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Techno-economical simulation and study of a novel MSF desalination process

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HIGHLIGHTS

- A novel MSF desalination configuration called “brine extraction” was investigated.
- An iterative, analytical mathematical model was developed to simulate MSF.
- The model was verified against the operating data of the 1 MIGD plant
- Brine extraction can be a worthwhile modification to typical MSF desalination plant

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ABSTRACT

Multi stage flash (MSF) desalination has proven to be the most reliable desalination technology for the Gulf region. As part of the continual quest for more sustainable and environment-friendly desalination technologies, this study investigates a proposed novel method for improving the thermodynamic and economic efficiency of MSF desalination. The proposed method has been tentatively named “brine extraction”. The technique involves extracting a part of the cooling brine from the water boxes and re-injecting this extracted brine directly into the flashing chambers; i.e. the extracted brine will not pass through the brine heater or high-temperature flashing stages. Economically speaking, brine extraction is expected to reduce the surface area of condenser tubes at the brine heater and high temperature flashing stages, and shift the vapor condensation heat load to lower temperature flashing stages, where a cheaper condenser tube material is used. More importantly, brine extraction is expected to reduce both the heating steam and the specific electrical power consumption of the MSF process.

A computer model of conventional MSF desalination was constructed and verified against the currently operational MSF plant “Ayoun Mousa” located in Egypt. After the computer model was validated, a model of a 16.2 MIGD brine recirculation MSF plant was constructed and its performance was studied with and without the novel configuration named “brine extraction”. Single-point brine extraction, where a single stream of brine is extracted, performed better than multiple-point brine extraction, where multiple streams are extracted at multiple points. Single-point brine extraction is also favored because it will cause minimal increase in complexity and reduction in the robustness of the MSF process, as only a single stream of brine will be redirected. At the optimum extraction ratio of 9%, single-point extraction yielded a 7.23% increase in gain output ratio (GOR), a 3.47% decrease in electrical consumption, and a 3.90% decrease in total cost. Although the reduction in the cost of water is marginal, the reduction in electrical consumption and improved GOR indicate that the implementation of brine extraction at high top brine temperature (TBT) could be a promising technology in the case of solar-powered MSF, where the high expense of supplying thermal and electrical energy has been the most prohibitive factor.

1. Introduction

Desalination, the process of separating dissolved salts from brackish water or seawater, is growing in popularity. 97% of the Earth's water is seawater, and natural fresh water resources are scarce by comparison. As such, the ability to convert saline water into fresh water has been met with great interest worldwide. Many countries around the world now find themselves turning to desalination to meet freshwater needs for agriculture, industry, human consumption, sanitation, and so on. This is especially true for the Gulf region, where natural sources of freshwater are very scarce, and salt water is abundant, causing the Middle East to account for 65% of global desalination capacity [1].

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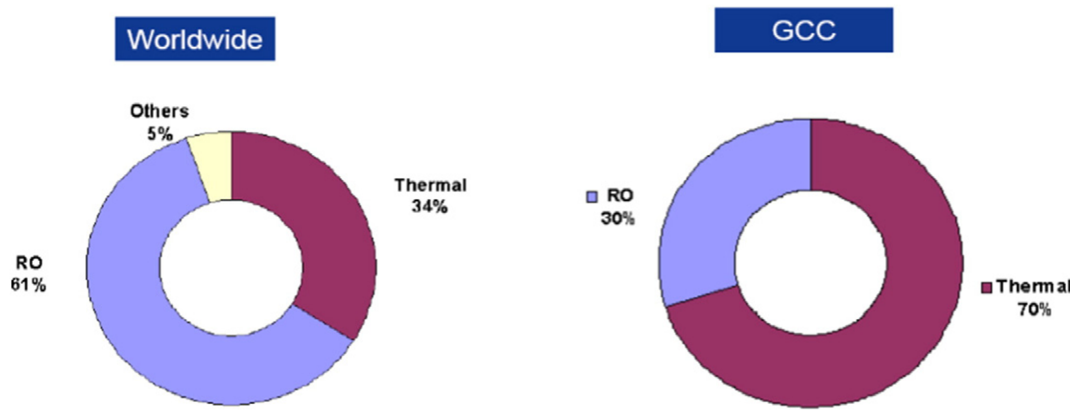

Fig. 1. Desalination capacity per desalination technology.

