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Stand-alone Solar Monitoring System using Internet of Things for Fertigation System

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Abstract: This paper present the development of a solar photovoltaic (PV) monitoring system and design the stand-alone solar PV system for the fertigation system. With the implementation of the Internet of Things (IoT), users can monitor the performance of the solar system through the Blynk application. The parameters involved for the evaluation of the solar panel's performance including the voltage, current, power, temperature, and dust density. Arduino Mega as the microcontroller for the sensors has been connected with the NodeMCU ESP8266 device as a medium to communicate between the microcontroller and the Blynk application. As a result, the data from the sensors are collected and displayed on the mobile phone in real-time, thus capable to evaluate the performance of the solar PV system for the fertigation system.

Keywords: Arduino Mega, Blynk application, Fertigation System, Solar PV System, IoT

1. Introduction

Electrical energy is one of the important resources for human life and it is obtained majorly from non-renewable sources. As the non-renewable source such as fossil fuels are on the verge of depletion, the cost to obtain the sources will be increasing as they become scarcer [1]. Besides, the fossil fuel consumption affects the environment in terms of global warming. In fact, some farmers consumed the fuel sources as to power up their farm machinery such as the generator to turn on the motor pump [2]. This situation happens because of the difficulty for the electrical grid system to be implemented at the farm, which in rural areas.

In order to fix this problem, the renewable source is used for the generation of electricity. One of the most widely used renewable power sources is solar energy, as we obtain it every day and it is free [3]. Because of it, solar photovoltaic (PV) products are growing considerably on the market. However, as time goes by, the environment factor can degrade the performance of PV power [4]. In addition, most

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of the solar panels are placed in a remote area and it requires close maintenance from the staff. Because of that statement, this project will build an IoT based model for the monitoring system of the stand-alone solar photovoltaic (PV) for the farming sector.

In this project, Blynk as an IoT will be used as a monitoring algorithm that will determine the performance of the solar PV system. The Blynk application will display five (5) parameters which are the current, voltage, power produced, temperature and dust density on the solar PV in real-time [5]. The users can access the Blynk application anytime just by logging in to the application on the mobile phone. This monitoring system capable to operate with the implementation of Arduino Mega microcontroller and NodeMCU as the medium for the data transmission from the sensors to the Blynk application.

2. Methodology

In this section, the methodology of the solar PV system development in the fertigation system is discussed with the implementation of the monitoring system and IoT.

2.1 Development of solar PV monitoring system

The first important step to be carried out first before developing the monitoring system is designing the whole monitoring process for the stand-alone solar PV. For this project, the components used are solar panel, solar charge controller, battery, motor pump as the load, Arduino Mega, ESP8266 NodeMCU, INA219, voltage sensor, temperature sensor and dust sensor. Figure 1 shows the block diagram of the solar PV monitoring system by using IoT.

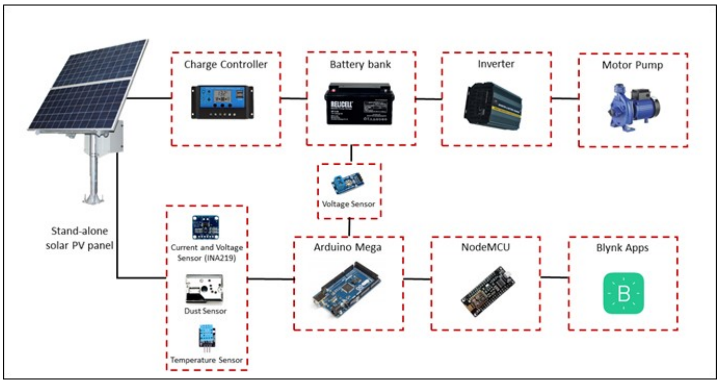

Figure 1: Block diagram of stand-alone solar PV monitoring system using IoT

2.2 Solar PV system development

Basically, there are five (5) steps that are needed to be carried out and calculated for the development of the solar PV system by referring to a research paper by Al-Shamani entitled Design and Sizing of Stand-alone Solar Power Systems [6]. Firstly, calculate the daily energy consumption of the load, followed by the determination of the solar sizing based on the load requirement. The third part is the calculation of battery sizing. Next is the charge controller sizing for the fourth part and finally is the inverter sizing for the solar PV system.

