Design of plant pest spraying machines using solar cell power

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Abstract. Plant pest spraying machines are now starting to develop using a variety of technologies ranging from diesel to electric power. However, this technology has problems such as limited fuel capacity in diesel engines and a lack of electricity demand for electric batteries. If the sprayed area is too large, the capacity for fuel and battery requirements is insufficient. In this study, we will explain how to apply solar cells to make a plant pest spraying machine so that when spraying will occur simultaneously the process of charging or charging the battery by solar power So that the need for battery capacity is met for spraying over a large area. The process of making this tool is done by assembling several components such as solar panels, SCC (solar charge controller), spray tanks and lithium batteries.

1. Introduction

Spraying is a very important job in a farm. Spraying pesticides has aim to protect plants from insect attack[1]. In spraying farmers usually use a hand operated spray pump or fuel. This conventional spraying causes casualties or tired toward the user because the construction is too heavy and impractical in hell. This motivates researchers to design and model a spray machine that uses solar power. In this design we have another objective to overcome the level of casualties in handling when doing spraying, to reduce the level of vibration when still using a fuel-operated spray pump, to produce an environmentally friendly spray machine due to fuel removal[2].

Nowadays, many non-conventional energy resources used daily, one of them is solar energy. Solar energy is available in natural unlimitedly. Indonesia is in equator, so the solar energy is quite high potential because the sun shines in the whole year. The sun shines about 6 to 8 hours per a day. Meanwhile the ideal length of time to produce electricity for solar panel is 4 to 5 hour per day. Pesticide sprayer using solar energy can save the cost more than previous sprayer or conventional sprayer. Principally, this solar-energy sprayer absorb solar energy using solar panel which contains photovoltaic cell, then the solar energy will be converted into electrical energy. The produced energy will be stored in a DC battery in a form of voltage afterword it will be used to work the DC pump of sprayer machine [3].

2. Research Methodology

2.1. Research design

The research used some methods, those are study of literature, experiment, and observation., Afterward the researcher conducted planning or constructing some tools or equipment. Then the researcher conducted testing the tool and observed the parameter.

2.2. Research process

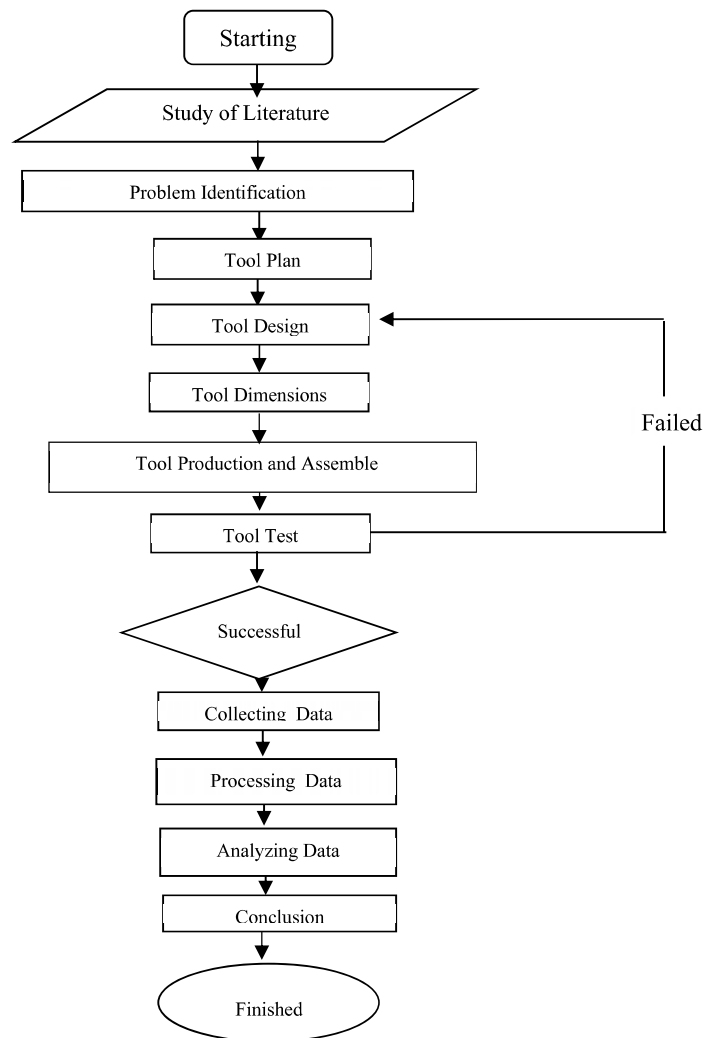The following is the procedure in research as,

