Development of an Automated Solar-Powered Water Pump Using Arduino

Nurul Muthmainnah Mohd Noor[1], Muhammad Faisal Zulkeflee[2], Ya'akob Yusof[1]*
[1]Advanced Mechanical Research Group, Fakulti Kejuruteraan Mekanikal, Universiti Teknologi MARA, Cawangan Pulau Pinang, Kampus Permatang Pauh, 13500 Permatang Pauh, Pulau Pinang, Malaysia
[2]Fakulti Kejuruteraan Mekanikal, Universiti Teknologi MARA, 40500 Shah Alam, Selangor, Malaysia
**nurul.muth@gmail.com*

ABSTRACT

Agricultural sector is one of the main sources of economy for our country. Therefore, an effective irrigation system is needed to provide better quality in their output especially for the food sector. The main purpose of this project is to design and develop a solar water pump system that can perform the process automatically. The water pump system was designed using CATIA before being fabricated using PVC tubes. This system uses an ultrasonic sensor that determine the water level in the tank. In this system, the pump was powered by a photovoltaic panel and controlled by Arduino Uno. The solar powered pump consists of the pump with an electrical motor and the solar panel whose function is to supply power to the load. The solar panel converts solar energy to direct-current (DC). This system was implemented with an Android application to connect it with the farmer as its user. Results from the tests conducted shows that the solar energy can be used effectively to regulate the irrigation system. This is a reliable system to be used in rural area as it is a renewable power supply and at the same time able to lessen the dependency on the conservative source of electricity.

Keywords: *Automation, autonomous control, controlling machines, electronic application, system intelligent.*

Introduction

In the world of globalization, the agricultural sector has becoming the important things for our livelihood. Without the good plan of agriculture sector,

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it can make low living standards and inequality growth in the long term. Therefore, most countries in the world make the agriculture as their primary source of economy before the industrial subdivision [1]. People still rely on agriculture for their income even though there are many commercial options coming up such as automotive industrial, communication industrial and banking industrial. The agriculture sector becomes important because it is the source of food supply, medicine, clothing, and employment all over the world [2]. However, it is no easy to carry out the agriculture activities. There are a lot of requirement that need to be handled carefully especially in the irrigation system. A key challenge in the ASEAN countries include Malaysia is to manage energy, water, and food resources to ensure these resources can be useful to the life in the long term [3]. Most farmers especially in rural area are facing a lot of problems in the pouring the water in the field to keep their crops healthy. The locations where no electricity is necessary to pump the water for consumption also a key challenge to manage the food resources [4]. They use a fuel-powered pump to pump the water to the tank as their irrigation system. This pump required the fuel to generate the power and it will become a burden to farmers to get the fuel supply [5]. To overcome this problem, introducing the solar panel that generate a new energy from the sun is a good idea. This energy can be used to replace the conventional or traditional method in producing a power. It can give significantly help and accelerate the development of agriculture in many other poor remote areas.

Solar power system is usable energy that generated from the sun and then form in electric or thermal energy [6]. Solar energy can be captured in many ways such as by using photovoltaic solar panel. This panel will convert the sun's rays into usable electricity. Aside from using photovoltaics to generate electricity, solar energy is commonly used in thermal applications to heat indoor spaces or fluids. For example, For instance, solar hot water system can generate a large amount of water with optimize effective cost [7]. This system can be used in most of the environments conditions as they employer the solar energy to produce useful heating.

The photovoltaic cell is also an efficient approach for using the solar energy. Photovoltaic utilize a semi-conductor to absorb the radiation from the sun and then, when the semi-conductor absorbs this radiation it emits electrons to create a flow of electric circuit [8]. Then the direct current (DC) electricity will feed to a solar inverter to be converted to alternating current (AC) electricity. Therefore, one of the applications of this technology is used in irrigation systems for farming. The pump receives electricity directly from the solar panel and this system is designed to pump the water only during day times while battery coupled can pump the water both during day and night. This is a green way for energy production which provides free energy after the system is developed.

In addition, by using this system, it absolutely can reduce the cost such as the installation cost and maintenance cost. The advantage of solar water pump is it are reliable in regional and remote areas such as in rural area such as in Bangladesh, Africa, and ASEAN country. Another advantage is easy to transport and relocate which is the solar water pumps can be organized as per the needs of the farm and have extremely low operating costs. Therefore, the solar water pumping system is the perfect solution for regions with sunny days and plenty of water on their grounds.

