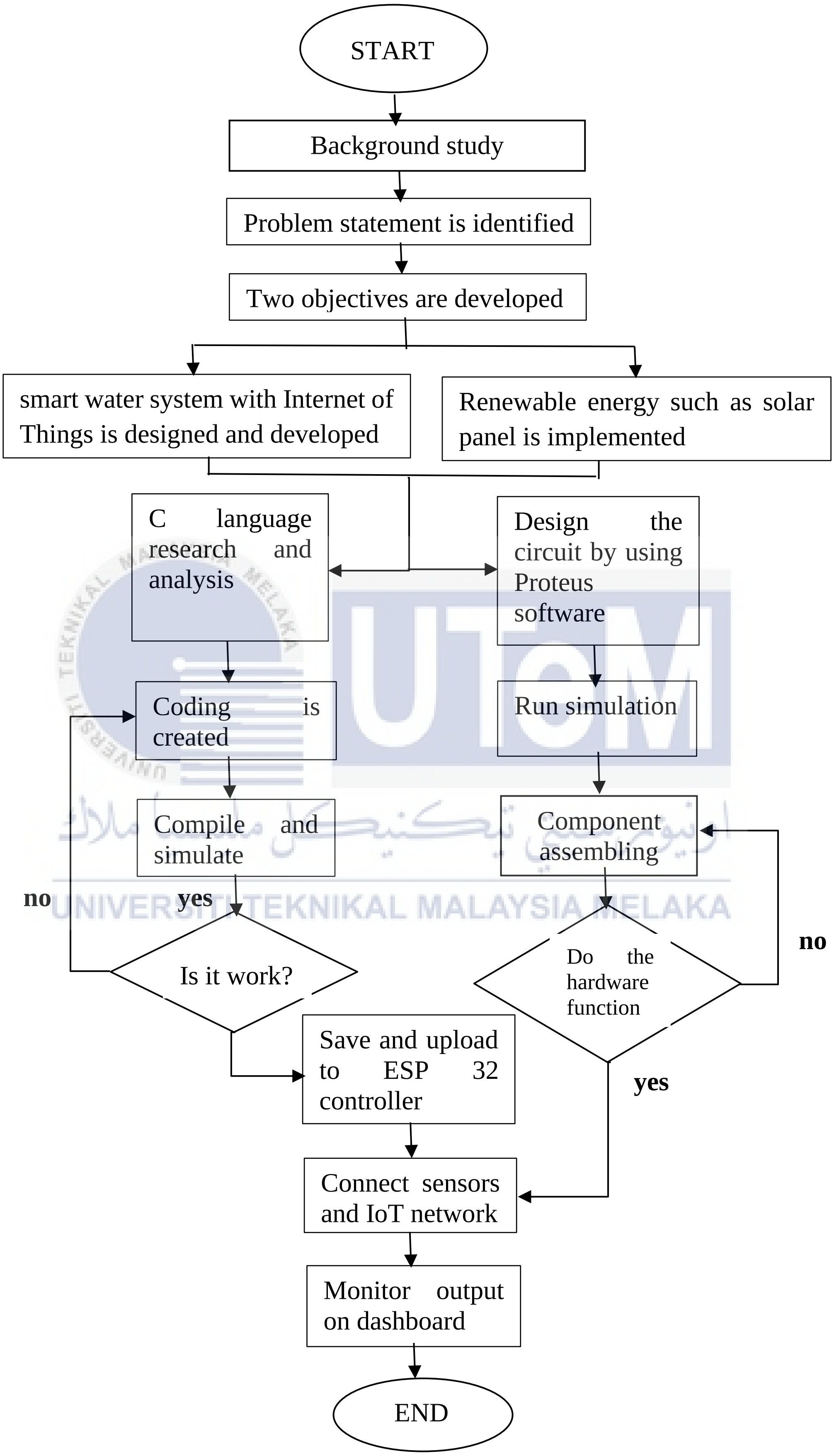


Figure 3.2: Flowchart of project methadology

A detail explanation for the project methodology will be dicussed here.

a. Software development

In this part, I will start to do some research and findings of C language programming that will be used to communicate with controller. Next,I will create programming code and perform compilation process to avoid error in code. This process will be repeated there until there is no error in the coding. Lastly, I will upload this program into a controller to test with a complete hardware circuit.

b. Hardware development

First, I will build the circuit as in simulation software and run some test to avoid any error on hardware connection. After getting a result from the simulation, I will find each hardware that will be used in the project through store. Lastly, each hardware parts will be assembled and going through testing process to make sure it works.

c. Project development

After setting up the hardware and software configuration, it will be integrated in project development. The Arduino Uno board will be configures with sensors and wireless network. Then, I will do some test on the Arduino to make sure it can transmit data between Arduino and Wi-Fi module. In order to monitor the output parameters. I will create a webpage. Lastly, for alerting process I will create an application to send push notification.

3.2.2 Project schedule

In order to finish project, a schedule will be needed to show time span for acertain work that needs to be done. With the use of a Ganttt Chart, project planning can achieve easier and faster where it can show what work need to be done on a specific period. Figure 3.3 shows the planning of the project where software and hardware development of the project should be completed by semester one. For a project development which consists of prototype building and IoT network, it should be done in semester two.

	SEM I																			SEM BREAK					SEM II															
Aktiviti Projek *Project Activities*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Meeting with supervisor to confirm FYP title and proporsal preparation	X	X	X	X									SEMINAR PSM I																									SEMINAR PSM II		
Proporsal submission				X																																				
Background study & literature review				X	X	X																																		
Programming language research					X	X	X	X	X																															
Hardware construction								X	X	X	X	X		X																										
Software development														X	X	X									X	X	X	X												
Hardware development																												X	X	X	X	X								
Project prototype																																X	X	X	X	X	X			
PSM report submission																																								X

Figure 3.3: Project Gantt Chart

3.2.3 Data Collection

This part focuses on gathering data from previous study. In this phase, data is collected includes resources and material, background studies and hardware and software requirements. These resources were gathered through several platforms which consist of internet articles, books, journal papers, research papers and material from libraries.

In doing data collection, there are many ways to create a smart water system by using a different type of sensors and wireless transmission. For example, ultrasonic sensor is used to detect water level in tank and water leakage sensor to detect water leakage in th pipeline to avoid water wastage. Other than that, the use of Arduino Uno and ESP 32 wi-fi module are used for sending data wirelessly in an IoT network can improve reliability of data collected.

Throughout this phase, each hardware functionality that related to this project had been studied and compared with previous research. The study includes a detailed specification of each part and its operation. The collection of data comprises within project scope and limitation.

3.3 Project Implementation

In this section, it covers the hardware and software requirements and ways to use it on the project. In the project design part, it will explain in detail about circuit operation, block diagram of the project and its flowchart. Lastly, in project development, it covers monitoring and notification used in this project.

3.3.1 Hardware development

For hardaware requirement, it consists of two parts which are sensors and controller. Hardware being used in this project are:

a. Ultrasonic sensor

An ultrasonic sensor is an electronic device that measures the distance of a target object by emitting ultrasonic sound waves, and converts the reflected sound into an electrical signal. Ultrasonic waves travel faster than the speed of audible sound (i.e. the sound that humans can hear). Ultrasonic sensors have two main components: the transmitter (which emits the sound using piezoelectric crystals) and the receiver (which encounters the sound after it has travelled to and from the target).

In order to calculate the distance between the sensor and the object, the sensor measures the time it takes between the emission of the sound by the transmitter to its contact with the receiver. The formula for this calculation is D = 0.5T x C (where D is the distance, T is the time, and C is the speed of sound ~ 343 meters/second). For example, if a scientist set up an ultrasonic sensor aimed at a box and it took 0.025 seconds for the sound to bounce back, the distance between the ultrasonic sensor and the box would be:

Distance = 0.5 x 0.025 x 343

= 4.2875 meters

Figure 3.4 : Ultrasonic sensor

This ultrasonic sensor in this project is used as water level sensor in the water tank.

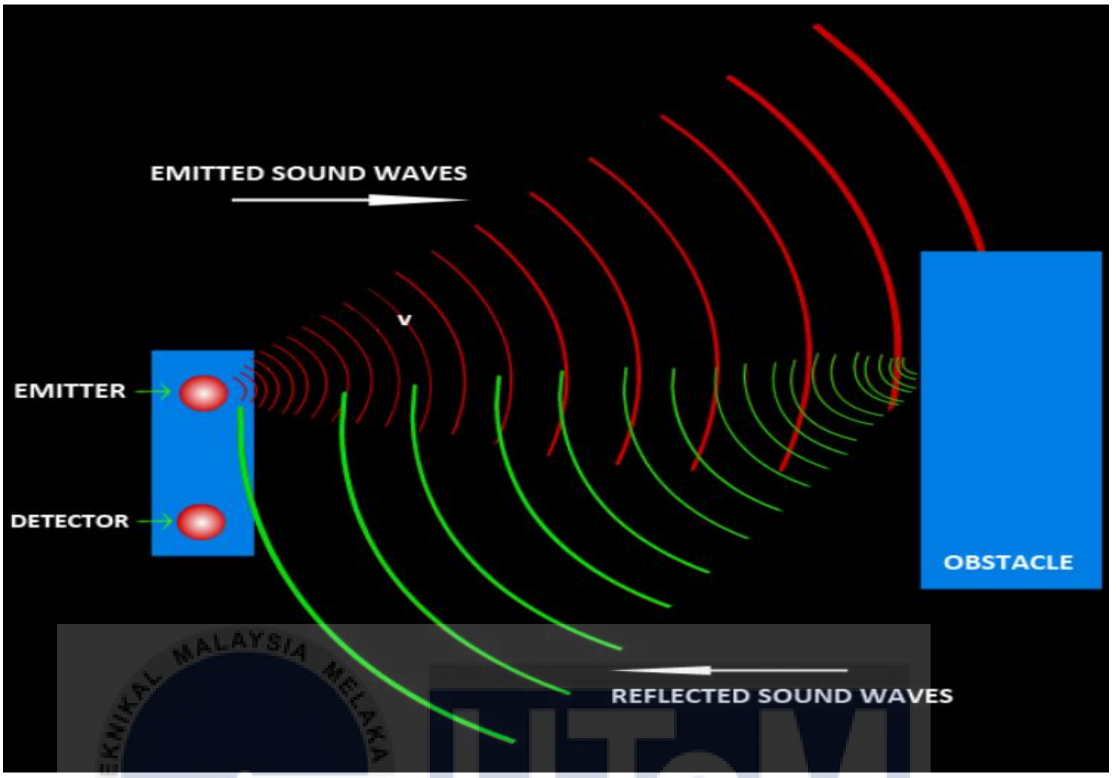


Figure 3.5: Ultrasonic sensor working illustration

Parameter	Minimum	Type	Maximum	Unit
Operating voltage	4.5	5.0	5.5	V
Quiescent Current	1.5	2	2.5	mA
Working current	10	15	20	mA
Ultrasonic Frequency	-	40	-	kHz
Effectual Angle	0	15	-	Degree
Ranging Distance	2	400		cm
Trigger Input Pulse Width	-	10	-	uS

Table 3.1: Specification and limitation of ultrasonic sensor HC-SR04

b. DHT 22

Figure 3.6: DHT 22

This sensor is to sense temperature and humidity with an accuracy of ±1°C and ±1%, the sensor can measure temperature from -40°C to 80°C and humidity from 0% to 100%.

c. ESP 32

The ESP 32 module integrated with TCP/ IP protocol that can provide internet access to any controller board. The module uses UART communication and supports up to 3.3V of DC voltage. As shown in Figure 3.5, the ESP 32 is a low-cost board that comes with onboard processing and storage functions. This feature allows it to be integrated into IoT based project and provide minimal loading runtime.

