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Thermal Energy Harvesting using Photovoltaic System for Small-Scale Seawater Distillation

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ABSTRACT

Photovoltaic systems can be utilized for many purposes. In the present study, the photovoltaic system is used to produce electricity to power the distillator. A distillator is an equipment to convert seawater into freshwater. Distillators are important to be used for fishermen to help them produce fresh water from seawater when fishing at sea. This study aims to develop a prototype of a distillator by utilizing electricity from a photovoltaic system and to test the prototype's performance in producing fresh water. In this study, the solar panels used in the experiment had a power of 80WP and 100WP. The electricity from the panels was used to heat the elements in the distillator prototype to distill seawater, which will later be used to produce the freshwater needed by fishermen at sea, so they no longer need to carry fresh water when fishing. The experiment found that the highest efficiency of 80W solar panels was 12.813 %, while the highest efficiency of 100 W solar panels was 8.610%. The 9-hour experiment could produce approximately 120 ml of distilled water.

1. Introduction

Communities can face various obstacles while trying to obtain fresh water, especially in residential regions with varying environmental circumstances. People who live in areas with lots of clean water sources do not encounter any problems. However, people who live on small islands, near the shore, or in fishing villages usually encounter particular difficulties. In the coastal villages, where the majority of people are fishermen, they struggle to produce clean water when they go out to sea due to limited boat capacity [1].

To address those challenges, it is essential to implement appropriate technology. The present research aims to convert seawater into freshwater by distillation using solar energy that has not yet been used. Using this method, freshwater is produced by turning the liquid phase of seawater into

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vapor steam [2]. The distillation process uses solar panels to capture solar power. The temperature at which seawater will transform into steam is 100 ^{o}c at one atmosphere (1 atm).

Indonesia, an equatorial country, receives strong, direct sunlight. Because of this, it is believed that solar energy can meet the nation's energy needs [3]. Not only is it the most promising renewable energy source, but it also has enormous potential to meet the world's energy needs [4,5]. This energy has become more and more popular in recent years, and it is considered economically feasible [6]. This source can be converted into electricity utilizing available radiation without a chemical reaction [5]. Moreover, the investigation and assessment of photovoltaic energy utilization for energy resources ranging from small–scale designs such as water collector, water cooling and dust removal, and dehydrator, as well as large or industrial scale such rooftop system, until a micro-grid system for an island [7-11].

Generally, the utilization of solar panels as the energy source for the distillation process has also been conducted by several researchers. Hameed *et al.,* [12] designed a distillator unit powered by solar energy that also includes solar tracking to increase the efficiency of the photovoltaic system. A similar solar-powered distillator was also built and tested by Qtaishat and Banat [13] that employed the membrane distillation (MD) method as the main distillation method. Rejab *et al.,* [14] performed research that harvests thermal energy from solar radiation using a thermoelectric generator (TEG). Economic evaluation of a standalone system was performed by Saffarini *et al.,* [15].

The desalination method that will be used in the present study is distillation, where the solar irradiation captured by the solar panels will be used to produce electricity to heat a heating element so that the seawater becomes steamy and then processed again to become fresh water. In the previous research, calculations have been made to design an efficient desalination utilizing the engine heat waste [16]. Based on this calculation, a prototype was built and tested by Nuary [17].

2. Methodology

2.1 Solar Panel Efficiency

Solar cell efficiency (η) is the ratio of the output power to the power of the sun's intensity can be calculated by the following equation [18]:

$$\eta = \frac{Pout}{Pin} x100\% \tag{1}$$

where η is solar panel efficiency (%), *Pin* power intensity of the sun (W), and *Pout* maximum power output (W).

The output power (Pout) of the solar cell, namely the product of the open circuit voltage (Voc) with the short circuit current (Isc) and the filler factor (FF) produced by the solar cell can be calculated by the following equation [19,20]:

$$Pout = Voc\ x\ Isc\ x\ FF \tag{2}$$

where *Voc* is open circuit voltage (Volts), *Isc* short circuit current (Amperes), and *FF* fill factor.