Figure 1. Diagram of Research process

The first step is to start, then the second step is to study the literature. At this stage the researcher collects data directly from reference journals and books related to solar cell-based spray machines. In the third stage,

the researcher identified the problems in the field related to the spray machine, what are the constraints in agriculture, both in terms of time and cost. After knowing the problems in the field, the researchers tried to plan an appropriate sprayer in the field based on farmers' constraints so far. Then the fifth step is for the researcher to design a solar cell-based spray machine which is used as an alternative to solve the spraying problem in agriculture. Then the researchers purchased several components of the spray machine and solar cells, after which they made solar cell support equipment. after the equipment is complete the next step is to assemble a solar cell-based spray machine. The next step is testing the tools, while testing includes spraying time with a volume of 15 liters of water with three types of nozzles. the second test is to measure the discharge of water sprayed by each nozzle. when the test is successful it is continued for data collection and collection. if it does not work, a new design is planned. if the tool is successful and gets the data, the next step is data processing. Data processing is done by collecting all test data that is done with the help of Microsoft Office. Data processing can be presented in tables and graphs, then data analysis is carried out to determine the performance of the spraying machine, water discharge and how long it takes to spray. After the data analysis is complete, the researcher can draw conclusions. After knowing the conclusion, the research is considered complete.

2.3. Tool design

Figure 2 shows design of solar energy sprayer machine figured by software inventor. In the picture of this solar cell-based spray machine there are several components, including: Solar panels, spray tank, battery, nozzle, indicator battery, on-off switch, motor switch, dc pump, charger from home electricity. The volume of the tank is 15 liters, this tank is not made but is already available in the market under the brand Matsukawa Japan Technology.while the solar panels used have a size of 10 Wp. In the design of this tool is made simple because to facilitate the performance of users in the field.
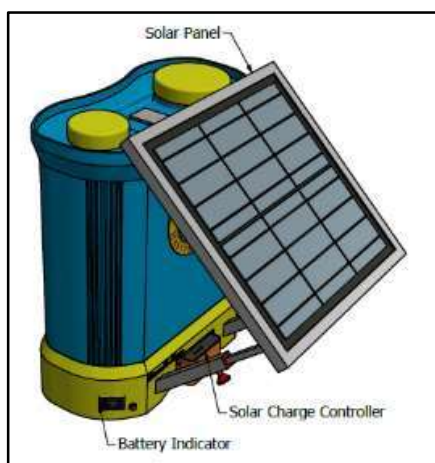

Figure 2. Design of solar energy sprayer machine

2.4. The component of sprayer machine

   a) Solar panel

Solar energy is unlimited renewed environmentally friendly energy. One of the important components produced energy is solar panel. Solar panel has a function to change sun shining become electricity caused by attraction between electron in the silicon using photon of sun shining[2].

Figure 3. Solar panel

Figure 3 shows an image of the solar panels used in the spray machine. in this study using a 10 Wp polycristalline type solar panel. Solar panels are the main component for generating electrical energy from sunlight. This solar panel has a dark blue color. The current is output from the solar panel to produce a DC current.

The following table is specification of solar panel used in this research.