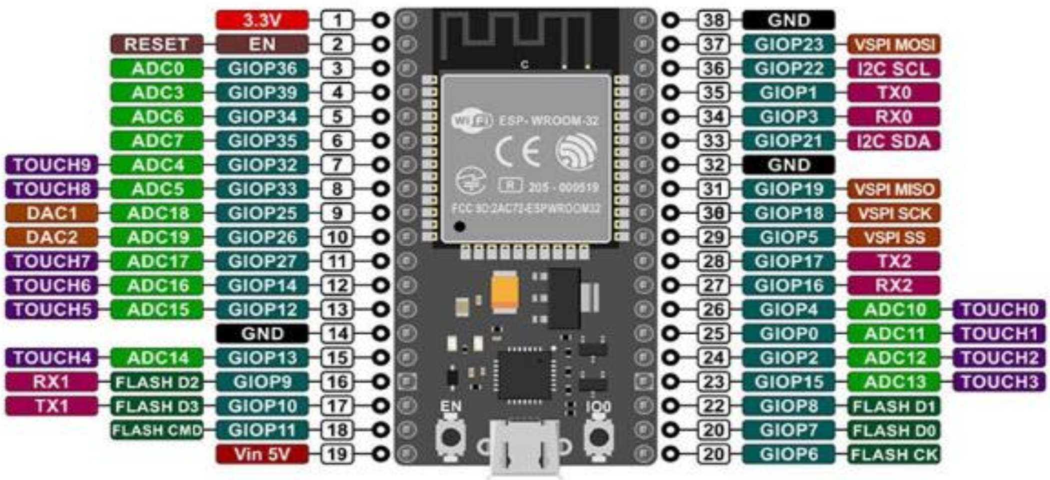


Figure 3.7: ESP 32 pinout

3.3.2 Software development

In this section, Proteus was used to design electronic hardware. It provides building of prototype before moving to the real complex circuit. In this software, a complete circuit was created which consist of sensor and each module before moving on the real hardware connection.

