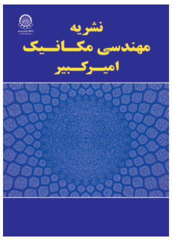

Amirkabir Journal of Mechanical Engineering

Amirkabir J. Mech. Eng., 50(6) (2018) 427-430
DOI: 10.22060/mej.2017.12982.5491

Optimization of a Hybrid Multi-effect Desalination with Thermal Vapor Compression and Reverse Osmosis Desalination System Integrated to A Gas Turbine Cycle

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ABSTRACT: The present study aimed to recognize the optimized configuration of hybrid multiple effect evaporation and reverse osmosis desalination and gas turbine cycle. To achieve this goal, first, a thermodynamic and thermoeconomic model was developed for different parts of the cycle. Six configuration for hybrid desalination plant were. In fact, one of the important goals of the present study was to investigate whether the integration of hybrid desalination plants is useful from thermodynamic and economical points of view. Two approaches were considered in the optimization study. In the first approach, the water production of multiple effect evaporation desalination plant was fixed at 70000 m^3/day and the capacity of reverse osmosis desalination was considered as 50%, 75% and 100% of thermal desalination capacity. In the second approach, the water production of multiple effect evaporation desalination plant was not fixed but the total production rate of hybrid desalination plant were given at 105000, 122500 and 140000 m^3/day. The final conclusion showed that the first configuration could be chosen as the best one because it had the maximum value of exergy efficiency and minimum value of cost of water in both first and second optimization approaches.

Review History:

Received: 7 June 2017
Revised: 2 August 2017
Accepted: 6 September 2017
Available Online: 18 September 2017

Keywords:

Multiple effect evaporation desalination system
Reverse osmosis system
Optimization

1- Introduction

The simultaneous use of thermal and osmosis technologies has gained wide acceptance in the past few years which a few numbers of which have focused on plants (METVC+RO). The basic challenge is how the METVC and RO should be combined with each other. Considering the limitations of previous studies and in continuation of previous researches [1,2], several possible configurations of METVC and RO have been first proposed in this study and then the optimum configurations of METVC and RO and the gas turbine cycle have been investigated to achieve the optimum amounts of the key thermodynamic parameters. The interaction of METVC and RO plants is studied as several configurations since the product and brine streams of both units are considered in various scenarios. Consequently, the optimum integration of METVC+RO hybrid desalination with a gas turbine cycle was investigated by two approaches with respect to total production capacity.

2- Methodology

The system under consideration comprises a gas power plant, a recovery boiler, METVC desalination, and RO desalination, a schema of which is shown in Fig. 1. Since the present paper does not intend to study the effect of power plant performance factors, the description of the power plant model is excluded. In particular, the integration between heat recovery steam generator (HRSG), METVC, and RO desalination units is discussed here.

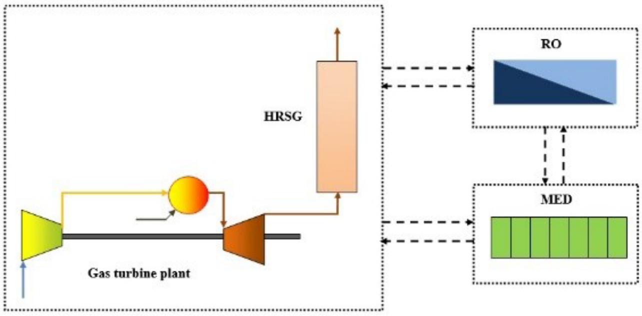

Fig. 1. A schematic diagram of the gas power plant, HRSG, METVC desalination, and RO desalination

2- 1- Hybrid (METVC+RO) desalination plants

The following points need to be considered while connecting METVC and RO desalination units:

- A rise in the RO feed water temperature leads to increased passage of mass flow rate through membrane modules.
- The cost and concentration of the fluid flows must be calculated from one module as a feed fluid to the next.
- The required electrical energy of the RO units is supplied by the gas turbine power plant.

Based on the inputs and outputs of RO and METVC desalination, as many as six configurations were proposed as following:

2- 1- 1- Configuration 1

In this configuration, the feed water of the RO system is the outlet water of the cooling system in METVC desalination. The main attributes of this configuration are the higher temperature of cooling water related to feeding water and its

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similar concentration to that of seawater

2- 1- 2- Configuration 2

The production temperature of METVC and Multiple Stage Desalination (MSF) units is significantly higher than feed water temperature. This high temperature of production causes many problems in water transfer. In RO units, all the processes occur at a constant temperature. There is a heat exchanger in which the RO feed water temperature increases as the METVC output temperature declines.

2- 1- 3- Configuration 3

The difference between this configuration and Configuration 2 lies in the inlet of the heat exchanger. There is a heat transfer between the RO unit feed water and the brine water of METVC.

2- 1- 4- Configuration 4

The brine water of METVC is directly utilized as feed water of the RO unit in Configuration 4. A partial or full mixture of METVC brine water with sea water leads to the desired concentration of RO unit feed water. This higher concentration influences the economic aspects of the system.

2- 1- 5- Configuration 5

Unlike the previous configurations, the brine water of the RO unit is mixed with seawater and utilized as feed water in the METVC system. The advantage of this configuration is that the METVC system is more efficient in the desalination of higher concentration brine water. In this configuration, the temperature of METVC feed water is similar to seawater temperature.

2- 1- 6- Configuration 6

To identify the advantages of METVC+RO systems without using METVC and RO separately, these systems are separately investigated. In this configuration, there is no mechanical and thermal connection between METVC and RO units.

2- 2- Objective functions

Performance ratio, cost of water and exergy efficiency of the combined system are the most important characteristics of under study system which selected as objective functions and must be maximized.