Table 1. Specification of solar panel

Parameter	Specification
Type solar panel	Polycrystalline
Model	SLP010-12
Product	Solar land
Open circuit voltage (Voc)	21,6V
Optimum operating voltage (Vmp)	17,2V
Short circuit current (Isc)	0,68A
Optimum operating current (Imp)	0,58A
Maximum power (Pm)	10Wp
Standard test condition (Ir)	$1000W/m^2$, AM 1.5dan 25^0C
Length of PV	30 cm
Wide of PV	21,3 cm

Table 1 shows the specifications of the solar panels used in this study. The type of solar panel used is polycrystalline which can produce a maximum power of 10 Wp. This solar panel has dimensions of 30 cm long and 21.3 cm wide. The intensity of sunlight required during the test is 1000W / m^2 with a standard temperature of 25°C AM 1.5. The 10 Wp polycrystalline type solar panel specification has an open circuit

voltage (Voc) value of 21.6 volt and an optimum operating voltage (Vmp) of 17.2 volt. Besides the voltage, this solar panel also has a short circuit current (Isc) value of 0.68 A and an optimum operating curve (Imp) value of 0.58A.

   b) Tank
The storage tank serves to temporarily store the pesticide liquid. Storage tanks are available in various forms including vertical and horizontal cylinder open top and conical bottom, plate-shaped bottom. Large tanks tend to be vertically cylindrical, or have a rounded transition angle from the vertical side to the bottom profile. The material storage tank is made of plastic and has a tank capacity of 16 liters. This tank brand is Matsukawa Japan Technology.

Figure 4. Tank

   c) SCC (Solar Charge Controller)
Figure 5 shows figure of SCC, the function is to manage the filling solar panel into battery and using from the battery into machine.

Figure 5. SCC (*Solar Charge Controller*)

   d) Battery
Electrical battery is a device which has function to storage the energy which is produced from solar panel. when the battery supplied electrical energy , positive terminal is a cathode and negative terminal is anode [4]. The type of battery used in this study is a lithium battery with serial number 18650 with a voltage value of 3.7 volts and a current value of 2400 MAh. This solar cell-based spray machine uses 6 batteries arranged in series and parallel which are attached to the holder.

Figure 6. Battery

   e) Nozzle

Nozzle is a device to control the flow or characteristics of fluid flow (especially to increase the speed) when coming out (or coming in) closed pipe. Nozzle is often in form of pipe or tube with varying cross-sectional areas and can be used to direct or modify the flow of fluids (liquids or gases). Nozzles are often used to control flow rate, velocity, direction, mass, shape, and / or flow pressure.

Figure 7. Nozzle

   f) DC Pump

Pump is a tool used to move fluids mechanically system. In moving fluids, pump needs power to move mechanically system[2]. This pump has two canals; inlet and outlet.

Figure 8. DC Pump

2.5. Work series of solar energy-sprayer machine

Figure 9 shows a work series of solar cell-based sprayer machines which consist of 4 main parts, namely energy conversion, energy storage, DC drive and sprayers. The first unit of the system is called the energy conversion unit, in which there is a change in solar energy into electrical energy which is carried out on the solar panel with a photovoltaic effect. The current generated in the solar panel is DC (Dirrec Current). After the solar panel is connected to the SCC (Solar Charge Controller) which has functions to manage the incoming voltage on the battery so that the incoming voltage on the battery is constant and stable. The output from the solar panels is used to charge the battery[5]. Then enter the second unit, it is storage process. The power storage process uses a type of lithium battery with the serial number 18650. From the battery, it is then connected to a battery indicator which has functions to read several parameters such as voltage, current and resistance. After from the battery output, then it is connected to the DC pump. The DC pump is used to suck and drain the pesticide liquid in the tank. To activate the pump you can use a pump / motor switch. The pump rotation can be adjusted from the motor RPM switch; the goal is to produce a strong spray. Then enter the last part, namely the sprayer or sprayer. Spraying this pesticide liquid through a nozzle hole, this component functions to regulate and direct the flow rate of the pesticide liquid.
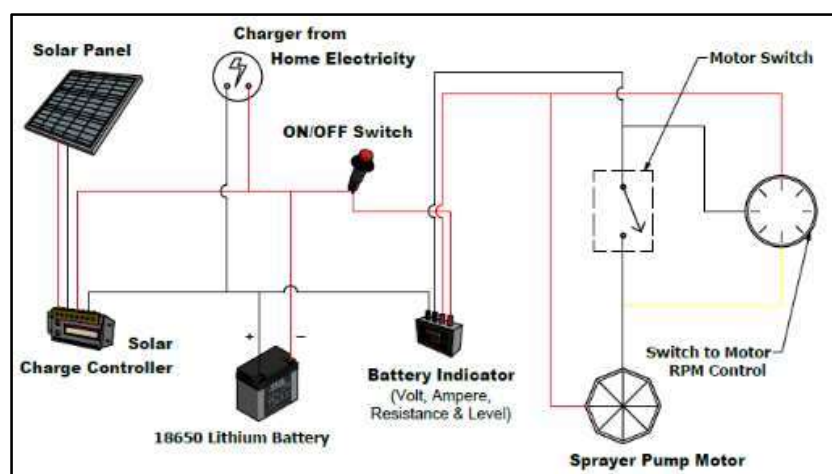