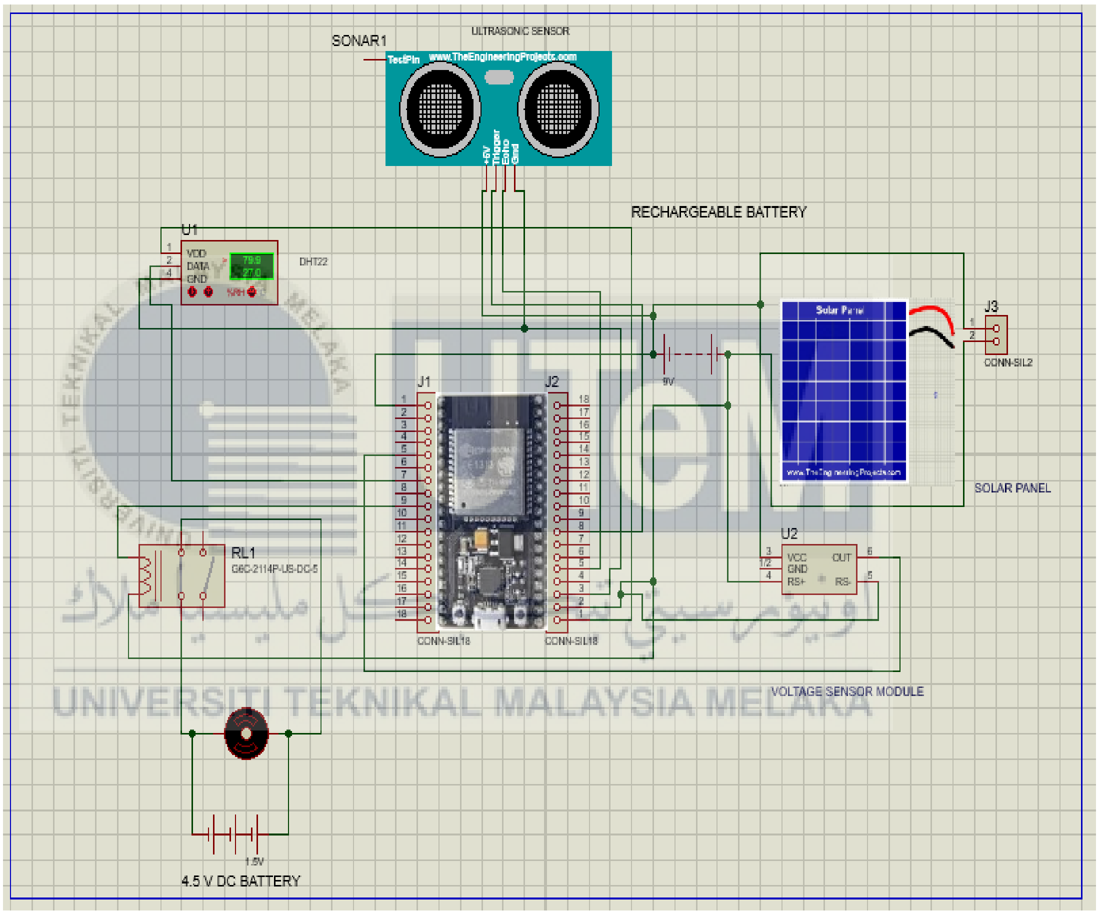


Figure 3.8: Proteus schematic diagram

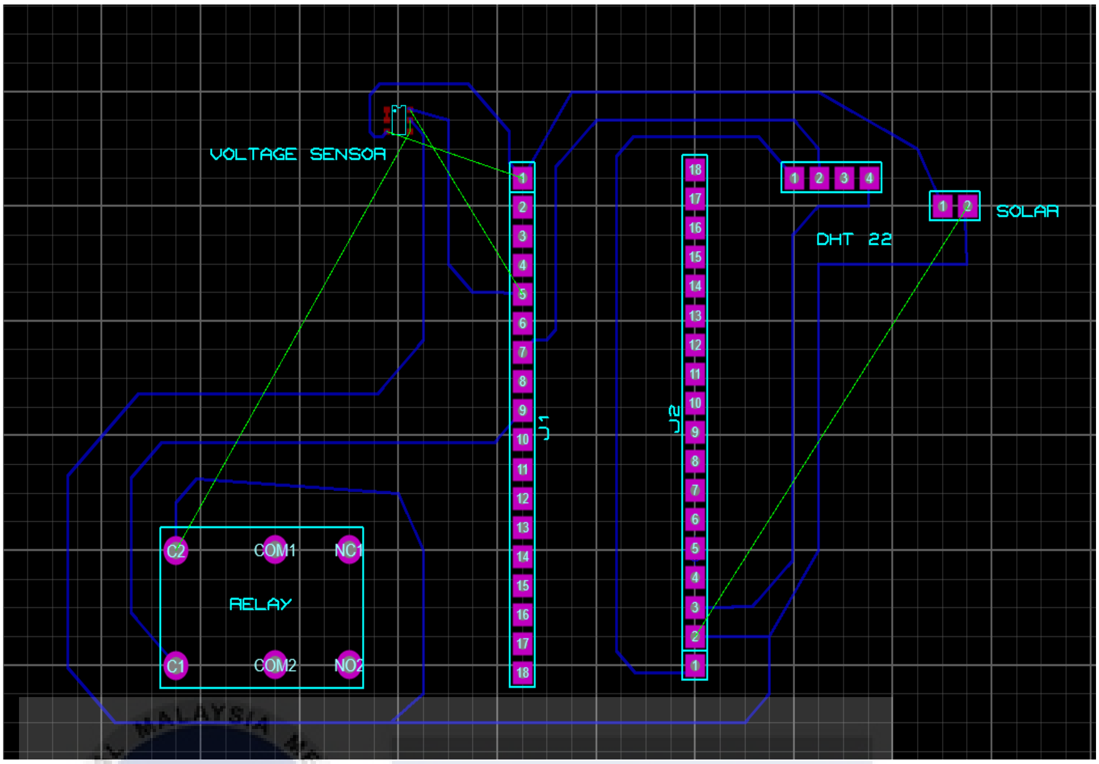


Figure 3.9: Proteus PCB circuit diagram

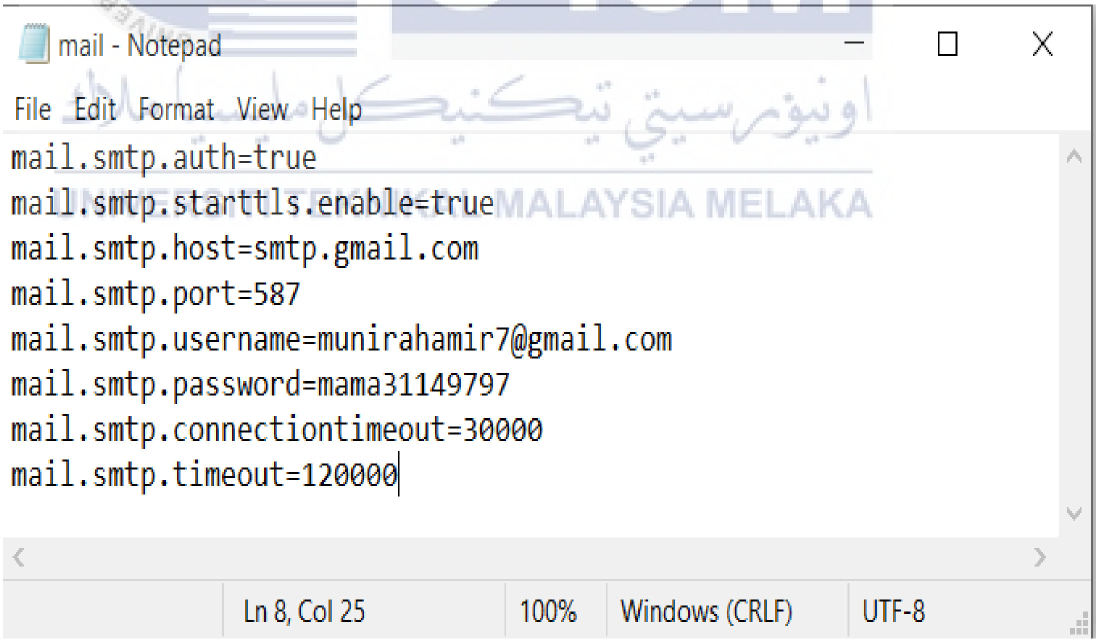


Figure 3.10: Mail.Properties file in blynk local server folder

server - Notepad

File Edit Format View Help

```
#hardware mqtt port
hardware.mqtt.port=8440

#http, plain web sockets and plain hardware port
http.port=8080

#if this property is true csv download url will use port 80 and will ignore http.port
force.port.80.for.csv=false

#if this property is true redirect_command will use 80 port and will ignore http.port
force.port.80.for.redirect=true

#secured https, web sockets and app port
https.port=9443

#address to bind to. by default bounded to all interfaces
listen.address=

#by default server uses embedded in jar cert to simplify local server installation.
#WARNNING DO NOT USE THIS CERTIFICATES ON PRODUCTION OR IN WHERE ENVIRNOMENTS REAL SECURITY REQUIRED.
#provide either full path to files either use '.' for specifying current directory. For instance "./myfile.crt"
server.ssl.cert=
server.ssl.key=
server.ssl.key.pass=

#by default System.getProperty("java.io.tmpdir")/blynk used
data.folder=

#folder for logs.
logs.folder=./logs

#log debug level. trace|debug|info|error. Defines how precise logging will be.
log.level=info

#maximum number of devices allowed per account
user.devices.limit=50

#maximum number of tags allowed per account
user.tags.limit=100
user.dashboard.max.limit=100

#defines maximum allowed widget size in KBs as json string.
user.widget.max.size.limit=20

#user is limited with 100 messages per second.
user.message.quota.limit=100

#maximum allowed number of notification queue. Queue responsible for processing email, pushes, twits sending.
#Because of performance issue - those queue is processed in separate thread, this is required due
#to blocking nature of all above operations. Usually limit shouldn't be reached.
notifications.queue.limit=2000

#Number of threads for performing blocking operations - push, twits, emails, db queries.
#Recommended to hold this value low unless you have to perform a lot of blocking operations.
blocking.processor.thread.pool.limit=6

#this setting defines how often we can send mail/tweet/push or any other notification. Specified in seconds
notifications.frequency.user.quota.limit=5

#this setting defines how often we can send webhooks. Specified in miliseconds
webhooks.frequency.user.quota.limit=1000

#this setting defines how big could be response for webhook GET request. Specified in kbs
webhooks.response.size.limit=96

#maximum size of user profile in kb's
user.profile.max.size=256

#number of strings to store in terminal widget
terminal.strings.pool.size=25

#number of strings to store in map widget
map.strings.pool.size=25

#number of strings to store in lcd widget
lcd.strings.pool.size=6

#maximum number of rows allowed
table.rows.pool.size=100

#period in millis for saving all user DB to disk.
```

Figure 3.11: Server.Properties file in blynk local server folder

```
profile.save.worker.period=60000

#period in millis for saving stats to disk.
stats.print.worker.period=60000

#max size of web request in bytes, 256 kb (256x1024) is default
web.request.max.size=524288

#maximum number of points that are fetched during CSV export
#43200 == 60 * 24 * 30 - minutes points for 1 month
csv.export.data.points.max=43200

#specifies maximum period of time when hardware socket could be idle. After which
#socket will be closed due to non activity. In seconds. Default value 10 if not provided.
#leave it empty for infinity timeout
hard.socket.idle.timeout=10

#enable DB
enable.db=false

#enable raw data storage to DB
enable.raw.db.data.store=false

#size of async logger ring buffer. should be increased for loads >2-3k req/sec
async.logger.ring.buffer.size=2048

#when true - allows reading worker to trigger hardware even app is offline
allow.reading.widget.without.active.app=false

#when enabled server will also store hardware and app IP
allow.store.ip=true

#initial amount of energy
initial.energy=100000

#ADMINISTRATION SECTION

admin.rootPath=/admin

#used for reset password page and certificate generation.
#by default current server IP is taken. could be replaced with more friendly hostname.
#it is recommended to override this property with your server IP to avoid possible problems of host resolving
#server.host=test.blynk.cc

#used for fallback page for reset user password, in most cases it should be the same as server.host
#IP is not allowed here, it should be blynk-cloud.com for Blynk app
#or *.blynk.cc for private servers with own apps
restore.host=blynk-cloud.com

product.name=Blynk

#email used for certificate registration, could be omitted in case you already specified it in mail.properties
#contact.email=

#network interface to determine server's current IP.
#only the first characters of the interface's name are needed.
#the default setting eth will use the first ethX interface found (i.e. eth0)
net.interface=eth

#comma separated list of administrator IPs. allow access to admin UI only for those IPs.
#you may set it for 0.0.0.0/0 to allow access for all.
#you may use CIDR notation. For instance, 192.168.0.53/24
allowed.administrator.ips=0.0.0.0/0,::/0

# default admin name and password. that will be created on initial server start
admin.email=admin@blynk.cc
```

Ln 16, Col 58

Figure 3.12: Server.Properties file in blynk local server folder continue

Command Prompt - java -jar server-0.41.12.jar -dataFolder \blynk local server

```
Microsoft Windows [Version 10.0.18362.720]
(c) 2019 Microsoft Corporation. All rights reserved.

C:\Users\munirah>cd C:\blynk local server

C:\blynk local server>java -jar server-0.41.12.jar -dataFolder \blynk local server

Blynk Server 0.41.12 successfully started.
All server output is stored in folder 'C:\blynk local server\.\logs' file.
Your Admin url is https://192.168.0.135:9443/admin
Your Admin login email is admin@blynk.cc
Your Admin password is admin
```

Figure 3.13: First time blynk local server is activated

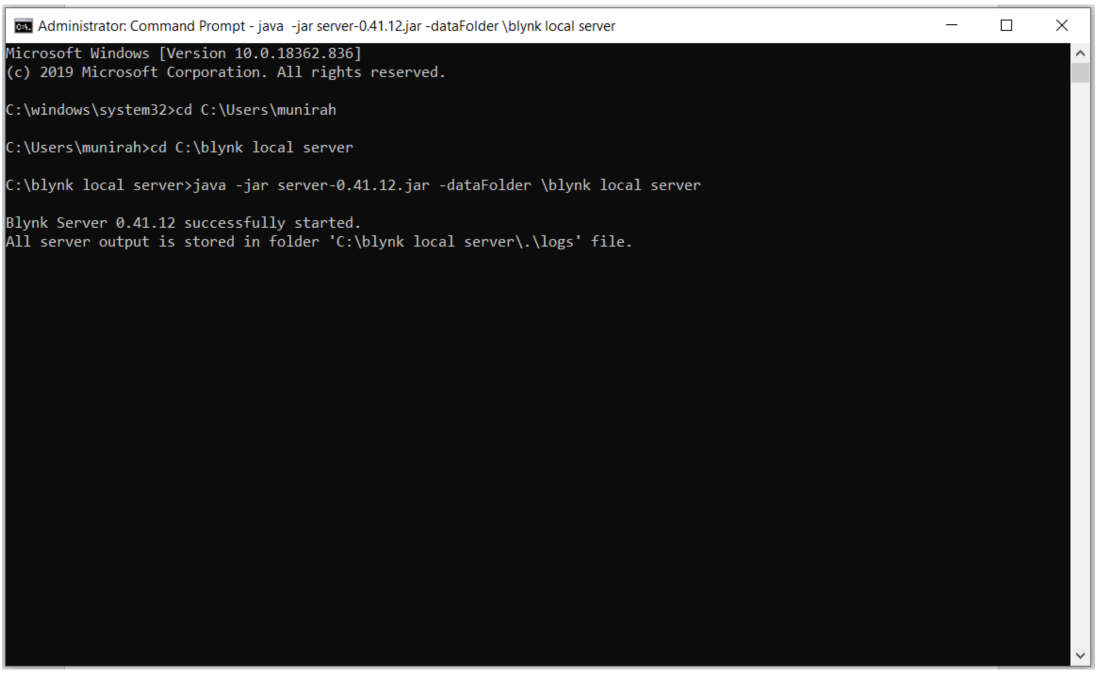


Figure 3.14: More than once blynk local server is activated

Figure 3.15: Blynk local server

This blynk local server is given when the local server is activated in command prompt. This server is then logged in with admin email and password also given in the command prompt. The information of user and project are in the server. The purpose of the server is that to increase the number of energy to 100,000 in the blynk app itself. If only the blynk app in smartphone is use, the energy limit is only 2000 energy to create the dashboard.

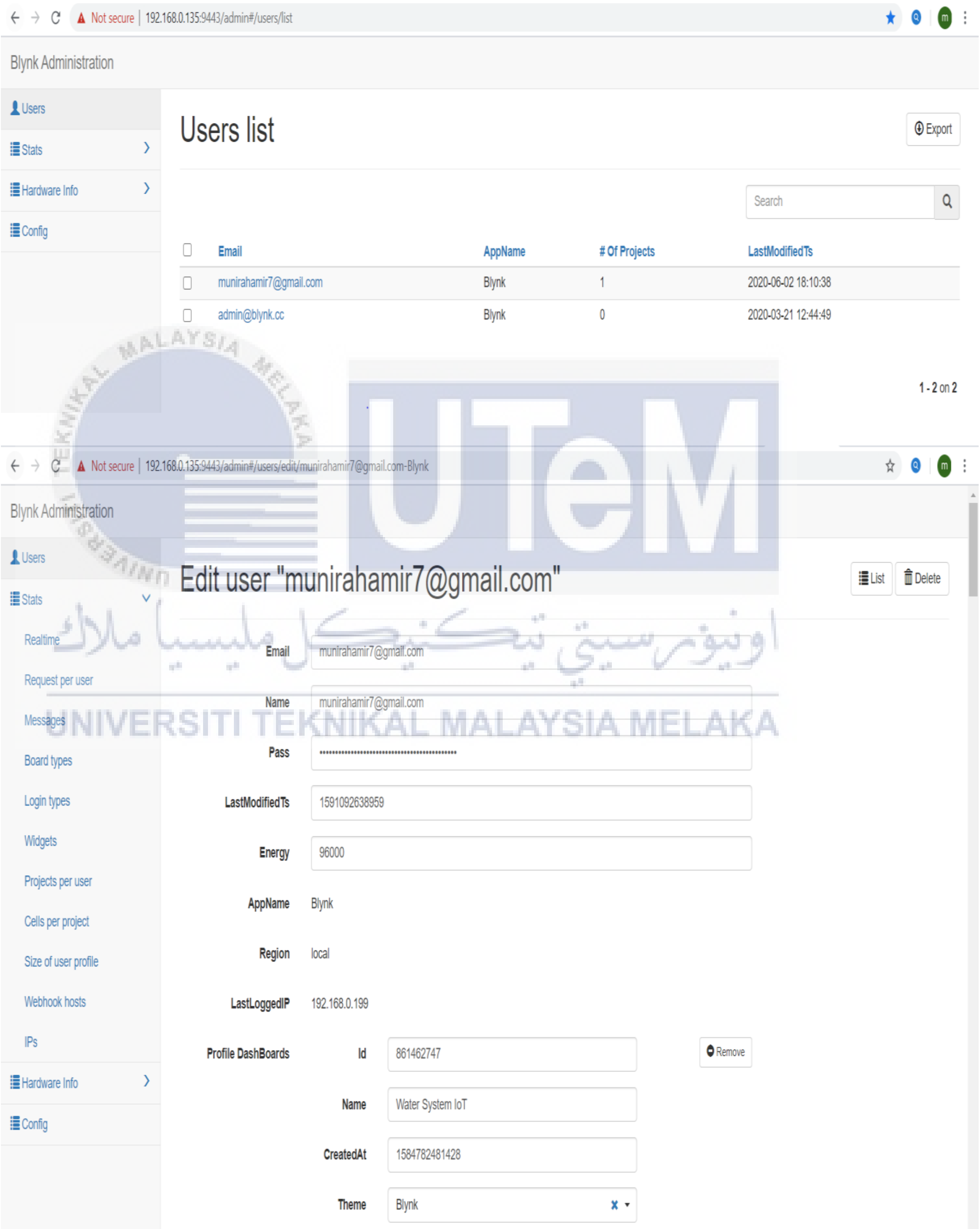


Figure 3.16: Users information in Blynk local server

Widgets

Export

Widget	Count
LabeledValueDisplay	4
Superchart	2
VerticalLevelDisplay	1
Tabs	1
TextInput	1