In this project, the water pump was used as a device to push the water from the disperse tank to the storage tank. The solar controller will generate the energy from the panel solar and this energy will be stored into the battery. The solar-powered water pump system come with the wireless technology, where it will be connected to the Android based monitoring device using Bluetooth connectivity. The Android applications will act like a switch button, where the user can control and monitor the irrigation system without the need to always going to the farm.

System Development

Concept Generation

In this project, the concept of water pumping system is generated by using a morphological chart. The morphological chart is a structural approach to concept generation to a defined design problem by combinations of the potential solution. In this case, there are three conceptual design of frame structure of solar water pump are sketched. Basically, the concept approach of these design that is to use a simple design with a light weight. Table 1 shows the criteria that consider in designing the water pump system.

From Table 1, the concept 2 is chosen by executing PVC pipe for material and connected with Bluetooth for wireless system, easy in fabrication with small size and light weight. After designing the conceptual design, the evaluation criterion as shown in Table 2 will be decided by apply a Pugh's method. The concept used for decision making in order to help us in selecting the best viable and most feasible option from a list given alternatives. First, the most important criteria are determined before to finalize our decision about the alternatives and then we select the best one based on the criterion. Therefore, the idea of using the Pugh matrix may be used to help evaluate a series of alternatives to make the best decision.

Table 1: Conceptual design for solar water pump system

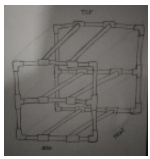
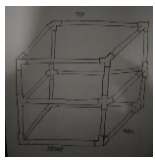
Criteria	Design 1	Design 2	Design 3
Concept design			
Body Material	Steel	PVC Pipe	PVC pipe
Fabrication	Difficult	Moderate	Easy
Wireless	Wi-Fi	Bluetooth	Bluetooth
Size	Big	Moderate	Small
Weight	Heavy	Moderate	Light
Cost	High	Moderate	Low

Table 2: Conceptual design evaluation by Pugh's method

Description		Existence Product			
Criteria	Weightage	Datum	D1	D2	D3
Durability	1	0	+	0	-
Reliability	1	0	+	+	0
Lightweight	2	0	0	0	+
Small size	1	0	-	0	+
Affordability	2	0	0	+	0
Portability	2	0	0	0	+
Safety	1	0	0	0	+
Cost					
*Material	2	0	0	+	0
*Maintenance	2	0	0	+	0
	Net score		1	7	5

From Table 2, the designs are named as D1 for design 1, D2 for design 2 and D3 for design 3. Using Pugh matrix, all three designs are compared with the existence product as the reference. Then, every criterion will be signed by +, 0 and – symbols. The set of criteria options will be summed together by multiplying the weight with the value of each criterion. After that, the design will be ranked based on the total up of net score for each design. The highest score shows that the best result of designing compared with the other designs by evaluating their criterion options. From the Table 2, D2 has the highest net score which is 7. In the next stage, D2 will be designed using CATIA based on the conceptual design chosen.

Development of the Controller

The development of the controller consists two part: its hardware and program. The controller is a comparative device that receives an input signal from a measured process variable then compares this value with a set point in order to determine the appropriate amount of the output signal required by the final control element. For hardware of controller includes determination of Arduino microcontroller, sensor, and actuator. In this project, the input from the sensor meanwhile the Arduino UNO is used as an interface between input and output. The Arduino UNO is an open-source microcontroller board based on the Microchip ATmega328P microcontroller that developed by Arduino.cc.

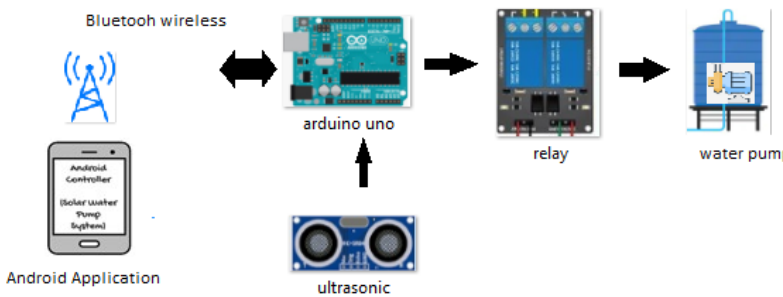


Figure 1: The controller system using Arduino UNO and connected with Bluetooth system

