Development of Solar Powered Sprinkler Robot Based on Watering Plant Using IOT Approach

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Abstract. Nowadays, solar energy’s popularity is growing consistently every year, along with the growth of amazing solar technologies, which is considered to be one of the most popular. Non-renewable energy like petrol and gasoline is being replaced with solar energy, which is renewable energy. The main objective of this project is to design and simulate a robot solar system. The robot is developed using Arduino Mega 2560 as the main brain of the system. This system is equipped with a solar tracking system to track the movement of the sun and LDR is used to detect the presence of sunlight. The solar tracker is used to get the maximum efficiency of solar energy and reduce power losses. In addition, the solar tracker can rotate from 0°-180°, which is the best angle for the solar panel to reach the sunlight. This robot will be attached to the sprinkler system to perform the watering process. This robot is developed for use in the agriculture field to reduce the manpower and cost of the watering process. Three analyses will be conducted in this project such as solar panel analysis, Wi-Fi connectivity analysis and sprinkler system analysis. The result shows the solar panel will gain the highest intensity of the sunlight at 12.00 pm and a sunny day compared to the other time and a cloudy day. The maximum range of Wi-Fi connectivity and the water pump, time used to finish the watering process and watering area will be discussed.

1. Introduction
Sprinkler robots are playing an important role in the agriculture field as it does not require extra workers to operate and can save a lot of costs and time for watering plants every day. Hence, this project is about developing a sprinkler robot which is supplied with solar energy, can be controlled by a smartphone and follow the line-tracker module. Solar energy is a type of renewable energy and it is also environment friendly. The solar system can convert sunlight into electricity that can be used as a direct current or alternating current by using an inverter [1-2]. This robot is equipped with a solar tracking system to track the movement of the sun and Light Dependent Resistor (LDR) is used to detect the presence of sunlight. The solar tracker is used to make sure the solar panel gets the maximum efficiency of solar energy and reduces the power losses. Moreover, the solar tracker can rotate from 0° to 180° for the solar panel to get exposed to the sunlight. The water tank is added to the robot for storing the water and it is connected to a pipe which is attached with the sprinkler for watering the plant. On the other hand, an ultrasonic sensor is added to avoid the robot from crashing with the obstacles. Arduino is used as a processor and acts as a brain to the system which processes the instruction from the input and gives the instruction to the output. Furthermore, this robot is controlled by a smartphone via Wi-Fi connection or run in an autonomous mode.
However, due to the inconsistent or unstable of the solar source due to the change of weather, the battery bank is used to become the storage for the power to overcome the insufficient solar energy and provide a constant and stable supply for the robot [2-3]. The source goes through the charge controller before it is stored in the battery bank to avoid being over charged, and the robot can run at any time even in the night as there is a battery bank for the supply of electricity. The solar panel that is built in a static form cannot get the full intensity of sunlight as it rises from the East and falls down to the West [3-5]. Then, the robot is equipped with a solar tracker to track the sunlight and achieve the maximum efficiency of the system. As the solar panel is non-water proof and perhaps malfunction if it drops with the water, the position of the water tank pipe in the attached sprinkler is redesigned to avoid the drop of water causing the system crash [6-7]. In this globalized world, there is a modern application that applies to agriculture fields like drones and irrigation systems, but it also has disadvantages such as cost and being limited to specific areas. To solve this problem, sprinkler robots are introduced to handle watering plants as it is costless and easy to interact with.

2. Methodology
This system gets solar energy supplies that are generated by the solar tracking system and convert it to DC electricity that is usually used in the robot. Then, electricity will be stored to the rechargeable battery via a charge controller. The controller which the controller is used to avoid over charging of the battery that may damage the battery and shortage of its lifetime. Furthermore, the 12V DC load will supply to the system from the charge controller. When the Wi-Fi shield is connected to the smartphone, the Arduino will receive the instruction and the processor will process data input and make a feedback output depending on the instruction given. For the solar tracker system, the Arduino board will receive the signal from the LDR that will be used as the sensor for sunlight and move the solar tracker toward the sun while for the mobile robot to run automatically, the signal from the IR line-tracking module will generate a digital output to make the system run in the straightway. Figure 1 shows the block diagram of the Mobile Robot Operation.