1 - 5 on 5

Configurations

Export

Name
twitter4j.properties
single_token_mail_body.txt
server.properties
mail.properties
gcm.properties
db.properties

1 - 6 on 6

Figure 3.17: Users information in Blynk local server continue

3.3.3 Overall project

Figure 3.18: Complete project hardware

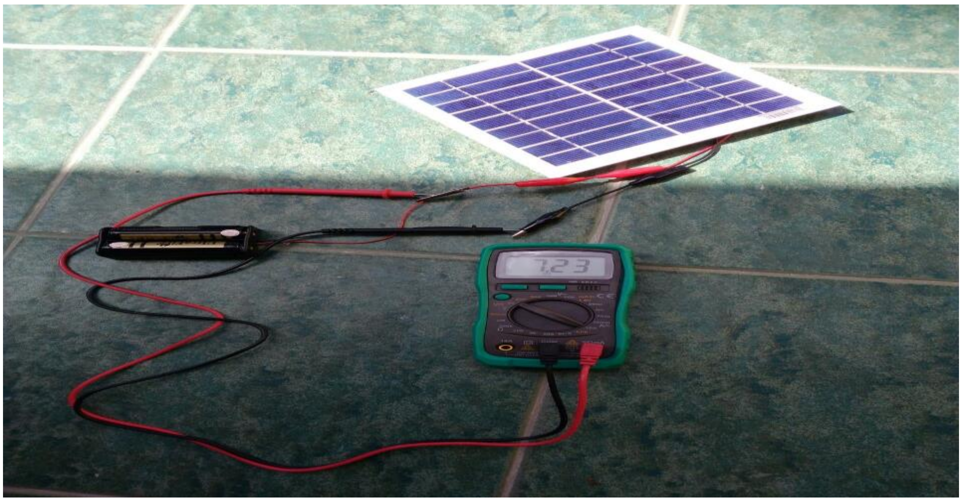


Figure 3.19: Solar implementation

CHAPTER 4

RESULTS AND DISCUSSION

This Smart Water System with IoT, the IoT platform is Blynk apps with blynk local server used to increase the energy for creating dashboard. In this chapter, the result from the dashboard designed will be discussed.

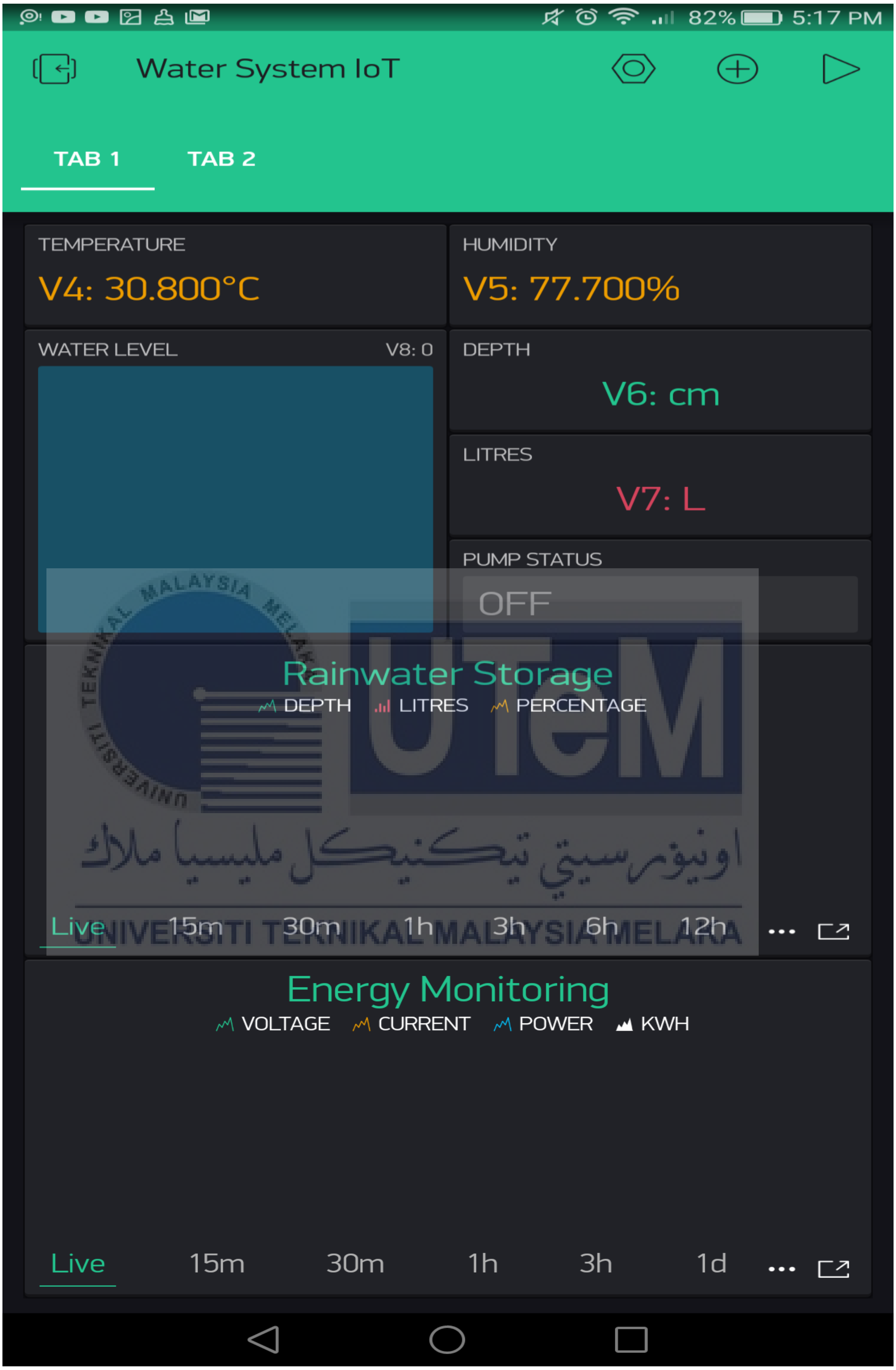


Figure 4.1: The overall dashboard

From Figure 4.1, the dashboard title is Water System IoT and there are several Virtual pins (V_x) used in this dashboard. For temperature, the virtual pin used is V4 whereas the humidity is V5, Depth is V6, litres is V7, percentage in Rainwater Storage subtitle is V8, water level is also V8. Depth and Litres in Rainwater Storage use the same pins which are V6 and V7 respectively.

From Figure 4.1, the Pump Status does not use Virtual pin because it is just a text output. Rainwater Storage subtitle parameter is already discussed in Figure 4.1 and the Energy Monitoring parameters consist of voltage (V) uses V0, current uses V1 (W), Power (W) uses V2 and kWh uses V3.

4.1: Result on temperature, humidity and rainwater storage

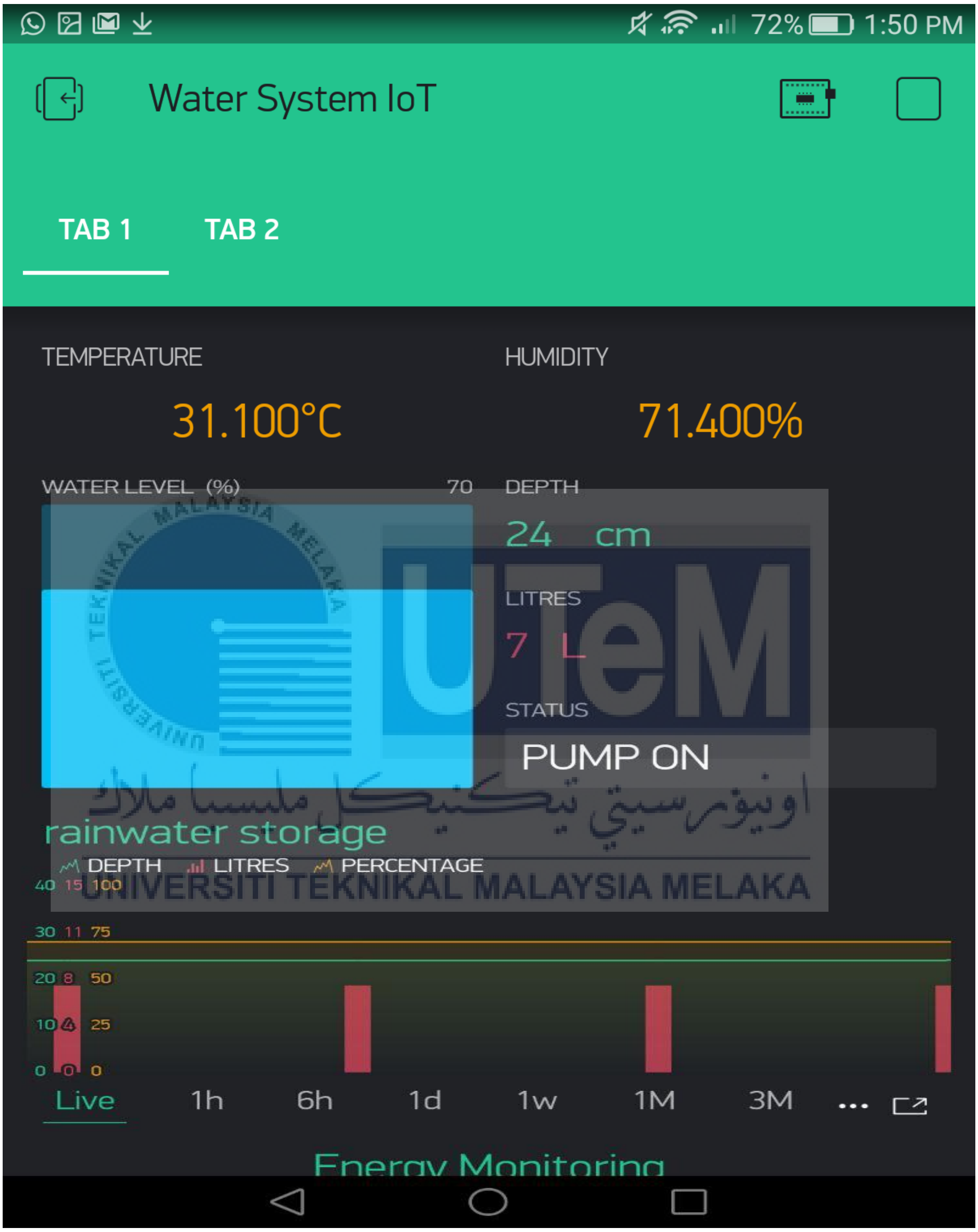


Figure 4.2: The online result of Water System IoT

From Figure 4.2, this result was taken at 1.50 p.m. as in stated in phone's clock means it is in the afternoon. The project was conducted indoor. The live temperature and humidity at that time are 31.1 °C and 71.4 %. the temperature is higher than a normal room temperature. From Nazhatulzalkis Jamaludin and her members (2015) written a journal entitled Thermal Comfort of Residential Building in Malaysia at Different Micro-Climates claimed that 32.6 °C is the highest indoor temperature in Kuala Lumpur at 1400 hours whereas 31.10 °C for temperature in Kuching is the highest at the same time and 32.6 °C the highest temperature at Bayan Lepas at the same time . Hence, the temperature recorded in this live data can be said is high as it closes to 32.6 °C reading with different in 1.5 °C.

