Performance Test of Solar – Powered Ice Maker Machine: Case Study in Bantul, Yogyakarta

P Wullandari1 and B B Sedayu1

1Indonesian Research Institute for Fisheries Post-harvest Mechanization, Ministry of Marine and Fisheries, West Imogiri Street km 11.5, Jetis, Bantul, Special Region of Yogyakarta, Indonesia 55781

E-mail: utides@gmail.com

Abstract. Research on performance test of a solar-powered ice maker machine has been conducted in Bantul, Yogyakarta. This study aimed to observe the correlation between intensity of sunlight to the power battery capacity rates generated from solar panels in regard with the performance of ice maker machine. The testing was conducted during various weather conditions i.e. sunny, cloudy and light rain. The type of ice maker observed was a flake ice maker machine with specifications of the production capacity of 105 - 120 kgs/day, producing flake ice with dimensions of 2 x 3 x 3 mm3. The energy of the machine was generated by nine solar panels with maximum power of 200 Wp (watt peak) per panel. A set of three panels was arranged in series, it was then coupled to other sets in parallel. The results showed that the power battery capacity was in corresponded to the sunlight intensity during sunny weather with the correlation: y = 0.009x - 26.08, while during cloudy and raining conditions, the power capacity rates of the battery showed a declining with the correlation: y = 0.008x - 23.92 and y = 0.007x + 69.41, respectively. The ice production capacity during sunny, cloudy and light rainy weathers were 4.34 kg ice/hour; 4.63 kg ice/hour and 4.17 kg ice/hour respectively. Input power from solar panels depends on the intensity of sunlight. The ice produced by ice makers in cloudy weather conditions is much greater than the ice produced during sunny or rainy weather conditions.

Keywords: ice maker, solar power, flake ice, various weather, performance

1. Introduction

Nowadays, we still rely heavily on fossil energy such as coal, natural gas and oil, which accounted for 78.3% of global energy consumption in 2014. Fossil energy is mainly used in the form of direct combustion to generate electricity and heat energy, which can cause environmental problems, such as air pollution and intensive CO2 emissions. Renewable energy with the advantages of unlimited resource and cleanliness can help us solve the problems from fossil energy. Renewable energy includes solar, wind, geothermal energy and so on, where solar energy is recognized as an important energy because of its equal distribution and cleanliness characteristics. Solar energy reaches the earth's surface with radiation, and can be utilized in two ways, namely: 1) with a solar collector to produce heat energy, 2)
by using photo voltaics to produce electrical energy. Statistics show that the total global solar thermal capacity and solar PV capacity reached 435 GW and 227 GW in 2015 respectively [1].

Based on irradiation data collected from 18 locations in Indonesia, solar radiation in Indonesia can be classified as follows: for the western and eastern regions Indonesia with the distribution of illumination in the Western Region of Indonesia (KBI) around 4.5 kWh/m²/day with a monthly variation of about 10%; and in the Eastern Region Indonesia (KTI) is about 5.1 kWh/m²/day with a monthly variation of about 9%. Thus, Indonesia's average solar exposure potential is around 4.8 kWh/m²/day with a monthly variation of about 9%. [3]

Solar energy can not only be used directly in heating but can also be used to generate cooling power. When compared with heating systems with solar energy, cooling systems require more solar irradiation energy. Solar thermal energy is transferred to cooling power which operates on an adsorption / absorption principle using different absorption / absorption work pairs [1].

Figure 1. Global solar thermal capacity in use and annual energy output from 2000 to 2015. (Source: [2])

Figure 2. Schematic drawing of solar thermal cooling technology. (Source: [1])
2. Materials and Methods
The hybrid ice machine (powered by electricity and solar energy) consists of three circuits, namely: (1) Ice maker, (2) Solar panels and (3) Box contains an inverter. Specification of ice maker machine are as follows: has a capacity of 105 - 120 kg ice / day, produces flake ice with dimensions of 2 x 3 x 3 mm [4].

![Image](image_url)

Figure 3. (a) Ice maker machine (Source : [4]) and (b) Arrangement of two hundred Watt peak solar panels. (Source : [4])

There are nine solar panels with polycrystalline tipe used in this machine with a maximum power of 200 Wp (watt peak) per panel. The three panels are arranged in series, then the three panels in the series are arranged in parallel.

Measurement of sunlight intensity is done with a lux meter. The working principle of lux meter is as follows: the sensor captures light, the light energy that shines on the photo cell is transmitted by the photo cell into electric current energy, the results of the measurements taken will be displayed on the panel screen, the reading of the results displayed by the panel screen is a combination of the wavelength effects that are captured by the light sensor. Inside the light sensor that has been opened, a green color appears which is a transducer sensor. In the transducer sensor there is a photoresistor or LDR (Light Dependent Resistor), which has a function of the luxmeter working principle [5]. LDR or Light Dependent Resistor is a type of resistor that its resistance value is influenced by the light being received. Magnitude resistance value in LDR depends on the amount of light received by the LDR itself [6].

