Design of Solar Power Generation System For Watering Mustard Plants In The Garden Area of Land 600 Sub-District Medan Marelan

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Abstract

Solar power plant (PLTS) is a power plant that works by utilizing renewable energy in the form of solar power as an energy source. This research proposes the design and a solar power generation system (PLTS) that is integrated with an automatic mustard plant watering system. The main objective of this research is to investigate the effectiveness of using solar energy as an energy source to run an automatic watering system for mustard plants and to find out how the influence of sunlight intensity, temperature, and humidity on the energy produced by photovoltaics. The experimental method is carried out by designing and building a PLTS system connected to a water pump for watering chili plants. The results of this study show that the amount of power produced by solar panels depends on the intensity of solar radiation that hits the surface of solar panels. Solar panels used as an alternative energy source with a maximum power of 50 Wp have an efficiency of 13.83%. In this study, the maximum sunlight intensity of 1009.62 W/m2 is able to produce a voltage connected to the load up to 14.84 V and a current of 1.40 A and the power generated reaches 20.78 Watt, with a solar panel temperature of 42°C. And based on the average power entering the battery, a 12 V 7.5 Ah battery can be fully charged within 420 minutes. This shows that the integration of PLTS in the watering system is able to provide adequate, stable and sustainable energy supply. In conclusion, this study indicates that the application of solar power in mustard plant watering systems has the potential to increase energy efficiency and crop yields, while reducing environmental impacts. With a deeper understanding of the technology and energy management, similar systems can be applied to larger-scale farms to support the sustainability of the agricultural sector.

Keywords: ***PLTS Electricity Source for Watering Mustard Plants***

Introduction

In the agricultural process mustard plants are often constrained in terms of watering because it is still often done manually, the location of the land is far from the house and the electricity network or there are other needs that result in irregular watering of mustard. This will result in the growth of mustard plants will not be good because of the lack of mineral intake. Of course this will have a negative impact on farmers where the mustard harvest will not be maximized and for consumers themselves will not get the desired mustard quality. The utilization of solar energy in the agricultural sector is the right solution considering that agricultural land is generally far from the power grid and in open areas. On agricultural land sunlight is abundant so that with renewable energy technology or Sora cell can be converted into electricity as an energy source for various agricultural tools. The modular nature of solar panels makes them applicable as needed.

This research aims to produce an environmentally friendly mustard watering device that uses renewable energy sources. The designed tool is expected to be able to speed up time and minimize labor costs in the mustard watering process and reduce the level of worker fatigue. For this purpose, a solar energy-based mustard sprinkler will be designed through solar photovoltaic technology that is effective and efficient by considering ergonomic aspects.

Literature Review

2.1 Solar Cells

A solar cell is a device composed of semiconductor materials that can convert sunlight into electricity directly. Often also used the term photovoltaic. Solar cells generally have a minimum thickness of 0.3 mm made from slices of semiconductor material with positive and negative poles. In solar cells there is a connection (function) between two thin layers made of semiconductor materials, each of which is known as a semiconductor type “P” (positive) and semiconductor type “N” (negative). P-type silicon is a surface layer that is made very thin so that sunlight can penetrate directly to the junction. This P part is given a ring-shaped nickel layer, as a positive output terminal. Under the P part there is an N type part which is coated with nickel as well as a negative output terminal.

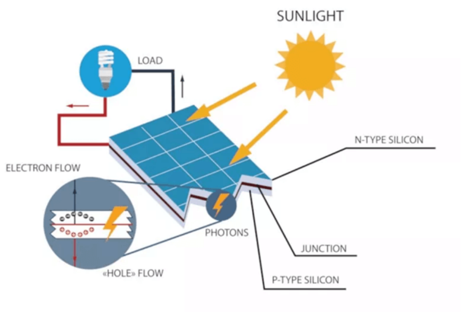

Figure 1. The Process of Solar Cells Converting Solar Energy into Electricity

The solar radiation available outside the earth's atmosphere or often called the solar radiation constant of 1353 $W/m2$ is reduced in intensity by absorption and reflection by the atmosphere before reaching the earth's surface. Ozone in the atmosphere absorbs short-wavelength radiation (ultraviolet) while carbon dioxide and water vapor absorb some of the earth's direct radiation or highlights by absorption, there is still radiation that is scattered by gas molecules, dust, and water vapor in the atmosphere before reaching the earth which is referred to as scattered radiation. To find out the power (P) input of solar cells is to have irradiation (Ir) and the area of solar panels (A) used, it can be defined by the following equatio:

$$P_{In} = I_r \times A \qquad (1)$$

Where:

P_{in} = Input Power (W)

I_r = Solar Irradiation ($/m^2$)
A = Solar Panel Area

While the Output Power (Pout) of solar cells can be found with the following equation:

$$P_{Out} = V \times I \quad (2)$$

Where:
P_{Out} = Output Power (W)
V = Output Voltage (Volt)
I = Output Current (Ampere)

The efficiency (η) of solar cells can be known when there is Input Power (Pinput) and Output Power (Poutout), with can be made with the following equation

$$\eta = \frac{P_O}{P_{In}} x100\% \quad (3)$$

Where:
η = Efficiency (%)
P_{In} = Input Power (Watt)
P_{Out} = Output Power (Watt)

2.2 Characteristics of Solar Cells

Solar cells receive varying amounts of sunlight in one day. This is because sunlight has a large intensity during the day compared to the morning. To find out the capacity of the power produced, measurements are made of the current (I) and voltage (V) on a group of solar cells called modules. To measure the maximum current, the two terminals of the module are short-circuited so that the voltage becomes zero and the current is maximum. By using an amper meter, a maximum current called short circuit current or Isc will be obtained. Measurement of voltage (V) is done on the positive and negative terminals of the solar cell module by not connecting the solar cell with other components. This measurement is called open circuit voltage or Voc. Open Circuit Voltage (Voc) is the maximum voltage capacity that can be achieved in the absence of current.

$$V_{OC} = \frac{kT}{q} In(\frac{Isc}{Is} + 1) \quad (4)$$

Where:
Voc = Open Circuit Voltage (V)
K = Bolyzman Constant (1.30 x 10−16)
q = Electron Charge Constant (1.602 x 10−19)
T = Temperature (°Kelvin)
Is = Saturation Current (Ampere)

To find out the short circuit current can be calculated using the equation:

$$Isc = (Ln + Lp) \quad (5)$$

Where:
Isc = Short Circuit Current (A)
G = Generation Level
Ln = Electron Diffusion Length
L = Diffusion Hole Length

Fill factor is a parameter that determines the maximum power of the solar panel, the amount of FF can be calculated by the equation

$$FF = \frac{Vmp\ x\ \text{Im}\ p}{Voc\ x\ Isc} \quad (6)$$

Where:
FF = Fill Factor
Vmp = Maximum Voltage (V)
Imp = Maximum Current (A)
Voc = Open Circuit Voltage (V)
Isc = Short Circuit Current (A)

To find the power calculation on the solar module with the following equation:

Pmax =Voc . Isc .FF (7)
Where:
Pmax = Maximum Power (W)
Voc = Open Circuit Voltage (V)
Isc = Short Circuit Current (A)
FF = Fill Factor

2.3 Process of Battery Receiving Current

Minimum battery requirements (battery is only used 50% to fulfill electricity needs). Thus the power requirement is multiplied by 2 times. The relationship between power and battery can be calculated with the following equation:

$$\mathbf{P_{Aki} = V \times I} \quad (8)$$

Where:
P_{Aki} = Battery Power (Ah)
V = Battery Voltage (Volt)
I = Battery Current (Ampere)

