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Experimental study on a modified solar power driven hybrid desalination system

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ABSTRACT

This paper offers a study on a modified solar power driven hybrid desalination system (SS-HDH). SS-HDH system consisting of a solar still (SS) and air humidification dehumidification (HDH) unit integrated with solar air-water heater. This study is implemented experimentally under the real daytime starting at 8:00 AM until 6:00 PM. The variations on the SS-HDH system performance and productivity, according to the different operating conditions were studied. The proposed hybridization method between HDH and SS units has led to a significant effect on the performance and productivity of both of them. The maximum productivity of the system reached to 18.25 l/m^2 day at mass flow rates of air and water equal 0.03 kg/s. The humidification efficiency reached about 79% and affected by increment on water mass flow rate more than the increment on the air mass flow rate. The system overall efficiency varies from 21% to 39%. The SS-HDH system performance influenced strongly by air mass flow rate. Gain output ratio (GOR) of about 2.57. Moreover, the smallest distilled water cost of 0.0081 US $/liter is achieved with the case of productivity equal 18.25 l/m^2 day. The uncertainty in calculating of performance parameters was about 5.68–7.8%.

1. Introduction

Water challenge in remote areas is considered one of the most critical challenges facing drinking, and agriculture needs. Desalination has become a suitable solution to overcome fresh water shortages in isolated regions. Renewable energy source, for example, solar energy, vitality is an adequate contrasting option to traditional fuels which can be utilized for saline water desalination to deliver the thermal energy by utilizing direct solar energy gathering devices. Small scale desalination systems represent a valuable source for the providing of fresh water when saline or brackish water is there [1]. The hybrid or integrated desalination system is an imperative subject in the field of water desalination. It communicates the combination of at least two processes for accomplishing a superior cost of producing water and permit a superior match between control request and water prerequisites with optimization of the component combination of the two processes than either alone can give.

In desalination, there are membrane and thermal (distillation) processes. The effective integration of desalination technologies is to reduce the running cost of desalination, power consumption and improved water quality [2]. The developments in solar still desalination and HDH methods are reviewed by many researchers [3–8]. Mahmoud et al. [9] investigated a solar powered desalination system utilizing coupling between solar still and two effects HDH system assisted by concentrating solar power device (CSP) and two PV panels. Their results presented that the increment in the air mass flow rate and the trough water depth makes the system productivity decrements. And also, the coupling of PVs with CSP caused a critical increment in the water productivity. Sharshi et al. [10] studied a solar driven desalination system comprises of an HDH unit and four solar stills. Their system based on usage the hot water outlet from HDH as a feeding for solar stills. They found that the system gain output ratio and the single solar still efficiency increment by 50% and 90% respectively. Tabrizi et al. [11] studied experimentally a multistage-solar still integrated with an HDH unit. They found that the daily system productivity enhanced by 113% and improves the thermal efficiency by 11%in the HDH unit presence. Their system productivity and efficiency were 5.4 kg/m^2 day and 39%. Sharshir et al. [12] presented a theoretical study about the performance of a modified wick stills using the glass cooling. Their results showed that the effect glass film cooling on the wick still productivity was about 5.3%, 30% respectively more than that without it for day and night times. Rajaseenivasan and Srithar [13] presented an experimental investigation on an HDH desalination system coupled with a solar collector utilized to heat the water and air together

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Nomenclature

Latin symbols

A	area, m^2
a	amortization factor, %
x	water salinity, *ppm*
I	actual energy absorbed from the solar radiation, W/m^2
$\dot{m}$	mass flow rate, kg/s
V	volume, m^3 or variable cost, US$
T	temperature, °C
GOR	gain output ratio, *dimensionless*
H	height, m
C	cost, US$
n	lifetime, year
N	running days per year, day
i	Interest rate, %

Greek symbols

ω	humidity ratio, $kg_{water\ vapor}/kg_{dry\ air}$
η	efficiency, dimensionless
λ	latent heat, kJ/kg

