Design and implementation of seawater eco distillatory using parabolic solar concentrator and photovoltaic pump for isolated island

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Abstract. Water is a primary human need. Of the total fresh water in the world, less than 1% are ready to drink and 11% of the total human population cannot achieve it. WHO/UNICEF by 2015 reports there are nearly 750 million people in the world who still have inadequate drinking water. The current condition is also occurs in the Ay Island which located in Banda Naira Islands, Central Maluku, Indonesia. Ay Island residents have to travel for 4 hours to the main island of Banda Naira to buy clean water. To overcome the current situation, the government have tried to provide clean water by building a $4 billion dam project in 2016. However, the dam project is not able to meet the needs of the resident because of the polluted water. In this research is proposed an Eco Water Treatment by using Parabolic Solar Concentrator and Photovoltaic Pump. This method consists of two main parts, PV Sea Water Pump and Solar PV-Distillator. The PV Pump is used to deliver water from the sea to the boiler, while the solar-powered distillator converts sea water into fresh water. Fresh water generated from the distillator have the same content as the Indonesian Minister of Health's standard. The system can provide clean water for 50 liter continuously based on capacity of the boiler each day depend on the weather and the temperature. From the experiment, proven that solar concentrator could increase the boiler temperature up to 300°C to boil the seawater and produce clean water.

1. Introduction
Water is the primary needs of living beings. In [1] said that 97.5 % of all water on earth is salt water, leaving only 2.5% as freshwater. As the result, less than 1% of the water on earth is available for consumption. However, [2] shared a fact that only 89% of the global population (6.5 billion people) used at least a basic drinking-water service, which is an improved drinking water source within a round trip of 30 minutes to get the water.

Indonesia is an archipelagic country that has an area of 1,910,931 km² [3], two-thirds of its area is the ocean. It is ironic because, with the affluence of the seawater, there are still millions of Indonesian inhabitants that having lack of clean water. For example, a case that occurred in Banda Naira islands, Maluku Tengah. To buy clean water, Ay Island residents have to cross the sea that takes approximately 4 hours to reach the Banda Island. In order to overcome the condition of lack clean
water, one of the sources that could potentially be used as clean water is the seawater which can be transformed to clean water by desalination process.

The process of desalination can be made with different techniques such as vapour pressure, chemical processes, membranes processes (reverse osmosis and electrodialysis), solvents extraction, and evaporation [4]. The desalination process could be generated by many kind of methods, one of the method is solar thermal energy or solar desalination. Considering the condition of Indonesia that crossed by the equator line made Indonesia has superfluous solar energy potential, so desalination using solar thermal is the right method to be applied in Banda Naira Island. Based on the report of Indonesian ministry of energy and mineral resources, Indonesia has solar energy potential of 112 GW. There are two modes of conversion in solar desalination: flat plate and solar concentrator. In this paper, the PV panel is using solar concentrator to multiply the reflected sunlight into one focus point better than flat plate.

2. Literature Review

The global community has begin to replace fossil fuel source into solar energy through photovoltaic (PV) system. As in this paper, the solar energy is used to generate electricity to pump clear water in some remote areas. The system planning for water pumping system depends on the estimation of solar irradiation and the water requirements as shown in [5], while in literature [6] provides the calculation of inverter to obtain high-efficiency, high-lifetime, and low-cost converter for an autonomous photovoltaic water pumping system.

The seawater desalination is an alternative way to provide clean water in the coastal area [7]. Seawater intakes can be obtained in two ways, by directly channel the seawater from the sea and the other method is indirectly from the sea through subsurface systems. In this paper, the water will be obtained directly from the sea to the boiler using PV pump. Based on the literature [8], the concentrator shown in figure 1, the system can be modeled into simple mathematical modeling and set up to get the stable point and efficient parabolic dish. The boiler material has been discussed in [9] with parabolic geometry shown in figure 1.

![Figure 1. Parabolic Geometry.](image)

This proposed system uses aluminium as a boiler material due to its excellent corrosion protection and good heat conductivity that suits the coastlines environmental conditions. This aims to accelerate the heat-conduction process of the boiler that heated using reflected solar radiation through the solar concentrator.

3. Research Method

The data of current water condition in Banda Island obtained by interviewing local coastal communities. The methodology of this research is presented in figure 2.
The literature review used for reinforcing the compiled hypothesis [10], [11]. It is related to the water problem condition in Banda Island. Devices were implemented by references retrieved from the literature review and study field. Basically, the system consists of three main components that illustrated in figure 3; which are photovoltaic, concentrator, and the desalinator. Photovoltaic is used to convert photon radiation, concentrator to convert thermal radiation, and desalinator to remove salt ion and other wasteful materials.

The energy converted by photovoltaic will be stored in a battery with a charge controller and an inverter. Then followed by concentrator suspension construction. The suspension is placed above the parabolic solar concentrator coated with chrome. The boiler is installed on the focal point of the solar concentrator. The process continued with the creation of desalination component consisting of a heater tank, hose pipe and condenser tank (for the cooling process). After all of the component is finished, it is coupled into single entity directly in the field.

In the laboratory scale trials, the electric components of photovoltaic, the parabolic solar desalination process and concentrator were done in the open area of ITS. The result of the desalination process will be tested again in ITS Environmental Engineering Laboratory to check the content of water desalination. The next trials are on university level through the exchange funding scheme from the Ministry of Research and Technology of higher education.