Based on Figure 1, the ultrasonic sensor and Bluetooth wireless are connected with Arduino UNO as the inputs. In the automatic irrigation system, the water outlet of the pump is controlled by the ultrasonic sensor. This sensor will be mounted on the top of tank (tank 1). The ultrasonic sensor detects water level in the storage tank. It will measure the distance of water level by sending a sound wave from a buzzer. By recording the elapsed time between the sound wave that being generated and the sound wave bouncing back, it is possible to calculate the distance between the solar sensor and the object. If the water level below than 5 cm, the pump will be generated to pump the water from the tank 2 to the tank 1. The system will be connected wirelessly via Android applications to give information to the user. The user can get any information regarding the water level through the application. The output for this system is a water pump. The water pump will be controlled by the relay module. This relay acts as an actuator for this system.

In term of electrical, the circuit is designed and developed using fritzing software. The software is easy to use. The list of components involve are (1) battery, (2) solar panel, (3) Arduino Uno (microcontroller), (4) Bluetooth, (5)

solar controller, (6) relay module, (7) ultrasonic sensor, (8) DC motor and (9) breadboard. The connection of circuit can be seen in Figure 2.

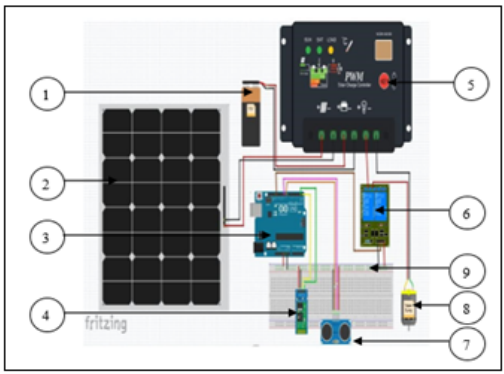


Figure 2: Components of solar powered water pump by fritzing software

Developing the Programming for the Solar Water Pump System

Apart from the water pump system, remote monitoring system is also developed. The system will monitor water level and pump functions through applications via mobile phones. The controller design is conducted based on the flowchart in Figure 3. The solar panel is converted energy and charge the battery through a solar controller. The ultrasonic sensor will sense the level of water in the tank 1. If the water level below 5 cm, the water pump will be on and deliver the water to the tank 1. If the water level is 10 cm and more, the water pump will be off. The data will be sent to the smartphone. There the user can monitor the water in the storage tank.

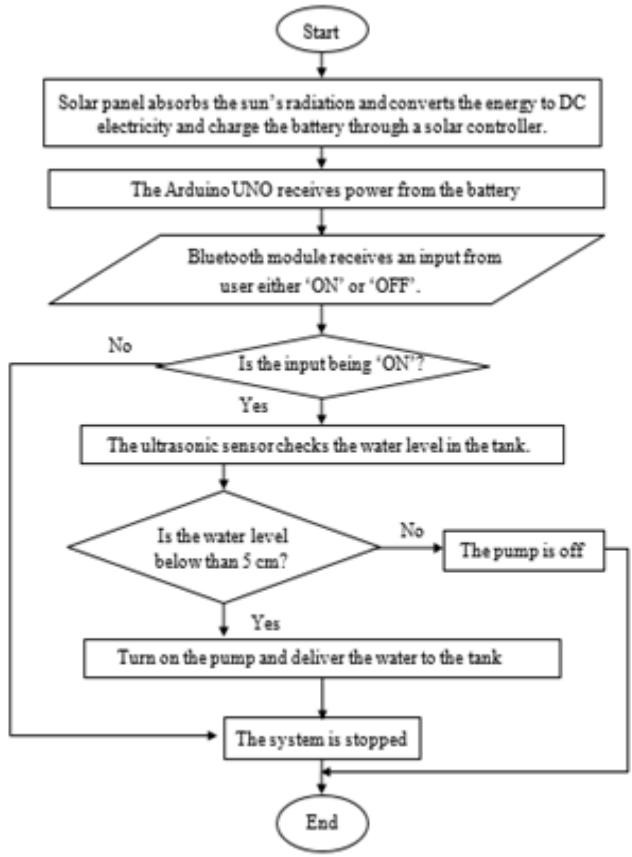


Figure 3: Flowchart of the water pump system

Results and Analysis

The prototype had been fabricated by using PVC pipe for the frame. The size of the prototype is about 520 mm x 590 mm x 650 mm. The weight is about 7 kg with equipped all components: two tanks, solar panel, battery, and electronic part. The protype consists of tank 1, tank 2, battery, pump, electronic part, and solar panel as shown in Figure 4.