Subscripts

a	Air
w	water
am	Ambient
o	Out
in	In
s	Saturation
cw	cooling water
dis	Distillate
ev	Humidifier
co	Dehumidifier
fw	feed water
SS	solar still
HDH	humidification and dehumidification
tank	Tank
csc	combined solar collector
swh	solar water heater
t	Total
c	Capital
fix	Fixed
op	Operation
main	Maintenance
prod	Product

Abbreviations

HDH	humidification dehumidification
SS	solar still
GOR	gain output ratio
MD	membrane distillation
SSF	single stage flashing
BC	bubble column
PV	photovoltaic
CSP	concentrated solar power

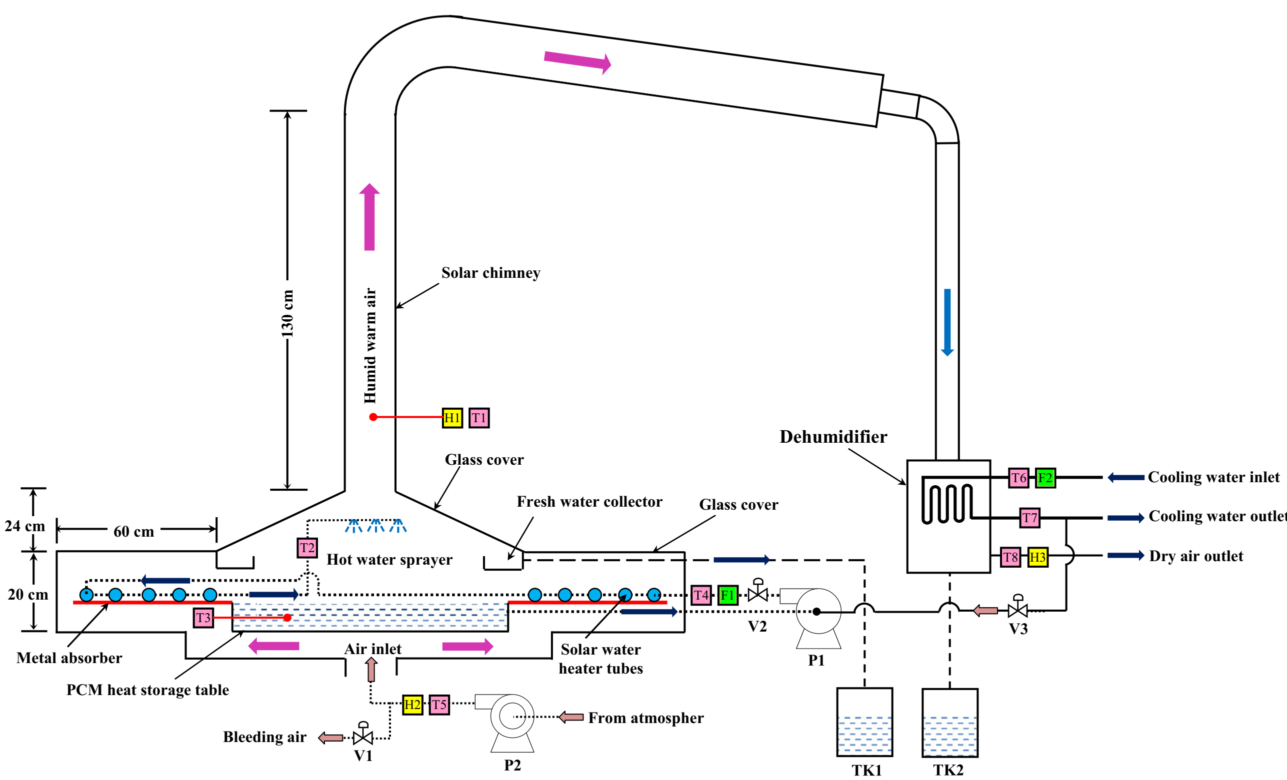

Fig. 1. SS-HDH experimental set-up schematic diagram.