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Automated Photovoltaic Irrigation and Monitoring System with Internet of Things for Fertigation System

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Abstract: Agriculture is the main source for Malaysians, especially in rural areas to generate income for daily living. However, some plants need very careful care to get more efficient results and need more workers to take care of them. The main objective of this project is to develop an automatic system to irrigate the plant using a photovoltaic (PV) power system and monitoring capability as well as the prototype of the project system. NodeMCU is being selected as a microcontroller for controlling the whole system while the soil moisture sensor and ultrasonic sensor are used to control the water pump to operate and monitor the level of water in the tank. The additional ESP-32 CAM in this system project also helps the user can monitor the plant physically in live streaming. The finding of this project is shown in the functionality of the automated system and the monitoring system with the internet of things tested. As a result of this finding, the system is able to operate automatically in irrigating the plant as well as successful in connecting the user with the IoT base to monitor the system and the plant physically. In the future, the water level in the tank can be automatically filled to ensure that the tank always has sufficient water to irrigate the plant.

Keywords: Photovoltaic Irrigation, Monitoring System, Internet of Things

1. Introduction

Currently, many devices and work can perform automatically for example car industry installed the door at the car by the automatic mechanism without being controlled by the human on the site. It can be called an automatic industry in installing the part of the car. Hence, the plantation also can be one of the industries that can make it run automatically in a way to increase production. One example is

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automated fertigation, which is a system that can irrigate the plant on its own. It allows the plant to take care of more things without requiring full attention from humans. It is quite familiar nowadays due to its ease of installation and high production results [1]. To keep its nutrient efficiency, the plant requires an adequate supply of water. According to previous research, after four weeks of using this fertigation system, there were able to conclude at the end of the project that the system was capable of keeping the plant alive and in healthy mode [2]. The use of this type of system clearly can schedule the system to run properly and ensure that the plant remains in a healthy state.

In addition, the United Nations established the Sustainable Development Goals (SDG's) to achieve universal actions to protect the planet, minimize poverty, and ensure that people enjoy peace and prosperity [3]. As a result, the United Nations (UN) mission, solar energy was one of those that addressed SDG's number 7 which is affordable and clean energy. This awareness is familiar that all designs and the house loads using a solar as a power generation source. The automated system primarily uses solar power generation to help people in saving money on their electric bills and is suitable for off-grid areas. Malaysia's weather is ideal for using solar as an alternative source and being a clean energy resource.

Furthermore, the IoT must be implemented daily to upgrade and become a modern world, such as smart cities, smart homes, energy conservation, and intelligent transportation. Besides, the Internet of Things (IoT) is an essential thing to the generation right now, especially for young people. People are most concerned about technology or accessing the internet. It can be proven when past research same says that IoT is progressively becoming an essential aspect of our life that can be sensed everywhere around us [4]. IoT is the devices that can be transmitted the data from the system into another medium that does not use or attach any cable, in other words, called wireless such as smartphone, laptop, etc.

2. Materials and Methods

The materials and methods for the design of an automated photovoltaic irrigation system and monitoring system discussed in detail on the materials used in subtopic 2.1 and subtopic 2.2 present the block diagram of the system process.

2.1 Materials

Photovoltaic (PV) System

- Photovoltaic (PV)
- Solar Charger Controller
- Battery

Automated Irrigation and Monitoring System

- NodeMCU ESP8266
- ESP-32 CAM
- Soil Moisture Sensor
- Ultrasonic Sensor
- Relay Module
- Water Pump

There are separated into two systems which are the power system and the control system. The power system consists of a PV, it absorbed the sun's energy and converted it to electricity. Besides that, the use of a solar charger controller in keeping the battery from overcharging and controlling the current coming from the PV panel. Finally, the battery was part of the power system. The battery is used to store energy that can provide power to the load even if the weather is cloudy and rainy.

Next is automated irrigation as a control system with monitoring capability. NodeMCU is to be the microcontroller and ESP8266 that connect the devices for the data transfer using Wi-Fi protocol. Next is ESP-32 CAM is used for the intelligent IoT application in live streaming of the plant condition. The soil moisture sensor also measures the level of soil moisture in order to determine the state of the soil moisture. Besides, the ultrasonic sensor is used in measuring the level of water in the tank to ensure there is no problem with the irrigation process if the water is not sufficient. In addition, the ultrasonic sensor is used to monitor the level of water in the tank to ensure that the irrigation process does not fail due to a lack of water. Last but not least, is the relay module and the water pump. These two components are linked in that the relay will control the circuit to turn the water pump on and off.

