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Ion exchange membrane deformation and its relevance in reverse electrodialysis

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Reverse electrodialysis (RED) is an innovative electro-membrane technology for electric energy generation from two salt solutions with different concentration. This different concentration is the driving force to a selective movement of ions from the concentrate channel to the dilute one oriented by Ion Exchange Membranes (IEMs). Typically, RED stack are made by piling alternatively cation exchange membranes and anion exchange membranes with the aid of spacers or profiles built on the membrane surface. Two electrodic compartments are placed at the two ends of the stack, where the ion flux generated is converted into an electric current able to circulate through an external load connected to the stack.

Several studies have been recently focused on the RED process optimization with the aim of increasing the net power density produced. On the one hand, the geometries and the hydraulic losses relevant to spacers, the fluid dynamics behavior of the solutions into the channels and the electro-chemical phenomena in the stack have been thoroughly analyzed. On the other hand, membrane deformation has been poorly studied, despite membrane deformation may strongly influence the performance of RED units by affecting shape and dimension of the channels, thus changing their hydraulic losses and electric resistance.

In the present work, an experimental and theoretical assessment of the deformation of a class of IEMs has been carried out, through a combined approach involving theoretical analysis, numerical modelling and experimental campaign focused on the characterization of IEMs under typical RED operation conditions. A Finite Element Method model was developed and experimentally validated allowing for a detailed prediction of membrane deformation within the RED stack and for an effective integration with a separately developed multi-scale modeling tool able to predict the power generation performance of a RED unit.

The effect of different channel configurations and operating conditions on membrane deformation and, consequently, on pressure drops and electrical variables characterizing the RED operation is thoroughly investigated and presented.

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