Utilization of solar power as DC water pump movement in hydroponic plants

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Abstract. Photovoltaics is used to convert sunlight energy into electrical energy, which can be used as a regulator of water circulation hydroponic planting methods that are easy, practical and attractive so that they can be used easily by the urban community in their operations. The use of solar power as a DC water pump driver in hydroponic plants was designed using several tools including 10 Wp photovoltaic and DC stepdown LM 7812 with 3.6 W power. This research was conducted in Agricultural Faculty Building, University of Sumatera Utara with a height of 2 meters from the ground. DC water pump could function optimally at 11.00 a.m. - 3.00 p.m. with an average sunlight intensity of 373.71 - 310.65 W/m² and an average temperature of 30°C - 33°C. Photovoltaics monocrystalline type produced daily energy of 224.75 Wh with an efficiency of 8.14% while polycrystalline produced 194.81 Wh of electricity with 7.57% efficiency. The results showed that monocrystalline PV was better than polycrystalline PV.

1. Introduction
Indonesia is a tropical country with a high radiation level, and have abundant potential energy with total average global irradiation is 2,111.9 – 2,427.5 W/m²/year and the average daily irradiation around 5.86 kWh/m², so it is well suited to use solar cells [1]. Utilization of solar power is one of the sources of renewable energy. The equipment used to convert energy from the sun that is the use of photovoltaic solar modules (PV) that convert sunlight into electricity. Electrical energy is generated from the photovoltaic can, directly and indirectly, be employed by the load. In this system, the load is served only when the available solar energy. Things that affect the performance of photovoltaic is a condition of climatology. The use of solar panels as a driving force of the water pump based on research the ability of DC pumps to lift water at a certain height, and many produced water discharge reach 3.2 m and Water discharge 38% greater compared to the use of the AC pump [2].

Considering the development of agricultural science and technology then the hydroponic system modifications need to be done in order to use in the Hydroponic growing system either since hydroponics system cannot be separated from the water it needs to be made to the system water circulation manager using solar power. Solar power can be a solution to the utilization of renewable energy. The purpose of this research is to discover the power, electrical energy and the actual efficiency of the photovoltaic when used against the influence of the intensity of the sunlight as a source of the activator of DC water pump at the hydroponic water spinach installation. The benefits of this research are to provide knowledge to urban communities in order to farm easily and increase revenue or as a hobby.
2. Materials and Methods

2.1. Research procedure

2.1.1. Manufacture of construction. Manufacturing set up hydroponics installation was constructed at the height of 2 meters above ground. Hydroponic construction consisting of 4 PVC pipe which was attached with a pipe elbow with 13 holes for plant and the distance between holes was 5 cm with plastic hoses at the upper end of the pipe, and a bucket was put under the hose as the water and nutrients container. The plastic roof was built and solar array was installed on top of a pole with the position on the side next to hydroponics installation then solar array was connected using wires to DC stepdown on poles and will be pumping water continuously (Figure 1).

![Figure 1. Hydroponics installation construction](image)

2.1.2. Implementation of the seedbed. Humid rockwool was stuffed into plastic containers as growing medium and the seed was spaced not too tightly. The seedbed was covered with black plastic so that it was not exposed to direct sunlight, and the water spinach was moved to the net pot after 7 - 8 days with four leaves and then put it into the pipe. Mixture of 13 liters of pure water and 130 ml of nutrients was filled into the drum as a nutrient solution and the plants were transplanted from the nursery to the pipe. Irrigation of the plant sprouts was done at 9.00 to 15.00 Western Indonesian Time, power and intensity of the sun’s light was measured using solar power meter and discharge of water per hour and observation was done on plant sprouts every 2 days until harvest (20 days) and the samples were taken from each pipe in the sample size of two samples at the beginning, in the middle, and at the end of the pipeline, with the following measures: a) count the number of leaves blossoms on the plant sprouts. b) Measure the width of the leaves of the plant water spinach with a slide rule. c) Measure the height of the plant sprouts from the base of the stem to the top of the leaf, and compare the efficiency of using photovoltaic monocrystalline and polycrystalline type.
2.2. Parameters research

2.2.1. Temperature and Intensity of sunlight. Environmental temperature measurement is done per hour by using a thermometer. Measurement of light intensity measurements can be done directly with solar power meters and using secondary data from Meteorology, Climatology and Geophysics of the Republic of Indonesia.