Evaluation and analysis of the test results are used to improve the performance of the equipment. During the final stage of research method, the conclusion is carried out after the research is finished. The withdrawal of the conclusion is including the work performance of the photovoltaic, parabolic solar concentrator and the condenser.
4. Analysis & Results

4.1. Photovoltaic and Pump Performance

In this experiment, we test the characteristic of solar cell installed on Power System Simulation Laboratory and the performance of the seawater pump. The inverter is controlled by DVC method with 50 Hz frequency and close loop MPPT model. In this experiment, the results of the experiment obtained in no load condition.

The current input of the inverter is 62.33 A, while the batteries capacity is 400Ah. Therefore, the needed current is 60A (by the assumption of maximum charging time) and the solar cell needed is 8 PV 100 WP.

To protect system electricity, the emergency switch is designed by taking data from measured voltage and current. Table 1 explains the amount of DC voltage from solar cell output.

Table 1. Solar cell voltage and current data experiment.

| Time   | Charge Controller 12V PV to Battery | Power (W) |
|--------|------------------------------------|-----------|
| Input (V) | Input (A) | Output (V) | Output (A) |          |
| 08:00  | 20.9   | 14.03 | 13.58 | 43.18 | 293.22 |
| 09:00  | 20.9   | 17.50 | 13.58 | 53.86 | 365.75 |
| 10:00  | 20.9   | 20.12 | 13.58 | 61.92 | 420.50 |
| 11:00  | 20.9   | 20.15 | 13.58 | 62.02 | 421.13 |
| 12:00  | 20.9   | 19.15 | 13.58 | 58.62 | 398.14 |
| 13:00  | 20.9   | 16.69 | 13.58 | 51.36 | 348.82 |
| 14:00  | 20.9   | 13.12 | 13.58 | 40.38 | 274.20 |
| 15:00  | 20.9   | 9.9   | 13.58 | 30.46 | 206.91 |
| 16:00  | 20.9   | 6.1   | 13.58 | 18.72 | 127.49 |
| 17:00  | 20.9   | 5.8   | 13.58 | 17.84 | 121.22 |
| Total  | 209   | 142.56 | 135.80 | 440 | 2977.41 |

Based on data experiment of 4 PV 100 WP, the system could produce 2,977.41 Wh/day. Meanwhile, based on our system we use 8 PV 100WP so it can produce 5,954.82 Wh/day.

4.2. Parabolic Solar Concentrator

The Parabolic solar concentrator is used to focusing the solar thermal radiation to one-point focus as shown in figure 4. The solar thermal energy is used to heat the boiler. So we need to determine the focal point of the solar concentrator in order to get the maximum temperature.

Figure 4. Parabolic Solar Concentrator Experiments.

By using the mathematical formula, the calculated focal point of the parabolic solar concentrator is 67.5 cm by assuming the reflectivity of material and copper conductivity is 90%. So, the surface area of the concentrator is 1.788 m². Therefore, the q reflected is 810W/m² with the power input is 1528.74W.
4.3. Distillator
The specification of the distillatory consists of Stainless SS401 material and 40 cm of boiler surface diameter. By using a mathematical formula, the surface of the boiler is 0.125m² and 57.216 of concentration ratio. Thus, the total energy produced is 1528.74 W. The boiling temperature of seawater is 110 while its rated temperature is 32°C, therefore, 78°C more is needed to boil the seawater. The volume of the seawater is produced by calculating the seawater mass and the volume, it is 51.3 kg. While the Q needed is 15.605.460 Joule. In this experiment, the water needs 45 minutes and 20 seconds to be boiled.

4.4. The Power Efficiency and Result
The power efficiency to boil the water is the ratio between the output power and input power, the output power is 5,737.3 watts by dividing the energy and time. So, the efficiency is 93.86% as the result of dividing the output power and input power times the parabolic components.

The chemical reaction process is separated material of the seawater by boiling the seawater until meeting its’ boiling point. Seawater boiling point is 110°C or 379°K. The Result will be steam and the salt material. The salt material will dispose of through the disposal valve.

| Table 2. Composition of Distilled Water. |
|------------------------------------------|
| pH | Conductivity |
|----|--------------|
| Before | After | Before | After |
| 8.01 | 6.015 | 36.006 | 441.9 |

Based on the experiment, the average pH of seawater is 8.01 while the average PH of seawater after distilled is 6.015. From the table 2 is known that the composition of salt is decreasing. The electrical conductivity test is to see how much the level of seawater salinity, if the conductivity is low, so the salinity is decreasing. And the salinity composition average before distillation is 36,006 ms and after distillation process is 441.9 ms. In this research, the pH level of water after distillation process is decreasing by 25%, while the conductivity of water is decreasing to 81.46%.

5. Conclusion
This paper shows application of PV pump and solar concentrator combination to provide clean water in a coastal area with water crisis by taking advantages from solar energy and seawater in Indonesia as the largest archipelagic country in the world. Within the experimental data with power efficiency greater than 80%, can be concluded that this system is decent to be applied. The system can provide clean water for 50 liter continuously based on capacity of the boiler each day depend on the weather and the temperature. The solar concentrator increases the boiler concentrator up to 300°C which enough to boil the seawater and produce clean water.

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