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Analysis and performance assessment of a novel ORC based multi-generation system for power, distilled water and heat

Mortaza Yari [a,*], Leyli Ariyanfar [b], Ebrahim Abdi Aghdam [b]

[a] Faculty of Mechanical Engineering, University of Tabriz, Tabriz, Iran
[b] Department of Mechanical Engineering, Faculty of Engineering, University of Mohaghegh Ardabili, Ardabil, Iran

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A B S T R A C T

In this paper, the coupling of a Humidification-Dehumidification Desalination (HDD) with an Organic Rankine Cycle (ORC) as a multi-generation system is proposed in two scenarios to generate power, distilled water and heat. The system is investigated from thermodynamic and economic viewpoints, and for achieving the best results, four organic fluids are examined in the ORC. In the first scenario, the outlet water of the ORC and HDD condensers are mixed and the flow enters to the HDD, as feed water. The heat of distilled water is absorbed by a water flow in a heat exchanger and mixed with the brine of HDD to heat production. In the second scenario, just the outlet water of the ORC condenser enters to the HDD, as feed water. The heat of distilled water is absorbed by a water flow in a heat exchanger and mixed with the brine of HDD and the outlet flow of the HDD condenser. The proposed multi-generation system works without external energy (heat). Results show that within four working fluids n-Octane has the best performance and scenario (II) produce more distilled water with higher recovery rate and lower cost. Also, scenario (II) produce more amount of heating flow, although with lower temperature and higher cost. Both of proposed scenarios have optimized in order to minimizing cost of distilled water; and scenario (I), based on its structure, has optimized to maximizing distilled water production and its recovery rate. Also, a multi-objective optimization is performed for both scenarios.

1. Introduction

Due to the increasing importance of energy, it is trying to maximum utilization of energy sources in the processes. So, the energy efficiency of the systems and processes are increasing to the highest level as possible, and at the same time, providing various requirements as system production has been one of the main aims. Therefore, multigeneration systems, which can generate power as well as distilled water, heating and cooling effects and etc are proposed recently. Also, the use of renewable energy resources has been more focused. In this way, Organic Rankine Cycle (ORC) is one of the promising choices which can use from different sources with wide temperature range as well as the renewable energies [1,2]. A summarized literature survey of the ORC based combined heat and power (CHP) systems, is provided in Table 1.

Various types of desalination with different methods can be coupled with the ORC. If an electrical desalination system would be coupled with the ORC, it needs to use a part of the generated power in the ORC and it is caused to decreasing the total efficiency of the system usually. If a thermal desalination system would be coupled with the ORC, it needs thermal energy which can be provided from the internal flows of the ORC or the waste heats and it can leads to increasing the total efficiency of system [19–27].

The Humidification-Dehumidification Desalination (HDD) system involves air humidification and dehumidification process and it work based on the fact that air can carry vapor and the amount of vapor in the air increases by rising the temperature. The HDD operates under atmospheric conditions by an air loop saturated with vapor and has three main sections: the humidifier, dehumidifier and heat source. In the humidifier, the hot water is sprayed in the air and then the hot and humid air leaves the humidifier and enters to the dehumidifier. In the dehumidifier, the vapor is distilled by contact of the humid air with a cool surface which causes the condensation of vapor in the air and therefore production of fresh water. The system can operate in natural air circulation mode or forced mode by using a fan. A natural model HDD unit, which has a simpler structure and lowers operational cost, consists

* Corresponding author.
E-mail address: myari@uma.ac.ir (M. Yari).

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Table 1
Summarized literature survey of the ORC based CHP.

Reference	Study	Assessment	Energy source	Source temperature (°C)	application
Ref. [3]	Theoretical	Technical	Biomass	100 to 140	Power and heating
Ref. [4]	Theoretical	Technical - Economical	Biomass	180 to 420	Power, heating, cooling and water
Ref. [5]	Theoretical	Technical - Economical	Biomass	70 to 500	Power and heating
Ref. [6]	Experimental	Technical	Natural gas	500 to 600	Power and heating
Ref. [7]	Theoretical	Technical	Biomass	950 to 1000	Power and heating
Ref. [8]	Theoretical	Technical	Geothermal	100	Power and heating
Ref. [9]	Theoretical	Technical – Environmental	Geothermal and solar	90 to 95	Power and heating
Ref. [10]	Theoretical	Technical - Economical	Distributed energy system	180 to 380	Power, heating and cooling
Ref. [11]	Theoretical	Technical	Biomass	250 to 400	Power and heating
Ref. [12]	Experimental	Technical	Natural gas	65 to 85	Power and heating
Ref [13]	Theoretical	Technical	Renewable	100 to 140	Power and heating
Ref. [14]	Experimental	Technical	Natural gas	90 to 150	Power and heating
Ref. [15]	Theoretical	Technical	Solar	180 to 230	Power and heating
Ref. [16]	Experimental	Technical	Biomass	310	Power and heating
Ref. [17]	Experimental	Technical	Natural gas	170	Power and heating
Ref. [18]	Experimental	Technical	Biomass	1400	Power and heating