2.2.2. Power and electrical energy. Electric power becomes the parameter consists of a theoretical and actual power. The power produced by the solar cell ($P_{out}$), measurement of electrical power generated from the Sun ($P_{in}$) and energy photovoltaic electricity generated (E) were calculated by Equations (1), (2) and (3) where $V$ is electric voltage (V), $I$ is electric current (Amp), $F$ is the intensity of sunlight ($W/m^2$), $A_c$ is a total PV area ($m^2$), and $t$ is time (h).

$$P_{out} = V \times I \quad (1)$$

$$P_{in} = F \times A_c \quad (2)$$

$$E = P_{out} \times t \quad (3)$$

2.2.3. Water discharged and plant growth. The water discharge that flowed was determined by Eq. 4 while observations of plant growth include the observation of the number of leaves, leaf width, and a height of water spinach observed every two days for 20 days. Where $Q$ is water discharge ($m^3/s$), $v$ is the volume of water and nutrients ($m^3$), $t$ is time (s).

$$Q = \frac{v}{t} \quad (4)$$

2.2.4. The efficiency of photovoltaic. The efficiency of the photovoltaic can be calculated by comparison of the solar module output power against power received by the solar modules are:

$$\eta = \frac{P_{out}}{P_{in}} \times 100\% \quad (5)$$

3. Results and discussion

3.1. Temperature and intensity of sunlight

Table 1 shows that the average temperature of the environment from May to August 2018 was around 28–33°C while the average intensity of Sun’s light displays at Table 2. The average temperature of Indonesia range from 25°C – 35°C [2]. One factor that into consideration the intensity of the Sun's light was the air temperature. The temperatures affected the performance of the solar panel. Ideally, a standard temperature working on photovoltaic 25°C, with increasing temperature the efficiency of the photovoltaic decreased. The highest temperature occurred in June with an average of 31.7°C at 9.00 – 15.00 while the highest temperature at 12.00 - 13.00 was obtained 30 - 33°C on bright environmental conditions.

Table 2 shows that the highest of sunlight’s intensity of sunlight was starting from 11.00 until 14.00 clock’s in June with the total intensity of the sun's light 3241.02 W/m² and at 13.00 clock’s was the highest intensity 541.28 W/m² with temperatures of 33°C (Table 1), while the lower intensity of the sunlight was in May of 184.94 W/m² at 9.00 with a temperature of 27°C means the intensity of sunlight higher in high temperatures.
Table 1. The average temperature in May to August 2018

| Time (h) | May (°C) | June (°C) | July (°C) | August (°C) | Average (°C) |
|----------|----------|-----------|-----------|-------------|--------------|
| 9.00     | 27       | 30        | 28        | 28          | 28           |
| 10.00    | 29       | 30        | 30        | 28          | 29           |
| 11.00    | 31       | 32        | 30        | 30          | 30           |
| 12.00    | 32       | 33        | 31        | 32          | 32           |
| 13.00    | 32       | 33        | 33        | 33          | 33           |
| 14.00    | 32       | 32        | 32        | 31          | 31           |
| 15.00    | 30       | 31        | 30        | 30          | 30           |
| Average  | 30.7     | 31.7      | 29.8      | 30.2        | 30           |

Table 2. Average intensity of sunlight

| Time (h) | May (W/m²) | June (W/m²) | July (W/m²) | August (W/m²) | Average (W/m²) |
|----------|------------|-------------|-------------|----------------|----------------|
| 9.00     | 184.94     | 244.15      | 202.37      | 210.42         | 210.47         |
| 10.00    | 341.75     | 272.87      | 325.24      | 272.58         | 303.11         |
| 11.00    | 400.54     | 386.57      | 355.70      | 352.03         | 373.71         |
| 12.00    | 451.58     | 509.73      | 444.99      | 469.57         | 468.96         |
| 13.00    | 420.80     | 541.28      | 499.95      | 512.33         | 493.59         |
| 14.00    | 293.57     | 432.05      | 428.18      | 426.08         | 394.97         |
| 15.00    | 213.94     | 344.64      | 333.53      | 350.51         | 310.65         |
| Sum      | 2758.70    | 3241.02     | 3034.95     | 3063.09        | 3024.44        |

Figure 2. Relationship of temperature with sunlight intensity in May to August 2018

