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Design recommendations for humidification-dehumidification solar water desalination systems

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Abstract

The productivity of the humidification-dehumidification solar desalination systems (HDHSDS) significantly increases when the temperature of the feed water increases, so, high temperature solar water collectors as parabolic trough or evacuated tube collectors are recommended for these systems. On the other hand, the effect of air temperature on the productivity of the HDHSDS is insignificant. Thus, the utilization of solar air heater is not recommended in these systems. Based on these recommendations, three research points are suggested for future work: 1) using the recovered PV thermal energy for heating the feed water in the HDHSDS. This will provide an annual fresh water productivity more than 833 L/m^2 of PV in addition to 278 kWh of electricity; 2) using phase change material with melting temperature around 90 ˚C as a thermal energy storage medium to provide feed water with high and almost constant temperature during the day and keeps the system in operation 24 h/day; 3) using the thermal energy rejected from the thermal power cycles for water heating in the HDHSDS.

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Keywords: Dehumidification; humidification; solar desalination.

1. Introduction

The shortage of potable water is the biggest challenge facing people in arid and remote areas. The use of solar energy in water desalination systems presents the perfect solution of this problem. The simple method of using solar

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energy in water desalination is the solar stills in which the desalination process takes place inside the device. El-Sebaii and Shalaby [1] studied the heat transfer mechanisms of the single basin V-corrugated solar still. They success to improve the design parameter of the single basin V-corrugated plate solar still and improve its thermal efficiency. The different designs and the factors affecting the performance of active and passive solar stills had been reported in detailed reviews [2-4]. A review article describing the recent methods that had been used for improving solar still productivity was presented by Velmurugan and Srithar [5]. All methods reported in these review articles aimed to improve the still productivity by reutilizing the latent heat of condensation [6], coupling the still to solar collectors [7] or solar ponds [8]. It is noticed that the productivity of solar stills is 3-7 L/m^2.day as reported in the literature [1-8], which is consider as low amount and insufficient from the economic point of view. This low productivity may be attributed to the large amount of latent heat lost through the solar still glass cover during the condensation process.

This drawback appeared in solar stills is solved in the humidification-dehumidification solar water desalination method. In which, the sea water is heated in the solar water collector then it enters the humidification chamber in contact with air stream. Because of the heat and mass exchange between the hot water and air in that chamber, the air is loaded by humidity. Then, the saturated moisture air with high amount of vapor enters the de-humidification unit in which the vapor condensation takes place.

In this paper, design recommendations for humidification-dehumidification solar desalination systems (HDHSDS) are given. The effect of mass flow rates and temperatures of saline water and air on the productivity of the desalination system are taken a lot of interest in this work. Based on these recommendations, three research points are suggested for future work.

2. Selection of temperature and mass flow rate of feed water and air

The humidification-dehumidification solar desalination system (HDHSDS) is mainly consists of solar water heater (SWH) which may be solar collectors or solar concentrators, hot water storage tank (HWST), humidifier (evaporative chamber) (H) and dehumidifier (condenser) (DH). Solar air heater (SAH) may be used to preheat the air before the entrance of the humidifier.

A humidification-dehumidification solar desalination system was theoretically studied by Orfi et al. [9]. Their system consists of SWH, SAH, H and DH. The sea water is firstly used as cooling water in condenser then it is heated by the SWH. The heated water from the SWH is pumped into the humidifier. Air is preheated using SAH before it enters the evaporative chamber. The system was studied when the air cycle is opened or closed. The calculated results showed that the importance of heating water before it enters the humidifier. They also found that the calculated productivity in a typical day of July when the mass flow rate of seawater of 0.08 kg/s and the air mass flow rate 0.05 kg/s for open and closed air cycle are 27.8 and 25.6 L/m^2.day, respectively. Whereas; the corresponding annual productivity are 6170 L/m^2 and 5791 L/m^2, respectively. Theoretical study of a HDHSDS was presented by Yamali and Solmus [10]. They used a double-pass flat plate SAH in order to heat the air before it enters the humidifier. In their system the SWH was not used. However, the effect of water temperature on the productivity has been numerically investigated with different air, feed and cooling water mass flow rates. They found that using double-pass SAH increases the productivity by 8% compared with single-pass SAH. The results indicated also that the system productivity increases by increasing the temperature of feed water at the inlet of the humidifier. It also increases by decreasing the temperature of cooling water and increasing its mass flow rate. Yildirim and Solmus [11] theoretically investigated the HDHSDS with using SAH and SWH. They found that the water heating has a major importance on the fresh water productivity. This due to the fact that the heat capacity of water is much higher than that of air. This means that the utilization of SAH with the HDHSDS does not lead to any significant improvement. Kabeel et al. [12] system consists of H, DH and evacuated tube SWH. The desalination unit is tested with closed loop of air and open loop of water. They studied the effect of water temperature, packing material and mass flow rate of water. They concluded that the maximum productivity is obtained when the ratio of cold water at the DH inlet to hot water at the H inlet is twice.

From the later results, it is concluded that the productivity of the HDHSDS is significantly affected by the temperature of the feed water, so, high temperature solar water collectors like parabolic trough and evacuated tubes collectors are recommended for these systems of solar water desalination. On the other hand, the effect of the air