Innovative design of hybrid flash desalination plants

LENI Systems

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GOAL:

The purpose of this work is to develop a decision support tool, which will systemically assess the advantages of hybrid desalination configurations (integration between thermal and membrane technologies) by investigating and optimizing these configurations as a function of project requirements and local conditions.

METHODOLOGY:

- Establish a database of up-to-date models of desalination technologies
- Perform a systematic generation of integrated hybrid desalination configurations
- Evaluate the proposed configurations with accurate performances indicators
- Optimize the design of these desalination configurations in a multi-objective framework

INITIALIZATION:

- Definition of context and project requirements
- Definition of performances indicators and objectives
- Definition of suitable desalination equipments

Multi-objective framework

- *Technical performance indicators (efficiency, energy consumption…)*
- *Environmental performance indicators (GHG emissions, water use…)*
- *Economic costs (investment and operating costs…)*

Reverse Osmosis Pressure Vessels

Local context and project requirements

- *Capacity and quality needed of desalinated water*
- *Amount and quality of local energy and water resources*
- *Project local constraints and conditions (plant location, energy cost,…)*

List of desalination equipments

- *Thermo-dynamic models of the technologies*
- *Multi-stage flash distillation* ***(MSF BR)*** *(Heat Recovery and Heat Rejection section)*
- *Brackish water Reverse Osmosis* ***(BWRO)***
- *Seawater Reverse Osmosis* ***(SWRO)***

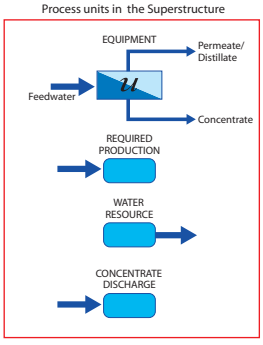
GENERATION OF SOLUTIONS:

- Hybrid desalination configuration defined by:
  - the choice of desalination equipments
  - the sizing of these equipments
  - the interconnecting piping network
- Systematic generation within a flexible Superstructure of all the feasible configurations which respect the project requirements
- Linear modelling of the Superstructure defined by a set desalination equipments implemented as **process units**

Constraints

- *Water needs and resources modelled as process units*
- *Mass conservation of salt and water in the equipments and in the water pipes*
- *Technical constraints for equipments*

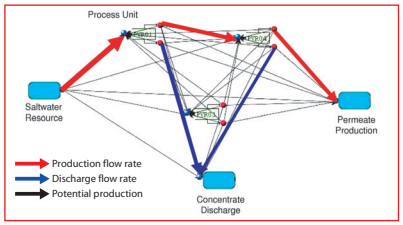
Process units in the Superstructure



Superstructure

- *Inputs and outputs of each equipment characterized with a salinity, temperature, pressure and flow rate*
- *Calculation of investment and operating costs, heat and power consumption*
- *Solving of the Superstructure with the minimization of a linear objective function*

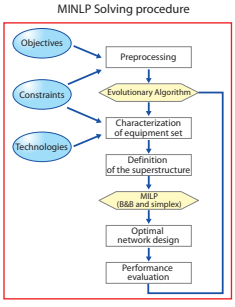
Example of Superstructure with one feasible hybrid desalination configuration displayed



OPTIMIZATION:

- Formulation of the design synthesis and optimization problem as a Mixed Integer Non Linear Programming (**MINLP**) Problem
- Resolution by decomposition into:
  - a Master **Non Linear Problem** (optimization of equipments) solved with evolutionary algorithm,
  - a Slave **Linear Problem** (optimization of sizing and piping network), solved with conventional mixed integer linear programming algorithms.
- Multi-Objective Optimization (MOO) of the configurations based on the performance indicators (specific cost in €/m^3 and water resource conversion rate in m^3 of desalinated water per m^3 of seawater)
- Optimal solutions represented by points on the so-called **Pareto curve**

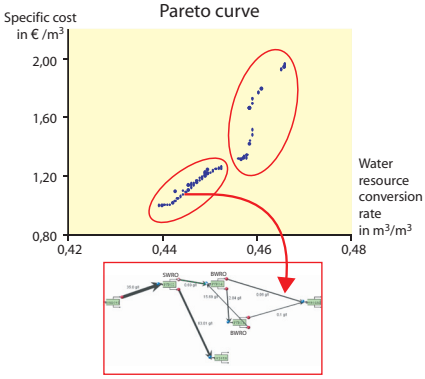
MINLP Solving procedure



CASE STUDY:

- Seawater quality: 35000 ppm
- Capacity desired: 40000 m^3/day
- Permeate quality: 100 ppm
- Objectives: Annual costs and water conversion rate

Pareto curve



Point of the Pareto curve defining an optimal desalination configuration

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