Modelling of Electrodialysis with Bipolar Membranes processes using a hybrid model supported by Artificial Neural Networks

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Sustainable production of acid and alkali solutions

Concept

Acid and base solutions, such as hydrochloric acid and sodium hydroxide, are widely produced bulk industrial chemicals. Their applications range from within the chemical industry to the water treatment and food industries. In many cases, dilute solutions are utilized with concentrations in the range 1-5 wt. %. To reduce transportation costs, especially in remote areas, and to minimize storage as well as the handling of hazardous chemicals, it is crucial to find sustainable processes for their in situ production and to develop efficient computational methods to ensure optimal operation.

ElectroDialysis with Bipolar Membranes (EDBM) is an innovative and effective process for the simultaneous production of acid and base solutions from salt solutions. This process uses monopolar ion exchange membranes, i.e., cationic and anionic membranes, but also bipolar membranes. When an electric field is applied to the membranes, the selective movement of the ions is accomplished and water dissociation, into protons and hydroxide ions, is promoted inside the bipolar membranes. The production of acid and base is obtained in different compartments as well as effecting the desalination of the salt stream.

Scientific approach

Firstly, an extensively experimental campaign was carried out with an EDBM semi-industrial unit (total membrane area of 19.2 m^2). The aim of this phase is to characterize the system in different operating conditions and process configuration (both continuous and discontinuous). Secondly, a mechanistic model was developed, started from a previous published model, considering the main features of a real large-scale system. The model was validated in two different process configurations using experimental results obtained from the first phase. Discrepancies between model and experimental results in the range of 2-11% were obtained.

Furthermore, recurrent and non-recurrent neural network were tested to model EDBM in both dynamic and stationary conditions, respectively. The discrepancy between experimental data and the model predictions resulted in a very low Mean Squared Error (MSE) demonstrating the good performance of this kind of network in describing complex nonlinear electro-membrane systems.

Research objectives

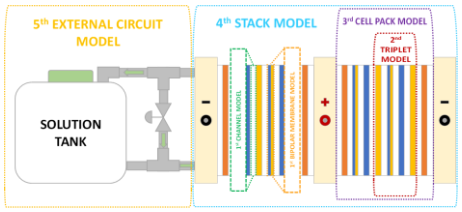
To compare the two different approaches, highlighting advantages and disadvantages, as well as to combine them into an hybris model to get the advantages of both, maintaining elevated prediction capability along with reduced computational demand.

The EDBM process will be extensively analyzed and optimized employing the different kind of model developed.

Large scale EDBM units

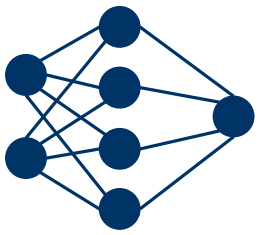
Modelling ↕ Optimization

Mechanistic model



gPROMS

Empirical model



MATLAB®

Hybrid model