![Block diagram of the Mobile Robot Operation.](image)

This project is a combination of all three systems which are mobile robot system, solar tracking system and sprinkler system. The solar tracking system used two Servo Motor MG995 with the LDR as input to sense the sunlight and obtain the max intensity of the sunlight. When the LDR captures the sunlight, the servo motor will move accordingly based on the sunlight. The mobile robot system controls using the smartphone and the motor of the system drives using L293D Motor Driver. The Wi-Fi shield is used as the access point of the Wi-Fi, so with the connection of the same web, the Wi-Fi shield will send the signal ‘F’ through the serial port of the ArduinoMega2560. When the Arduino Mega 2560 gets the request of ‘F’, the Arduino will perform the motor to run forward indirection. After that, the sprinkler system is run based on the controlling of a smart phone, and the 12V water pump is controlled by the 5V relay that acts as the switch for the pump.
2.1 Software and Hardware Development

2.1.1 Arduino Mega 2560
The Arduino Mega 2560 can be programmed by Arduino 1.8.12 Software. The Arduino software is used to compile, upload, and export to binary to have simulation in Proteus software as the coding of the system is run by using this software. The combination of the Proteus and Arduino is to determine whether the system can run smoothly or not.

2.1.2 Proteus 8 Professional
Proteus Design Suite is software that is used to simulate the microcontroller modules, PCB layout modules, and schematic capture. The simulation is tested with a combination of Arduino and to make sure the circuit can run smoothly and with no error occurs before continuing with the hardware part. The Figure 2 shows that there are 4 LDRs that are used as the sensor for the sense of the light to achieve the maximum intensity of the sunlight and also two motors that are represented as horizontal motor and vertical motor. The horizontal motor moves the solar tracker in clockwise or anticlockwise while the vertical motor moves the angle of the solar panel. The real circuit then is constructed to determine whether the simulation circuit can work in the form of the combination of hardware and software.

![Figure 2. The Circuit for Solar Tracking System.](image)

The Figure 3 shows that a line-tracking robot has been used as the sensor to detect the path that goes through. The Arduino will give the corresponding output as the instruction from the sensor has been sent. The motor will perform output as turning left, turning right, forward, and stop respectively. The real circuit then is constructed to determine whether the simulation circuit can work in the form of the combination of hardware and software as shown in Figure 4 to perform the movement of the robot by using a smartphone.

![Figure 3. The circuit for line-tracking robot.](image) ![Figure 4. The Real circuit.](image)
2.1.3 Water Sprinkler System and final product

The mobile robot is equipped with an ultrasonic sensor and IR line-tracking module which the ultrasonic sensor is to avoid the collision between the robot and wall when controlling the robot or can be said as to ensure that the robot is avoid from crash while IR line-tracking module is mainly equipped to this robot to minimize the time on controlling and also inspect on the robot as the plant in garden is always fix at their position so, IR line-tracking module is applied to following the path that has been already fix. Other than that, the LDR sensor is selected to sense of light because it is common and easy to get although it is not the best compared to other light detect sensor like photodiode and phototransistor, but it is enough to handle this project. As this project mainly is to be simpler and more costless, then LDR sensor is used to applied to this project. The solar panel will move based on the LDR sensor and it will move according to the sense of light of LDR sensor so, it is important that to apply a more suitable amount of sensor on the robot. With the applied of 2 LDR, the solar tracking system may not so optimise because the lack of sensor will not cover it up on movement of solar panel while with the 8 LDR, the solar tracking system is also not suitable because there are too much of sensitivity for a solar tracking system and the servo motor will be always operated to obtain a maximum light intensity as the output from LDR needed 55ms to process and also the output of motor will take time to response. So, the best match is 4 LDR to be applied to this robot. Furthermore, the condition of the tires and the material used in the design makes the mobile robot move smoothly. The water tank with sprinkler is designed as the dimension of 22.5cm x 10cm x 10cm, which means that about 2 litres of water can be stored into the tank for watering purpose. Figure 5 shows a Water Sprinkler System that consists of 12 V DC supply to run 12 V DC motor pump, relay as a switch to activate or deactivate motor pump and 9V battery to run the Arduino system to fully functioning. The mobile robot, solar tracking system and sprinkler system then is combined to form the sprinkle robot that is controlled via Wi-Fi by a smartphone. Each system has been tested to confirm that there is not a malfunction between the component and circuit. The Figure 6 shows the prototype of the Solar Powered Sprinkler Robot Based on Watering Plant.