2.2 Methods

The methodology for this project study is in designing an automated system and monitoring system with a photovoltaic (PV) power system as a power supply. This method will be further discussed in subtopic 2.2.1 consists of the concept connection of automated irrigation and monitoring system as well as the calculation for the PV system.

2.2.1 Concept of design the Automated Irrigation and Monitoring System.

The goal of this paper proposed is to develop and construct an automated system with IoT capabilities and a monitoring system that uses solar energy as a power source. The prototype will demonstrate how the entire system works. The finished prototype, which includes the solar system components, various sensors, and an ESP8266 microcontroller unit (MCU), will be critical in the system's deployment. Figure 1 shows the concept of the general connection of the automated irrigation and monitoring system

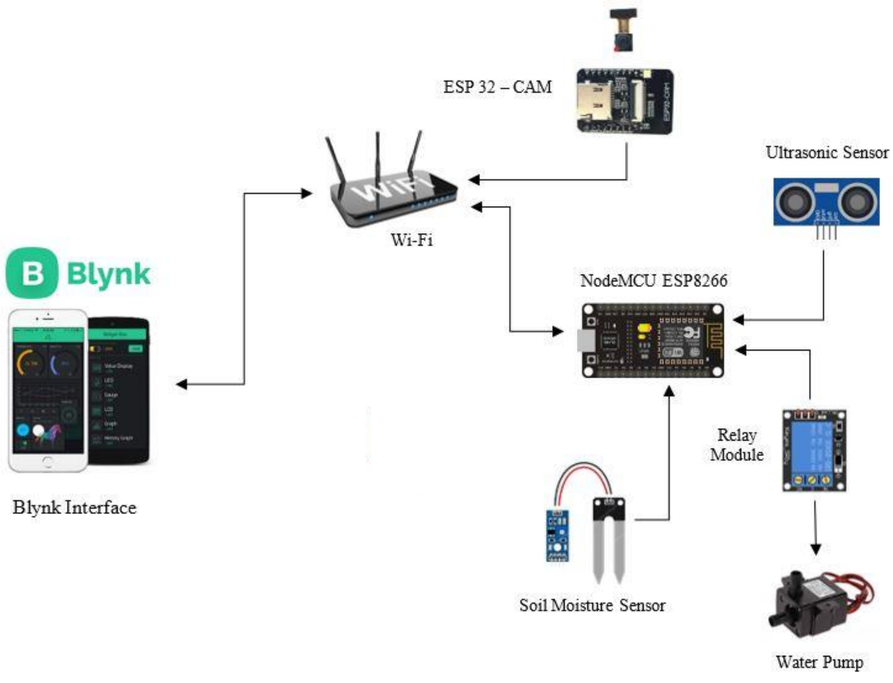

Figure 1: Connection of Automated Irrigation and Monitoring System with IoT

2.2.2 Calculation for Photovoltaic (PV) System

a. Energy Demand

The capacity of the load must be determined initially in order to create the whole solar panel system that will be stand-alone. The load is recorded in watts, while the time spent using or operating the device is measured in hours. Individual load energy consumption demand in Wh (watt-hours) is computed by multiplying the load power by the period of usage as follows Eq (1) [5] :

$$E_i = P_L \times T_u \qquad \textit{Eq. 1}$$

where the energy demand is in watt-hours, P_L is the power of load in watt (W) and the T_u is the time spent when operating the load in hours.

b. Battery Sizing

The calculation in equation 2 will help them determine what size battery they should have. Furthermore, the lithium battery may be utilised completely, as opposed to the lead-acid battery, which can only be utilised 50% of the time in Eq (2) [6].

$$\text{Battery Size (Ah)} = \frac{E_i}{(EN \times DD \times NV)} \text{ x } Dof \qquad \textit{Eq. } 2$$

where is battery size capacity is in Ampere-Hours (Ah), E_i is the energy demand in watt-hours (Wh), *Dof* is the days of autonomy, NV is the nominal battery voltage, *EN* is the efficiency of the cable, battery, charge controller and inverter and *DD* is the battery depth of discharge.

c. Photovoltaic (PV) Sizing

After calculating the total load to be energised by the PV system, determine the area of PV required to generate that amount of power. Internal losses are an inherent property of any panel. This is something to keep in mind. As the equation 1 the total watt-hours in the energy calculation, needed to divide the total watt-hours by the peak sun hours to determine the wattage of panels required in Eq (3) and (4)[6] .