The input power (Pin) is obtained by multiplying the received solar radiation intensity with the solar cell area using the equation [20]:

$$Pin = Ir\ x\ A \tag{3}$$

where *Ir* is the intensity of solar radiation (W/m^2) and *A* surface area of solar panels (m^2).

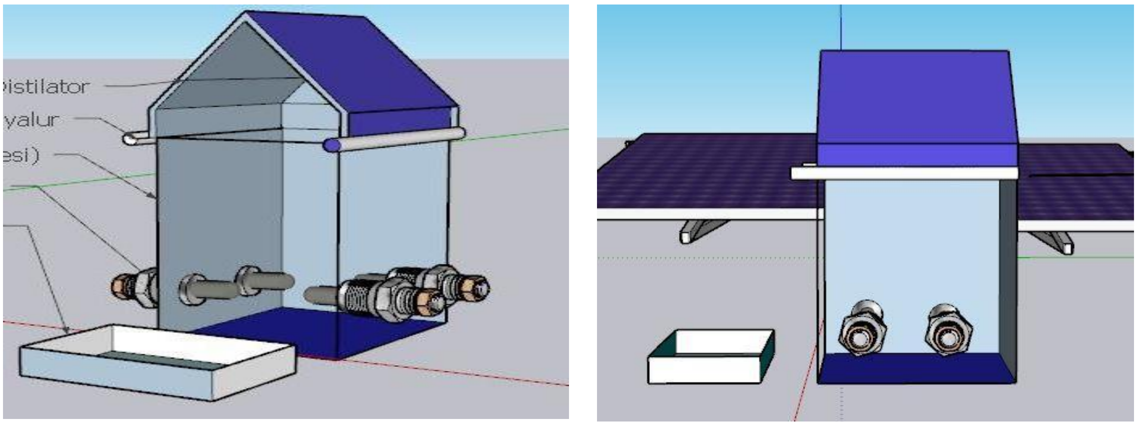
Filler Factor (FF) measures the solar cell quality. The FF is determined by dividing the theoretical maximum power with output power at the open circuit and short circuit [21]. To estimate the *FF* value, the following equation is used [20,22]

$$FF = \frac{Vm\ x\ Im}{Voc\ x\ Isc} \quad (4)$$

where *Vm* is the maximum voltage (Volt), *Im* maximum current (Amperes), *Voc* open circuit voltage (Volts), and *Isc* short circuit current (Amperes).

2.2 Experiment Tools and Design

Figure 1(a) is the front view of the distillator prototype design, which consists of the distillator roof, distribution pipe, container, and glow plug. Figure 1(b) is a side view of the distillator prototype design. The dimensions of the prototype cover are: length 16 cm, width 16 cm, and height 18 cm, with a roof slope of 50^o. Meanwhile, the dimensions of the seawater container are: length 16 cm, width 15 cm, and height 20 cm.



(a) Front view (b) Side view

Fig. 1. Distillator design

In the present study, a prototype distillator was tested, and the solar panel was connected to a power the plug, as shown in Figure 2. The distillator uses a photovoltaic with a power of 80WP (1 pcs) and 100WP (3 pcs) so the total power of the panels was 380WP and the specifications of the solar panel are shown in Table 1.