The average intensity of sunlight and temperature for 7 hours in from May until August 2018 is presented in Fig.2 which shows that the change in temperature of up to 33°C with an increase in the
intensity of sunlight to 541.28 W/m². The intensity of sunlight in June was the highest and the lowest in May ranged 184.94-541.28 W/m² at a temperature of 27°C – 33°C. According to [1] Indonesia belongs to the medium for the reception of the intensity of the sunlight which was around 10%-51% of 1000W/m² of solar energy. The intensity of the sun’s light in May–June 2018 is quite different to the year 2017, where on the Table 2 the highest intensity in the month of June of the year 2018 of 3241.02 W/m² with an average temperature of 31.7 °C and in 2017 the intensity of 2471.4 W/m² with temperatures the average 28.3°C, then it can be inferred that the intensity of the sunlight and the temperature is increasing every year. The difference in the intensity of sunlight each month due to the position of the sun is above the Equator and the environmental conditions that have a lot of smoke and pollution so that it can block light from the sun. The reduced light intensity is decreased when the positions of the sun is above the equator that occurs in June [1, 2].

3.2. Power and electrical energy
Photovoltaic electric power with direct measurement (actual) and theoretical calculation (theoretical) from May to August 2018 is displayed in Table 3 and 4, while electrical energy produced by the photovoltaic polycrystalline (F1) and monocrystalline photovoltaic (F2) is shown in Table 5.

### Table 3. Average of electrical power polycrystalline photovoltaic

| Time   | May (W) | June (W) | July (W) | August (W) | May (W) | June (W) | July (W) | August (W) |
|--------|---------|----------|----------|------------|---------|----------|----------|------------|
| 9.00   | 2.66    | 2.66     | 2.36     | 2.22       | 10.09   | 10.09    | 10.09    | 10.09      |
| 10.00  | 3.46    | 3.46     | 2.95     | 3.06       | 10.09   | 10.09    | 10.09    | 10.09      |
| 11.00  | 4.15    | 4.15     | 4.12     | 4.17       | 10.09   | 10.09    | 10.09    | 10.09      |
| 12.00  | 5.02    | 5.02     | 5.14     | 5.00       | 10.09   | 10.09    | 10.09    | 10.09      |
| 13.00  | 4.73    | 4.73     | 5.40     | 5.33       | 10.09   | 10.09    | 10.09    | 10.09      |
| 14.00  | 4.08    | 4.08     | 4.44     | 4.76       | 10.09   | 10.09    | 10.09    | 10.09      |
| 15.00  | 3.51    | 3.51     | 3.76     | 3.11       | 10.09   | 10.09    | 10.09    | 10.09      |
| Sum    | 27.61   | 27.61    | 28.17    | 27.65      | 70.63   | 70.63    | 70.63    | 70.63      |
| Average| 3.94    | 3.94     | 4.02     | 3.95       | 10.09   | 10.09    | 10.09    | 10.09      |

### Table 4. Average of electrical power monocrystalline photovoltaic

| Time   | May (W) | June (W) | July (W) | August (W) | May (W) | June (W) | July (W) | August (W) |
|--------|---------|----------|----------|------------|---------|----------|----------|------------|
| 9.00   | 3.16    | 2.90     | 2.37     | 2.37       | 10.20   | 10.20    | 10.20    | 10.20      |
| 10.00  | 4.15    | 3.74     | 3.50     | 3.05       | 10.20   | 10.20    | 10.20    | 10.20      |
| 11.00  | 4.65    | 5.12     | 4.93     | 4.62       | 10.20   | 10.20    | 10.20    | 10.20      |
| 12.00  | 5.57    | 5.06     | 5.97     | 5.98       | 10.20   | 10.20    | 10.20    | 10.20      |
| 13.00  | 5.37    | 6.40     | 6.12     | 6.66       | 10.20   | 10.20    | 10.20    | 10.20      |
| 14.00  | 4.65    | 5.29     | 5.41     | 5.83       | 10.20   | 10.20    | 10.20    | 10.20      |
| 15.00  | 4.00    | 4.32     | 3.61     | 3.91       | 10.20   | 10.20    | 10.20    | 10.20      |
| Sum    | 31.55   | 32.82    | 31.91    | 32.42      | 71.40   | 71.40    | 71.40    | 71.40      |
| Average| 4.50    | 4.69     | 4.55     | 4.63       | 10.20   | 10.20    | 10.20    | 10.20      |

