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Evaluation of MED system for desalination of Iranshahr steam power plant effluents using waste heat from boilers

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Abstract

Wastewater is one of the important source of pollution in industrial activities, including power plants. With control of industrial effluents, in addition to preventing its harmful effects, the consumption of water resources is also saved. Due to the high energy consumption of different desalination systems for the production of fresh water, as well as the thermal losses in power plants, a major part of the wastewater produced in power plants can be desalinated for reuse in processes that require water. In this study, the simulation of a multi-effect distillation (MED) unit for Iranshahr steam power plant is done in Thermoflow software, which requires thermal energy from the blowdown of boilers in power plant. Due to the presence of 870 m^3/day of wastewater from different power plant units, a MED unit with 12 effect with the ability to produce 290 m^3/day of fresh water per day is introduced. The steam consumption rate is 1.1 ton/h and Gain Output Ratio (GOR) and recovery ratio (RR) of the proposed system are 10.2, and 33%, respectivilya and the investment cost of the is 3290 $/$m^3$ of fresh water per day.

Keywords: Waste water desalination, Thermoflow software, Multi Effect Distillation, Steam power plant, Waste heat recovery.

1. Introduction

Nowadays, access to fresh drinking water has become a critical issue in many regions of the world, especially in hot and dry regions such as the middle east. Considering the energy consumption of water desalination operations, as well as the potential of different regions in terms of benefiting from appropriate solar radiation, application of sustainable sources is significant. Lower energy consumption or using waste energy from different industries will be a suitable choice, both economically and environmentally for fresh water production.

One of the main sources of energy and water wastage in power plants is the blowdown from the heat recovery boiler, which mainly constitutes 1-5% of the water in the cycle. Since the maximum impurity of waste water is 3500 ppm, it can be considered as quality waters. In addition, this water has high temperature (saturated water temperature at the pressure of the boiler drums), so a lot of energy is wasted without any recovery. Therefore, water recovery from the discarded water seems so significant.

Baccioli et al. [1] investigated different configurations of the combination of a small-scale MED system for seawater desalination to recover waste heat from the organic Rankine cycle (ORC). Goodarzi et al. [2] presented a technical and economic evaluation of a MED system that uses steam generated from flue gas waste heat. A study of exergy analysis and thermal economy of combined desalination system (MED) and Allam power generation system was done by Nazarzadehfard et al. [3]. The key advantage of their system is application of generated heat in power plant. Abdi-Khanghah et al. [4] designed an innovative multi-effect thermal vapor compression desalination device (MED-TVC) using mathematical modeling for installation in the Persian Gulf. Ghorbani et al. [5] investigated a parametric analysis and multi-objective optimization of a MED-TVC desalination system.

In most of the researches, the focus has been on the production of fresh water from the waste energy of power plants. And in less cases, the desalination of the wastewater in the power plant has been investigated by thermal losses. In the current research, the focus is on the Iranshahr steam power plant, located in the southeast of Iran, to desalinate its chemical effluents and effluents from cooling towers. By recovering a part of the wasted energy from Blowdown boilers, the reuired thermal energy for MED desalination unit is available. To simulate the considered process, Thermoflow software version 23 has been used and the best case scenario is presented.

2. information of IRANSHAHR steam power plant

Iranshahr steam power plant is located in Sistan and Baluchistan province. This power plant with a production capacity of 256 MW includes 4 steam turbine units of 64 MW. The three main effluents of Iranshahr power plant that are investigated in this research are saline effluent (Unit 10), cooling tower blowdown and boiler blowdown. The characteristics of these streams are shown in Fig. 1.

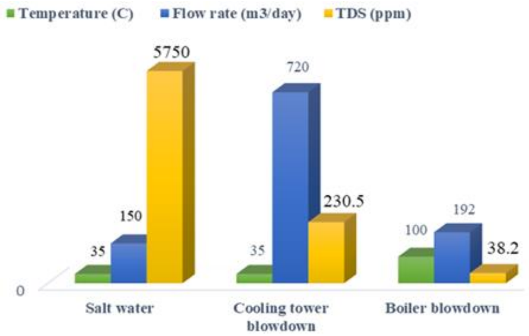

Figure 1. Characteristics of existing effluents in power plant

3. Simulation by Thermoflow software

Despite several different configurations for MED desalination, the simulation of the most common configuration Parallel/Cross Feed (PCF) is investigated in this simulation.

Several main parameters such as number of effect, inlet steam temperature and inlet steam flow rate and etc are nessaray to have a suitable simulation. In this research, the sensitivity analysis of each parameter is also done and finally, the best scenario is selected in terms of Gain output ratio (GOR) and recovery ratio (RR), according to the conditions of the power plant.