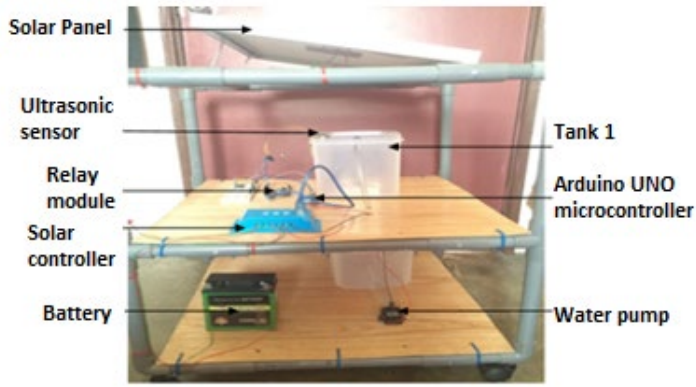


Figure 4: The prototype of the water pump system

In this project, the water level measurement was tested by using the ultrasonic that implemented with the Arduino UNO. This step is crucial to ensure Arduino UNO is successfully implemented to the system. Next, energy efficiency measurement was performed. The measurement was taken in three days with different weather in Shah Alam, Selangor. There are cloudy day - Monday (29/5/2017), sunny day - Wednesday (31/5/2017) and clear day - Saturday (2/7/2017).

Water Level Measurement

To start the system, the user needs to follow the steps in order to pair between Bluetooth connection with the Android applications. When the input command is ON, the ultrasonic sensor will start measuring the water level in the both tank. If the water level in the tank 1 is not enough the water pump will run automatically and stop until the water reach to a certain level that had been set. Table 3 showed how the system its works.

Table 3: Status of the solar water pump

Input	Ultrasonic sensor	Water level (cm)	Water pump
ON	Yes	X < 5	ON
		X = & > 10	OFF
OFF	No	Stop programme	

The average time taken for the water level from 5 cm to reach the maximum level 10 cm for three days were recorded as shown in Table 4 and the reading were repeated 5 times to obtain the average reading. The result shows the averaged time is slightly same.

Table 4: Time taken for the water level increase from 5 cm to 10 cm

Date	Reading (s)					Average time (s)
	1st	2nd	3rd	4th	5th	
29/5	30	29	31	32	30	30.4
31/5	29	29	30	31	30	29.8
2/7	31	31	32	30	30	30.8

Efficiency of Solar Panel

In term of efficiency, the solar panel depends on the weather in generating the energy. If the cloudy day, the efficiency of solar panel is low compared to the efficiency of solar panel during sunny day. The power output that generated from the solar is greater during sunny day compared during cloudy day. It can been seen in Figure 5. It is seen that the maximum energy was produced occurs in the three hours after the solar panel exposed to sunshine.

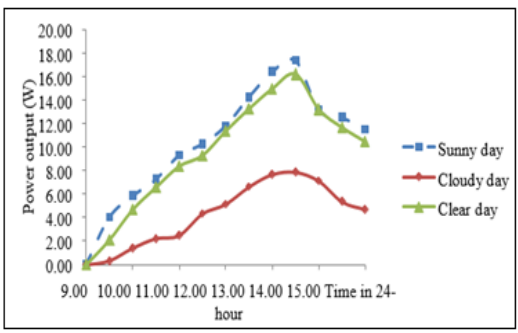


Figure 5: Power output for the three different weather

Conclusion

From the main objective of this project, it is concluded that the project successfully met its goal, which is to design a solar-powered water irrigation system. The system was designed and simulated using CATIA. The system was then implemented by using Arduino UNO as the microcontroller and Android device as the receiving end of it, using Bluetooth as the communication protocol. The system works successfully. It is believed that this prototype is able to demonstrate the effective usage of the renewable energy to meet with the electricity demand for the irrigation and livestock watering. This project will be further improved by implementing the internet of things (IoT), aligned with the IR4.0. Using IoT, more data can be captured

and transferred as well as analysed for the benefits of the system and this industry.

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