Based on Tables 3 and 4 shows that the highest the actual power 28.17 W and the theoretical power of 70.63 W (polycrystalline, F1) and also photovoltaic monocrystalline (F2) the actual power of 32.82 W with theoretical power of 71.40 W was in June. The output power of photovoltaic was affected by the intensity of the sunlight (Table 2). The theoretical power was higher than the actual power of any treatment (F1) and (F2) in the calculation of power theoretically indicates that the F2 was better than (F1). Based on Table 3 shows that the highest actual electrical power generated by photovoltaic
polycrystalline (F1) of 5.42 W in August at 13.00 o’clock. The electrical power generated by photovoltaic decreased as the temperature and the intensity of the sunlight the higher so that the surface of the solar panel heat up and cause the efficiency of photovoltaic also decreased [2][3]. Electrical power to the actual highest on Table 4 produced by photovoltaic monocrystalline (F2) occurred in August at 13.00 o’clock was 6.66 W. The differences generated power produced between (F1) and (F2) because of the process of making each photovoltaic. The photovoltaic manufacture for polycrystalline (F1) was by casting silicone so that the arrangement of crystals in it be random while monocrystalline photovoltaic (F2) was made by the silicone incision so the crystalline arrangement be fixed. Besides, the quality solar cell will affect the quality of the output voltage and current [3].

| Months | Electric energy of F1 (Wh) | Electric energy of F2 (Wh) |
|--------|---------------------------|---------------------------|
| May    | 193.27                    | 376.74                    |
| June   | 196.70                    | 393.05                    |
| July   | 194.18                    | 370.51                    |
| August | 195.09                    | 321.86                    |
| Sum    | 779.24                    | 1462.16                   |
| Average| 194.81                    | 365.54                    |

Based on Table 5 shows that the average electric energy generated from photovoltaic polycrystalline (F1) was 194.81 Wh with theoretical energy 401.04 Wh. The actual largest electric energy obtained of 196.7 Wh with a theoretical energy 365.54 Wh was in June due to the highest sunlight intensity. On the other hand, the average actual electrical energy of photovoltaic monocrystalline (F2) was 224.75 Wh with 401.04 Wh theoretical energy. The largest actual electrical energy produced was 229.74 Wh in June with the theoretical electrical energy of 457.17 Wh. Based on Table 5 shows that the energy generated by the (F1) is lower than the (F2) due to the power generated by the (F1) was lower(Table 3). This means the usage type of photovoltaic monocrystalline polycrystalline type is superior. Electrical energy demand could be supply to operate each of DC water pumps for 7 hours of operation and unused electrical energy amounted was 169.61 Wh for F1 and 199.55 Wh for F2.

### 3.3. Water discharge and plant growth

The average initial of water discharge and final water discharge on watering plants with hydroponics system utilizing solar panels as a driving force of the DC water pumps were shown in Tables 6 and 7. The debit difference between in May – June with in July – August 2018 was due to the influence of the power generated by photovoltaic output at 9.00 - 10.00 (Table 3 and 4) so that DC water pump could not operate optimally because water driven by the pump could not be achieved at the height of 1 m. This affects plant growth every month.

| Photovoltaics type | Average initial of Water discharge (m³/s) | Average final of Water discharge (m³/s) | Average head (m) |
|--------------------|------------------------------------------|----------------------------------------|-----------------|
| (F1)               | 5.21 x 10⁻⁷                             | 2.25 x 10⁻⁷                            | 0.30            |
| (F2)               | 5.21 x 10⁻⁷                             | 2.16 x 10⁻⁷                            | 0.30            |
Table 7. Water discharge in July – August 2018

| Photovoltaics type | Average initial of Water discharge (m³/s) | Average final of Water discharge (m³/s) | Average (m³/s) | Average head (m) |
|--------------------|------------------------------------------|----------------------------------------|----------------|-----------------|
| (F1)               | 5.21 x 10⁻⁷                              | 2.73 x 10⁻⁷                            | 3.97 x 10⁻⁷ | 0.30            |
| (F2)               | 5.21 x 10⁻⁷                              | 3.12 x 10⁻⁷                            | 4.16 x 10⁻⁷ | 0.30            |

Polycrystalline photovoltaic (F1) with power in Table 3 DC water pump could be operated starting at 11.00 – 15.00 with an average Water discharge 3.73 x 10⁻⁷ m³/s in May – June 2018 and average Water discharge in July – August 2018 was 4.16 x 10⁻⁷ m³/s. Whereas with the use of monocrystalline photovoltaic (F2) DC water pumps functioning at 10.00 – 15.00 o’clock in May – June 2018 with average Water discharge 3.68 x 10⁻⁷ m³/s and in July – August 2018 amounted to 3.97 x 10⁻⁷ m³/s. Considering of power generated photovoltaic water pump to move the DC and the average discharge of each month, it is concluded that using photovoltaic monocrystalline (F2) is better. Based on the results of the measurement of the discharge, the final discharge which is getting smaller as shown in Tables 6 and 7, is due to the development of spinach hydroponic plants to meet the hydroponic gutter until the final phase (20 days), which states that the flow rate of water in the gutter that passes through each inlet will be obstructed by the rooting of the plant so that the final discharge will be smaller than the initial discharge, and also affected by the need for plant water which increases every time.

