Evaluation of Solar Ponds and Aplication Area

Haci Sogukpinar[1] , *Ismail* Bozkurt[2], and *Serkan* Cag[3]

[1]Department of Electric and Energy, Vocational School, University of Adiyaman, Adiyaman 02040, Turkey
[2]Department of Mechanical Engineering, Faculty of Engineering, University of Adiyaman Adiyaman 02040, Turkey
[3]Department of Machinery and Metal Technology, Vocational School, University of Adiyaman, Adiyaman 02040, Turkey

Abstract. Solar ponds are heat storage systems where solar energy is collected and stored thermally. Solar ponds were discovered during the temperature variations in the lower regions of existing saltwater pond in the area is found to be higher than their surface. Later, it was constructed artificially and started to be used. These systems have heat storage capacity at moderate temperatures. Solar pons are used in many areas such as electricity generation, heating the environment, meeting the need of hot water, drying food and obtaining fresh water from salty water. In this study, the studies about solar ponds were summarized, the construction of solar pond was explained, and the application areas were examined.

1 Introduction

The ever-increasing energy demand open up the importance of the use of renewable energy resources. One of the most important renewable energy sources is the sun, although it varies according to the climatic conditions. There are many technologies that generate energy by using solar system. Solar ponds are one of the systems that convert solar energy into useable energy. Solar ponds can also be constructed artificially, like the ones in the nature. Heat energy collected and stored by solar ponds can be used for various purposes. There have been many studies on solar ponds. Bozkurt et al. [1-6] investigated the performance of the pond according to the cases of closed and open top surface with a transparent glass lid in order to reduce the heat losses from the surface of the solar ponds. In addition to this, the performance of the integrated system consisting of solar pond and flat plate solar collectors has been studied. The effect of solar collectors on the performance of the solar pond was determined. A numerical study was carried out on the effect of side wall shading on the performance of the solar pond. In the mentioned study, modeling was carried out for eight different situations, sunshine rates and solar pond performance values were calculated. The temperature distribution of the pond was determined according to the different insulation materials of the solar ponds.

Khodabandeh et al. [7] investigated the hydrothermal attributes and energy efficacy of the watere graphene nanoplatelet/platinum hybrid nanofluid flow in a horizontal spiral tube with four cross-sections used in bottom of solar ponds to determine the effect of geometry, Reynolds number and nanoparticles concentration on solar ponds. Alcaraz et al. [8] studied the design, construction, and operation of a 500 m^2 industrial solar pond in Granada (Spain). The system was used to deliver a heat stream of up to 60 °C to minimize the fuel oil consumption at the mineral processing facility. Also, the efficiency and economic analysis of the solar pond was determined during two years. Sayer et al. [9] determined to the influence of the thickness variation of all three zones on the performance of the solar pond. Furthermore, the impact of heat extraction from the heat storage zone on its temperature was investigated to examine the suitability of the deep of the solar pond for continuous power supply. Amigo et al. [10], studied the heat storage capacity of the ground beneath a salt gradient solar pond to demand a constant heat. For this purpose, a one-dimensional transient model was recommended to calculate the thermal behavior of the solar pond. Furthermore, as a case study, the solar pond located in Copiapo, Chile was modeled to evaluate the influence of the soil type and the depth to ground water the on the thermal performance of the heat storage zone temperatures. Assari et al. [11] investigated the temperature gradient, temperature behavior, and performance of two salt gradient solar ponds with thin plastic with mixed medium and conventional in the heat storage zone to determine the effect of porous medium on the efficiency of solar pond. Monjezi et al. [12] presented the mathematical model which is used to determine the temperature profile of a solar pond for the heat extraction in batch or continuous, modes for salinity gradient solar ponds. Furthermore, the performance of a solar pond in Middle Eastern and Mediterranean weather conditions was compared. Erden et al. [13] investigated to point out the performance of hydrogen production of the flat-plate collectors assisted by a solar pond system. The system was design to produce electric and hydrogen from the electrolysis and ORC to obtain the performance increase of the components. Assari et al. [14] studied phase change material (PCM) in solar ponds in order to control the stability of solar ponds during the heat extraction and improving thermal energy storage or total performance of the solar ponds. An internal heat exchanger was used in the heat storage zone. The temperature change of the system was measured and analyzed. It was shown the assisted phase change material pond decreases the temperature difference between night and day.

In this study, the recent studies on solar ponds were summarized, the structure and construction of solar ponds was discussed and the usage areas were investigated.

