Solar Photovoltaic Power Generation for Distillation Process

M I Mowaviq1,*, A Junaidi1, T W O Putri1, and D Rosanda1

1 Department of Electrical Engineering, Institut Teknologi PLN, Jalan Duri Kosambi, Jakarta Barat, Indonesia

* Email: mowaviq@itpln.ac.id

Abstract. Indonesia is an archipelago which is one of the countries with the longest beaches in the world. One of the great potentials of the sea can be used to produce freshwater in coastal areas. One of the processes of converting seawater into freshwater vapor is the distillation process. The freshwater vapor condenses and turns into water. Distillation is carried out by evaporating seawater so that the freshwater is separated from the salt. In this research, the distillation process is assisted by a solar power plant with photovoltaic panels. The hardware design consists of a solar panel, solar charge controller, battery, inverter, pump, electric heater, temperature sensor, and level sensor. The solar panel uses a total of 1200Wp with a voltage of 12V. The battery uses a 12V 100Ah battery and a 1000W electric heater. Meanwhile, the pump power is 48W. From the test results, it was found that in one hour, 1.3 liters of freshwater were obtained with a total capacity of 10 liters of water. The use of solar photovoltaic in a distillation system would be better if combined with direct solar energy heating methods.

Keywords: Distillation system, solar photovoltaic, electric heater, seawater

1. Introduction

The need for clean water is a very basic need in human life. The use of clean water is very important for household, public and industrial consumption. Fresh water needs can be met in several ways. In urban areas, the provision of clean water is managed by the Drinking Water Company or carried out independently by the community by taking groundwater. However, in coastal areas that are far from springs, there are still many people who do not get clean water facilities. Meanwhile, in coastal communities, sea water is so abundant.

Coastal areas have abundant water potential, it is seawater that cannot be consumed directly. So, there needs to be another solution for provision clean water that can be consumed. Indonesia as an archipelago has a sea area of 5.8 million km2 or 70.8% of the total area of Indonesia. Besides having the potential for abundant sea water, it also has the potential for high sunlight intensity. These two potentials can be utilized to produce clean and consumable fresh water.

The method that can be used to get fresh water from seawater is the distillation method. The water distillation is one of the feasible solutions to overcome the freshwater crisis[1]. Distillation is the settling of sea water by evaporating the water and condensing the vapor so that it separates between salt minerals and produces fresh water. In Indonesia, with an average of 12 hours of sunlight a day, it can be used as an energy source for distillation of sea water. In general, the use of solar energy is done conventionally...
to evaporate sea water. The distillation process using solar still work in six hours[2] or during the peak solar hours[3]. Meanwhile, the need for fresh water continues for a full day.

This study aims to answer the problem of the need for fresh water in coastal areas by utilizing solar energy to carry out the seawater distillation process. As well as the use of solar power plants to increase the yield and efficiency of the distillation process. Desalination plants powered by renewables can in principle be used to address some of the challenges arising from depleting water reserves around the world [4]. Solar energy is a relatively free renewable, clean, green, and environmentally friendly energy resource produced from the sun, using different technologies like solar thermal and photovoltaic (PV) modules to generate heat and electricity, respectively[5]–[8]. Solar energy refers to the radiant energy emitted, transmitted or received by the sun in the form of electromagnetic energy [9]. This research focus on solar power generation using photovoltaic for distillation system.

2. Design and Method

2.1. Distillation Systems

Distillation is one of the oldest and most common methods for the purification of liquid. Distillation columns are made up of several components, each of which is used either to transfer heat energy or enhance material transfer. A typical distillation unit contains several major components:
a) A vertical shell where the separation of liquid components is carried out.
b) Column internals such as trays/plates and/or pickings, which are used to enhance component separations.
c) A reboiler to provide the necessary vaporization for the distillation process.
d) A condenser to cool and condense the vapour leaving the top of the column.
e) A reflux drum to hold the condensed vapour from the top of the column, so that liquid (reflux) can be recycled back to the column [10].

In this research, sea water distillation design can be shown in Fig.1.

Figure 1. Front View of Distillation System Design
The process of distillation process of sea water in this research is below:
1) Water pump suck up sea water of the reservoir to heating chamber until full.
2) After heating chamber is full, the pump stop, the heater is on, and the valve is closed.
3) The electric heater work until 90°C and the condensation pump is on.
4) The water vapor enter the condenser and change to water dew.
5) The water dew flow to collection drum.