For humidity, the recorded is 71.4 % which from Nazhatulzalkis Jamaludin and her members (2015), they found that 74 % to 86% are the ranges for the annual relative humidity in Malaysia. For the Rainwater Storage subtitle, the graph shows that the reading of the depth of the water tank, litres in the tank and percentage of water level in the water tank. Refer Figure 4.3.

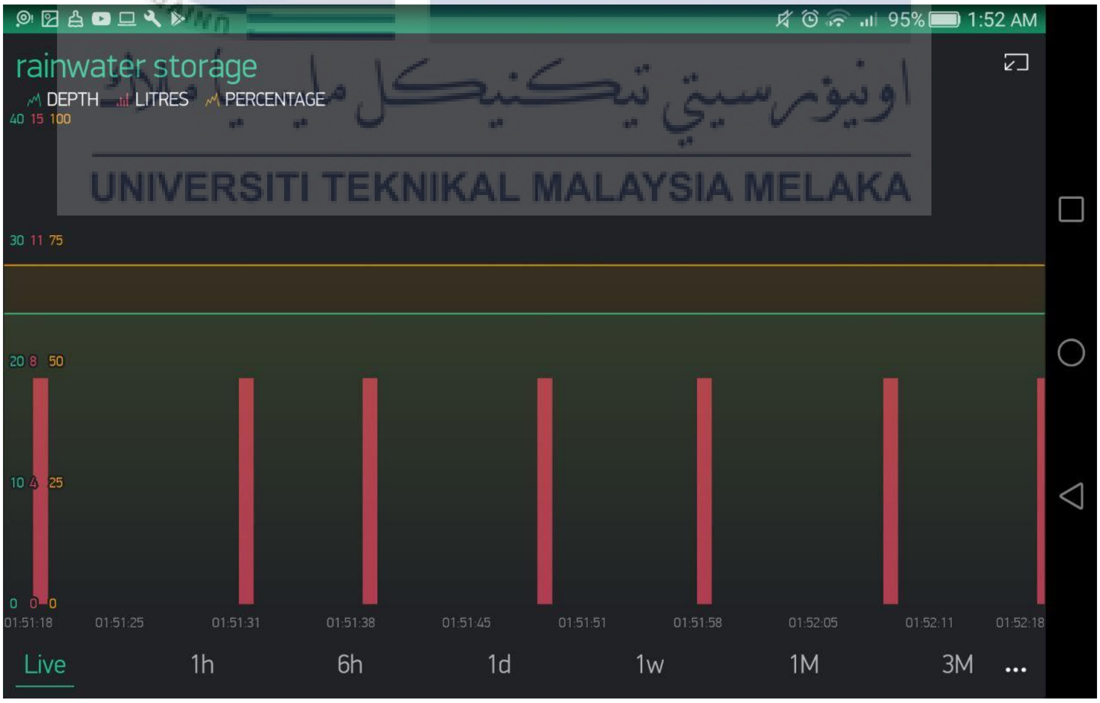


Figure 4.3: The Rainwater Storage recorded

This figure shows a data graph consists of the depth, litres and percentage of the rainwater storage tank versus time with 1 second different. Here are the formula used in designing this system.

$$\text{Depth (cm)} = 32 \text{ cm of water tank} \qquad \text{eqn. (1)}$$

$$\text{Litres (L)} = \frac{(\pi \times \text{radius (water tank)} \times \text{radius (water tank)} \times \text{Depth})}{1000} \qquad \text{eqn. (2)}$$

For the percentage of water level, the calculation below justify the data:

$$\text{Percentage of rainwater tank} = \frac{\text{Litres}}{\text{Total litres}} \times 100\% \qquad \text{eqn. (3)}$$

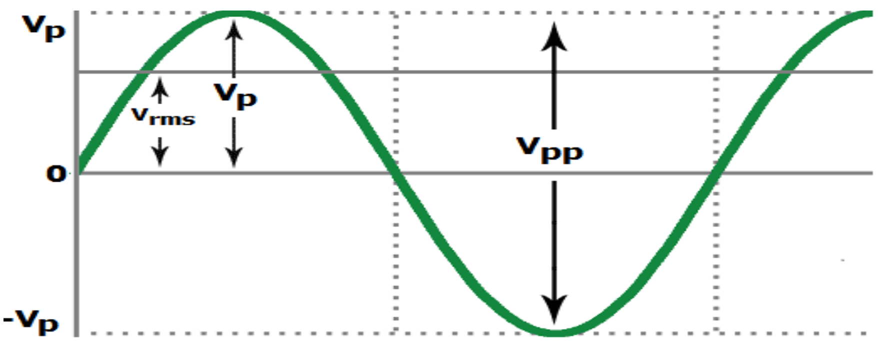
By using eqn.(3):

$$\text{Percentage of water tank} = \frac{7\text{ L}}{10\text{ L}} \times 100\%$$

$$= 70\ \%$$

The calculation of the percentage of rainwater storage tank is same as the online dashboard in Figure 4.3.

4.2: Result on energy monitoring



$$\text{Vrms} = \frac{1}{\sqrt{2}} \times \text{Vp} = 0.7071 \times \text{Vp} \quad \text{———— eqn. (4)}$$

$$\text{Vrms} = \frac{1}{2\sqrt{2}} \times \text{Vpp} = 0.35355 \times \text{Vpp} \quad \text{———— eqn. (5)}$$

$$\text{Vrms} = \frac{\pi}{2\sqrt{2}} \times \text{Vavg} = 1.1107 \times \text{Vavg} \quad \text{———— eqn. (6)}$$

$$\text{Vpeak} = \text{Vpeak-to-peak} \times 0.5 \quad \text{———— eqn. (7)}$$

$$\text{Vpeak} = \text{Vrms} \times \sqrt{2} \text{ (or 1.414)} \quad \text{———— eqn. (8)}$$

$$\text{Vpeak} = \text{Vaverage} \times \frac{\pi}{2} \text{ (or 1.57)} \quad \text{———— eqn. (9)}$$

Figure 4.4: Graph and formula for energy monitoring data

Source: https://circuitdigest.com/calculators/rms-voltage-calculator

Source:http://www.learningaboutelectronics.com/Articles/Peak-voltage-calculator.php

From Figure 4.4, I can conclude that it is important to prove with theory and also do analysis on the voltage sensor itself.

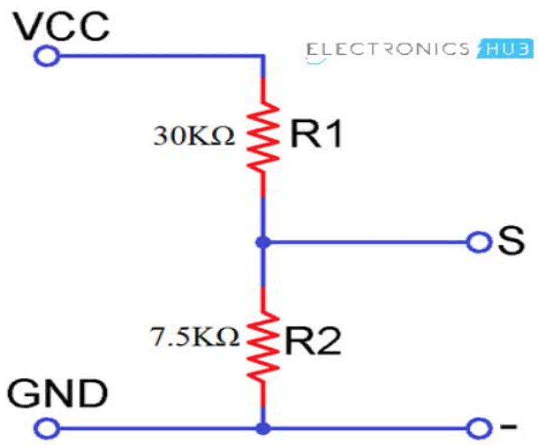


Figure 4.5: Circuit diagram of internal voltage sensor module

Source: https://components101.com/sensors/voltage-sensor-module

From Figure 4.5, the circuit is voltage divider circuit consists of 2 resistors which R1 is 30 kΩ and R2 is 7.5 kΩ to get output voltage (S).

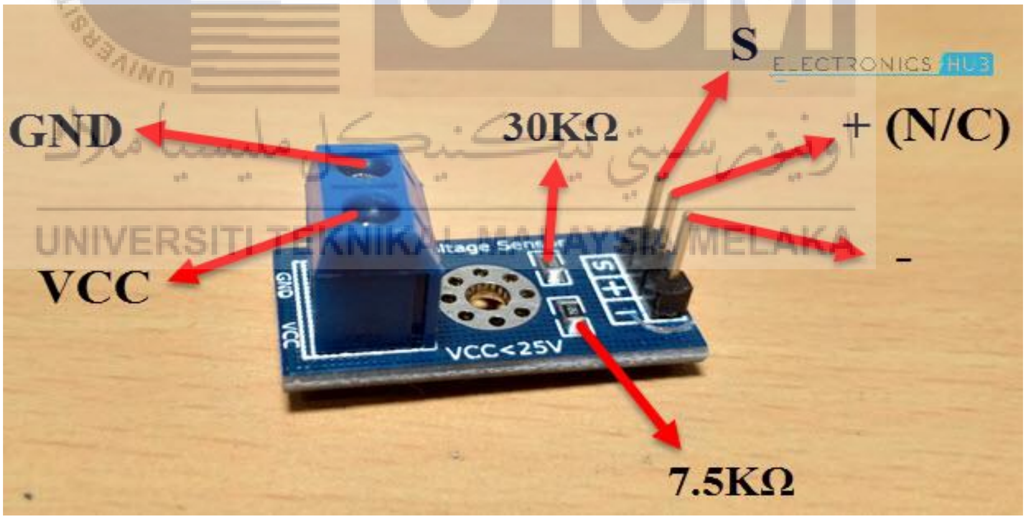


Figure 4.6: Voltage sensor pinout

Voltage divider formula:

$$\text{Vout} = \frac{\text{R2}\ (\Omega)}{(\text{R1}\ (\Omega)+\text{R2}\ (\Omega))} \times \text{Vin} \qquad \text{———— eqn. (10)}$$

From Figure 4.5 and Figure 4.6, I can conclude that it is important to prove the project data with theoritical and also do analysis on the voltage sensor itself. Voltage sensor module used is designed for Vcc = 0 - 25 V range as in Figure 4.6, we can use voltage divider to find output voltage. Since this circuit is just a simple voltage divider , we can eliminate the voltage sensor module by just designing it on the PCB board. Total cost reduction = RM 12.00 + RM 15.90 = RM 27.90.