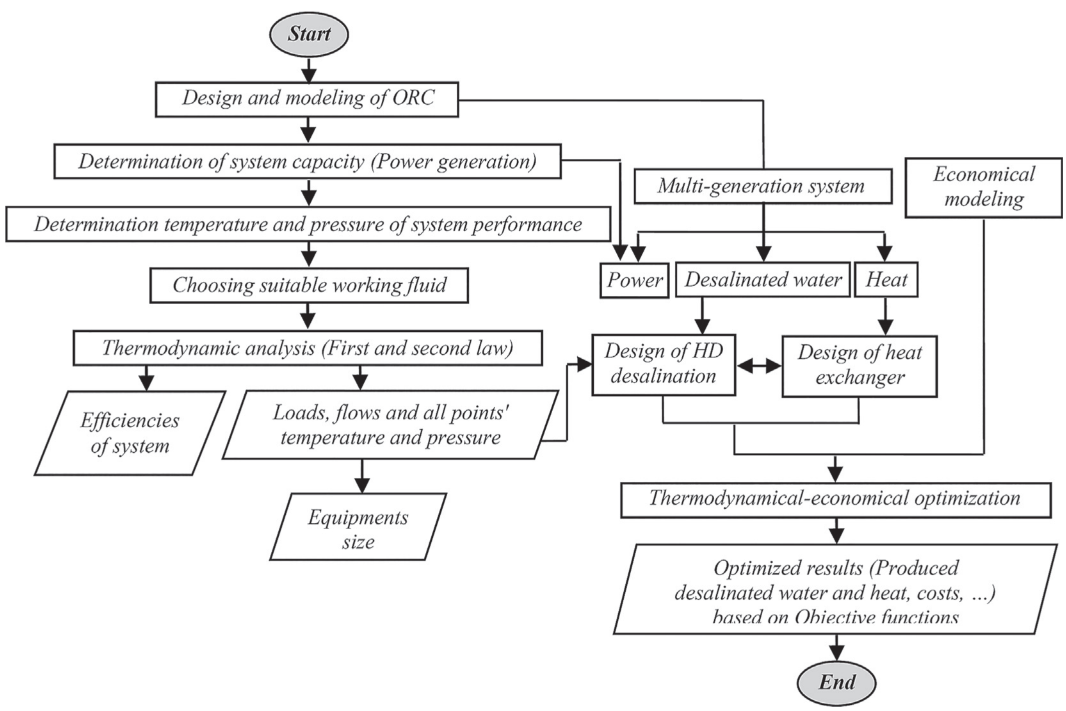

Fig. 1. Comprehensive algorithm of study.

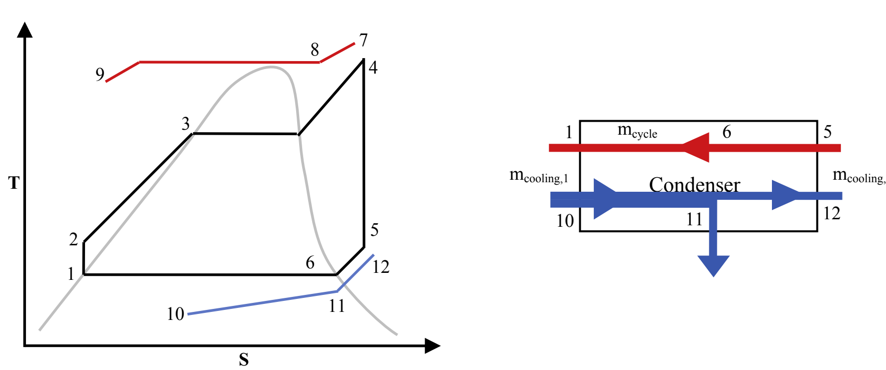

Fig. 2. a. Schematic T-S diagram of ORC . b. Schematic diagram of ORC condenser.