Research Methodology

3.1 Research Design

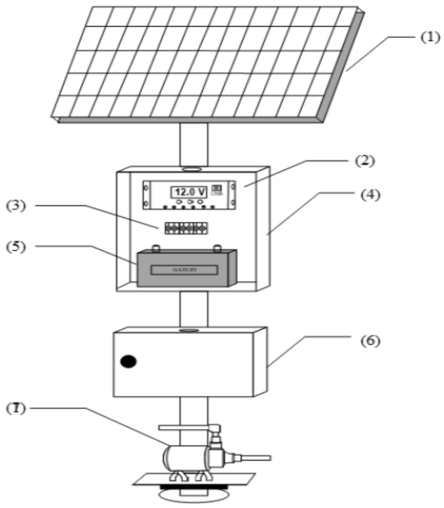

Figure 2. Design

3.2 Solar Panels

In the design of this research using 1 unit of monocrystalline solar panels, which functions to absorb solar energy which will then be converted into electrical energy which is first stored into the battery through the SCC. The specifications of the solar panel are as follows:

Table 1. Specifications of Solar Panels Used

Model	SP50-18p
Peak Power	50 Wp
Max. Power Volt (Vmp)	17,8V
Max. Power Cerrent (Imp)	2,81 A
Open Circuit Current (Vsc)	21,89 V
Short Circuit Current (Isc)	3,03 A
Power Tolerance	±3%
Max. System Voltage	1000 V
Series Fuse Rating (A)	12
Number By Pass Diode	1
Operating Temperature	-4 °Cto + 85°C
Maximum System Voltage	1000V DC
Panel Dimension Size	P = 67 Cm L = 54 Cm

Calculation of Solar Intensity on Solar Panels:

P = 50 Watt

A = p x I

= 67 x 54 = 3618 cm^2 Or 0,3618 m^2

Settlement

I = P/I

= 50,018 Watt / 0,3618 m^2

= 138,24 W/m^2 Or 0,013824 W/cm^2

Where:

I = Sunlight Intensity (W/m^2)

P = Solar Panel Power (Watt)

A = Solar Panel Cross-Sectional Area (m^2). So, every 1cm2 of solar panel cross section can receive 0.013824 W/cm^2 of sunlight

3.3 Solar Panel Efficiency Calculation

P = 50,018 Watt

A = 0,3618 m^2

G = 1000 W/m^2

Settlement:

$$\eta = \frac{P}{G\,x\,A} x100\%$$

$$= \frac{50{,}018}{100W / m^2 x0{,}3618 m^2} x100\%$$

$$= 0{,}1382\, x100\%$$

$$= 13{,}82\%$$

Then the efficiency of the solar panel above is 13.82%

3.4 SCC (Solar Charge Controler)

Scc functions to regulate the current and voltage in the solar panel system that works based on the set mode. Also as a safety and also maintain the durability of solar cell equipment in the process of work. The specifications of the SCC that will be used, as follows

Table 2. Specifications of SCC Used

Rated Voltage	12/24 V
Rated Current	10 A
Max PV Voltage	50V
Max PV Input Power	130w(12V) 260w(24V)

3.5 Terminal Block

Serves as a connector between components

3.6 Acrylic Box

Serves as a place of control and protection so that certain components are not exposed to water or direct sunlight

3.7 Battery

Useful as a store of energy received from solar panels, which is then distributed energy to operate the load. The battery specifications used are as follows:

Table 3. Battery Specifications Used

Standby Use	13,5-13,9 V
Cycle Use	14,5-14,9 V
Initial Current	Less Thant 2,25 A
Kapasitas	7,5 Ah

3.8 Arduino box

Function as an automation system for watering mustard plants

3.9 DC Water Pump

The pump is used as a workload to distribute water as a watering can to plants. The motor pump used in the research is a DC motor because it is more effective and easy to implement. The following are the specifications of the DC water pump used

Table 4. Battery Specifications Used

Model	Earth 2203 - 2
Voltage	DC – 12 V
Ampere	3,0 A
Flow	4,0 Lpm
Pressure	100 Psi / 6,8 Bar