2 Solar pond

Solar ponds are also artificially constructed considering similarities in the nature. As seen in Figure 1, the solar pond consists of three zones. The area located on the upper surface of the pond which contains tap water is called the Upper Convective Zone (UCZ). Below UCZ there is Non- Convective Zone (NCZ). NCZ is made up of layers of increasing density. This density difference prevents heat transfer between the heat storage zone and the surface of the pond, only heat transfer occurs by conduction. Thus, the NCZ acts as a transparent insulating material. Finally, under the NCZ, there is the Heat Storage Zone (HSZ). HSZ is made up of very dense brine and is the place where solar energy is stored as heat energy. At the same time, the heat exchanger is installed in this region for heat extraction from the system. When solar pools are first built, a very intensive salt water solution is prepared and filled up to a certain height from the bottom of the pond and the HSZ is created. Then, for each layer forming the NCZ, saline solutions are prepared separately at different densities. Layers are formed at certain thicknesses to reduce the density toward the surface of the pond. During this process a plate is used which floats on salt water so that the layers do not mix.

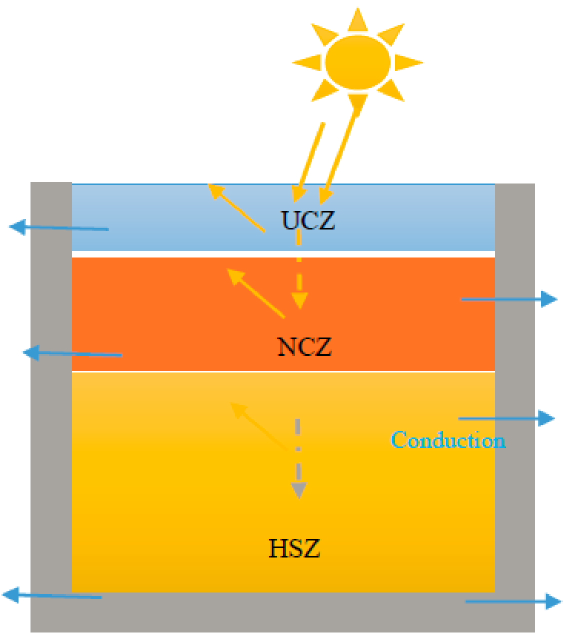

Fig. 1. The zones of solar pond

Thus, the desired salinity gradient is obtained. The prepared solutions are slowly poured onto the plate to form salt water layers at desired thicknesses. Finally, the UCZ is created using tap water and the solar pond becomes ready to store heat. Temperature sensors are placed at certain intervals within the pool to monitor the temperature changes of the solar pond. At the same time, the density of the saline solutions drawn through the thin hoses placed at regular intervals is measured by hydrometers, ensuring density.

3 Aplication area

Solar ponds are low temperature solar energy applications that can achieve temperatures between 70-100 ^{o}C. The stored heat is used in many areas such as electric generation, drying of food, heating, domestic hot water, desalination etc.

Ding et al. [15] used a small scale passive electric power generation unit to generate electricity from the heat available in the solar pond. The power generation system which consists of 120 commercially available thermoelectric cells was fabricated and tested experimentally. The system produced the maximum electric power of 40.8 W under the condition of 99 ^{o}C.

Ding et al. [16], investigated the capability of solar pond in generating electricity experimentally using a plate type power generation unit. The heat stored energy in the heat storage zone of the solar pond was used as the heat source needed for generating electricity by utilizing thermoelectric cells. The system was tested with different hot water temperatures and flow rates to determine the performance enhancement utilizing copper mesh as insertion. The system is able to generate 35.9W of electricity at the flow rate as low as 5.1 liter per minute at the hot water temperature of 81 ^{o}C.

Singh et al. [17] investigated the combined system of thermosyphon and thermoelectric modules to generate electricity from solar ponds. The temperature difference of the solar pond in the range 40–60 ^{o}C is available between the heat storage zone and upper convective zone which can be applied across the hot and cold surfaces of the thermoelectric modules to make it work as a power generator. Figure 2. shows the concept of generating electric power from salinity-gradient solar pond using a combination of thermosyphon and thermoelectric cells.

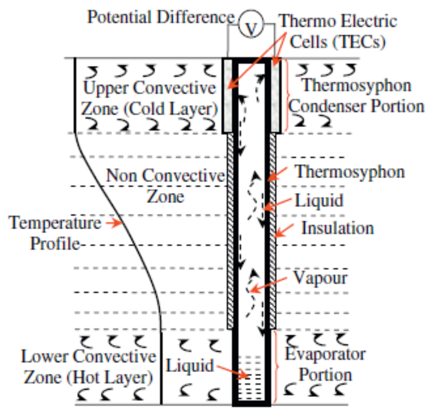

Fig. 2. The concept of generating electric power from salinity-gradient solar pond using a combination of thermosyphon and thermoelectric cells [17].