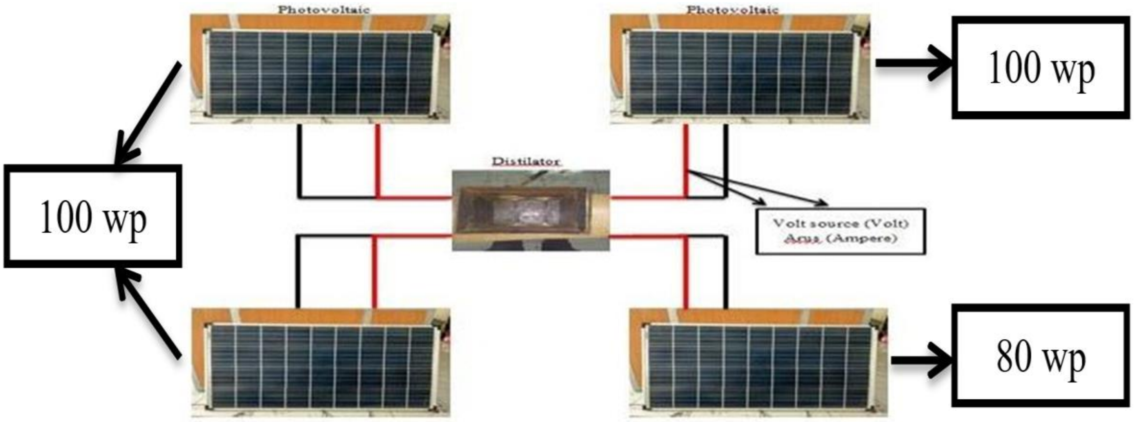


Fig. 2. Tool design and connection

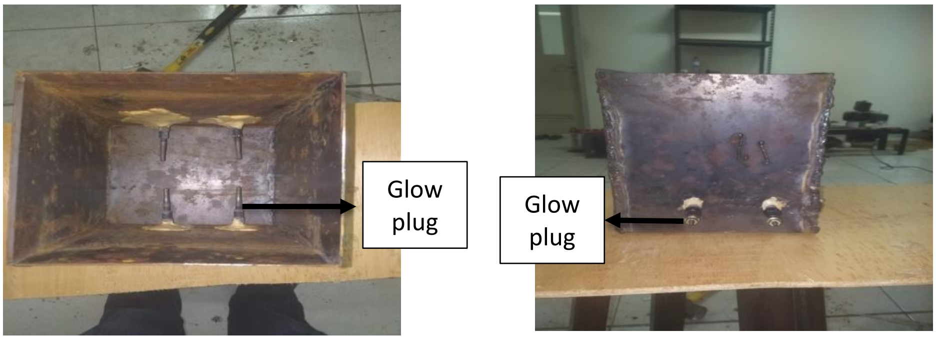
Table 1
Solar panel specification

	80WP	100WP
Model	SP80-12P	PSP-100W
Cell Type	Polycrystalline	Polycrystalline
Pmax	80WP	100WP
Vmp	18V	17.6V
Imp	4.45A	5.70A
Dimension	900x510x30 mm	1020x670x30 mm

2.3 Data Collection Method

Before testing the prototype developed in this research, seawater for the distillation process and a data collection equipment was prepared. The steps of data collection are as follows
- (i) Connect the solar panel glow plug to heat the distillator prototype.
- (ii) Put seawater in a container.
- (iii) Measure the temperature of the water in the container using a water temperature thermometer every 60 minutes for one day of testing.
- (iv) Measuring the volume of fresh water produced by the prototype.

Figure 3 shows the completed distillator prototype, which is (a) the top view of the prototype and (b) the front view of the prototype. Figure 4 shows the entire circuit of the distillator prototype, where the DC electricity produced by the solar cell is then transmitted to the glow plug (Figure 3) to heat the seawater in the distillator prototype. The photo was taken when the experiment was ready to be conducted.



(a) Top view (b) Front view

Fig. 3. Completed distillator prototype

Fig. 4. Overall part of the distillator prototype installation

3. Results and Discussions

3.1 One-Day Distillator Test Results

Using the tools connection shown in Figure 2, the experiment was conducted from 8.00 until 17.00 (9 hours). The received solar radiation during that period is shown in Figure 5.

In Figure 5, we can see that the graph of the intensity of sunlight which was taken at 08.00 has increased and reached its peak at around 13.00, and the intensity of the sun began to decrease from 14.00 to 17.00.