Sunlight is captured by the solar panel, then the solar panel generates a voltage, after that the voltage enters the control, then enters the battery with the load, the heavier the load takes electricity from the battery. The ice maker performance test with solar power sources is carried out by measuring the intensity of sunlight (lux) per unit time, recording power input and voltage from the solar panel, battery voltage and capacity, battery charging current, current discharge current from the battery and the weather conditions at the time of testing.
3. Results and Discussion

In photovoltaic (PV) solar systems, one of the main problems at present is that only 15 - 20% of the solar energy captured in PV panels can be converted into electricity, with the rest converted to heat [2]. The unit used is lumen / m$^2$. Lumen (lm) is the photometric equivalent of the watt, incorporating the "standard observer" eye response. One watt is equivalent to 683 lumens at a wavelength of 555 nm [3]. The solar panel frame assembly is carried out in the southern part of our office (Figure 5).

![Figure 4. Knockdown of the solar panel frame.](image)

![Figure 5. Research’s place.](image)

Source: Anonym, 2021 [7]

3.1. The relationship between the intensity of sunlight and power input from solar panel in a sunny weather

The relationship between the intensity of sunlight and power input from solar panel in a sunny weather is presented in Figure 6. Figure 6 shows that the relationship between sunlight intensity and power input from solar panels is linear with the equation of $y = 0.009x - 26.08$. The higher the intensity of sunlight received by solar panels, the greater the power input obtained from solar panels. The minimum intensity of sunlight is 5,890 lumens / m$^2$, while the maximum sunlight intensity is 102,000 lumens / m$^2$. The
minimum power input from the solar panels is 27 watts, while the maximum power input from the solar panels is 1,026 watts.

The minimum capacity of the battery is 42% (at a voltage of 22.3 volts) while the maximum capacity is 100% (at a voltage of 24.6 - 25.8 volts). The minimum battery voltage is 22.3 volts, while the maximum battery voltage is 25.8 volts. The total ice production for 8 hours was 34.71 kg of ice, or about 4.34 kg of ice / hour.

In clear weather conditions, the earth's surface receives about 1000 watts of solar energy per square meter. Less than 30% of the energy is reflected back into space, 47% is converted into heat, 23% is used for the entire working circulation above the earth's surface, a small part of 0.25% is accommodated by wind and waves and there is still a very small part (0.025%) is stored through the process of photosynthesis in plants [3].

Figure 6 shows the relationship between the intensity of sunlight and the power input from the solar panels in Bantul in a sunny weather condition is linear with the equation $y = 0.009x - 26.08$. Thus it can be concluded as follows:

1. The power input from the solar panel depends on the sunlight intensity,
2. The value of 0.009x is called the slope which determines the direction of the linear regression. The higher the intensity of sunlight, the higher the power input from the solar panels (indicating a positive relationship),
3. This slope also estimates the rate at which the power input from the solar panels increases on a daily basis,
4. The value - 26.08 is referred to as the intercept. The results of this study mean that at the value of X = 0, the value of the power input is - 26.08 watts.

The determination coefficient ($R^2$) is 0.933, so the correlation coefficient (R) is 0.966. This means the correlation between the intensity of sunlight with the power input of solar panel is 0.966. The meaning of the correlation value can be seen in Table 1.

![Figure 6. The relationship between the intensity of sunlight and power input from solar panel in a sunny weather.](image-url)
Table 1. The explanation of correlation coefficient’s value. [8]

| Correlation coefficient’s value | Explanation  |
|---------------------------------|--------------|
| 0 – 0.199                       | Very low     |
| 0.2 – 0.399                     | Low          |
| 0.4 – 0.599                     | Enough       |
| 0.6 – 0.799                     | Strong       |
| 0.8 - 1                         | Very strong  |

From Table 1, it can be concluded that the correlation between the intensity of sunlight with the power input of solar panel is very strong.

3.2. The relationship between the intensity of sunlight and power input from solar panel in a cloudy weather

The relationship between the intensity of sunlight and power input from solar panel in a cloudy weather is presented in Figure 7. Figure 7 shows that the relationship between sunlight intensity and power input from solar panels is linear with the equation of $y = 0.008x - 23.92$, the higher the intensity of sunlight received by the solar panels, the greater the power input obtained from the solar panels. The minimum intensity of sunlight is 6,440 lumens / m$^2$, while the maximum sunlight intensity is 109,500 lumens / m$^2$. The minimum power input from the solar panels is 58 watts, while the maximum power input from the solar panels is 1,038 watts.

![Figure 7](image-url)

**Figure 7.** The relationship between the intensity of sunlight and power input from solar panel in a cloudy weather.

The minimum capacity of the battery is 60% (at 23 volts) while the maximum capacity is 100% (at 24.6 - 26.5 volts). The minimum battery voltage is 23 volts, while the maximum battery voltage is 26.5 volts. The total ice production for 8 hours was 37.03 kg of ice, or about 4.63 kg of ice / hour.