Figure 3. Graph of growth the number of leaf water spinach for 20 days after planting

Figure 4. Graph of growth leaf width water spinach for 20 days after planting
Figure 5. Graph of growth plant height water spinach for 20 days after planting

Based on Figure 3 displays the added difference number of leaves on the plant sprouts on polycrystalline (F1) and monocrystalline (F2), in May has strands of leaves more than in July with a volume of solution 13130 ml consists of 13 liters of water and nutrient solution nutrient as much as 130 ml in the month has the same average number of leaves, leaf width, and height of the plant, this is because each of the treatment accorded the same solution. Figure 4 shows the difference between the widths of the leaves of the plant water spinach on each treatment. The widest leaf width of 1.6 cm in May belonged to installations of photovoltaic monocrystalline (F2). Figure 5 shows a difference between water spinach with treatment (F1) and (F2), due to the intensity of the sun’s light difference.

3.4. Efficiency of photovoltaics

The solar energy was utilized as a driving force of the DC water pump, the efficiency of hydroponic plants produced by photovoltaic polycrystalline type (F1) and photovoltaic monocrystalline (F2) average efficiency in May, June, July and August 2018 with measurements directly (actual) and theoretically (theoretical) obtained for each month were shown in Table 8.

| Month  | Efficiency F1       | Efficiency F2       |
|--------|---------------------|---------------------|
|        | Actual (%)          | Theoretical (%)     | Actual (%)          | Theoretical (%)     |
| May    | 7.57                | 14.49               | 8.14                | 13.69               |
| June   | 6.14                | 14.97               | 6.95                | 14.15               |
| July   | 5.91                | 15.01               | 6.30                | 14.03               |
| August | 5.77                | 13.82               | 6.36                | 13.06               |
| Sum    | 25.39               | 58.29               | 27.75               | 54.93               |
| Average| 6.34                | 14.57               | 6.93                | 13.73               |

Based on Table 8 shows that the actual highest efficiency was by using monocrystalline (F2) with the efficiency was 8.14 %, while polycrystalline photovoltaic (F1) was 7.57% that means the (F2) was better than (F1). The use of monocrystalline solar panel is better than type polycrystalline. Efficiency for photovoltaic polycrystalline generally ranged from 13-18% and 15-20% for monocrystalline photovoltaic [4]. The factors that influence the value of efficiency is the determination of the appropriate angle. Besides, the solar panel placed on the static support pillar with a mounting angle of 15° and the lack of sunlight absorption at the time of testing, thus impacting the output of solar cells so that the actual efficiency lower than theoretical efficiency[5][6].
4. Conclusions

Environmental temperature at 9.00 – 15.00 with range 28°C – 33°C and luminous intensity averages 210.47 – 493.59 W/m² that can affect the efficiency of the photovoltaic. DC water pump can function optimally at 11.00 - 15.00 with the intensity of sunlight on average 373.71-310.65 W/m² with an average temperature of 30°C-33°C. Maximum power occurred at 13.00 with the results of the measurements of photovoltaic power monocrystalline was 6.66 W, while power from photovoltaic polycrystalline was 5.42 W. Maximum electrical energy generated from photovoltaic monocrystalline with the energy of 224.75 Wh and photovoltaic polycrystalline amounted to 194.81 Wh for 7 hours of measurement. The average water discharge range 3.68 x 10⁻⁷-4.16 x 10⁻⁷ m³/s with the best plant growth conditions in May – June 2018 and the total luminous intensity of the Sun in June ranges 2366.33-2672.07 W/m². The actual efficiency monocrystalline photovoltaic 8.14%, higher than the polycrystalline is 7.57%. Advanced research needs to be done about the utilization of solar energy as a driving force of different water pump to find out the efficiency panel and need to do follow-up research a prototype system of photovoltaic can control panel to get efficiency maximum.

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