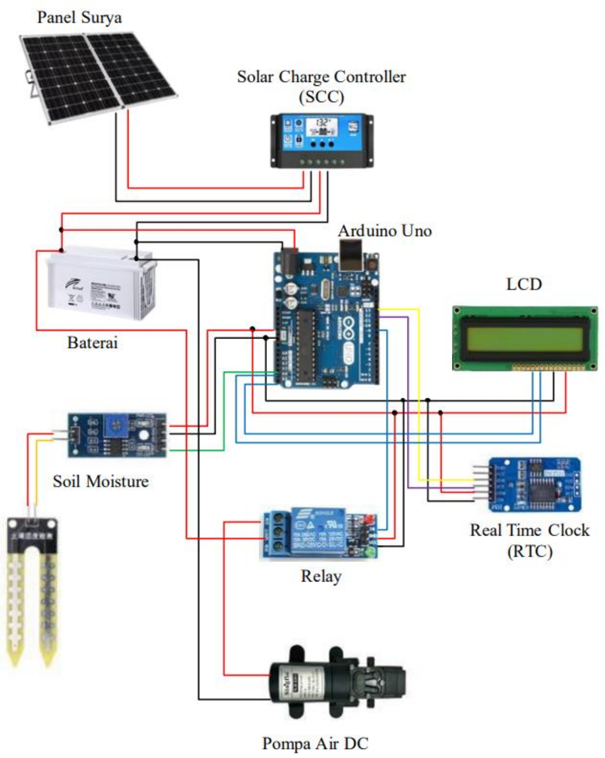

Figure 3. Overall Tool Set

Results

4.1 Measurement Results of Solar Panel Output without Load

The data measured is the light intensity which determines the level of illumination illuminated by the sun, the voltage and current produced by the solar panel. The test results can be seen in the table below:

Table 4 Measurement Results of Solar Panel Without Load Day I

Hours	Sunlight Intensity		Voltage (Volt)	Current (Ampere)	Temperature (°C)
	(Lux)	(W/m2)			
08.00	34.370	271,52	21	2,11	32
09.00	66.810	527,80	20,28	2,02	33
10.00	94.160	743,86	20,44	2,02	35
11.00	101.240	799,80	21,19	2,10	36
12.00	27.890	220,33	20,74	2,02	30
13.00	9.745	76,98	19,31	1,89	29
14.00	74.200	586,18	20,51	2,03	31
15.00	98.620	779,10	21	2,06	32
16.00	86.630	684,37	20,06	2,01	32
17.00	10.840	85,63	19,48	1,90	29
Average			**20,40**	**2,01**	**31,9**

On the first day of testing, it can be seen the measurement results of the Monocrystalline Solar Panel without load, and obtained the maximum voltage of the solar panel at 11.00 WIB of 21.19 V and a maximum current of 2.10 A with a light intensity of 101,240 Lux (799.80 W/m^2). And the minimum voltage of this solar panel measurement at 13.00 WIB is 19.31 V and the minimum current is 1.89 A with a light intensity of 9,745 Lux (76.98 W/m^2)

Average power

$P_{Average} = V_{Average} \times I_{Average}$
$= 20{,}40$ V x 2,01 A
= 41 Watt

Table 5. Measurement Results of Solar Panel Without Load Day II

Hours	Sunlight Intensity		Voltage	Current	Temperatur
	(Lux)	(W/m2)	(Volt)	(Ampere)	e (°C)
08.00	9.294	73,42	19,09	1,94	29
09.00	35.540	280,77	20,38	1,98	31
10.00	42.920	339,07	20,43	2,03	32
11.00	98.220	775,94	21	2	35
12.00	127.800	1009,62	21,25	2,15	42
13.00	86.130	680,43	20,66	2	35
14.00	9.540	75,37	17,31	1,76	30
15.00	9.662	76,33	18,16	1,77	30
16.00	4.820	38,08	16,41	1,59	28
17.00	3.339	26,38	11,85	1,12	27
Average			**18,65**	**1,83 A**	**32,1**

Average power

$P_{Average} = V_{Average} \times I_{Average}$
$= 18{,}65$ V x 1,83 A
= 34,13 Watt

Table 6. Measurement Results of Solar Panel Without Load Day III

Hours	Sunlight Intensity		Voltage	Current	Temperature
	(Lux)	(W/m2)	(Volt)	(Ampere)	(°C)
08.00	7.105	56,13	18,68	1,87	29
09.00	43.910	346,89	20	2,08	31
10.00	71.310	563,35	20,34	2,11	33
11.00	23.810	188,10	20,03	2	30
12.00	41.870	330,77	20,09	2	31
13.00	19.060	150,57	19,36	1,88	29
14.00	18.690	147,65	19	1,89	29
15.00	37.370	295,22	20,04	2,04	30
16.00	22.710	179,41	19,57	1,92	30
17.00	9.750	77,02	17,34	1,70	29
Average			19,44	1,95	**30,1**