Figure 7 shows the relationship between sunlight intensity and the power input from solar panels in Bantul in cloudy weather conditions is linear with the equation $y = 0.008x - 23.92$. Thus it can be concluded as follows:

1. The input power from the solar panel depends on the intensity of the sunlight,
2. The value $0.008x$ is called the slope which determines the direction of the linear regression. The higher the intensity of sunlight, the higher the power input from the solar panels (indicating a positive relationship).
3. This slope also estimates the rate at which the power input from the solar panels increases on a daily basis.
4. Value -23.92 is referred to as an intercept. The results of this study mean that at the value of $X = 0$, the value of the power input is -23.92 watts.

The determination coefficient ($R^2$) is 0.919, so the correlation coefficient ($R$) is 0.959. This means the correlation between the intensity of sunlight with the power input of solar panel is 0.959 (very strong) [8].

3.3. The relationship between the intensity of sunlight and power input from solar panel in a rainy weather

The relationship between the intensity of sunlight and power input from solar panel in a rainy weather is shown in Figure 8. Figure 8 shows that the relationship between sunlight intensity and power input from solar panels is linear with the equation $y = 0.007x + 69.41$, the higher the intensity of sunlight received by the solar panels, the greater the power input obtained from the solar panels. The minimum intensity of sunlight is 13,200 lumens / m$^2$, while the maximum intensity of sunlight is 84,000 lumens / m$^2$. The minimum power input from the solar panels is 97 watts, while the maximum power input from the solar panels is 739 watts.

The determination coefficient ($R^2$) is 0.90379, so the correlation coefficient ($R$) is 0.959. This means the correlation between the intensity of sunlight with the power input of solar panel is 0.959 (very strong) [8].

Figure 8. The relationship between the intensity of sunlight and power input from solar panel in a rainy weather.

The minimum capacity of the battery is 67% (at 23.3 volts) while the maximum capacity is 100% (at 24.6 - 25.3 volts). The minimum battery voltage is 23.3 volts, while the maximum battery voltage is 25.3 volts. The total ice production for 8 hours was 33.32 kg ice, or about 4.17 kg ice / hour. The initial water discharge is 0.18 liters / second.

Figure 8 shows the relationship between the intensity of sunlight and the power input from the solar panels in Bantul in rainy conditions is linear with the equation $y = 0.008x - 23.92$. Thus it can be concluded as follows:

1. Input power from solar panels depends on the intensity of sunlight,
2. The value 0.008x is called the slope which determines the direction of the linear regression. The higher the intensity of sunlight, the higher the power input from the solar panel (indicating a positive relationship),
3. This slope also estimates the rate at which the power input from the solar panels increases on a daily basis,

The determination coefficient ($R^2$) is 0.904, so the correlation coefficient (R) is 0.951. This means the correlation between the intensity of sunlight with the power input of solar panel is 0.951 (very strong) [8].

4. Conclusions

1. Input power from solar panels depends on the intensity of sunlight.
2. The ice produced by ice makers in cloudy weather conditions is much greater than the ice produced during sunny or rainy weather conditions
3. The higher the intensity of sunlight, the higher the power input from the solar panel (indicating a positive relationship),
4. The correlation between the intensity of sunlight with the power input of solar panel is very strong

5. References

[1] Anonym 2016 Renewables : global status report [http://www.ren21.net/wp-content/uploads/2016/10/REN21_GSR2016_FullReport_en_11.pdf], April 23, 2021
[2] Wang R Z, Xu Z Y, and Ge T S 2016 Introduction to solar heating and cooling systems 1. [https://doi.org/10.1016/B978-0-08-100301-5.00001-1]
[3] Widayana G 2012 Pemanfaatan energi surya. Jurnal pendidikan teknologi dan kejuruan. 9. 10.23887/jptk-undiksha.v9i1.2876.
[4] Wullandari P, Hakim A R and Sarwono W 2019 Mesin pembuat es hibrid untuk mencukupi kebutuhan es di daerah 3T Aplikasi teknologi pengelolaan perikanan tangkap Amafrad Press, p. 59 – 189.
[5] Dewi P S 2011 Luxmeter [https://www.slideshare.net/pramitasylvia/luxmeter-ppt]. 13 Desember 2018
[6] Supatmi S 2021 Pengaruh sensor LDR terhadap pengontrolan lampu Majalah Ilmiah UNIKOM 8 2
[7] Anonym 2021 Loka riset mekanisasi pengolahan hasil perikanan Retrieved from Loka Riset Mekanisasi Perikanan - Bantul - Google Maps
[8] Anggraeni M 2008 Kajian penggunaan poly Aluminium Chloride (PAC) dalam proses pemurnian nira aren dan lama pemurnian terhadap karakteristik nira aren (Arenga pinnata Merr). Skripsi Fakultas Teknologi Industri Pertanian, Universitas Padjadjaran.