3.1. Number of effects

Due to the limitation in the amount of effluent flow in the power plant, the amount of cooling water consumed by the desalination plant is important. For this purpose, in addition to the flow of produced-fresh water, the amount of cooling water consumed by the desalination plant is given in the results.

The influence of number of effects on the GOR and required cooling water is shown in Fig. 2.

Increasing the number of effect causes the temperature difference between the input feed to each effect, and the temperature of each effect is reduced until the heat transfer is done well and improves the performance of the system. So, the thermal efficiency of the design also increases. Of course, if the number of stages increases, the initial investment costs is increased too. According to this figure, it can be seen that there is a direct relationship between the GOR and the increase in the number of effect. But the main limitation in the studied power plant is the amount of available cooling water or salt water. As shown in Fig. 1, the total amount of available cooling water is equal to 870 m^3/day.

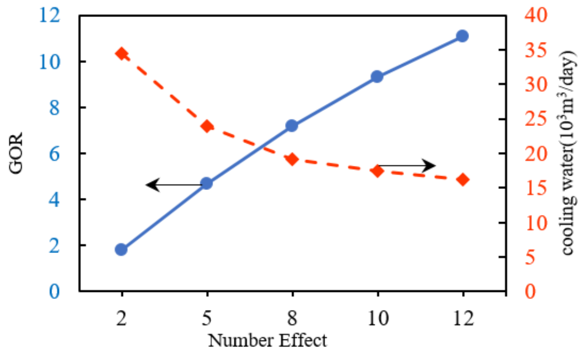

Figure 2. The variation of GOR and required cooling water versus the number of Effect

3.2. Inlet steam flow rate

The steam energy entering the system has a direct effect on its flow rate and temperature. In this way, reducing the input steam flow rate decreases the input energy to the system, and as a result, less energy is exchanged between the steam and the input feed to the effect.

Table 1. The effect of the inlet steam flow rate

STEAM FLOW RATE (m^3/day)	DISTILLED WATER (m^3/day)	COOLING WATER (m^3/day)	GOR
192	905	83980	
123	617	57456	4.7
86.4	406	38275	
54.1	258	23950	

According to the results obtained in Tab. 1, steam flow rate has no effect on the GOR of the system, but the amount of fresh water produced as well as the amount of cooling water consumed is directly related to the reduction of steam flow rate entering the system. If all the available (192 m^3/day) in the power plant is used, it is possible to produce more than 900 m^3 of fresh water per day with only with five effects, but the required cooling water is much more than the amount which is available in the power plant.

3.3. Final results and estimation of required investment cost

The modeling of the MED destillation has been done in the Thermoflow software to achieve the best results, and the final results are shown in Tab. 2.

According to the results presented in this table, the amount of produced-fresh water and required cooling water is 290 and 870 m^3/ day, respectively. Also, the consumption of steam flow rate is 1.1 ton/hour, which is about one seventh of the available steam blowdown of the power plant (8 tons/hour).

Table 2. The results of premier scenario

STEAM FLOW RATE (ton/hr)	DISTILLED WATER (m^3/day)	COOLING WATER (m^3/day)	GOR	RR (%)
1.1	290	870	10.2	33

To estimate the required investment cost in the proposed MED desalination system, Kosmadakis et al. [6] have presented the following equation:

$$C = 6291 \times D^{-0.135}\left[(1-0.8) + 0.8 \times \left(\frac{N}{8}\right)^{1.277} \times \left(\frac{70}{T}\right)^{1.048}\right] \quad (1)$$

In which, D is the capacity of the water desalination system in terms of m^3/ day, N is the number of effects , and T is the temperature of the available heat source. By applying the conditions of the premier scenario (capacity: 290 m^3/day, number of effects: 12 and heat source temperature: 100 ℃), the cost of the MED desalination plant is caculated to be around $954,000 which is equivalent to about $3,290 of capital cost per cubic meter of produced-fresh per day.

4. Conclusion

Due to the presence of various effluents in Iranshahr steam power plant, to compensate part of the water consumed by the power plant, the wastewater desalination system has been investigated by recovering part of the wasted thermal energy from the power plant. The summary of the results is as follows:

- Using all the available steam capacity of the power plant in the amount of 8 tons per hour is not operational, because in this case the required cooling water flow rate is much higher than the amount of wastewater available in the power plant.
- The scenario of using all the available salt water capacity in the amount of 870 cubic meters has been chosen as the selected scenario, because the consumption steam flow rate is 1.1 tons per hour, which is about one seventh of the available steam of the power plant (8 tons per hour).
- By returning the condensed liquid steam to the water cycle of the power plant, more than 26 cubic meters of water can be saved per day.
- According to the results of the selected scenario, 290 cubic meters of fresh water is produced per day in the MED desalination plant with 12 stages, which confirms the 33% recovery rate of the power plant's effluent. In addition, the efficiency coefficient of the proposed system has been calculated as 10.2.

5. References

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