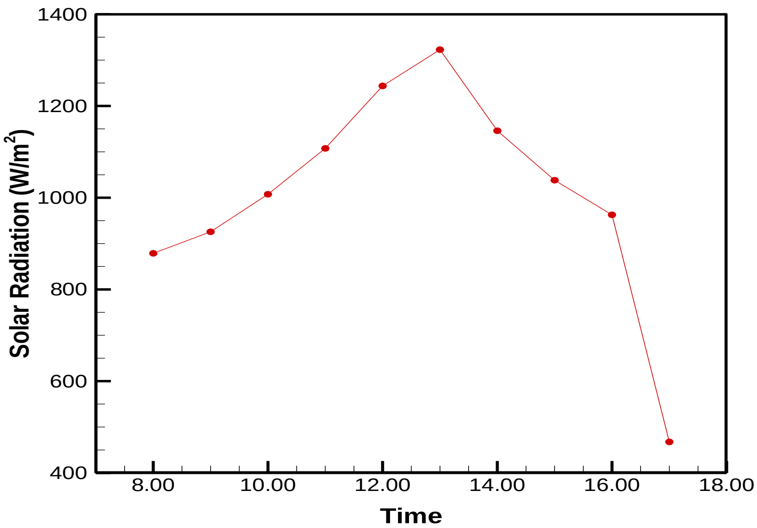


Fig. 5. The relationship between time and the intensity of solar radiation

With the solar radiation shown in Figure 5, the system produced voltage and current as shown in Figure 6. In Figure 6, it can be seen that the volt source generated by the solar panel at 08.00 has increased and reached its peak point at 13.00, and decreased from 14.00 to 17.00, while the current generated by the solar panel at 08.00 has increased and reaches its peak at 13.00, and decreases at 14.00 to 17.00. This is because the greater the intensity of sunlight, the greater the power generated from the solar panel, and when the intensity of sunlight decreases, the power generated from the solar panel also goes down.

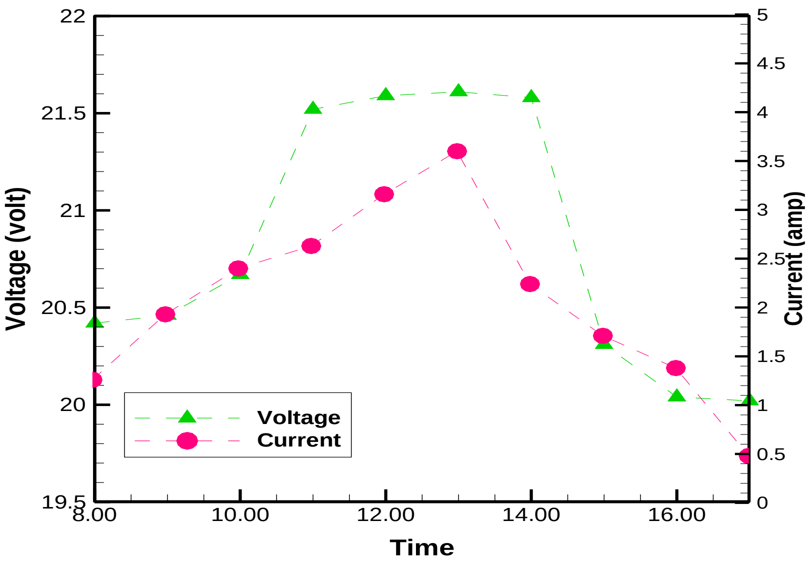


Fig. 6. The relationship between time with voltage and current

In the experiment, the temperature of seawater was also measured. The volume of seawater put in the container was 3.5 liters. The change of the seawater temperature is shown in Figure 7.

In Figure 7, it can be seen that the initial temperature of sea water at 08.00 was 20°C and then increased and reached its peak temperature at 13.00. The temperature dropped again from 14.00 to around 47°C at 17.00. This corresponds to the intensity of sunlight, which began to decrease so that the volts and currents captured by solar panels also decreased.

When the seawater was approximately 60 °C, the seawater started to vapour that produce distilled water. So based on Figure 7, it can be predicted that the distilled water was produced approximately from 10.00 to 15.00. The total produced distilled water was 120 ml, which is shown in Figure 8.

