New Procedures and Operational Aspects for Applying Ultracapacitors in Water Treatment Processes: Capacitive Deionization

E. García-Quismondo[1], C. Santos[1], J. Palma[1], and M. Anderson[1,2]

[1] Electrochemical Processes Unit, IMDEA Energy Institute, Ave. Ramón de la Sagra 3, Mostoles Technology Park E28935 – Mostoles (Madrid) SPAIN

[2] Environmental Chemistry & Technology Program, University of Wisconsin-Madison, WI, USA 53706
nanopor@wisc.edu

Capacitive Deionization (CDI) is an electrochemical process that allows one to desalinate water while simultaneously storing energy in an easy-to-use, cost-effective and environmentally friendly manner. The key to CDI (see Fig. 1) is the adsorption of charged species in the electrical double layer of an electrode upon polarization by a Direct Current power source [1]. In the regeneration step, a wash solution is circulated while the electrodes are depolarized, so that ions are desorbed from the electrodes and pass into the bulk of the solution, resulting in a stream of higher concentration. These two stages are essentially the same as charging and discharging an electrochemical double layer capacitor [2].

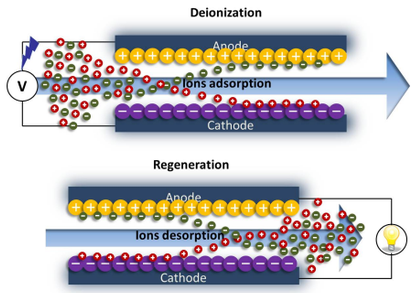

Figure 1. Capacitive Deionization showing deionization and regeneration steps.

However, the fact of using circulating water solutions instead of an ideal electrolyte, and the need for replacing the electrolyte when the deionization finishes and regeneration starts, provokes certain anomalies not previously found in electrochemical capacitors, particularly with respect to energy recovery.

Furthermore, it is appropriate to consider an operational mode of replacing the electrolyte when deionization finishes and regeneration begins. This is defined by a deionization stage where the liquid flowing through the system is an untreated water that may show high electrical resistivity, and therefore its ability to conduct electric current will be low (let us say low I_{charge}). This stage has to be followed by a regeneration step where the fluid is a concentrated washing solution showing good electrical conductivity allowing high $I_{discharge}$ [3].

This asymmetric operational procedure for CDI may provoke significantly different performance in electro-sorption and desorption processes, particularly when these two stages are consecutive, and could be useful in real-world conditions such as those integrated with renewable energy systems in order to mitigate the impact of short-term power fluctuations caused by the intermittent nature of clean energy solutions (i. e. wind power generation and solar power). In these situations, a CDI system should be capable of being flexible with respect to the ability to change rates of current since fast power modulation and continuous operation are required.

Since these features are relevant for the CDI process, strategies for operating these systems are likely to have major impact on the practical application of this technology [4][5]. Therefore, with the objective of developing this process to the point of making these systems an option for use in water treatment plants, these operational aspects are studied and discussed as part of CDI process optimization and aimed at improving energy recovery and separation of both water streams involved.

[1] R.F. Service “Desalination freshens up”, Science, 313 (5790), 2006, 1088-1090.
[2] P.M. Biesheuvel, B. van Limpt, A. van der Wal, “Dynamic adsorption/desorption process model for capacitive deionization”, J. Phys. Chem., C113, 2009, 5636-5640.
[3] E. García-Quismondo, R. Gómez, F. Vaquero, A. López Cudero, J. Palma, M.A. Anderson, Phys. Chem. Chem. Phys., 2013, 15 (20), 7648 – 7656.
[4] M.A. Anderson, A.L. Cudero, J. Palma “Capacitive deionization as an electrochemical means of saving energy and delivering clean water. Comparison to present desalination practices: Will it compete?”, Electrochimica Acta, 55, 2010, 3845-3856.
[5] S. Porada, R. Zhao, A. van der Wal, V. Presser, P. M. Biesheuvel, Progress in Materials Science, 2013, Accepted Manuscript DOI: http://dx.doi.org/10.1016/j.pmatsci.2013.03.005