Since ESP 32 microcontroller operating voltage is 0 - 3.3 V, so, the output voltage from voltage sensor should within that range. Here, calculation of output voltage for the voltage sensor if the input is maximum (25 V):

By using eqn. (10),

$$Vout = \frac{7500\ \Omega}{(30000\ \Omega + 7500\ \Omega)} \times 25\ \mathrm{V} = 5\ \mathrm{Vout}$$

The output voltage is 5 V and this is higher than 3.3 V operating voltage, so it may harm the ESP 32 microcontroller if the input voltage is 25 V. Since this rechargeable battery used has 7.4 V maximum, so this sensor can be used. Here, the calculation of maximum rechargeable battery:

By using eqn. (10),

$$Vout = \frac{7500\ \Omega}{(30000\ \Omega + 7500\ \Omega)} \times 7.4\ \mathrm{V} = 1.48\ \mathrm{Vout}$$

The input voltage for the pin is 1.48 V which below than the maximum pin operating voltage. After some time, the rechargeable battery voltage is getting lower. To answer this, the output from the voltage sensor is the voltage drains from the rechargeable batteries.

Figure 4.7: Energy monitoring data in noon

Figure 4.7 shows data gives reading of rms voltage (Vrms), rms current (Irms), apparent power (W) and kWh (RM).

From Figure 4.7, we can assume the voltage use is 4.3 Vrms. From the formula eqn. (6), we can calculate the Vpeak and Vpeak-peak.

By using eqn. (7),

$$\text{Vpeak} = \text{Vrms} \times \sqrt{2} = 4.3\ \text{V} \times \sqrt{2}$$

$$= 6.0811\ \text{Vpeak}$$

The maximum voltage for the rechargeable battery is 7.4 V. The value shows that is 1.3189 V below the maximum.

By using eqn. (6),

Vpeak-peak = Vpeak $\times$ 2

= 6.0811 Vpeak $\times$ 2

= 12.1622 Vpeak-peak

In term of voltage out from voltage sensor to the pin, the calculation is:

By using eqn. (10),

$$\text{Vout (to the pin)} = \frac{R2}{(R1+R2)} \times \text{Vin (from battery)}$$

$$\text{Vout (to the pin)} = \frac{7500}{(30000+7500)} \times 6.0811 \text{ Vpeak} = 1.2162 \text{ Vout}$$

Day / Time	Day 1 (Vp)	Day 2 (Vp)	Day 3 (Vp)	Day 4 (Vp)
8-11	6.72	7.0	1.68	5.32
11-2	6.72	7.0	3.36	5.6
1-5	7.0	7.56	5.04	7.28
TOTAL (increment per day)	0.28	0.56	5.04	2.24

Table 4.1: Charging voltage

Voltage actual (Vp)	Voltage rms actual (Vrms)	Voltage rms (Vrms)	Current rms (Irms)	Power (W)	kWh (RM)	Error (%)
5.88	4.16	4.30	0.04	0.172	0.0020	3.255
4.06	2.87	3.01	0.0556	0.1672	0.0020	4.65
4.11	2.91	3.05	0.1479	0.4505	0.0020	4.59
3.56	2.52	2.62	0.0430	0.1127	0.0003	3.82
3.79	2.68	2.74	0.1095	0.3005	0.0020	2.19

Table 4.2: Data retrieved from Blynk app

Table 4.1 shows the data of solar charging is manually recorded by using multimeter for 4 days for 8 hours per day starting from 8 a.m. till 5 p.m. while Table 4.2 is the tabulated data for energy monitoring section whic voltage actual (Vp) is manually recorded by using multimeter during the Blynk online mode. This comparison between the manual data and the Blynk data is then produced the percentage error between them.

4.3: ESP 32 deep sleep mode analysis

In ESP 32, there are five advanced power management mode. The chip can switch between different power modes according to the power requirement. The five configurable modes are active mode, modem sleep mode, light sleep mode, deep sleep modeand hibernation mode. In this subsection, the comparison between active mode and deep sleep mode will be discussed.

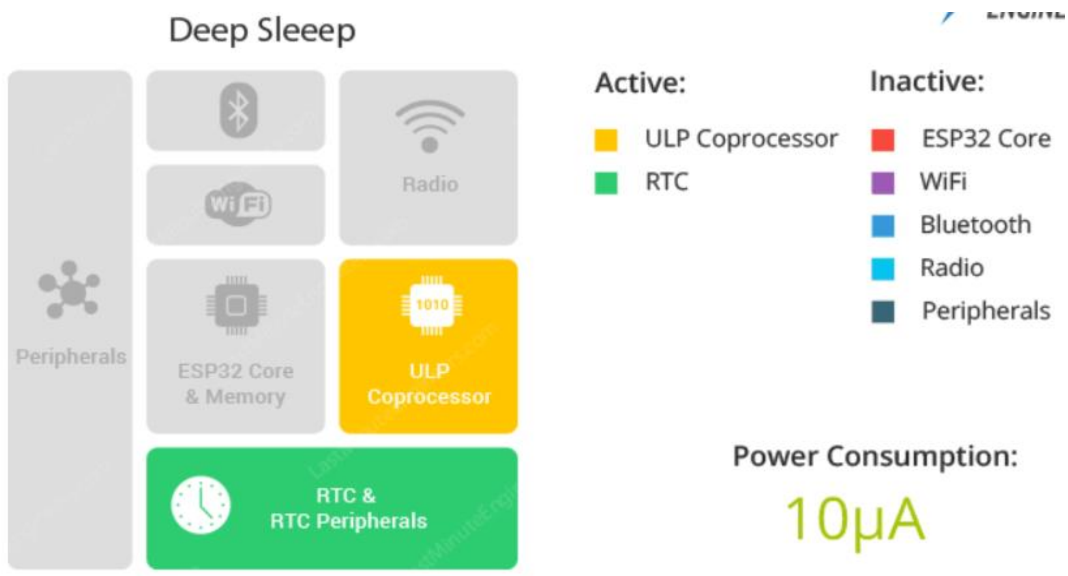


Figure 4.8: Deep sleep mode of ESP 32

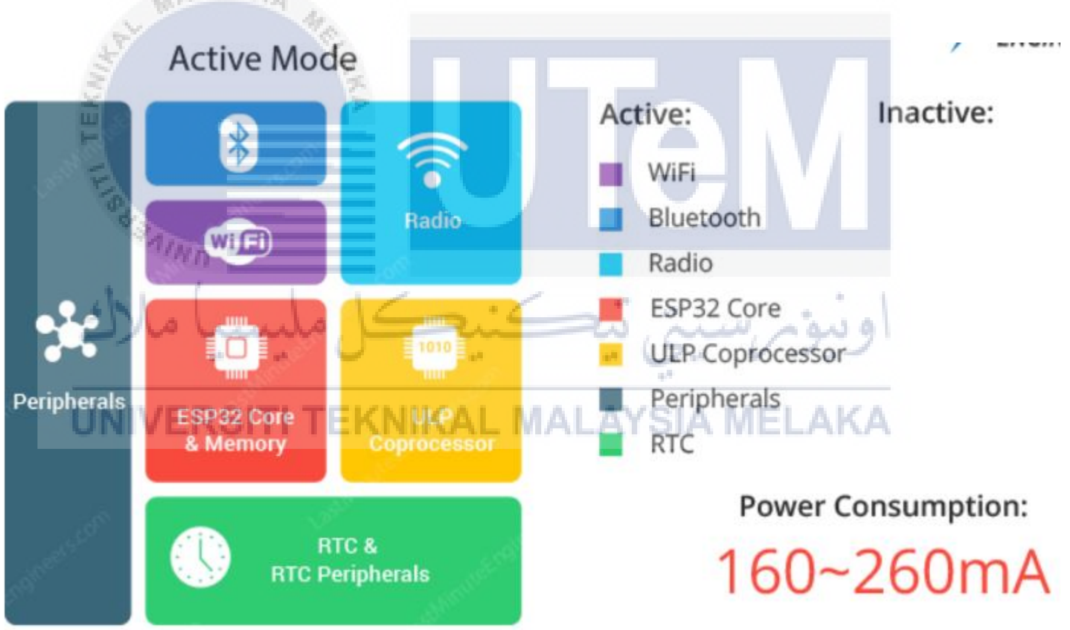


Figure 4.9: Active mode of ESP 32

Source: https://lastminuteengineers.com/datasheets/esp32-datasheet-en.pdf

From Figure 4.9, the active mode is also known as the normal mode. All chip features are switch on. Since everything is ON at all times, the chip uses more than 240 mA current to operate and can go maximum until 790 mA if WiFi and Bluetooth are functions together. For Figure 4.8, during deep sleep, only ULP coprocessor, RTC controller & RTC peripherals are power ON and RTC memories (slow and fast). The range of current consume forthis chip is 0.15mA to 10 µA. During this mode, the main CPU is powered OFF, while the ULP coprocessor measures sensors and wakes up the main system according to the measured data from sensors and this sleep pattern is known as ULP sensor-monitored pattern.Since the RTC memory is powered ON , therefore the data are preserved during this time and after the chin wakes up, the data can be obtained.

1. Percentage of saving of minimum (160 mA):

$$\frac{10\ \mu A}{160\ mA} \times 100\% = 62.5\ \mu A$$

$$= 6.25\ mA\ \%$$

Percentage of current saved = 100% - 6.25mA % = 99.99375% saved

2. Percentage of saving of maximum (260 mA):

$$\frac{10\ \mu A}{260\ mA} \times 100\% = 38.462\ \mu A$$

$$= 3.8462\ mA\ \%$$

Percentage of current saved = 100% - 3.8462 mA% = 99.99615 % saved

4.4: Result of rainwater and paid tap water analysis

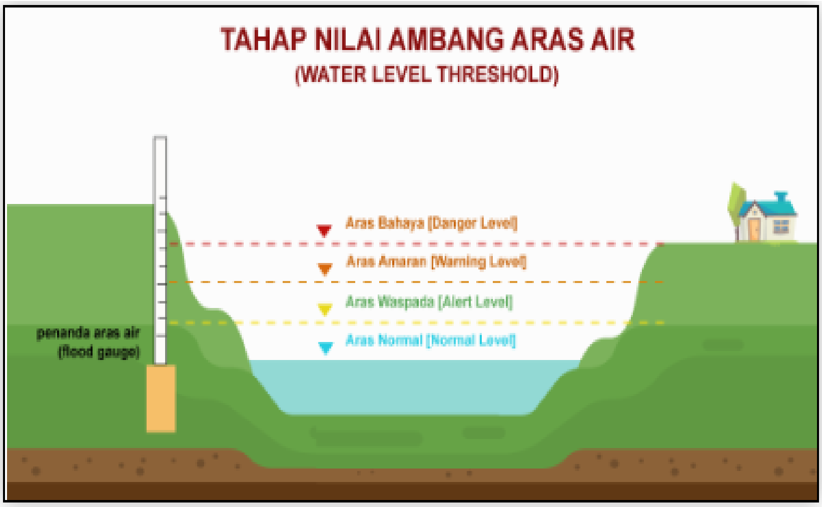


Figure 4.10: River water level

Source:http://forecast.water.gov.my/index.php/hujan/datahujan/?state=SEL&lang=#

No.	State	Last Updated
1	Perlis	25/06/2020 07:00:00
2	Kedah	25/06/2020 07:15:00
3	Pulau Pinang	25/06/2020 07:00:00
4	Perak	25/06/2020 07:15:00
5	Selangor	25/06/2020 07:15:00
6	Wilayah Persekutuan Putrajaya	No Data Available
7	Wilayah Persekutuan Kuala Lumpur	25/06/2020 07:00:00
8	Negeri Sembilan	25/06/2020 07:15:00
9	Melaka	25/06/2020 07:00:00
10	Johor	25/06/2020 07:15:00
11	Pahang	25/06/2020 07:15:00
12	Terengganu	25/06/2020 07:15:00
13	Kelantan	25/06/2020 07:15:00
14	Sabah	19/02/2020 15:00:00
15	Sarawak	25/06/2020 07:15:00
16	Wilayah Persekutuan Labuan	No Data Available

Water Level Legend

Normal
Alert
Warning
Danger

Figure 4.11: River water level for 25 June 2020

Source:http://forecast.water.gov.my/index.php/hujan/datahujan/?state=SEL&lang=#

Based on Figure 4.11, Selangor and Wilayah Persekutuan have normal water level in water tank storage. Here are the description of the water level colour coded.