2.2.1 Load calculation

In order to know the correct sizing of the solar panel, we need to consider what kind of load do the system will have. The important parameter for the load is the energy consumption. So, the specification that needs to be considered is the power rating of the load, the amount of the load used and the operation hour of the load per day. To determine the energy consumption of a load, the Eq. 1 needs to be used [6].

$$E = P \times n \times h \qquad \text{Eq. 1}$$

where E is daily energy consumption in Wh, P is the power rating of the load, n is the amount of load used and h is the operation hour of the load per day. However, the energy consumption must consider the energy lost in a system. In this case, 30% of the energy lost is assumed, thus the daily energy consumption must be multiplied with safety factor which is assumed to be 1.3. Eq. 2 shows the equation of the total consumption [6].

$$E_T = E \times k_1 \qquad \text{Eq. 2}$$

where E_T is the total daily energy consumption and k_1 is the safety factor considering losses which assumed to be 1.3.

2.2.2 Solar sizing

In this part, the calculation for the sizing of the solar PV panel will be discussed. Since there is various kind of size for the PV panel, we need to ensure that the power produced by the PV panel will be able to supply it to the load. Thus, a few considerations need to be identified. The total watt needed for a day from the load must be clarified first. Then, for the minimum peak sun hours per day, it depends on the climate of the location of the PV panel being placed. Eq. 3 shows the formula of the total watt needed for the PV panel [6].

$$P_{PV} = \frac{E_T}{t_{min}} \qquad \text{Eq. 3}$$

where P_{PV} is the watt needed for PV modules and t_{min} is the minimum peak sun hours per day. Next, the amount of PV panels needed for the system must be calculated. The maximum power of the panel is obtained from the specification of the PV panel itself. Eq. 4 shows the formula for the calculation of the amount PV panel needed for the system.

$$N_{PV} = \frac{P_{PV}}{P_{\max(panel)}} \qquad \text{Eq. 4}$$

where N_{PV} is the number of PV panel and $P_{\max(panel)}$ is the maximum power produced by the PV panel.

2.2.3 Battery sizing

For the sizing of the battery, the autonomy days of the battery is considered. Meaning that how long does the battery can supply the source before it drains. For the efficiency of the battery, it is assumed as 0.85 and the depth of discharge is 0.5. Most of the battery minimum sizing is 12 V, however, if we want to increase the rating of the battery, the batteries must be connected in parallel since the voltage in series is the same. Eq. 5 below shows the equation of the capacity of the battery in Ah [6].

$$C_{battery} = \frac{E \times D_{autonomy}}{\eta_{battery} \times DOD \times V_{\mathrm{DC}(battery)}} \qquad \text{Eq. 5}$$

where $C_{battery}$ is the battery capacity in Ah, E is the daily energy consumption, $D_{autonomy}$ is the autonomy days, $\eta_{battery}$ is the efficiency of battery which assumed to be 0.85, DOD is the depth of discharge of battery and $V_{DC(battery)}$ is the voltage of nominal battery.

2.2.4 Charge controller sizing

The charge controller is a regulator that confines the current rate that goes from the PV panel and to the battery. Since we want to hinder any overcharging or draining of a battery that can lessen the lifespan of it, this charge controller is essential. Basically, there is various kind of charge controller according to the size, features and how suitable it is to carry the current. In order to calculate the correct sizing, Eq. 6 shows the formula on how to obtain a suitable current rating for the charge controller [7].

$$I_{rated} = I_{SC} \times FOS \quad \text{Eq. 6}$$

where I_{SC} is the short circuit current in Ampere and FOS is the factor of safery which assumed to be 1.25.

2.2.5 Inverter sizing

For the sizing of the inverter, it must be bigger than the watt of the load estimated around 30% bigger. This is because to ensure that the inverter is able to carry the amount of the watt using at one time. Eq. 7 shows the formula where the sizing of the inverter is calculated with an assumption of 30% energy losses [6].

$$P_{inverter} = P_T \times k_2 \quad \text{Eq. 7}$$

where $P_{inverter}$ is the sizing for inverter, P_T is the total watt of all load and k_2 is the safety factor considering losses which is assumed to be 1.3.

