



INDIAN INSTITUTE OF TECHNOLOGY GUWAHATI  
SHORT ABSTRACT OF THESIS

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Programme of Study : Ph.D.

Thesis Title: **Optimal Design of Multi-stage Flash (MSF), Reverse Osmosis (RO) and Hybrid MSF-RO Seawater Desalination Processes Using Differential Evolution Algorithm.**

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**SHORT ABSTRACT**

The Ph.D. thesis attempts to provide a cost (minimal freshwater production cost) based rank guideline for alternate MSF, RO and hybrid MSF-RO process configurations. Alternate process configurations include 3 MSF configurations (MSF-BR, MSF-OT and MSF-M processes), 6 retentate reprocessing RO configurations (SRO, TRO-RSR, TRO-RP, TRO-SRB-RR, TRO-SFRB and TRO-SFRR processes), 5 permeate reprocessing RO configurations (TRO-PSR, TRO-SFB-PR, TRO-PBPR, TRO-SFPB-PR, TRO-TSRP-PR processes), and 20 hybrid MSF-RO process configurations (hybrid 1 – 20 processes). Among optimization methods, the thesis deliberates upon the efficacy of differential evolution (DE) algorithm as a potential non-deterministic optimization technique with respect to other non-deterministic (simulated annealing (SA), genetic algorithm (GA)) and deterministic (sequential quadratic programming (SQP) and multi-start SQP (MS-SQP)) optimization techniques and their combinations (DE-SQP and GA-SQP techniques). While coded DE algorithm was adopted for the seawater desalination process optimization study, MATLAB built in optimization toolbox solvers have been adopted for SA, GA, SQP, and MS-SQP optimization methods to enable the comparative assessment of the alternate process networks. Non-linear programming (NLP) optimization models have been formulated for identified alternate networks with freshwater production cost as objective function. In addition, the thesis also focused upon sensitivity studies with respect to variations in operating (feed concentration and top brine temperature) and cost parameters (steam, o&m, chemicals, membrane replacement cost multipliers etc.,).

Among various combinations of MSF processes and optimization methods, the MSF-BR process and DE algorithm have been identified to provide lowest freshwater production cost of 1.0785 \$/m<sup>3</sup>, which is marginally better than the value reported in the literature (1.104 \$/m<sup>3</sup>). Similarly, for alternate retentate reprocessing seawater desalination RO networks, TRO-SFRR process configuration has been evaluated to provide lowest freshwater production cost (0.9084 \$/m<sup>3</sup>), which is lower than that reported in the

literature for SRO process (1.0108  $\$/\text{m}^3$ ). Among RO networks with permeate reprocessing schemes, TRO-TSRP-PR process provided lowest freshwater production cost using DE algorithm (0.9529  $\$/\text{m}^3$ ). Among various combinations of hybrid MSF-RO processes (hybrid processes 1 – 20), it has been analysed that hybrid 14 process configuration provides minimal freshwater production cost (0.9421  $\$/\text{m}^3$ ). Compared to the DE, all other optimization methods provided either inferior or infeasible optimal solutions.

Thus, based on extensive optimization studies for various alternate MSF, RO and hybrid MSF-RO seawater desalination processes, the minimal freshwater production cost based hierarchy is TRO-SFRR > TRO-RSR > TRO-SRB-RR > Hybrid 14 process > TRO-TSRP-PR > SRO etc., Thus, it can be inferred that retentate reprocessing RO networks can be evaluated to be competitive on an economic basis with respect to hybrid MSF-RO processes and even the conventional SRO process. Further, it has been confirmed that the MSF-BR process is ranked 27 among the considered 34 process configurations. Considering that all solutions obtained are close to the global optimal domain, the solutions reported in the Ph.D. thesis could serve as useful benchmarks and guidelines to further research in the vast field of global optimization of MSF, RO and hybrid MSF-RO seawater desalination for processes using non-deterministic optimization techniques such as DE.