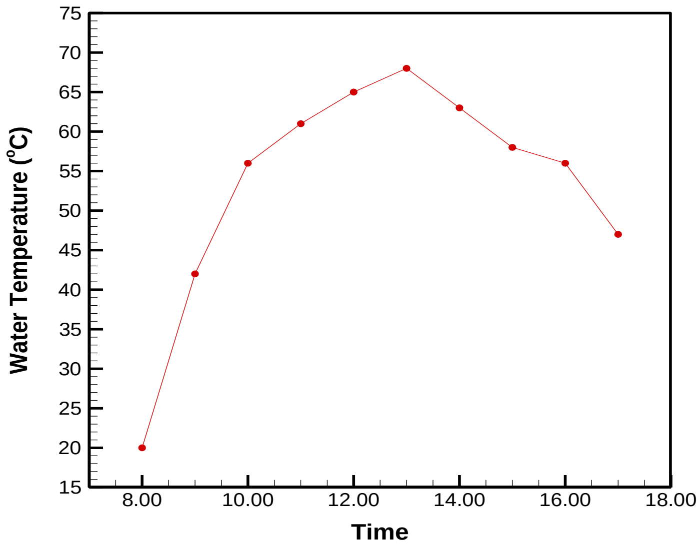


Fig. 7. The relationship between time and seawater temperature in one day

Fig. 8. Produced distilled water volume

3.2 Effectiveness of Distillator Prototype Production

Based on the produced volume of distilled water, the efficiency of distillator (ε) can be determined. To determine the effectiveness of the prototype distillator is as follows

$$\varepsilon = \frac{Distilled\ Water\ Volume}{Total\ Water\ Volume} x100\%$$

$$\varepsilon = \frac{0.12}{3.5} x100\% = 3.428\%$$

So, the efficiency of the distillator prototype in the present study was 3.428%.

3.3 Calculation of Solar Panel Efficiency

Besides the efficiency of the distillator, it is also important to compute solar panel efficiency. Eq. (1) was used to calculate this efficiency. The result of calculation of solar panels (80 WP and 100 WP) is shown in Figure 9.

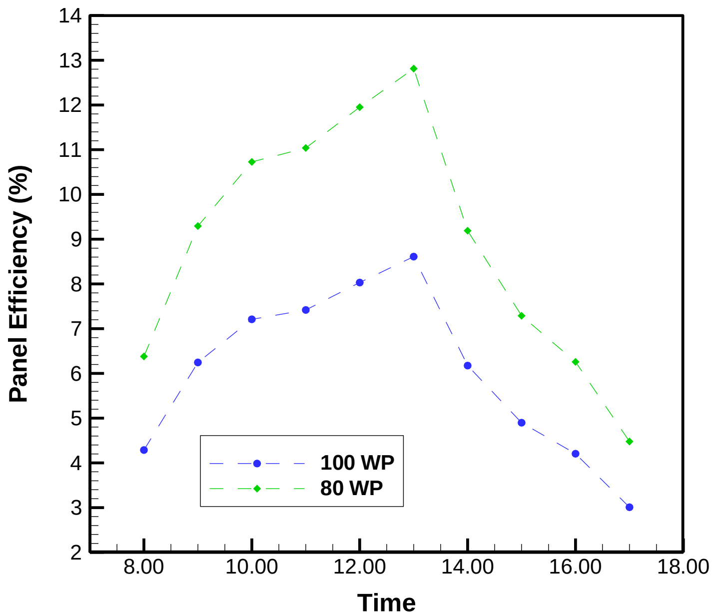


Fig. 9. Comparison of 80WP and 100WP solar panel efficiency

In Figure 9, it can be seen that the efficiency of the solar panel at 08.00 has increased and reached its peak point at 13.00, and decreased at 14.00 to 17.00. It can also be noted that efficiency was also influenced by the intensity of sunlight. It can be observed that at 13.00, the efficiency of the solar panel was at its peak, and also, the efficiency of the 80WP solar panel was higher than the efficiency of the 100WP solar panel. The highest efficiency 80WP solar panel used during the experiment was 12.813 %. The highest efficiency of the 100WP solar panel used during the experiment was 8.610%.