2.3 Hardware component and software of the designed system

In this section, all the electronic components that utilized are list and discussed below. There are five (5) components all together that will be used to complete the monitoring system and enable the data collection based on the required parameter.

2.3.1 Solar PV panel

In this project, the solar PV panel that is used for the development of the system for the prototype model is assumed to use 20W polycrystalline solar panel. Table 1 are tabulated for the specification of solar panel.

Table 1: Specification of Solar Panel

Feature	Specification
Power Max	20 W
Voc	21.18 V
Isc	0.52 A

2.3.2 Arduino mega

The Arduino Mega comes with a USB connector, 16 analog input pins, 54 digital I/O ports for connecting via an external device. 14 pins out of 54 digital I/O ports can also be used for PWM output [8].

2.3.3 NodeMCU

The NodeMCU which is also known as ESP8266 is a device that possess a WiFi microchip module that able to give any microcontroller accessing to the Wi-Fi network [9]. By adding a power supply to the module, it can be programmed as a standalone (STA) Wi-Fi connected device and runs at 3.3V input.

2.3.4 Voltage sensor

A voltage sensor is an electronic device that can measure the value of the voltage supply [10]. The voltage sensor built up is based on the concept of the voltage divider. It allows the use of a microcontroller's analog input to measure voltages far greater than they can sense.

2.3.5 INA219

The INA219 is a device that is functional to obtain the shunt current and power with the implementation of I2C communication [11]. This device is capable to measure the shunt voltage, bus voltage, load current and power.

2.3.6 DHT11 Temperature sensor

The DHT11 is a simple and ultra-low cost electronic sensor for temperature measurement. It uses capacity moisture and a thermistor to measure the air around it and transmit a digital signal on the data pin based on the data pin at Arduino Mega [12].

2.3.7 Optical dust sensor

The optical dust sensor is one of the device that is capable to measure the density of the dust on an object [13]. It requires 7VDC in order to power it up and very low current consumption (11mA).

2.3.8 Arduino IDE

The Arduino IDE is an open source software where all the coding for the Arduino board can be executed [14]. Basically, it is used for uploading the code in the Arduino Device. The main code created on the IDE platform, also known as a sketch, will eventually generate a Hex File that is then transferred and uploaded to the board's controller.

2.3.9 Blynk

Blynk is one of the IoT platforms which is available in IOS and Android application that is designed specifically for any the IoT project [15]. The platform was designed to allow data from several sensors and actuators to be incorporated into the Internet. It is becoming much easier to monitor the data from IoT with real-time monitoring.

3. Results and Discussion

In this section, the results obtained are discussed. The first result shows the specification of the Solar PV system in the Fertigation Sector. The second result shows the hardware development and simulation result of the monitoring system. The third part shows the data monitoring by using two different approaches and lastly is the implementation of IoT which the Blynk application.

3.1 Solar PV system design

The calculation of rating for each of the loads is shown in Table 2 below by using the Eq. 1 in subtopic 2.2.1. The operating hour of the motor pump is 0.25 which is equal to 15 minutes per day since the plant needs to be watered 3 times per day with a duration of 5 minutes.

Table 2: Rating of motor pump for fertigation system

Load	HP	Power	Time used	Energy
Motor Pump	0.5	0.373kW	0.25h	0.09325kWh

Table 3: Result for the real solar system development in fertigation system

Detail	Design Value	Hardware Rating
Solar sizing	30.30 W	40 W
Battery capacity	54.85 Ah	55 Ah
Charge controller sizing	2.96 A	10 A
Inverter rating	484.9 W	500 W

Based on the result shown in Table 3, it can be concluded that the suitable battery capacity for this solar PV system for the fertigation system is 12V 55Ah with 3 days' autonomy. A 40W of solar PV panel should be used for this system to be powered. For the charge controller rating, it should be rated 10A at 12V. Finally, the inverter rating that should be used is 500W rating.

