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Comprehensive assessment of a multi-generation system integrated with a desalination system: Modeling and analysing

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ABSTRACT

A new system for providing multiple outputs from solar energy capture (multi-generation) is proposed. The main objective of the system is to supply electricity, heating, cooling, and water to the residential sectors. The proposed system uses solar energy as its source to integrate two Rankine Cycle, a single effect absorption system, an electrolyser unit and a Reverse Osmosis desalination system. The system employs, as a working fluid, a molten salt, for a parabolic trough solar collector cycle, and Lithium bromide-water as a working fluid in the absorption system. The main objectives of this research are firs to analyze the system through energetic and exergetic, then evaluate the system from environment point of view. The effects of various parameters on the system efficiency and production are evaluated and the results show that the overall energy and exergy efficiencies of the system are 33.52 and 20.69%, respectively. In addition, the results of the environment assessment shows that if the system works in an environment with a lower ambient temperature is more efficient.

1. Introduction

The growth of global energy demand causes an increase in carbon dioxide emissions [1]. A significant number of the environmental issues are due to the use of fossil fuels in buildings. It is estimated that 32% of the world energy supplies are used in buildings, including 8% in commercial buildings and 24% in the residential sector [2]. Therefore, it is worth concentrating on efforts to decrease building emissions. According to Fig. 1, the least attention is given to the use of renewable energies.

Due to the increase in energy consumption and to decrease the effect of greenhouse gases, the use of renewable energy is becoming more popular [4]. As a strong-growing alternative energy sources, renewable energy technologies have come out to supply green power generation for the future [5]. Solar is responsible for many novel approaches to reduce fossil fuels [6], because it is abundant, non-polluting and inexhaustible. Therefore, reduction of fossil fuels consumption has been done in numerous countries with enough daily solar radiation [7]. Also, it is cheap, renewable, and environmentally friendly [8]. Approximately 170,000 TW of solar radiation falls on the earth surface during a year [9].

The renewable energies, especially solar energy, have been used in some multi-generation systems. The previous studies have shown that multi-generation systems can play an important role in the reduction of emissions related to energy production [10]. Multi-generation systems that use renewable sources are practical to provide various needs of a public unit. Furthermore, they produce the power of clean energy with high efficiency [11]. The production of multiple outputs from one system improves the overall efficiency of the system [12]. Multi-generation systems with combination of two renewable energy sources can increase the overall efficiency of a conventional plant up to 70% by providing useful outputs such as cooling, heating (and hot water) [13].

Various studies have been conducted on multi-generation systems;

Khalid et al. [10] designed and evaluated a multi-generational system based on biomass and solar energy through energy and exergy analysis. Space heating, electricity, hot water, and cooling were the system outputs. Also, they studied the impacts of varying the main factors on the system. The overall energy and exergy efficiencies of the system were calculated to be 91.0% and 34.9%, respectively. The results showed that the system was more economic and efficient in comparison with running individually solar and biomass systems.

Sharifishourabi et al. [14] have proposed a multigeneration system to supply electricity, dry air, hot water, hydrogen, cooling and heating to the residential sectors. The system involved an ORC, a single effect absorption system, an electrolyser and a dehumidification system. The overall energy and exergy efficiency of the system have found to be 70