Average power

$P_{Average} = V_{Average} \times I_{Average}$
$= 19{,}44$ V x 1,95 A
= 37,90 Watt

4.2 Measurement Results of Solar Panels with Load

The data measured is the light intensity which determines the level of illumination illuminated by the sun, the voltage and current produced by the solar panel when loaded to determine the energy obtained. The test results can be seen in the table below:

Table 7. Measurement Results of Solar Panels with Load Day 1

Hours	Sunlight intensity		Voltage (Volt)	Current (Ampere)	Temperature (°C)
	(Lux)	(W/m2)			
08.00	34.370	271,52	12,63	1,23	32
09.00	66.810	527,80	12,85	1,23	33
10.00	94.160	743,86	13,26	1,27	35
11.00	101.240	799,80	13,61	1,29	36
12.00	27.890	220,33	12,29	1,15	30
13.00	9.745	76,98	12,07	1,12	29
14.00	74.200	586,18	12,11	1,23	31
15.00	98.620	779,10	13,43	1,27	32
16.00	86.630	684,37	12,30	1,26	32
17.00	10.840	85,63	12,08	1,13	29
Average			12,66	1,21	**31,9**

Average power

$P_{Average} = V_{Average} \times I_{Average}$

$= 12{,}66\ V \times 1{,}21\ A$

$= 15{,}32\ Watt$

Table 8. Measurement Results of Solar Panels with Load Day II

Hours	Sunlight intensity		Voltage (Volt)	Current (Ampere)	Temperature (°C)
	(Lux)	(W/m2)			
08.00	9294	73,42	12,14	1,14	29
09.00	35.540	280,77	12,42	1,23	31
10.00	42.920	339,07	12,64	1,25	32
11.00	98.220	775,94	13,81	1,27	35
12.00	127.80 0	1009,62	14,84	1,40	42
13.00	86.013	680,43	13,98	1,32	35
14.00	9.540	75,37	12	1,22	30
15.00	9.662	76,33	12,02	1,22	30
16.00	4.820	38,08	11,89	1,20	28
17.00	3.339	26,38	11,70	1,19	27
Rata-Rata			**12,74**	**1,24**	**32,1**

Average power

$P_{Average} = V_{Average} \times I_{Average}$

$= 12{,}74\ V \times 1{,}24\ A$

$= 15{,}80\ Watt$

Table 9. Measurement Results of Solar Panels with Load Day III

Hours	Sunlight intensity		Voltage (Volt)	Current (Ampere)	Temperature (°C)
	(Lux)	(W/m2)			
08.00	7.105	56,13	12,13	1.13	29
09.00	43.910	346,89	12,42	1,25	31
10.00	71.310	563,35	13,05	1,27	33
11.00	23.810	188,10	12,26	1,22	30
12.00	41.870	330,77	12,44	1,25	31

Hours	Sunlight intensity		Voltage	Current	Temperature
	(Lux)	(W/m2)	(Volt)	(Ampere)	(°C)
13.00	19.060	150,57	12,17	1,21	29
14.00	18.690	147,65	12,17	1,20	29
15.00	37.370	295,22	12,65	1,24	30
16.00	22.710	179,41	12,19	1,15	30
17.00	9.750	77,02	12,02	1,12	29
Rata-Rata			**12,35**	**1,20**	**32,1**