Thermal desalination is particularly popular in the Gulf Cooperation Council (GCC) countries as shown in Fig. 1, with MSF desalination alone accounting for 45% of the total desalination capacity, making MSF desalination the predominant desalination technique in terms of water production in GCC countries [2]. In the UAE in particular, thermal desalination accounts for a large percentage of total desalination expenses. A market forecast of the UAE's desalination expenses shows that by the year 2016, thermal desalination will account for 51% of all of the country's desalination expenses [2].

However, as MSF desalination remains one of the most popular desalination technologies worldwide, its energy consumption and greenhouse gas emissions are substantial. Only 13% of MSF technologies are powered by solar energy worldwide, with the remaining 87% being largely powered by fossil fuels [3]. MSF desalination requires large amounts of thermal and electrical energy, which solar power has been unable to provide affordably thus far-solar-powered MSF has, in some cases, been ten times as expensive as fossil fuel-powered MSF, purely due to the increased cost of energy [4].

As part of the efforts at Masdar Institute to promote sustainability and clean energy, this work investigates a novel MSF configuration called “brine extraction” that, as described by Fath [5], is expected to improve the efficiency of the MSF process both from an economic perspective and thermodynamic perspective. Most importantly, this novel configuration is expected to reduce energy consumption by the MSF process, which is anticipated to make the integration of solar power with MSF desalination more cost effective.

2. Research conducted

2.1. Thermal modeling of MSF with brine extraction

The vapor production in a conventional MSF plant decreases across the flashing stages due to the increase in latent heat and thermodynamic losses. For example, the vapor production across the recovery section of the Ayoun Mousa desalination plant in Egypt is shown in Fig. 2. This trend is common in all MSF plants. The production is higher at the high-temperature stages, meaning that the vapor condensation load is highest at the initial stages, where condenser tubes are made of more expensive material. The proposed MSF configuration with brine extraction, shown in Fig. 3, aims to shift this region of high production and high condensation load to the lower temperature stages, whose condenser tubes are made of less-expensive material.

Brine extraction will work as follows: a certain percentage of the brine recirculate will be extracted from the condenser tubes of the high-temperature flashing stages, and injected directly into the flashing chambers of the low-temperature stages. In other words, the extracted brine will not pass through the brine heater. Brine extraction shifts the vapor generation and condensation heat load to lower temperature flashing stages, where a cheaper condenser tube material is used. Economically speaking, brine extraction is expected to reduce capital expenditures (CAPEX) by reducing the surface area of condenser tubes at the high temperature flashing stages and brine heater. Brine extraction is also expected to reduce operating expenditures

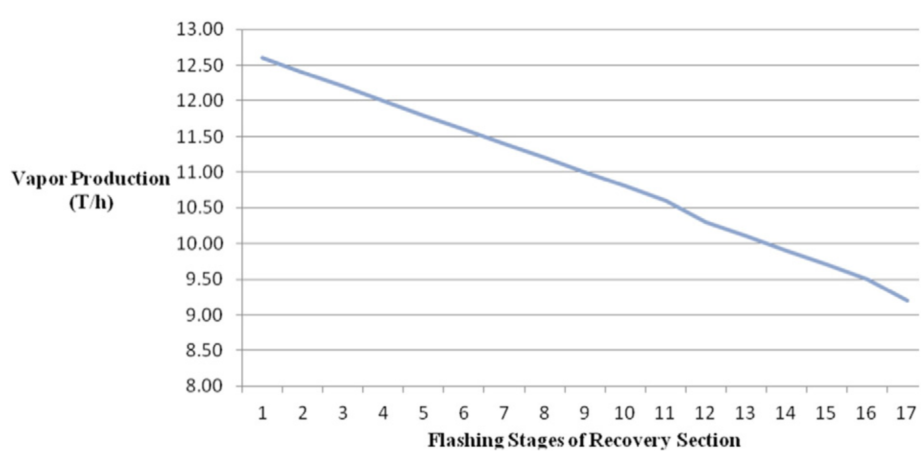

Fig. 2. Vapor production trend for the recovery section of the Ayoun Mousa MSF plant in Egypt.