To find out how much energy is needed can be calculated by the formula:

$$Q = m \cdot c \cdot \Delta T + m \cdot U \quad (1)$$

$$Q = W \quad (2)$$

$$W = P \cdot t \quad (3)$$

From those formulas, we can calculate amount of energy, how long the system work, and how the design of photovoltaic solar generation. The calculation can be shown in Table 1.

| Symbol | Quantity                        | Value      | Unit          |
|--------|---------------------------------|------------|---------------|
| $c$    | heat capacity of water          | 3.850 J/kg°C |               |
| $T_1$  | First temperature               | 25 °C      |               |
| $T_2$  | Last Temperature                | 120 °C     |               |
| $U$    | Laten heat of vaporization      | 2,260,000 J/kg |         |
| $P_h$  | Power of heater                 | 1,000 W    |               |
| $P_p$  | Power of pump                   | 48 W       |               |
| $t$    | Time                            | 0.83 h     |               |
| $W_h$  | Work of heater                  | 0.83 kWh   |               |
| $W_{pc}$ | Work of condenser pump         | 0.028 kWh  |               |
2.2. Solar Power Generation
Solar Power Generation based on working principle of photoelectric. When the sun shines on the semiconductor p-n junction, a new hole-electron pair is formed. Under the action of the p-n junction electric field, electrons flow from the p region to the n region, and the holes flow from the n region to the p region[8]. A conducting wire connects the cathode, the load, and the anode in series to form a circuit. Hence, an electric current is generated to supply the external load. Solar panel or solar module is the combination of multiple solar cells connected together and a solar array is the combination of multiple solar panels or solar modules in concert [5]. The diagram of solar power generation can be shown in Figure 3.

![Diagram of Solar Power Generation](image)

Figure 3. Diagram of Solar Power Generation

3. Result and Discussion
The main function of inverter is to change the variable dc voltage input of the transformed power supply into non-interference ac sine wave output, which can be supplied to the corresponding equipment or fed back to the power grid. Inverter in addition to the conversion of ac and dc voltage, but also can perform such as: disconnect the circuit, to avoid the current surge damage to the circuit. In addition, functions such as tracking the maximum power point (MPPT) and storing data and controlling the charge and discharge of batteries can help improve the efficiency of power generation [9].

![Graphic of Light Intensity Measurement](image)

Figure 4. Graphic of Light Intensity Measurement
Solar panel testing is done by measuring the light intensity and power produced. The test was carried out for 7 days. The solar panels used are 300Wp solar panels. From the results of the tests carried out, it can be obtained a suitable solar power plant design. The results of the sunlight intensity test can be seen in Figure 4. Meanwhile, the resulting output power can be seen in Figure 5. From the data obtained, the average sunlight intensity is 69141 lumens. Meanwhile, the average energy produced by solar panels 300Wp for a day is 280 Wh. So, to meet the needs of the distillation system there are at least 4 of 300Wp solar panels. Meanwhile, in the distillation test, in one hour, 1.3 liters of fresh water can be obtained.

4. Conclusion
The energy required for the distillation process is quite large, so that if only photovoltaic solar panels are used, it will absorb a lot of costs. Therefore, the use of photovoltaic solar panels would be better if combined with direct solar heating. In addition, there is not too much fresh water obtained from the distillation process. So, it is advisable to use a heater with a larger capacity to speed up the evaporation.

References
[1] M. F. Remeli, B. Singh, N. Amirah, M. S. Meon, and W. N. Fadilla, “Solar Distillation Thermoelectric Power Generation,” IOP Conf. Ser. Earth Environ. Sci., vol. 268, no. 1, 2019.
[2] P. A. Mehta, A. Vyas, N. Bodar, and D. Lathiya, “Design of Solar Distillation System,” Int. J. Adv. Sci. Technol., vol. 29, pp. 67–74, 2017.
[3] S. Abhishek, A. S. Kumar, E. Anjana, M. Rahul, and S. Jisma, “Water purification using solar thermal and solar PV,” in 2018 International Conference on Emerging Trends and Innovations In Engineering And Technological Research, ICETIETR 2018, 2018, pp. 1–4.
[4] V. Rallabandi, N. Alawhali, O. Akeyo, and D. M. Ionel, “Simulation Studies for a Multi-MW Hybrid Wind-Solar PV System for Desalination Plants,” 7th Int. IEEE Conf. Renew. Energy Res. Appl. ICRERA 2018, vol. 5, pp. 1413–1416, 2018.
[5] R. Liu, S. Bimenyimana, G. N. Osarumwense Asemota, M. Xu, J. De Dieu Niyonteze, and L. Li, “Assessment of power generation performance characteristics using different solar photovoltaic technologies,” J. Phys. Conf. Ser., vol. 1311, no. 1, 2019.
[6] Z. Ma, Y. Zhang, and H. Li, “Energy efficiency analysis of inland ship photovoltaic system based on PVsyst,” IOP Conf. Ser. Earth Environ. Sci., vol. 242, no. 2, pp. 6–11, 2019.
[7] D. Van Tai, “Solar photovoltaic power output forecasting using machine learning technique,” J. Phys. Conf. Ser., vol. 1327, no. 1, 2019.
[8] R. Li, “China’s photovoltaic power generation technology and application,” IOP Conf. Ser. Earth Environ. Sci., vol. 300, no. 4, 2019.
[9] Y. Wang, “Solar Photovoltaic Power Generation Technology Research,” *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 677, no. 3, 2019.

[10] K. Patil, P. Choudhary, and T. Bhatia, “Distillation Operations: Methods, Operational and Design Issues,” *Natl. Conf. Adv. Heat Mass Transf. FAMT*, no. June 2014, p. 10, 2009.