Average power

$P_{Average} = V_{Average} \times I_{Average}$

$= 12{,}35\ V \times 1{,}20\ A$

$= 14{,}82$ Watt

4.3 Battery Measurement and Calculation Data

Calculation in battery capacity is done to determine the length of charging and usage of the battery. Calculation of Battery Charging Time on Solar Panel Measurements With No Load Day I Can be calculated with the following equation:

$$\text{Battery Charging Time (Hours)} = \frac{\text{Battery Capacity Current (Ah)}}{\text{Charging Current}\,(A)}$$

$$= \frac{7{,}5Ah}{1{,}21A} = 6{,}19\,Hours$$

For day I with an average current out of the SCC of 1.21 A takes 6 hours 19 minutes to fully charge the battery. Calculation of Battery Charging Time on Solar Panel Measurements With No Load Day II Can be calculated with the following equation:

$$Battery\ Ch\arg ing\ Time\,(Hours) = \frac{Battery\ Capacity\ Current\,(Ah)}{Ch\arg ing\ Current\,(A)}$$

$$= \frac{7{,}5Ah}{1{,}24A} = 6\,Hours$$

For day II with an average current out of the SCC of 1.24 A takes 6 hours to fully charge the battery. Calculation of Battery Charging Time on Solar Panel Measurements With No Load Day III Can be calculated with the following equation

$$\text{Battery Charging Time}\,(Hours) = \frac{\text{Battery Capacity Current (Ah)}}{\text{Charging Current}\,(A)}$$

$$= \frac{7{,}5Ah}{1{,}20A} = 6{,}25\,Hours$$

For day III with an average current coming out of the SCC of 1.20 A, it takes 6 hours and 25 minutes to fully charge the battery. To prove this, battery charging tests were carried out with solar panels in an empty (0%) to full (100%) battery state

Table 10. Battery Charging Measurement

Time (Minutes)	Solar Panel Output Voltage	Battery Voltage	Battery Condition
0	11,5 V	11,4 V	0 %
60	11,9 V	11,9 V	10 %

Time (Minutes)	Solar Panel Output Voltage	Battery Voltage	Battery Condition
120	12,2 V	12,1 V	30 %
180	12,1 V	12 V	48 %
240	12,1 V	12 V	70 %
300	12,8 V	12,8 V	80 %
360	13,2 V	13,1 V	90 %
420	13,4 V	13,4 V	100 %

From the table above, it can be seen that the time needed to charge the battery for 420 minutes or about 7 hours with a reference charging voltage reaching 13.4 V and with cloudy sunny weather conditions.

4.4 Calculation and Testing of Battery Life with Pump Load

From the specification data listed on the equipment, the calculation results can be known using the following equation:

Load = 36 W / 12 V = 3 A
Battery= 12 V / 7,5 Ah

$$Ketahanan\ Aki\,(Jam) = \frac{\text{Battery Capacity Current}\,(Ah)}{\text{Load Current}\,(A)} - \text{Battery Deficiency}\,(20\%)$$

$$= \frac{7{,}5Ah}{3A} - \text{Deficiency}\,(20\%)$$

$$= 2\,Hours$$

Longevity of 12V 7.5 Ah battery against 3 A DC pump load then the equipment can be operated for 2 hours

Table 11. Battery Life Measurement Results Under Load

Time (Minutes)	Load Voltage	Load Current	Load Power	Battery Voltage
0	12	2,20	26,4	12,4
60	11,8	2,18	25,7	11,8
120	11,3	2,13	24,4	11,3
180	11	2,1	23,1	11
240	10,9	1,9	20,7	10,9

From the table above, it can be known from the measurement data based on field measurements, the battery life can last ± 4 hours non-stop by obtaining current measurements at loads below 3 A with a voltage drop every hour.

Conclusion

Based on the results of design and analysis that has been done, this system test can be concluded as follows:

1. The design of a solar power plant (PLTS) using 50 Wp solar panels for this automatic mustard plant watering system is able to work properly and PLTS is able to supply the energy needed by the pump and the system can operate as desired
2. The effect of intensity, temperature is very influential on the energy produced by PLTS. In this study, the maximum sunlight intensity of 1009.62 W/m2 was able to produce a voltage connected to the load up to 14.84 V and a current of 1.40 A and the power generated reached 20.78 Watt, with a solar panel temperature of 42°C

3. The performance of the solar power plant application in the mustard plant watering system has positive potential. This system can help reduce dependence on fossil energy sources and reduce negative environmental impacts

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