Danger Level: River water level that may cause flooding where evacuation to be initiated.

Warning level: River level increasing to near flooding level & early prepare for any evacuation action

Alert level: River level significantly increase above normal level

No.	Station ID	Station	District (Data)	Last Updated	Daily Rainfall						Rainfall from Midnight (24/06/2020)	Total 1 Hour (Now)
					18/06/2020	19/06/2020	20/06/2020	21/06/2020	22/06/2020	23/06/2020		
1	3013002	Taman Desa Kundang	Hulu Langat	25/06/2020 07:15:00	1.0	42.0	8.0	0.0	0.0	21.0	-	0.0
2	3218101	Sg.Langat di TNB Ponsoon	Hulu Langat	25/06/2020 07:15:00	28.0	0.0	0.0	8.0	4.0	1.0	-	0.0
3	3119104	Genting Peres	Hulu Langat	25/06/2020 07:15:00	32.0	19.0	0.0	1.0	10.0	10.0	-	0.0
4	3017082	Sg. Langat di Batu 12	Hulu Langat	25/06/2020 07:15:00	12.0	5.0	0.0	18.0	2.0	1.0	-	0.0
5	3018103	Sg.Semenyih di Kg.Pasir	Hulu Langat	25/06/2020 07:15:00	15.0	7.0	25.0	3.0	17.0	0.0	-	0.0
6	2917112	Sg.Langat di Kajang	Hulu Langat	25/06/2020 07:15:00	1.0	9.0	4.0	11.0	2.0	0.0	-	0.0
7	2918106	Sg.Semenyih di Rinching	Hulu Langat	25/06/2020 07:15:00	29.0	8.0	1.0	10.0	28.0	0.0	-	0.0
8	3118104	Sg.Langat di Batu 20	Hulu Langat	25/06/2020 06:45:00	21.0	0.0	0.0	6.0	4.0	27.0	-	0.0

Figure 4.12: 6 days of rainfall recorded in Kajang, Selangor area

Source:http://forecast.water.gov.my/index.php/hujan/datahujan/?state=SEL&lang=#

USAGE	TARIFF CODE	RATE (RM)	MIN. PAYMENT (RM)
Domestic Usage 0-20 m^3 21-35 m^3 35 m^3 & above	10	 0.57 1.03 2.00	 6.00
Commercial (Inclusive of Public Swimming Pool) 35 m^3 35 m^3 & above	11	 2.07 2.28	 36.00
Goverment Department	12	1.61	17.00
Place of Worship	13	0.46	6.00
Ship	14	4.23	
Charitable Organisation	15	0.58	6.00
*Bulk meter only *Condominium / Apartment	17	1.38	173.00
*Low Cost Flat / Apartment	18	0.80	35.00
*Army Camp / Estate / Government Quarters	21	1.00	12.00

Figure 4.13: Latest rate bill in Selangor

Source: https://www.airselangor.com/my-water-smart/water-tariff-information

According to Figure 4.13, this is the rate of water bill in Selangor categorized by type of usage and sectors.

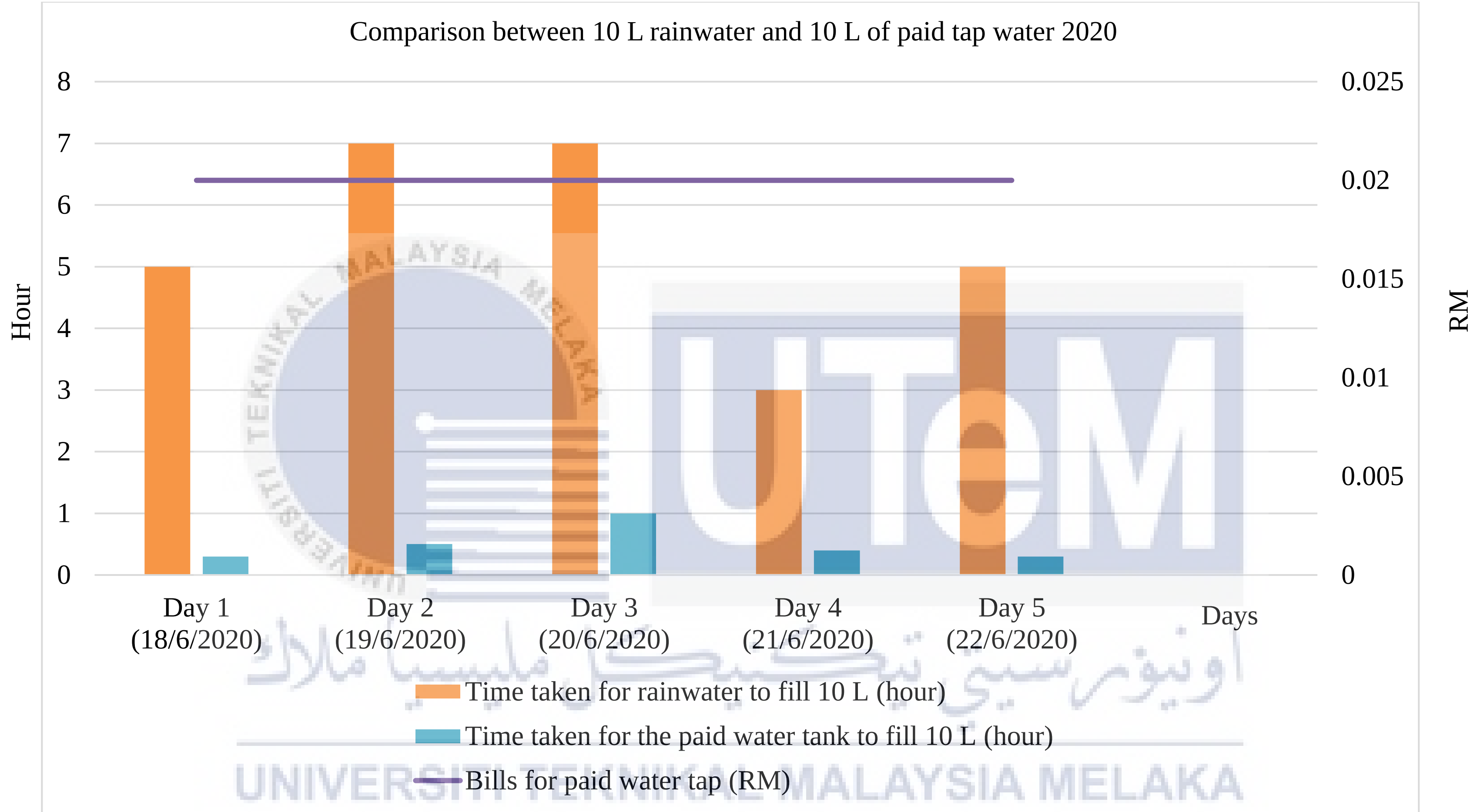


Figure 4.14: The graph of time taken and bills versus days

Conversion table: Liters to Cubic meters

LITERS		CUBIC METERS	CUBIC METERS		LITERS
1	=	0.001	1	=	1000
2	=	0.002	2	=	2000
3	=	0.003	3	=	3000
4	=	0.004	4	=	4000
5	=	0.005	5	=	5000
7	=	0.007	7	=	7000
8	=	0.008	8	=	8000
9	=	0.009	9	=	9000
10	=	0.01	10	=	10000

Figure 4.15: Coversion from litres to cubic metre

The formula to calculate the water bill is as shown below. The rate price is obtained from Figure 4.13.

$$\text{Water bills (SYABAS)} = \text{Water used } (m^3) \times \text{RM } 1.03 \quad \text{eqn. (11)}$$

This project used 10 L of water tank, therefore, by using eqn. (11),

$$10\text{ L} = 0.01\text{ m}^3$$

$$\text{Water bills per 10 L used} = 0.01\text{ m}^3 \times \text{RM } 1.03$$

$$= \text{RM } 0.01 \text{ per used in a 10 L tank}$$

Example of a paid water tap, if a house used 40 m^3 per month, the calculation will be:

By using eqn. (11),

$$20\text{ m}^3 \times \text{RM } 0.57 = \text{RM } 11.40$$

$$15\text{ m}^3 \times \text{RM } 1.03 = \text{RM } 15.45$$

$$5\text{ m}^3 \times \text{RM } 2.00 = \text{RM } 10.00$$

$$\text{Hence, bill total} = \text{RM } 36.85$$

Let assume the paid water used per month is 10 m^3 , so, the total will be:

By using eqn. (11),

$$10\ m^3 \times RM\ 0.57 = RM\ 5.70$$

$$\frac{\text{RM } 31.15}{\text{RM } 36.85} \times 100\% = 84.5319\%$$

Hence, the reduction from the monthly total bill is RM 5.70 and the new bill total is RM 31.15 equivalent to 84.5319 %.

This calculation proved that how this rainwater harvesting system can save cost for consumer used for domestic and even industries. The above calculation is for small ratio (10 L water tank), the same calculation can be applied for industries.

4.5: The project cost

No.	List of Components	Unit	Price (RM)
1.	ESP 32 Microcontroller	1	40.00
2.	Solar Panel 9V & 3W	1	50.00
3.	Rechargeable battery	1	28.00
4.	Relay module 5V	1	5.00
5.	DC submersible water pump 3-5V	1	15.00
6.	DC battery	1	3.90
TOTAL			141.90

Table 4.3: The financial budget of project

Therefore, the overall project cost is RM141.90 as calculated in Figure 4.16.

CHAPTER 5

CONCLUSION AND FUTURE WORKS

This Smart Water Management with IoT project has successfully done. The objectives are achieved. After reviewing the overall project, the project can help in achieving several Sustainable Development Goals. Among all 17 Sustainable Development Goals (SDG), I discover that this project mostly related to SDG 2, 3, 6, 7, 11 and 12

SDG 2 also can be achieved from this project implementation. This goal is no hunger which to end hunger, achieve food security and improved nutrition and promote sustainable agriculture. Storing rainwater can helps farmer to have consistent supply for their plantation. Therefore, the plantation can still survive even there is a water supply issue from water service management due to prolong hot weather and also lack of rain. Hence, the yields can be distributed to citizens will impact of no hunger in any area even if the country is facing critical clean water storage. Climate change and 'natural' disasters such as droughts, landslides and floods have a significant effect on food safety. Disaster risk management, adaptation to climate change and mitigation are key to raising the quality and quantity of harvests. This project can be a back up plan for the upcoming unpredictable season that may affect the water level in dam.

