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Modeling seawater reverse osmosis system under degradation conditions of membrane performance: assessment of isobaric energy recovery devices and feed pressure control benefits

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ABSTRACT

A transient model of seawater reverse osmosis (SWRO) system enables systematic assessment of membrane performance in response to changes in time-series parameters, operating conditions, or ancillary equipment. In this study, we describe the effects of energy recovery device (ERD) and feed pressure control on the SWRO plant in terms of energy consumption (reduced) and water quantity (increased) using a numerical model at pilot scale. In the simulation, two types of isobaric ERD, i.e. pressure exchanger (PX) and dual work exchanger energy recovery (DWEER), were used to quantify changes of the mass flow rates of inflow and outflow in the system. Also, temporal variation in the raw feedwater quality was addressed in the model with adaptive feed pressure control to maintain the amount of produced water under fouled membrane conditions. Results showed that the observed recovery and rejection rates in the pilot-scale plant had an excellent agreement with their predicted values under different seawater feed concentrations varied over a year (NSE = 0.9990 and 0.9987, respectively). Both PX and DWEER were found to affect the concentration and stream of influent directed to the reverse osmosis module, in which PX showed slightly higher recovery rate than DWEER that had the volumetric flow loss of the pressurized feed. While water quality and quantity of the permeate declined progressively in non-steady state simulation of membrane fouling, increasing the feed pressure linearly improved the performance of the pilot plant, higher recovery rate and lower energy consumption than a constant pressure mode. Therefore, this study demonstrates that the dynamic simulation model for the SWRO system not only describes deterioration of membrane performance at the pilot scale, but also can be used to search alternative devices and operation modes that achieve water quality and quantity targets with efficient energy use.

Keywords: Seawater reverse osmosis; Energy recovery device; Feed pressure control; Membrane fouling; Energy consumption

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