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Solar Energy Hybrid System for Seawater Distillation in the Coastal Regions

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Abstract

Coastal regions and small islands in the open sea areas are commonly poor in fresh-water resource availability. Because of its high-level of hardness, the seawater is in general not much used for everyday life. In tropical countries like Indonesia, the daily duration of solar irradiation throughout the year does not vary much, with an average of about 12 hours a day. The solar energy can be used to evaporate seawater and to produce fresh-water coming from the steam condensation through a distillation process. It is shown in this research that using a hybrid system the fresh-water production can be extended to the period when the solar radiation is insufficient, so that the solar energy usage can be maximized. It can be used for heating the seawater directly in an evaporating house while being used at the same time to produce electricity using solar cells. As the voltage generated by the solar cells was not of constant value depending on the incident irradiation, a cuk converter being operated based on the Pulse-Width Modulation (PWM) principle has been used to stabilize the voltage fed into a battery at 15V-level. It was furthermore used to supply the heating system after being inverted into an AC voltage waveform. It would be functioning when the solar irradiation was not sufficient to evaporate the seawater directly. The internal temperature of the evaporating room was known using a sensor PT100. The sensor data needed to be conditioned before being processed furthermore in a microcontroller Arduino Uno. After reaching the desired temperature setting point, a relay circuit module would operate to cut off the current and to turn on/off the heating system. The generated steam has been passed through a condenser to produce the fresh-water. The results of the study showed that an amount of 3.5 litres of seawater being evaporated during 10 hours would produce 1.076 litres of fresh-water using a total power of 184.06W.

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Keywords: distillation; hybrid system; seawater; solar energy

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1. Introduction

Water is an absolute necessity for humankind in undergoing all the daily life activities. The water commonly comes from the sources like rain water, ground water and river water. For example in Indonesia, the percentage of water-users of the water-supply authorities is around 16.08%, that of the ground-water utilizing pumps 11.61%, that of water-wells 49.92% , springs 13.92%, river water 4.91%, rain water 2.62%, and others 0.08%, as [1]. The data shows that the majority of Indonesian people utilize the well's water to meet their water needs in their households. Coastal areas and small islands in the high seas are commonly in a great need of fresh-water availability. Water resources in such regions are generally of poor quality, as they produce brackish or even salty water. Due to its location along the equator, the availability of daily sun radiation in Indonesia along the year is relatively similar, around 12 hours a day. Energy from the sun may be used to evaporate seawater in a distillation process, resulting in fresh-water from the condensing vapor [2-4].

This research paper proposes to maximize the utilization of solar energy in the distillation process. The solar energy can be used not only to heat the seawater in a container being called as the evaporator house, but also to power solar cells to generate electricity which can be used to charge a battery/accumulator. The battery can be used to run a seawater distillation process whenever the direct use of solar energy is not possible, resulting in a so-called hybrid system combining two sources of power to produce heat for the distillation system, as shown in Fig. 1. A typical datasheet specification of the solar cells is indicated in Table 1.

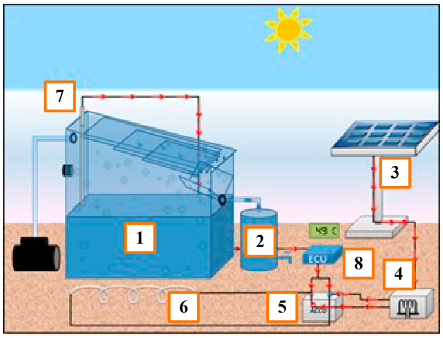

Fig. 1. The working principle of the solar-energy hybrid-system for seawater distillation.

Table 1. Specification of the solar cells considered in this paper.

Parameters	Value
Maximum Power (P_{max})	50 Wp
Short Circuit Current (I_{SC})	3.12A
Maximum Power Current (I_{mpp})	2.92A
Open Circuit Voltage (V_{OC})	21.63V
Nominal Voltage (V_{mpp})	17.13V

2. Materials and Method

As seen in Fig. 1, the sun radiation heats directly the evaporator house (1) to result in fresh-water in the condenser (2), besides also being captured by the solar photovoltaic system (3) to produce electrical energy. The Cuk converter (4) is used to stabilize the solar-cell output voltage at 15 volts, before being used to charge a battery (5). The battery is used as the power-supply for the heating elements (6) after inversion into AC voltage.

The battery is used whenever the direct heating using solar energy is not sufficient for the evaporation process, or whenever the temperature sensed by the sensor PT100 (7) in the evaporator house does not reach a predetermined set point, for example during the cloudy day or the night. The temperature data are processed using a microcontroller Arduino Uno in the electronic control unit (ECU) (8).

The battery capacity should be adapted to the load need as well as to the required usage period. The use of battery enables flexibility in maintenance as well as in providing larger capacity of current. The heating elements are equipped with a relay module to cut off the current whenever the required temperature is achieved.

The Arduino Uno is an ATmega 328-based microcontroller board, which has a 6-pin analog input and 14 digital I/O pins (6 of which can provide the PWM output), 16 MHz clock speed, a USB connection, jack power, ICSP header, and a reset button. In application, the board can be connected to a computer just by using a USB cable.