Another method of the generating electric from the solar pond is the use of organic rankine cycle. The system is configured the salt gradient solar pond matches the sources of an organic rankine cycle and the surface layer serves as cold source to cool the condenser while the bottom layer supplies the evaporator with heat. Fig. 3 shows the principle of a solar pond power plant [18].

The power plants of the solar ponds were constructed and operated at different sites around the world; 5 MW–250,000 m^2 at Beith Ha'avara, Israel; Ein Boqek, Israel 150 kW/6250 m^2; Yavne, Isreal 6 kW/1500 m^2; Alice Springs, Australia 15 kW/1600 m^2); El Paso, USA 70 kW/3350 m^2 [18]

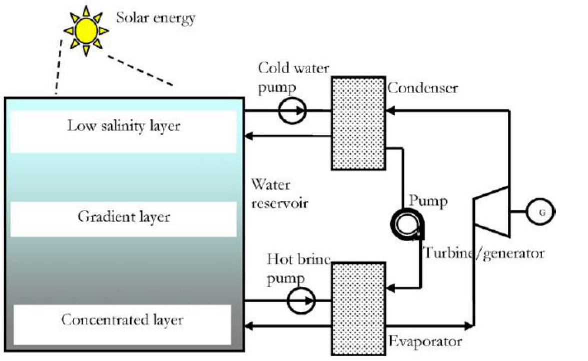

Fig. 3. The principle of a solar pond power plant [18].

Ranjan et al. [19] investigated the active solar distillation systems integrated with solar ponds. The capacity of heat energy in solar ponds storage zone available at about 50–100 °C to power desalination units even during cloudy days and off-sunshine hours. Fig. 4 shows the solar distillation system integrated with salinity gradient solar pond.

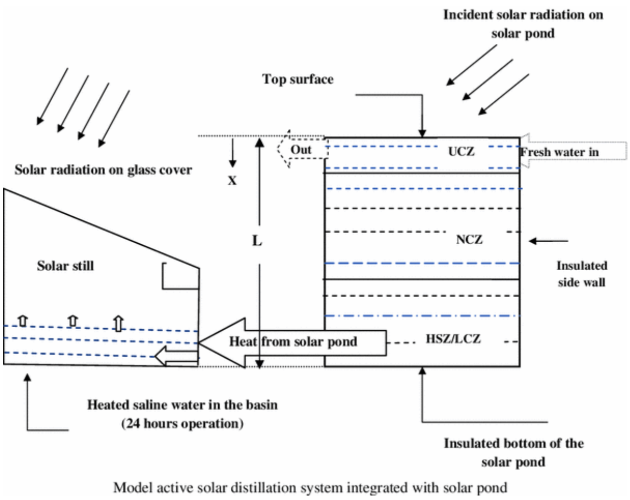

Fig. 4. The solar distillation system integrated with salinity gradient solar pond [19].

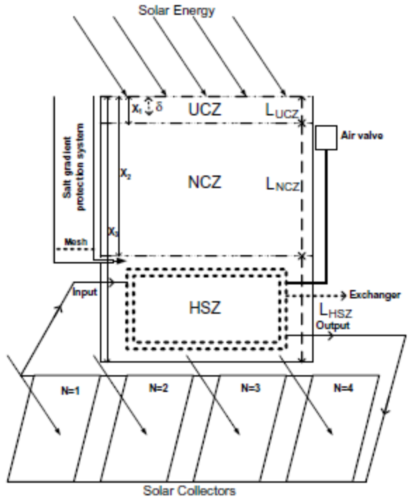

Fig. 5. The integrated solar pond with flat plate solar collectors [20].

Bozkurt et al. [20] studied heat storage performance investigation of integrated solar pond and collector system. Experimental studies were performed using 1, 2, 3 and 4 collectors integrated with solar pond. The integrated solar pond efficiencies were determined experimentally and theoretically according to the number of collectors. Figure 5 shows the integrated solar pond with flat plate solar collectors.

4 Conclusion

Solar ponds are systems that can collect and store solar energy at low temperatures (70-100 °C). High temperatures are undesirable because they negatively affect the gradient structure of the system. For this reason, the heat obtained in the solar ponds can be either used directly or transferred to other systems as heat sources. Solar pond is used directly for applications such as drying foods, domestic heating, and the distillation of the salty water. In cases where higher temperatures are needed, it is possible to use the solar ponds with the systems such as solar collectors, heat pumps. Electricity generation from solar ponds can be carried out using thermoelectric cells or organic rankine cycles.

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