Besides, SDG 3 suits this project which the goal is good health and well-being where it ensures healthy lives and promote well-being. Since we are living in the developing country that has many factories release wastes to the river and polluted them, the river that is our main source of raw water needs filtration process before it is safe enough to supply to the consumer. Since it is highly polluted, better technologies and methods are needed to filter that raw water. It is different when it compares to rainwater where it is claimed to be much cleaner before it touches the ground when filter. Hence, rainwater collection that designed for drinking does not need expensive technology to filter it compared to river water or dam water. Therefore, the dwellers will get a better water consumption that ensures a good health and well-being.

For SDG 6, since raw source water or even clean water is a big issue in Malaysia where not all states get continuous consistent supply. Since we are lack of clean water especially in the future, to save the raw water, this project has introduced the initiative to secure raw water or clean water that is mainly use for important matter such as for drinking and bathing by collecting rainwater in the tank. This project saves the raw clean water which it can be used for general cleaning, watering plants and etc. This implementation is not well-known enough and less encouragement among Malaysians. Well, if this project is implemented to most of the houses and industries, the water service company will see the result on the impact of the clean water level that can sustains for months or days. Regardless, the consumer must follow the encouragement in order to see this effective result.

This project also related to SDG 7, which is affordable and clean energy. This goal is to ensure access affordable, reliable, sustainable and modern energy for all. In this project, it uses solar panel as source of battery to power up ESP 32 microcontroller. The solar panel used is 9V and 3W with 7.4 V rechargeable battery. This solar system is the replacement of using normal battery that is disposable when energy falls to 0 volt. Even though rechargeable battery is more expensive than non-rechargeable battery, but it has to just buy once and it has longer lifetime, can be recharged many times and ideal choice for high drain gadgets and electronics that drain very much energy quickly while non-rechargeable battery has lower price and it only suitable for low-drain devices which low-drain devices only use occasional or very low power over an extended period of time besides need to purchase every time the battery is 0 V. Therefore, the renewable energy is used in this project which guarantees energy efficiency and also society can access this renewable energy by placing solar under the sun.

Furthermore, the next SDG that related to this project is SDG 11 which the goal is sustainable cities and communities. This goal aims to make cities and human inclusive, save, resilient and sustainable. This project contributes to this goal which citizens are encourage to have rainwater storage system so urban and rural areas has backup water source since Malaysia has water issue. Save a lot on clean water when citizens start to use rainwater for specific tasks that unnecessary to use clean water while clean water for important use such as drinking and bathing. It promises the source of clean water in the tank to maintain at certain level in certain period of time instead of drains too fast due to high demand.

Besides, this project contributes in SDG 12 which the goal is responsible consumption and production to ensure sustainable consumption and production patterns. Since this project uses rechargeable battery, so it saves from wasting chemicals that use to design battery. Hence, useful chemicals can be preserved for longer time for the future. Besides, the uses of stored rainwater can save the clean water from empty in the tank. Since rain fall rate in Malaysia is inconsistent nowadays and hot weather that can dry up the water raw source such as river, dam and even tank (clean water). Evaporation can happen everywhere and even faster during hot weather. Other than that, the increase in population, living areas and industries are the major cause of the high demand. Industries need constant supply of water of course the water cannot be preserved in certain period as it should. Hence, every sector should take initiative to collect rainwater to minimise the use of clean water that necessary for food, drinks and health.

This project consists of a few important elements that can be discussed which are solar panel, ESP 32 microcontroller, motor, voltage sensor, DHT 22 sensor, ultrasonic sensor and collected rainwater. In this project uses 9V and 3W solar panel as source power for microcontroller ESP 32. The solar uses 7.4 V rechargeable battery to store power gained by sunlight exposed. From the result, it is proven that this microcontroller can function depends on this solar. Although motor is used in this system by connecting relay to the microcontroller, it still can support the microcontroller to be function all the time because not all time the motor works as the motor only starts working when the water level is below the set value.

For the microcontroller, it is a wise choice of using ESP 32 despite size of it, it also consumes 3.3 V only to function, it save power a lot, the WiFi inbuilt also helps in implementing the Internet of Things (IoT) or real time data despite consists of many pins compared to Arduino Uno and ESP8266. This microcontroller requires less maintenance other than its price which worth buying to replace if it damages. This IoT system can helps any user to react early or standby with the components needed to do maintenance or repair the damage. Hence, it is user friendly as it does not take time too long to do maintenance and also environment friendly as user does not need to drive twice or more to check and maintain the electronic parts and hardware parts.

For voltage sensor type below 25 V used, this voltage sensor is to retrieve data of voltage, current and power of the rechargeable battery that only 7.4 V maximum. The result shows the battery performance in real during charging with solar and also the drain for the microcontroller. The voltage sensor not only can provide voltage data but also the current and power by using formula as in the code. Therefore, no use of current sensor makes the system much cheaper as one sensor can give three significant data. The voltage, current and power reading are in rms value.

The mechanical device use in this project is a submersible dc motor. This motor requires 3.3 to 5 V of functional range. This low voltage motor is suitable to this project as the water pressure needed for the water flows is low. It also saves energy and produce almost lowest sound among all other motor. This motor is connected to 5V single relay as interface between ESP 32 and motor. Low voltage means low in cost that makes the overall system in a very good price. For higher litres of water stored in tank, it is recommended to use higher voltage motor 12 V and above to accelerate the water flows rate per second.

The other element in this project is the rainwater collection. The rainwater seems to be important as it is the next option after the clean water supplied by water service company. It is also use as back up for every house in Malaysia. The use of rainwater obviously can reduce the water bills of the consumer despite it is much cleaner than underground water and river as it does not contact with soil or ground that may have dissolved chemicals. The rainwater also is much cleaner if it is far away from industry area. The disadvantage of using this rainwater is that it produces smell or odour if it is kept for longer time. So, user need to change water regularly when days the water is not been used.

From this Smart Water Management with Internet of Things (IoT), there are some improvement can be done in the future. Many aspects of improvement will be discussed in this section.

In terms of renewable energy in the concept of energy harvesting, the first energy that can be harvested is sunlight since Malaysia receives sunlight for 8 hours per day, this energy is suitable to use in this system. The higher power of solar panel is advisable to be chosen as it provides higher current where it can allow faster energy supply to the devices. But, rechargeable battery also must comply the solar panel used otherwise the battery cannot perform charging or even get damage if the solar panel has very high voltage. Solar panel with trusted brand of course absorbs very efficient sunlight energy but it is expensive. It is recommended for bigger project to maximise the energy storage over period and minimise losses.

Second energy harvesting that is suitable to use in this project is rain drops. We can use piezoelectric to convert mechanical energy from rain drops to electrical energy. One piezoelectric can provide up to 1 V. This piezoelectric sensor is also suitable to use in Malaysia as our rain fall rate is high per year. This method can replace the solar energy during raining. More efficient power can be generated if the sensors are aligned in parallel way. Hence, the system can get constant supply for power devices.

Besides, since rainwater is much cleaner than any ground raw water source, we can create it suitable for drinking. Special treatment or filter is needed to further process the collected rainwater so it is more worth the consumers which obviously can reduce much lower water bill cost. There are some rainwater filters which are already sold in the market that can be integrated with the system as added value to the consumer. The rainwater filter for drinking is not popular in Malaysia but in western region, this method is already be implemented by their citizen on their own initiative to reduce water bill cost and when they build house in the area that far away from the water supply such as in the village, jungle or mountain. This way also seems can overcome odour issue where the chemicals that produce odour from the rainwater are filtered out. Thus, this collected filtered rainwater can be stored longer without any worries and harm.

The water tap that is integrated to the tank or hose can be improved by changing the nipple to the sprinkle or spraying nipple which it is more efficient in water flows as it reduces water wastage and water bills but larger areas can be covered by this way such as watering plantation area, fields and cleaning a large area. The normal water tap is claimed to waste more water than the sprinkle or spraying one.

Besides, the microcontroller can switch to five different power modes which are active mode, modem sleep mode, light sleep mode, deep sleep mode and hibernation mode. Refer Figure 5.1.

Power mode	Active	Modem-sleep	Light-sleep	Deep-sleep	Hibernation
Sleep pattern	Association sleep pattern			ULP sensor-monitored pattern	-
CPU	ON	ON	PAUSE	OFF	OFF
Wi-Fi/BT baseband and radio	ON	OFF	OFF	OFF	OFF
RTC memory and RTC peripherals	ON	ON	ON	ON	OFF
ULP co-processor	ON	ON	ON	ON/OFF	OFF

Figure 5.1: Five different modes of ESP 32

Source: https://randomnerdtutorials.com/esp32-deep-sleep-arduino-ide-wake-up-sources/

Power mode	Description	Power consumption
Active (RF working)	Wi-Fi Tx packet 14 dBm ~ 19.5 dBm	Please refer to Table 10 for details.
	Wi-Fi / BT Tx packet 0 dBm	
	Wi-Fi / BT Rx and listening	
Modem-sleep	The CPU is powered on.	Max speed 240 MHz: 30 mA ~ 50 mA
		Normal speed 80 MHz: 20 mA ~ 25 mA
		Slow speed 2 MHz: 2 mA ~ 4 mA
Light-sleep	-	0.8 mA
Deep-sleep	The ULP co-processor is powered on.	150 μA
	ULP sensor-monitored pattern	100 μA @1% duty
	RTC timer + RTC memory	10 μA
Hibernation	RTC timer only	5 μA
Power off	CHIP_PU is set to low level, the chip is powered off	0.1 μA

Figure 5.2: Comparison of different power modes power consumption

Source: https://randomnerdtutorials.com/esp32-deep-sleep-arduino-ide-wake-up-sources/

Besides, water quality sensor can be used in the rain water tank. It is recommended to use this sensor after applying the filter or treatment so consumer can double check if their filtered water is safe enough to be consumed. From the results, if the water quality is below the expected, the owners know their filters need to change and clean. This is because the water parameters that the sensor can read are the conductivity, pH, salinity, dissolved oxygen, chlorine residual and turbidity. This sensor guarantees the consumer health in term of drinking water quality.

Next, this system can be designed in far area by placing the rain water tank at the area that receive rain fall rate the highest and then distribute it to the certain radius area so it helps the area that receive lower rain to get constant water source.

Other than that, government can give subsidiary to houses in Malaysia to encourage Malaysian in implementing this smart water management with IoT.

Therefore, this Smart Water Management with Internet of Things (IoT) is useful to consumer. Better improvement should be made in the future. The lesser the cost and more efficient of the system are better. The criteria of the water tank also need to consider as the larger the surface area, more water can be stored. Also, many water tanks provided to collect rainwater, more water can be stored and hence, the water can stay longer to be used. The overall system is not expensive and is affordable for every house to have it. The ESP 32 microcontroller is the most expensive components among others but if consumers buy in big number, the price will drop and the system will much worth with price. It does need frequent maintenance visit which it can be monitored by IoT platform which the overall dashboard as in Chapter 4.

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