3.2 Circuit configuration of the solar monitoring system

In this section, all the sensors are combined and connected to the Arduino Mega microcontroller. For the data transferring into the Blynk application, NodeMCU is connected to pin TX and RX of the Arduino Mega. As a result, the full version of the circuit connection is designed in the software FRITZING as shown in Figure 2.

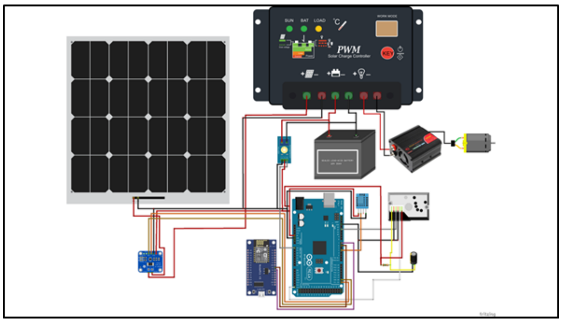

Figure 2: Circuit of solar monitoring system in fritzing

However, the simulation cannot be executed as some of the sensors devices are not available in the library software. Hence, the real implementation of the connection for the monitoring system is done. Figure 3 shows the developed prototype for the monitoring system. Under the solar panel, there is the connection of the circuit for the sensors that are connected with the microcontroller. Figure 4 shows the connection of the sensors with the microcontroller.

