Energy Conversion and Management 175 (2018) 337–356

Contents lists available at ScienceDirect

Energy Conversion and Management

journal homepage: www.elsevier.com/locate/enconman

Thermodynamic and economic evaluation of a novel concentrated solar power system integrated with absorption refrigeration and desalination cycles

Mehdi Mehrpooya[a,b,*], Bahram Ghorbani[c], Seyed Sina Hosseini[a,b]

[a] Department of Renewable Energies and Environment, Faculty of New Sciences and Technologies, University of Tehran, Tehran, Iran
[b] Hydrogen and Fuel Cell Laboratory, Faculty of New Sciences and Technologies, University of Tehran, Tehran, Iran
[c] Faculty of Engineering Modern Technologies, Amol University of Special Modern Technologies, Amol, Iran

ARTICLE INFO

Keywords:
Concentrated solar power
Absorption refrigeration
Multi-effect desalination
Exergy analysis
Economic analysis

ABSTRACT

In this study, an innovative concentrated solar power plant integrated with desalination process and absorption refrigeration cycle aimed at supplying power, fresh water and refrigeration, was developed and exergetically assessed. The system comprised a concentrated solar thermal power plant with parabolic dish collectors and steam turbine, a multi-effect desalination process with parallel feed of seawater, and a single-stage ammonia-water absorption refrigeration system. Generally, the collectors provided 21,030 kW thermal power to the steam power plant and 4632 kW of which was converted to electrical power in steam power plant. The absorption refrigeration cycle produced 820.8 kW refrigeration and the desalination cycle provided fresh water at a rate of 22.79 kg/s. The integrated system was simulated in Aspen Hysys and all the components of the integrated system were individually scrutinized based on the second law of thermodynamics; as well, the exergy destruction rate and exergy efficiency of each component were obtained and discussed thoroughly. According to the results, about 86% of the total exergy destruction rate of the system belonged to the distillation column and heat exchangers. The overall exergy efficiency of the cycle was 66.05%, while, the net overall thermal efficiency of the integrated system was 80.70%. The results of the economic analysis showed that the proposed integrated structure had an investment return period of 5.738 years and a net annual profit of 6.828 million US$ per year. Moreover, the impact of various factors on the performance of the integrated system was investigated using sensitivity analysis.

1. Introduction

Since energy plays a more and more important role in human life, well-being, and economic and industrial growth of the countries across the globe, meeting the growing demand for energy in a secure and environmentally friendly manner is a big challenge [1]. Meanwhile, according to the BP statistical review of world energy (2017) [2], the majority of the global energy consumption (85.5%) is met by fossil-based fuels, i.e. oil, natural gas and coal, speculated to be fairly responsible for a large share of overall carbon dioxide (CO_2) emissions [3], global warming, climate change [4], ecosystem toxicity and health risks [5]. In addition, the scarcity, fast depletion, and unreliable distribution of fossil fuels [6] have caused an intensified search for alternative renewable sources of energy [7]. Concentrated Solar Power (CSP) is one of the most promising solar energy harnessing technologies in providing heat and power [8], in which the incoming solar radiation is absorbed by a set of solar collectors (high-magnification mirrors) and then the absorbed heat is delivered to a working fluid which can be used in power cycles, cooling systems and many other applications [9]. The high potential of CSP systems in hybridizing with other energy conversion systems [10], the better performance in effectively and efficiently dealing with the intermittency of the natural resources than other renewable energy resources [11], and providing a dispatchable electricity generation through thermal energy storage [12] have been confirmed as the advantages of CSP systems. Currently, the developed CSP technologies are available in four types, including parabolic troughs, Fresnel mirrors, solar towers, and solar dish collectors, each has its own specifications, configurations and pros and cons [13].

To date, a great deal of research is focused on the application of CSP technologies in different energy consuming processes, including desalination [14], electricity generation [15], hydrogen production [16], cooling, multi-generation [17] and also hybridizing with other

* Corresponding author at: Renewable Energies and Environment Department, Faculty of New Sciences and Technologies, University of Tehran, Tehran, Iran.
E-mail address: mehrpooya@ut.ac.ir (M. Mehrpooya).

https://doi.org/10.1016/j.enconman.2018.08.109
Received 9 February 2018; Received in revised form 30 August 2018; Accepted 31 August 2018
0196-8904/ © 2018 Elsevier Ltd. All rights reserved.