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Nomenclature

Abs	absorber
ARC	Ammonia Rankine cycle
B	boiler
CO	condenser
COP	coefficient of performance
d	destruction
SEAS	single effect absorption system
EES	Engineering Equation Solver
ELE	electrolyzer
En	energy
$\dot{m}$	mass flow rate
MW	molar mass of H2
ORC	organic Rankine cycle
P	pressure
P1	pump1
P2	pump2
P3	pump3
P4	pump4
RO	Reverse Osmosis
T	turbine
$\dot{Q}$	heat transfer rate
s	entropy
h	enthalpy
EV	absorption evaporator
Ex	exergy
EX1	expansion valve1
EX2	expansion valve2
G	generator
PTSC	parabolic trough solar collector
HX	heat exchanger
HT	hydro turbine
η	energy efficiency
ψ	exergy efficiency
ε	utilization factor
T	temperature
F	filter
TG	turbine generator
b_n	number of RO trains
ΔP	trans-membrane pressure
RR	recovery ratio
ρ	density
k_m	membrane permeability resistance
J_w	volumetric permeate flow rate
A_{mem}	area of membrane
$\Delta\delta$	trans-membrane osmotic pressure
C_w	membrane wall concentration
R	membrane rejection coefficient
k_{mass}	mass transfer coefficient
D_s	diffusivity
d	feed channel thickness
Re	Reynolds number
N_{ch}	number of feed channels
NP	number of pressure vessels
μ	dynamic viscosity
W_m	membrane width
Sc	Schmidt Number
HHW	higher heating value
$\dot{E}_{x_{in}}$	input exergy rate
$\dot{Ex}_{des,tot}$	total exergy destruction rate
η_{ex}	overall exergy efficiency of the system
f_{ei}	exergoenvironmental impact factor
C_{ei}	exergoenvironmental impact coefficient
θ_{ei}	exergoenvironmental impact index
θ_{eii}	exergoenvironmental impact improvement
f_{es}	exergy stability factor
θ_{est}	exergy sustainability index

and 53% respectively.

Almahdi et al. [15], developed a solar multi-generation system based on hydrogen production. In their system, three ORCs, two absorption systems, a heat pump and an electrolyzer were used. The system was able to generate 18.8 L/s of hydrogen. The overall energy and exergy efficiency of the system were determined to be 20.7 and 13.7%, respectively.

Ozturk and Dincer [16] studied a multi-generation system which produced hot water, heat, electricity, cooling, and hydrogen using renewable energy input. The system consisted of organic Rankine cycle, Rankine cycle, an absorption system, and an electrolyzer. Results showed that the exergy efficiency of the multi-generation system was higher than that of the sub-system efficiencies.

Islam and Dincer [17] developed and analyzed a combined solar and geothermal energy-based system for multi-generation purposes.

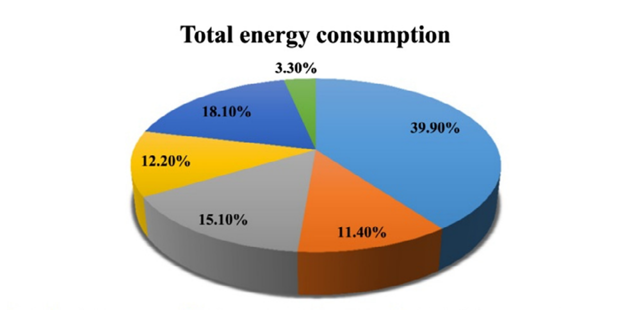

Fig. 1. Total energy consumption in 2014 [3].

The proposed system included two ORC power cycles, two thermal energy storage systems, a heat pump, an absorption chiller, and a drying system. They compared the system's energy and exergy efficiencies when it was working in multi-generation and single generation modes. The energy and exergy efficiencies were found to be 51% and 62%, respectively in multi-generation mode, whereas these efficiencies in single generation mode were in the order of 22% and 54%, respectively.

Hassoun and Dincer [18] assessed performance of a multi-generation system powered by an Organic Rankine Cycle which used solar energy as a prime energy source. The system developed to meet the demands of a net zero energy building such as electricity, fresh and hot water, heating, and cooling. The exergetic analyses showed that the overall exergy efficiency of the system was 44.67% and increased to 58.8% by multi-objective optimization.

Mohammadi et al. [19], evaluated a combined cooling, heating, and power system integrated with a wind turbine and compressed air energy storage system through energy and exergy analysis . The results showed that the system could generate 33.67 kW of electricity, 2.56 kW of cooling and 1.82 tonnes per day of hot water with an energy efficiency of 53.94%. Exergy analysis revealed that the highest amounts of exergy destruction belonged to the wind turbine, the combustion chamber, and the compressed air storage systems, respectively.

Ezzat and Dincer [20] evaluated a new multi-generational system through energy and exergy analysis. Their system consisted of a heat pump system, a single effect absorption chiller, a single flash geothermal system, thermal energy storage, a drying system, and a hot water system. The system had the overall exergy and energy efficiencies