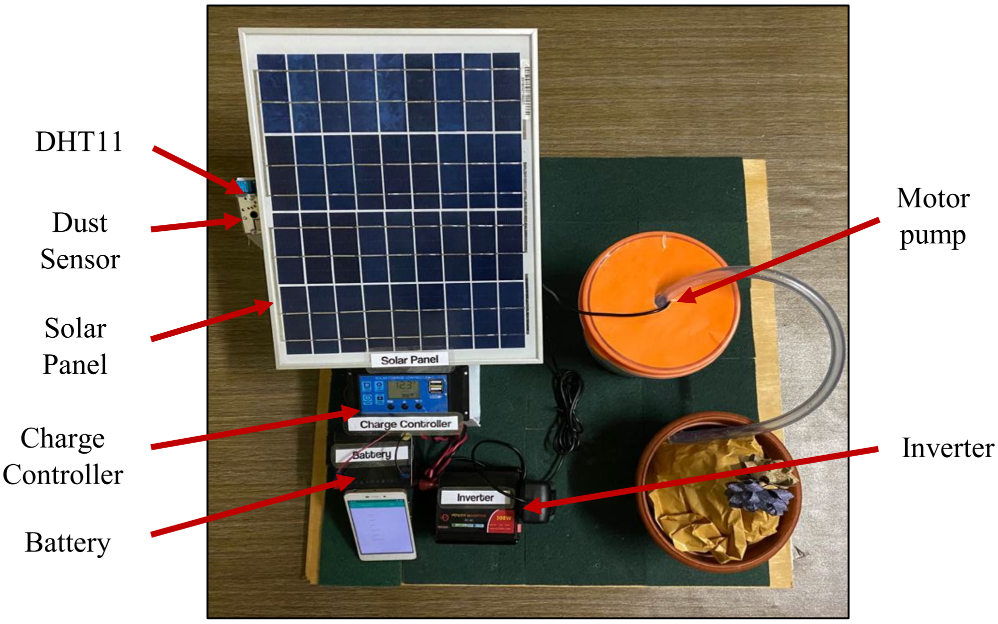

Figure 3: Prototype of solar monitoring system

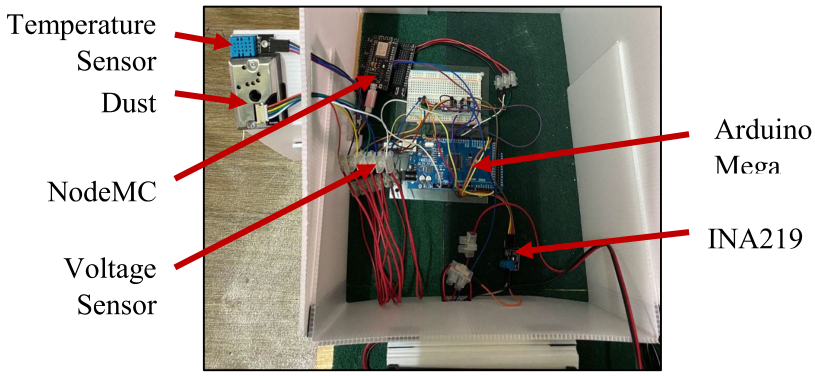

Figure 4: Component of hardware design

3.3 Performance of solar monitoring system

In order to ensure whether this system is successfully working or not, several data of reading from the sensors were recorded and the reading from manual testing from the multimeter was compared. The reading that being observed are voltage, current, and power produced by the solar panel. The testing was held on 22nd July 2020 at the front of the house in Taman Universiti, Parit Raja. Table 4 shows the result of data obtained from sensors and multimeter.

Table 4: Result of data obtained from sensor and multimeter

Time	Temperature (°C)	`Reading from sensor			Reading from multimeter		
		Voltage (V)	Current (mA)	Power (W)	Voltage (V)	Current (mA)	Power (W)
12.35	37.50	12.86	7.4	0.096	12.90	9.1	0.117
12.40	36.60	12.83	6.4	0.082	12.85	7.2	0.093
12.45	35.00	12.70	6.1	0.078	12.73	6.8	0.087
12.50	34.60	12.84	7.1	0.092	12.86	7.5	0.096
12.55	38.00	12.96	8.6	0.112	12.99	9.5	0.123
13.00	36.00	12.59	6.0	0.076	12.62	7.3	0.092

Based on the observation from the result above, the value of voltage, current and power are different between reading from the sensor and reading from the multimeter. As the differences between reading are quite noticeable, thus, a percentage for the differences between them were needed to be calculated in order to determine the sensitivity of the solar PV system. The formula to determine the percentage difference is shown in Eq. 8. The reading A is representing the reading from the sensors meanwhile reading B represents the reading from the multimeter. The percentage of differences calculated are tabulated in Table 5.

$$Percentage = \left| \frac{|ReadingA| - |ReadingB|}{\left(\frac{|ReadingA| + |ReadingB|}{2}\right)} \times 100\% \right| \qquad \text{Eq. 8}$$

where *ReadingA* is the reading from sensor and *ReadingB* is the reading from multimeter.

Table 5: Percentage of difference for each measurement parameters

Time	Reading form Sensor	Reading form Multimeter	Percentage Difference (%)
		Voltage (V)	
12.35	12.86	12.90	0.31
12.40	12.83	12.85	0.16

12.45	12.70	12.73	0.24
12.50	12.84	12.86	0.16
12.55	12.96	12.99	0.23
13.00	12.59	12.62	0.24
	Current (mA)		
12.35	7.4	9.1	20.61
12.40	6.4	7.2	11.76
12.45	6.1	6.8	10.85
12.50	7.1	7.5	5.48
12.55	8.6	9.5	9.94
13.00	6.0	7.3	19.55
	Power (W)		
12.35	0.096	0.117	19.72
12.40	0.082	0.093	12.57
12.45	0.078	0.087	10.91
12.50	0.092	0.096	4.26
12.55	0.112	0.123	9.36
13.00	0.076	0.092	19.05

Based on Table 5 above, there are three (3) parameters that are calculated for its percentage difference, which are the voltage, current and power. The percentage difference for the reading of voltage shows a lower percentage than the current and power, which varies from the range of 0.16% to 0.31%, which indicates that the value of voltage is accurate. The value of voltage from two (2) different approaches differ with ±0.04V. However, the percentage differences for reading of current shows the highest percentage especially during the early testing with a range of 5.48% to 20.61% with a ±1.8 mA. For the reading of the power produced, the percentage error is also quite high since the manual reading of the power is calculated by using the current reading from multimeter. The percentage difference ranging from 4.26% to 19.72%.