4. Conclusions

Based on the results of the analysis and discussion that have been stated in the previous section, it was found that the distillator concept proposed in the present study can be used to distill seawater into freshwater. It was also found that the highest solar radiation occurred at around 13.00 while the highest voltage and current at that time were found to be 21.6 volt and 3.6 amp, respectively. The highest seawater temperature at that time was found to be the highest one. Moreover, the volume of distilled water produced during the one-day test was 120ml. The highest efficiency of 80 WP solar panels was 12.813%, while the highest efficiency of 100 WP solar panels was 8.61 %.

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References
[1] Zulfa, Nely, Hefni Effendi, and Etty Riani. "Preliminary rapid fishing port water quality assessment with pollution index." *Advances in Environmental Sciences* 8, no. 1 (2016): 96-106.

[2] Widiantoro, Anang, and Dwi Songgo Panggayudi. "Design and Development of Sun Energy with Solar Cell and Distillation Systems to Convert Sea Water to Be Salt and Fresh Water." *JEECS (Journal of Electrical Engineering and Computer Sciences)* 3, no. 2 (2018): 413-420. https://doi.org/10.54732/jeecs.v3i2.128

[3] Silalahi, David Firnando, Andrew Blakers, Matthew Stocks, Bin Lu, Cheng Cheng, and Liam Hayes. "Indonesia's vast solar energy potential." *Energies* 14, no. 17 (2021): 5424. https://doi.org/10.3390/en14175424

[4] Hasan, Muhammad H., T. M. Indra Mahlia, and Hadi Nur. "A review on energy scenario and sustainable energy in

