Energy analysis of electrodialisys with bipolar membranes for chemicals production

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Introduction. Electrodialysis with bipolar membranes (EDBM) is an emerging electro-membrane process suitable for the simultaneous production of acid and base streams. Its environmentally friendly nature together with the wide application fields of its products have recently increased the attention toward this process [1].

EDBM can be employed for *in situ* production of chemicals, reducing transportation, handling and storage costs and burdens, but also integrated with other technologies into circular approaches for the valorization of residual streams, recovering high value materials and minimizing discharged volumes. Notwithstanding these promising aspects, reduced performances were registered in some cases [2], especially for high chemicals concentration targets. This suggests that EDBM should be employed preferably when diluted acid and base streams are needed (below 5 wt.% in the case of sodium hydroxide and hydrochloric acid) and that more effort should be dedicated in selecting the process conditions and plant configurations minimizing energy consumption.

The aim of the present work is to study EDBM behavior in different process configurations (both continuous and discontinuous) and to energetically characterize it to choose the most appropriate configuration depending on products requirements and process capacity.

Methodology. A fully validated distributed parameters multi-scale model [3] was employed to simulate three different process configurations, namely open-loop, closed-loop and feed & bleed. The model is capable of predicting also non-ideal phenomena, such as concentration polarization, undesired fluxes (i.e., osmotic, diffusive and electroosmotic) and current leakages via manifolds. The configurations were studied under different conditions (i.e., process capacity and target concentrations) and compared in terms of the energy use efficiency fixing final products target and salt conversions.

Results and discussion. Results demonstrated that the open-loop configuration shows the best performances at low target concentrations and process capacity, due to the absence of back-mixing effect between outlet products and inlet streams, which cause irreversible dissipative phenomena. However, at high target concentrations, elevated current densities or reduced channel velocity in the stack should be adopted, which, in turn, lead to a significant performance reduction. Instead, feed & bleed turns to be the most competitive at high target concentration and medium-high capacity, due to the increase in current utilization, as the current density rises. Finally, the closed-loop configuration results the most flexible in terms of process capacity, but shows lower performance with respect to the other two configurations. This can be related to the high impact of chemical energy losses due to mixing phenomena in the solutions tank.

This analysis can guide the selection of the most appropriate process configuration to reduce energy consumption, also highlighting the most relevant features for EDBM process coupling when variable sources of energy have to be adopted, such as renewable energies or smart grid integration.

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