2.2 MIT App Inventor 2

As the system controls through the smartphone, the MIT App Inventor 2 show in Figure 7 is used to create the software application to control the robot using a smartphone. MIT App Inventor 2 is an online platform designed to teach computational thinking concepts through development of mobile applications. The applications are created by dragging and dropping components for robot function and movement into a design view and using a Visual Blocks Language to program application.
behaviour. The Wi-Fi is used as the medium for controlling the robot, the application is connected via IP address to perform the corresponding function.

Figure 7. MIT App Inventor for Sprinkler Robot Controller.

3. Result and Analysis

3.1 Solar Panel Analysis

The solar panel absorbed solar energy to generate electrical energy. From the Table 1, shows that analysis for the solar panel on a sunny day. The result is recorded at the time from 10.00 am to 5.00 pm (1 November 2020) which is a sunny day in Nibong Tebal, and meaning that the solar panel will gain the highest intensity of the sunlight throughout that day. The result for output power is calculated using this equation:

\[ P = IV_{\text{out}} \]  \hspace{1cm} (1)

The solar panel output is recorded as input voltage whereas the charge controller output is recorded as output voltage.

Table 1. Analysis for the solar panel on a sunny day.

| Time   | Voltage (V) | Current (A) | Power (W) |
|--------|-------------|-------------|-----------|
|        | In | Out | In | Out |               |
| 10:00 am | 17.29 | 12.64 | 0.51 | 0.53 | 6.699    |
| 11:00 am | 17.81 | 12.64 | 0.54 | 0.58 | 7.331    |
| 12:00 am | 19.69 | 12.89 | 0.61 | 0.62 | 7.992    |
| 1:00 pm  | 19.38 | 12.85 | 0.58 | 0.62 | 7.967    |
| 2:00 pm  | 19.52 | 12.87 | 0.59 | 0.59 | 7.593    |
| 3:00 pm  | 17.82 | 12.82 | 0.52 | 0.54 | 6.923    |
| 4:00 pm  | 17.21 | 12.81 | 0.52 | 0.52 | 6.661    |
| 5:00 pm  | 16.38 | 12.57 | 0.49 | 0.54 | 6.788    |

From the Figure 8 shows that the graph of voltage against time which blue line represented solar panel output and orange line represented charge controller output. As from the graph, it shows that there is a maximum peak in the blue line which is 19.69 V at 12.00 pm and that there is a higher intensity of sunlight at 12.00 pm compared to the other time. The orange line is nearly linear because of the charge controller that limited the voltage to a constant 12 V to provide a consistent output for load and prevent the shortage of battery life.

The charge controller acts like a centre of control of the power source. The charge controller is used to restrict the voltage that comes out from the solar panel as the voltage output is too high that can damage the battery life while in charging and because the load cannot handle the high-power
supply and burns. When the voltage that is over 12 V goes through to the charge controller, it will regulate the voltage to 12 V.

![Figure 8. Graph of voltage against time.](image1)

From the Figure 9 shows that the graph of current against time in which the blue line represented current without load and orange line represented current with load. From the graph, it shows that both lines are nearly the same because of the current that obtained from the solar panel is constant and fixed.

The Figure 10 shows that the graph of power consumption against time. From the graph, it shows that the output power from 6.699 W at 10.00 am increases to the peak which is 7.992 W at 12.00 pm. This is because there is higher intensity of the sunlight at 12.00 pm, and the output voltage that occurs from the solar panel is the highest, which is 19.69 V. As for the equation of output power, it can be concluded that when there is an increase in voltage, the output power will also increase.