During 12.35 p.m., the current shows the highest percentage with 20.61% in differences between the sensor's value and multimeter's value. This might happen because of the inconsistent value displayed on the multimeter. Moreover, the multimeter operates with calculating the average data and it will display once a second. Because of it, there is a slight difference in reading with the sensors. Meanwhile, the data from the sensors present faster and it keeps on updating in a second. This situation actually will affect the reading coming from sensors as there is a possibility of noise from the power supplies, which makes the reading higher or lower than the multimeters'.

In terms of the connection of the circuit, in order to obtain the data for current, the connection for the multimeter must be in series with the circuit, thus there could be some error happen during the data collection process such as human error or instrument error because the probes of multimeter are not connected securely with the wiring of solar. Thus, it is recommended to use a clamp meter to replace the multimeter since the clamp meter did not require probes for the current measuring. However, since the value of the current is smaller in this prototype, the clamp meter has difficulty and error in measuring smaller values especially current in milliampere (mA).

3.4 Implementation of IoT

In this part, the Blynk application will display the reading of the sensors used in this project, which are the reading of voltage, current, power, temperature, dust density and battery capacity. This will ease the monitoring system as it does not require for the person to come to farm every day just to monitor the condition of the solar. The data transmission from the Arduino Mega to NodeMCU is same, with a delay of 1 seconds only. With this delay, the data can be monitored with real time data displayed. Figure 5 below shows the interface of the Blynk application with the value displayed on it.

In addition, the dust sensor has operated in this monitoring system as to show that the dust accumulated on the surface of solar panel gives effect to the reading of voltage since the sun irradiance towards the solar panel is restricted. Thus, if the reading of dust density is high, a notification is sent to the Blynk application as shown in Figure 6 with a caption of “Solar Panel is Dusty. Please clean it.” .

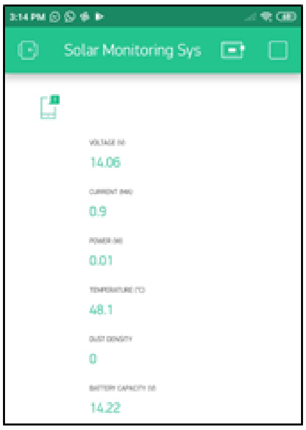

Figure 5: The solar monitoring system in blynk application

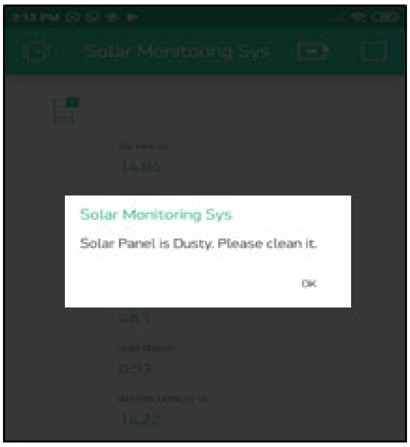

Figure 6: The notification alert when solar panel is dusty

4. Conclusion

In conclusion, the solar monitoring system using IoT has been established successfully in this project with the monitoring system for the energy produced by the solar energy sources. With the implementation of IoT, it has eased the monitoring process from another place by using the Blynk application, suitable for both Android and IOS users. This solar PV monitoring system eventually will help the users to evaluate and predict the performance of the solar panel. The users can decide what is the predictive maintenance need to be done to ensure the solar PV system operate smoothly and able to supply continuous electricity to the load. There are several recommendations of works that can be proposed for a better result in the future:

- In order to improve the different percentage of the current reading, it is encouraged to measure the current using the clamp meter during the real implementation of the solar PV system in fertigation system. The monitoring system should be tested on the real setting of the farming set so that the reading of the parameters needed can be obtained correctly.
- It is better to build or implement more accurate sensors so the value will be displayed correctly. The accuracy can be set by calibrating the offset value of the sensors.
- For a better circuit approach, it is recommended to design the circuit in Printed Circuit Board (PCB) as to ease the connection between the sensors with the microcontroller. Moreover, with the PCB circuit, any error regarding the wire disconnection can be avoided.
- It is recommended to create a webserver for the data collection since in this project, the Blynk application only can display the data in real time and it cannot be stored for a reference. Hence, it is better for the webserver to have the ability to automatically stored and analyzed the data of monitoring system.

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