Figure 9. Work series of solar energy-sprayer machine

2.6. Assembling tool

Figure 10 shows the final result of assembling a solar cell-based pest spray machine. The assembly process begins with the manufacture of a solar cell frame made of iron in which the solar panels are attached to the frame with rivets, then the frame and solar panels are attached to the top of the spray machine tank. The tilt of the solar panel can be adjusted using a support rod made of iron, the slope of the solar panel can be adjusted with an angle of 200, 300 and 400. Furthermore, the solar panel is connected to the SCC (solar charge controller) and the battery, so that the battery can be charged with voltage from solar panels. From the battery, it is connected to a pump which functions to suck the pesticide liquid mixed with water through the nozzle.
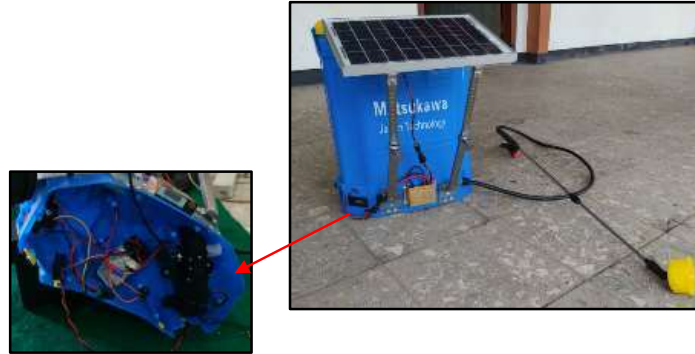
Figure 10. Tool assembling

2.7. Analyzing Data
These are some analyzing used after tool test:
    a) Calculationn input power because of the sun radiation
    Power input because of sun radiation can be calculated using the following formula:

$$P_{in} = I \; x \; A$$

Noted:
P_{in} = input power because of sun radiation (Watt)
I   = Intensity ofsun radiation (W/m^2)
A   = wide area of solar panel (m^2)

    b) Calculation of maximum power on solar panel
    Maximum power on solar panel can be reached from multiplication of opened series $-$ voltage, short circuit current, and fill factors

$$P_{max} = \; V_{oc} \; x \; I_{sc} \; x \; FF$$

Noted :
P_{max} : power of solar panel (watt)
V_{oc} : potential difference (volt)
I_{sc} : current (ampere)
FF   : *Fill factor*
 FF value can be reached by using the following formula or equation:

$$FF = \frac{V_{mp} \; x \; I_{mp}}{V_{oc} \; x \; I_{sc}}$$

    c) Calculation efficiency of solar cell
    Efficiency value on solar cell can be reached from the result of ratio between output power on solar panel and input power on sun radiation[6]

$$\eta = \frac{P_{out}}{P_{in}}$$

d) Calculation of flow rate on nozzle
   Flow rate (L/min.) = Volume of liquid collected in cylinder /Time [7].
   Flow rate on nozzle can be calculated using the following formula or equation :

$$Q = \frac{V}{t}$$

Noted:
   Q   : flow rate (liter/minute)
   V   : Volume pesticide liquid (liter)
   t   : time/duration (minute)

3. Result and Discussion

3.1 Calculation surface area on solar panel

To calculate the input power of the reaction intensity of solar radiation, we must first calculate the surface of the solar cell module. In which, the solar cell module has a length of 30 cm and a width of 21.3 cm. After found the length and width, you can calculate the PV area with the following formula.