Nomenclature

A_a	surface area of the concentrator (m^2)
A_c	surface area of the receiver aperture (m^2)
A_w	cavity internal area of receiver (m^2)
$\mathscr{A}$	ash contents of the component (wt%)
B	mass flow rate of the brine (kg/s)
c	geometrical concentration ratio (–)
C_P	specific heat capacity (kJ/kg)
$\mathscr{C}$	carbon contents of the component in wt.%
$\mathbb{C}$	cost (US$)
D_1	distillated mass flow rate (kg/s)
D	mass flow rate of the desalinated water (kg/s)
$\mathbb{D}$	diameter
$\mathfrak{D}_s$, $\mathfrak{D}_t$	pressure drops in shell side and tube (Pa)
$\dot{E}x$	exergy rate (kW)
ex	specific exergy (kJ/kg)
F	mass flow rate of the seawater (kg/s)
$\mathfrak{f}$	material Factor (–)
$\mathscr{f}$	dilution factor (1.3×10^{-5}).
g	gravitational acceleration ($9.806\ m/s^2$)
Gr_l	Grashof number (–)
G_{on}	extraterrestrial radiation incident (W/m^2)
G_{sc}	solar constant ($1367\ W/m^2$)
h	specific enthalpy (kJ/kg)
h_c	convection heat transfer coefficient between the absorber and ambient air ($W/m^2\,K$)
H_0	extraterrestrial solar radiation on a horizontal surface (W/m^2)
H_d	daily diffuse solar radiation (W/m^2)
$\mathscr{H}$	hydrogen contents of component (wt%)
I_s	beam solar radiation reached to concentrator surface (W/m^2)
I_d	hourly diffuse solar radiation on the horizontal surface (W/m^2)
K	thermal conductivity of the ambient air (W/m·K)
K_t	clearness index of a day (–)
$\mathbb{W}$	wight (N)
$\mathbb{L}$	length (m)
L_{Log}	local geographical longitude
M	molar mass (kg/mole)
$\dot{m}$	mass flow rate (kg/s)
N	number of the effects
$\mathscr{N}$	nitrogen contents of component (wt%)
$\mathbb{N}$	surface area (m^2)
Nu_l	Nusselt number (–)
$\dot{n}$	mole rate (mole/kg)
$\mathscr{O}$	oxygen contents of component (wt%)
P	pressure (bar), power consumption (kW)
$\mathscr{Q}$	heating load (kW)
Q_1	heat supplied by heating steam in first stage (kW)
Q_i	heat supplied by heating steam in effects (kW)
Q_l	power lost in the receiver (W)
Q_r	power reached to the receiver (W)
Q_s	power reached on the surface of the dish (W)
Q_u	thermal power reached to receiver (W)
$\dot{Q}$	rate of heat transfer (kW)
r	mole fraction (–)
$\mathscr{R}$	universal gas constant (8.314 J/mol·K)
Ra	entrainment ratio of the steam ejector (–)
s	specific entropy (kJ/kg·K)
$\mathscr{S}$	sulfur contents of component (wt%)
T	temperature (K)
T_N	temperature of the heating steam in the final effect
T_s	temperature of heating steam line in the first effect
T_w	receiver temperature (°C)
$T^{'}$	temperature of the desalinated water from the previous effect
$\dot{W}$	rate of shaft work (kW)
$\mathbb{W}$	shell weight (lb.)
x	salinity percent (%)

Greek

$\mathscr{e}$	standard chemical exergy of the component in the stream (kJ/mole)
ρ	Reflectance
τ	transmittance
α	absorptance
γ	intercept factor
η	efficiency (%)
φ_1	tilt angle of cavity (Radian)
β	coefficient of thermal expansion (1/°C)
ν	kinematic viscosity (m^2/s)
δ	declination
$\varnothing$	latitude
ω_s	sunset hour angle
ε_{eff}	effective infrared emittance of cavity
ε_c	cavity surface emittance
σ	Stefan–Boltzmann constant ($5.67 \times 10^{-8}\ W/m^2\,K^4$)
ω	hour angle
Δ	difference
$\mathscr{i}$	annual interest rate
$\mathscr{z}$	real interest rate (%)
$\aleph$	annual inflation rate (%)
$\mathscr{Y}$	economic life cycle of thesystem (year)

Subscript

0	reference state
a	ambient
acap	annualized capital
arep	annualized replacement
amain	annualized maintenance
aope	annualized operating
b	brine
c	collector, convection, cold
cap	capital
des	destruction
eff	effective
ev	entrained vapor
evap	evaporator
ex	exergy
f	seawater
gen	generator
h	hot
hs	heating steam
HX	heat exchanger
i	desalinated water, stream number *i*, inpt
j	stream number, component number,
k	conduction
ms	motive steam
o	optical, output
r	receiver, radiation
s	sun
ST	steam Turbine
v	Vapor

Download English Version:

https://daneshyari.com/en/article/10140155

Download Persian Version:

https://daneshyari.com/article/10140155

Daneshyari.com