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# Experimental performance evaluation of a combined solar system to produce cooling and potable water

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**Abstract**

In this paper, a combined system for domestic use in rural areas is designed and constructed. This system combines simultaneously a solar desalination unit and an intermittent solar operated absorption cooling unit. The desalination unit works at sub-atmospheric pressure where decrease of the saline water evaporation pressure allows a much reduction of energy required to operate the unit. The desalination unit consists of a solar basin connected to an external water-cooled condenser. The LiBr–$H_2O$ absorption cooling unit operates intermittently to match solar operation mode. Photovoltaic panels are employed to supply heat of generation process. The experimental performance of the constructed system at different climatic conditions is presented. The most efficient performance of the system is obtained in the month of August. The maximum desalination unit efficiency and minimum evaporator temperature of absorption cooling unit are 40% and 4.7 °C, respectively. Energy efficiency of 13.75% for the entire system is recorded.



*Keywords:* Solar energy; Desalination; Absorption cooling; Exergy; Efficiency

## 1. Introduction

The worldwide energy consumption has rapidly increased, basically due to the dramatic growth of the emerging countries' populations, economic and technological developments, etc. Unfortunately, the majority of such energy demand is obtained by fossil fuels whose future availability and environmental impact have becomes severe issues. Meanwhile, there is an increasing concern to fulfill energy demands of rural communities where electricity supply is not available, but renewable energy is abundant. Therefore, it is reasonable to consider renewable energy sources such as solar, wind, biomass, wave and tide (Dincer, 2000). Out of the various renewable sources of energy, the utilization of solar energy has attracted the greatest attention (Kalogirou, 2014). Recent comprehensive reviews have indicated that solar energy proves to be the best candidate for many purposes such as sea water desalination (Sharon and Reddy, 2015; Li et al., 2013; Kalogirou, 2005) and cooling systems (Otanicar et al., 2012; Wang et al., 2009; Fan et al., 2007).

In this framework, the sustainable development of energy systems requires an implementation of combined and integrated systems, especially with renewable energy options, for better efficiency, cost effectiveness, resources use and environment (Dincer and Zamfirescu, 2012).

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**Nomenclature**

| | |
|---|---|
| $A$ | area, m$^2$ |
| $\dot{E}x$ | rate of exergy, W |
| $h_{fg}$ | latent heat of evaporation, J/kg |
| $m$ | mass, kg |
| $P$ | pressure, kPa |
| $\dot{Q}$ | rate of heat transfer, W |
| $T$ | temperature, °C |

*Greek letter*

| | |
|---|---|
| $\eta$ | efficiency, % |

*Subscripts*

| | |
|---|---|
| 0 | dead state |
| E | evaporator |
| ex | exergy |
| f | fresh water |
| g | glass |
| PV | photo voltaic |
| Q | heat |
| sys | system |
| w | saline water |

*Abbreviations*

| | |
|---|---|
| AB | absorber |
| ACH | absorption chiller |
| AHs | auxiliary heaters |
| ARS | absorption refrigeration system |
| *B* | battery |
| BOP | balance of plant |
| CO | condenser |
| COP | coefficient of performance, – |
| CPC | compound parabolic concentrator |
| CR | condensate receiver |
| EC | evaporation chamber |
| EV | evaporator |
| GE | generator |
| *H* | heater |
| *I* | solar radiation meter |
| PM | electric power meter |
| PV | photovoltaic |
| PV/T | photo voltaic/thermal |
| SW | Sea water |
| TC | temperature controller |
| TES | thermal energy storage |
| *V* | valve |

Ratlamwala et al. (2013) carried out a comprehensive thermodynamic investigation of a novel integrated system, consisting of a solar photovoltaic/thermal (PV/T) collector and a quadruple effect absorption cooling system, for the production of freshwater and cooling. The ammonia–water pair was considered as a working fluid for the absorption system. The energetic and exergetic utilization factors of their developed system were found to be varying from 3.3 to 4.3 and 0.4 to 0.5, respectively. In the studies of Gude and Nirmalakhandan (2008) and Gude et al. (2011), a solar desalination process, utilizing waste heat rejected by an absorption refrigeration system (ARS), was evaluated. A sensible heat thermal energy storage (TES) unit was included. The thermal energy to maintain the evaporation chamber (EC) at a desired temperature was provided by the TES system, whose temperature was set at 50 °C. The thermal energy required to maintain the TES at this temperature is provided by the heat rejected by an ARS. The results of their study showed that the thermal energy rejected by an ARS of cooling capacity of 3.25 kW along with an additional energy input of 208 kJ/kg of desalinated water was adequate to produce desalinated water at an average rate of 4.5 kg/h.

Calise et al. (2014) presented a novel solar system producing simultaneously: electrical energy, thermal energy, cooling energy and domestic water. The simulation analysis of the polygeneration system included solar PV/T collectors, a multi-effect distillation (MED) system for seawater (SW) desalination, a single-stage LiBr–H2O absorption chiller (ACH) and additional components, such as storage tanks, auxiliary heaters (AHs) and balance of plant (BOP) devices. The MED simulated specific consumption was 95 kW h/m$^3$. This result was achieved by 8-effect unit and both CPVT thermal and electrical efficiencies were around 20% and 50%, respectively. A thermoeconomic analysis was also presented to determine the optimal values of the most important design variables.

Other researchers (Yuan et al., 2005; Ghali et al., 2011) considered combining the mechanical vapor compression air conditioning system with desalination. Yuan et al. (2005) integrated a desalination and air conditioning systems utilizing the heat rejected by the condenser and the heat sink of the evaporator to evaporate the sea water and then condense it on the cold surfaces of the evaporator. The water output of the combined system exceeded the output of an improved solar still that reduced the latent heat of condensation and lowered the temperature of the cover glass. However, the conventional solar still component did not exist in the integrated system and it relied on electrical energy to produce fresh water. If the air-conditioning system was not running, then no potable water would be produced. Ghali et al. (2011) investigated the operation of the combined solar distillation and air conditioning system. The proposed system was simulated to predict distillate output from the cooling coil for the combined system, exit air temperature and humidity from