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Energy saving methodology for the SWRO desalination process: control of operating temperature and pressure

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Abstract

This study proposes a new operation methodology for energy saving in the Fujairah seawater reverse osmosis (SWRO) plant, as the optimum feed pressure is determined at the controlled operating temperature. To this end, two functional models were developed by genetic programming (GP) using two-year operational data. The data revealed that the required feed pressure for the plant operation was potentially overestimated. Based on the developed models, simulation of a three-step sequential control was carried out to reduce and optimize the required feed pressure. The simulation results first indicate that the temperature control significantly reduces the required feed pressure at a reasonably high temperature. Second, as the permeate water flow rate (PFR) is determined by the optimized feed pressure instead of the permeate pressure actually used to maintain a steady PFR in Fujairah, the required feed pressure could be substantially reduced. As a result, the proposed methodology can potentially reduce the required feed pressure, by approximately 10 bar, under

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the identical performance of both PFR and permeate water total dissolved solids (TDS). This study implies that the optimization of operation and management of MSF-hybridized SWRO processes can considerably improve the efficiency of the desalination process in terms of energy and, eventually, cost saving.

Keywords: Seawater reverse osmosis (SWRO); Desalination; Optimization; Required feed pressure; Temperature correction factor (TCF); Genetic programming (GP)

1. Introduction

Due to increases in population and environmental pollution, water shortage is becoming an evermore serious global problem. In addition, the costs incurred by conventional drinking water production have also been increasing due to the deterioration of freshwater resources (i.e., rivers, lakes, and groundwater). Accordingly, humans have started to focus more on seawater, with more than 97% of the total amount of water on Earth, as a means of supporting insufficient freshwater resources. Current desalination processes for converting seawater to freshwater, i.e., seawater reverse osmosis (SWRO) and multistage flash (MSF), have been used as alternative means of securing water resources. Especially, since the cost of water production using SWRO desalination processes is gradually decreasing due to advances in desalination technology [1], compared to MSF processes, SWRO has become a popular solution for increasing the water supply.

To improve the SWRO process efficiency, a number of studies have been conducted to investigate factors affecting process performance, such as operating pressure, operating temperature, concentration polarization, degree of fouling and scaling, water quality, and specific membrane characteristics [2–6]. In particular, it is believed that the operating pressure and temperature can be used as controllable factors to improve process performance as the net driving pressure (NDP), which is strongly influenced by the operating pressure, is capable of controlling the permeate water flow rate (PFR) [6]. Also, the operating pressure can affect the total dissolved solids (TDS) in the permeate; in a previous study [7], it was shown that the operating pressure could be reduced by controlling the expected permeate TDS. However, the study did not consider the temperature effect on the SWRO process, as an increase in the operating temperature causes corresponding PFR and permeate water TDS increases due to a decrease in water viscosity [7,8]. This result implies that there is potential to further reduce the operating pressure at a reasonably high temperature under identical PFRs.

Therefore, this study focuses on controlling both the operating temperature and pressure as a means of optimizing the Fujairah SWRO process, and saving energy. To simulate the process performances (i.e., the PFR and permeate TDS) according to the operating conditions, two functional models based on two-year operational data sets were generated using genetic programming (GP). To determine the optimized feed pressure, simulations of three-step sequential controls were carried out by adding the PFR control and then removing the permeate pressure control as the main control of the operating temperature, using the generated models.

2. Materials and methods

2.1. Data description

The Fujairah desalination plant in the United Arab Emirates (UAE) is currently one of the largest desalination plants in the world and can produce 100 MIGD (454,000 m^3/day) of freshwater as a hybrid system consisting of MSF (62.5% of total freshwater production)