A = p x l

   = 0,3 m x 0,213 m

   = 0,063 m²

3.2 Input power from intensity reaction of solar radiation

Input power is the power generated in an area of solar panels due to exposure to solar radiation. This input power is also often referred to as the energy produced by solar panels. The input power can be obtained from the multiplication of the panel area with the intensity of the sunlight.

$$P = I_r \ x \ A$$

$$= \frac{1000W}{m^2} \ x \ 0,063m^2$$

$$= 63 \ Watt$$

3.3 Fill factor (FF)

Fill factor is important parameter for solar cell, it can be defined as maximum power output ($V_{mp} \ x \ I_{mp}$) is divided to the score of V_{oc} and I_{sc} [8].

$$FF = \frac{Vmp \ x \ Imp}{Voc \ x \ Isc}$$

$$= \frac{17,2 \ V \ x \ 0,58 \ A}{21,6 \ V \ x \ 0,68 \ A}$$

$$= \frac{9,976}{14,688}$$

$$= 0,679$$

3.4 Calculation of maximum power on solar panel

Maximum power on solar panel can be reached by multiplication of opened-series voltage(Voc), short circuit current (Isc), and *fill factor* generated by solar cell, in order getting the following formula:

$$Pmax = Voc \; x \; Isc \; x \; FF$$

$$Pmax = 21,6 \, V \; x \; 0,68 \, A \; x \; 0,679$$

$$= 9,97 \text{ watt}$$

3.5 The efficiency solar cell

The efficiency of solar cells can be calculated from the division of the maximum power (Pmax) generated by the solar cells with the input energy obtained from multiplying the intensity of solar radiation and the surface area.

$$\eta = \frac{Pmax}{Ir \; x \; A}$$

$$= \frac{9,97 \, Watt}{1000 \frac{Watt}{m^2} x 0,063 m^2}$$

$$= \frac{9,97}{63}$$

$$= 0,158$$

3.6 Testing tools

3.6.1 The length of spraying for 15 liter water

The following table is a table of the results of testing tools to find out which sprayer takes 15 liters of water. In testing, it used 3 types of sprayer; sprayer 1, sprayer 2 and sprayer 3. Those three types of sprayer that distinguishes is the shape of the sprayer and its dimensions. The following table shows the duration of spraying.

Table 2. Testing the duration of spraying

Kinds of Nozzle	Volume (ltr)	Duration of spraying (min)
Nozzle 1	15	11.30
Nozzle 2	15	09.00
Nozzle 3	15	07.30

Table 1 shows that the sprayer on a spray machine that takes the greatest time to spend 15 liters of water is sprayer 1 with duration 11 minutes 30 seconds. While the sprayer that requires the shortest times of spraying is sprayer 3 with duration 7 minutes 30 seconds. The duration of this spraying is influenced by the amount of each hole in the sprayer. The greater the number of holes in the sprayer, the greater the water come out so that the spraying time is shorter, and vice versa.
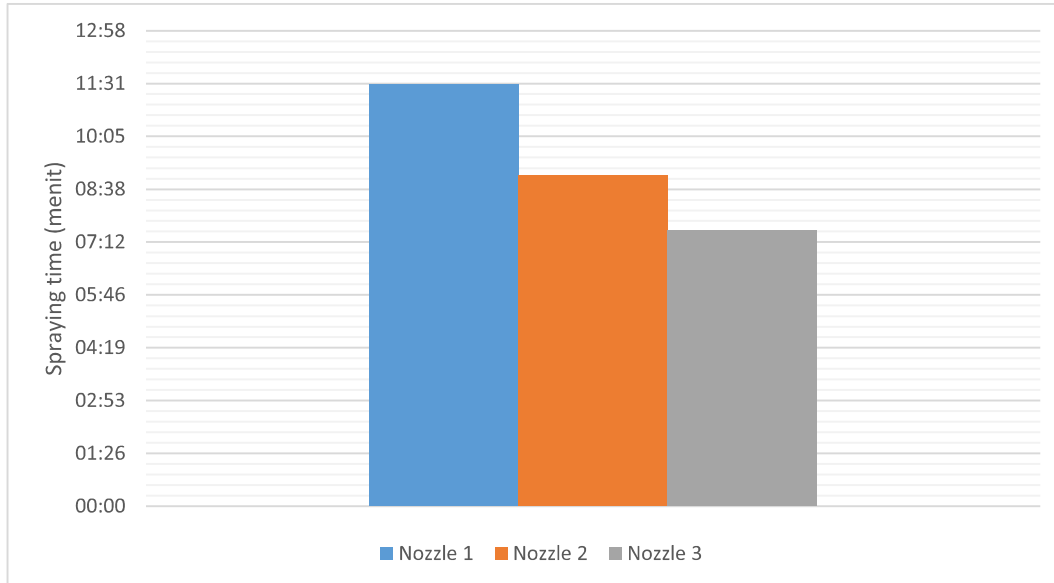
Figure 11. The duration of spraying based on the nozzle