![Figure 10. Graph of power consumption against time.](image2)

The Table 2 shows that the result of the solar panel analysis is on a cloudy day. The result is recorded at the time from 10.00 am to 5.00 pm (10 November 2020) which is a cloudy day in Nibong Tebal. From the Table 2, it shows that the output voltage from the solar panel is lower than the 12 V, which means the solar panel cannot act as the main supply for the system as the system required 12 V to operate, the battery is used as the main supply to the system. The output power is also reduced compared to a sunny day as the output voltage of the solar panel decreases. The battery is not charging because the power supply from the solar panel is not enough.
Table 2. Result of solar panel analysis is on a cloudy day.

| Time | Voltage (V) | Current (A) | Power (W) |
|------|-------------|-------------|-----------|
| 10.00 am | 7.28        | 0.51        | 3.713     |
| 11.00 am | 7.85        | 0.54        | 4.239     |
| 12.00 pm | 10.81       | 0.62        | 6.702     |
| 1.00 pm  | 9.69        | 0.64        | 6.202     |
| 2.00 pm  | 8.51        | 0.48        | 4.085     |
| 3.00 pm  | 7.29        | 0.57        | 4.155     |
| 4.00 pm  | 7.87        | 0.53        | 4.171     |
| 5.00 pm  | 7.72        | 0.60        | 4.632     |

From the Figure 11, it shows that there is a huge reduction of output voltage from the solar panel on a cloudy day compared to a sunny day. This causes the battery to act as the main supply for the system, and it can be concluded that the solar energy is consistent but depends on weather. When the weather is not suitable for capturing the sunlight, the output voltage will decrease while when the weather is suitable for capturing the sunlight, the output voltage will increase.

Figure 11. Graph of voltage against time in comparing with sunny and cloudy day.

3.2 Wi-Fi Connectivity Analysis
The Table 3 shows that the analysis of the range connectivity of the Wi-Fi. The maximum range in connection of the Wi-Fi is 100 m, which means if the range is more than 100 m, the connectivity will be lost, and the robot will not get instruction from the smartphone.

Table 3. Analysis of range connectivity of the Wi-Fi

| Distance (m) | Wi-Fi Connectivity |
|--------------|--------------------|
| 10           | Connected          |
| 20           | Connected          |
| 30           | Connected          |
| 40           | Connected          |
| 50           | Connected          |
| 60           | Connected          |
| 70           | Connected          |
| 80           | Connected          |
| 90           | Connected          |
| 100          | Connected          |
| 110          | Disconnected       |
3.3 Sprinkler System Analysis
The sprinkler system of the robot has been justified by the flow rate of the water pump, time used to finish the watering process and water area. The 180° sprinkler head is attached to this system as the exposure wire from the solar tracking system is unfavourable with water. Mainly, the water pump that has been equipped to the sprinkler system is a 12V water pump with 240 litres per hour flow rate and the size of the water tank is equal to $2.25 \times 10^{-3} \text{ m}^3$ or $2.25 \times 10^{-3} \text{ litres}$ and takes 2 minutes and 6 seconds to finish the watering process. The area that has been watered is approximately $106.08 \text{ m}^2$. That means, every 2 minutes and 6 seconds need to be filled in the water, and the watering process is run in a short duration. So, there is a restricted or limitation for the robot to carry out the watering process as the size of the water tank is fixed and cannot be replaced with the larger water tank because the motor of the mobile robot may not effort with the weight of the larger water tank.

4. Conclusion
The ‘Solar Powered Sprinkler Robot Based on Watering Plant Using IOT Approach’ has been created and designed using the SolidWorks software. After that, the circuit is constructed and simulated in the Proteus software for detection of the error. Moreover, the solar tracker can follow the movement of the sun based on the received amount of light on the LDR. By using the smartphone, the robot can be controlled easily. This project not only uses the solar tracking system but also combines it with the sprinkler system to have a technology that has the advantage of both systems. Furthermore, this project uses Arduino as the controller for the system. If there are something that wouldn’t expected happened, the system may not have predicted for that as the system is restricted to the scope of work and the data that may be differ and improvement can be carry out for a more complete system.

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