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Energy consumption of reverse osmosis seawater desalination — possibilities for its optimisation in design and operation of SWRO plants

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ABSTRACT

Seawater desalination with reverse osmosis has taken a noteworthy upturn in recent years. One of the reasons for the success of the membrane process is its lower energy consumption in comparison to the thermal desalination processes. Due to advances in the efficiency of energy recovery systems of the seawater desalination stage (1st pass) of SWRO – plants in the last decade this advantage of membrane processes has even increased. Now, however, the energy consumption of an SWRO is also influenced by a huge number of additional factors. These are of an external nature as well as determined by design and configuration of the plant. Environmental conditions and – stipulations dependent on the location of the plant and furthermore the influence of operating modes are additional factors. The individual systems of an SWRO plant – in particular its pre-treatment stage as well as its first and second passes are very closely cross-linked systems in regard to its energy consumption. During energy optimisation in design and operation of an SWRO besides the choice of the manner of the energy recovery in the 1st pass special attention must also be directed to the pre-treatment process and the interaction of these systems. Ways to optimize design and operation of a seawater reverse osmosis plant under the aspect of lowering its energy consumption are investigated. After listing the basic design parameters for SWRO engineering, additional system design features and configuration aspects for of pre-treatment and RO systems influencing its energy consumption are identified and their degree of influence discussed. With a technical design framework optimized for low energy consumption an exemplary SWRO system of commercially size is developed. This plant is investigated concerning the range of its specific energy consumption at different seawater feed conditions. Then additional options for energy saving during operation of the SWRO are examined. Finally it is shown, what cost saving potential is generated by a certain range of energy saving margins under plant lifecycle aspects. For plant design and determination of the specific energy consumption of the SWRO, an SWRO plant calculation and design model was used, which covers different pre-treatment and RO configurations and the design and energy consumption of the SWRO plant systems including potabilisation and subsystems like additional wastewater treatment and sludge dewatering facilities of an SWRO. A characteristic SWRO plant size (20,000 m^3/d net output capacity) and configuration (two pass RO system) was selected for modelling purposes. With the most efficient energy recovery system, the work exchanger specific energy consumption under themodelling conditions for the 1st + 2nd RO parts of the SWRO plant is in between of about 3.6 to nearly 4.0 kWh/m^3. The Turbocharger energy consumption is about 0.5 kWh/m^3 higher, such of Pelton turbine about 0.7–0.8 kWh/m^3 more. The overall consumption of

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an SWRO plant of this system configuration with various types and efficiencies of pre-treatment, a two pass RO part and treatment of process wastewater and sludge dewatering adds up to between 3.9 and 5.6 kWh/m^3, depending on feed temperature and type of pre-treatment and energy recovery systems. Considering the various aspects to be taken into account for optimization of energy consumption in seawater reverse osmosis plants and the fact, that in most cases these measures are offset by increases in capital costs for equipment or possibly also in chemical consumption, optimisation of the energy consumption of SWRO plants during planning and operation is a quite extensive and complicated matter and a demanding engineering task.