Figure 12. Kinds of nozzle on the sprayer machine

Figure 12 shows kinds of nozzle used on the sprayer machine. Of the three nozzles, the number of the holes makes the difference.

3.6.2   Nozzle flow rate

Table 2 shows the results of the flow rate test at the nozzle. The nozzle flow rate can be obtained from the ratio of the volume of water in the spray tank to the length of time required during spraying. In table 2 the smallest nozzle flow rate occurs in sprayer 1 with 1.33 liters per minute. While the largest nozzle flow rate occurs in sprayer 3 with 2.05 liters per minute.

Table 3. Nozzle flow rate

Kinds of Nozzle	Volume of water (liter)	Length of spraying (minutes)	Q (liter/minutes)
Nozzle 1	15	11.30	1,33
Nozzle 2	15	09.00	1,67
Nozzle 3	15	07.30	2,05

4. Conclusions

The pest spraying machine based on the solar cell was successfully made. This system was developed in order to increase the working capacity of farmers by reducing the time and fatigue of the hands of a farmer in pumping the sprayer machine. The operation of this sprayer is very simple and environmentally friendly. The advantage of this tool is that it can charge the battery directly when spraying during the day.

5. References

[1]   Poudel B, Sapkota R, Shah B R, Subedi N and GL Anantha Krishna 2017 Design and fabrication of solar powered semi automatic pesticide sprayer *International Research Journal of Engineering and Technology (IRJET)* **04** 2073-2077.
[2]   M Mukesh K, Wadavane D, Ankit N, Dipak V and Chandrakant G 2018 Solar operated pesticide sprayer for agriculture purpose *International Research Journal of Engineering and Technology (IRJET)* **5** 3365-3369.
[3]   Suthar R Ronak 2018 Design and development of spray sprinkling mechanisme for agriculture use *International Journal for Technological in Engineering* **6** 4850-4855.
[4]   B Murthy K, Kanwar R, Yadav I and Das V 2017 Solar pesticide sprayer *International Journal of Latest Engineering Research and Applications (IJLERA)* **2** 82-89.
[5]   Kumar S 2017 Design of solar hybrid pesticide spray system *International Journal of Technical Research & Science* **2** 482-487.
[6]   Issa, W.A, Abdulmumuni, B, Azeez, R.O, I.N Okpara, Fanifosi, J.O and O.B Ologunye 2020 Design fabrication and testing of a movable solar operated sprayer for farming operation *International Journal of Mechanical Engineering and Technology (IJMET)* **11** 6-14.
[7]   Singh K, Padhee D, Parmar AK and Sinha BL 2018 Development of a solar powered knapsack sprayer *Journal of Pharmacognosy and Phytochemistry* **7** 1269-1272.
[8]   Y. Ooyama and Y. Harima, 2012 Photophysical and electrochemical properties, and molecular structures of organic dyes for dye-sensitized solar cells *ChemPhysChem* **13** 4032-4080.

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