A Novel Approach for Targeting and Optimal Design of Efficient Seawater Reverse Osmosis Desalination Networks

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Seawater reverse osmosis (SWRO) desalination processes are widely used. The optimal design of such systems resembles a network synthesis problem and has been addressed using superstructure optimization approaches. However, to date these approaches suffer from a limited ability to identify structurally distinct design alternatives, despite requiring significant computational times to determine globally optimal solutions, even for simple cases involving superstructures of only two membrane units. Moreover, existing approaches do not adequately take into consideration water quality information to keep the optimization problems solvable within reasonable times. However, SWRO design strongly depends upon the quality of the feed water and the product water specifications. This casts doubt about the relevance of the results obtained from current superstructure optimization approaches. This paper introduces a novel approach to optimal SWRO design that addresses the major shortcomings of previous approaches.

We introduce a novel SWRO synthesis approach, based on the coordinated use of process superstructure representations and global optimization. The approach determines globally optimal solutions to the SWRO network synthesis problems from optimization of full superstructures. It further supports design engineers with a better understanding of the design space and trade-offs between complexity and efficiency. This is achieved through reduced superstructures of distinct design classes. The approach takes into consideration all relevant process conditions and constraints typically associated with SWRO systems. Thermodynamic insights have led to lean superstructure representations throughout which can be solved within short computational times.

In contrast to previous approaches that consider sea water to consist of two components only, i.e. “water” and “salt (TDS)”, our superstructure models account for detailed water quality information to ensure practicality. The models capture the performance of the most commonly used membrane elements, as predicted by commercially used simulators including ROSA (Dow) and IMSDesign (Hydranautics) and allow tracing of individual components throughout the system. A detailed economic assessment captures all the significant capital and operating costs associated in SWRO processes, including intake, pre and post treatment.

The approach is illustrated using a case study involving four different seawater qualities for which design targets and optimal designs are obtained within short CPU times.