Indonesia." *Renewable and Sustainable Energy Reviews* 16, no. 4 (2012): 2316-2328. https://doi.org/10.1016/j.rser.2011.12.007
[5] Mekhilef, Saidur, Rahman Saidur, and Azadeh Safari. "A review on solar energy use in industries." *Renewable and Sustainable Energy Reviews* 15, no. 4 (2011): 1777-1790. https://doi.org/10.1016/j.rser.2010.12.018
[6] Langer, Jannis, Jaco Quist, and Kornelis Blok. "Review of renewable energy potentials in Indonesia and their contribution to a 100% renewable electricity system." *Energies* 14, no. 21 (2021): 7033. https://doi.org/10.3390/en14217033
[7] Zohri, Muhammad, Prabowo Prabowo, Suwarno Suwarno, Ahmad Fudholi, Sena Abraham Irsyad, Ajeng Tri Rahayu, Yadi Radiansah, Dalmasius Ganjar Subagio, Yusuf Suryo Utomo, and Aep Saepudin. "Simulation Approach of Photovoltaic Thermal Based on Water Collector with Rectangular Model." *CFD Letters* 16, no. 8 (2024): 121-137. https://doi.org/10.37934/cfdl.16.8.121137
[8] Amran, Nik Muhammad Hazwan Nik, Siti Lailatul Mohd Hassan, Ili Shairah Abdul Halim, Nasri Sulaiman, Noor Ezan Abdullah, and A'zraa Afhzan Ab Rahim. "Effect of Water Cooling and Dust Removal on Solar Photovoltaic Module Efficiency." *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences* 105, no. 1 (2023): 184-193. https://doi.org/10.37934/arfmts.105.1.184193
[9] Wagiman, Abdullah, Chan Jun Wei, Ee Min Ci, Martin Ling Teck Seng, Mahmod Abd Hakim Mohamad, and Zamri Noranai. "Design and Performance Evaluation of Hybrid Photovoltaic Thermal Solar Dehydrator." *Journal of Advanced Research in Applied Sciences and Engineering Technology* 28, no. 2 (2022): 181-189. https://doi.org/10.37934/araset.28.2.181189
[10] Kadir, Nurul Atiqah, Ahmad Zaidi Abdullah, Nurhafiza Azizan, and Nurul Nadirah Mohd Hussin. "Investigation of Solar Energy Production by Photovoltaic (PV) System Using Rooftop Coating as Passive Cooling Technique at Bukit Tinggi, Malaysia." *Journal of Advanced Research in Applied Sciences and Engineering Technology* 46, no. 2 (2025): 37-49. https://doi.org/10.37934/araset.46.2.3749
[11] Akter, Farzana, Kazi Ahasan Ekram, Md Araful Hoque, and Mohammad Joynal Abedin. "An Assessment of Solar Micro-Grid System in the Islands of Bangladesh for Sustainable Energy Access." *Malaysian Journal on Composites Science and Manufacturing* 12, no. 1 (2023): 31-42. https://doi.org/10.37934/mjcsm.12.1.3142
[12] Hameed, Kamran, Muhammad Muzammil Khan, Ijlal Shahrukh Ateeq, Syed Muhammad Omair, Muhammad Ahmer, and Abdul Wajid. "Solar power water distillation unit." In *Journal of Physics: Conference Series*, vol. 450, no. 1, p. 012015. IOP Publishing, 2013. https://doi.org/10.1088/1742-6596/450/1/012015
[13] Qtaishat, Mohammed Rasool, and Fawzi Banat. "Desalination by solar powered membrane distillation systems." *Desalination* 308 (2013): 186-197. https://doi.org/10.1016/j.desal.2012.01.021
[14] Rejab, Muhammad Nazri, Omar Mohd Faizan Marwah, Muhammad Akmal Johar, and Mohamed Najib Ribuan. "Real-time Thermal Energy Harvesting from Solar Radiation in Malaysia at Low-Temperature Difference." *Journal of Advanced Research in Fluid Mechanics and Thermal Sciences* 107, no. 2 (2023): 117-132. https://doi.org/10.37934/arfmts.107.2.117132
[15] Saffarini, Rasha B., Edward K. Summers, and Hassan A. Arafat. "Economic evaluation of stand-alone solar powered membrane distillation systems." *Desalination* 299 (2012): 55-62. https://doi.org/10.1016/j.desal.2012.05.017
[16] Asti, A. I. R. "Distillator Design by Utilizing Exhaust Gas Heat of Ship Engine." *Universitas Hasanuddin, Makassar*, 2019.
[17] Nuary, A. "Distillator Prototype by Utilizing Heat Exhaust Gas of Engine Ship Propulsion." *Universitas Hasanuddin, Makassar*, 2019.
[18] Purwoto, Bambang Hari, Jatmiko Jatmiko, Muhamad Alimul Fadilah, and Ilham Fahmi Huda. "Efisiensi penggunaan panel surya sebagai sumber energi alternatif." *Emitor: Jurnal Teknik Elektro* 18, no. 1 (2018): 10-14. https://doi.org/10.23917/emitor.v18i01.6251
[19] Kim, Sangmo, Van Quy Hoang, and Chung Wung Bark. "Silicon-based technologies for flexible photovoltaic (Pv) devices: From basic mechanism to manufacturing technologies." *Nanomaterials* 11, no. 11 (2021): 2944. https://doi.org/10.3390/nano11112944
[20] Pido, Rifaldo, Syukri Himran, and Mahmuddin Mahmuddin. "Analisa Pengaruh Pendinginan Sel Surya Terhadap Daya Keluaran Dan Efisiensi." *Jurnal Teknologi* 19, no. 1 (2018): 31-38.
[21] Jasim, Qusay Kamil, and Najim Abd Jassim. "Experimental and theoretical study to improve the performance of splits in Iraq." *Journal of Engineering Sciences and Information Technology* 6, no. 7 (2022): 35-45. https://doi.org/10.26389/AJSRP.K061122
[22] De Vos, Alexis. "The fill factor of a solar cell from a mathematical point of view." *Solar Cells* 8, no. 3 (1983): 283-296. https://doi.org/10.1016/0379-6787(83)90067-4