2- 3- Optimization approaches

In this approach, the level of METVC product is constant at 70000m^3/day. The level of RO product is 50%, 75%, and 100% of the METVC product. Achieving a high level of production by the METVC unit is the main purpose of this approach.

The levels of the RO products are restricted, and they are 35000, 52500, and 70000 m^3/day. Hence, the total products of the two units are 105000, 122500, and 140000 m^3/day, respectively.

In the second approach, the level of the METVC product is not constant, and the economic and thermodynamic aspects of the two units are investigated. The total levels of products are considered the limitation, and they are 105000, 122500, and 140000 m^3/day.

3- Results and Discussion

As it can be seen in Fig. 2, the product cost in the second approach has lower amounts. This is due to a decrease in METVC unit production and the increase in RO unit production that causes a decrease in the cost of the final product.

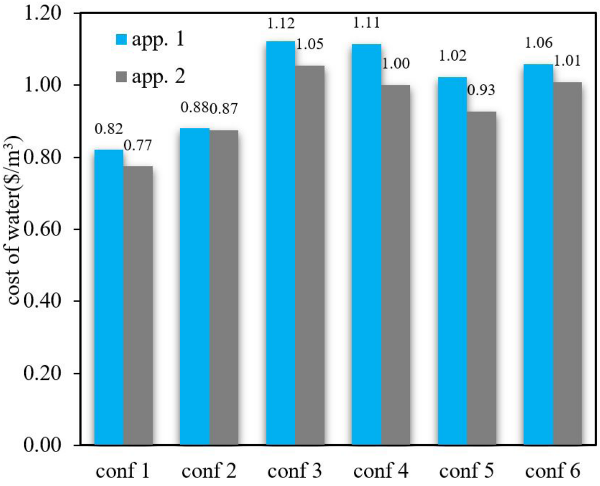

Fig. 2. The comparison of obtained freshwater price in 1st and 2nd optimization approach in the capacity of 105000 m^3/day.

The comparison of product cost in optimum solution of two approaches shows that in configuration 2 the cost of fresh water has partly same for both approaches due to the main share of METVC unit in fresh water in both.

Figs. 3 and 4 show the pareto front of multi-objective optimization processes. For better presentation, all pareto fronts are presented in a unique graph. Since minimizing the cost of the product and maximizing exergy efficiency are the objective function of the optimization process, configuration 1 is the best at first approach as well as the second approach.

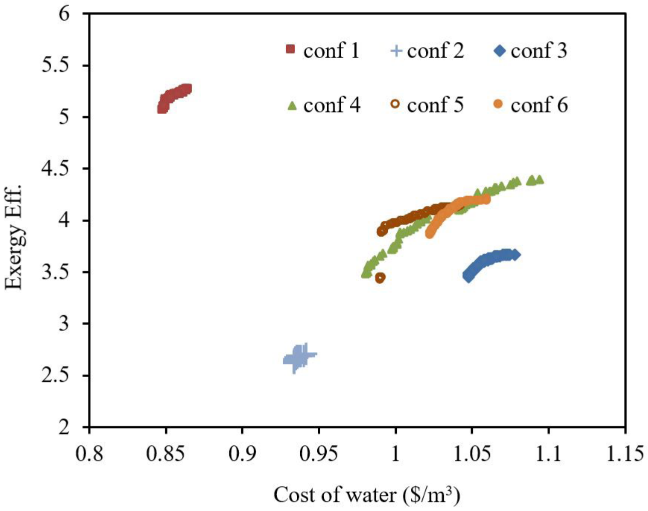

Fig. 3. Pareto front of Multi-objective optimization in the first Approach

On the other hand, after configuration 1, the Second configuration have the minimum cost of the product in both approaches, however, the value of exergy efficiency is the lowest value.

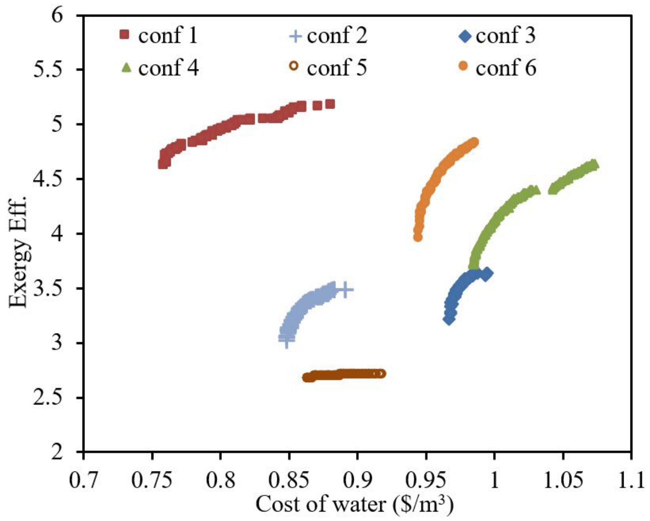

Fig. 4. Pareto front of Multi-objective optimization in Second Approach

4- Conclusion

The final conclusion shows that the first configuration could be chosen as the best one because it has the maximum value of exergy efficiency and a minimum value of the cost of water in both first and second optimization approaches. The second configuration had an acceptable status within different configurations because of its low cost of water although it had the lowest value of exergy efficiency.

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Please cite this article using:

S. E. Shakib, M. Amidpour, M. M. Ghafooryan, Optimization of a Hybrid Multi-effect Desalination with Thermal Vapor Compression and Reverse Osmosis Desalination System Integrated to A Gas Turbine Cycle, *Amirkabir J. Mech. Eng.*, 50(6) (2018) 1333-1350.

DOI: 10.22060/mej.2017.12982.5491