Dynamic modelling of electrodialysis with bipolar membranes unit using NARX recurrent neural networks

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Acid and base solutions, such as hydrochloric acid and sodium hydroxide, are widely produced basic 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 to 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 in the face of uncertainties and the need for agile production schedules.

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. For a target concentration of 1 mol l^{-1} of sodium hydroxide, a current efficiency between 60-80 % and specific energy consumption of between 1.4-2.6 kWh kg^{-1} were obtained at pilot scale [1].

The adoption of such technology at industrial scale requires reliable modelling tools capable of predicting both dynamic and stationary operations as process inputs vary e.g. energy supplied to the system and the target concentration of chemicals. Nonlinear Autoregressive models with Exogenous inputs (NARX) neural networks have been successfully implemented in many dynamic systems with complicated nonlinearities [2].

The present work applies, for the first time, NARX neural networks to EDBM systems in order to predict the behaviour under various operating conditions. The model predicts the main variables of the system, i.e., solution concentrations and the voltage that should be applied to the membrane stack. Experimental data collected at the pilot plant scale (19.2 m^2 of total membrane area) were used to validate the model. 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.

The paper will describe a general procedure to apply NARX models to dynamic nonlinear systems, necessary to avoid instability issues, based on the experience gained from this work.

References

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