$$SP = \frac{E_i}{PSH} \text{ x } F_{safe} \qquad \textit{Eq.}3$$

$$N_{SP} = \frac{SP}{SP_{max}} \qquad \textit{Eq.}4$$

where *SP* is the solar panel in watt (W), E_i is the energy demand (watt-hours) while PSH is the peak sun hour and F_{safe} is the factor safe. The N_{SP} is the number connection of solar panel and the SP_{max} is solar panel maximum power.

d. Solar Charger Controller

Solar charger controllers play the role of regulators, controlling the current and voltages flowing from solar panels to batteries and loads [7]. That is significant for the batteries in terms of their over- and under-cycling behaviour in Eq (5).

$$I = I_{SC} \times N_{sp} \times K_{safe} \qquad \textit{Eq. 5}$$

where *I* is the rated current of the charger controller in Ampere (A), I_{SC} is the short circuit current of the solar panel, N_{SP} is the number connection of solar panel and the K_{safe} is the factor of safety in ensure that regulator can supports the maximum current produced by the solar panel.

e. Inverter

As a first step in sizing the inverter, the actual power drawn from the load that will be running at the same time must be determined. The inverter operation involves converting a direct current (DC) signal to an alternating current (AC) signal. This inverter ensures that the condition of the alternating current waveform is stable for the load application. The Eq (6) shown in how to determined the size specification of the inverter [8].

$$P_{iv} = P_L \times \text{L}_{\text{safe}} \qquad \textit{Eq.6}$$

where P_{iv} is the power specification of the inverter, P_L is the power load rating of AC loads and L_{safe} is the safety factor.

f. Cable Sizing

The size of cables is critical for stand-alone solar systems in Eq (7) because they connect the various components of the PV system to each other and to the electrical load. In general, their size is determined by the maximum current carrying capacity and should be sufficient to reduce voltage drops and resistive losses [9].

$$A = \frac{\mu \times L \times I_{max}}{V_D} \times 2 \qquad Eq.7$$

where A is the cross-sectional area of the cable, μ is represents the resistivity of the conducting wire material in ohm-meter, L is the length of cable, V_D is the voltage drop in cable and I_{max} is the maximum current carried by the cable.

3. Results and Discussion

The results and discussion section present data and analysis of the study. This section can be organized based on the stated objectives, the chronological timeline, different case groupings, different experimental configurations, or any logical order as deemed appropriate.

3.1 PV Sizing for Automated Irrigation System

This result assumes the case study in designing the PV system covered for the 100-eggplant crop on the 20m area. The several components and system measurement specifications are presented in Table 1, 2, and 3.

Table 1: Load requirement (Water pump)

Specification	Value
Power Rating, P_L (W)	373
Load Operating Hours, T_u (h)	0.40
Energy Demand, E_i (Wh)	149.2

Table 2: Battery sizing system

Specification	Value
Autonomous days *(Dof)*	2 days
Nominal Battery Voltage *(NV)*	12V
Battery Depth of Discharge *(DD)*	0.7
Peak Sun Hour *(PSH)*	3 hours
Efficiency of the cable, battery, charger controller, and inverter *(EN)*	0.85
Safety Factor $(K_{safe}, F_{safe}\ and\ L_{safe})$	1.3

Table 3: Overall of PV System Specification

Specification	Calculated	Selected
Photovoltaic (PV)	65W	80W
Number of PV panel	0.81	1
Battery	41.79Ah	45Ah
Charger Controller	6.5A	8A
Inverter	484.9W	500W

Based on the result in Table 3, it can be shown that the calculated is from the calculation and the selected is based on the approximately calculated value for the solar automated system. The solar panel will be 80W, and the battery will be 12V, 45AH. The specifications of this battery allow it to last two days, and the peak sun hours in Malaysia are three hours. Aside from that, the charge controller must be rated at 8A, and the inverter system must be rated at 500W.

3.2 Performance of Automated PV Irrigation System

The automated system fertigation system result is shown in Table 4, which is tabulated the relationship between the PV system, the condition of the soil with the soil moisture level, and the component that is triggered depending on the system setup. Soil moisture seniseing important in this automated system as a main controller for the automated system includes the motor pump.

