Simultaneous Water and Energy Optimization in Large Scale Systems

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Abstract

Water and energy are key resources in the process industry. The water-energy nexus considers the interdependence of water and energy resources and their effect on the environment. The increasing awareness of environmental regulations has heightened the need for process integration techniques that are environmentally benign and economically feasible. Process integration techniques within water network synthesis require a holistic approach for the sustainable use of water through reuse and recycle and regeneration reuse and recycle.

Conventional methods for water minimization through water network synthesis often use the "black-box" approach to represent the performance of the regenerators. The degree of contaminant removal and cost of regeneration are represented by linear functions. This, therefore, leads to suboptimal operating conditions and inaccurate cost representation of the regeneration units.

This work proposes a robust water network superstructure optimization approach for the synthesis of a multi-regenerator network for the simultaneous minimization of water and energy. Two types of membrane regenerators are considered for this work, namely, electrodialysis and reverse osmosis. Detailed models of the regeneration units are embedded into the water network superstructure optimization model to simultaneously minimize water, energy, operating and capital costs. The presence of continuous and integer variables, as well as nonlinear constraints renders the problem a mixed integer nonlinear program (MINLP). The developed model is applied to two illustrative examples involving a single contaminant and multiple contaminants and one industrial case study of a power utility plant involving a single contaminant to demonstrate its applicability. The application of the model to the single contaminant illustrative example lead to a 43.7% freshwater reduction, 50.9% decrease in wastewater generation and 46% savings in total water network cost, which include energy considerations. The multicontaminant illustrative example showed 11.6% freshwater savings, 15.3% wastewater reduction, 57.3% savings in regeneration and energy cost compared to the water network superstructure with "black-box" regeneration model. The industrial case study showed a savings of up to 18.7% freshwater consumption, 82.4% wastewater reduction and up to 17% savings on total water network cost.