Table 4: Relationship Performance of Automated Irrigation with PV System

Date and Time	PV System	Condition	Soil Moisture (%)	Device Trigger
07/11/21 / 11.30 am	PV Voltage: 19.5V Battery Voltage: 13.10V Load Voltage: 13.10V Temperature: 36.6°C	Dry	39	-System Activated -Water Pump ON -LED ON
07/11/21 / 11.35 am	PV Voltage: 20.1V Battery Voltage: 13.53V Load Voltage: 13.53V Temperature: 37.2°C	Wet	61	System Activated -Water Pump ON -LED ON
07/11/21 / 11.40 am	PV Voltage: - Battery Voltage: 12.60V Load Voltage: 12.60V Temperature: 36.7°C	Wet	70	System Activated -Water Pump ON -LED ON
07/11/21 / 11.45 am	PV Voltage: 20.03V Battery Voltage: - Load Voltage: 20.03V Temperature: 37.0°C	Wet	90	System Activated -Water Pump ON -LED ON

The motor pump will be triggered depending on the soil moisture sensor level as shown in Table 4 with the LED green also on. The soil moisture level is indicated on the percentage value which is 0 to 100%. There are very low and high values for the analog output from the moisture sensor which are 616 and 384 respectively. In this case, the system had been set in the coding Arduino for 40% for dry condition and 60% for wet condition. All the percentages values are depending on the types of plants that be used

3.4 Performance of Automated PV Irrigation System

The purpose of this prototype as shown in Figure 2 is to demonstrate the concept and functionality of the system, which will be powered by a solar system. Otherwise, this system was well-designed to avoid causing damage to the fertigation part's main system in a short period. This solar system's specification provides power to the fertigation system's main controller.

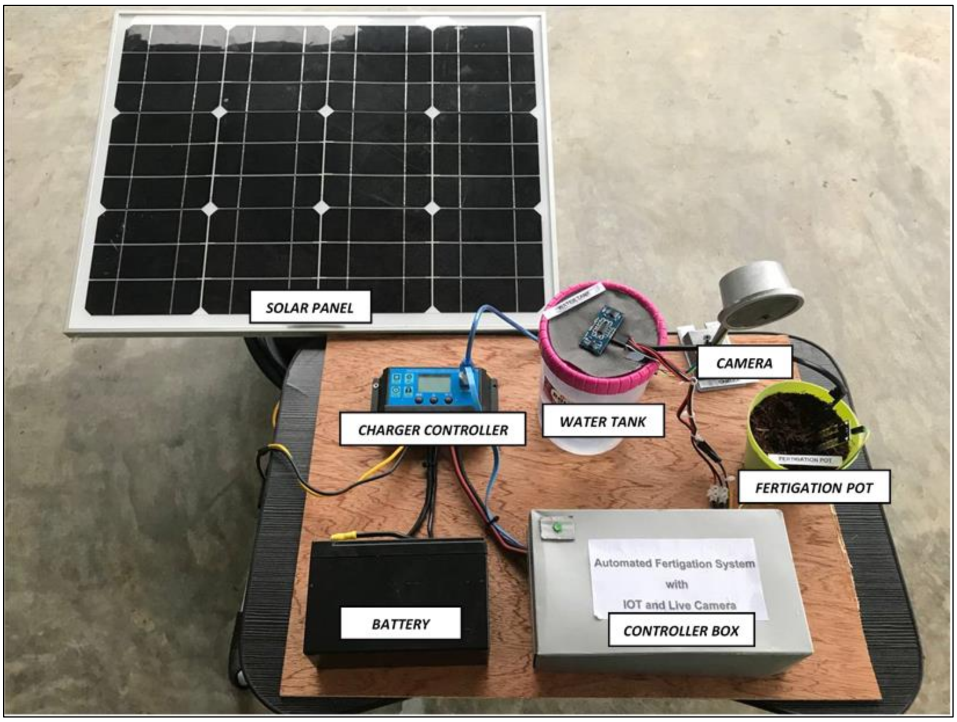

Figure 2: Prototype of Automated Irrigation System and Monitoring Capability

4. Conclusion

In conclusion, this paper shows on the project system has been working properly with the prototype and the automated system with the monitoring capability to change the irrigation traditional to modern ways. In comparison to conventional use, the result from the plant may help the plant with appropriate nutrients can produce the best products. Hence, solar energy also can be demonstrated how clean energy may help people to reduce pollution while also saving them money on their monthly bills. Awareness must be raised regularly for all farmers and people to profit from it.

Lastly, several improvements need to be upgraded for future studies based on the findings of this project study as listed below.

- The system has to be entirely automated, including the filling of the water tank
- The fertilizer tank must have been filled according to the fertilizer ratio, which varies depending on the type of plant.
- The Internet of Things (IoT) must be more accessible so that the system can be controlled from a distance away from the plantation.

- The live camera base can use for other efficient bases to be more high resolution and clear photo.
- The protective devices as MCB and SPD can be added in prototype design regarding their suitable limitation of voltage and current in helps to protect the system from damages because of the instability of power sources.

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